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TELECOM DYNAMICS

History and State of the Swedish Telecom Sector and its Innovation System 1970 - 2003

Final Report

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Telecom Dynamics
History and state of the Swedish telecom sector and its innovation system 1970-2003

T^2 – Tillväxt i Telekom

Analys av telekomsektorns innovationssystem
1970-2003
(Swedish title)

FINAL REPORT

May 2004

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1 INTRODUCTION

1.1 Background

The telecom sector has contributed substantially and increasingly to economic growth in recent decades. Rapid technological development, innovation and diffusion have turned telecom into a major growth generator, globally and particularly so in Sweden.[1] The Swedish telecom sector has been extremely dependent on the manufacturer Ericsson and its capability to generate innovations, and the success of Ericsson in mobile communications during the 1980s and 1990s has been a major growth driver for the Swedish economy. The Swedish economy and its innovation system have been crucially impacted by the prosperity of one single firm – Ericsson – for better for worse.

At the turn of the millennium, the telecom sector underwent a major shock, coinciding with the burst of the "IT bubble". Ericsson went from billion-dollar profits to huge losses, with collapsing stock prices (which in turn affected the economy negatively). Only substantial cost-cutting, primarily in the form of reduction of personnel, in Sweden and abroad could save the company. In just a few years Ericsson was essentially halved, and is just about to show black figures again.

Worries are raised that this downturn will have long-run negative consequences for the Swedish telecom sector (and Ericsson). A large part of the qualified R&D personnel was laid off, investment rates were dramatically lowered, market shares for Swedish firms went down, and pessimism ruled in the industry. Therefore, Sweden's ability to produce commercially successful innovations, its innovation potential, vis-à-vis other countries could have been downgraded.[2]

Against this background VINNOVA, at the request of the Swedish government, developed a proposal for a national program to strengthen the competitiveness and development of the Swedish IT/Telekom sector. The proposal was put forward in December 2002. In the proposal, VINNOVA pointed to Sweden's relatively low public R&D funding in the IT/Telekom sector. VINNOVA emphasized the need for a more offensive strategy and suggested a substantial increase of government funding in the short run (2003-2004, SEK 350 million) and in the longer run (2003-2007, SEK 3150 million). However, only small features of their suggestions were taken into account by the government.

This lack of action from the Swedish government could partly be explained by an ambiguity concerning what should be done and why. It seems that the state and dynamics of the telecom sector are unclear to the actors involved. To exemplify, opinions differ on what have been driving forces for growth, the causes of the downturn in recent years, the state of the sector, its future prospects, and the competitiveness and dynamics of the Swedish industry. Some leading telecom economists suggest that the telecom industry is entering an era of maturity and emerging cyclicity[3], while others claim continued growth prospects. Clearly, however, ambiguities regarding the state and dynamics of the sectors will lead to ambiguities on what actions are needed. There is a need to investigate the evolution of the telecommunications sector.

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[1] See e.g. Edquist and Henrekson (2001, 2002a,b) and Lind (2002)

[2] Ericsson and Sjödin (2002)

[3] E.g. Noam (2002)

The Department of Innovation Engineering and Management at Chalmers University of Technology has a long tradition in studying telecommunications (primarily mobile communications) and innovation issues in general. Recent research at the Department indicates that, although the traditional segments of the industry are maturing (e.g. fixed telephony), other parts are likely to emerge and drive growth in the coming decades. In particular, mobile data services (and supporting products) have been identified as major future growth segments. The dynamics driving growth in mobile data are complex and difficult to analyze. Especially a need to improve our understanding of entrepreneurial-, innovation-, investment- and standardization-driven growth processes was identified, in addition to investigating the evolution and state of the sector.

These needs, notably the last one, were perceived also at VINNOVA, where telecom systems are identified as a so-called strategic growth area (*tillväxtområde*). A thorough analysis of the historical development of the sector (1970-2003) was needed as input to a number of concurrent and upcoming activities, such as coming foresight analyses and the growth barometer project. This project aims to fulfill those needs.

1.2 Purpose

The primary purpose (Research Purpose 1, RP1) of this study is to map and analyze the telecom sector (or industry/innovation system). RP1 covers the time period from 1970-2003 and includes:

a) mapping and analysis of the whole telecom sector;
b) the Swedish telecom innovation system (henceforth STIS), its evolution, status, competitiveness, and barriers and drivers for innovative activity.

This part of the study includes collection and analysis of available qualitative as well as quantitative data.

A second purpose (RP2) is to summarize and review "state-of-the art" innovation systems theory in order to evaluate its usefulness for analyzing (a national sector), identify weaknesses and consequently assess the need for further research. Based on RP1 and RP2, the project is to give preliminary policy recommendations as well as suggestions for further theoretical and empirical research.

1.3 Project execution

The project was conducted mainly during the second half of 2003 at the Department of Innovation Engineering and Management in collaboration with VINNOVA (Lars Olsson, Anders Hedin, Rolf Nilsson et al.). Sven Lindmark was project leader and the team included Erik Andersson, Mattias Johansson and Erik Bohlin. Advisory support has been provided by Mats Magnusson and Sören Sjölander from the same department, and by innovation system researchers at the Department of Industrial Dynamics also at Chalmers. In particular, the work by Staffan Jacobsson *et al.* on functional analyses of innovation systems has influenced the later stages of the project.

The project time plan was divided into three phases, where the first phase included an inventory of existing analyses in the form of literature, statistics, etc., the second phase summarizing the available analyses, and the third phase validating and complementing existing analyses with e.g. interviews. Each phase was started and concluded with meetings between the project team and VINNOVA.

As it turned out, Phase Two was far more resource-demanding and time-consuming than anticipated. In addition, indicator statistics were not readily available as anticipated. Therefore the industry expert validation and indicator analysis have been downplayed and interpretation and analysis of secondary sources emphasized further, in comparison to the original proposal.

1.4 Methodological considerations and delimitations

There is a wealth of material available on the evolution of the telecom sector. Hence the project has focused on collecting, summarizing, contrasting, interpreting and analyzing available studies and data. Some parts of the sector, in particular data communications, were found to be loss-covered by the literature and thus required more extensive search for information.

Delimitations of STIS have been discussed in several instances with VINNOVA. While the national delimitation is conceptually clear at a first glance, it is difficult to operationalize, as illustrated by the "Swedishness" of Ericsson (Table 1-1).

Table 1-1 How Swedish was Ericsson (spring 2000)?

Category	% Swedish
Employees	42.6
Top 300 managers	70.0
Corporate top managers (12?)	83.6
Board	66.7
R&D	50.0
Research	46.0
Sales	4.0
Ownership	50.0
Voting share	98.0

Source: Åsgård & Ellgren (2000:172)

In addition, STIS involves a large number of products and services, suppliers, subsystem and component suppliers, as well as other actors, and is therefore difficult to delimit. Further, the concept of an innovation system is ill-defined, or defined in such a way that it becomes difficult to operationalize. For these reasons, and time and resource limitations, all aspects of the telecom sector and its innovation system, internationally and in Sweden, could not be covered. Instead a pragmatic approach had to be taken where delimitations must be made, based on our own and others' good judgment. For further specification and discussion regarding these delimitations, see Chapters 2 and 3.

In order to compensate for the excessive breadth of the study, one sub-sector was chosen to examine in depth. The field of fiber optics was chosen for several reasons. First, most of the important development in the field took place in 1970-2003. During this period, fiber optics has undergone several phases: emergence, growth, maturation, a boom and a bust, with the present phase being one of possible rejuvenation or decline. Second, policy relevance seems to be particularly high. The shifting investment strategy of the industry, especially the major player Ericsson, makes it an interesting case for policy analysis and action. Quite early, fiber optics was embraced by Ericsson (with government support), which spent considerable resources on catching up and innovating in the field. However, in recent years Ericsson has divested much of its development, a fact which opened up for substantial venture capital and government investments. One may hypothesize that the withdrawal of the main actor calls for policy and government support, and that the actions so far taken by the government can be evaluated. In addition, the sheer size of government spending in research institutes involved in fiber optics makes it an interesting case. Finally, data availability allows relatively deep analysis in a short time frame.

Another choice made early in the project was to divide the sector into four "segments"(Figure 1-1): (1) one dominant but maturing segment (fixed telephony); (2) one revenue growth-generating segment where Sweden has been very successful (mobile telephony); (3) another growth generator (notably in terms of traffic) with a potentially disruptive effect, where Sweden has been less successful (Datacom/Internet); and (4) a potential future growth segment (mobile data). Thus the relative importance of these segments for economic growth has changed over time, and is expected to do so continuously. This change has primarily been driven by innovation. This segmentation, while having advantages for analyzing growth and innovation, differs from traditional divisions into e.g. manufacturing and service sectors, thus delimiting the availability of indicators and statistics.

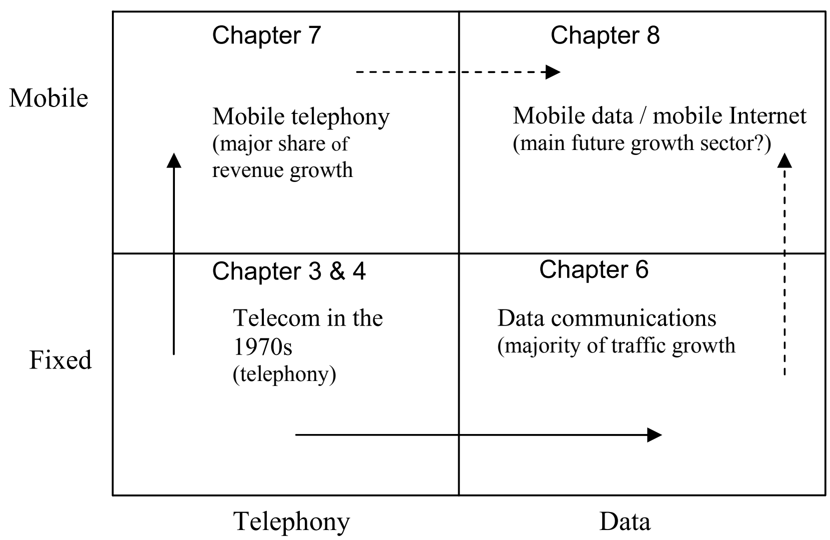

Figure 1-1: Main growth trends in telecom in 1970-2003

Finally, as identified in Chapter 2, innovation system literature lacks coherence and is difficult to operationalize. During the course of the project a promising framework was identified and adapted for the purposes of this study. It was found to yield important insights, but the framework also needs further development, especially in terms of operationalization. Further, it works best when applied in distinct technological fields and for distinct periods of time. STIS for the period 1970-2003 is simply too broad a unit of analysis.

1.5 Overview of Report

The report is structured as follows. Chapter 2 includes a review of the innovation systems approaches, dividing the literature into four broad streams: (1) the national innovation systems approaches, (2) the triple-helix approach, (3) the approaches focusing on a specific technological field or sector, and finally (4) the regional, district and cluster approaches. Starting from this review, a framework for analyzing the functions of innovation systems is proposed, to be applied in the subsequent chapters.

Chapter 3 investigates broadly the telecom sector, beginning with the PTT regime of the 1970s. A number of trends prevalent since then and leading up to the current state of the sector are elaborated on. These interdependent trends are e.g. persistent market growth, rapid growth of mobile data communications deregulation, intensified competition and internationalization, rapid technological change and shift in locus of R&D from PTTs to suppliers, increasing importance of standardization and patenting, convergence and divergence.

Chapter 4 investigates the Swedish sector. The importance of the sector for the Swedish economy and national innovation system is first investigated. The main actor groups and their relative importance are then identified. STIS has been extremely dependent on two actors, Televerket and Ericsson, the former declining in importance, the latter increasing. Therefore, (1) a thorough investigation of the operators' market with an initial emphasis on Televerket and (2) an investigation of the supplier market with a focus on Ericsson are called for, as well as an investigation of the interaction between the two. The R&D and capital market components of STIS are also investigated.

The remaining four empirical chapters are structured in a coherent pattern. In each chapter, the general international development is investigated, followed by in-depth studies of the Swedish sector with an emphasis on the innovation system. Each chapter is concluded with functional analysis of the innovation systems (with reference to the analytical framework outlined in Chapter 2). In Chapter 5 the fiber optics innovation system is investigated. Chapter 6 investigates the evolution of data communications and the Internet. A major issue here is why Sweden has not been able to develop a competitive data communications industry. In Chapter 7, the mobile telephony sector, where Sweden has been particularly successful, is investigated, followed by Chapter 8 on the emerging mobile data innovation system.

Chapter 9 concludes the report by summarizing the main observations, and by making a preliminary SWOT analysis of the STIS. In addition, some preliminary policy implications and suggestions for further research are provided.

2 INNOVATION SYSTEMS

The purpose of this chapter is to review the literature on different systems of innovation approaches in order to provide a thematic overview, assess developments, and investigate criticism that has been raised by researchers from within as well as outside the field of interest.[4]

The chapter can be outlined as follows: first a brief overview of the evolution and development of innovation theory will be provided, whereafter brief overviews of various system or network approaches to innovation will be accounted for. Next, criticism that has been raised against these will be discussed. Finally, an innovation-systems approach for the purposes of this study will be proposed.

2.1 The development of innovation theory

The development of innovation theory over the past 20-30 years has involved a major reformulation and, as it also provides the background against which many of the approaches that will be discussed below originated, it will be given a brief and general treatment.

After WW2, a simplistic linear model of science and technology "push" came to dominate in the new science councils that advised governments and led to a general increase in R&D budgets. The R&D system came to be viewed as the source of innovation. Technology was viewed either as embodied knowledge or as exogenous knowledge creation, with knowledge itself akin to information, and therefore a public good. With the view of technology as being like any other good, and of information as freely accessible, its transfer was assumed to be costless, which provided further rationale for public provision and subsidy of research.[5] This was despite the fact that authors pointed out that technical change did not depend on just R&D, but on many other related activities. However, R&D measures were frequently used as a surrogate for all these activities that helped to promote new and improved products and processes. This tendency was further reinforced by the simple fact that R&D measures were the only ones available.[6]

Gradually, however, empirical evidence began to cast serious doubt on both the theoretical and practical usefulness of these linear models.[7] Although basic science was still regarded as important, ample research in the 1950s through the 1970s showed that invention and innovation included many important factors for innovative success other than R&D.[8] Evidence accumulated in favor of, for example, economic growth depending more on efficient diffusion than being first, on how work organization was related to incremental innovations, on the interaction with market and related firms etc., leading to the gradual replacement of the linear model with a more interactionistic approach in the late 70s and early 80s. Rosenberg, for example, and his studies of innovation in the 70s rejected linearity and instead emphasized learning feedbacks, which gave rise to the chain-link model.[9] This period was followed by substantial research, reaching conclusions of non-optimality, non-linearity,

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[4] This chapter has been written by Mattias Johansson (Sections 2.1, 2.2 and 2.3) with contributions from Sven Lindmark (Section 2.4)

[5] Mytelka & Smith (2002:1471)

[6] Freeman (1995:46)

[7] Mytelka & Smith (2002)

[8] Freeman (1995)

[9] Kline & Rosenberg (1982)

and then importance of learning and interaction,[10] and also revealing more and more systemic aspects of innovation.[11] Another important aspect for the development of innovation theory and policy was that OECD in the 60s, and later on other organizations as well, involved independent researchers more readily in their work.[12] This allowed social scientists to influence policy-making with regard to technical innovation, as well as making these organizations become important loci of consensus-building because of easier access to policy-making circles. As the economic crisis of the 70s was partly a crisis of understanding in mainstream economic models, it led to serious questioning of the earlier static and allocative approaches. Thereby, a niche was generated in which heterodox analysts and officials within the less hierarchically structured organizations could interact around problem-oriented analyses.[13]

While the failed delivery of understanding of mainstream macroeconomic approaches may be one reason for the spread of innovation-theory approaches, another reason might be that the extreme division of specialization among policy institutions and policy analysts had become such a big practical problem that analytical concepts helping to overcome these were welcomed.[14] In the EU, however, it was not until the focus shifted to regional development policies that the kind of interactions which theory suggested to be critical for innovation became more fully integrated into EU programs.

2.2 Innovation Systems – Concepts and definitions

The two words "innovation" and "system" are common to many approaches, so an initial recapitulation of these may useful, along with a presentation of definitions and concepts related to the components of these words.

2.2.1 The innovation aspect

In the late 70s, Christopher Freeman, in his paper "Determinants of Innovation", summarized innovation nicely as a "*coupling process, which first takes place in the minds of imaginative people somewhere at the ever changing interface between science, technology and market. The coupling is more than an intuitive flash; it is a continuous creative dialogue over a long period of research, experimental design and development*" (1979, 211). That is, the innovation process is seen as cumulative and evolving interaction, learning, and tacit knowledge, and there is also an underlying notion of Schumpeter's new combinations. This is common to most approaches, although their emphasis differs.

Otherwise, most approaches differ along two dimensions regarding what is included in the concept of innovation. The first concerns whether it is only technical innovations or if, for example, organizational and institutional innovations (not necessarily related to the production function) are included as well. The second dimension concerns whether it is only the generation of innovation, or also the subsequent diffusion, adoption and utilization of the innovation, that is focused upon. In addition to this, innovation is sometimes described as a process, while at other times it merely represents the outcome of a process.

[10] Mytelka & Smith (2002)

[11] Carlsson & Jacobsson (1993)

[12] Edquist (1997); Freeman (1995); Mytelka & Smith (2002)

[13] Mytelka & Smith (2002)

[14] Lundvall et al. (2002)

2.2.2 The system aspect

Many of the approaches surveyed here include the notion of a "system" in one way or another, but the ways in which it is used and defined differ mainly along two dimensions. The first dimension concerns what is meant by applying the concept of a system. Usually it is that the determinants of innovation are not only found within individual firms, and that there are strong systemic effects in the sense that strong dependencies exist between the different components; and because the components of the system interact, their characteristics derive from the system.[15] How strongly this is emphasized, however, differs widely between the approaches. Sometimes the concept of "determinants" is used in a way almost presupposing that they can be centrally planned and coordinated[16]; at other times the "system" is referred to in rather loose terms, only differing from approaches applying a network concept in that it may be somewhat better delineated, or in that the interactions are somewhat more institutionalized. This implies that in most approaches, perhaps with the exception of some studies on technological systems, the systems are very loosely coupled. The delineation of the systems is itself often somewhat arbitrary and partly dependent on the knowledge of the researcher.

The second dimension concerns the components included in the system. Often, this is rather vaguely defined in general terms and referred to as, for example, *"actors, markets, networks and institutions"*[17], or *"the elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge"*[18]. Since there are some conceptual ambiguities as to what is included in different concepts, the definitions are far from consistent. The approaches also differ as to how broadly the system is defined, i.e. how many components are included, and this is in turn also partly related to how broadly innovation has been defined. However, the studies frequently come to focus on a few components which are considered to play a major role, such as R&D, the universities, and governments. The degree of specification is also partly dependent on the level of aggregation upon which the approach focuses.

2.2.3 The role of institutions

The role of institutions is emphasized in all versions of the innovation-systems approaches, at the same time as the concept of institutions is used in very different senses. Hence it deserves a heading in its own right. The confusion occurs because institutions are sometimes referred to as including everything from actors to organizations, markets and rules for conduct, while others separate organizations as concrete things and define institutions as *"sets of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals and groups*"[19]. Due to the concept's importance, it is at times argued that a further taxonomy thereof is needed.[20] However, the purpose here is mainly to point out its distinctive uses in the different approaches for the sake of awareness.

2.2.4 National Innovation System

Of the different approaches, the National Innovation System (NIS) approach is probably the most widespread. It is really not one coherent approach, so variations in its use can be discerned, both in academia compared to policy and within both arenas. Although it is

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[15] Hughes (1987)

[16] E.g. Lundvall et al. (2002)

[17] Bergek (2002)

[18] Lundvall (1992:2)

[19] Edquist (1997:46)

[20] Edquist (1997)

important to remember that the concept has not evolved separately in academia and policy, the focus here will be on how it is used in academia.

The notion of "systems" had been widely present in works by, for example, innovation theorists such as Rosenberg, technology historians like Hughes, and technology systems analysts, and was immanent in comparisons of the US system with that of other countries. The "innovation system" concept itself, however, was introduced by Lundvall (1985), with "national" added by Freeman in 1987 in his attempt to explain the institutional factors of Japan's superior technological development.

NIS is sometimes summed up in terms of two approaches related to the works of Lundvall (1992) and Nelson (1993).[21] According to Lundvall, a distinction can be made between a narrow definition, including organizations and institutions involved in searching and exploring, and a broad one, including all parts and aspects of the economic structure and set-up affecting learning as well as searching and exploring, where the production system, the marketing system and the system of finance present themselves as subsystems in which learning takes place.[22] Nelson's volume essentially followed the narrow definition, while Lundvall and his collaborators focused much more on a conceptual account of the characteristics of learning. Another distinction with regard to these two approaches has been made by Miettinen (2002) who views Lundvall's approach as more "scientistic" while Nelson's is considered to be more moderate. The former is considered to believe that the "determinants" of innovations can and should be defined, and that they constitute a basis for the holistic and deliberate planning and development of a national innovation system. The latter instead suggests that we can compare the national institutions contributing to innovation with one another and learn from these comparisons. The comparisons, however, do not themselves constitute a basis for the planning of a national system.

The NIS approach promoted by Lundvall and colleagues originated more than 20 years ago from the increasing awareness that new knowledge is not solely a product of R&D but also the result of, for example, production engineering, customers and marketing. The Aalborg version of the NIS concept may be seen as a combination of four elements: the neo-Schumpeterian reinterpretation of national production systems, empirical work based on the home-market theory of international trade, the microeconomic approach to innovation as an interactive process and, finally, insights into the role of institutions in shaping innovative activities.[23] Inspiration and ideas were derived from, for example, innovation theory[24], evolution theory[25], and studies on long-term relationships[26]. The focus was to start with macroeconomic issues, but it gradually moved also toward issues related to microeconomic dynamics, although without losing a strong orientation towards policy.

Nelson's and his collaborators' project resulting in the book of 1993 shared many precedents of Lundvall, but was first and foremost an attempt to understand the reasons for difference in economic growth rates between industrialized countries. Thus a study was conducted from a given framework with the nation as a potentially useful unit of analysis.

The spatial boundary

[21] Mytelka & Smith (2002)

[22] Lundvall (1992)

[23] Lundvall et al. (2002)

[24] e.g. Kline & Rosenberg (1986)

[25] e.g. Nelson & Winter (1982)

[26] e.g. Christopher Freeman and others at SPRU

The system boundary in NIS is on one of the highest levels of aggregation, namely nations. The reason according to Lundvall et al. (2002) is the importance of the policy dimension; for as long as nation-states exist as political entities with their own agendas related to innovation, it is useful to work with national systems as analytical objects. Nelson (2000) agrees that there are certain aspects which reveal that nationhood matters and exerts strong influence on, for example, firms and the educational system, but also acknowledges that the concept may suggest more uniformity and connectedness within a nation than is the case. Different sectors can thus for the most part be discussed independently.

Innovation
Innovation as conceived by Nelson and Rosenberg (1993) is narrow in the sense that it is restricted to technical innovations, but broad in the sense that they also encompass the processes by which firms master and bring into practice innovations that are new to them, whether or not these are new to the universe or even the nation.[27] Lundvall also applies the wider definition of an innovation's diffusion and use, but deviates in mentioning "new forms of organization" and "institutional innovation"[28] not relating directly to the production function. Although not specifying the concept explicitly and systematically, their use implies an altogether broader concept of innovation than that of Nelson.

In relation to innovation, NIS also incorporates the notion of interactive learning in one way or another – especially in Lundvall (1992), who bases it on the tradition of learning curves and cumulative experience[29], although radically transcending this in focusing on social interactions in networks of, for example, users and producers.[30]

System
The use of the "system" concept differs somewhat in regard to what is actually meant by it, and to what components that are focused upon. The term "system" implies interdependencies between elements in the system, and it is inherent in the NIS approach that the elements to some extent derive their characteristics from the system. The degree to which this is the case, however, is not specified. What differs is that in Nelson and Rosenberg, systems (on the national level at least) are not consciously designed to the same degree, and distinct elements in the system may even be in conflict with each other. In Lundvall, on the other hand, there is a tendency to try to define all the determinants in a system and then attune them into a common strategy,[31] implying a greater belief that systems can be planned and designed.

Regarding the components of a system, the definitions are often rather vague. Freeman (1987), for example, defines it as "*the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies"*, Nelson and Rosenberg (1993:5-6) define it as *"a set of institutional actors that, together, play the major role in influencing innovative performance"*, while Lundvall (1992:2) defines it as "*the elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge...and are either located within or rooted inside the borders of the nation"*. A later definition expands the concept further, as it is argued that there is a need to broaden and deepen the concept, partly implied by the broad definition of innovation. Innovation systems thus *"work through the introduction of knowledge into the economy [which] requires active learning by individuals and organizations taking part in*

[27] Nelson & Rosenberg (1993:4-6)
[28] Lundvall (1992:8, 9, 14, 17)
[29] See e.g. Arrow (1962)
[30] Miettinen (2002)
[31] Lundvall et al. (2002:227)

processes of innovation of different kinds. The efficiency of these learning activities and, hence, the performance of the innovation systems depends on economic, political and social infrastructures and institutions. It also depends on past experiences as they are reflected in the tangible and intangible aspects of the structure of production and on values and policies."[32]

Despite a certain vagueness in definitions, some components usually come into focus. Thus Freeman focuses on the role of government, education and training, efforts to import and improve the best technologies, cooperation between government and industrial concerns, and vertical integration.[33] Nelson singles out organizations supporting R&D as the most important actors, although large firms and the educational systems etc. are given prominent roles as well. Lundvall specifies in particular two universal components: institutions and the industrial structure, as these deeply influence human initiative and creativity in the innovation process. There are, however, no clear criteria for identifying the most important institutions or, for that matter, the most important aspects of the industrial structure. Other authors focus on still other, but partly overlapping, aspects such as the importance of physical, economic and knowledge infrastructures in a system,[34] or the role of large firms, incentives and institutions[35] – the latter in terms of whether the financial system gives weight to long-term performance or not, and the power and prestige given to financial (as opposed to technical) competence in the methods of management.

Common to all versions of the NIS approach is the central role given to institutions. Whereas the term sometimes seems to include everything from actors to organizations and norms[36], there is more often a distinction between organizations as concrete things and institutions understood as norms, habits and rules that are deeply ingrained in society and play a major role in determining how people relate to each other and how they learn and use their knowledge.[37] The distinction is important in order to study the interaction between the two. According to North (1990), organizations are partly formed by the institutional framework and are, at the same time, vehicles for change; the players follow the rules but they also influence them. It is important to note that organizations are consciously created formal structures with an explicit purpose. Institutions, in contrast, may develop spontaneously and are often not characterized by a specific purpose. Institutions regulate the relations between people and groups of people, within as well as between and outside organizations. This means that the pattern and the content of communication and interactions in the economy are affected by its institutional set-up. Since innovations result from interactive learning processes, institutions affect innovation. Ideally the basic functions of institutions should be to reduce uncertainty by providing information, to manage conflicts and cooperation, and to provide incentives, as well as channeling resources into innovation activities.

Since institutions are a key component, it is argued that a better taxonomy is needed, but this has yet to appear though there are some attempts.[38]

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[32] Lundvall et al. (2002:225)

[33] Miettinen (2002)

[34] Smith (1997)

[35] Patel & Pavitt (1994)

[36] E.g. Niosi et al. (1993), Patel & Pavitt (1994)

[37] Edquist & Johnson (1997)

[38] E.g. Edquist (1997), Lundvall et al. (2002)

2.2.5 Triple Helix

The Triple Helix model is largely the product of Etzkowitz and has been further elaborated by, for example, Leydesdorff. The approach draws inspiration from, for example, evolutionary theory and the possibly changing nature of knowledge production. The idea is that the expansion of the higher-education and academic-research sector has provided society with a realm in which different representations can be entertained and recombined in a systemic manner.[39] The degree of innovativeness is explained as a product of coalition-building and networking patterns leading to a clustering and a nesting of inclusion mechanisms.[40]

There are two different interpretations of the Triple Helix model.[41] The first focuses on reaching a consensus about activities among the representatives of academia, industry and government and with the involvement of "innovation coordinators". However, more often it is the second interpretation, the evolutionary Triple Helix model, which is mentioned and which is also the one to be discussed here.

Spatial boundaries

As for the spatial boundaries, the model does not refer specifically to nations, regions or sectors. Rather it can be applied to all these different contexts. The view is that there is no need to conceptualize arrangements between industry and government as being made exclusively between national governments and specific industrial sectors, although this may be done as well.

Innovation

Innovation is defined in rather broad terms, encompassing not only technical innovations but also, for example, institutional innovations aiming to promote closer relations between faculties and firms. Moreover, innovation can be defined at different levels and from different perspectives within this complex dynamics, and can only be defined in terms of a process.

Innovation is viewed in close relation to the system and the actors, as both the innovator and the innovated system are expected to be changed by the innovation. These structural changes are in turn expected to change the dynamics, which leads to the opportunities found within the system being recursively driven by the contingencies of prevailing and possible technologies.

System / helix

The model sets out to explain the convergence of the three worlds of public research, business and governments. These thus become the basic components in the system, or more in line with the model, each representing one strand in the helix and possibly relating to the other two. Of these, it is especially the role played by the universities as promoters of development that is stressed. Focusing on universities makes it analytically different from the other approaches, as these mainly consider firms having the leading role in innovation. The government's role is limited but more crucial. It has to define the normative framework appropriate for planning of individual incentives for reorienting academic and industrial actors towards a higher level of integration.[42] The model can also be represented by three factors:[43] the actors, the institutions, and the rules and regulations. The actors are the "micro"

[39] Etzkowitz & Leydesdorff (2000)

[40] Elzinga (2002)

[41] Viale et al. (1998)

[42] Etzkowitz & Leydesdorff (2000)

[43] Viale et al. (1998)

level and perform according to roles and models of action which involve various and varied cultures of the three worlds of academia, government and business. Institutions refer to the "meso" level, being those that organize production and make use of technological knowledge, whereas the rules and regulations operate on the "macro" level and are essential in order to set guidelines for policy incentives.

The model assumes that, within specific local contexts, the universities, government, and industry are learning to encourage economic growth through the development of what has been called "generative relationships", i.e. loosely coupled relations and joint undertakings that persist over time and induce changes in the way agents come to conceive their environment and how to act in it.[44] The focus is on the network overlay of communications and expectations which is expected to develop among the helices, and which reshapes the institutional arrangements among universities, industries, and governmental agencies. The driving force of the interaction in the network of communication can be specified as the expectation of profits, where profits may mean different things to the various actors.

Analytically the drivers are not conceptualized as ex-ante causes, but in terms of expectations that can be evaluated only ex post. From the evolutionary perspective, selection (ex post) is structure-determined, while variation may be random. The foundation of the model in terms of expectations leaves room for uncertainties and chance processes to a degree not explicitly discussed in other approaches.

The use of the term "system" also explicitly refers to the fact that systems can be more or less systemic in character, although in no way deterministic. Going along with Hughes (1987) it is stated that in some phases intentional actions may be more successful in shaping the direction of technological change than in others. Much focus is put on dynamics, and the model hypothesizes that systems can be expected to remain in transition. Moreover, the dynamics of the system are non-linear. The system also consists of different subsystems and, at each level, cycles are generated which guide the phasing of the developments. The higher-order transformations (longer-term) are induced by lower-order ones, but the latter can be seriously disturbed by events at a next-order system's level.[45] This also allows for tensions that need not be resolved. A resolution would hinder the dynamics of a system which lives on the perturbations and interactions among its subsystems. However, critics find that convergence and agreement are highlighted while conflict and exclusion mechanisms are toned down. It is a model of consensus, giving a picture of smooth and peaceful cooperation across institutional borders.[46] Finally, the system is grounded in a culture that it continually has to reproduce through negotiations, the creation of expectations, and institutionalization.

2.2.6 Technological and Sectoral Systems of Innovation

The Technological Systems (TS) approach and the Sectoral Innovation Systems (SIS) approach are similar and therefore treated under the same heading. The TS approach has mainly been developed by Carlsson and colleagues, drawing inspiration from, for example, literature on technological systems, earlier innovation theory[47], and the "development blocs" of Dahmén.[48] The SIS approach is primarily advocated by Malerba, and draws on similar lines of literature.

[44] Viale et al. (1998)

[45] Etzkowitz & Leydesdorff (2000)

[46] Elzinga (2002)

[47] E.g. Kline & Rosenberg (1986)

[48] Carlsson et al. (2002)

Neither of the approaches should be regarded as standing in opposition to the NIS approach, but rather as complementary in that studies are conducted on a different level of analysis.

Spatial boundary
Compared to NIS, both TS and SIS differ in referring to a technology or industry/sector instead of a geographical area. These boundaries do not necessarily coincide with national boundaries, and may be different from one area to the next. The delineation may often be somewhat arbitrary and partly based on informed guesses by the researcher.[49] In the TS approach, technology areas can refer to at least three levels of analysis: to a technology in the sense of a knowledge field, to a product or an artifact, or finally to a set of related products and artifacts aimed at satisfying a particular function (competence bloc).[50] Similarly, the SIS approach is based on the idea that the forces that account for the dynamics of SIS and shape their spatial boundaries should be found in some specific features of technologies. What characterize the different technological regimes operating in different sectors are the particular combinations of opportunity and appropriability conditions, degrees of cumulativeness of technological knowledge, characteristics of the relevant knowledge base, and means of knowledge transmission and communication.[51] The interaction of the various factors of TR affects in various ways the features of SIS.

Innovation
Innovation is viewed as mainly technical innovations, although social innovations are mentioned as well, and is by its nature an interactive process involving both users and producers. Apart from the generation of innovation, the approaches are also concerned with its subsequent diffusion, arguing that the impact of a new technology on an economic system is determined by its diffusion.[52] In fact, in the TS approach it is argued that technology transfer could be seen as a core activity in an innovation system, and that the function of invention and innovation is to expand the opportunity set for various economic agents. The SIS approach[53] is also concerned with the underlying knowledge base of innovation, in terms of its accessibility, cumulativeness, and degree of appropriability, which in turn shapes the development trajectory of the sector.

System
The technological system is defined as a "*network of agents interacting in a specific technology under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology*".[54] It involves three types of networks: buyer-supplier, problem-solving, and informal networks, of which it is the problem-solving network that is focused upon and that really defines the boundaries of the systems. Important as the networks may be, their boundaries may however be difficult to define, since various actors will draw different boundaries as a result of different perspectives, intentions, and interpretations.[55] What is more pertinent in the TS and SIS approaches compared to the NIS approach is the greater emphasis put on microeconomic aspects, i.e. clusters of firms, firms, or even units in firms. In TS this takes the form of a particular interest in development blocs and in firms' abilities to generate and take advantage of business opportunities, including for example

[49] Carlsson et al. (2002)
[50] Carlsson et al. (2002)
[51] Breschi and Malerba (1997)
[52] Carlsson et al. (2002)
[53] Malerba (2002)
[54] Carlsson & Stankiewicz (1995:49)
[55] Carlsson & Stankiewicz (1995)

firms' ability to learn from experience, to perceive opportunities, and willingness to take risks etc.[56] or as involving selective capability, organizational capability, functional capability, and learning or adaptive capability. Otherwise there is not much discussion as to what exactly constitutes a system, but the usually mentioned actors like universities, industry and other professional organizations as well as other interest organizations etc. are included.

In SIS, the central actors are firms and the selection environment that they operate in. The system is composed of the group of firms active in developing and making a sector's products and in generating and utilizing a sector's technologies.[57] Such a system of firms is related through processes of interaction and cooperation in artifact-technology development, and through processes of competition and selection in innovative and market activities. Emphasis on firms is thus even stronger in the SIS approach.

In the TS approach, the term "system" also denotes that there are more or less strong systemic effects between the components, referring to earlier systems literature of Hughes. Each component is viewed as dependent upon the properties and behavior of at least one other component in the set, and because of this, components cannot be divided into independent subsets. This also has the result that the system as a whole is often considered to be the primary unit of analysis.

The TS approach is also concerned with the function, or purpose, of each system. In TS, the function of an innovation system as a whole is to generate, diffuse and utilize technology.[58] This can be broken down into a number of functions important for an innovation system to work. In Jacobsson and Bergek (2003) for example, the functions important for an evolving energy technology were the creation and diffusion of new knowledge, supply of resources, guidance of direction of search, creation of positive external economies, and formation of markets. Related to each of these functions is one or several inducement and blocking mechanisms, promoting or hindering the function. These may operate on different levels of aggregation, which can for example be government policy as well as the behavior of the firms themselves. There may be general functions and mechanisms, as well as some specific to certain technological systems.

2.2.7 Regional (or local) Systems of Innovation and Networks

Whereas the other approaches may be said to be more homogeneous, in spite of conceptual diffusion, what is here regarded as Regional Innovation Systems is a broader range of studies including cluster studies. The theoretical underpinnings are those of Marshall, economic geography, and some aspects of regional science literature. As for the networks, many of these stem from sociology and works of for example Mark Granovetter.

In many respects these approaches are similar to TS and SIS, as they focus on lower levels of aggregation. However, they also differ, and primarily in that they take their point of departure in geographical areas and to a very small extent concern themselves with the specific technologies or knowledge areas involved. Again the main focus is on a static or comparative static analysis.

Spatial boundary

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[56] Carlsson & Stankiewicz (1995)

[57] Breschi and Malerba (1997)

[58] Carlsson et al. (2002)

In Regional Innovation Systems the outer boundary of the system is defined primarily in geographical terms. However, that boundary itself is less well defined than, for example, in NSI where it is the nation. Sometimes the boundaries are drawn according to industrial areas, such as in Route 128 or Silicon Valley[59], while others like Niosi (2000) consider regions to be urban agglomerations, basing this boundary on the finding of Zucker et al. (1998) that most externalities (both knowledge externalities and venture capital activities) take place within a maximum of 50-100 km. It is also important that the regions have a certain degree of innovative activity, which implies that the focus is on urban agglomerations with some kind of industry and/or universities. In cluster theory, the geographic scope is set by the components with strong links, and it can thus range from a single city to countries. Moreover, the boundaries are not given but continuously evolve.

Thus, drawing boundaries seems often to be, in Porter's words "*a matter of degree, and involves a creative process informed by understanding the most important linkages and complementarities across industries and institutions to competition*".[60] As suggested above, this is not only applicable to RIS but holds valid for all other approaches except NIS where the national boundary is given.

Innovation

Innovation is a basic component also in these approaches, as it is important for economic growth. However, it is usually not much elaborated upon but mostly investigated in terms of how relationships enable it. Exceptions include Cooke et al. (1997) who define it in Schumpeterian terms of technology-related changes in terms of new products, processes or forms of organization, but broaden it to include also institutional change, and changes in how actors relate to each other. Thus, their definition of innovation becomes very broad.

System

The term "system" is used at times but is rarely elaborated upon as such. Often it seems to denote the relationships between different actors within an area or industry. The systems are not consciously designed and there is no clear causality; rather, their co-evolution is emphasized. As in most other approaches there is no optimal method of coordination and planning. Efforts to protect one individual sector often have unintended consequences for linked sectors. Cooke et al. (1997) discuss the concept a bit further but end up with much the same, although more explicitly stated, view as described above. That is, a system denotes relationships or interactions which are structured in a certain way or/and have become institutionalized. As in most IS approaches, perhaps with an exception for some studies on technological systems, the system is loosely coupled.

More often the focus is on the different components comprising the system. Generally, importance is put on institutions (including organizations), firms, networks and the infrastructure. In the regional analysis of Saxenian (1994), emphasis is especially put on institutions and organizations like universities, financial institutions etc. as well as on culture and the role of infrastructure. Most of these relate to the common pool of resources in a region. Porter (1998:211-212) in his cluster analysis focuses on much the same components, but also puts greater emphasis on for example the role of competition, the skill of local demand and supply etc.

Relationships and networks play a vital role in these approaches. The performance of a region or cluster cannot be explained by approaches that view firms as separate from the social

[59] Saxenian (1994); Malmberg & Maskell (1997)

[60] Porter (1998:199)

structure and institutions of the local economy.[61] Both Porter and Saxenian refer to the concept of embeddedness, thus relating to Granovetter and network theory or a more socioeconomic approach. The geographic proximity promotes the repeated interaction and mutual trust needed to sustain collaboration and to speed the continual recombination of technology and skill, but spatial clustering alone does not create mutually beneficial interdependencies. One also has to look at the institutions, like trade associations etc., and infrastructures that support the region's network-based system in order to explain it. In these networks, the informal relationships are often emphasized over the formal alliances. The role of these networks is very similar to how their role is interpreted by, for example, Bergek & Jacobsson (2003) within the TS approach.

The role of government is to support the institutions, organizations and infrastructure etc. needed for the development of a region or a cluster. It is argued that this is better done locally due to the difficulties of public officials to pick the right issues, and due to the specificity of each region. The institutions should be created in a way that promotes a decentralized process of industrial self-organization without sacrificing individual autonomy and flexibility. Regional policy should be designed to catalyze and coordinate – rather than directly manage – relations among myriad public and private actors that populate a regional economy.[62] This is similar to the discussion of Jacobsson & Bergek (2003) on stimulating the functions of a TS through inducement mechanisms, while removing obstacles in the form of blocking mechanisms.

The approaches are similar to TS and SIS in covering everything that has strong linkages to the area or cluster in focus, but are at the same time broader. To simplify, the SIS focuses on horizontal relations between direct competitors with similar activities operating in the same product markets, while the cluster approach also focuses on the importance of vertical relationships between dissimilar firms.[63]

As for the network theories, these are similar to the approaches discussed above, although there is a greater focus on networks as the primary unit of analysis, and often also a focus on lower levels of aggregation. Works of, for example, Håkansson, Powell and Granovetter could be included in one or another orientation of network theories.

2.2.8 Measurement and methodology in the approaches

The methodology and ways of measuring the institutions, or parts of the different approaches, are very similar and thus treated under the same heading. More often than not the same tools, i.e. methods and measures, are used – but used in order to construct and point to slightly different things. In all approaches qualitative as well as quantitative measures are used, although focus might differ. Another thing that differs is the level of aggregation at which measurement is carried out (see Figure 2-1 for a rough description).

Because of the size and complexity of the system in NIS (and therefore, the number of linkages among components at lower levels of aggregation), the empirical emphasis in the studies carried out thus far is mainly on statics or comparative statics. But there is nothing in principle preventing a more dynamic analysis.[64] Thus, studies are often undertaken through measuring and comparing aggregated data. For example, for firms, data on R&D and patents

[61] Saxenian (1994:6)

[62] Saxenian (1994)

[63] Miettinen (2002)

[64] Carlsson et al (2002)

are used; and for universities, there are data on R&D inputs, and on outputs in the form of numbers of papers published, and of citations made to them by scientific peers. The R&D measures are often assumed to reflect parts of the wider processes of learning, as well as the discovery of new things.

Although emphasis may be on quantitative studies, more qualitative assessments have been made as well, to provide insights for the historical trajectories or paths guiding system evolution.

Roughly the same methods and measures are used in TS and SIS. Although smaller in its conceptual framework, the dynamic character that is emphasized is still difficult to capture. Thus, like other approaches they often rely upon traditional measures of aggregated data with complementary descriptive material to capture the historical trajectories. Although the knowledge base is one of the cornerstones in these approaches, the study of the knowledge base of a technology is a daunting if not impossible task, even if the technology is very "narrow".[65] Thus most studies within TS, and for that matter SIS, analyze the evolution of artifacts and derive the knowledge base from the requirements therein.

Clusters and RIS can, like TS and SIS, be examined at various levels of aggregation depending on what issues to expose. Much measurement is on aggregated data complemented with descriptive data. Innovative activities, for example, are measured by the granting of patents to locally based inventors or the launching of new products designed and developed in the area. The size and innovativeness of clusters were measured through several indicators: the number of firms, total employment and patents were most important. Due to a close alignment with network theory, there are also studies conducted using various methodologies for mapping networks in terms of frequency of interaction, centrality etc.

Finally, in Triple Helix the unit of analysis can change in order to obtain different perspectives on the system under study. In terms of methodology, this challenges our conceptual apparatus, since one has to be able to distinguish whether the variable has changed or merely the value of the variable. Case materials enable us to specify the negative selection mechanism reflexively. Selection mechanisms, however, remain constructs. Policies have to be updated in terms of bottom-up processes and thus come to be understood in terms of reflexive feedbacks, instead of control.

2.2.9 Summary

To summarize, the different approaches differ not so much in what they want to achieve but rather in the analytical focus, and also regarding what level of aggregation is studied (see Figure 2-1). As for the National Innovation Systems, many of those approaches pay primary attention to firms, although other actors of course are considered important as well. As the name implies, these approaches are also more concerned with higher levels of aggregation. The Triple Helix model instead takes its primary point of departure in universities, as a result of the perceived new knowledge economy, and although the level of aggregation is not specified, it often relates to regional economies. Technological Systems, on the other hand, begin with the knowledge base and technologies involved, which also set the boundary of the system. However, often the level of aggregation studied is below national levels, and sometimes comes down to departments or individuals in firms. Regional Innovation Systems and networks, finally, are not really a homogeneous set of approaches. Nonetheless, these

[65] Holmén (2002)

approaches tend generally to put greater emphasis on networks and sociological aspects than the other approaches, and as a result, studies are often conducted on somewhat lower levels of aggregation. However, although somewhat different, the approaches are by no means to be viewed as mutually exclusive. Instead they can often be viewed as complementary, although the underlying variations and the reasons for these should be kept in mind.

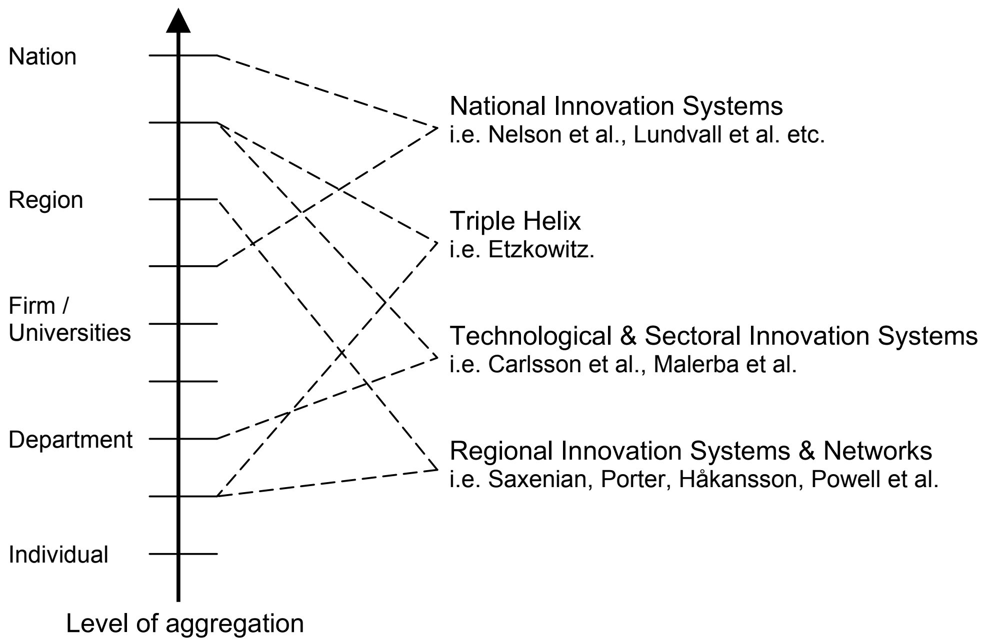

Figure 2-1: Level of aggregation focused upon in the different approaches.

2.3 Discussion of Systems of Innovation literature

Having been around for about 15 years, the innovation-system approaches in general have gained a lot of attention in both literature and policy-making. Although positive in many respects, the approaches are not without problems, something which researchers within the community as well as outsiders have pointed out. In the following some of these problems will be discussed.

2.3.1 Weakness of concepts

In reviewing the literature on NIS, Edquist (1997) lists as one of nine common characteristics of innovation-system approaches their conceptually diffuse nature, for all attempts to define the boundaries have faced constant difficulties.[66] The diffuse nature is sometimes argued to be useful as it makes the approaches more pragmatic and flexible[67], or because it makes it possible to integrate more disparate areas of research within the same framework.[68] However, it also imposes limits on integrating it in any theoretical discourse, e.g. growth theory, since it becomes more of a broad conceptual construct. In Miettinen's opinion this holds truer for Lundvall and the Scandinavians who are developing conceptual schemes more directly for policy purposes, which tends to result in a less critical introduction of concepts with weaker anchoring in empirical research, than for the Americans who tend to require more conceptual rigor and stronger empirical grounding.[69]

[66] Miettinen (2002)

[67] Edquist (1997)

[68] Miettinen (2002)

[69] Miettinen (2002)

Spatial boundary

Looking more closely at the concepts, the spatial boundaries – whether geographical or related to technology or other factors – may not pose a problem as such. Rather, the different approaches can be viewed as complementary. What boundary to choose is more a matter of what research questions one sets out to answer.

Innovation

The term innovation is generally used rather broadly. Although sometimes narrowed down to include mainly technical innovations, it has also been broadened to include not only the generation, but also the diffusion and utilization, of innovations new to firms. This in turn affects what is needed for encompassment in the system definition: when the concept of innovation is broad in both dimensions, it becomes necessary to include quite a lot in the system definition. For this reason it is probably useful to narrow down innovation in at least one of its dimensions.

System

The discussion of the term "system" has been strangely limited, given its central role in many of the approaches.[70] This is true especially for what is meant by a "system" but to a lesser degree also for the components constituting a system.

In TS[71] and Triple Helix[72] where attempts have been made to further elaborate on the term, much is taken from earlier systems literature. The interdependencies may thus be more or less strong, and may lead to more or less systemic effects (i.e. the system is more than the sum of the parts), but in no way implies any determinism in the system. One consequence is that the components cannot be viewed as independent subsets; another is that it takes time before evolving areas become systems in this sense, as it takes time to develop such interdependencies. However, the term "system" more often relates only to systemic effects in the form of interdependencies as a result of the interactive nature of innovation, something that has been questioned. It is argued that the central mechanisms of interaction in no way presuppose the concept of a system, nor do the principles of the evolutionary approach or, for that matter, the idea of interactive explanation imply or presuppose this.[73] However, the critique is justified only insofar as, by applying the term "system", one considers it possible to define all the essential factors or "determinants" affecting technical change and attempts to construct a systemic model of them – that is, if one echoes a belief in the possibility of centralized control over the development of societies, suggesting that authority be given to transnational, national and regional high-level councils to coordinate policies across sectors. For this would constitute a "causal" explanation which presumes, at least implicitly, that the definition of the determinants makes the control, optimization and improvement of the system possible, something characterized as "scientism and prescriptive rationality" by Storper (1997:283). Ironically enough, it thus becomes based on the old idea of linear causality it seeks to reject, as the determinants determine the development of the system.

This discussion is also important regarding to what extent a system can be consciously designed or not. This is an open question, and most certainly also one that strongly relates to what industry is concerned with. While it probably is too much to expect that a system can be consciously designed in its entirety, the opposite is not likely either. Different parts can be

[70] Miettinen (2002), Archibugi & Howells (1999)

[71] E.g. Carlsson et al. (2002)

[72] E.g. Etzkowitz & Leydesdorff (2000)

[73] E.g. Niosi et al. (1993:219), Miettinen (2002:48, 53-54)

consciously designed; for example, the educational programs directed to a certain area are thus designed. However, for these parts to yield a systemic whole may be out of the control of the designer, and instead be something that evolves. This distinction between which parts have evolved and which parts have been consciously designed is an important one to make and keep in mind.

Regarding the components included in a system, other problems may be discerned. Firstly, the ambition of some approaches (especially that of Lundvall et al.) to create a reasonable theory of all essential factors that influence innovation is an unrealistic project, given that the innovative activity of a nation is a complex, multifaceted, heterogeneous and ever-changing phenomenon for which we do not even have satisfactory definitions.[74] Secondly, the components are often rather vaguely defined, making them difficult to operationalize or integrate into theoretical frameworks. Thirdly, it is difficult to make a clear-cut distinction between what is internal and what is external to the system. In a RIS, TS, or SIS there are always factors or components at the national level impacting, although not specifically part of the RIS, TS, or SIS. Similarly, on the national level there are foreign firms investing in R&D, although the economic returns are appropriated elsewhere. Thus, different systems come to overlap each other and the delimitation of each necessarily becomes somewhat arbitrary, informed by the researchers' educated guesses.

2.3.2 Weak treatment of important processes

As many of the approaches (especially NIS) focus on higher levels of aggregation and structural issues, and by their very nature take a top-down view of firms' innovative activity[75], there is at times a lack of more thorough discussion of the processes involved, especially as to the micro-level.

There is a general stress on interaction, and more specifically on interactive learning and knowledge flows, but there are very few references to, let alone analyses of, the specific nature of these interactions in terms of flows and linkages connecting the actors in a network. This neglect of linkages and flows is curious, given that networks form one of the cornerstones in defining a system.[76] In attempting to conceptualize and study learning, different kinds of learning and knowledge have been listed; but even in this version, learning itself still tends to remain a black box. Knowledge and learning are but two important processes that are insufficiently understood and incorporated in the conceptual frameworks. Other important processes that need further investigation are those of the dynamics of a system and how these come about, or power aspects and their influence on a system.[77] According to Miettinen, these issues cannot be resolved unless we study the interactions between people, i.e. the micro-level of analysis, understanding the nature and quality of these interactions in regard to some particular key technology or social practice, instead of constructing comprehensive holistic, explanatory system models[78]: what was learned, how, by whom and at what level of work or organization.

Other important processes which are weakly or only implicitly treated are diffusion and competition. While diffusion of knowledge is emphasized in most approaches, it is primarily the diffusion of innovative products and services that generate economic growth, at least in

[74] Miettinen (2002)

[75] Archibugi & Howells (1999:5)

[76] Archibugi & Howells (1999)

[77] Lundvall et al. (2002)

[78] Miettinen (2002)

the short term. Although recognized, these processes of diffusion are poorly treated (with some exceptions, e.g. technological systems). In addition, innovation-system approaches concentrate on internal mechanisms of complementarities, possibly as a reaction to competitive analysis[79], which more or less neglects these relations. However, neglecting competitive relations (regarding inputs, e.g. personnel, as well as outputs) may be dangerous. To exemplify, no matter how well an innovation system functions, it might never take off into self-sustained growth if there are other, more competitive innovation systems elsewhere.

2.3.3 Weak treatment of important areas

Related to the weak treatment of important processes is a sometimes insufficient treatment of important aspects or areas of an innovation system.

The role of entrepreneurship is often mentioned, but not as often investigated in depth, in spite of its importance for the development of new sectors. There is a vast literature on entrepreneurship, spin-offs etc. but little has been incorporated in the IS literature. The same goes for how investments influence systems and, for example, what impact long-term versus short-term funding has on an Innovation System.[80] Archibugi & Howells (1999) also note that much of the discussion which indirectly refers to firm-level action considers individual firms as simply reacting to changes that are occurring within the wider system, or within the more specific network or institutional level. There has been little discussion about firm behavior and technology strategy in terms of their relationship to systems of innovation approaches, even though firms represent important actors within the innovation system. This may, however, be dependent on the level of analysis chosen, and exceptions also include for example Carlsson & Stankiewicz (1995) who make studies on this level and do consider the issue of individual firm behavior in their outline of a technology system.

In the IS literature, as elsewhere, there is also a disproportional interest in high-tech sectors at the expense of more “low-tech” sectors, although the latter often may contribute to a more substantial part of the economy. Also, the service sector of economy has been increasing in the West, but for the most part IS literature is still directed toward the manufacturing sector. In for example mobile Internet, a large proportion is constituted by service providers whose patterns of interaction and innovation processes may be different from those in manufacturing industries. With some exceptions this is, however, an area that has been insufficiently treated.

2.3.4 The micro-macro gap

While innovation is a phenomenon much associated with the micro-level, much of the system-oriented literature focuses on macro-levels and the structures and different allocation perspectives tied to innovation. But analysis of innovation, and what characterizes it, also needs to look closer at the micro-level. It demands a view of both and a bridge between them, but currently there is little consensus as to what this micro-macro bridge would look like.[81] There is no well-articulated or verified framework linking institutional arrangement to technological and economic performance. The absence of a unified theory that relates innovation to growth and distribution and links macro-approaches to the micro-level has slowed the application of innovation theory to policy areas.[82] Perhaps the biggest task that remains in the development of the innovation-systems approach lies in providing better linkage between the more aggregate, macro-level studies and the micro-level analysis of firm

[79] E.g. Porter (1980)

[80] Patel & Pavitt (1994) being one exception.

[81] Hauknes (2002)

[82] Mytelka & Smith (2002)

relationships and behavior. In terms of the conceptual framework of the approach, it is at this meta-level that the role of institutions and wider organizational networks is crucial, and where further empirical work beckons.[83]

2.3.5 Ability to operationalize

Turning the different analytical frameworks into practically useful instruments has so far turned out to be problematic. One of the reasons is, as discussed above, conceptual vagueness. The larger the aggregate, the more difficult it is to define the actors or nodes and thus to analyze the quality of their interactions. On the other hand, when setting out to refine taxonomies, broadening and deepening the concept at the same time, as well as making it more dynamic, it soon becomes far too complex to make a useful policy instrument out of it, to say the least. This may be more applicable to the approaches aiming at systematizing and measuring all factors essential for innovation. The more moderate and comparative studies[84] may be more fruitful as they measure the differences of innovation-related institutions and their interactions, and seek to learn the results, keeping in mind the significant historical (and geographical) differences between nations and between different fields of technology and industry.[85] In doing this, many of the approaches have singled out a couple of components on which they have come to focus; however, the emphasis and arguments for the most important ones differ. One possible solution may be to make use of the different levels of analysis of the different approaches, using studies on higher levels of aggregation to find indicators from which studies on lower levels of aggregation can focus, instead of defining all the determinants of innovation.

Similarly, the lack of new measurement tools has also limited the translation into effective policy instruments, as some of the central mechanisms or phenomena postulated cannot be studied with the traditional data and methods used in economics. The tendency, therefore, has been to recreate linearity in formal models and to rely on the indicators used by more conventional approaches. Thus, attempts to operationalize, for example, the distribution power of innovation systems, i.e. "the proportion of knowledge ready for distribution", use output measures such as publications and patents that are common to other approaches, and measure the absorptive capacities of firms, as elsewhere, by quantitative indicators such as the amount of in-house R&D (in value or numbers of scientific and technical employment) and the cost of licensing. There are also problems capturing the dynamics emphasized in many approaches. Thus far, the empirical emphasis in the studies carried out is mainly on statics or comparative statics. This is due to the size and complexity of the system and, therefore, the number of linkages among components at lower levels of aggregation[86], as well as the incomplete character of the formal synthesis of some approaches.[87] For an immature system (if one may even call it a "system") the measurement problems are even greater. Some studies have, however, tried to solve them by applying more qualitative methods, describing the developments of different areas.

The traditional methodologies often relied upon can, nonetheless, be used for many purposes. While that is true, it is important to remember that these are not without problems themselves. On a country level, for example, international comparisons of inputs to basic research in universities and related institutions are particularly difficult, given the often arbitrary nature

[83] Archibugi & Howells (1999)

[84] See e.g. Nelson (1993)

[85] Miettinen (2002)

[86] Carlsson et al (2002)

[87] Lundvall et al. (2002)

of the distinction made in statistical practice between research and teaching, and because of the sometimes different academic and institutional structures in countries.[88] These problems are not insurmountable but need to be noticed in order to avoid biases.

In the literature, the issue has also been raised that IS, so far, mainly has been used as an ex-post rather than as an ex-ante concept.[89] It has been largely a descriptive, a posteriori, science to date, offering little predictive value. This critique, however, hinges upon what one believes a social science can do. It can never be predictive in the sense of the natural sciences.[90] The critique thus relates to the previous system discussion and seems to be based on an immanent dream of determining the determinants, and then controlling these in order to set the direction for the future. However, one can learn from descriptive, ex-post studies and apply these lessons to future decisions, and this is certainly done. Another way to look at it is, instead, as in Triple Helix, where the analytical drivers are no longer conceptualized as ex-ante causes, but in terms of expectations that can be evaluated only ex post.[91] Using the evolutionary perspective, the ex-post evaluation criterion is selection which is structure-determined. It could, however, be argued that the unit of analysis can itself change selection structure through its expectations, something not encompassed in the evolutionary perspective.

2.3.6 Conclusion

To conclude, it may be said that although the Innovation System approaches are problematic in some ways, they may still serve their purpose of providing a conceptual framework from which one might gain better insights into the developments of certain areas. However, although better definitions and a better taxonomy could be useful, further research might be better off by not reducing systems further, that is, broadening and deepening at the same time with the immanent dream of a central planning function. There are some parts of a system that can be consciously organized, while others evolve spontaneously either on the basis of that consciously designed system or independently of it.

Further research may benefit by focusing on the shaping of the dynamics of innovation and technological systems. Moreover, additional attention should be paid to other sectors of the economy than the high-tech sectors – that is, the increasingly important service sectors as well as low-tech sectors, since they make up large parts of the economy, and while the processes and systems of innovation may be different there. Along with this, there are also neglected areas such as the role of infrastructure in innovation systems that could be more closely investigated. From a theoretical point of view, perhaps more important is to try to integrate the Innovation System literature with growth theory and also to link the different innovation-system concepts to each other.

2.4 The innovation-system approach proposed here

The review in the previous sections suggests that applying aspects of sectoral/technological systems is quite natural given our focus on the telecommunications sector. In the following we will describe what aspects we will make use of, and how we will make use of them as part of our analytical framework.

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[88] Patel & Pavitt (1994)

[89] E.g. Archibugi & Howells (1999)

[90] E.g. Flyvbjerg (2001)

[91] Etzkowitz & Leydesdorff (2000)

2.4.1 System boundaries

The boundaries can be defined either spatially/geographically or sectorally/technologically[92]. The spatial one is fairly straightforward; at least when it comes to nations, since the boundaries of a nation are well-defined. In practice, there are still problems, especially when it comes to which actors to include in the innovation system. Foreign firms investing in R&D are naturally part of e.g. a Swedish innovation system, although the economic returns are partly appropriated elsewhere. Similarly, foreign activities of Swedish firms will influence the performance of the system. Thus both actors in Sweden and Swedish actors active abroad will influence the innovation system and may or should be considered in an innovation-system analysis. Both aspects will be considered in this report, depending on which subsector is analyzed and what data are available.

The technological/sectoral boundaries delimit the systems to specific technological fields or product areas. The technological-systems approach defines the systems in terms of the technical knowledge base used. However most of their case studies are in fact implicitly defined by the product area boundaries. Some studies do take an explicit knowledge-base delimitation approach[93], also identifying the severe methodological difficulties involved. This is one of the reasons why we will not use the knowledge approach in this study. The other reason, of course, is that the Swedish telecommunications sector is – a sector. According to Breschi and Malerba 1997:131) a sector is a group of firms active in developing and marketing a sector's products and in generating and utilizing a sector's technologies. This definition is somewhat tautological and, as mentioned by Edquist (2003:9), it is not self-evident what a sector is; its boundaries are partly arbitrary and partly a theoretical construction. Thus we have to be pragmatic, using definitions made in other studies, in classification systems and databases.

2.4.2 Innovation

Innovation is defined by inventions with some economic significance (e.g. which have been produced and commercialized). The inventions dealt with here are primarily technical, if not stated otherwise. Inventions are defined as improvements in technical systems; i.e. there can be product, process or service innovation. Innovation is sometimes used also to describe the process leading up to an innovation (as described above), but can instead and more logically be labeled – an innovation process.

2.4.3 System functionality and components

Regarding the system as such, it is important to note from the outset that we do not follow the line of literature implying a causality that can be planned and coordinated in a centralized way. Our view of the term "system" in no sense denotes any kind of determinism, but rather relates to the systemic effects in the form of more or less strong interdependencies between the components of a system. Thus, the different components are to varying degrees dependent on the properties and behavior of at least one other component and cannot be separated analytically. In some phases intentional actions may be more successful in shaping the directions of technological change than in others, one example being in the formation states of a system. Moreover, we are dealing with rather loosely coupled systems that can be said to remain in transition.

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[92] In addition IS can be functionally delimited (Edquist 2003:7). The functional dimension will be further discussed in the next section.

[93] E.g. Holmén (2001)

Important components in the systems include, in general terms, technical systems, actors/organizations, knowledge, institutions, and relations. Technologically innovative activity aims at improving products/processes/services, and these need to be outlined and understood. We hereby label such systems *technical systems*. The innovation systems are defined by, and to a large extent held together by, these technical systems; this is especially so for large infrastructural ones. It is primarily through the functions (and the improvement of functionality) of these systems that economic growth is generated.[94] A secondary, but very important, effect is that supplying, operating and, not least, improving these systems is an important economic activity.

Organizations are defined in line with Edquist and Johnsson (1997:47) as formal structures that are consciously created and have an explicit purpose. Organizations may be firms, universities, research institutes, standard-setting agencies, regulatory bodies, venture capitalists and other investors etc. Organizations are a subset of the broader term *actors*, which also includes individuals and groups of individuals. Of particular importance in emerging systems are prime movers or systems builders, i.e. an actor or set of actors so powerful that it can strongly influence the innovation process. Institutions are regarded in line with e.g. North (1990) and Edquist and Johnsson (1997:46) as habits, routines, rules or laws that regulate the relations and interactions between actors. The role of institutions varies with respect to what function they play; some influence the connectivity of the system, whereas others influence the incentive structure or structure of demand.[95] Given its prominent influence on the dynamics of the sector, the regulatory framework (the regulators and the regulation they impose on the sector) needs to be recognized specifically. Standards are also recognized specifically, as sets of technical specifications adhered to by a producer, either tacitly or as a result of a formal agreement or in conformity with regulatory authorities.[96] *Relationships* are links between components, the actors, involving technical links in the case of technical systems, market and non-market links in the case of actors, including feedback links, which are what make the systems dynamic. Networks are sets of such links. These are important channels for transfer of knowledge, for the identification of problems and the development. Networks increase the resource base of individual actors.[97]

Lastly, to include "all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations" is not feasible. In fact, as Edquist (2003:10) puts it, it is an unresolved 'catch-22' problem for innovation systems theory. Thus we will limit ourselves to the most important factors, and will do so according to our own and others' judgment.

2.4.4 Analytical framework

Systems can in general be described by their functions, both as a whole and for the various subsystems or parts. For innovation systems, however, this functionality is often rather vaguely defined. As a starting point we define the overall function of the innovation system as being to develop/generate, diffuse and use innovations.[98] But as the function of the innovation system is broad and vague, the division into sub-functions becomes a difficult venture, and indeed there are different ways to conduct that classification. The most obvious way is of course to begin with the functions of (a) developing/generating, (b) diffusing, and (c) using innovations.

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[94] See e.g. Lindmark (2002)

[95] Jacobsson and Bergek (2000)

[96] David and Steinmueller (1994)

[97] Jacobsson and Bergek (forthcoming)

[98] In line with e.g. Edquist (2003:5) and Carlson et al. (2002)

On a more detailed level, Jacobsson and Bergek (forthcoming) suggest, on the basis of an extensive review of the literature, that five basic interdependent functions need to be served in a technological system. The first is (i) the creation and diffusion of *"new" knowledge*. Possible sources may be R&D, identification of problems, search and experimentation, learning-by-doing/using and imitation. The second is (ii) *the guidance of the direction of search* among users and suppliers of technology. This function includes guidance with respect both to the growth potential of a new technology and to the choice of the specific design approaches (e.g. standards). It also includes the supply of incentives for actors to engage in innovative work, i.e. companies must feel that they get a reasonable return on investments. Thirdly we have (iii) the function of *supply of resources* such as capital and competencies. The fourth concerns (iv) the *creation of positive external economies*, both market- and non-market-mediated. It involves the facilitation of information and knowledge exchange, and is aided by connectivity between different actors in the system and the feedback loops between them. Finally, the fifth function is (v) *the creation of markets*. Since innovations rarely find ready-made markets, these may require stimulation or even creation. This process may be affected by governmental actions to remove legislative obstacles, by various organizations' measures to legitimize the technology, and by incentives.

After scrutiny of these functions, and familiarization with the innovation systems in the empirical cases, it was found that one essential function seemed to be missing, namely (vi) *providing incentives for innovative activity*. These incentives could be financial (e.g. tax reductions, loans), related to appropriability conditions (IPR, revenue sharing among actors). Expectations are also an important incentive for innovative activity.[99]

These six functions are unlikely to be exhaustive, but can serve as a useful basis for analysis from which the different *inducement* and *blocking mechanisms* may be related and derived, helping to explain the development of the sector studied. For a new technology to be developed and diffused, and for a supporting industry to evolve, all functions need to be served to some degree. Whether or not this happens depends on inducement and blocking mechanisms. Both kinds of mechanisms can be related to the components of the system described above, and the same actor may simultaneously act in both an inducive and a blocking manner. A government policy, for example, may spur some activities in a sector or its parts, while unintentionally hindering others. Inducement mechanisms can, for instance, come from development and marketing efforts of firms, changes in relative prices, feedback from early users, formation of standards or regulation, or policy intervention in the form of reduced taxes or intellectual property rights. Blocking mechanisms can arise from actors' poorly articulated demand, local search processes limited to existing knowledge bases, increasing returns to adoption of established technology, and market control by incumbents. They may also be the results of poor connectivity, or too strong connectivity, in networks, or institutional inadequacies like legislative obstacles, failures in the education system and underdeveloped organizational power of new entrants.[100]

2.4.5 Functional dynamics

According to Bergek (2002), the study of functions has the advantage of capturing the dynamics of the system, for instance by drawing successive maps of how the functions are serviced, or by examining feedback loops in the system. However, it is important to keep in

[99] Late in the course of the project, it was found in discussions with S. Jacobsson that he also had identified a missing function, namely the identification and exploitation of new combinations, i.e. to what extent new and existing firms innovate and/or develop new applications, or how strong the entrepreneurial function is (Carlsson and Jacobsson, 2004).

[100] Bergek (2002)

mind that different functions are likely to play different roles and their relative importance differs between phases of the development of a system. In the literature on product/industry life cycles[101] it is commonplace to identify a number of phases which differ in terms of market growth, character of technological change, entry and exit patterns of firms etc. For the sake of simplicity we identify the following phases: (1) the formation or birth phase, (2) growth phase, (3) maturity phase and (4) a decline phase. For innovation-system approaches, the early phases have been most interesting to study.

In the formative period, the literature has emphasized the existence of competing technological solutions, limited markets, many entries, high uncertainty in terms of technologies, markets and regulation. Jacobsson and Bergek (forthcoming) point at the need to go beyond these features in order to understand how the constituent components of the innovations systems emerge and functions gain strength. They emphasize four features of that process: (1) market formation, (2) entry of organizations, (3) institutional change and (4) the formation of technology-specific advocacy coalitions.

Market formation involves the processes of subsequently entering new segments or applications, in which the new technology is superior in some respect and thus constitutes a protected space for the innovation system to develop. Here learning processes can take place, technology be improved and customer preferences be formed, and subsequently new segments can be penetrated.[102] In addition, these niches generate a space where elements fall into place, in particular firms entering and filling gaps in the innovation system, and bringing in new knowledge. In addition, new entrants may raise the returns for subsequent entrants. Such external economies may come in the form of information flows in networks, increased availability of complementary resources, including legal and accounting services, in turn attracting new firms and capital. Through these processes the technology becomes increasingly legitimized.[103]

Finally it should be noted that the development and formation of well-functioning innovation systems take time, often several decades. The process may be particularly difficult if the new system has to compete with an existing one, since all components (institutions, markets, resource bases of incumbent firms, and networks) and functions may be biased towards the old incumbent technology.

2.5 Summary

The development of innovation theory over the past decades has involved a major reformulation. The simplistic linear models that dominated after WW2 were gradually called into question by empirical evidence, and in the 1970s alternative models emerged that took for example learning, relations, and systemic aspects into account. In the 80s and 90s more systems-oriented models emerged. Being developed in cooperation with policy-makers in the OECD and EU, they also received increasing attention within these circles.

Most of the Innovation System approaches have the concepts of innovation and system in common, although their interpretations differ. Regarding innovation, the difference refers to whether only technical innovations are considered, or also organizational and institutional innovations. Another difference is whether it is only the generation, or also the subsequent

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[101] See e.g. Levitt (1965), Polli and Cook (1969), Mueller and Tilton (1969), Abernathy and Utterback (1978) Porter (1980), Kotler (1991), Tushman et al. (1997) and Klepper (1997)

[102] See e.g. Christensen (1997) and Levinthal (1998)

[103] Jacobsson and Bergek (forthcoming)

diffusion, adoption, and utilization that is focused upon. Regarding systems, the approaches primarily differ in what is meant by a system, and what the included components are. Usually, the term “system” denotes that there are strong interdependencies between the components, thus making it important to look at the whole and not only the parts to find the determinants of innovation. The degree to which this system is regarded as consciously designed or spontaneously evolved also differs. As for the components included, these are often actors like firms, universities, institutions, networks and markets, with emphasis differing among the approaches.

Apart from this, the levels of aggregation on which studies are made differ among the approaches. In the National Innovation Systems approaches, emphasis is often on firms, and they are, as the name implies, concerned with higher levels of aggregation. The Triple Helix model is more concerned with “the new knowledge economy”, and thus focuses on universities. The level of aggregation is not specified, but it often relates to regional economies. Technological Systems and Sectoral Innovation System emphasize knowledge bases, technologies, and sectors, which also set the boundary of the system. The levels of aggregation studied are often below national levels, sometimes coming down to departments or individuals. Regional Innovation Systems and Networks, finally, are not a homogeneous set of approaches. Nonetheless, these approaches tend generally to put greater emphasis on networks and sociological aspects than the other approaches, and studies are often conducted on somewhat lower levels of aggregation.

The IS approaches, however, are not free from criticism and problems. The approaches have been criticized for being vague in definitions and concepts, for weak treatment of important processes like learning etc., for an overly focus on high-tech sectors, and thus neglect of low-tech and service sectors. There are also some problems operationalizing, for example, the shaping of the dynamics in systems, leading at times to a reliance on old measures and a tendency to recreate linearity. The most pertinent problem, though, is to align IS with growth theory, as it presently is more of a conceptual framework.

While there are some problems with the conceptual frameworks, they still serve as useful analytical frameworks in order to generate a greater understanding of what drives innovation, and thus growth. Further research could improve on their detailed understanding, as well as linking the different, complementary approaches to each other.

For the purposes of this study, we propose a sectoral/technological systems approach, including also a national dimension. This is natural, given our focus on the telecommunications sector. Still, drawing the boundaries is fraught with difficulties. It is not self-evident what a sector is; the boundaries are partly arbitrary and partly a theoretical construction. Neither is it evident what constitutes the national aspect. Thus we have to be pragmatic, using definitions made in other studies, in classification systems and in databases.

Innovation is defined by inventions with some economic significance (e.g. that they have been produced and commercialized). The inventions dealt with here are primarily technical, if not stated otherwise. Important components in the systems include, in general terms, technical systems, actors/organizations, knowledge, institutions, and relations.

As a starting point we define the overall function of the innovation system as being to develop/generate, diffuse and use innovations. This functionality is deemed to be too broad and vague. Therefore an analytical framework is proposed. It is adapted from and draws heavily on the works of Staffan Jacobsson and Anna Bergek.[104] Six basic interdependent functions need to be served in a technological system. The first is (i) the creation and diffusion of *"new" knowledge*. Possible sources may be R&D, identification of problems, search and experimentation, learning-by-doing/using and imitation. The second is (ii) *the guidance of the direction of search* among users and suppliers of technology. This function includes guidance with respect both to the growth potential of a new technology and to the choice of the specific design approaches (e.g. standards). Thirdly, it is necessary (iii) to *supply incentives* for the actors to engage in innovative activity. These incentives could be financial (e.g. tax reductions, loans), related to appropriability conditions (IPR, revenue sharing among actors). Expectations are also an important incentive for innovative activity. Fourth, we have (iv) the function of *supply of resources* such as capital and competencies. The fifth function concerns (v) the *creation of networks and other sources of positive external economies*, both market- and non-market-mediated. It involves the facilitation of information and knowledge exchange, and is aided by connectivity between different actors in the system and the feedback loops between them. Finally, the sixth (vi) is *the creation of markets*. Since innovations rarely find ready-made markets, these may be require stimulation or even creation. This process may be affected by governmental actions to remove legislative obstacles, by various organizations' measures to legitimize the technology, and by incentives.

For a new technology to be developed and diffused, and for a supporting industry to evolve, all functions need to be served to some degree. Whether or not this happens depends on inducement and blocking mechanisms. Received literature suggests that such an approach is most useful in the early stages of the evolution of innovation systems, i.e. the formative and growth phases. Four features of that process has been emphasized: (1) market formation, (2) entry of organizations, (3) institutional change and (4) the formation of technology-specific advocacy coalitions.

This framework will be applied to the state and dynamics of the some of the subsectors, namely fiber optics, data communications, mobile telephony and mobile data. It must be pointed out, however, that the choice of analytical framework was made quite late in the project, and therefore the analysis will be delimited in the sense that empirical material was gathered without having this framework in mind.

[104] E.g. Jacobsson and Bergek (forthcoming), Bergek (2002)

3 EVOLUTION OF TELECOMMUNICATIONS

The purpose of this chapter is to survey the most important international developments and trends in telecommunications and to map and preliminarily analyze those developments.[105] While interesting in itself, this overview also provides a setting for the investigation of the Swedish telecommunications sector and its innovation system (Chapter 4), as well as for the subsequent chapters (6-**Error! Reference source not found.**). Section 3.1 therefore introduces the sector, some basic definitions, the underlying technology and the main actor categories. Section 3.2 gives the background by describing the evolution the sector until 1970. Section 3.3 summarizes key features at the point of departure – the PTT regime of the early 1970s. Section 3.4 investigates a number of interrelated key trends between 1970 and the early 2000s. Section 3.5 analyzes the recent downturn in telecommunications, its driving forces and consequences, including some speculations into the future. Section 3.6 summarizes and concludes the chapter.

3.1 Introduction to telecommunications

The delineation of the sectoral innovation system will depend on the characteristics of the technical systems, as mentioned in Chapter 2.[106] This section will introduce some general definitions and basic features of telecommunications, telephone and datacom systems, terminals and services, fixed and mobile.

3.1.1 Definitions

Telecommunication is defined simply as communicating at a distance, as the word implies. Telecommunications usually refer to the underlying technology or, as defined by ITU (2000), "Any transmission, emission or reception of signs, signals, writing, images and sounds or intelligence of any nature by wire, radio, optical or other electromagnetic systems". This definition applies to at least two different kinds of communicating at a distance, traditional telecommunications and broadcasting. These are usually separated from each other. *Broadcasting* implies some kind of one-to-many, one-way communication, i.e. simultaneous transmission from one sender to a number of receivers. Broadcasting usually refers to radio or television broadcasting.[107] This report focuses on two-way communications (between two parties), not on broadcasting.

The most common form of telecommunication is *telephony*, which refers to speech communication, associated with the functions of the public switched telephone network (PSTN). This means the use of telephone numbers in order to obtain a temporary connection over this public network. In the following we will distinguish between telephony and the more general concept of speech telecommunications. Data communication is here defined as non-voice two-way communications.

Radio communication can be defined as telecommunications by means of radio waves, or "a method of communicating over a distance by modulating and radiating electromagnetic waves".[108] *Mobile communications* usually refer to telecommunications where the customer

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[105] This chapter has been written by Sven Lindmark.

[106] See also Lundgren (1995) and Lindmark (2002)

[107] In Internet a number of intermediate forms have emerged such as "multicasting", "anycasting" and "unicasting".

[108] Langley (1986). In everyday language "radio" often refers to what is actually a radio receiver/transmitter or the programs of radio broadcasting.

access, i.e. the first communication link, uses radio transmission, thus making the user "mobile" also while communicating and not restricted by a fixed communications station.[109]

3.1.2 Telecommunications basics

The global telecommunications network is probably the largest and most complex technical system that man has ever created. For the purpose of this report it is therefore necessary to bring some clarity to its structure and main features.[110]

Telecommunications networks are mainly composed of nodes (switches, routers etc.) and links (cables, radio links, etc.), and terminals (telephones, data terminals, etc.) connected to the network (see Figure 3-1). The *switches* provide the function of establishing a connection from a desired inlet to a desired outlet within a set of inlets and outlets for as long as is required for the transfer of information. Switches must be capable of handling all service categories described below.

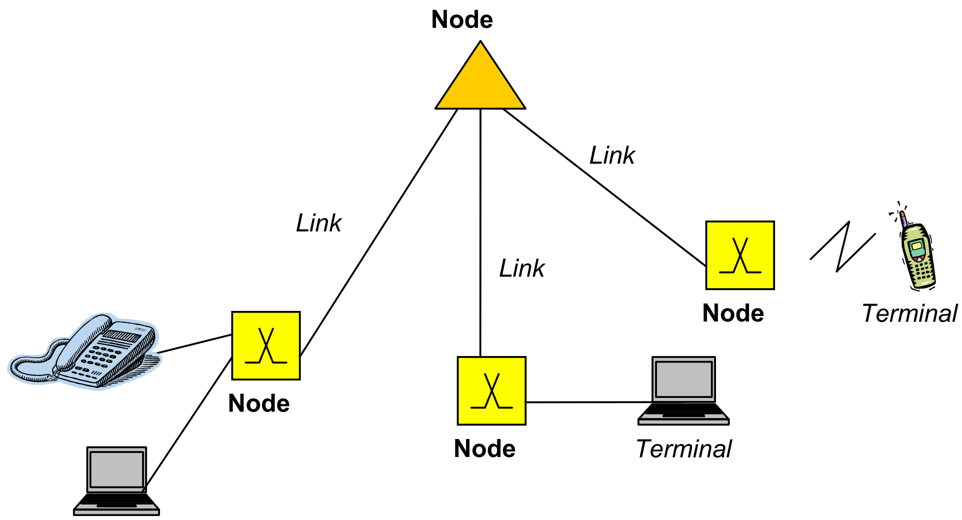

Figure 3-1 Main components of a telecommunications system

Source: Adapted from Ericsson and Telia (1997:22)

Traditional switches are circuit-switched, which essentially means that a dedicated connection is established between two terminals. Demands posed by data communication have led to new types of switching, i.e. packet-mode switching and cell switching (including ATM – Asynchronous Transfer Mode). In business networks, yet other techniques are used, such as distributed packet switching by means of buses and rings (e.g. Ethernet[111] and Token ring) and the fiber-distributed data interface (FDDI) standard.

A switching system can roughly be divided into two functional units: (1) the switch unit which performs the actual connection between two lines, and (2) the control unit which issues commands to control the switch. Different generations may accordingly be classified by the techniques used to perform these functions. The control function may be direct or indirect, the

[109] Or rather more mobile than if she/he were attached to a fixed network by wire.

[110] This section draws heavily on Ericsson and Telia (1997)

[111] It should be pointed out that Ethernet is not limited to business networks only.

indirect control requiring some kind of memory.[112] For packet switching, the switching node is often labeled – router. A substantial part of the node functionality today is implemented by software.

Throughout most of their history, telecommunications networks have used a network hierarchy, although originally local exchanges were connected in a mesh structure. Operators usually use four or five levels, ranging from the international level to local exchanges. In most cases, packet-switched networks (as well as other non-circuit-switched techniques such as frame-relay and ATM) do not have the same hierarchical structure. After the equipment is connected in a concentrator, the connection leads to a more or less mesh-shaped transit network. Relatively large networks may be built with no hierarchy. However, with increasing traffic and Quality of Service demands, it is likely that also very large packet-switched networks such as the Internet will use some kind of hierarchy.

Three major categories of *transmission* media are used for transmission in the links of the networks. These are: (1) copper (paired cable and coaxial cable), (2) optical glass fiber, and (3) radio waves which are used in terrestrial point-to-point systems or area coverage systems (cordless, WLAN, mobile telephony etc.) and for point-to-point or area coverage communication via satellite. Optical systems have advantages in terms of capacity, quality and economy (see further Chapter 5). Copper-based systems are able to keep up only over the very last section – to the residential subscriber – where the need for capacity has been small so far, although a large installed base of copper lines is kept for economic reasons. For the same reason, coaxial cables are still used between exchanges although in recent years their main use has been for cable TV.

Information is transmitted over carriers. By allowing the transferred information to manipulate a carrier in some way (e.g., by turning light waves on and off, or altering the frequency or amplitude of radio waves etc.) the information can be detected by a receiving exchange or terminal. This manipulation of the carrier is called modulation (for which there are several techniques, e.g. shifting the amplitude, frequency or phase of signals). If the carrier wave is modulated into discrete signals, the system is usually labeled "digital", while if modulated continuously and variably it is labeled "analog". Expressed differently, analog signals may have any value at any time, while digital signals are described by a limited series of numbers specifying the signal strength in time. One advantage of digital signals is that they can be regenerated, i.e. information signals distorted due to attenuation are read and interpreted, and recreated and amplified to their original appearance before they are forwarded. This makes noise and other disturbances disappear. This is not the case with analog transmission where disturbances are amplified as well.

Carriers are exclusively analog in nature in the sense that they carry waves of some kind, light waves or electromagnetic waves. The GSM system is representative of the combination of digital information on an analog carrier, since the voice coder is placed in the mobile telephone. In ordinary fixed telephony, the voice coder is usually located in the local exchange or in the access node. As noted by Bekkers and Smits (1998), the distinction between analog and digital communication is surprisingly vague considering how frequently the terms are used.[113]

[112] Bohlin (1995), based on Granstrand and Sjölander (1990), provides an illustrative systematization of transitions in switching.

[113] Bekkers and Smits (1998:98-99). See also Langley (1986) and Calhoun (1988).

Multiplexing is a technique for transmitting several "calls" on the same physical connection (such as a wire pair) used in both analog and digital networks. There are many techniques for achieving this, including (1) frequency division multiplexing (FDM), (2) time division multiplexing (TDM), and (3) wavelength division multiplexing (WDM), the last being used mainly for optical-fiber transmission.

The network is usually divided into the *transport* (or trunk) network and the *access* network, where the trunk network is composed of multiplexed channels that connect the switching nodes while the access network links the switching nodes to the user terminals. The transport network, during the time period studied, has been both digitized and increasingly composed of optical fibers. The access network, which is also known as a subscriber network and local network (or local loop), accounts for about 50% of the investments in telecommunications networks. In recent years a vast number of technologies have been used, ranging from copper pairs, CATV coaxial, and optical fiber to radio.

A number of basic *services* are delivered over the network, e.g. voice, data and video transmission. Telecommunications networks were for many decades optimized to the telephony service (which is a special category of voice services). In recent decades new bearer networks have come into being alongside the telephone network, mainly as a result of the growth of data communication services (including multimedia services) and mobile services which pose differing demands on a communications network than do telephony. To exemplify: telephony tolerates relatively poor transmission quality because of the redundancy built into natural language and speech. In addition, the people engaged in a telephone conversation can easily overcome temporary disturbances and interruptions. Delays on the other hand must be kept below a certain value. Much data traffic, by contrast, is relatively insensitive to delay (within reasonable limits) whereas poor transmission quality can cause bit errors and, as a result, worthless information. Because reliable transmission is so important, mechanisms have been introduced which will guarantee error-free transfer of information. Another difference is that telephony generates a relatively continuous stream of information, while data traffic is more intermittent (or bursty). During a telephone call, most of the capacity is used for transfer of "useful" information, while a line for data traffic might not be efficiently utilized even when traffic is formally in progress.

These differences, in terms of the performance demands posed on the network, have led to differing technical solutions. For instance, networks carrying telephony (with a few exceptions) are circuit-switched, in the sense that connection between subscribers who want to come into contact with each other are set up and remain established throughout the call, irrespective of whether users speak with each other or not, and there is no chance of any other subscriber using that particular accessible capacity. Packet switching has been developed to expand the degree of utilization in data networks when traffic sources (computers) are only sending scattered information. Each data traffic packet has an address that controls the switching process in the exchanges (nodes). Some networks, such as B-ISDN/ATM are fully integrated, i.e. designed to handle all kinds of services.

For the network to operate in a way that answers the purpose intended, various functions must be linked so that they interact. This necessitates transfer and exchange of control information, an activity that is called signaling. For communication between the processors of the exchanges, there is special *signaling* equipment that sends and receives signaling information. At the user end, some parts of the signaling is actually still performed by the users, i.e. when we pick up the handset, dial a number and hang up. The most widely used signaling system of today is SS7. In packet-switched networks, signaling information is transferred in an address label in each data packet. The information in the label is analyzed in each node, which enables the data packet to be routed through the network.

Terminals constitute the “last” nodes in the networks (i.e. they terminate the network). Terminals include telephones, pay phones, faxes, mobile phones, computers, etc. The terminal often has some interface (input/output) device through which a user can communicate with the terminal and the network. This communication includes both control information and the information to be communicated over the network.

Another important distinction is between public and private networks. A private network is restricted to a dedicated user group, e.g. a company, while a public network can be accessed by anyone (usually after acquiring a subscription).

3.1.3 Identification of subsectors (segments)

As mentioned in Chapter 1, this project has chosen to divide the telecommunications sector into four subsectors (or segments). These are:

- Traditional telecom – voice telephony (POTS)
- Mobile telephony
- Data communications
- Mobile data communications

This delineation has been made primarily with a growth and innovation rationale in mind. In the early 1970s, telecommunications were dominated (>95%) by *fixed telephony*, i.e. POTS (Plain Old Telephone Services). Already back then, POTS was a maturing application in some advanced countries. Approaching the later part of the time period studied, it was even declining in the sense that both the number of subscribers (users) and revenues were falling in e.g. OECD countries. Still, it has been the dominant application throughout the period studied, and a flow of radical and incremental innovations has improved its functionality and lowered the costs so that it has become almost a universal service.

Mobile telephony has been the main growth segment throughout the period (1970-2003), particularly in the last decade. This growth has been propelled by the benefits of mobility and by innovations in technology improving the performance and affordability of terminals and services by orders of magnitude. Mobile telephony has also been particularly important for Sweden, not least through Ericsson’s successful exploitation of the technology in the 1980s and 1990s. Partly, this success can be explained by the formation of an innovation system, where the developments during the 1970s were particularly important. Therefore it is particularly important to ask why and how this could happen, and whether this success can be replicated in some sense.

Data communications, in particular the Internet (a network of networks used for datacom), has been the second growth segment, also driven by rapid technological change and innovations (not only technical ones), although the economic effects of the Internet have yet to match those of mobile telephony. On the supply side, Sweden is lagging in terms of not having a competitive industry. Thus, it is particularly interesting to ask why, and contrast this development with the development of mobile telephony. Another important issue is that data communications open up completely new actor categories and growth segments, displaying different logic and growth dynamics than does the traditional telecommunications sector (including mobile). Adding to these features, the possibilities of supplying voice services over datacom networks mean that the emergence of data communications, and the Internet in particular, has a potentially disruptive effect on the telecommunications industry.

Finally, *mobile data communications* (sometimes labeled mobile Internet) is still in an embryonic phase. There are indications of a very high growth potential, and perhaps mobile data communications constitute the most important growth segment in telecommunications, where the future growth is highly dependent on the innovative capability of the sector at large. Here, the innovative capability of the Swedish innovation systems will determine how competitive our industry will be in the future. The embryonic stage of this segment means that it will be more receptive to policy action, and therefore it is particularly relevant for Vinnova to understand more of its dynamics. Still, mobile data communications has a fairly long history in Sweden, starting with Mobitex in the 1980s, from which much can be learned.

To sum up, four segments have been identified: (1) one dominant but maturing segment (fixed telephony); (2) one revenue growth-generating segment where Sweden has been very successful (mobile telephony); (3) one growth generator (in particular in terms of traffic) with a potentially disruptive effect where Sweden has been less successful (datacom), and (4) the potential future growth market (mobile data). These are illustrated in Figure 3-2.

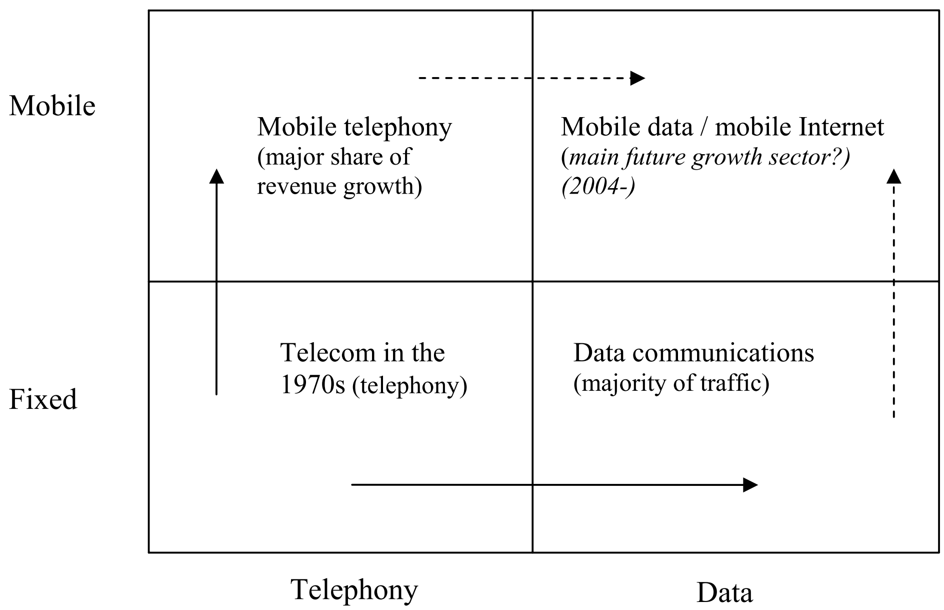

Figure 3-2 Main growth trends in telecom in 1970-2003

Dividing the sector in this way is not without problems. For instance, statistics are often categorized according to other criteria. In addition, the convergence of networks and services makes it difficult to account for the development in a structured manner. Nevertheless, we aim to pursue the analysis according to these assumptions, since it will serve the overall purpose of the project well. Note, however, that the following section of this chapter will not explicitly distinguish the development along these tracks.

3.1.4 Actor and function identification

In this section a preliminary identification of the main components of the innovation system of the telecommunications considerations will be made.

The telecommunications industry has traditionally divided its actors into the following actor categories (thus empirically grounded as the most important actor groups):
- equipment manufacturers (e.g. Ericsson)
- operators (e.g. TeliaSonera)
- standard bodies (e.g. ETSI)
- consultants (e.g. TietoEnator)
- regulators (e.g. PTS)
- distributors/retailers (e.g. GEAB, the phone house)
- end-users/subscribers

These categories, if adapted to a specific subsector, are quite sufficient to describe the actor development of the sector. For the purpose of this report a more innovation system-oriented approach might be called for instead. Based on these traditional demarcations, earlier studies of telecommunications, and the simple definitions of the technical systems provided in Section 3.1.2, we have identified the following actor/functional categories to start with:
- Producers of equipment (networks and network components, terminals and terminal components including the necessary software)
- Users of that equipment
- Distributors/retailers of that equipment
- Producers and users of services that is delivered over that equipment
- Organizations that standardize the equipment and or the services delivered using the equipment (standard bodies)
- Organizations that regulate the production and use of equipment and services (regulators)
- Organizations that help the other actors in providing and using equipment and services (consultants)
- Organizations that provide other necessary resources needed for the above actors (financing, skilled labor etc.)

So far, these actor/functional categories have little to do with innovation. If we define innovations as commercialized technical inventions, and technical inventions as improving the technical systems (in terms of functions, performance and cost), we may identify the following additional actor categories:
- actors that innovate (new/better/less costly equipment and services)
- actors that finance or invest in such innovation activities
- actors that provide education and training necessary for innovative activities

This generic actor/function description must be left open and flexible at this point. It must also be kept in mind that one actor category (or specific actors) may deliver several functions, and vice versa. In addition, new functions may appear and the match between actors and functions may change over time. For instance, in the 1970s, there was no end-user market for telephones, since they were the property of the PTTs as part of the customer premises equipment, and not owned by the end-users themselves. Content development is also a new function that was not relevant when simple telephony was the main service – the content was produced in the telephone conversation. Thus there was no need for content providers – a new actor group. To conclude, the actor categorization used in this report will therefore be based on the one used in industry language.

3.2 Telecom pre-1970s

This section investigates the developments of the sector leading up to the state of industry in the early 1970s – the PTT regime. Although outside the scope of this project, this process will be elaborated on since it is important to know the dynamics leading up to the PTT regime in order to understand the changes of liberalization during 1970-2003.

3.2.1 Technical evolution

Communication at a distance (i.e. telecommunication) has always been a human need, and technologies for improving the fulfillment of that need have progressed along the evolution of humankind.[114] The birth of (electrical) telecommunications technology was marked by the development of telegraphy. Telegraphy, i.e. the use of electrical signals[115] to convey long-distance messages, emerged as a response to user needs and from advances in electrical science and technology during the late 18th and early 19th centuries. As the transportation of goods and people over land and sea improved and became increasingly commercially important, so did the need and means for moving information (postal services also expanded rapidly in the 1800s). Railways, the military, stockbrokers and newspaper agencies are early examples of time-sensitive user groups that demanded faster communication of information.

More or less independent developments in England, Germany, and the United States (by Samuel Morse) led to viable commercial telegraphs in the 1840s, with Morse's system eventually becoming the dominant solution (or dominant design or standard). Local networks were constructed and connected into national inland networks. In the 1880s major parts of the world had been connected through telegraphy networks.

Technically, telegraphy was restricted by a number of factors. The rate of transmission was constrained by the capacity (and supply) of telegraphers and the attenuation of signal strength, as well as difficulties in cable-laying. A number of technical solutions, e.g. mechanical transmitters and receivers and new coding schemes, emerged as responses to these limitations. In spite of its improvements, telegraphy was soon to be more or less outcompeted by another invention – the telephone.

In the 1850s–1870s several inventors (e.g. Reis and later Gray and Bell) worked with developing techniques to transmit voice electrically. In 1876, Bell filed a patent on a technique he had developed to vary an electrical current continuously (with the variations of human speech) by using magnetic induction and, later, variable resistance circuits – the first telephone was invented. A stream of inventions, modifications and improvements, made by more or less independent innovators who set up manufacturing and service companies to exploit these inventions, characterized the development of telephony during the last decades of the 19th century. Well-known examples of entrepreneurs involved in this development were Edison, Bell himself and Lars Magnus Ericsson, founders of General Electric, Bell/AT&T and LM Ericsson respectively.

It should be noted that, although Bell himself had a vision of a large communication network, the applications of the telephone were not clear at this time. It was not clear whether telephony was a two-way communication or broadcasting device. Bell's early systems were one-way systems, and telephony was used for point-to-point private lines, entertainment, education, and news services. Telephony was also viewed by many as a cost-effective

[114] This section draws on Lindmark (2002:130-135) unless otherwise stated.

[115] There were competing alternatives, such as chemical telegraphy.

extension of the telegraphy system. Another common use was dedicated direct lines between two parties. Techno-economic limitations prevented the network from developing for too many purposes, and two-way switched telecommunications eventually prevailed.[116]

Telephony subsequently diffused through the following century, eventually to be available to most households and firms in the industrialized world. This diffusion was enabled by mainly gradual, but sometimes radical, improvements in technology. These improvements can be divided into three broad areas: (1) transmission, (2) switching and (3) signaling.[117] Improvements in *transmission* (and switching) enabled telephony to move from local to long-distance. It was the radical improvements in cabling, the introduction of amplifiers, and the developments of commercially viable automatic switching that allowed linkage of inter-exchange lines (trunks) into long-distance networks. Telephony could then seriously begin outcompeting telegraphy due to its superior functionality.

Multiplexing was another area of improvement in the field of transmission. In the early days of telephony, only one telephone conversation could be carried on a single line, and only for quite short distances. In the 1930s, Frequency Division Multiplex (FDM, i.e. the division of the spectrum into frequency bands of about 4 kHz, each carrying one speech channel which was created by modulating a carrier tone), allowed transmission of several conversations on a single line. Transmission was further improved by the introduction of low-cost repeaters based on vacuum tubes (and later transistors). Improved cabling, in the form of e.g. loading coils, twisted pairs and coaxial cables, further added to improvements in transmission, as did developments of microwave radio and satellite links. Microwave became the dominant transmission medium in the long-distance network in the 1950s and 1960s. The first communication satellites were launched in the early 1960s. The main applications for satellite communications were television broadcasting, intercontinental links, and communications access in sparsely populated regions.

In order to build a network (not just private lines), the need for *switching* arose very soon. The first manual telephone switches (or exchanges) were introduced as early as 1878. Electromechanical switches (e.g. Strowger, rotary and later crossbar) enabled automatic switching to replace manual (which was very uneconomical). The development of transistors and integrated circuits provided a basis for development of stored program control (SPC) and electronic switches, introduced in the late 1960s (treated in more detail in Section 3.4)

Various signals are sent over the telephone network in order to control operations and indicate status. With the introduction of automatic switches, the *signaling* functions also had to be automatic. Early signaling methods employed direct current. Digital transmission was made possible by common-channel signaling, where a separate data link is used for transmitting signaling information. Since signaling controls the entire network, standardization of the signals becomes important, for instance AT&T's signaling system No. 7.

3.2.2 The emergence of an industry

The roots of the structure of the telecom industry of the 1970s can be traced back to the emergence of postal services and telegraphy. In many countries, national postal service providers eventually obtained the rights to provide national telegraphy (after an initial phase of competition in some countries). The reasons for governments to engage in telegraphy were manifold: (1) state security; (2) cross-boarder interconnection; (3) private economic

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[116] See also Bekkers (2001:25).

[117] It should be pointed out that there were other areas of importance along which technology progressed, for instance terminals.

incentives were not deemed enough to make telegraphy widely available, which in turn was deemed important for industrial growth. The idea of universal service also emerged, meaning that telegraphy was considered a public good that should be accessible to all. This could be achieved by monopolies overpricing long-distance and international traffic, subsidizing less economically attractive traffic. The telegraph organizations were large employers. For instance, Western Union, the dominant private telegraph operator, was the largest US corporation of that time. Equipment supply for telegraph networks was often a domestic affair, although in the wireless telegraphy industry internationally powerful suppliers like Marconi emerged later on.[118]

In contrast to the (mostly) state-owned telegraph stations and networks, telephony was initially provided by a number of competing private companies. The business model was a public service based on subscriptions. The Bell company started networks at a rapid rate in the US, initially facing competition from e.g. Western Union. Eventually the patent rights gave Bell a virtual monopoly on the US market. Telephony spread rapidly to Europe as well, first at a local basis. Entrants included Bell, local investors and the telegraph authorities. Customers faced a lack of interconnectivity, partly as a result of technical difficulties, partly because dominant operators prevented it.[119]

Initially, telephony posed little threat to telegraphy, since only local calls were possible. Advancements in transmission and switching technology allowed for long-distance calls, in some countries provided by private operators, in some by the governments. In the beginning of the 20th century, international telephony services were started. By then, telegraph traffic started to stagnate. Its decline was further accelerated with the introduction of Telex in the 1930s.[120]

3.2.3 Establishment of the PTT system

Already in the early 20th century, the telecommunications service industry had developed a structure that would essentially be kept until the liberalization and internationalization starting in the mid-1980s. Around the turn of the century, telephony operations and service provision developed from local competition (with foreign and internationally competing operators) into national monopolies, in most countries. This monopolization was partly due to the economies of scale in operations and network externalities on the demand side. In many countries, national postal and telegraphy service providers (PTs) became increasingly interested in telephony, and eventually obtained a monopoly also on these services (PTTs). One exception was the Bell system in the US, which emerged as a *de facto* monopoly (almost 80 percent market share) consisting of local operating subsidiaries and long-distance company – American Telephone and Telegraph (AT&T). As a rule, the PTTs were government-owned. Governments thus had a dual-role as both monopoly operators and regulators via licenses. Parts of this process are elaborated below.

By the late 19th century governments started to take a greater interest in providing telephony services. Of decisive importance was the fact that they started to build or take over long-distance networks. This interest had its background in a number of considerations, regarding why telephony should be a monopoly and why governments should control this monopoly. The rationales for the monopoly were essentially the following[121]:

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[118] Bekkers (2001:16-20) and Noam (1992:3-22)

[119] Bekkers (2001:25)

[120] Bekkers (2001:26)

[121] Bekkers (2001:27) See also Karlsson (1998:30-31) and Noam (1992, Ch. 5)

- Telephony was considered to be a natural monopoly, i.e. the consideration that only monopolistic firms can achieve financial and societal optimum (because of e.g. economies of scale, network effects, etc.)
- Ensuring compatibility and connectivity (often lacking in case of multiple systems)
- The need for comprehensive long-term planning, which could be achieved only if it was centralized for a whole country
- Circumventing negative external effects (primarily in the form of excessive wiring)
- Ensuring technical integrity
- The claimed poor quality of private networks

The main arguments for nationalization were[122]:
- Profitability was the main argument, since operating telephone networks was a very profitable business. In addition, telephone networks posed a threat to the loss-making telegraph. Until WW II, net profits of telephone operations were used to cover budget deficits.
- The government could provide universal service by means of cross-subsidization.
- Anyway, private monopolies should be prevented. Market competition would lead to price competition, shakeout and mergers, and in the long run private monopolies.

The European countries took different routes to this government monopolization. According to Bekkers (2001:28), the following seems to have been the most common pattern. The governments started to build and operate long-distance networks that interconnected with the private networks. Next, local networks were acquired and/or built up, where such networks did not yet exist. Then, after having gained control over all networks, government secured exclusive rights to exploitation of telephony services through a legal monopoly. These routes are summarized in Table 3-1 for some important markets.

Table 3-1 Early telephone developments in Germany, the UK, France, Netherlands and the US

Country	First initiator	Initial expansion	Intermediate step	Nationalization
Germany	The PTT (Reich-post)	Between rural post offices	Roll-out for private usage, starting in Berlin	Not applicable
UK	Private party (UTC) followed by the Post Office	In larger cities	Government failed in initiative; municipalities to build their own networks	Government acquired the private network in 1911 below real value
France	Private party with concession, strongly regulated	In a dozen larger cities	Government starts building networks in smaller cities and long-distance	Government nationalized private network after license expired in 1889
The Nether-lands	Private parties with concession	In most larger cities	Municipalities take over private networks or build new ones	Government had bought private and municipal network in 1927, except for the largest three which were nationalized in 1940
US	One private party protected by patent	Rapid local and long-distance deployment		Not applicable. Private local monopolies where Bell served 80% of the population

Source: Bekkers (2002:40)

[122] Bekkers (2001:27). See also Carlsson (1998:30-31) and Noam (1992, Ch. 5)

World War I and the depression strongly influenced the development of the telecommunications industry. Rebuilding the telecom systems was costly. New technology, e.g. in the form of extended cabling capacity and automated switches, could reduce costs, but in turn was costly to develop. These increased development costs led to a trend towards supplier industry concentration, moving from small-scale businesses to large telecommunications manufacturers. Following this trend, the PTTs started to become more dependent on a limited number of large equipment manufacturers.

In World War II many telephone networks were destroyed in Europe. Much emphasis was therefore laid on rebuilding the telecom infrastructure. Governments seized the opportunity to build up national supply industries. Formerly separate, post, telegraph and telephone administrations were merged in some countries and achieved tremendous power.[123] According to Noam (1992:22-23) this was partly because they became part of powerful industry-political alliances (the "post-industrial complex" in Noam's terms) comprising the PTTs themselves, their enormous work-force (often the largest employer in a country), trade unions, users, left-wing political parties, national equipment manufacturers, and the newspaper publishing industry (which was subsidized). All actors benefited from their monopolies.

3.2.4 Development of a supplier industry

Much of the supplier industry co-emerged and co-evolved with the PTTs. During the early years, a large number of inventions and improvements were made, often by individual inventors, who formed companies to exploit these inventions. Well-known examples of entrepreneurs were Thomas Alva Edison, Alexander Graham Bell and Lars Magnus Ericsson, founders of General Electric, Bell/AT&T and LM Ericsson respectively. Some telecom suppliers, such as Siemens and Ericsson, could start manufacturing equipment since Bell had not patented the telephone in all countries.

As mentioned above, during the first decades these firms could operate on a relatively small scale. However, as networks became increasingly automated, the infrastructure became more complex, time- and resource-consuming to develop. Only larger companies could bear the costs of R&D, and the supplier industry became increasingly concentrated, also since the PTTs sourced from a few sources only, including national suppliers and foreign subsidiaries. A system of protected national champions emerged (see further below).

3.2.5 Diffusion

Progressive technological development, build-out and investment made telephone networks diffuse, fairly slowly but consistently, through the organizational and residential communities.[124] Still, by the early 1970s, the telephone was not a common good, even in the most advanced markets, i.e. United States and Sweden (see Figure 3-3). In many countries, supply of telephone lines could not match the growing demand, presumably partly due to inefficiencies of the PTTs. Therefore, there were long waiting lists to get a telephone subscription in many advanced countries.

[123] Bekkers (2001:35)

[124] For an investigation of how the telephone diffused in the US see Fischer (1992)

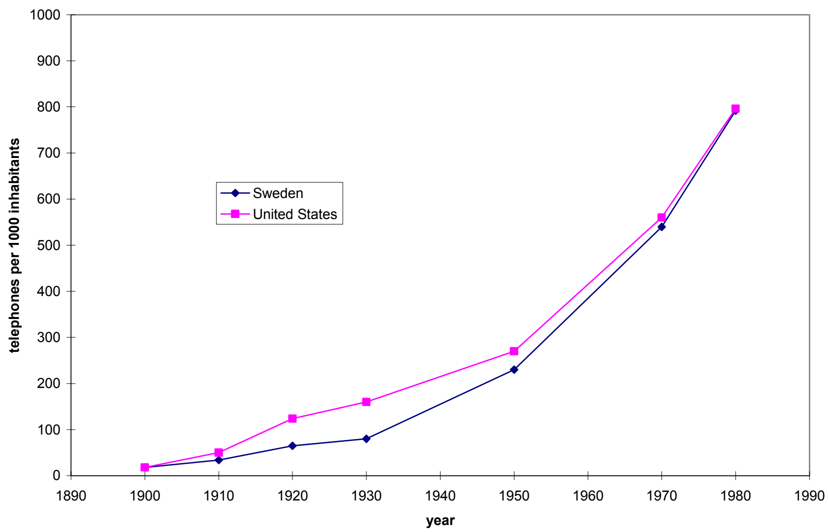

Figure 3-3 Telephone penetration in the United States S and Sweden

Source: Lindmark (2002)

Note: These figures are not fully consistent with later OECD figures indicating that Sweden had higher penetration levels than the US.

One important trend during this time was a shift from local traffic to long-distance traffic. The automation of the telephone network was first directed towards the local networks. When direct (automatic) distance dialing (DDD) began in the 1950s in the US, there was a clear shift in calling patterns (demand), as shown by Figure 3-4, illustrating relative growth in local exchange traffic versus toll (long-distance) traffic. This phase Calhoun (1992) denotes the network era, and Bohlin (1995) the long-distance era. Bohlin (1995:130-131) emphasizes that network construction was oriented around increasing capacity in the long-distance network, instead of being primarily directed at extending the local loop and subscriber base. Put in demand terms, the telephone had shifted from being an instrument of local communications, neighborhoods and local business to becoming an instrument for overcoming distances.

Concurrently the society became more mobile (e.g. through increasing diffusion of automobiles) and more urban. New and more far-reaching types of communication were called for, partly delivered by telephony. However, it was in a sense a bulk and standard type of commodity – the plain old telephone system (POTS), typified by the standard black telephone of Ma Bell (the Bell System). Just like the notorious black T-Ford, telephony was a mass-produced good, with demand driven by fast economic growth and far-reaching social changes in the 1950s and 1960s, and supply driven by cost minimization and emphasis on economies of scale and single supply (natural monopoly).[125]

[125] Bohlin (1995:130-131).

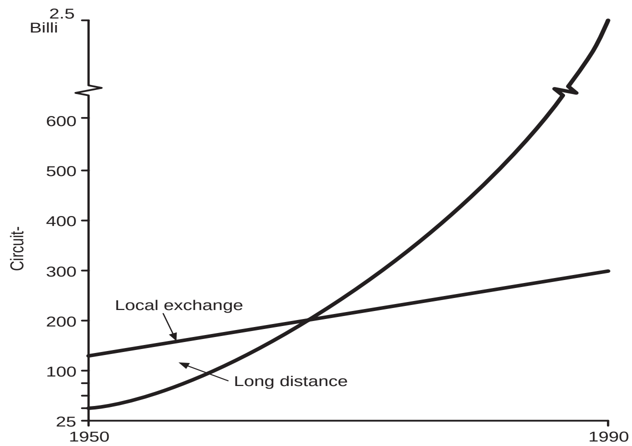

Figure 3-4 Relative size of local vs long-distance network

Source: Calhoun (1992, p. 57, quoting FCC data)

3.2.6 Standardization

In the early phases of telephony there were many incompatible competing telephone systems, where dominant actors tended to keep their technology incompatible with competitors' technologies in order to leverage the attractiveness of having a larger subscriber base. After shakeout of competing actors, the PTT administrations could specify their national system by themselves. The components were pulled together by a single agent, and therefore the need for collective standard development at the national level disappeared for many years. Since competition had disappeared, coordination in order to facilitate international links was the prime driver of standardization.[126]

International standardization started with the advent of telegraphy. Different coding schemes (Morse, Cooke and Wheatstone etc.) and other procedures caused interconnectivity problems at national and international levels. Messages had to be translated by hand, which was time-consuming and caused errors. This situation caused a need for standardization, and for co-ordinating rules, procedures and tariffs. A number of regional arrangements and conventions were signed, eventually leading up to the International Telegraph Convention and the formation of the International Telegraph Union (ITU) in 1865, the first genuine international intergovernmental organization ever. Upon its first meeting, the ITU chose the Morse system, which can be regarded as the first international standard in telecommunications. They also agreed upon tariffs and QoS matters.[127]

The emergence of radio telegraphy in the early 1900s posed new demands on standardization. First and foremost there was the technical issue of avoiding interference. Thus, frequencies had to be coordinated. Economic and political issues were raised too, e.g. since the Marconi company abused its dominant position by refusing communication with non-Marconi companies. Germany, protecting the interests of Siemens and AEG, sought to break Marconi's dominance and initiated international radio conferences (where they were opposed by Italy and the UK) eventually leading up to the International Radiotelegraph Convention (1906) – a framework for allocating radio frequency bands for particular services. At a

[126] It is notable that economies of Scale were not recognized as important enough for the PTTs to engage in other types of standardization.

[127] Bekkers (2001:109-110)

conference in 1912, Marconi was forced to have its operators communicate also with stations using other equipment.[128]

In 1934 the radio convention joined the ITU (which was accordingly renamed International Telecommunications Union). The main functions of the ITU became[129]:

- *Radio frequency management.* The ITU allocates frequency bands for certain services. Member states are bound to this allocation, although the assignment of frequencies is actually made by the member states themselves, and they do not always comply.
- *Standardization.* ITU provides standards for many areas, mainly for communication between countries.
- *Forum for commercial agreements*, for instance regarding tariffing principles.

In the 1920s ITU extended its scope to telephony issues. Special committees were formed for telephony (CCIF), telegraphy (CCIT) and radio (CCIR). CCIF and CCIT were later merged into CCITT. After World War II, ITU became a specialized agency of the newly formed United Nations, and a frequency registration board (IFRC) was set up to manage frequency issues. This structure was essentially kept until 1992, when ITU became divided into a radio communications sector (ITU-R), a telecommunications standardization sector (ITU-T) and a development sector (ITU-D focused on developing countries). By the early 1970s ITU was dominated by the National Regulatory Administrations (NRAs) represented by the PTTs. In recent years, this has changed to include sector members including among others operators, suppliers, associations, regional organizations, and satellite operators.[130]

ITU produces standards in the form of recommendations, which are not binding. These include:[131]

- interconnection standards, i.e. standards of connection between network elements (e.g. E1/T1, SS7)
- access standards, i.e. the interface between networks and subscribers (e.g. ISDN)
- terminal device standards (modems, faxes etc.) (V-series for modems and X-series for packet switching)
- reference standards (e.g. OSI)

ITU did provide some standardization in the radio area, although not so often concerning compatibility, but more often related to performance criteria (frequency use, channels spacing, satellite orbits etc.) and only for some parts of the sector (maritime, satellite, paging etc.). Regarding mobile telephony, ITU played no active role until the third generation, when it tried to harmonize a number of divergent proposals.[132]

Clearly, both as a regulatory body and as a standards body, ITU left a number of needs unfulfilled. Some of these needs were instead addressed on the national and regional levels. In Europe, as a consequence of the integration movements in postwar Western Europe's regional cooperative bodies, the European Post and Telecom administrations formed the European Conference of Postal and Telecommunication (CEPT) in 1950. This was also part of more far-reaching cooperation between the PTT administrations, for instance in the form of shared R&D (see below). During the first decades CEPT was essentially involved in administrative,

[128] Bekkers (2001:110-111)
[129] Bekkers (2001:111)
[130] Bekkers (2001:111-123)
[131] Bekkers (2001:122-123)
[132] Bekkers (2001:123-124)

technical, operational and commercial activities, including standardization, definition and implementation of new services and tariffs.[133]

CEPT did not consider itself to be primarily a standardization organization. It recognized the pre-eminence of ITU, and regarded itself as supplementary to ITU. Its role when it came to standardization was threefold. First, it agreed on common proposals to ITU. Often in ITU, regional and other groupings join forces and come up with proposals to ITU. CEPT had an integrating role for the European members in this respect.[134]

Second, CEPT encouraged its members to coordinate the introduction of the same ITU recommendations if these allowed for several variants (which they often did). Finally, CEPT produced European standards. However, CEPT standards were often commercial failures, and not implemented by its members. For example, Teletex (the envisaged replacement of Telex) was a commercial failure, while the Videotex recommendation was a technical one in the sense that Videotex specification included “options” allowing the continuation of nationally developed systems. The GSM standard, originally developed within CEPT, became a success, though.[135]

CEPT had a rather tense relation with the Commission of the EC. The two organizations had some common objectives regarding harmonization and the build-up of a Europe-wide telephone network. However, CEPT’s limited membership structure was not in line with EC requirements on a well-balanced representation of actors and transparency.[136] On the other hand, EC included only a subset of the CEPT membership states.

3.3 Point of departure (1970)

What was the state of the telecom sector in 1970? This question will be investigated qualitatively and quantitatively in the following section. [137] The investigation will start with the PTTs, since these were immensely important for the development of the sector.

3.3.1 PTTs

In the 1970s most PTTs were fully owned by the government, but acting as fairly independently entities. Notable exceptions to this state ownership were found in Finland and the US. The governments often required the PTTs to make minimum profits. These profits were used for reduction of budget deficits and to finance military expenses etc. How much their profits could be used for network investments became a delicate issue, creating some tension between PTTs and the government. It should be noted that even after the PTTs became corporatized, the state as the sole or major shareholder received both dividends and corporation taxes.

As identified in the previous section, telecommunication calls for a variety of regulatory measures, including (in those days) e.g. management of radio frequencies, (which if left to the market would lead to interference), the reach of exclusive rights, obligations, rights of way and procurement issues. For reasons of efficiency, some regulatory tasks (when there was no

[133] Bekkers (2001:124-125)
[134] Bekkers (2001:126-127)
[135] Bekkers (2001:126-127)
[136] Bekkers (2001:127)
[137] This section draws on Bekkers (2001:44-161) unless otherwise stated.

conflict of interest) were delegated to the PTTs. In some international organizations, the ITU and CEPT, PTTs acted on behalf of governments.

A number of aspects of the activities of the PTTs relate to public interest. First and foremost, public interest required the services of the PTTs to be available to anyone – everywhere (irrespective of place of residence), meeting a certain level of quality (availability, blocking rate, time to realize a request of connection, repair times, range of services offered, etc.) not exceeding a certain price level. These requirements were often mandated by law. In addition, a well-functioning telecommunications infrastructure was generally seen as a condition for successful trade and to attract investments. Moreover, the sheer size of the PTTs meant that their personnel and employment policies were important; they represented significant voting power and labor union representation.[138]

Some of the PTTs were vertically integrated, i.e. they were engaged also in manufacturing. The incentives to buy in-house were fed by expectations about efficiency, cost-cutting and co-ordination of product development and production, with the long-term planning of network investments. In Italy for instance, Italtel and the operator had the same parent company. In Sweden, Televerket owned substantial manufacturing facilities and was engaged in product development. Telefónica of Spain also owned substantial interest in suppliers. The prominent example was of course Western Electric, which was part of the Bell system.

In conclusion, the PTTs had enormous power partly because of the growing importance of telecommunications and their sheer size. Apart from their own positions of influence, much of their power arose from allowing other groups of society to share the benefits of monopoly. Equipment manufacturers (as will be elaborated on below) acted as oligopolies collaborating with the PTT monopolist, with limited competition, high entry barriers e.g. in the form of standards designed to discourage and delay outsiders, and their product development partly financed by others. So the PTT system was profitable and reassuring for insiders, but it was also inefficient. To put it in the words of Noam (1992:5) its inefficiencies were long hidden by a general pervasive trend of improving electronics technology. This trend included rapidly falling costs, which were due to the electronics, computer and component industries.[139]

3.3.2 Organization of the supplier industry

There were two categories of manufacturers during the PTT era: (1) the national champions and (2) the internationally oriented ones. The national champions received large parts of national procurements, but on the other hand were dependent on domestic sales. Examples of such firms were Siemens in Germany; NTT's family of domestic suppliers in Japan – primarily NEC, Fujitsu, Hitachi and Oki; Alcatel/CGE and Thomson in France; Italtel and Telettra in Italy; GEC and Plessey in the UK. Internationally oriented ones were largely independent of their home market, usually having development and production facilities in foreign markets, presenting themselves as a local rather than international company. The prime examples were ITT, Ericsson and to some extent GTE. Ericsson is investigated elsewhere in this report. ITT established itself as a major international supplier in the 1920s, when it acquired Bell's international manufacturing facilities, which the latter firm was forced to dispose of. ITT also held a number of operating concessions in e.g. South America. GTE also held operating concessions.

[138] Noam (1992:23)

[139] Noam (1992:4-5)

Telecommunications equipment has by tradition (and in accordance with Section 3.1.2) been divided into switching, transmission and terminals equipment. As mentioned above, when networks grew increasingly complex, equipment R&D (especially in switching) grew increasingly costly.[140] Switching accounted for increasing shares of the telecommunications equipment market, and its importance increased as digital SPC switches became a necessity, and even more so when they later were applied to cellular mobile telephone systems. Only a handful of companies were successful in developing such switches, as will be shown below. Consequently, the equipment supplier market became more dependent on scale, leading to a shakeout and internationalization, with a few large – and to various degrees internationally active – equipment suppliers possessing the necessary technological competence and production facilities. As a result, in the early 1970s the industry consisted of a few large-scale suppliers. Among the most important ones were (in a plausible size-ranking order): AT&T, ITT, Siemens, Ericsson, GTE, Northern Telecom, NEC, Thomson, Philips, Alcatel, GEC, Plessey and Italtel, including also Fujitsu and Hitachi.

The manufacturers, including also the national champions, had relatively high levels of independence; they owned production facilities and technical know-how, initially protected by patents. However, the importance of patenting diminished as a result of the PTTs' system of procurement. In this regime the market shares of each equipment supplier were high in a country (the four largest suppliers in a country usually held more than 90% of the market in most countries). The PTTs as a rule purchased equipment from the national supplier, and sometimes subsidized its R&D.[141]

Throughout the history of telecommunications, cartels have been common. Sometimes the cartel agreements were made superfluous by procurement practices of PTTs, which had the aim to favor the domestic industry and to control market shares of the suppliers, which often were fixed for long periods of time. The practices applied to all important supplies: telephone devices, cables and switching, even after free trade rules made trade barriers disappear in the 1980s, through means of long-term commitments and preferential standard-setting and certification policies. Often equipment was specified in detail, making it expensive to adapt to divergent national standards. These policies gave the PTTs the power to determine which suppliers could participate in the lucrative national telecom market. They also made it difficult to make products for divergent national standards.[142]

[140] A digital switch cost roughly USD 1 billion to develop.

[141] Noam (1992:24)

[142] Noam (1992:319)

The main features of the supplier market in some important countries are summarized in Table 3-2.

Table 3-2 Equipment market in selected markets in 1970s [1984])

Country	*Supplier market*
West Germany	Two dominant suppliers: Siemens and Standard Elektrik Lorenz (SEL, an ITT company). DPBT opted for multiple suppliers with same standard design, where suppliers got fixed quotas and were required to license out.
France	France is a special case since the PTT system of procurement was strengthened during the 1970s and 1980s (see also below). Initially ITT and Ericsson subsidiaries were dominant suppliers. DGT used a policy of multiple suppliers selected through bidding procedures. In practice certain market shares were reserved for national suppliers. Two main suppliers, Alcatel/CGE and Thomson, were strengthened as ITT and Ericsson were forced to sell their subsidiaries to Thompson. Later these firms were nationalized in the early 1980s, and merged their telecommunications activities into Alcatel/CGE. The state-owned company bought the remaining part of ITT and became the second largest telecom supplier in the world. Meanwhile, Ericsson had bought the relatively small CGCT company.
UK	Three major British firms (GEC, STC [an ITT subsidiary] and Plessey) were strongly favored.
Italy	Very closed and partly vertically integrated, through a common ownership of SIP (operator) and Italtel which got 40% of the market and had almost no exports. Telettra also had large market share.
Spain	Telefónica partly vertically integrated. Held interests in most Spanish manufacturers who in turn had a 90% share of the market.
Sweden	Partly vertically integrated, where Televerket satisfied most of its equipment needs either through its manufacturing arm TELI or Ericsson. Less than 10-20% of orders went to international suppliers.
US	Vertical integration. AT&T procured from its manufacturing arm Western Electric. GTE also procured internally.
Japan	A system of "controlled competition" (see Fransman 1995). Telecommunications equipment was developed jointly by NTT and a closed group of suppliers (NEC, Fujitsu, Hitachi and Oki). The structure was competitive in the sense that NTT punished and rewarded performance of the suppliers, by increasing and decreasing their market shares.

Sources: Compiled from Bekkers (2001:44) in turn based on Eward (1994:162-63, 116, 183), Meurling and Jeans (1994:122-124) and Noam (1992:83,181,207,255); and Fransman (1995)

3.3.3 R&D and patenting

The locus of innovation was in the research labs of the PTTs (see further Section 3.4.6 and Fransman 2003). Some R&D (with an emphasis on D) was performed by the manufacturers. Still, R&D expenses of manufacturers were to a large extent indirectly or directly financed by the PTTs. Sometimes high prices allowed manufacturers to recoup R&D investments and trial costs; sometimes R&D was directly paid for by the PTT or the government. Prices could then be dumped on the international market. Thus, the R&D financing functioned in effect as subsidy for the export activities of the national champions.[143]

Patents were of relative unimportance in the PTT era. Because of the procurement practices of the PTTs there was very limited competition between the suppliers. In addition, much research was either paid for by or jointly conducted with the PTTs, which in turn did not compete with each other. As a result, patents were deliberately avoided. It was considered inappropriate to charge the PTTs (and to some extent other suppliers) with licensing fees,

[143] Bekkers (2001:66-70)

since they covered development costs. And as discussed above, if there was more than one manufacturer supplying equipment to the PTTs these were required to license the technology to the other suppliers.

3.3.4 Governments and industrial policy

In addition to their role in owning and controlling the PTTs, governments had an important policy role to play, through actions aimed at either strengthening certain actors or limiting their powers, the latter being of particular importance in the US. Through the PTTs, governments often favored national suppliers or foreign suppliers with domestic manufacturing facilities or collaboration with domestic firms. Governments also supported exports by granting export credits. For instance, during 1984-1988, the Swedish government granted export credits in the range of SEK 1 billion. The government also supported R&D in the national industries, sometimes by indirectly subsidizing them through high purchase prices, sometimes through direct funding and sponsoring. Compensation orders were also important, or if large foreign orders were placed, governments often made sure that components were supplied by the national industries to the highest degree possible.[144]

On a supra-national level the European Community/Union (EC) was founded in 1957, but it was not until the 1980s that it started to play an increasingly important role for telecommunications.

3.3.5 End-users

The end-users did not have a significant representation that influenced the other actors – neither the residential users nor the large firms and organizations. Although the PTTs were obliged with universal service, user requirements and interests were more assumed than assessed. Thus, although user needs did matter for the development of services, prices and innovation, influence was rather indirect.

3.3.6 International standardization, collaboration regulation and policy

As mentioned above, much of the telecommunication networks could be classified as national specifications, although some aspects were handled through ITU and CEPT. The US and Japanese standard bodies of today had not yet been formed, although the predecessors of TIA had been active since the 1920s. The emergence of communications satellites, truly international in scope, led to the formation of Intelsat in 1964. Other standardization organizations of importance were ISO, IEC, and CEN/CENELC.

Telecommunications policies were important issues also outside pure telecommunications-related forums. Discussions in e.g. the EC and OECD were a reaction to the narrow perspective of the PTTs in their own international bodies. The Organization for Economic Co-operation and Development (OECD), formed in 1961, played a role, in particular regarding information policy, e.g. the identification and discussion of issues of transborder data flows, privacy and national sovereignty. It also issued several influential reports and became an important source of comparing services, usage, rates and performance of the member countries. Telecommunications issues also spilled over to GATT (General Agreement of Tariffs and Trade), established soon after WW II to stimulate world trade by avoiding protectionism and bilateralism.[145] The major international organizations involved in telecommunications policy issues are summarized in Table 3-3 (also covering later periods of time).

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[144] Bekkers (2001:66-70)

[145] Noam (1992:302)

Table 3-3 Major international organizations in different policy areas between 1947 and 1993

Area	*International organizations*
Jurisdictional rights	ITU, and various UN committees
Radio transmission interference	IFRB (ITU), CCIR (ITU), WARC (ITU)
Technical and procedural barriers	CCITT and CCIR (ITU), CEPT, ANSI (later), ISO and IEC
Prices and market shares	CCITT Study group 3, WATT (ITU), INTELSAT, GATT

Source: Adapted from Karlsson (1998:28) based on Zacker (1996:130-).

The international regime can be described in terms of principles and norms, where the most visible ones are the governing of global commons such as frequency spectrum and satellite orbit slots, and technical standardization required to provide universal service. Another less visible one is the jointly provided services, which extended the national monopolies into the international area and to the formation of an intergovernmental cartel, which promoted loyalty and preservation of monopolies, freedom of setting prices, while paying a fixed fee (termination rate) to the receiving country. This system quite naturally led to over-pricing of international calls.[146]

When it comes to regulation, to put it somewhat overly simply, in the PTT era telecommunications were strongly regulated on the one hand, and not regulated at all on the other hand. The PTT regime was firmly in place, either *de jure* or *de facto*. Besides this, there was no particular regulation of importance apart from frequency issues and some other minor technical issues.

3.3.7 Summary — state of the sector in 1970

Table 3-4 summarizes indicators of the state of the sector in 1970. Some observations can be made from the statistics. First, although the sector was very important in absolute terms (more than USD 15 billion of yearly investments, and more than USD 34 billion in yearly service revenues) telecommunications were not ubiquitous. The large European countries had main line penetration rates of less than 15%. The US numbers correspond to roughly half the world's telecom service sector by most measures. Sweden stands out, however, as the most advanced market, for instance in terms of main line penetration.

[146] Karlsson (1998:29-30) referring to Cowhey (1990a)

Table 3-4 Key telecom-related figures in the OECD countries (1970)

Country	*Annual investment (mUSD)*	*Main lines (000s)*	*Telephone sets*	*Main lines per 100 inhab.*	*Total. service revenue (USD)*	*Waiting list*	*Population*
Australia	376	2 704 000	3 913 000	21.10	518 871 104	60 056	12 817 000
Austria	82	969 000	1 427 000	12.98	156 707 696	105 094	7 467 000
Belgium	123	1 343 541	2 036 000	13.92	237 180 000	7 221	9 651 000
Canada	720	6 514 000	9 750 011	30.55	1 590 648 832	..	21 324 000
Denmark	96	1 249 003	1 687 858	25.34	215 333 328	433	4 929 000
Finland	47	863 000	1 181 000	18.74	75 952 384	3 064	4 606 000
France	708	4 268 000	8 774 000	8.41	1 625 976 704	363 734	50 772 000
Germany	1 163	8 587 000	13 835 000	14.16	2 495 819 776	584 733	60 651 000
Greece	87	887 000	1 045 000	10.09	117 033 336	175 801	8 793 000
Iceland	197	57 593	70 900	28.15	..	..	204 580
Ireland	18	234 000	307 000	7.93	42 356 612	11 344	2 950 000
Italy	468	6 461 000	9 371 000	12.04	1 143 545 600	..	53 661 000
Japan	1 677	16 403 000	23 010 000	15.81	3 183 519 488	3 165 000	103 720 000
Korea	47	481 207	633 818	1.51	71 504 032	..	31 923 000
Luxem.	n/a	82 000	111 000	24.12	11 316 000	3 047	340 000
Netherlands	169	2 202 000	3 411 000	16.89	382 209 952	140 449	13 039 000
New Zealand	n/a.	841 000	1 203 000	29.82	108 634 784	15 426	2 820 000
Norway	73	742 300	1 146 300	19.14	153 453 072	26 500	3 879 000
Portugal	45	542 000	750 000	6.47	64 521 740	49 863	8 380 000
Spain	271	2 845 000	4 569 000	8.40	281 902 848	588 218	33 876 000
Sweden	139	3 603 000	4 506 000	44.80	527 333 184	0	8 043 000
Switzerland	227	1 945 000	3 026 000	31.04	295 547 584	33 536	6 267 000
UK	1 022	9 213 000	14 967 000	16.56	1 859 851 264	122 787	55 632 000
US	7 258	69 039 000	120 218 000	33.67	19 444 840 448	42 000	205 050 000
Total	15 004	142 075 644	230 948 887		34 604 059 768	5 498 306	710 794 580

Source: Compiled from ITU, World Communications Database.

3.4 Main trends

In this section a number of interrelated pervasive trends affecting the telecommunications market between 1970 and 2003 are identified and discussed. These are: the (1) growth of markets, (2) technological progress, (3) digitalization, and the resulting (4) convergence and divergence, (5) the changing role of standardization, (6) the changing R&D regime, (7) liberalization and the resulting (8) changing industrial structure.

3.4.1 Market growth

Perhaps the most relevant trend has been the growing economic importance of telecommunications, in almost every measurable term. One relevant measure is the proportion of household expenditures spent on telecommunications equipment and services. Such measures are available from OECD, from which we have obtained data only for the period between 1990 and 2000. These are shown in Figure 3-5 for different consumption sectors.[147]

[147] The figures include also postal consumption, but these are almost negligible compared to telecoms (see e.g. OECD 2003a:32)

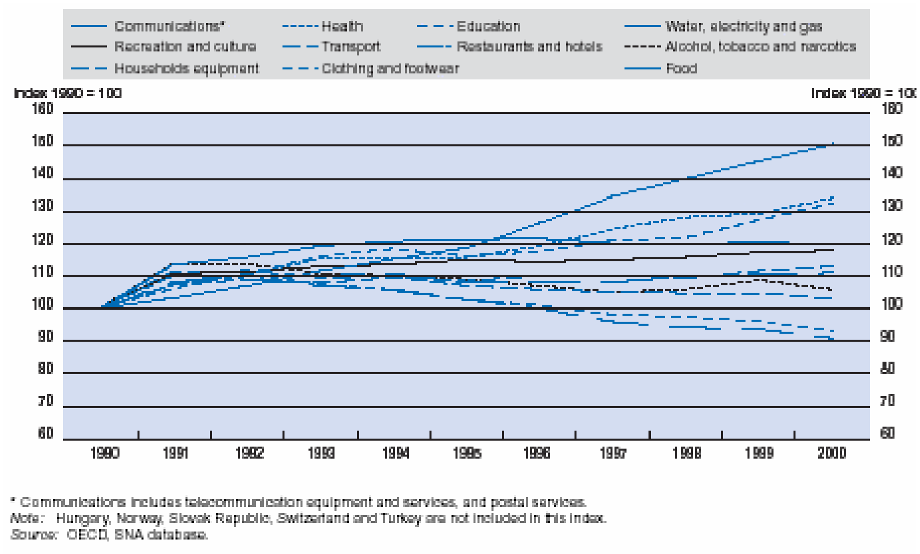

Figure 3-5 Changes in the proportion of different service/product categories of household income

Source: OECD (2003a:31)

The trend is clear, although it is unclear how the trend looks before the 1990s. Clearly, communications account for a growing share (from 1.6% to 2.3% of the total household expenditures), accelerating in 1995 primarily as a result of mobile telephony and Internet, and the impact of liberalization of traditional services. In absolute numbers, this corresponds to a rise in annual consumption from USD 534 in 1990 to USD 933 in 2000, of which the majority of spendings is on services (roughly ten times more is spent on services than on equipment).[148]

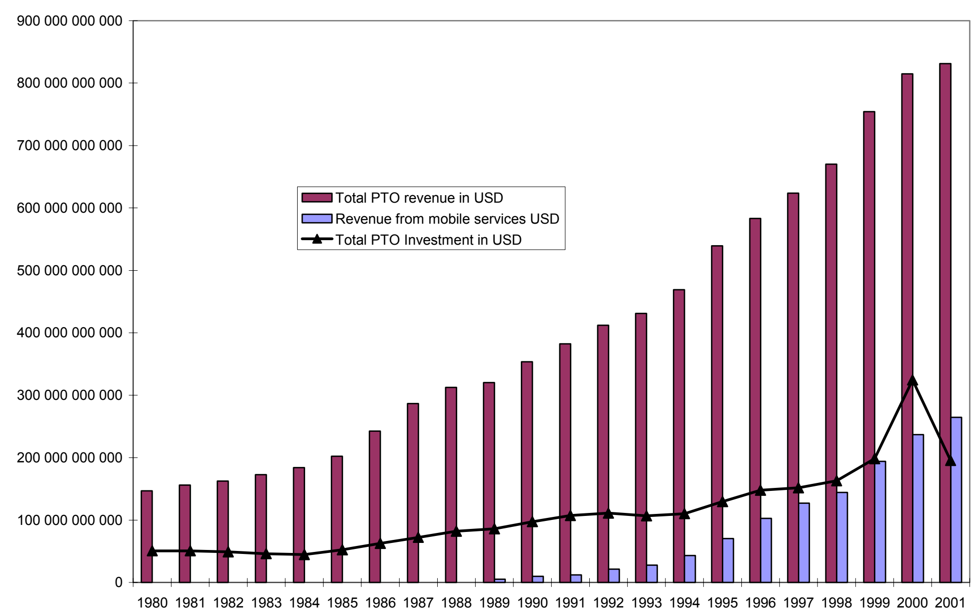

Figure 3-6 Trends in telecommunications revenues and investments

Source: OECD Telecommunications database.

[148] OECD (2003a:31-32)

Figure 3-6 illustrates the long-term trends in telecommunications revenues and investments. Clearly there is a sustained and accelerated growth in revenues, although the growth slowed down in 2001, presumably as a result of the crisis, partly as a result of major markets reaching maturity. It is notable, though, that the market as a whole continued to grow throughout 2001, despite the crisis. The crisis is most clearly displayed in operators' investments, which grew throughout the period, accelerating in the late 1990s, peaking in 2000, to fall back again in 2001 – clear signs of an investment bubble. A final observation is that it was mobile revenues that accounted for the lion share of the growth in revenues in 1990s. The revenue impact of the Internet is much harder to determine since it cuts across a range of platforms and services.

Relating the telecom service revenues to GDP (in the OECD area) also displays an interesting pattern of increasing proportions, at least during the early 1980s and 1990s, also continuing throughout the crisis. Between 1980 and 2001, the proportion has grown from less than 1.77% to 3.35%, i.e. more than doubled, most of the growth taking place in the 1990s.[149] Further, research has shown that the majority of productivity growth in the manufacturing industry in a number of European countries in the 1990s can be attributed to the information and communications industry, and in particular the telecom manufacturing industry.[150]

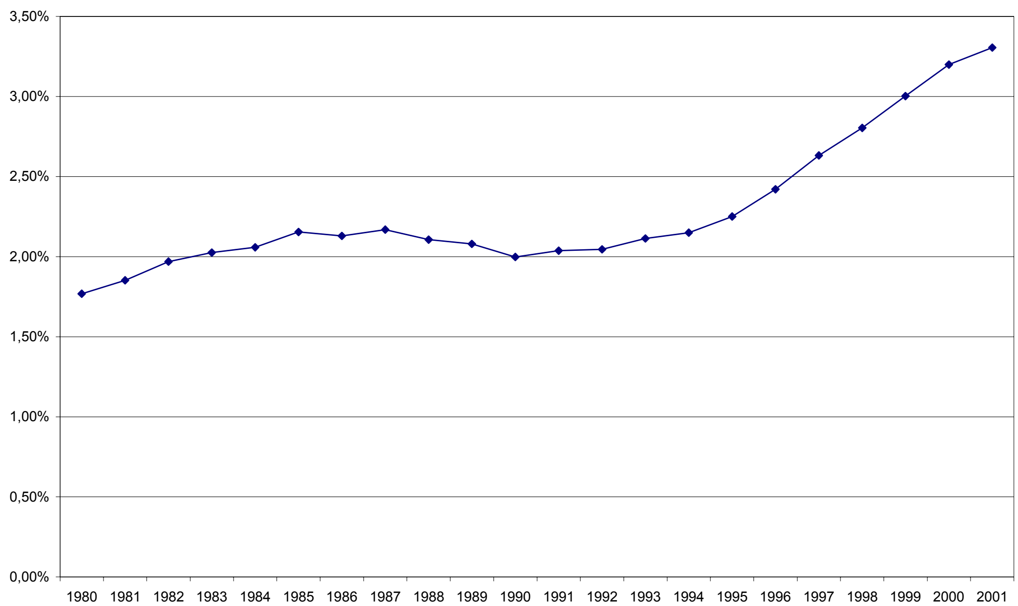

Figure 3-7 Telecommunications revenue as a percentage of GDP

Source: OECD telecommunications database.

Comparisons of different countries in terms of telecom revenues per capita as conducted in OECD (2003a:64) show an average annual telecom revenue per capita of USD 600-800, with Sweden slightly above average. The top markets are instead the US, Norway, Japan, Switzerland and the UK (which all had strong currencies in 2002).

Regarding number of subscribers, Figure 3-8 shows overall growth through the last decade, although fixed telephone lines have stopped growing in recent years. Instead the rapid growth has been in mobile communications and the Internet, of which an increasing share has been in broadband connections.

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149 It might have been interesting to relate these growth trends to the economy at large. This is, however, beyond the scope of the present report.

150 Edquist and Henrekson (2002b) and Lind (2002a)

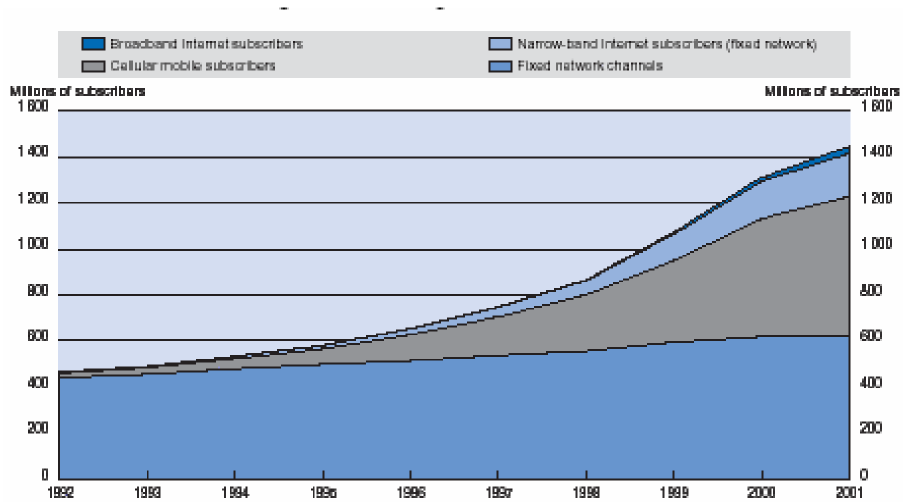

Figure 3-8 Access growth in OECD countries

Source: OECD (2003a:13)

In conclusion, in the high-income countries (OECD), telecommunications has been an important and growing part of the economy. According to every measured aspect, telecommunications has expanded throughout the time period, including also the first years of the crisis.[151] The plain old telephone service has grown but is mature and maybe even declining (in terms of revenues and number of users), although this has not been fully shown above. Cellular mobile communications has contributed the lion's share of subscriber and revenue growth, but is also maturing, at least in the OECD. Data communications, in particular Internet data communications, is the other major source of growth, although less in terms of revenue, and more difficult to measure. Since data communications are more traffic-intensive than voice, while the number of fixed line connections is decreasing in several countries, demand for capacity is increasing.[152] Perhaps the combination of the two into mobile data will become a third growth area.

The telecom industry is also expecting major growth opportunities to come in developing countries. Still, both mobile and fixed telephony are growing in emerging markets, notably China. As seen in Figure 3-9, there were around 17 both fixed and cellular subscribers per 100 inhabitants in China in 2002, up from very low levels in the mid-1990s. Cellular telephony is growing at a much faster rate than fixed, and by 2003 the number of cellular subscribers will probably have overtaken the number of fixed subscribers. The rapid growth in combination with a large population makes the Chinese market extremely attractive for all industry actors. At the same time, the Chinese are catching up technology-wise. A large number of Chinese manufacturers for the domestic market are beginning to attack the international market as well. India may follow suit, lagging China by a few years.

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[151] It should also be noted that this is true even though the cartel-monopoly rents from international, long-distance and leased lines have gradually disappeared.

[152] OECD (2003a::88)

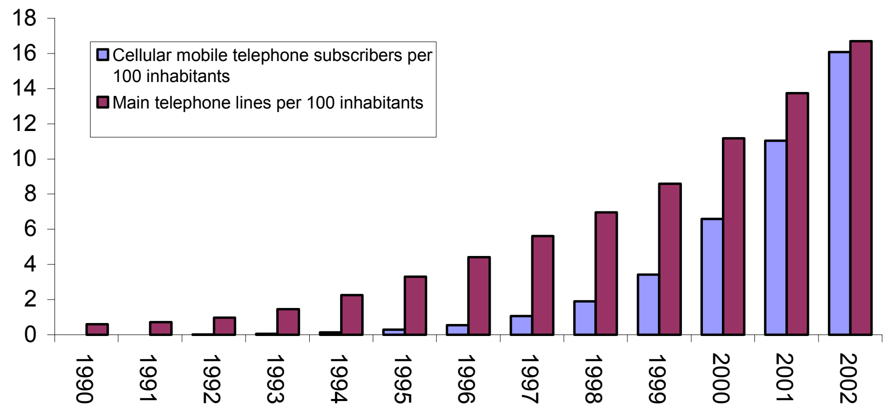

Figure 3-9: Cellular subscribers and main lines per 100 inhabitants in China, 1990-2002

Source: ITU World Telecommunication Indicators 2003.

3.4.2 Technological progress

A second pervasive trend in telecommunications is the rapid technological change taking place in all parts of the network. It is far beyond the scope of this report to investigate all those developments. However, some salient features will be briefly described here. First, technological change in telecommunications has been very rapid, partly as a result of independent developments in the electronics and component industries, partly as a result of the large amount of R&D efforts by labs of operators and equipment suppliers. To put it in somewhat simplified terms, a Moore's law-like exponential performance development has essentially been valid for telecommunications and the various components of the system, although at different speeds. Such a development for mobile telephones is illustrated in Figure 3-10.

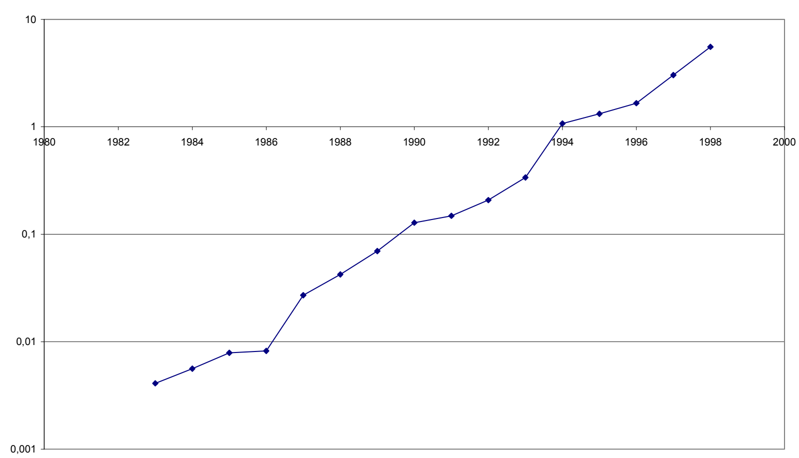

Figure 3-10: Performance/price developments of cellular telephones

Note: 1/weight (grams)/price of identified best-performing model for each year
Source: Lindmark (2002)

Technological progress has sometimes been gradual, sometimes radical. Development has sometimes been characterized by technological leaps, sometimes been more continuous (in particular if economic performance is compared to e.g. the costs), as illustrated by the fiber optics development in Figure 3-11.

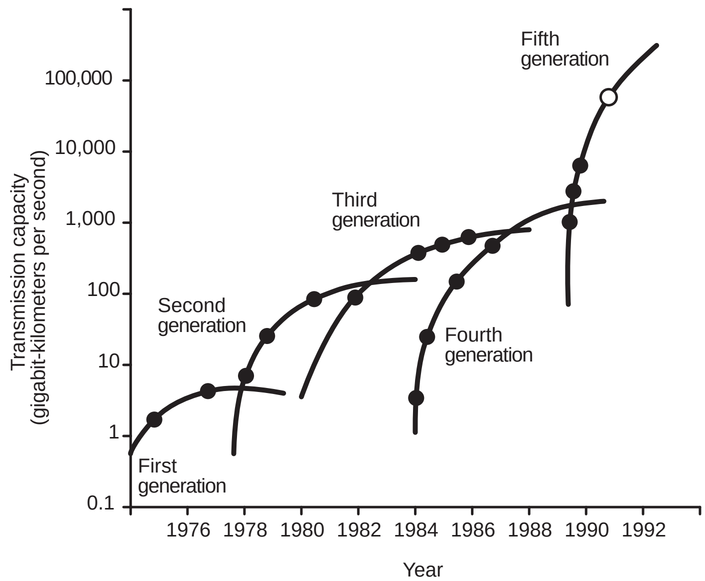

Figure 3-11: Transmission capacity evolution of fiber optics

Source: Huber et al. (1992) citing Scientific American (1992, January, p. 116).

Technology progressed in three broad areas: (1) transmission, (2) switching and (3) signaling[153]. Regarding *transmission*, we have already touched upon how improvements in cabling and introduction of amplifiers facilitated long-distance telephony. Multiplexing was another area of improvement in transmission. In the early days of telephony, only one telephone conversation could be carried on a single line, and only for quite short distances. In the 1930s, Frequency Division Multiplex (FDM, i.e. the division of the spectrum into frequency bands of about 4 kHz, each carrying one speech channel which was created by modulating a carrier tone) allowed transmission of several conversations on a single line. Transmission was further improved by the introduction of low-cost repeaters based on vacuum tubes (and later transistors). Improved cabling, in the form of e.g. loading coils, twisted pairs, coaxial cables and more recently optical cables, further added to improvements in transmission.

Since the days of Marconi, radio technology has competed with cables in transmission. Recent developments include the introduction of microwave radio and satellite links. Microwave became the dominant transmission medium in the long-distance network in the 1950s and 1960s. Digital microwave radio was introduced in the late 1970s, facilitating advanced multiplexing techniques and thereby further increasing capacity. The science fiction novelist A. Clarke conceptually outlined "geostationary"[154] satellites in 1945. Satellites had to wait for suitable space technology to develop (1950s and 1960s). The first communication satellites were launched in the early 1960s. The main applications for satellite communications were television broadcasting, intercontinental links, and communications access in sparsely populated regions. Compared to optical fibers, satellites offer less capacity, and a noticeable time delay restricts the utility of the communications.

[153] The terminal development will be treated in other chapters.

[154] If a satellite is placed at a certain height with a certain speed it will continuously "fall around the earth". In theory there are an infinite number of such orbits, their height being related to the velocity of the satellite. At a height of about 30-40,000 km above the earth, it takes 24 hours for the satellite to rotate around the earth. Thus, if the satellite is placed above the equator and rotates in the same direction as the earth, it will appear stationary above the earth. This orbit is called the geosynchronous orbit. Three such satellites suffice to cover the populated parts of the earth.

The technological development of the access network (i.e. the part of the network between subscribers and their local exchange) was rather slow until 1980, but then it accelerated, which has led to a situation of technological competition between different technologies. During the long and largely static period until 1980, the access network was almost totally dominated by copper lines between the subscribers and their local exchange. Copper pairs were used in the public switched telephone network (PSTN) in the first place; secondly, for leased lines; and thirdly, in the telex network. New access solutions started to develop in the 1980s. Many of them were just complementary to the public copper-based telephone network – analog, cellular mobile networks; public data networks; and cable-TV (CATV) networks, to name a few. But radio technology soon turned out to be capable even of competing with copper lines in the PSTN, especially in areas with low subscriber density. A fourth type of transmission medium (in addition to copper pairs, radio, and the coaxial cable of the CATV networks) captured the trunk networks in the 1980s: optical fiber. In the 1990s, it became very competitive even in large parts of the access network, thanks to a favorable price trend.[155] Such price trends and their performance trends (in terms of quality, dependability and availability) broaden the fields of application of the transmission media and technologies. Copper pairs, for example, are also used for broadband services.

The evolution of *switching* techniques became of crucial importance, not only for telephony but also for the introduction of cellular mobile telephony. Electromechanical switches (e.g. Strowger, rotary and later crossbar) enabled automatic switching to replace manual (which was very uneconomical). The development of transistors and integrated circuits (see below) provided a basis for development of electronic switches. In the 1970s, the first digital switches were launched. The perceived convergence with data services provided an impetus for the development of the ATM (Asynchronous Transfer Mode) switches of the 1990s, where information is packaged in so-called cells. ATM is flexible in terms of cell arrival time (asynchronous) and bit speeds, providing increased flexibility for integration of broadband ISDN (Integrated Services Digital Network) services. Finally, the most disruptive change of them all was perhaps packet switching, developed outside the telecom industry, in the US and the UK in the 1960s, with the really important effects starting to become visible in the last decade.

With the introduction of automatic switches, the *signaling* functions became automatic. Early signaling methods employed direct current. Digital transmission was made possible by common-channel signaling, where a separate data link is used for transmitting signaling information. Since signaling controls the entire network, standardization of the signals becomes important. CCITT (see Chapter 4) specified the first standardized signaling system in 1968 (SS6). When CCITT specified a new standard in 1976 (SS7 – Signaling System No. 7), a worldwide standard could be implemented.

Another trend is the increasing importance of software. According to a NUTEK pre-study (Olsson 2000), there are several indications that the shares of value and R&D have increased rapidly to very high levels in telecommunications, according to some estimations from around 5% in the early 1980s to over 80% in year 2000.[156] According to the same study, the share of software R&D for Philips GSM was 60% in the year 2000. Others estimate the software share of R&D costs in mobile communication to be 70% and increasing. According to Ericsson and Telia (1997), in the mid-1990s, software accounted for 70-80% of the development costs of a switching system. The total software volume continues to grow as systems become increasingly complex and are expected to support an increasing number of services. They

[155] Ericsson and Telia (1997:239-240)

[156] Olsson (2000:5)

mention the AXE system as an example. In the year 1977, there were 150 software blocks in the central processor of the system, where each block contained about 2,000 "program words" of 16 bits, for a total of about 300,000 16-bit words. Fifteen years later (1992), in the same central processor there were about 3.6 million 16-bit words – a tenfold increase.[157] Actually, most node functions in a modern telecom system are implemented by means of software. Some functions are implemented using a combination of hardware and software; others consist entirely of software. Since the total software volume in an exchange is tremendous – with millions of instructions included, which in turn poses demands on program structures, the use of high-level software languages, organization of software development (design, production, operation and maintenance), flexibility for changes, fault-tolerance, as well as the capacity of processors that execute the programs – software needs to be organized so that different activities can be facilitated.[158] It seems that the share of software development has been increasing rapidly to very high levels in telecoms, although more reliable statistics are needed.[159]

Finally, related to many of the above trends, but emanating outside the telecom industry, were the Internet-related datacom and data processing technologies such as packet switching, TCP/IP, WWW, email and browsers. These will be further treated in Chapter 6.

To sum up, technological change in telecommunications has been dramatic, with rapidly improving functionality, performance improvements and cost reductions, possibility for new services and products as a result. The technical systems are also becoming increasingly complex, with diversity of terminals, transmission, switching and access technologies and standards, which in turn pose demands on development, not least in software. In the next section we will focus on one particularly important trend – digitalization.

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[157] Ericsson and Telia (1997)

[158] Ericsson and Telia (1997)

[159] Olsson (2000)

3.4.3 Digitalization

3.4.3.1 Patterns of digitalization

Digitalization has played an important role for shaping and reshaping the telecommunications industry.[160] First we will briefly describe how digital technology has been applied in the network. In sum, in the 1960s digital techniques were applied to long-distance transmission. The first digital switches and optical fibers were introduced in the mid-1970s, with microwave and satellite systems following later in the same decade. In mobile telephony it took until the early 1990s for the first digital systems to be introduced. However, many large parts of the world's telephone networks, not least the access networks, are still analog.

As a rule digitalization has been implemented step-wise in the networks. Starting with a completely analog network, digitalization began with the introduction of pulse code modulation (PCM) in the interoffice transmission network in the 1960s.[161] The second digitalization stage included digital switches, made available in the market in the late 1970s and early 1980s. Digital switches were made possible by favorable price/performance ratios of large-scale integrated circuits (LSI). With this second stage, it was no longer necessary to deploy analog-to-digital/digital-to-analog converters for the completely digitalized paths, improving network quality and reducing equipment costs. (As described above, digital transmission options multiplied in the 1970s and 1980s with digital coaxial cable, microwave and fiber optics. As fiber optics became increasingly deployed starting in the 1980s, digital transmission became more and more equated with this transmission medium. The final stage is end-to-end digitalization in which the final link, the local loop, is completely digitalized. This stage is as yet only remotely achieved, even among advanced carriers.

Initially, the final stage of digitalization was often connected not only with an integrated digital network, end-to-end, but also with the integrated services digital network – ISDN. A standard for ISDN networks was developed in 1984 by CCITT. In this standard a range of voice and non-voice applications is supported by the same physical network, connecting all services to the same local-loop copper pairs (four wires are required in the lowest capacity application). High-capacity applications were envisaged, B-ISDN, in which fiber optics are directly connected with the customer premises equipment. In the early and mid-1990s, the vision of an all-fiber network gained political momentum in the economic triad (Europe, Japan and the United States), partly spurred by the initiatives and declarations on Information Superhighways by Vice President Al Gore of the United States.

Table 3-5 shows the pace of digitalization for a number of key operators, using the standard industry measure. As investigated by Bohlin (1995) there was an over-riding trend of accelerating the pace of digitalization compared to plans, among carriers.

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160 Parts of this section draw heavily on Bohlin (1995:115-129)

161 Calhoun (1988:147)

Table 3-5 Digitalization development[(a)] (1980-1991)[b)] – an overview

Company/Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
AT&T[c)]	-	-	-	-	80	-	-	-	-	98	100	100
BellSouth[d)]	-	-	-	-	4	11	18	28	35	45	51	57
BT[e)]	-	-	-	-	-	-	-	2	10	23	38	47
France Telecom[f)]	-	11	15	22	35	44	50	55	64	71	78	81
GTE[g)]	-	-	-	-	15	30	44	55	63	69	74	80
NYNEX[h)]	-	-	-	-	4	9	16	24	38	49	56	60
NTT[i)]	-	-	-	-	-	-	-	-	18	28	39	49
Televerket[j)]	-	6	8	10	14	18[k)]	22	26[k)]	29	37	38	47

Notes:

a) For all carriers except AT&T, digitalization is defined as number of main lines in use connected with a digital (time-division switched) exchange. For AT&T, digitalization is defined as traffic switched by an digital exchange. b) For purposes of divestiture effective 1 January 1984, data for US companies start in 1984. c) Source: Annual Report (1983, p. 10); Telephony (1987, Feb. 2, p. 13), Annual Report (1988, p. 4). d) Source: BellSouth. e) Source: BT Annual Report (1991, p. 37). f) Source: France Telecom Annual Reports (1981-1991). g) Source: GTE. h) Source: NTT. Year indicates fiscal year. i) Source: NTT. j) Source: Televerket, Sveriges officiella statistik (1980-1986), Televerket, Annual Reports (1987-1991). k) Interpolation.

Source: Bohlin (1995: 203)

Approaching more recent years, the process of digitalization is nearing completion (apart from access networks) across the OECD area. Most wireless networks are digital. In the fixed networks the proportion of all lines connected to a digital exchange is now 97% (Table 3-6). Notable are the low rate of digitalization in Spain and the low level of digitalization in Korea (aiming for completion in 2005).[162]

[162] OECD (2003a:91)

Table 3-6 Digitalization in the OECD area

	1993	1995	1997	1998	1999	2000	2001
Australia	40	62	84	95	100	100	100
Austria	54	72	82	92	100	100	100
Belgium	54	66	83	83	91	100	100
Canada	85	94	99	100	100	100	100
Czech Republic	10	17	55	64	74	86	95
Denmark	46	61	86	100	100	100	100
Finland	62	90	100	100	100	100	100
France	86	100	100	100	100	100	100
Germany	41	56	100	100	100	100	100
Greece	22	37	47	75	91	93	96
Hungary	27	53	73	79	81	86	88
Iceland	66	100	100	100	100	100	100
Ireland	71	79	92	100	100	100	100
Italy	57	76	94	98	100	100	100
Japan	72	90	100	100	100	100	100
Korea	59	63	67	69	74	80	88
Luxembourg	82	100	100	100	100	100	100
Mexico	65	88	90	98	100	100	100
Netherlands	93	100	100	100	100	100	100
New Zealand	95	97	100	100	100	100	100
Norway	60	82	100	100	100	100	100
Poland	10	48	58	62	68	77	90
Portugal	59	70	88	98	100	100	100
Slovak Rep.	5	26	51	62	67	70	74
Spain	41	56	81	86	87	87	87
Sweden	67	91	99	100	100	100	100
Switzerland	48	66	99	99	99	100	100
Turkey	74	77	82	83	84	87	89
UK	75	88	100	100	100	100	100
United States	78	82	86	90	93	95	97
OECD	69	82	88	92	95	95	97

Source: OECD (2003a:108).
Note: Figures do not include the local loop.

Local loop digitalization is still under way, which is very costly and a bottleneck for further service expansion. The local loop technology is a legacy from the days of telephone invention in the 1880s, subsequently refined over the years. But the fact remains that local loop is optimized for voice traffic by analog communication, and ill-suited for digital technologies in several respects.[163] Moreover, the technical, economic and usage features of the wired access network are completely different from the rest of the network. For instance, the local loop has dedicated instead of shared facilities, contributing to a low utilization rate. The operating environment of the local loop is far more rough (e.g. open air) than other parts of the network, necessitating other types of technical solutions. The final digitalization phase can then be expected to be very costly, given current technologies. For the whole network in the United States, it has been estimated that the replacement of the local loop by digital fiber technology is 10 times as expensive as replacing the whole telephone switching stock, or corresponding to roughly 500 BUSD.[164] A complete replacement of Japan's network with fiber and broadband technology was estimated to about the same figure, 500 BUSD (53 trillion yen) – see MPT (1994). Against such a backdrop, increasing attention has been devoted to

[163] Calhoun (1992:114-115) provides an elaboration of the technical problems associated with implementing ISDN in old vintages of local loops.

[164] Calhoun (1992:76)

development scenarios of the local loop, in which a range of technologies including digital radio technologies, DSL and fiber optics have been suggested as partly competing and complementary alternatives.

3.4.3.2 Driving forces and consequences

Now, what is the essence of digitalization and its effects on the network? At the very basic level, all digital information transmitted and processed is in the form of discrete information signals, represented by so-called binary digits (bits), whereas analog signals are continuously varying signals. The bits streams in telecommunications are of the same kind as data in computers – with appropriate software telecom, bits can be stored, copied, retrieved and manipulated as in computers.

In telecommunications, there are two primary performance effects of digitalization[165]:

1. Significantly improved quality and distance insensitivity. There are two factors involved here. First, signal deterioration due to distance is reduced since digital information can be regenerated without increases in noise. Second, it is possible to obtain an error control of the regenerated signals, ensuring the quality and stability of the signal.
2. A platform for introducing computer software capabilities into the network. This factor is of dynamic nature, generating a new set of capabilities when complemented by computer software and electronics. This simple change in information structure provides a platform for a whole new set of capabilities and opportunities. In particular, software nodes and capabilities can be introduced into the network, generating new types of services. One could thus think of a digital network as a new type of infrastructure, upon which numerous applications – many not yet realized – could be built. The opportunities for dynamic chain effects are ample.

A consequence of the first factor is that it is possible to utilize multiplexing without raising the error rate in any problematic fashion and without the overhearing and cross-talk effects of analog multiplexing. Hence, speed and transmission capacity can be increased. Moreover, there are cross-effects between the two. High signal quality over long distances gives new degrees of freedom in network architecture design, in turn making new software-based services and features easier to implement. Service-generating software nodes can be centralized to a few locations, instead of being duplicated throughout the network, reaping benefits of economies of scale. A related feature is that routing can be more flexibly performed, ensuring higher reliability (more redundant paths) and lower costs (more opportunities for concentration and scale effects). Thus, with digitalization a new type of network design emerges.

If we bring in the cost structure of the new digital technologies, the trend towards a new type of network structure becomes even clearer. There is a fundamental trade-off between transmission and switching. With electronic switching, it has been possible to 'decentralize' switching to remote units. With fiber optics, transmission for high-density routes is much cheaper than in a previous era. Together with the distance insensitivity of digital communications, these two factors allow a network structure that is less hierarchical, instead looking more like a 'meshed' network structure, where comparatively more switches are interconnected with each other directly. This in turn contributes to a network that is more redundant as well as safer. Another redundancy and reliability effect of digitalization is the fact that computer-based surveillance and monitoring can be increasingly integrated with the network operations, ensuring higher quality.

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[165] Calhoun (1988) and NTIA (1992:91):

Returning to the second digitalization effect, digitalization paves the way for a network that integrates data with communications. The trend towards convergence has wider implications than that, however, impacting related industries and actors.[166] Convergence is related not only to technologies but also to services and actors.

The increasing integration with software not only builds a platform for a new type of network and convergence, but also provides a base for the multiplication and proliferation of new services. New services can be built into new software, existing software can be expanded with new features, existing software in switches and nodes can be easily updated and changed. Granted, the software update in switches is not as easy and cheap as software update in personal computers, but there is a vast difference between updating switching software compared with updating electromechanical capabilities.

Lastly, with digitalization, telecommunications have embarked upon a technological 'trajectory' that is still dynamic and developing, with consequences and implications that we cannot foresee as of yet due to the ongoing and future changes (Dosi 1982; Freeman, 1993).

On the cost side, digitalization has also been favorable. Electronic equipment costs have plummeted; physical sizes of switches have been reduced due to increasing miniaturization of electronics and, with the wide diffusion of digital network equipment among telcos, up-front R&D costs of equipment suppliers become less burdensome, in turn allowing further price reductions (that each new generation requires escalating R&D, contributing to industrial concentration, is another issue). Moreover, as described above, digitalization of copper transmission provided a much more efficient utilization of existing facilities.

Finally, related to the possibilities elaborated above, digitalization improves the opportunities for competition by making it easier for different operators to provide services to the same facilities, bill for and differentiate their services etc. Thus digitalization has been one main driver of liberalization.

3.4.4 Convergence and divergence

As mentioned in the previous section, one of the main consequences of digitalization has been *convergence*. The notion of convergence has been widely used by practitioners and analysts to describe the development of the ICT field. In general, the notion lacks precise and rigorous definitions and is surrounded by conceptual ambiguities (Bohlin et al. 2000). It is not clear even to industry experts what is actually meant by convergence or the consequences it might have. Hence, again there is a need for conceptual clarification and empirical analysis, which will only briefly be touched upon here and calls for further research.

3.4.4.1 Conceptual clarification

In general terms, convergence refers to a process where different entities become more alike with respect to something, normally a feature or characteristic of those entities.[167] In other words, there is a convergence of A and B with respect to some feature F (or F-type convergence of A and B), if A and B become more similar with respect to F. (The term is sometimes used for routes that merge into one, for instance roads or rivers, although to speak of integration or fusion is less ambiguous in such a case.) There may be a confluence/fusion of A and B if they join into C (constituting some elements of both A and B). Thus, there seem

[166] OECD (1992)

[167] It can also be said that the distance between them, along the dimension of that feature, becomes shorter.

to be two distinct, but sometimes confused, meanings of convergence. Here we will distinguish them by using the terms "convergence" and "fusion" respectively.[168]

"Technological convergence" (Rosenberg [1963] 1976), "technology fusion" (Kodama 1992) and "industrial convergence" (e.g. Greenstein and Khanna 1997) seem to be most commonly used in the literature. In a study of the American machine tools industry, Rosenberg ([1963] 1976: 9-31) coined the concept of technological convergence. He refers to the fact that the employment of similar skills, techniques, processes, and problems became common to a wide range of industries, which were unrelated as regards usage (of their produced products). On a technological basis, these industries (exemplified by firearms, sewing machines, bicycles, and automobiles) became more closely related (in terms of their use of similar machine tools). To put it somewhat differently, the Rosenbergian case of technological convergence can be expressed as inter-industry technological diffusion of machine tools. If industries overlap with applications, technological convergence could also be expressed as a broadening of the application base of a technology (or set of technologies), or in Lindmark (2002) terms: a case of application diversification of a technology. A generic or pervasive technology (or set of technologies) such as machine tools was diffused to a broad range of industries or applications.[169]

Another frequently used concept is that of "industrial convergence", referring to the process of industries (suitably defined) becoming more similar with respect to the set of participants (most often the producers). Literature has tried to explore the relationships between technological and industrial convergence.

A further useful distinction is that of Greenstein and Khanna (1997) – convergence in substitutes and convergence in complements. Such a distinction is important since the economic effects are different. Products converge in substitutes when users increasingly consider products interchangeable with each other, which in turn occurs in two ways. First, a given set of users may be willing to use the products as substitutes in an increasing number of tasks. Second, an increasing number of users might begin to consider the products as substitutes in a given number of tasks. Convergence in substitutes generally leads to widening technical opportunities and increased competition. In our terminology, a convergence in substitutes constitutes a convergence of products with respect to the functions they perform and the applications in which they are used. Products converge in complements when they increasingly work better together than separately. Products may converge in complements with respect to tasks and users, analogously to the process of convergence in substitutes. A convergence in complements often leads to new products which have to await development of complementary components – system integration tools and the standardization of interfaces. Depending on the system level of analysis, a particular category of convergence may be of either kind. A convergence in complements at component level may take place simultaneously with a convergence in substitutes at system level. Moreover, if user bases shift and technologies improve, relationships may shift from predominantly complementary to predominantly substituting.[170]

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[168] Some (more) empirically grounded definitions are found in European Commission (1997) and SOU (1999). The European Commission (1997) distinguishes between (a) the ability of different network platforms to carry essentially similar kinds of services and (b) the coming together of consumer devices such as the telephone, television and personal computer. SOU (1999) distinguishes between (1) network convergence, (2) service convergence, (3) apparatus convergence and (4) market convergence.

[169] Similarly, general-purpose technologies (e.g. machine tools, rail transport and steam engines) diffused into and enhanced productivity in most industries (Bresnahan and Trajtenberg 1995).

[170] Greenstein and Khanna (1997) also stress the importance of where in the "value chain" convergence occurs. The value chain draws on Porter (1985) considering the firm as a bundle of activities that collectively produce value for the end-user.

The concept of convergence in complements is quite similar to that of "technology fusion", which is the process of combining two or more existing technologies into a hybrid or new one, e.g. optics and electronics into opto-electronics (Kodama 1992). If two entities fuse, they become entities in a larger system that may perform a different set of functions than the original ones. Such fusion processes often give rise to entirely new products and industries. It is reasonable to assume that the new system will require competencies partly overlapping with the old ones, but also some new ones (at least the system integration competence).

3.4.4.2 Convergence in telecommunications

Technological convergence has been observed for decades in ICT. Computers and telecommunications were initially separate techno-economic fields. Then digitalization triggered a process of technological convergence, allowing voice, data, and images to be carried over the same networks. The introduction of digital computer (stored program) control switching marked a first wave of computers being used in telecommunications. As telephone networks increasingly became digitized, a number of telecommunications companies had to accumulate skills in software and microelectronics. In the 1970s and 1980s, analysts and practitioners recognized this technological convergence (i.e. two product classes converging with respect to technology, but also as one technology diversifying into a new application), and envisioned an industrial convergence as well. Leading firms in those industries started a process of entering the other industry.[171]

As is widely observed (Mansell 1993; Duysters and Hagedoorn 1998; Gambardella and Torrisi 1998) these entries failed as a rule; technological convergence did not lead to an industrial convergence. Literature suggests that the most natural explanation is that if markets and industries preserve differences in the nature of their products and customers, their assets, competencies and capabilities will remain different. In the terminology proposed here, the failed entries can be classified as a halted process of supplier convergence, partly to be explained by a lack of convergence with respect to applications and market segments and the accompanying capabilities needed to serve these.[172]

Thus there are number of convergence processes taking place at different levels in the sector and its innovation system, in complicated patterns and with non-trivial consequences. Possibly it could be claimed that digitalization at the technical system level drives convergence at technical knowledge, actors and institutional levels, where the latter have difficulties to adapt and adjust. Convergence requires complicated patterns of collaboration in innovation systems. Especially the institutional regimes seem to be slow to adapt. Intellectual property systems have trouble in adapting to this, as have standardization regimes and the regulatory framework. Finally, and perhaps somewhat paradoxically, convergence drives divergence.

3.4.4.3 Divergence in telecommunications

With the emergence of digitalization opportunities in the 1970s and digitalization implementation in the 1980s, possibilities for tele-services expansion increased, i.e. a more differentiated or divergent range of applications and services could be provided. As discussed in the previous section, digitalization provided a platform for new types of services and

[171] See Bohlin et al. (2000) for an overview of convergence in computing and telecommunications.

[172] Other explanations include lower than expected economies of scope, continuing importance of economies of scale (Malerba et al. 1991), and the fact that technological convergence did not affect the technology bases of firms, due to organizational inertia (Duysters and Hagedoorn, 1998). Thus, it appears that (similarly to the case of surviving firms in technological discontinuities), explanatory factors are found at technological, organizational and market levels.

convergence between media and services. Digitalization has the potential to offer increasingly customized services, befitting a society that has shifted towards individualization and increasingly differentiated needs (cf. the broad social trends identified by Toffler, 1985). Moreover, the emergence of computer networking, starting with some modest modem services in 1957 in the Bell System but expanding with the pervasive diffusion and innovations in computers, has necessitated service expansion in terms of data networks, in particular the Internet (see further Chapter 6).

Figure 3-12 illustrates the proliferation of telecommunications services over time. Note that the bulk of service expansion took off with the advent of electronics and new digital technologies in the 1970s. Not directly shown in the figure is that the new technology has produced dynamics and cross-effects in several types of services. A case in point is modern cellular telephony, e.g. the Nordic mobile telephone system (NMT) launched in 1981, which requires advanced microelectronics in the switches in order to perform adequately with respect to some critical capabilities (roaming, tracing speed of mobile terminals, etc.). There are several other examples that could be enumerated in this context: the relationship between data applications and digitalization, digitalization and video/image technologies and services, etc. Note furthermore that telecommunications technologies have become more closely integrated with broadcasting through e.g. video and tele-newspapers, as suggested in the figure.

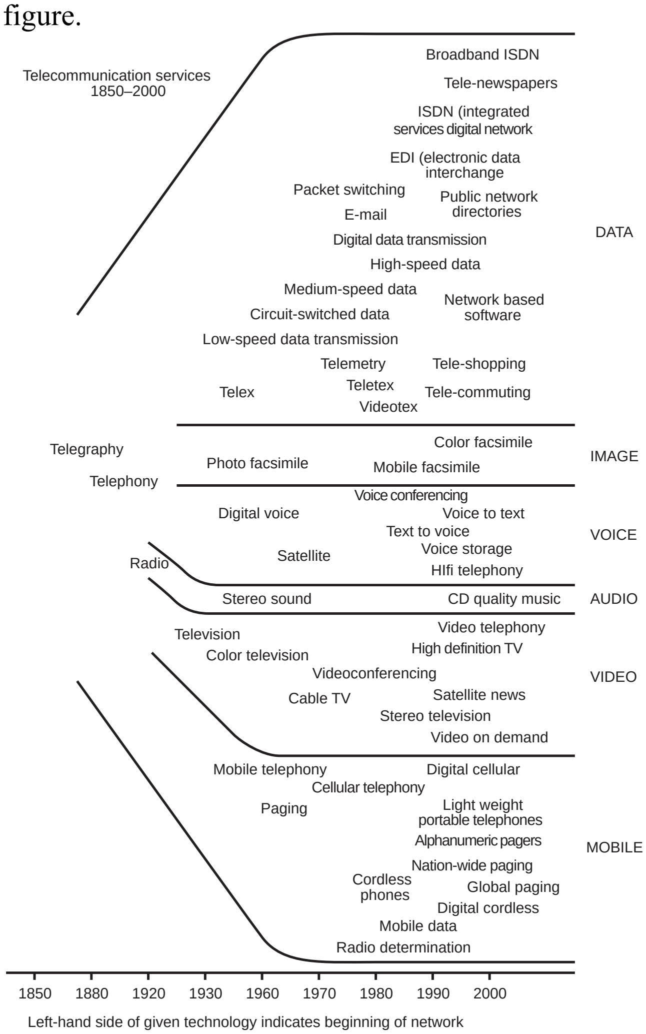

Figure 3-12: Evolution of telecommunication services

Source: Minoli (1991:4)

Another illustration (see Table 3-7) of this service expansion is the case of AT&T. In just five years, between 1987 and 1992 – the final stages of AT&T's network digitalization – AT&T increased the number of services offered from 56 to 214 and the number of service areas from 11 to 17. Admittedly, the representation, counting the number of services and service areas, is somewhat crude as one could argue that it represents only a proliferation of service labels without any change in content. However, an inspection of the service description in the source, the product and service catalog of AT&T (Telecom Publishing Group, 1987, 1992), reveals that the labeling effect does not explain much – there is a change in service content as well. Granted a few cases of labeling proliferation, this also represents something – a need for increasing differentiation.

Table 3-7: **AT&T's service expansion 1987-1992**

1987 service category	No	1992 service category	No
Credit card services	4	Credit card services	11
Data communication services	8	Data communication services	17
		Directory services	3
Electronic messaging	1	Electronic messaging	12
		Facsimile services	4
Fiber-optic services	1	Fiber optics services	2
		Fraud protection services	4
		Information services	6
		ISDN services	3
Long-distance services	23	Long-distance services	96
Microwave services	1	Microwave services	1
Multiplexor services[a]	1	Multiplexor services[a)]	3
Packet switching services	1	Packet switching services	2
Private line services	8	Private line services	31
Software-defined services	1	Software-defined services	8
Teleconferencing services	7	Teleconferencing services	11
		Videoconferencing services	2
Total number of service categories	11	Total number of service categories	17
Total number of services	56	Total number of services	216

[a)] The 1992 list does not separate multiplexing services as a separate service category, only as options within a service. For comparability, the multiplexing options are presented separately.

Source: The Desktop Guide to AT&T's Products and Services, 1987 and 1992, Telecom Publishing Group

Another aspect of the service expansion era and its concomitant digitalization is that the widespread adoption of computers and computer networking is contributing to an increasingly integrated network in terms of technology, in turn providing a platform for service generation and combinations, an opportunity of a multiplicative nature. The current tele-service expansion phase has not reached full maturity, though, as the network is not yet completely digitalized – the last mile is still missing.

It is possible to connect divergence with the push for liberalization and competition as well. Clearly, the liberalization process started in advanced countries. As basic telephony growth came to maturity and technology opportunities presented new options for service expansion, there was an interest among telephone carriers to go into new growth areas, but these were difficult to contain in a monopolistic framework (e.g. computer data services) although carriers tried. On the other hand, there was a concern of other actors to delve into the network and compete, as the network promised to provide a bridge towards services with future growth. Therefore, liberalization and competition ensued.

Given the strong economic incentives to utilize the existing network and its embedded structure, the network of the future will hardly be homogeneous. Rather, it will be a patchwork of different co-existing technologies, partly overlapping and complementary. The opportunities for a new type of network structure based on digital and fiber technologies, including a trend towards more redundancy due to cheap transmission and more decentralized switching and control features closer to the user, both contributing to an increasingly 'meshed' instead of hierarchical network, will not immediately produce a new type of network. Instead, a more appropriate image for the future network is something that captures the multiplicity, the dynamics of service expansion, overlapping (overlay) nature, multiple actors and technologies: a 'network of networks' (Noam, 1992), a 'laminar' network (Calhoun, 1992), a 'network mosaic' (Bruce et al., 1988), a 'super-industrial' network (Toffler, 1985), 'multiple' networks (OECD, 1992).[173] For short, we can label this new type of networks in the tele-service era as *service-expanding networks,* emphasizing the direction and dynamics of network evolution, together with the multiplicity, i.e. plural, nature of the network (still, the image of a network is retained).

3.4.5 Standardization

From its state during the PTT era, the standardization regime changed radically in several ways: (1) from national proprietary to becoming increasingly internationalized and open, as did competition. Following that, (2) standardization became of increasing importance to the competitiveness of the manufacturing industry, thus of strategic and industrial-political importance. (3) The locus of influence changed from operators to suppliers. (4) Formal standardization bodies became increasingly complemented with ad-hoc consortia, resulting from a combination of rapid technological change and convergence. (5) Standards came increasingly into competition with anther institutional regime – patents. Finally (6) the increasing stress on the standardization regime will be touched upon. First, however, some key events will be investigated.

In Europe, where the changes were most visible, the intensified policy of EC resulted in the creation of a new European Telecommunications Standardisation Institute (ETSI). As mentioned before, the EC recognized the telecommunications sector as becoming of increasing strategic importance for its member countries in the 1980s. A first phase of community policy was initiated in 1984 with the aim of moving the sector forward to establish common development lines. One important aspect was this early policy which recognized the importance of European standards development, in order to cope with the problem of national fragmentation created by different national specifications.[174] A second phase of Community policy was initiated in 1987 with the publication entitled "Green Paper on the Development of Common Market Telecommunication Services and Equipment".[175] The Green Paper included an action plan whose essential objective was to "develop the conditions under which the market will offer European users a greater variety of telecommunication services with better quality and lower cost". A major objective was to facilitate the member countries' taking advantage of the economies of scale that a common market would offer.[176] Therefore, the Green Paper (and other forces, such as investigations undertaken by CEPT itself) called for better coordination of standardization activities,

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[173] DOJ (1987) proposed another image that gained widespread recognition in the industry, namely the so-called 'geodesic' network.

[174] European Commission (1998). The ACTS (Advanced Communications Technology and Services) program took over from RACE in 1994 under the fourth framework program. See Chapter 8.

[175] European Commission (1987) as quoted by Jagoda and de Villepin (1991).

[176] European Commission (1987) as quoted by Jagoda and de Villepin (1991).

involving not only the administrations but also other interest groups such as the manufacturing industry. The Green Paper also recommended a separation of the regulatory and operating parts of the PTTs (CEPT included both these entities), and separation of telecom from postal standardization. As a result ETSI was established.

In 1988, ETSI commenced its activities, and most of the CEPT standardization activities (including GSM) were gradually transferred to it. ETSI was not, like CEPT, restricted to the administrations, but included also members from industry, user groups and other (non-PTT) operators and service providers, as well as non-European organizations (provided that they had some R&D activity going on in Europe).[177]

Some changes also took place in the US and Japan during the 1980s. In the US, in 1988, TIA (the Telecommunications Industry Association) was created (it had predecessors, though) as one of many SDOs accredited by the official US SDO – ANSI. The TIA also coordinates US positions for international bodies (such as IEC and ITU). TIA is fully oriented on the manufacturing sector. Another ANSI-accredited body created in the 1980s is the Committee T1.[178]

Two major standard bodies were formed in Japan during the time period: (1) TTC in 1985 and (2) ARIB in 1995. TTC was formed in response to the liberalization of the Japanese telecommunications market. It includes Japanese suppliers, operators and branches of foreign suppliers. When necessary, TTC cooperates with ARIB, which deals specifically with radio standards and other aspects of radio communications.[179]

Two other increasingly important national standardization bodies are TTA of Korea and CWRS of China. The Korean Telecommunications Technology Association (TTA) was founded in 1988 as part of the Korean industry policy effort to establish the country as a leading telecommunications nation. In the 1990s the Korean industry was increasingly active on the worldwide telecommunications market, and the TTA supports this by lobbying for having Korean standards adopted on an international level, in particular in mobile communications. Lately China has been pursuing a similar catching-up, determined to internationalize, influence standards, take the lead, and focus on a mobile approach like Korea. The China Wireless Telecommunications Standard (CWTS) group was created in 1999 for this purpose.[180]

In summary, a number of national and regional telecommunications standards bodies were created as a result of the recognition of the increasing importance of standardization. The increasing importance of standardization in telecommunications and information-based industries in general has been observed by others (e.g. David and Steinmueller 1994, Shapiro and Varian 1999), and is confirmed by this study. We will continue this discussion on a more general level, in a quest of trying to come to grips with changes taking place.

In general terms, compatibility standards could be expected to be important for any large technical system where components cannot be easily assembled under the control of a single agent (David and Steinmueller 1994). Such standards define the interfaces between the components and how those components can be successfully integrated into the network. Thereby compatibility standards simplify the process of developing and designing the

[177] Meurling & Jeans (1994); Garrard (1998) and personal communication with T. Haug (2000).

[178] Bekkers (2001:155-158)

[179] Bekkers (2001:158-160)

[180] Bekkers (2001:155-158)

components of the systems and realizing potential complementarities of subsystems. Standards allow specialization and economies of scale, and facilitate innovation and diffusion of complementary systems, thus stimulating diffusion among sellers of complementary products. As a result, compatibility standardization increases the availability, technical performance and user utility of applications, and will thus stimulate buyer diffusion – leading to dynamic economies of scale, which in turn further increase the attractiveness of the focal technical systems that were standardized in the first place. Thus, compatibility standards, if successful in design and timely in implementation, increase the viability of both the technical and actor systems, strengthen some of the positive feedback loops already at hand, and foster the evolution of the techno-economic systems as a whole.[181]

The internationalization and increased openness of standards, particularly evident in mobile and data communications, is simply a result of the general liberalization and internationalization of the telecom sector. In this process, international competition between standards and between firms has become evident and intertwined. In a case of competition between standards, or rather competition between technical systems that are to a certain degree defined by standards, positive feedback loops will work more or less[182] in favor of the more widely adopted standard, and the market becomes locked in to one or a few standards.[183] Sponsors of the "winning" standards are likely to come out more successful than sponsors of unsuccessful standards. The increasing importance of standardization will therefore have a number of other strategic consequences, as will be shown by the case of mobile telephony where positive feedback processes have worked in favor of GSM and its sponsors.

Meanwhile operators' (notably the former PTTs') influence on standard-setting has decreased. Influencing standards requires technical competence and commitment of resources, which have to be weighed against the possibilities to influence the outcome and appropriability of benefits that arise from standardization. The deregulation of and increased competition in the mobile communications market have reduced the incentives for the former monopolies (like any other operator) to engage in extensive standard-setting, since the standards are available free of charge to competitors. In some cases (such as UMTS licenses in Sweden) the former monopolies may even, as a result of licensing procedures, be denied access to standards they once invested in developing.

The majority of compatibility standards (at least in mobile communications) are "anticipatory standards", i.e. standards that are created ahead of products. Such standards are based on collective R&D and consensus-based product design (or rather architecture and interface design). Since companies differ with respect to their technological bases (Granstrand 1994), strategies and patent positions, they will try to influence the standards to align them with those technological bases, strategies and patent positions. This is one major explanation why systems suppliers (such as Ericsson) have devoted more and more resources to standard-setting. Since international competition between standards clearly affects the competition between companies, to be able to pick and promote the winning standards is of increasing importance not only to management but also to policy.

Now, the complexity of the technical systems (in the sense of many interdependent subsystems and the number of interfaces between them) increases as a result of convergence and broadening of the applications space. Therefore, achieving compatibility by standardization becomes a time-consuming venture. In combination with rapid technological

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181 Lindmark (2002)

182 Depending on the strength and time-lags of the feedback loops and the degree of incompatibility between standards.

183 See Arthur (1988), Katz and Shapiro (1994), Shapiro and Varian (1999)

change, this makes anticipatory standardization more difficult to achieve in a timely way, and is not easily handled within a single standardization regime. These factors have rendered the traditional institutional framework for standard-setting obsolete, to be replaced with a mix of standard-setting by official and unofficial consortia, *de facto* standardization, and ex-post introduction of gateway devices. These observations of an increasing number of consortia are in line with what has been noticed by students of standard-setting in the ICT-based industries in general (e.g. Hawkins 1999). In addition, since younger and younger technologies are standardized, intellectual property rights have increasingly been conflicting with standardization (as observed by e.g. Farrell 1989, Shurmer and Lea 1994, Granstrand 1999, and Beckers 2001).

In conclusion the pace, importance and complexity of standardization have increased from the 1970s. The process of liberalization and internationalization in the sector has made standards more international and open, while at the same time competing standards have clashed on the market. Following this, aligning standards to the technological competence bases of firms and nations has become an important part of corporate strategies and industrial policies. This has led to the formation of regional and national telecom SDOs. The complexities of technologies, with multiple interdependencies between and in the networks, have made the activities of SDOs very much interdependent on each other. Combined with rapid technological change and convergence, the formal standardization bodies became increasingly complemented with ad-hoc consortia. The importance of anticipatory standardization, including technology as recent as feasible into standards, has led standards to come increasingly into competition with anther institutional regime – patents. Finally, the convergence with data communications has put further stress on telecommunications, as will be investigated in Chapter 6.

3.4.6 Research and Technological Development

3.4.6.1 The changing R&D regime

Section 3.4.2 investigated technological change in the telecom sector. In this section we take the analysis one step further by analyzing changing regimes of innovation, e.g. in terms of R&D spending. In doing so, we start from Fransman's (2003) analysis of the evolution of the telecommunications industry. Fransman in turn begins with the Schumpeterian emphasis on innovation as the engine of change in an industry, which in turn is dependent on the technological regime. The technological regime is defined by the conditions under which technological knowledge is created, which determine what kinds of technological change are created and the opportunities and constraints that exist in the use of that knowledge. This will in turn influence the kinds of learning paths and patterns in which the firms involved will engage.[184] Finally, in order to fully understand the technological regime change we must understand the innovation system and its change.[185]

[184] Fransman (2003:36). See also Nelson and Winter (1977); Breschi and Malerba (1997); Malerba and Orsenigo (1997)

[185] Fransman (2003:39)

According to Fransman (2002) the telecom industry changed from the old PTT structure, via a transition stage, to the current "Infocommunications industry". The main features of the innovation system of the old regime and the new "Infocommunications industry" are summarized in Table 3-8. First, there was a change of locus of innovation. Innovation was mainly located in the central research labs of the monopoly operators such as AT&T's Bell laboratories, BT's Martlesham Laboratories, France Telecom's CNET laboratories, or NTT's Electrical Engineering Laboratories. The role of the national preferred equipment suppliers was basically to fine-tune development and manufacture the products.

Table 3-8: The innovation systems of the old PTT regime and new Infocom industry

The PTT innovation system	The Infocom innovation system
Closed innovation system	Open innovation system
High entry barriers	Low entry barriers
Few innovators	Many innovators
Fragmented knowledge base	Common knowledge base
Medium-powered incentives	High-powered incentives
Slow, sequential innovation:	Rapid, concurrent innovation:
- Research-prototype-trials-cutover	- New forms of innovation (e.g. concurrent cooperative innovation by remote innovators)

Source: Adapted from Fransman (2003:69)

This innovation system actually worked quite well. A stream of radical and incremental innovations emerged from the labs. Although there were no real market incentives to make it work well, there were other incentives. First, there were political pressures to improve service. Second, there was a spirit of "cooperative competition" between the national systems to produce innovations. This applied also to the skilled force of "technological men" (Bohlin 1995) tasked with innovation. However, the system was closed in the sense that PTT designs were specific to each operator (i.e. the knowledge base was fragmented) and the circle of manufacturers was also closed. Thus barriers to entry were high. Finally, the innovation process was rather slow and sequential.[186]

Over time, the equipment suppliers underwent a learning process and became able to conduct more research- and design-intensive activities. In order to grow, they entered markets where the entry barriers of the PTT systems were lower. Meanwhile some markets (US, Japan and UK) opened up to new entrants. Entry barriers to become an operator were lower than before, since the new entrants could source technology from specialist suppliers. These new entrants did not have to engage in costly R&D. Consequently the market outside the closed national PTTs began to expand, which opened up for a new breed of R&D-intensive international specialist equipment suppliers. In order to stay competitive, the incumbent operators also decided to leave more R&D to their suppliers and to source also from other suppliers than their initially preferred ones. Incentives to compete with innovation were higher for equipment suppliers in this transitional regime than for the PTTs in the old one. As a result, R&D was intensified. International standards started to emerge and opened up the system making the knowledge base less fragmented and somewhat less sequential.[187]

[186] Fransman (2003:35-43)

[187] See Fransman (2003:44-54)

Currently, the transition regime is in turn undergoing change, since it is being disrupted by the Internet regime, coming from outside the industry. The disruptive technologies of e,g. packet switching, TCP/IP and WWW have led to a number of further changes. Perhaps most important (and treated elsewhere in this chapter) are the new layers of competition, introducing new markets for e.g. connectivity, navigation and middleware, applications, content packaging etc. In terms of the innovation features, a number of other changes occurred (see again Table 3-8). First, the innovation system further opened since virtually anyone could create innovations, in particular when the VC industry expanded. The entry barriers are lower, and entry is facilitated by a common knowledge base regarding key technologies and global de facto standards (software, TCP/IP, html, WAP). Further, the globalization of markets increased the incentives to innovate, making the rate of innovation higher. Finally, increased modularity and flexibility of new networks (packet-switching versus circuit-switching) made the innovation process less linear.[188]

Now, what have been the patterns of R&D spendings in telecoms? Time has not allowed a systematic mapping of R&D spendings, but some indications are given below (see Figure 3-13, Figure 3-14, Figure 3-15 and Figure 3-16). First, it seems plausible that R&D spendings in the early 1970s were in the range of 5% of sales for equipment manufacturers and higher for operators (see e.g. Steinbock 2003:68). As mentioned above, equipment manufacturers increased that percentage substantially, to 10-15% by now. The former PTTs lowered these, differently depending on the circumstances. By 1990, the three giant former monopolies AT&T, BT and NTT's R&D intensities were 7.3%, 3.8% and 2.1% respectively. By 1999 these figures had changed to 0.9%, 1.8% and 3.9% (Figure 3-13 below). The tables also indicate that Telia has spent a relatively high share of turnover on R&D in recent years. The high R&D inputs of large former PTTs led to relatively large patenting portfolios (in spite of the fact that patenting was not highly prioritized). In a compilation of operator USPTO patenting statistics, AT&T had the strongest portfolio (1,057 USPTO patents granted 1995-2001), followed by BT (449), France Telecom (302), NTT (266), Telecom Italia (74) and Telia (51).[189]

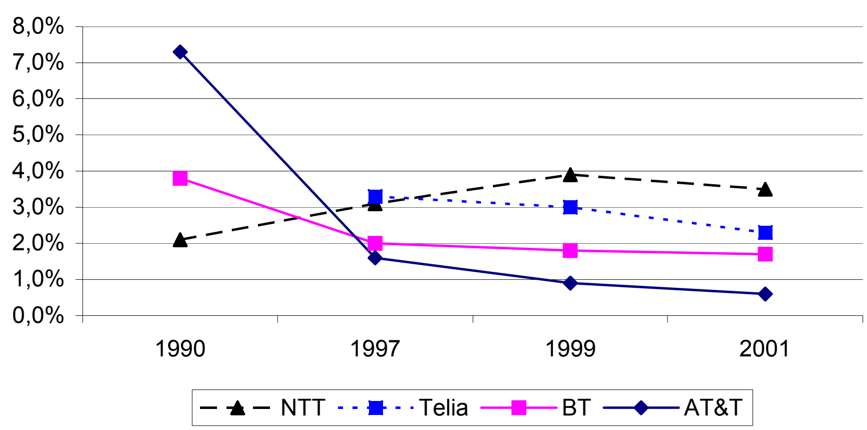

Figure 3-13: R&D as share of total turnover for selected operators (1990, 1999, 2001)

Source: Fransman (2003:84) and OECD (2003a:80)

As mentioned above, the equipment manufacturers spent rapidly increasing amounts on R&D during the 1990s. Figure 3-14 and Figure 3-15 show rapid increases among the top five equipment manufacturers in the late 1990s. The figures also indicate that Ericsson was the

[188] Fransman (2003:69-70)

[189] OECD (2003a:80)

equipment manufacturer that spent most on R&D in recent years, both in absolute and in relative terms.

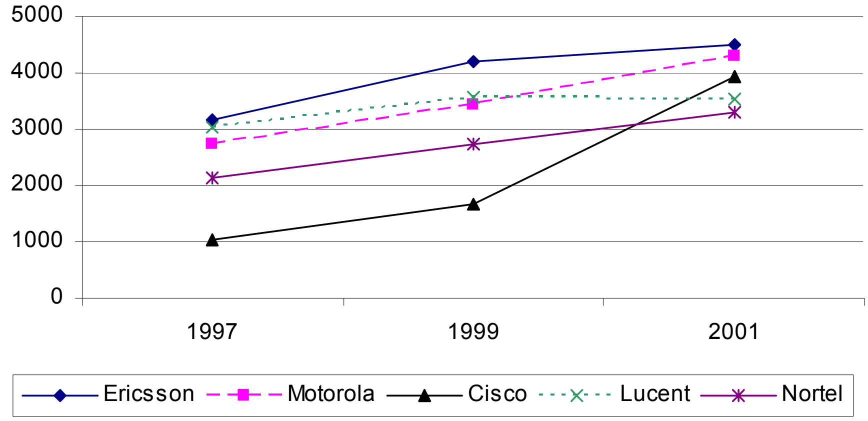

Figure 3-14: Top five equipment manufacturers regarding R&D expenditure (1997-2001)

Source: OECD (2003a:81)

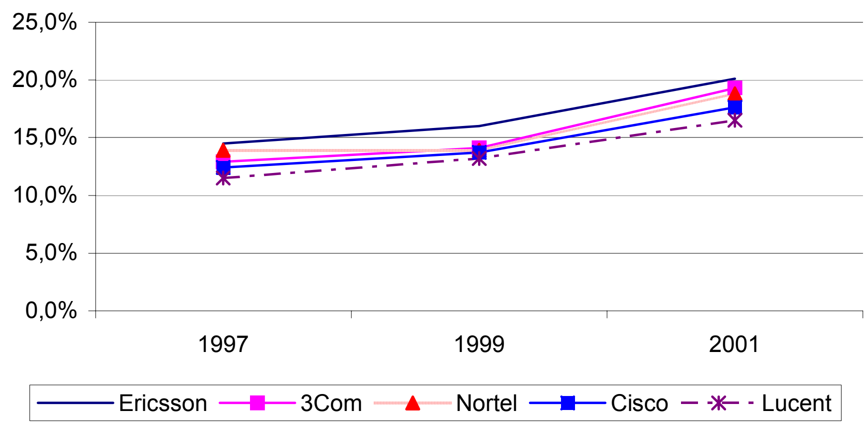

Figure 3-15: Top five equipment manufacturers regarding R&D as share of total turnover (%) (1997-2001)

Source: OECD (2003a:81)

Patent statistics show a somewhat different picture. The five equipment manufacturing companies with most USPTO patents granted in the late 1990s were the large Asian electronics conglomerates, accompanied by the US telecom equipment manufacturer Lucent (Figure 3-16 below). Of the telecom equipment manufacturers, Motorola and Siemens also had more patents granted in the period. With both these firms active in many other technological fields besides telecom, it seems plausible that Ericsson has a comparably strong position also in telecoms patenting.

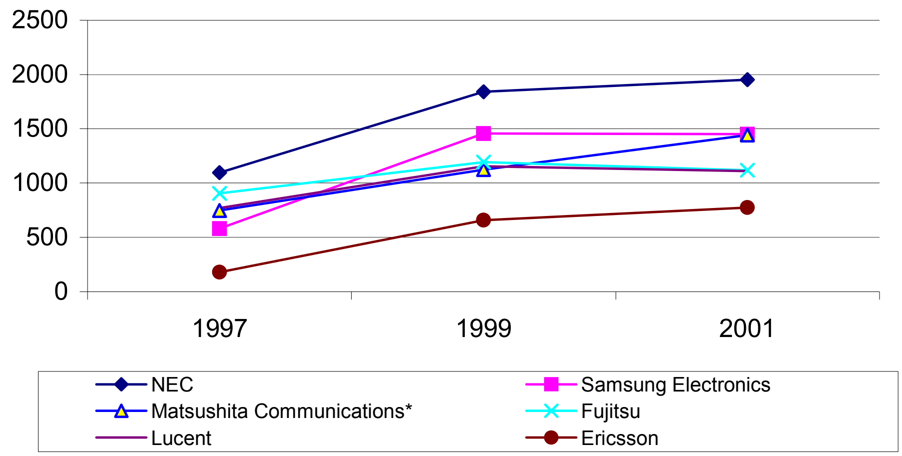

Figure 3-16: Top five equipment manufacturers (+ Ericsson) regarding USPTO patents granted (1997, 1999, 2001)

Source: OECD (2003a:81)

In general, development costs have been escalating in telecommunications, not least for switching. The digital switching platforms cost about one billion USD each to develop (see Table 3-9). According to OECD (2003a:68) the leading operators and carriers taken together spend increasing amounts on R&D. Between 1997 and 2001 equipment manufacturers' R&D investments increased from USD 27 to 38 billion, while operators' spendings were fairly flat at USD 6-7 billion. This spending increase corresponds to almost a doubling in patenting activity, with USPTO patenting increasing from some 6,400 to 11,500 patents from suppliers, and from 170 to 600 patents from carriers in the same time frame. Thus the patenting increased more than R&D spending, possibly as a result of the increased importance of patenting in telecommunications (see Section 3.4.6.3)

Table 3-9 R&D expenditure on digital switching platforms, 1987

Switching platform	Development costs (billion dollars)
System X (GEC-Plessey)	1.4
System 12 (ITT)	1.0
E-10 (Alcatel)	0.75
5ESS (AT&T)	0.7
DMS (Northern Telecom)	0.7
EWSD (Siemens)	0.7
Total	0.5

Source: Noam (1992:320)

The increase in innovative activity might be even higher than indicated by R&D spendings and patents. Many of the new software and service innovations are difficult to patent and do not always show up in R&D statistics. In addition, given a higher entrepreneurial activity in the Infocom industry, there may be a shift in innovative activities from large actors to entrepreneurial start-ups. This would not show up in R&D statistics either. If this is true, data from e.g. the VC industry could partly compensate. We leave this question for further research however.

Table 3-10 and Table 3-11 give an overview of the R&D activities of some main actors in recent years. The observation that equipment manufacturers spend more is reinforced. In 2001, a trend of increased R&D spendings was broken, however, and in 2002 spending decreased sharply, mainly as result of some traditional telecom giants (Ericsson, Lucent, Nortel, Alcatel) cutting back on R&D, due to cost-cutting in trying to come to grips with multi-billion pound losses. In relative terms, Ericsson's cut-backs were the most drastic. Note also the relatively low spendings of the Japanese manufacturers, presumably a result of the high spendings of NTT.

Table 3-10 R&D statistics for a selection of telecom carriers

Company	2002 R&D Investment		Sales	R&D/ Sales	Profit	Previous R&D Investment			
	£M	*Change (%)*	*£M*		*£M*	*2001*	*2000*	*1999*	*1998*
NTT	2046	-3.7	60381	3.39%	271	2125.2	1871.9	998.3	1512.3
Deutsche Telekom	586.6	0.0	34995	1.68%	-13547	586.6	456.2	456.2	433.2
BT	380	5.0	18727	2.03%	3064	362	364	345	268
France Telecom	375.4	1.6	30394	1.24%	-9977	369.5	292.6	386.6	501.2
Telstra (Aus.)	194.1	-24.5	7064	2.75%	2217	257	211.9	187.4	94.4
Vodafone	164	49.1	30375	0.54%	-5365	110	72	46	36.8
AT&T	157.7	-21.9	23496	0.67%	-4039	201.8	249.7	341.6	411.2
KT (Korea)	143.7	-27.5	8586	1.67%	1915	198.1	161	105.5	94
SK Telecom	101.7	48.7	4883	2.08%	1332	68.4	41.2	37.8	40.5
TeliaSonera	83.1	-10.5	4240	1.96%	-693	92.8	111.4	111.9	121.8
Alltel. USA	73.9	-30.5	4959	1.49%	1127	106.4	133.6	94.4	124.9
Telefónica	61.5	-44.7	18250	0.34%	-562	111.3	69	58.8	50
Telenor	47.6	-42.0	4364	1.09%	-269	82.1	46.9	47.3	37.1
KDDI	46.8	74.6	14833	0.32%	340	26.8	4.5	0	0
Total	4462.1	-5.0	265547	1.68%	-24 186	4698	4085.9	3217	3725

Source: R&D Scoreboard database http://www.innovation.gov.uk/

Table 3-11 R&D statistics for a selection of telecom suppliers

Company	2002 R&D Investment		Sales	R&D/ sales	Op. profit	Previous R&D Investment			
	£M	*Change*	*£M*		*£M*	*2001*	*2000*	*1999*	*1998*
Motorola	2331.8	-13.1%	16572	14.1%	-1643	2682.1	2756	2135.5	1797
Nokia	2261.7	1.6%	19565	11.6%	3287	2226.5	1941.0	1320.5	868.0
Cisco	2141.7	-12.1%	11749	18.2%	1683	2436.1	2532.4	990.1	633.8
Ericsson	2090.9	-37.1%	10392	20.1%	-1186	3324.8	2988.4	2361.2	1997.9
Fujitsu	1831.2	-13.3%	26208	7.0%	-2887	2111.5	2099.2	2067.8	2026.3
NEC	1550.6	-11.2%	24575	6.3%	373	1746.3	1805.6	1649.6	1812.2
Alcatel	1544.7	-23.5%	10785	14.3%	-3047	2018.6	1982.1	1374.6	1179.1
Lucent	1434.8	-34.4%	7653	18.7%	-4108	2186.4	2495.8	2801.4	2284.6
Nortel	1385.1	-30.8%	6559	21.1%	-2365	2002.6	2487.7	1806.3	2614.4
Mitsubishi	1070.9	4.2%	19100	5.6%	-661	1028	910.7	954.6	1033.9
Broadcom	443.6	59.9%	673	65.9%	-1202	277.4	155.7	67.4	23.8
Qualcomm	280.5	8.9%	1888	14.9%	302	257.6	211.4	236.7	217
Total	18367	-17.6%	155719	11.8%	-11545	22297.9	22366	17765.7	16488

Source: R&D Scoreboard database http://www.innovation.gov.uk/

3.4.6.2 Government R&D

One reason for operators to keep up some R&D is that some of them are mandated by government to carry out R&D (e.g. NTT, Korean carriers, France Telecom and Canadian operators). As a rule, government-owned operators spend more on R&D.[190] In fact, governments have directly and indirectly financed R&D in telecommunications throughout the time period, but in changing ways. In the PTT era it was primarily done through the PTTs, sometimes in the form of over-priced equipment purchases. In some countries like France, PTT administrations subsidized R&D directly.[191] National government funding has continued until now, increasingly performed by agencies such as STU, Nutek and Vinnova in Sweden and Tekes in Finland. Joint subsidizing appeared, it seems, in the 1980s. In digital mobile communications, for instance, several Franco-German consortia, partly government-funded, were created with an aim of strengthening the manufacturing industries in the two countries.[192]

European-wide funding has become more and more important for the sector. The first initiative appears to have been COST[193], with a background in a concern within the EC regarding the rapid technological development in Japan and the US, and the risk that Europe would fall behind. COST projects were most active in the late 1970s and 1980s. Also countries outside the EC were allowed to participate in COST; e.g. Sweden was represented by Televerket which participated in many COST projects (which to a certain degree paralleled RACE).[194] In the 1980s, the EC realized that Europe was lagging behind, particularly in ICT. This was partly attributed to the large benefits US companies derived from military and space research. In a first step the ESPRIT program was initiated in 1984, focusing on five ICT-related technological fields, although not explicitly on telecommunications (although the field could indirectly benefit from progress in components and applications).[195] To deal with this weakness, the RACE program was initiated, focusing on broadband networks.

RACE was jointly funded by the EC and the manufacturing industry.[196] The objectives of RACE were threefold: (1) to stimulate cooperation between telecom industry and administrations across Europe; (2) to facilitate market liberalization; (3) to establish consensus on the development of specific telecommunications technology and infrastructure for implementing an Integrated Broadband Communications Network (IBC) across Europe by the middle to late 1990s.[197] The latter objective guided the research activities of RACE.[198]

RACE became divided into three phases: (1) a definition phase, (2) RACE I and (3) RACE II. RACE started with a definition phase that lasted between 1984 and 1986, and was aimed primarily towards integrated broadband networks.[199] The definition phase established that there was a need for a European framework for collaboration in R&D in telecommunications, and led to a decision adopted by the European Council in December 1997, calling for the first phase of RACE within the Second Framework for Research and Development.[200] The second

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[190] OECD (2003a:68)

[191] Bekkers (2001:68-69)

[192] Lindmark (2002). See further Chapter 0.

[193] COST – Cooperation in the field of Scientific and Technical Research

[194] Lernevall and Åkesson (1997: 694.)

[195] Another program was EUREKA, aimed at transforming technology into marketable products.

[196] RACE – Research and Development of Advanced Telecommunication Technologies

[197] Initially IBC was labeled B-ISDN, but was soon relabeled (Dupuis 2001e:179).

[198] Tuttlebee (1993:332-333).

[199] Tuttlebee (1993:332-333), RACE (1994) and Dupuis (2001e:180).

[200] Schwarz da Silva (2001:116).

phase of RACE – RACE II – was pursued in the context of the Third European Framework Programme (1992-1995). In RACE II other issues, for instance mobile communications issues of mobility, were given increased attention.

The ACTS (Advanced Communications Technologies and Services, lasting 1995-1998) framework (in the 4th Framework programme) continued and further expanded RACE II research in telecommunications. It could be mentioned that, in terms of resources and projects, the mobile communications part of ACTS was far more ambitious than in RACE. In ACTS more than 100 out of 630 million ECU in funding were allocated to mobile communications. Some 37 projects were related to mobile communications.[201] The trends of increased funding for ICT in general have continued into the 5th framework IST programme. At this writing, the first projects within a 6th framework programme have started.

3.4.6.3 The changing patenting regime

Patents have more and more become a competitive tool in telecommunications. In the early years, patents had a major role to play – Bell's telephone patents being the prime example. These patents were to become the basis for Bell system. Protection of patents was pushed more and more into the background during the PTT regime. Exclusive relations between operators and their suppliers, and the procurement practices used, resulted in limited competition, thus restricting the potential of patents. Manufacturers felt a limited need to patent, since they did not have any competitors. Manufacturers did not patent extensively either, since they faced limited competition and were often denied the possibilities to take out license fees, due to clauses in supply contracts or as a result of joint R&D arrangements.[202]

All this changed as a result of the internationalization of the manufacturing industry, liberalization, and the increasing importance of international anticipatory standards, including state-of-the-art technology covered by patents. It was the GSM case that brought out the conflict, where the aggressive patenting strategy (used in the US and in the radio industry) clashed with European procurement policies and a European manufacturing industry where patents were considered as something to be resolved with gentlemen's agreements (see further Chapter 0). Since then, pro-active patenting policies have been of utmost importance, in particular for suppliers.[203]

This has several implications. Patents must be used with caution as indicators of technological activity in telecommunications. In addition, the Swedish innovation system's patenting regime must be efficient enough to ensure competitiveness.

3.4.7 Liberalization

3.4.7.1 Definitions

One of the most important trends in the telecommunication sector in recent decades is that of the break-up of the PTT system and introduction of competition. A number of terms, often vaguely defined, have come to signify this change process, e.g. deregulation and liberalization. In line with Karlsson (1998:31-33) we would like to make a few definitions first. Liberalization is taken to mean a process of increased freedom, often through the removal of restrictions. In economic theory this concept has come to signify a change in market structure, towards intensified competition. Regulation is usually taken to mean governmental control or restriction of private economic activity. Deregulation is then the

[201] Garrard (1998:477) and ACTS (1999).

[202] Bekkers (2001:61, 64-

[203] See e.g. Granstrand (1999); Bekkers (2001) and Lindmark (2002)

process of lowering that control, e.g. by lowering entry barriers and by reducing government involvement. However, in the case of Sweden for instance, in some parts of the sector, it was rather a process of re-regulation. Additional important concepts and processes include (1) the corporatization of PTTs into publicly held companies, (2) their subsequent privatization, meaning that the government divested parts of its shares to private investors, and (3) separation and establishment of a regulatory authority.

3.4.7.2 Driving forces

Which were the driving forces of liberalization? Clearly these were a number of technological, political and economic factors, interacting in a complex manner.[204] Many students of telecommunications have tried to analyze which were the significant ones. Here we will provide a selection of the explanations given by Noam (1992: Ch. 4). Noam (1992:44-45) emphasizes the increasing importance of telecommunications in the growing service and information economy; i.e. telecommunications became increasingly important and costly, making a number of large users (which accounted for a substantial part of the traffic in the networks) seek low-cost transmission in the form of private networks. These could be built by using new technology. Since the PTTs had used the revenues from such users to subsidize residential ones, the regime came under serious stress. To exemplify, in the US roughly one third of the telecom investments were made by non-carriers in the mid-1980s, compared to 0% in the mid-1970s.[205]

Noam (1992, Ch. 3) also proposes an explanation called “network tipping”. Here the breakdown of the monopoly is seen as a product of its success in making the services universal. When the system expanded, the cross-subsidies created an incentive for some user groups to leave the system. The redistributive nature of the network was thus unstable, because it led to divergent interests, which could not be accommodated by a single system. This system could only be held together as long as arbitrage was prevented, if the minority could not exercise political power and had no choice but to stay in the system.

When approaching maturity[206] the equipment industry started pushing for upgrading the network and introducing new services, such as ISDN, IBN, cable television and Videotex. The industry also paid increased attention to international activities in order to compensate saturation in home markets, which in turn exerted pressure to (at least partly) open up these markets (previously protected from competition). This in turn put pressure on prices. In addition, the cost for incremental subscribers rose as networks were reaching maturity. In combination with a general tendency for lower efficiency in monopoly markets, there were forces pushing the cost curve upwards for the PTTs (all else being equal, disregarding for instance technological development). Finally, the equipment suppliers teamed up with the large non-carrier customers, which (as stated above) increasingly invested and took ownership over their investments, first in equipment, then in wiring, then in establishing private networks through the use of PBX (instead of public switches), LANs, etc. Therefore, the equipment industry, previously protecting the PTT structure, lost part of its incentives to continue to do so.[207] Finally, technological development (satellites, fiber optics) made transmission costs become less and less dependent on distance, further eroding PTTs’ policies to overprice long-distance and international services.[208]

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[204] Karlsson (1998:43)

[205] Noam (1992:46)

[206] The very rapid expansion and emerging saturation is a quite recent phenomenon in the highly developed countries, most passing 50% penetration mark during the late 1970s and approaching 100% in the late 1980s.

[207] Noam (1992:45-46, 48)

[208] Noam (1992:52)

Noam (1992:46-47) proceeds to argue that rapid technological development (improving capacity, reducing cost and manpower need) led to rapid productivity gains, in turn lowering the minimal size needed to form profitable alternative networks. In addition, the divergence of new applications and services made it difficult for a single network to service all specialized needs. Thus, diseconomies of scale and scope grew in importance, while at the same time increased traffic densities made alternative networks viable.[209] Technological development also made new alternative transmission paths emerge. For local distribution, the segment with the greatest characteristics of natural monopoly, several such alternative paths emerged, e.g. cable TV networks, satellite, cellular, and microwave multipoint distribution. For PTTs trying to gain control of these paths also, it meant that they had to diversify into new areas which were partly occupied already by other actors.[210]

As mentioned in previous sections, divergence was accompanied by convergence. Previously separate products, services and sectors, such as telecom, computing, office equipment and broadcasting, started to merge. This created tension and competition with other industries entering telecom and the PTTs entering other fields such as computers, TV, electronic publishing, modems, electronic mail, answering machines and so on, leading to conflicts of interests.[211] Adding to this, a second sector started to emerge, mainly in the US – an independent computer and components industry. These firms formed direct relations with users without protective mediation by the PTTs, in what Noam calls a "services-information industry coalition" (in the US including firms such as American Express, IBM, Time-Warner, TWA, Silicon Valley firms and Citicorp).[212]

Finally, there were pressures from within the PTTs, in particular those that bore the burdens of the postal sector. Engineers were attracted to the high-technology private sector with much higher salaries. Management realized that in order to cope with the inevitable competition, the PTTs had to be transformed into more flexible and independent structures. These and other factors drove corporatization of the PTTs.[213]

In addition to these factors, we would like to add the one given by e.g. Karlsson (1998b), namely policy diffusion. There was a general liberalization trend, of which telecommunications was part, with the US as prime mover and the policy advocated in particular by the WTO (World Trade Organization).

3.4.7.3 Patterns of liberalization

The process of liberalization in telecommunications started in the 1960s and has been ongoing since then. Drawing heavily on Karlsson (1998:36-43) (unless stated otherwise) we will briefly describe the developments on a few major markets including also the Nordic ones.

The transition of the PTT regime started in the US domestic market, which was a regulated monopoly dominated by AT&T and its local Bell operating companies. The first step towards a competitive regime was a result of the Hush-A-Phone controversy in the 1950s, regarding permission to connect privately owned equipment to AT&T's network. In 1968, in a similar case (the Carterfone case), FCC ruled in favor of permission. When the FCC took over testing

[209] Noam (1992:47, 50-51)

[210] Noam (1992:51-52)

[211] Noam (1992: 52)

[212] Noam (1992:48-49)

[213] Noam (1992:53-54)

and registration of such (terminal) equipment in 1968, the competition on the interconnect equipment could start effectively.

In the late 1960s, AT&T's long-distance monopoly was challenged by MCI (Microwave Communications). In 1969 FCC permitted MCI to establish a radio link between Chicago and St. Louis. This was the beginning of the end of infrastructure monopoly, reinforced by FCC's Specialized Common Carrier decision which regulated competition. By 1981 liberalization of entry to the telecommunications market was essentially complete.

Two main tasks remained: (1) the pursuance of the antitrust case against AT&T and the (2) adaptation of regulatory policies to the competitive conditions. Already in 1974 the Justice Department had brought a suit against AT&T, claiming that they had monopolized the long-distance service and equipment manufacturers market, largely through exclusionary practices of the local operating companies. In 1982, a decision was taken to break up AT&T into seven regional operating companies (RBOCs) and a long-distance service provider and equipment manufacturer (AT&T), at the same time opening up the market for enhanced services. The decision went into force in 1984. The main challenge since then was to find a coherent policy, with the first serious try being the 1996 Telecommunications Act.

In Japan, the market had been split up between NTT, providing domestic services, and KDD providing international services. US and domestic business interests wanted to open the VAN market (Value Added Network) to new providers, based on the fact that Japan lagged the US in introduction of new services. Reform debates took place in the early 1980s, followed by the introduction of a new regulatory framework in 1985, in which competition was introduced, introducing two types of carriers: those with and without infrastructure. At the same time NTT was partly privatized.

In Europe, it was the UK that took the first step towards liberalization. In 1981, the government of Margaret Thatcher introduced a policy of deregulation, privatization and liberalization in the British telecom market, pursued through the Department of Trade and Industry (DTI). A separate regulator, OFTEL (Office of Telecommunications), was created to ensure competition. As a part of this liberalization pursuit, the British Post Office's telecom branch became British Telecom (BT), which was gradually offered to the public (as a result of the telecommunications act of 1984). Moreover, competition (or rather the *duopoly* concept) was introduced. Mercury Communications (owned by Cable & Wireless) was set up as a competitor to BT to provide telephone services, but without the universal service obligation. DTI also appointed a panel of experts to investigate the liberalization of value-added services. Their advice was to set up a duopoly in the mobile telephony market as well.

Britain became the pilot case for competition, liberalization and deregulation in Europe, not least in the mobile communications market. For instance, in 1989 four consortia were licensed to provide so-called Telepoint services. Furthermore, in 1989 three consortia obtained licenses to provide so-called Personal Communications Network (PCN) services in the 1800 MHz band. Also, five paging licenses were issued; a number of national and regional mobile radio licenses, and six licenses for mobile data, were issued between the years 1983 and 1989. This could be compared with the rest of Europe where, by the end of this period, there were almost no competing operators of mobile communications services anywhere on the Continent. The developments in the UK were, however, monitored closely by other countries.

The rest of the countries in the EC were slower to implement liberal policies. The initiatives taken by the European Commission in the mid-1980s became important. In 1984 the

Telecommunications Action Programme was approved, emphasizing the importance of coordinated efforts, common infrastructure projects, common R&D projects, creation of community-wide equipment markets and standards. These issues were emphasized in the so-called Green Paper (see above), which became the most important policy document guiding also an agenda of services and equipment liberalization. These concerted efforts were guided by a desire to avoid dominance primarily by the US in the sector, while at the same time the US government began to press Europe (and other countries such as Japan) to open up its telecom markets. After the Green Paper, the member states embarked on an agenda of equipment and services liberalization. Although these efforts could be claimed to have been quite successful, considering the differences of national regimes, the European markets were less open in 1992 than the US market was in 1984.

Turning to the Nordic countries, with the exception of Finland, strong monopoly situations were maintained quite long. In Norway, a monopoly was maintained until 1988, when regulatory activities were separated from the Norwegian PTO, and competition gradually became introduced. In Denmark, in 1990 a proceeding structure of local operating companies and national PTT for long-distance and international communications was consolidated into the monopoly operator TeleDenmark, which was partly privatized in 1992. Finland had a unique system of competition and co-operation between the state-owned operator, local co-operatives and private companies. The state-owned operator was then corporatized into Telecom Finland, more competition was gradually introduced, and the Finnish market was completely opened up in 1994.

To sum up the international development, one can in line with Karlsson (1998:40) identify three different groups of countries: (1) US, UK, and Japan which advocated and implemented radical regime reforms (later Sweden and in particular New Zealand could be claimed to have adopted this strategy – see Table 3-12); (2) continental Europe with a cautious path to reform, mainly pushed by the European Commission, and (3) developing countries being initially very conservative, although with an increasing interest in liberalization. International concerted efforts, e.g. in the ITU, were characterized by a *laissez faire* approach, weak influence on liberalization, and a weakening influence on standardization. The legitimacy of ITU was questioned in the late 1980s, which led to a fundamental reorganization in 1993. Other organizations such as GATT also challenged the regime, trying to define international telecommunications as trade in services. In Europe, CEPT was broken up; standardization activities moved to ETSI and operators' activities to ETNO (European Telecommunications Network Operators). Only regulatory affairs remained in CEPT, recently dominated by the EU.

The liberalization status of the early 1990s in the industrialized countries can be summarized as in Table 3-12. The US/Canada, UK, Japan, Sweden and New Zealand stood out when it came to having liberalized the market, while some major European countries were still very closed. Data communications, digital cellular and paging were the most liberalized services, while telephony (in particular analog mobile, local and international telephony) was the least liberalized.

Another area of change was the question of foreign ownership. Most PTTs had been transformed into corporations, and privatization was going on in some countries. Privatization also raised the issue of foreign ownership. While some governments felt a need to retain some control of the carriers, other stimulated foreign entries. As a consequence, restrictions on foreign ownership differed widely between countries, ranging from 0% in many countries to 20% in Japan, to no restrictions as in the UK. These restrictions could also differ between service categories, and special rules were often applied to former PTTs.[214] By 2003, a majority of OECD had no foreign ownership restrictions, while several maintained a "golden share" or some other type of control, usually aimed at ensuring that the dominant telecommunications operator did not come under control by a single investor.[215]

To lessen the restriction on foreign ownership could also be part of a strategy to make the former PTTs more competitive (if tight ownership rules applied to a firm, it could be argued that it should not be allowed ownership in other markets). Other measures to make the PTOs more competitive were to: (1) combine formerly separate entities into a major national PTO (as in Australia where Telecom Australia and OTC merged into AOTC, and in Denmark as mentioned above); (2) lifting restrictions on international activities (e.g. RBOCs and NTT); and (3) encouraging them to join forces, as was the case with the Unisource joint venture.[216]

Table 3-12 Level of liberalization in OECD countries

Country	*PSTN*			*Data*		*Mobile*			*Lib. index*	*PTO*	*Status*
	local	trunk	Int.	X.25	LL	Analog	Digital	Paging		Corp.	Private
Australia	D	D	D	D	D	M	CC	C	9	75/89/92	No
Austria	M	M	M	M	M	M	M	M	0	92?	No
Belgium	M	M	M	19923	M	M	M	M	0.5	91	No
Canada	M	C	M	C	C	RD	D	C	10	Always	Always
Denmark	M	M	M	1993	M	M	D	M	1	90	92 (49%)
Finland	1993	1993	M	C	C	D	D	D	8	87	No
France	M	M	M	1993	M	D	D	D	3.5	90	No
Germany	M	M	M	1993	M	M	D	1993	2	90	Discussed
Greece	M	M	M	1997	M	N	1993	M	1	42	No
Iceland	M	M	M	M	M	M	M	M	0	No	No
Ireland	M	M	M	1993	M	M	M	M	0.5	84	No
Italy	M	M	M	1993	M	M	1993	M	1	n.a.	n.a.
Japan	C	C	C	C	C	RD	C	C	15	52	85 (35%)
Luxembourg	M	M	M	1993	M	M	M	M	0.5	92	No
Netherlands	M	M	M	1993	M	M	1993	1993	1.5	89	Discussed
New Zealand	C	C	C	C	C	C	C	C	16	87	90
Norway	M	M	M	1993	M	M	D	1993	2	90	No
Portugal	B	D	M	1997	B	M	D	M	3	89/90	91
Spain	M	M	M	1997	M	M	M	C	2.5	24	24
Sweden	C	C	C	C	C	C	C	C	16	93	Discussed
Switzerland	M	M	M	M	M	M	M	C	2	92	No
Turkey	M	M	M	M	M	M	M	M	0	84	No
UK	C	C	D	C	C	D	C	C	14	68/81	84 (99%)
USA	PC	C	C	C	C	RD	C	C	14.5	Always	Always
Total	11.5	14.5	10	21	15.5	10	20.5	21.5			

Key:
C = Competition (Index =2), PC = Partial competition (1.5), D = Duopoly (1) , RD = Regional Duopoly (1) , B = Competition at the border of concession (0.5), 199X = Competition expected to be introduced during 199X, M = Monopoly, N = No service

Source: OECD (1993:16)

[214] OECD (1993:19)

[215] OECD (2003a:29)

[216] OECD (1993:15)

In the last decade (1993-2003) the trend of liberalization continued, as illustrated in Figure 3-17. In 2003, only Turkey still had a monopoly structure in the OECD area. In some areas liberalization has been slower; for instance, the pace of PTO privatization was slow in many countries. In 2003, some countries had not yet started to privatize the PTOs, while the general trend had been an increasing private ownership, in a number of cases declining below the 50% level (Austria, Germany, Greece, Japan, Korea), while other cases had been requiring majority ownership (France, Norway, Switzerland). The 3G licensing was followed by some governments trying to intervene by assisting carriers with enormous debts. This triggered the issue of privatization again, in order to avoid conflicts of interest.

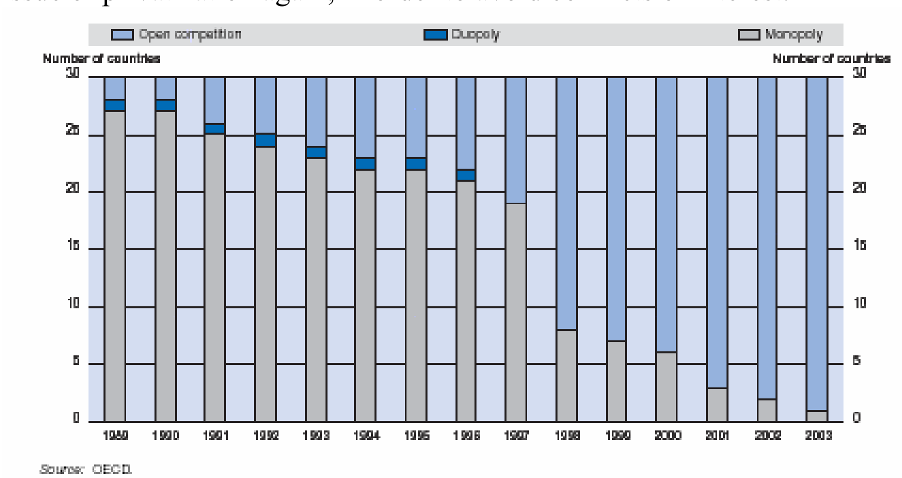

Figure 3-17 Competition in the fixed network

Source: OECD (2003a:14)

Having liberalized the market, the government had to redesign regulatory frameworks in order to sustain and stimulate competition, lower barriers to entry, and stop dominant operators from abusing their market power. Some recent regulatory safeguards have been (see OECD 2003a:41-57, for a detailed regulatory overview of the OECD countries)[217]:

- *Interconnection.* This has been an important issue from the start. In recent years, fixed-to-mobile interconnection has seen increased concern among regulators, where mobile operators terminating calls are viewed as having a bottleneck position. Within the European Union, the designation of some operators as having significant market power in the mobile termination market has led to the imposition of cost-oriented termination charges, price-caps etc.
- *Carrier selection*. Most OECD countries had by 2003 implemented carrier selection and pre-selection.
- *Number portability*. Most OECD countries introduced number portability in the late 1990s and early 2000s.
- *Local loop unbundling.* Local loop unbundling (i.e. the process in which incumbent carriers lease, wholly or in part, the local segment of their telecommunications network to competitors) was a key regulatory issue in most advanced markets. In particular, Japan displayed rapid increase in unbundling, reflecting the demand for unbundled loops for high-bandwidth applications.
- *Internet and regulation.* In particular Voice over IP (VoIP) has been an issue of debate, where an increasing number of regulators have taken the position that it should be treated as voice over PSTN.

[217] OECD (2003a: 29-30): See Michalis (2004) for an overview of EEC directives related to liberalization (and harmonization), 1988-1999.

In the US, it was not until 1996 that Congress finally legislated a sweeping overhaul of the more than 50 years old Communications Act. The Telecommunications Act of 1996 refocused federal communications policymaking after years of confused, multi-agency and intergovernmental attempts to regulate and make sense of the telecommunications industry. The bill relied on increased competition for development of new services in broadcasting and cable, telecommunications, information and video services while it reasserted Congress' leadership role as the dominant communications policymaker.[218] Its effects have been widely discussed since then, but this debate is beyond the scope of this report to summarize.

In Europe, by 1998 the EC had established a framework (based on a number of earlier directives, aimed at creating a single telecom market and with the Commission as the central policy actor. In some respects it failed to meet its objectives (e.g. local loop unbundling and 3G licensing). A new framework was adopted in 2003, with the member countries having until July 2003 to transpose it into national legislation. It comprised a package of directives covering all electronic communications networks (e.g. fixed, mobile, television broadcast, cable TV) and associated services and facilities (e.g. conditional access systems) with the exception of broadcast content and e-commerce. The new framework aims to link the degree of regulation to the degree of competition and in turn limit regulatory intervention to a minimum. It includes a listing of 18 markets in which specific regulation (e.g. price controls) may be called for.[219]

3.4.8 Industry evolution

3.4.8.1 General structural trends

The industry structure of telecommunications has undergone major structural changes since the stable and mature PTT regime of the 1970s. As a first observation we would like to emphasize that the increasing complexity of technologies and the opportunities offered have led to a radically different actor space. In the old regime, there were PTTs which offered services over networks that they operated by themselves. Equipment suppliers manufactured and partly developed equipment (switches, transmission and terminal equipment) for the operators, which made the equipment and services available to the end-users.

In the new regime the actor system has expanded in several dimensions. First, in a transitional stage, the *number of players* involved in network operations and service provision increased dramatically as a result of liberalization and lowering entry barriers. Second, in the Infocom regime, the number of *actor categories* expanded substantially. Equipment supply has been extended with a number of products (routers, servers, etc.). In addition, service provision has been partly separated from network operations. Furthermore, the Internet has opened up a number of new layers of activity, e.g. a connectivity layer (including service provision, Internet access, Web hosting), a navigation and middle-ware layer etc. (see Table 3-13). This is just one way to analyze and illustrate the opening up and increasing complexity of the actor system.

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[218] http://www.museum.tv/archives/etv/U/htmlU/uspolicyt/uspolicyt.htm [Accessed January 24, 2004]

[219] Michalis (2004)

Table 3-13 Layer/activity structures change in telecom industry

	PTT regime		Infocom industry	
Layer/activity	***Ex. activity***	***Example firms***	***Ex. activity***	***Example firms***
Customer				
Applications (including content and content packaging)	-	-	Web design, on-line information services, broadcasting etc.	Reuters, MSN, Aftonbladet, Napster
Navigation middleware	-	-	Browsers, search engines, portals, directory, security, etc.	Yahoo, Netscape, etc.
Service/connectivity	Voice, fax	AT&T, Televerket, NTT	Telephony, Internet access, Web hosting etc.	See below plus IAPs and ISPs
Network	PSTN	AT&T, Televerket, NTT	DSL network, cellular, Ethernet, frame relay, ISDN, etc.	AT&T, TeliaSonera, QWEST, Colt, Vodafone, Energis, etc.
Equipment	Switches, transmis-sion, CPE	AT&T, Ericsson, ITT, NEC	Switches, transmission, CPEs, router, servers, billing software etc.	Lucent, Ericson, NEC, Cisco, CMP

Source: Adapted from Fransman (2003:37, 66)

In the following we shall delimit ourselves to the changes taking place in the traditional markets – the operator market and the market for equipment supply.

3.4.8.2 Competition in the operators' market

Following the liberalization in the US, UK and Japan in the mid-1980s a number of new entrants rushed into the industry, e.g. long-distance carriers MCI and Sprint in US, Mercury in the UK and DDI, Teleway Japan and Japan Telecom in Japan. When other markets opened up, data communications, mobile communications, long-distance and international services became attractive fields of entry. The break-up of AT&T into a long-distance carrier and seven regional Bell operating companies (RBOCs) further added to the multitude of carriers. The history of how all these emerged, collaborated, formed joint ventures, spun off mobile divisions, which in turn merged, etc. is a far too time-consuming undertaking to account for here in detail. Instead, we will briefly describe some trends and make a few snapshot observations.

Table 3-14 Summary of top 15 telecommunications operators in 1990/91

Operator	*Country of origin*	*Revenue (USDm)*	*Profits (USDm)*
NTT	Japan	43 174	3 594
DBP Telekom	Germany	25 117	4 523
BT	UK	23 364	4 782
FT	France	21 116	1 041
AT&T	US	20 410	883
GTE	US	19 621	2 191
SIP	US	16 402	676
BellSouth	US	14 300	2 409
Nynex	US	13 229	793
Bell Atlantic	US	12 280	1 996
Ameritech	US	10 818	1 656
Pacific Telesis	US	9 985	1 630
US West	US	9 957	1 760
Telefónica	Spain	9 699	947
SW Bell	US	9 332	1 541
Top 15		**258 963**	**31101**

Source: OECD (1993:36)

Table 3-14 summarizes the top 15 network operators from the major economies (of which 9 are from the US). It can be noted that all of them were incumbents, most of them extremely profitable, still being able to collect monopoly rents in a majority of segments.

By way of comparison, a similar list is shown in Table 3-16. Some new entrants had made their way into the top 10 list, i.e. WorldCom and Vodafone. The appearance of some specialist mobile operators (Vodafone) is notable. So is the share of mobile revenue of most of the top operators. A few ISPs also made it to the list – e.g. AOL – and huge losses were made by some operators (NTT, AT&T, Vodafone, BT, QWEST, KPN, C&W, et al.). These losses will be analyzed in Section 3.5.

As mentioned above, incumbents only slowly adapted (in terms of ownership, R&D spending, organization etc.) to the competitive market. The new entrant operators were very different from the old PTTs, with according to Steinbock (2003:12) the Nordic service-driven PTTs somewhere in between. The old PTTs were heavy in engineering (as were the Nordics) while the new entrants focused on marketing sales and customer service (see Table 3-15).

Table 3-15 Share of staff in different functions for different groups of operators

	National PTTs	***Nordic PTOs***	***New entrants***
Engineering	56	50	>20
Marketing sales and customer services	20	32	60
Support functions	18	14	13

Source: Steinbock (2003)

Table 3-16 Major OECD area telecom operators and ISPs (2001)

Name of PTO	Country	Revenue	Net income	Employees	Mobile revenue
NTT	Japan	96 121	-6 683	213 000	42 553
Verizon	United States	67 190	389	247 000	17 393
AT&T	United States	52 550	-6 842	117 800	0
SBC Communications	United States	45 908	7 242	193 420	8 647
Deutsche Telekom	Germany	43 133	-3084	257 058	13 069
France Telecom	France	38 416	-7393	211 554	11 995
Worldcom	United States	35 179	1 501	61 800	0
Vodafone (Group)	UK	33 109	-23 413	67 178	33 109
BT	UK	31 616	-4186	108 600	0
Telefonica	Spain	27 726	1 881	161 029	5 121
Telecom Italia	Italy	27 516	-1 846	109 956	9 152
Sprint	United States	26 071	-1 402	83 700	9 725
Bell South	United States	24 130	2 570	87 875	5 227
KDDI	Japan	23 393	107	9 300	17 230
Qwest	United States	18 370	-4 023	61 000	660
Japan Telecom	Japan	14 022	-543	3 300	11 063
BCE Inc.	Canada	14 007	295	75 000	1 032
AT&T Wireless	United States	13 610	-963	33 000	13 610
Korea Telecom	Korea	12 351	862	48 668	3 453
Telmex	Mexico	11 881	2 515	67 550	0
KPN Telecom	Netherlands	11 481	-6 692	45 720	4 172
Telstra	Australia	10 778	1 897	44 977	1 680
Cable & Wireless	UK	8 567	-7 425	10 200	362
Swisscom	Switzerland	8 513	2 937	17 784	2 357
Nextel	United States	7 689	-2 625	13 400	7 689
Alltel	United States	7 599	1 067	23 955	3 640
Cegetel / SFR	France	6 821	N/A	8 400	4 414
TDC	Denmark	6 500	158	19 130	2 085
MMo2 (Group)	UK	6 197	-1 241	14 000	6 197
Telia	Sweden	5 537	181	17 149	1 588
AOL (ISP Revenues)	United States	5 353	N/A	N/A	N/A
Total Top 31		**741 334**	**-54 759**	**2 432 503**	**237 223**

Note: MUSD
Source: OECD (2003a:21)

In Section 4.2.9 (Table 4-7, Table 4-8 and Table 4-9) will be shown the market shares of new entrants in the three main segments of access, long-distance and telephony. Clearly, competition has gone much further in the initially more lucrative international and long-distance markets, while the local loop is still dominated by incumbents. Despite the many fixed public-switched telecommunication network (PSTN) operators, facilities-based competition, as measured by new entrants' share of access lines, has been slow to develop. The United Kingdom and the United States, both early starters in introducing telecommunications competition, are ahead of most other OECD countries in the development of PSTN facilities-based competition.

A related trend in the operators' market has been internationalization. The main drivers for internationalization were technological development (mainly digitalization) which opened up new possibilities to provide services competing with existing infrastructure, new service opportunities, and of course liberalization/deregulation. This trend (re-)started in the 1980s and accelerated in the early 1990s, and has been going on since then. We will not pursue the analysis any further in this report; see instead Bohlin and Granstrand (1995) and Johansson (1994).

3.4.8.3 Suppliers

The major telecommunications equipment suppliers were (in a plausible size-ranking order): AT&T, ITT, Siemens, Ericsson, GTE, Northern Telecom, NEC, Thomson, Philips, Alcatel, GEC, Plessey and Italtel, including also Fujitsu and Hitachi. See Bekkers (2002:49) for market shares and dependence of switching equipment.

Table 3-17: Ranking of infrastructure suppliers (revenues)

Rank	*1980*	*1990*	*2000*
1	Lucent (AT&T)	Lucent (AT&T)	Lucent
2	ITT	Alcatel	Nortel
3	Siemens	Siemens	Ericsson
4	Ericsson	NEC	Nokia
5	GTE	Nortel	Alcatel
6	Nortel	Ericsson	Motorola
7	NEC	Bosch	Siemens
8	Thomson	Motorola	Cisco
9	Philips	Fujitsu	NEC
10	Alcatel	GPT	Marconi
11	GEC	Philips	Fujitsu
12	Plessey	Italtel	Hughes
13	Italtel	Ascom	IBM
14	Fujitsu (?)	Nokia	Samsung
15	Hitachi (?)	Matra	PTIC (China)
16		GTE?	Matsushita

Sources: Adapted from Bekkers (2001:48) OECD (1993:33) and IDATE (2003)
Note: The difference of sources limits the possibilities to compare between the years.

As can be observed in Table 3-17, the structure of the supplier industry has been fairly stable, as a result of high technological entry barriers. Consequently, there is an overlapping set of suppliers in the list for the different years. Some consolidation did take place in particular during the 1980s, after digital switches had been developed. The development costs were high, and the development was pursued in an era of recession. The results in terms of functionality differed among the competitors. Nortel and Ericsson were two of the firms that strengthened their positions. Other firms failed. Notable is the exit of ITT, whose telecom interests were acquired by Alcatel. Alcatel was in turn a result of the nationalization, consolidation and subsequent privatization of the French telecom supplier industry. The British firms were also merged in GPT, which was later merged with Marconi. Thus some consolidation did take place (see e.g. Fransman 1995, for an elaboration).

The growth of new markets makes its mark primarily in changes from 1990 to 2000. Mobile communications have affected the revenues of suppliers even more than operators. The suppliers that were strong in mobile have strengthened their competitiveness. Notable is the rise of Motorola, Ericsson, and more recently Nokia and Samsung. The latter also signify the rise of suppliers from rising markets such as Korea and later China (PTIC). Finally, the rise of data communications provided an opportunity for market-leading Cisco to enter the list.

3.4.9 Other important trends

The trends elaborated on above are by no means comprehensive. Some other trends worth mentioning are briefly discussed here. First, investment levels increased persistently from 1970 to 2000, escalating in the late 1990s, driven by backbone investments, new entrants, and in particular investments in 2G cellular mobile telephony.

Another key trend is that prices of telecommunications have decreased rapidly, notably compared to other consumption goods. This trend is driven by innovation and competition. See e.g. OECD (2003a:32-33 and Ch.6).

There seems to be a trend of firms to move downstream in the value chain. This could be exemplified by suppliers outsourcing production of equipment, and operators outsourcing operations of networks. The equipment suppliers have consequently entered the market of operating networks. To exemplify, it has become an increasing business to take over more and more of operation, and building of operators' networks. Such activities include license application, business planning, securing finance, researching subscriber behavior and topography, cell-planning, procurement, construction, testing, network expansion, subscriber management, monitoring system performance, and training of personnel.[220]

3.5 The bust and beyond (2000 -)

The bust of the telecommunications industry around the millennium shift is, to paraphrase Fransman (2003:7), the most remarkable industrial collapse in postwar history. In March 2000, at the height of the telecoms boom, the total stock market value of telecom operators and suppliers was USD 6300 Billion. Only 18 months later it had fallen to USD 3800 billion, a fall of USD 2500 billion (more than SEK 20,000 billion!). This fall continued for a year or so (see Ericsson's share price in Figure 3-18 as an example). Between 1996 and 2001, a total USD 1800 of debt had been accumulated in these firms. In 2002, France Telecom and Deutsche Telecom posted operating losses of more than USD 10 billion each, and the same year Nortel, Lucent and Alcatel posted average losses of some USD 4 billion dollars. More than 500,000 jobs were lost in the industry in 2001. How could this happen, in a growth industry? What were the driving forces, and what are the consequences? Here an attempt is provided to answer these questions, drawing on the analyses made in particular by Fransman (2003:7-33) and OECD (2003a:15-20). Further analyses of this complex phenomenon and its causes and consequences are needed, however.

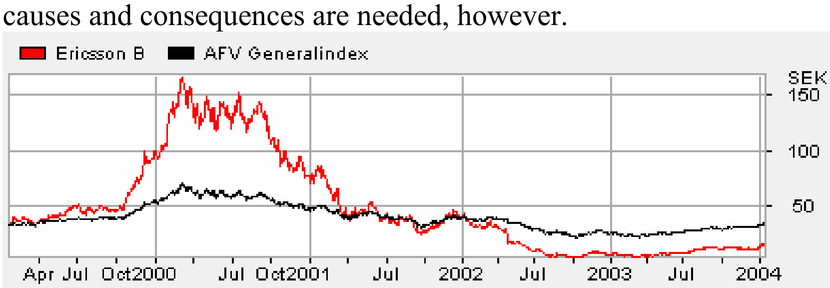

Figure 3-18: Ericsson's share price (1998-2003)

Source: Adapted from figure by Ecovision, accessed at www.afv.se, 040120

The telecoms bust cannot be understood without first understanding the boom of the late 1990s. This boom was partly driven by unrealistic expectations of market growth (fuelled by

[220] See e.g. Ericsson Annual Report Business Review (2000:40) and Steinbock (2003)

e.g. unreliable Internet statistics), with unrealistic growth projections in business plans and an immature financial market, as well as a maturing mobile market in need of renewed growth and fuelled by a questionable 3G licensing regime.

Fransman (2003:9-13) analyzes the unrealistic market expectations in terms of four consensual and faulty visions. These were: (1) a continued explosive demand for bandwidth. (2) New entrants would out-compete incumbents, in spite of the latter's advantages in economies of scale and scope. It was argued that incumbents were constrained by their legacy networks (which in turn provided an opportunity for the newcomers to attack with superior technology) and unfit organizations. (3) It was also assumed that the financial market would support the fittest of these new entrants. Finally, (4) technological change was expected to reinforce the other three visions. Actors were not troubled by the fact that technology could erode profits and revenues on the supply side – price elasticity of demand would compensate. These expectations were more or less shared by all in the actor system, including regulators, who saw the possibility of significant entry and competition.

Not surprisingly, probably not even ex ante, there were several flaws in these expectations. There was no real evidence that demand for bandwidth would increase at the expected rates. In fact, parts of the expectations were based on flawed statistics (e.g. that the Internet "doubled every 8 months" or so). Although the market did continue to grow, it did not grow at the pace projected in the business models of the new entrants or plans of the incumbents. The actors further failed to recognize the interaction with supply and how many actors the increasing demand could sustain. They also failed to recognize falling barriers to entry and lack of possibilities to differentiate services, leading to price competition, driving prices towards marginal cost. In addition to these factors, we could add the coinciding burst of the Dot Com bubble and a general investment downturn in the economy.[221]

For incumbent operators there was a long-term downward pressure on revenues and profits from long-distance and international calls, having been the main profit generators in the past (this will be exemplified with the Swedish market in Chapter 4). New growth in mobile and data communications could not fully compensate for this. For new entrants, profits were falling for the same reasons as for incumbents, while at the same time they had to finance build-out of networks, with revenues expected to come in the future. However, the financial markets failed to recognize this as a problem, and continued to finance the build-out, based on the faulty expectations of future revenue streams. The bubble was further fed by the ability to borrow against rising value of stocks. This was the same type of investment–revenue mismatch that was experienced in the "dot-com bubble". The financial community also failed to realize the time it would take for the new entrants to establish a competitive presence in the local loop.[222]

The financial community thus continued to provide capital for unrealistic business models and for entries in new geographical markets and new services. The prime example became the UMTS (3G) licenses in Europe. In 2000, the governments received some USD 100 billion in spectrum revenues, as a result of the auctions. The largest participants were Vodafone (BUSD 19.2), DT (13.8), BT (13.8), FT (10.1), KPN (7.4), and Hutchison Whampoa (7.0), Telefónica and Sonera. The debt levels were substantially raised as result. Meanwhile the operators continued to acquire other operators, raising debt levels even further. The largest of these acquisitions was Vodafone's acquisition of Mannesmann for USD 128 billion (Vodafone expanded its interest in a vast number of countries as well). DT acquired One-to-One in the

[221] Fransman (2003:9-14) and OECD (2003a:17)

[222] Fransman (2003:15-17) and Noam (2002)

UK and Voicestream and Powertel in the US, in total amounting to more than USD 40 billion. FT acquired Orange for 23.7 billion etc. For some players, these debt levels could be sustained due to the strength of their core business (e.g. Vodafone). However, some of the operators could not, even though their core business was sound. The over-investments and acquisition excess and resulting high debt levels led to write-downs (in the range of USD 300 billion in 2001, as a result of both extraordinary write-downs and market exits; see Figure 3-19). Some operators started to sell off foreign operations, trying to reduce their debt. BT for instance divested its mobile operations (mmO2) and sold a number of foreign holdings.[223]

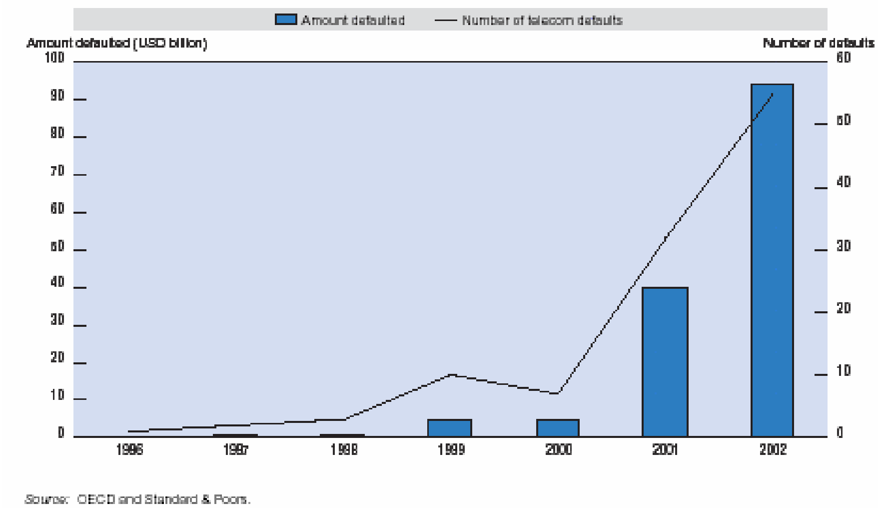

Figure 3-19 Telecommunications sector defaults

Source: OECD (2003:14)

The bust hit the suppliers in the form of a "real" decline in revenues. Fuelled by the faulty expectations, huge investments were made by both incumbents and new entrants during 1996-2000. By 2000, these investment rates could not be sustained, while at the same time the general economic downturn led to a decrease in business customers' investments. Adding to this, operators' Internet services revenues fell as a result of the "dot-com" crash. The share prices of the manufacturers started to fall as they failed to meet expectations. Faced with cost structures adapted to false market expectations, their profits were rapidly turned into huge losses (even Cisco made losses, but not Nokia). Credit rating of the suppliers fell sharply, which worsened the crises.[224] [225]

Now what is the outlook for the telecommunications industry after the bust? There has been a financial recovery and restructuring of major players (both operators and suppliers). The core business of most operators is still sound, and cut-backs have restored cash-flows of many suppliers to acceptable levels. A somewhat smaller and less fast-growing industry than in the years before the bubble seems to be emerging.

Speculating somewhat into the future, we may expect growth at modest levels in the coming years. This growth is likely to come in broadband and in mobile data, and the services and

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[223] OECD (2003a:15-19)

[224] Fransman (2003:26-28)

[225] Primarily the infrastructure suppliers were hit hard by crises. Mobile handset sales did not drop to the same extent as infrastructure supply did, but it also declined as a result of maturing markets, increasingly dominated by replacement sales and one dominant actor – Nokia – so successful that it eroded the possibilities of profitability for other ones.

products complementing those services. Emerging markets like China and India will continue to spur growth. IP telephony is another growth area, but the impact for incumbent operators will mainly be one of substitution. Prices will continue to fall, in particular in cellular, where oligopolistic overpricing may come to an end as the market matures and new entrant 3G operators may compete on price in order to make it attractive for customers to migrate. In addition, they may face a threat from WLAN operators and possibly IP telephony. These tendencies may further erode profitability.

However, others warn against simply extrapolating the trends of the past into the future. Leading telecom economist Eli Noam (2002) asserts that telecommunications have now entered an era of cyclicity and slow growth, which will lead to an oligopolistic market structure, which in turn would call for a new regulatory regime, rather than much-hoped-for unregulated competition.

3.6 Summary and conclusions

The telecommunications sector is defined by actors embarking on economic activity related to telecommunications systems. Telecommunications is in turn defined as communication at a distance, between two or more parties, using electromagnetic systems. Telecommunications systems are composed of nodes (switches, routers etc.) and links (cables, radio links, etc.), and terminals (telephones, data terminals, etc.) connected to the network, which were described in this chapter.

At the heart of the sector lie the organizations that are developing, producing, selling, distributing, providing services over (and content for), standardizing and regulating these systems. Common industry denotations for such organizations include infrastructure and terminal suppliers, operators, retailers, subscribers and end-users, standard bodies, regulators etc.

Four segments of the telecom sector have been identified: (1) one dominant but maturing segment (fixed telephony); (2) one revenue growth-generating segment where Sweden has been very successful (mobile telephony); (3) one growth generator (in particular in terms of traffic) with a potentially disruptive effect, where Sweden has been less successful (Datacom); and (4) a potential future growth market (mobile data). Thus the relative importance of these segments for economic growth has changed over time, and is expected to continuously do so. This change has primarily been driven by innovation.

Electrical telecommunications (telegraphy) emerged in the mid-1800s, with telephony following a few decades later. It was not clear from the start what telephones should be used for. Quite soon, two-way voice communications emerged as the dominant application. This service and its inherent characteristics served as focusing devices (Rosenberg [1969] 1976) for the subsequent development. During the whole period the technological development, capacity expansion and diffusion progressed interdependently, in a pattern typical for large technical systems. A number of technical improvements in signaling, transmission and switching allowed this expansion and diffusion of the network; in the development, technical bottlenecks and reverse salients served as inducement mechanisms for technical change, and their solutions in turn generated new bottleneck problems (as observed by Rosenberg [1969] 1976 and Hughes 1983, 1987).

These and other techno-economic developments enabled the telephone network to become the network for communications, connecting humans and subsequently machines all around the globe, although its diffusion into over 90% of homes took more than a century (in the high-income countries). Telephony became a mass-produced good, the demand for which was driven by fast economic growth and far-reaching social changes in the 1950s and 1960s, and the supply of which was driven by cost minimization and emphasis on economies of scale and single supply.

The structure of telecom in the 1970s was established very early in the 20th century, with antecedents in the early developments of postal and telegraphy systems. In most countries, initial competition in local telephony was replaced by national monopolies (in the US private local monopolies), often merged with postal and telegraphy monopolies, including also a regulatory function. After the Second World War a system of primarily domestic systems developed, with resulting mutual dependence of operators and manufacturers.

Compatibility standards have been important in telecommunications, as could be expected for any large technical system where components cannot be easily assembled under the control of a single agent (David and Steinmueller 1994). Such standards define the interfaces between the components and how those components can be successfully integrated into the network. Quite naturally, the need for international standardization (and coordination in general) emerged quite early, and with it a number of standard bodies – ITU, CEPT etc.

A number of interrelated pervasive trends were investigated in this chapter: (1) growth of markets, (2) technological progress, (3) digitalization, and the resulting (4) convergence and divergence, (5) the changing role of standardization, (6) the changing R&D regime, (7) liberalization, and the resulting (8) changing industrial structure.

In the high-income countries, telecommunications has become an important and growing part of the economy. According to most measured aspects, telecommunications has expanded throughout the time period, including also the first years of the crisis. POTS are mature and probably even declining (in terms of revenues and number of users). Instead there are two pervasive growth trends in telecommunications: (1) the increasing mobility enabled by radio communications and (2) the increasing share of data communications induced by developments in computing. Cellular mobile communication has contributed the lion's share of subscriber and revenue growth, but is also maturing; at least in the high-income countries. There is still a lot of untapped potential in Asia, not least in China with India lagging by a few years. Data communications, in particular Internet data communications, is the other major source of growth, particularly in terms of capacity and traffic, although less in terms of revenue and more difficult to measure. Therefore, while the number of fixed line connections is decreasing in a number of countries, demand for capacity is increasing.

Technological change in telecommunications has been dramatic, with rapidly improving functionality, performance improvements and cost reductions, and possibilities for new services and products as a result. The technical systems are also becoming increasingly complex, with diversity of terminal, transmission, switching and access technologies and standards, which in turn pose demands on development, not least in software.

Digitalization has played an important role for shaping and reshaping the telecommunications industry. In sum, in the 1960s digital techniques were applied to long-distance transmission. The first digital switches and optical fibers were introduced in the mid-1970s, with microwave and satellite systems following later in the same decade. In mobile telephony it took until the early 1990s for the first digital systems to be introduced. Digitalization started in the core of the networks (the interoffice transmission links) in the 1960s to expand towards the terminals in a stepwise manner, at an accelerating rate in the 1980s and early 1990s. By now, the process of digitalization is nearing completion across the OECD area, but local loops are still mainly analog.

The importance of digitalization is two-fold. First, and this was the initial driving force, the performance of networks is improved. Second, and more importantly in the long run, it provides a platform for introducing computer software capabilities into the network. This factor is of dynamic nature, generating a new set of capabilities when complemented by computer software and electronics. This simple change in information structure provides a platform for a whole new set of capabilities and opportunities. In particular, software nodes and capabilities can be introduced into the network, generating new types of services. Thus digitalization drives a process of convergence between computing and telecommunications.

Convergence, although conceptually vague, means that technologies and actors are merging, calling for institutional change as well. This convergence was perceived by the industry, starting a largely failing process of telecom firms entering into competing and vice versa. In recent years, the convergence of datacom and telecom has spurred renewed activity. The effects of digitalization have been even more dramatic in the sense that it has opened up possibilities for a wide range of new services and new layers that could be entered by new actors, to be serviced by a wide range of technologies.

The importance and complexity of standardization processes have increased since the 1970s. The process of liberalization and internationalization in the sector has made standards more international and open, while at the same time competing standards have clashed on the market. Following this, aligning standards to the technological competence bases of firms and nations has become an important part of corporate strategies and industrial policies. One result has been the formation of regional and national telecom SDOs. The complexity of technologies, with multiple interdependencies between and in the networks, has made the activities of SDOs very much interdependent on each other – and time-consuming. Combined with rapid technological change and convergence, the formal standardization bodies became increasingly complemented with more flexible ad-hoc consortia. The importance of anticipatory standardization, with a need to include as recent technology as possible in standards, has led standards to come increasingly into competition with another institutional regime – patents. Finally, the convergence with data communications has put further stress on telecommunications, as will be investigated in Chapter 6.

The R&D intensity of telecommunications appears to have increased in telecommunications, spurred by higher incentives to innovate and new generations of technology being more costly to develop. This trend was broken with crises, however, when several of the suppliers cut back their R&D. The character of R&D has also changed greatly since the PTT era. Back then, the locus of R&D activities was in the research labs of the PTTs. Gradually the equipment suppliers became more capable of development, which they could leverage to a larger customer base because of liberalization. A new breed of operators emerged, flexible and with little or no R&D, since technology could be readily supplied by the manufacturers. The character of R&D further changed with the emergence of the Internet regime, creating new layers of actors, with lower barriers to entry and to innovation, open standards, higher incentives to innovate, and presumably more emphasis on services innovation and innovation in start-ups, these innovations in services and start-ups being more difficult to capture with indicators. The changing regime has also meant that patents have become more of a competitive tool than before. As part of industrial policy, governments have been spending more on targeted research programs, instead of financing R&D through the PTTs.

One of the most important trends in the telecommunication sectors in recent decades is that of the break-up of the PTT system and introduction of competition. A number of terms often vaguely defined have come to signify this change process, e.g. deregulation and liberalization. There were a number of technological, political and economic factors, interacting in a complex manner. For instance, when networks started reaching maturity, the cross-subsidies created incentives for some user groups (large organizations with increasing communications costs). New technologies allowed other means of providing them with telecommunications, and also made the cost structure less dependent on distance. Therefore a new market opened up for the equipment industry, which previously had benefited from and thus protected the PTT regime. The convergence further contributed, since it provided incentives for a new type of suppliers (the computer industry) to enter telecommunication. The PTTs responded by entering new types of services, and incentives were created from inside the PTTs where management realized that, in order to cope with the inevitable competition, the PTTs had to be transformed into more flexible and independent structures. In addition to these factors, we would like to add the one given by e.g. Karlsson (1998b), namely policy diffusion. Moreover, there was a general liberalization trend of which telecommunications was part, with the US as prime mover.

The transition of the PTTs' regime started in the 1960s in the US domestic market, where the AT&T monopoly was challenged by MCI. In 1982 a decision was taken to break up AT&T into a long-distance operator and seven regional operating companies. Early deregulation followed in Japan and the UK in the early and mid-1980s, while continental Europe followed a cautious path to reform, mainly pushed by the European Commission with the introduction of GSM as a major opportunity to start the process. The process went into full swing in the 1990s. By now, most high-income countries have more or deregulated markets, with developing countries still lagging. Having liberalized the market, the governments had to redesign regulatory frameworks in order to sustain and stimulate competition, lower barriers to entry, and stop dominant operators from abusing their market power. A number of complementary reforms (interconnection, carrier pre-selection, number portability) have been introduced since then for these purposes. Internet remains an issue to solve for regulators, though.

Coinciding with the digitalization of the telephone network and deregulation, the telecom operators' market structure started to break up in the 1980s. Telecom operators encountered competition on their home markets and began to internationalize, not least in the field of mobile telephony. Large numbers of new entries, mergers and acquisitions have taken place since then. This process accelerated in the 1990s, when the market was further fragmented by the increasing importance of data communications over the telephone network, notably in the form of Internet. Compared to the operators' market, the supplier structure has been fairly stable, with a few mergers in the 1980s and the rise of mobile and datacom specialists and Asian suppliers. The large suppliers have grown larger and more R&D-intensive.

Finally, the bust of the telecommunications industry around the millennium shift is, to paraphrase Fransman (2003:7), the most remarkable industrial collapse in postwar history. The telecoms bust cannot be understood without first understanding the boom of the late 1990s. This boom was partly driven by unrealistic expectations of market growth (fuelled by e.g. unreliable Internet statistics), with unrealistic growth projections in business models and an immature financial market, as well as a maturing mobile market in need of renewed growth and fuelled by a questionable 3G licensing regime. This led to over-investment, in particular in 3G licenses, but also in network capacity and in acquiring other operators, raising debt levels enormously to levels that could not be sustained, leading to write-downs, divestments, bankruptcies and halted investments. Faced with cost structures adapted to false market expectations, equipment suppliers' profits were rapidly turned into huge losses. Downsizing among suppliers has enabled some to reach profitability again. However, although faced with continued growth prospects in emerging markets and in new services and products, the industry is still licking its wounds. Financial markets, for instance, seem to be overly cautious. When the market eventually enters a growth phase again, the main actors and national innovation systems are likely to differ in their capabilities to capture shares of that growth. Sweden's position in this respect will be investigated in the following chapter.

4 EVOLUTION OF THE SWEDISH TELECOM SECTOR

Chapter 4 investigates the Swedish sector.[226] The importance of the sector for the Swedish economy and national innovation system is first investigated in Section 4.1. STIS has been extremely dependent on two actors, Televerket/Telia and Ericsson, the former declining in importance, the latter increasing. Therefore, (1) a thorough investigation of the operators' market (Section 4.2) with an initial emphasis on Televerket/Telia, and (2) an investigation of the supplier market with a focus on Ericsson, are called for (Section 4.3), as well as an investigation of the interaction between the two (Section 4.5). The main actor groups and their relative importance as of the early 2000s are identified in Section 4.4. Section 4.6 is a brief note on the educational system The STIS R&D (Section 4.7), and capital market (Section 4.8) components are also investigated. Section 4.9 concludes and summarizes the chapter.

4.1 Importance for the Swedish economy and innovation system

There is a widespread perception that telecommunications are important for the Swedish economy. This section aims to qualify that statement, by summarizing available findings and statistics. First, the contribution from telecommunications to economic growth and wealth will be discussed. Second, the size (in terms of revenues and expenditures) of the sector relative to the total economy and to other countries will be investigated. Finally, some statistics and inputs and outputs from the telecom innovation system will be presented.

4.1.1 Telecommunications in the Swedish economy

There is clear evidence of telecommunications contributing significantly to economic growth. Edquist and Henrekson (2001a) make a strong argument. First they show that productivity growth in the ICT sector (defined as ISIC 30 & 32) has been much higher than in other sectors throughout the 1990s in a number of major countries. In Sweden the difference is even higher, and more concentrated in telecom products (ISIC 32). They also show that productivity growth was remarkably much higher in that sector than in other sectors. Lind (2002a) takes their analysis one step further by showing that the contribution of the ICT sector (now defined as ISIC 30-33) to total productivity growth in the manufacturing industry has been increasing, from insignificant levels in the 1980s to an average of 48% in 1997-2000. Further, the majority of these 48% can be explained by telecom products (ISIC 32). Measuring instead "value added", the contribution from telecom products is 50%.[227]

[226] This chapter has been written by Sven Lindmark and Erik Andersson.

[227] One should bear in mind that these figures are for the boom years of the late 1990s.

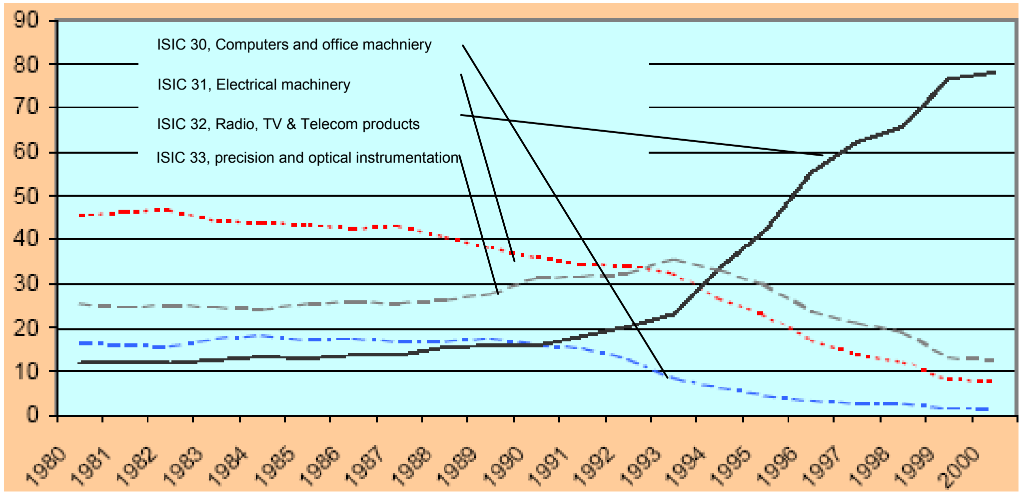

Figure 4-1: Telecom industries' share of value added in the total ICT sector, 1980-2000

Source: SCB as presented in Lind (2002b:11)

In conclusion, almost half of the economic growth in the manufacturing industry in Sweden in the late 1990s stems from the productivity improvements in the telecom sector. According to Lind (2002) a high rate of productivity improvements is nothing new in telecoms (it has been high since the mid-1980s). It is the growing size of the sector combined with productivity improvements that have contributed substantially to growing wealth in Sweden. The degree of telecom specialization within the ICT industry in Sweden is very high. Together with Finland, Sweden is the OECD country most dependent on the telecom product sector of the ICT industry. In 2000, telecom products (ISIC 32) constituted as much as 90% of Finnish ICT exports and 85% of Swedish ICT exports (Figure 4-2).

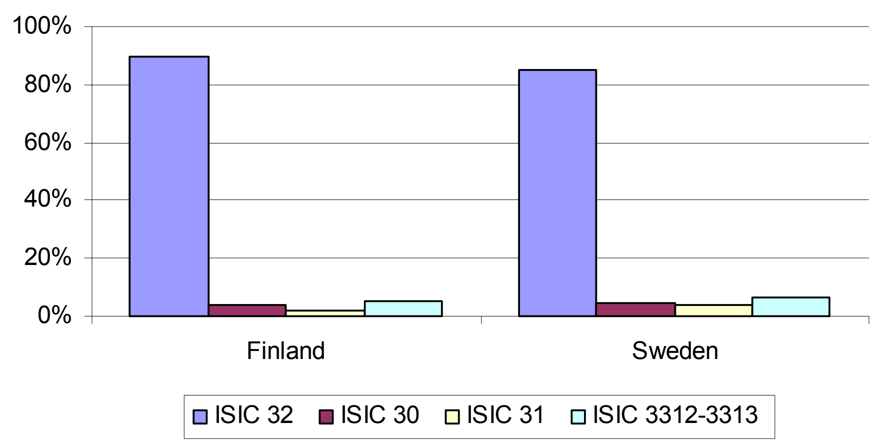

Figure 4-2: Composition of ICT sector exports, 2000 (selection of countries)

Source: OECD, International Trade in Commodity Statistics (ITCS) and Structural Analysis (STAN) databases, August 2002.

Now, since the sector is so dominated by Ericsson, the Swedish economy will overly depend on the fortunes of this one single firm.[228] Few nations (besides Finland) are so dependent on one firm. With Figure 4-2 in mind, the drastic decline of communications equipment exports

[228] It should be noted that no assessments of the impact of the recent telecoms bust have been found by the authors of this report, to date.

in 2001 (shown in Figure 4-3), indicates an enormous drop in total Swedish ICT exports, starting in 2001. The trade balance in communications equipment decreased, but was still positive in 2001.

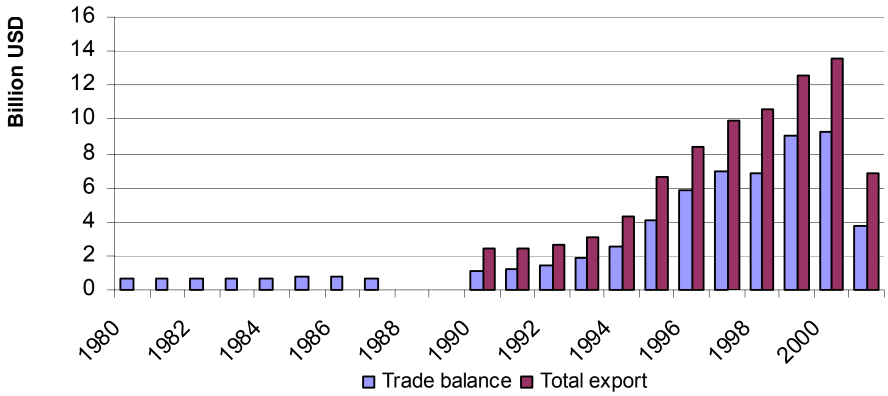

Figure 4-3: Trade balance and total Swedish exports of communications equipment (billion USD), 1990-2001

Source: OECD - Telecommunications database

Although the beginning of the new millennium has been weak for the ICT industry as a whole, the telecom industry has been particularly hard hit. The 500 largest IT companies in Sweden between them made losses of SEK 78.6 billion in 2002, down from losses of 30.4 billion in 2001. The major part of the losses was produced by Ericsson and TeliaSonera. If the results of these companies are subtracted, the total industry figures show more modest losses of 7.6 billion in 2002.[229] This tendency is also seen in export statistics. During the strong period in the late 1990s, Sweden's share of the total OECD communications equipment exports increased to between 8 and 9% in 1996-1999 (Figure 4-4). In 2001, the figure fell back to just above 4%, the lowest figure in a decade. Although no further investigations of the numbers have been made, it is reasonable to assume that telecom equipment has decreased as a relative share of ISIC 32 (with e.g. TV sets increasing in relative importance), rather than Swedish industry losing its foothold in the industry.

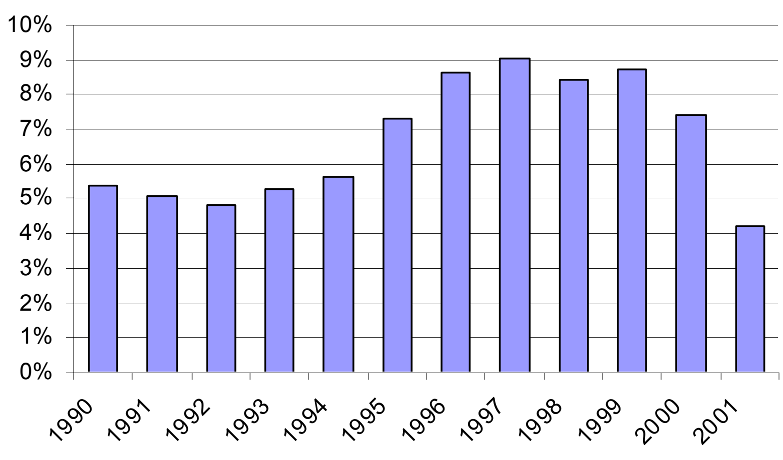

Figure 4-4: Swedish share of total OECD communications equipment exports, 1990-2001

Source: OECD - Telecommunications database 2003-09-15

[229] Veckans Affärer, No. 22, 26 May 2003

If we break up the export figures, transmission equipment emerges as the single most important area. Although the available statistics are somewhat crude, with largely undefined posts, the increased importance of wireless equipment during the 1990s is indicated. The Swedish industry's strength in equipment rather than phones is also indicated; telephone sets have constituted a very limited share of Swedish telecom exports during the last decade.

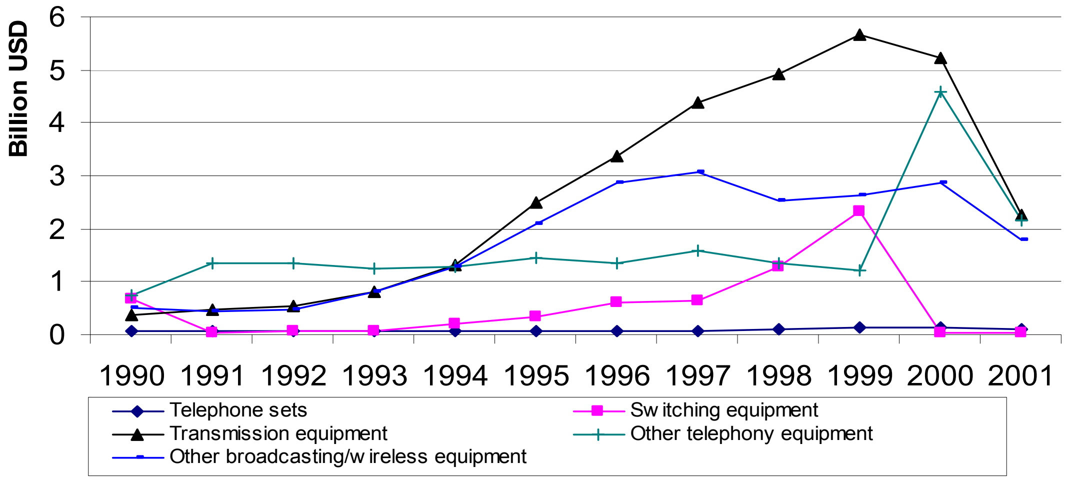

Figure 4-5: Swedish exports of telecom equipment by type (billion USD), 1990-2001

Source: OECD Telecommunications Database 2003

The development of the telecom operations sector has been less turbulent than the communications equipment industry. The revenues of e.g. TeliaSonera have continued to grow throughout the early 2000s, when the equipment manufacturers struggled for survival. According to statistics provided by SIKA, there were 117 companies offering telecom services (including cable TV) in 2001. Of these, 31 had more than 50 employees each.[230] Postal and telecommunications services as a share of total value added have increased marginally, from a little over 2% in the 1980s to above 2.5% during the 1990s. The employment as a share of total employment has had the opposite development (see Figure 4-6).

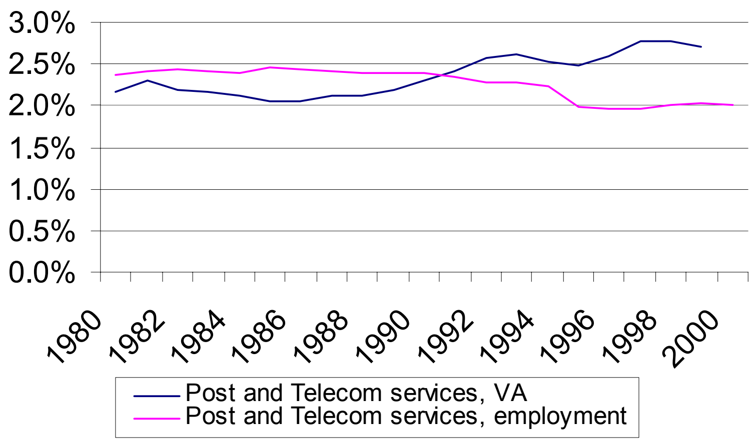

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Figure 4-6: Post and telecommunications (ISIC 64) value added and employment as share of total industry, 1980-2001
Source: OECD

[230] Statistics available at http://www.sika-institute.se

4.1.2 Indicators of Innovation

4.1.2.1 Input: the role of telecom-related R&D in Sweden

In this section we will briefly investigate the importance (or size) of telecom-related R&D in the Swedish economy, relative to other high-income countries. From Figure 4-7, it seems clear that the R&D "sector" is relatively large in Sweden compared to other countries, and that it is growing. Presumably (just drawing on the indicators presented Figure 4-8) this large share can to a high degree be explained by private R&D in particular.

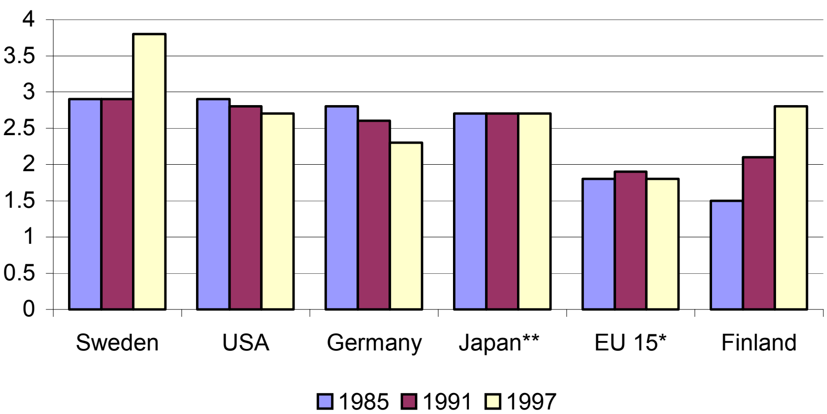


Figure 4-7: R&D as share of GDP (%)

Note: * Year 1996 instead of 1997, ** Year 1995 instead of 1997
Source: SIKA (2001)

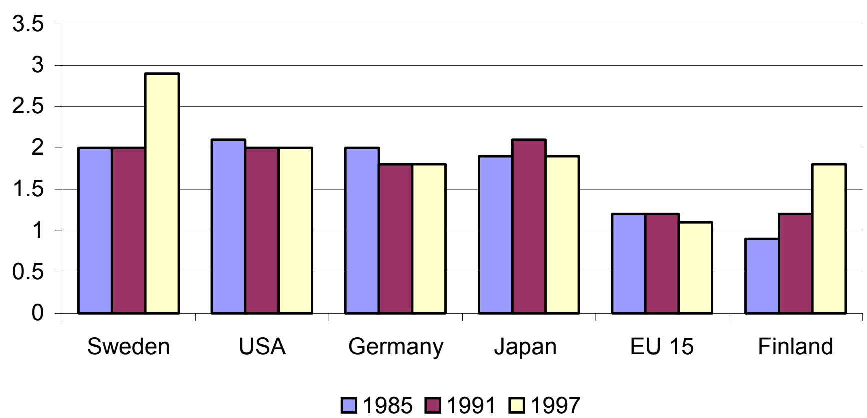


Figure 4-8: Business R&D as share of GDP (%)

Note: * Year 1996, ** Year 1995
Source: SIKA (2001)

How much of this growing and relatively large share is due to telecommunications? Figure 4-9 indicates that the answer is: very much. Sweden is, relative to its size, among the countries that spend the greatest share of their wealth on telecom R&D, and is also among the countries for which this share has grown the most. Of the total private R&D expenditures in 1997, the electronics industry accounted for more than 22 percent, or over SEK 11 billion. The "tele-products" industry (telecom and radio and TV equipment) accounted for more than three quarters of the SEK 11 billion. In 1997, the private sector represented 75% of the total Swedish R&D expenditure.[231]

Bearing in mind the many possible sources of errors in the statistics, it is still fairly safe to assume that telecommunications are relatively more important for the national R&D system in Sweden than in most other countries, and are the main R&D contributor and R&D growth driver in Sweden.

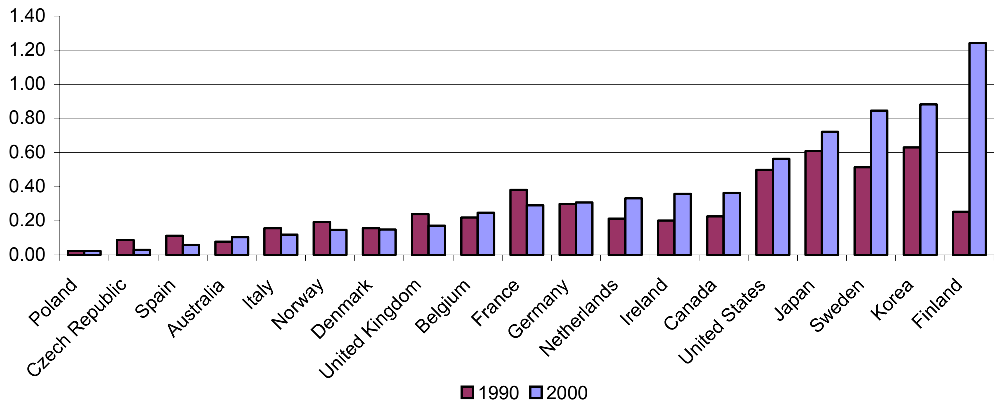


Figure 4-9: Business R&D expenditure by selected ICT manufacturing industries, as a percentage of GDP (1990 & 2001)

Note: 2000 or latest available year. Data are for 1990 or closest year for manufacturing, and 1992 or closest year for service industries.

Source: OECD, ANBERD database, May 2003.

However, when it comes to the computing hardware sector, the opposite seems to hold. During the 1980s, Sweden spent a comparatively small share of the BERD (Business Enterprise R&D) in the computing field. The weak Swedish position in the computing field did not improve during the period until 1992 (see Figure 4-10),

231 Facts about information and communications technology in Sweden 2001, Swedish Institute for Transport and Communications Analysis (SIKA), Fäth & Hässler, Värnamo, 2001

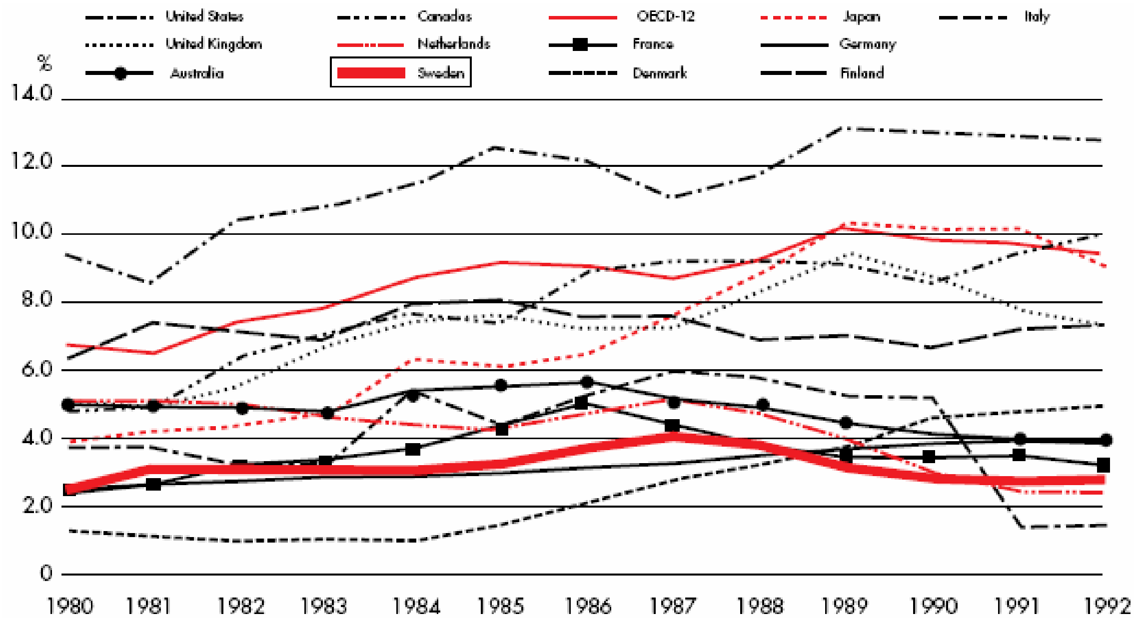


Figure 4-10: Share of business enterprise R&D expenditure on office, computing and accounting machinery for the period 1980 to 1992

Source: Teldok (1997:178)

Swedish R&D and production of telecommunications equipment are almost exclusively performed by domestic actors (see Figure 4-11). In 1998, the share of Swedish telecom equipment production being carried out by foreign affiliates was as low as 5%. The figures for R&D were even more striking, showing that foreign affiliates accounted for less than 1% of R&D.

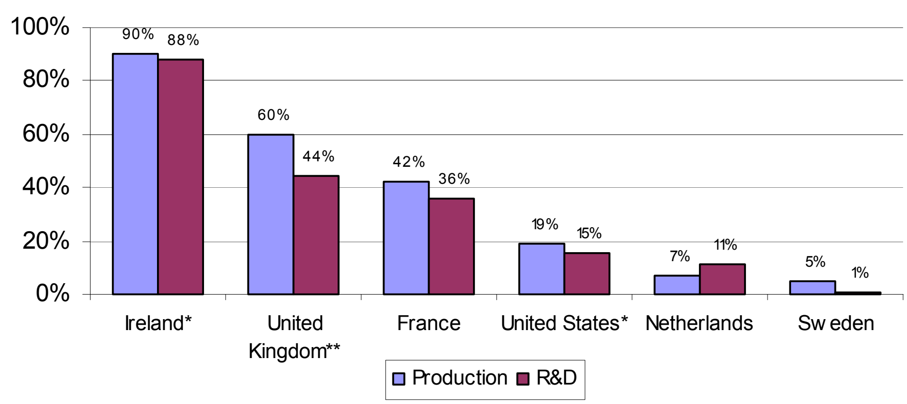


Figure 4-11: Share of Production and R&D by foreign affiliates in radio, TV and communications equipment (ISIC 32), 1998

Note: 1997 data. ** 1999 data

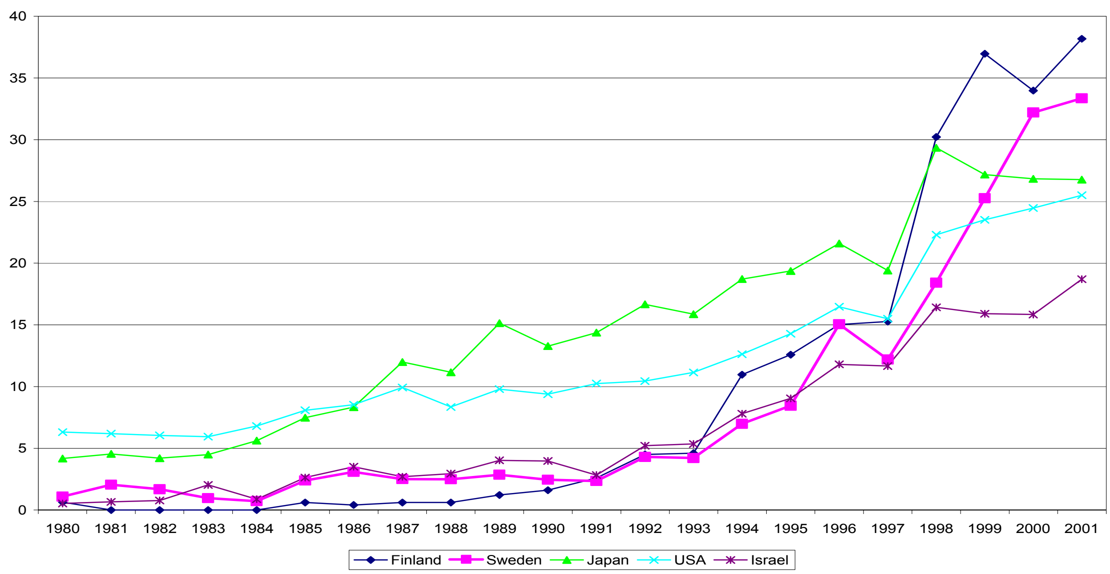
Source: OECD, Activities of Foreign Affiliates (AFA) and Foreign Affiliates Trading Services (FATS) databases.

In conclusion, telecom has been the major driver of growth in the R&D component of the Swedish National Innovation System while the corresponding computing part has been relatively low (the reasons for the latter will be further investigated in Chapter 6). Swedish telecom R&D is almost exclusively carried out by domestic actors. It may be hypothesized that, for telecoms R&D, Ericsson's growth, in particular in mobile communications, has played an important role. If so, the Swedish R&D system overly depends on the success and failure of one product area of one firm. This has been a strength for Sweden, but may equally prove a threat and weakness. Understanding the evolution and status of that firm is therefore mandatory in any study of the Swedish sector (see Section 4.3). The evolution of Swedish R&D in telecommunications will be detailed in Section 4.7.

4.1.2.2 Output: patenting

Although patents are questionable to use as an indicator of innovation activity, some observations can be made from received statistics. First, Sweden's telecom patenting per capita has increased dramatically from a relatively normal patenting intensity in the 1980s to a position second only to Finland (Figure 4-12). Presumably, this change is a combined effect of intensified technological activity in the Swedish sector in general and an increased propensity to patent among Swedish telecom firms (Ericsson). The high patenting intensity of US and Japanese firms can partly be explained by a high patenting propensity in general.[232]

As discussed in Chapter 3, the patent strategies of telecom equipment manufacturers have changed during the period, with a general increase in patenting activities for both defensive and offensive purposes. Although this is mirrored also in the Swedish figures, the rapid increase during the 1990s (challenged only by Finland) goes beyond this general increase.



Source: OECD

Figure 4-12: USPTO telecom patents per million inhabitants, 1980-2001 (5 most telecom patenting-intense countries 2001)

As shown in Table 4-1, Sweden ranks internationally high in both patenting generally and telecom patenting, both measured per million inhabitants and as share of total patenting.

[232] See e.g. Granstrand (1999)

Table 4-2: Swedish patenting in comparison with OECD countries

	Swedish rank among OECD countries 2001
Total patents per million inhabitants	3
Telecom patents per million inhabitants	2
Telecom patents as share of total patenting	3

Source: OECD

On a company level, the patent portfolio of Ericsson is considered internationally very strong. In an attempt to rank telecom equipment manufacturers' patent portfolios, the research from CHI together with the magazine Technology Review has created a patent scorecard. By measuring how often a company's patents are cited by others in patent applications, and multiplying this by the number of US patents, an indication of relative intellectual property strength is provided. Ericsson was ranked highest in 2002, with an average third place in 1997-2001.

4.2 Evolution of the Swedish telecom services market

4.2.1 The early phase of competition (1870s – 1910s)

The early days of telephony in Sweden were characterized by intense competition. The first telephone connections in Sweden were established in 1877.[233] The International Bell Telephone company entered the market in 1880 with local systems in Stockholm, Göteborg and Malmö. The main operator of telegraphy services, the government-owned Telegrafverket, initially refrained from involvement in telephony, limiting its activities to establishing a local Stockholm network connecting government offices in 1881. Several domestic firms were also attracted to the market, the main one being the General Telephone Company (Stockholms Allmänna Telefonaktiebolag – SAT), which within one year serviced more than three times as many subscribers as Bell. Bell did not supply its competitors with equipment; Ericsson was established in 1878 and could supply viable alternatives. The operators engaged in a fierce rivalry (primarily in Stockholm) based on price and service quality. Eventually, SAT was victorious. By 1888, Bell gave in, and the two networks were merged.

This was not the end of the era of competition, however. Primarily in rural areas a number of firms, mutual associations, cooperative societies, and municipalities established themselves and began to connect via long-distance lines. Long-distance lines were mainly constructed by Telegrafverket, which also began to acquire and build local networks. In Stockholm it began expanding its small governmental system into a public system. Throughout the 1890s Telegrafverket acquired most of the private networks in Sweden. The only exceptions were a few provincial networks and STA's large networks, which Telegrafverket attempted to acquire several times before finally succeeding. Eventually, the battle was to stand between Telegrafverket which dominated long-distance telephony and SAT which dominated in Stockholm. Many other operators were forced out of the market because of high access fees and difficult-to-meet technical specifications. Within Stockholm, the vigorous competition led to reduced rates, high technical performance, and experimentation with services and billing schemes, making Stockholm's telephone system the most advanced in the world. The government, with its superior resources and power, eventually took control of SAT in 1918 and integrated it in 1923. Telegrafverket, subsequently named Televerket, thus became the

[233] This section draws on Noam (1992:203-211) unless otherwise stated.

sole public operator on the Swedish market (except for other state administrations, such as the state railway company, which partly provided for their own communications). Televerket's monopoly, de facto though never legal, remained unchallenged for many years to come.

4.2.2 Televerket's monopoly

The stable monopoly regime between the 1910s and 1960s was characterized by network expansion, increased traffic and technological development. In the 1930s it was possible to call from Sweden to anywhere in the world. Almost immediately after formation of the monopoly, Televerket started to automate the network. Long-distance traffic was fully automated by 1949, and international traffic began automation by the 1960s. The national network was completely automated by 1972. Televerket began laying coaxial cable in the 1940s and radio links in the 1950s, substantially increasing capacity.[234] In 1970, Televerket employed more than 40,000 persons, with more than 3.6 million main lines installed, the highest penetration in the world at that time (see Chapter 3). Thus, also after monopolization Sweden continued to stay in the forefront of telecommunications deployment.

According to Karlsson (1998:25) four features of Televerket's role need to be pointed out. First, Televerket had a powerful position in relation to the ministry. Second, Televerket was never linked to the postal service. This meant that it did not have to worry about telephony substituting for postal services and about supporting the postal sector. Third, Televerket was a public enterprise, a fact which contributed to its independence. Finally, it had an important division of equipment manufacturing, which meant that it could develop its own manufacturing and R&D expertise, and became a powerful purchaser.

By the 1970s, Televerket was still organized as a public enterprise under the supervision of the Ministry of Transport and Communications. This form, rather unique to Sweden[235], made Televerket more independent than a regular civil service authority. On the other hand, the government imposed more restrictions and control than would have been the case had it been a state-owned limited liability company (*Aktiebolag – AB*).[236] Public enterprises differed from firms in the sense that they were not independent legal subjects. They were also subordinate their ministries, had to follow administrative laws and regulations, and were subjected to principles of public access to their records, and their decisions could be appealed against to the government. They did not own their assets in a legal sense, but only administered state property, and they did not enjoy full freedom when it came to economic and personal matters. All major decisions had to be taken by the government or the Parliament. On the other hand, they were rather unconstrained regarding internal economic matters. They could decide how to use their operating income and cover costs. To the government they were only obliged to account for the yearly write-offs and profits. The government did have some influence on prices, in particular for communications. This price control was socially motivated and an instrument to ensure universal service.[237]

Televerket's management included a board (Telestyrelsen), consisting of external experts and political representatives, and a Director General who was responsible not to the board but to the government. Televerket had a double mandate from the government. First, it should act as a public authority and make decisions within its area of competence. Second, it should act in a

[234] Karlsson (1998:24)

[235] In the early 1970s there were seven such public enterprises (Karlsson 1998:79-80)

[236] Karlsson (1998:79)

[237] Karlsson (1998:80)

business-like manner and make profits that could be returned to the state budget. This double role obviously created problems.

Televerket was dominated by civil servants and engineers, generating a genuine engineering culture with a strong technological focus. It had a tradition of educating its own staff through the "School of telecom" (*Teleskolan*). Educational facilities included general introductory courses for non-skilled workers as well as higher-degree engineering studies. Consequently, not very many university graduates were employed in Televerket in the period in question, a situation that did not change until the 1980s and 90s. This practice was maintained for many years and had a great impact on the character of the organization.[238]

4.2.3 Televerket 1970-1993

In the 1970s and 1980s, Televerket expanded into a variety of new activities, employing a range of new technologies, indicating that it was in the forefront of innovation (although no systematic comparison with other countries has been made here)[239] In terminal equipment it had offered answering-machines since the 1950s, and modems for datacom since the early 1960s. The first fully electronic telephone (Diavox) was introduced in 1982, facsimile in 1980 and Teletex in 1981. Electronic PBXs, developed by Ellemtel, were introduced in 1979, and a number of new models developed with Ericsson or Northern Telecom were introduced in the following decade.

In the switching field, the AKE 12 developed by Ericsson was introduced in 1968, while a similar switch developed by Televerket itself was introduced in 1970, followed by the Ellemtel-developed digital SPC switch AXE in 1980. Transmission lines improved with the introduction of PCM in 1970. Digital radio links were introduced in 1977, and an INTELSAT satellite station was opened in 1971. Major resources were also invested in fiber optics in the 1980s, in particular for the long-distance and international networks. By 1987, Televerket had a nationwide digital network based on 100 AXE switches and digital optical fiber and microwave links, with a capacity for 1.75 million subscribers.

New networks for data and mobile communications were also introduced. In the early 1980s circuit-switched (Datex) and packet-switched (Databas 300, later Telepak and eventually Datapak) data networks were introduced. Videotex was launched in 1982, and ISDN on trial basis in the early 1990s. In mobile communications, Televerket had been very inventive, with the MTA and MTB automatic systems launched in the major cities in the 1950s and 60s. A nationwide manual system – MTD – was launched in 1970, and two cellular systems (NMT 450 and NMT 900) developed in cooperation with the other Nordic telecom administrations were launched in 1981 and 1986.

Starting in the 1970s, Televerket was becoming more market-oriented, partly triggered by the emergence of datacom services. In the old years Televerket had been forbidden to market its services. In the mid-1970s, Televerket established two new market departments – one for telephony and one for data – which among other things were allowed to advertise (based on economic considerations).[240]

Another important activity was the MP project, a strategic project related to market and product development, including among others Bertil Thorngren. The group concluded (in

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[238] Hauknes and Smith (2003:10)

[239] This and the following two paragraphs draw heavily on Karlsson (1998:73-74) and Hauknes and Smith (2003:16).

[240] Karlsson (1998:96-97)

1978) that, although there would be a strong growth in demand, it could not be taken for granted that Televerket would enjoy all the benefits of that growth. In particular an expected convergence of computing and telecommunications technology would lead not only to new data-related services, but also to a convergence of actors utilizing the globally available technology, it was claimed. Drawing from experiences in the US, the MP group anticipated that competition would intensify in the future, for instance through the growth of private data networks into public integrated voice and data networks. Since Televerket had no legal monopoly protection, these threats were believed to be particularly serious for Sweden, not only in new services but for the traditional business. The MP report became influential for Televerket's adaptation to a more competitive market, in particular since much of its content was embraced by the new Director General Hagström, among other things leading to the gradual corporatization of Televerket, described below.[241]

4.2.4 Deregulation

One of the most pervasive trends during the analyzed time period, internationally and in Sweden, has been deregulation. According to Karlsson (1998b) there were a number of major driving forces relevant for the Swedish case, the key ones being (1) economic interest driven by technological development and (2) policy diffusion.[242] First, technology played a crucial catalytic role. The pervasive development of microelectronics and computer technology in the 1960s and 1970s made a number of new actors want to take advantage of that development. Large telecom users, e.g. banks and insurance companies, had a lot to gain from more competition and political reform. These groups were supported by a number of trade and manufacturing companies in the emerging electronics and computer sector. Joining forces with the liberal and conservative parties, they initiated and promoted the process of liberalization.

Second, with respect to policy diffusion, there was a general liberalization trend, of which telecommunications was part. In Sweden a number of other sectors were liberalized in a manner similar to telecom. The Swedish situation was also influenced by liberal tendencies both generally and in telecommunications in other countries (with the US as prime mover) as well as the policy advocated in particular by the WTO (World Trade Organization). Finally, as mentioned before, Televerket was never protected by a legal framework. This fact enabled Sweden to liberalize in a stepwise manner.

The monopoly largely remained until the early 1980s, when a deregulation process started. The process can be broken down into a few key aspects (based on Karlsson 1998b). First, *telecommunications equipment market* was deregulated. Televerket had traditionally enjoyed a monopoly in the area of subscriber equipment. Apart from the case of mobile phones (which had been liberalized with the introduction of MTD in the early 1970s), this process of deregulation started in 1980, when the monopoly sector became limited to public voice communications equipment and modems. Then different categories of equipment were further removed from the monopoly sector, such as telex (1984), telephones (1985), PBX (1988-89). By 1989 the equipment market was completely open to competition. The major political decisions were taken in 1981 (the first demarcation), 1985 (to abolish the telephone monopoly) and 1988 (to completely remove monopoly). This liberalization was largely driven by the lobbying efforts of private equipment suppliers and large users.[243]

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[241] Karlsson (1998:97-99, 100-101)

[242] See also Chapter 3

[243] Karlsson (1998:219-220)

The second aspect was *infrastructure competition*. In the area of telecommunications networks, Televerket had statutory monopoly. One exception was mobile telephone networks which had been operated in various parts of Sweden since 1964. The rights of these were mainly restricted by (1) limited frequency spectrum and (2) automatic connection to Televerket's PSTN. For these reasons, the sector became nearly monopolized in 1981. However, a government decision granted Comvik a permit to operate an automatic mobile telephone network the same year. Then in 1985, the Parliament (*Riksdagen*) decided that the cable TV market should be opened to competition. Comvik Skyport received a permit for an international business service in 1988, and Comviq GSM and Europolitan for digital mobile telephony in 1988 and 1990 respectively. In 1991, interconnection rights conditions and rights to operate third-party networks were established, and finally in July 1993 the new telecommunications legislation introduced a licensing system and the conditions for competing operators were regulated.[244]

Another key aspect of liberalization in the Swedish market was the *separation of operations from regulatory responsibilities*. In relation to terminal equipment issues, the regulatory authority was separated from Televerket in two steps. First, the functions for testing and approval of equipment were conducted by the Office for Approval within Televerket, starting in 1981. The Committee for Connection of Telecommunications Equipment became a separate body of appeal from 1982. Second, the National Telecommunications Council (Statens Telenämnd, STN) assumed both functions in 1990. The right-wing parties argued for a complete separation throughout the 1980s, supported by Televerket itself, which in 1987 wanted to go further and separate also the frequency board.[245] Further to the separation of regulatory authorities, the frequency administration was separated from Televerket in 1992, and integrated with STN. The new agency was called the National Telecommunications Agency (Telestyrelsen). Also here the final step of separation was taken in July 1993 when the agency overtook the responsibility of the telecom network, including among other tasks the licensing of operators.[246]

A final, very important aspect of the liberalization was corporatization and privatization of Televerket. This process, beginning with a stage of being organized as a public corporation, started according to Karlsson (1998:139-40) when a first company, Telefabrikation AB, was established in 1966. It should also be mentioned that the public enterprise form had been scrutinized on several occasions during the postwar period, through a number of public inquiries. In particular, Televerket itself was of the opinion that the organizational form was not appropriate. Two other major events were the partial offer on the Stockholm stock market in 2000 and the merger with Sonera in 2003. The major political decisions were taken in 1980 (to establish Teleinvest AB), 1981 (to introduce a new financing procedure), 1986 (to establish Teli AB), 1991 (to change the organizational status of Televerket) and 1993 (to establish Telia AB).

In essence, also according to Karlsson (1998:139-40) the management of Televerket was the driving actor in this process of corporatization. Two major proposals (1979 and 1990) put the issues of market orientation, corporatization and privatization, on the agenda. The non-socialist government went one step further in 1980 and initiated the corporatization of TeleLarm AB and Teli AB, although the Teli decision was delayed due to trade-union conflicts. The liberal and conservative parties continued arguing for more flexible forms of public enterprises, opposed by the Social Democrats for social and regional policy reasons.

[244] Karlsson (1998:304)

[245] Karlsson (1998:219-220)

[246] Karlsson (1998:304)

After Televerket's own proposal in 1990, even the Social Democrats changed their standpoint and prepared for corporatization, which was finalized by a non-socialist coalition in 1993, also indicating a future privatization, initially opposed by the Social Democrats.

4.2.5 Sweden's telecom service position around 1990

Also during the later phases and gradual deterioration of the monopoly, Sweden stayed among the leading telecom nations in most respects (see Table 4-3). Swedish telephone penetration remained outstanding throughout the time period in both fixed and mobile. Televerket's telephone tariffs were among the lowest; the quality and technical sophistication of the networks was high, clearly above international standards.

Table 4-3 Indicators of Sweden's telecommunications performance in the early 1990s

Indicator	*Sweden*	*OECD average*	*Rank*
Main line penetration (%) (1990)	68.33	42.58	1
Business telephone charges (basket USD PPP) (1991)	494	1004	4
Business telephone charges (basket USD PPP) (1991)	215	370	2
International telephone charges (basket USD PPP) (1991)	92.5	100	8
Faults in 1990 per lines (QoS) a)	12	20-30 (est.)	2
Average waiting time (months 1988)	0	7	1[b)]
Mobile penetration (% end 1990)	5.7	1.3	1
Mobile charges (Basket USD PPP 1991)	976	1537	6
Digitization (subscriber lines digital % 1991)	56	39	2

[a)] All countries did not provide statistics
[b)] 10 out of 22 countries had no waiting time

Source: Compiled from OECD (1993)

4.2.6 The new Swedish Regulation 1993 – 2003

On July 1, 1993, a new telecommunications act entered into force, which radically changed the Swedish telecommunications market. Prior to this, there was no proper legislation within the telecommunications field. The 1993 Telecommunications Act meant that Swedish telecommunications became a modern marketplace, and several added amendments ensure this.[247]

The political objective of the Telecommunications Act was to grant access for everybody, regardless of localization, to efficient telecommunications services at the lowest possible cost, and to ensure that telecommunications would be sustainable and accessible during crises and wartime.[248] The means for achieving this objective was to create scope for and maintain efficient competition within all parts of telecommunications through legislation and implementation of the laws.[249]

The law was quite gentle, imposing very few restrictions on the market. Virtually unlimited access to the Swedish market was established without provisions for reciprocity[250] and there are no provisions that particularly protect Swedish interests.[251] The purpose of the law was to ensure that operators met certain basic requirements in order to ensure good service quality and durability. The basic requirements were that sufficient financing resources and technical

[247] The title of the law is "Telecommunications Act (1993:597) including amendments (1996:416) and (1997:397)".
[248] Telecommunications Act (SFS 1993:597), section 2
[249] Telecommunications Act (SFS 1993:597), section 3
[250] I.e. only operators from countries with open markets are allowed to enter the Swedish market.
[251] ProCivitas (1997)

competency were available, and that some public duties, such as defense and services to the handicapped, were fulfilled.[252]

One aim was to prevent Telia from acting upon its dominant position. This was done through: (1) imposing bundling restrictions (e.g. fixed and mobiles services), (2) placing special requirements on interconnection of operators with "significant market power" although in fact Telia was forced to start negotiating with any firm wanting to interconnect.[253] Moreover, (3) cross-subsidies were not allowed and there was a temporary price cap on subscription fees for Telia.[254] Telia was given a universal service obligation (USO), i.e. the obligation to provide telecommunications services to everybody in Sweden.[255]

Parallel to the Telecommunications Act, a new Competition Act (*Konkurrenslagen*) was introduced on July 1, 1993. This law imposes very different terms on players with 'significant' market shares[256] than others, thus facilitating for new entrants. In addition, the Marketing Act (*Marknadsföringslagen*) was introduced in the beginning of 1996, further enhancing the preconditions for efficient competition within the telecommunications sector. These laws together made up the most relevant legislation for the telecom operators in the Swedish market.

During its ten years of existence the Telecommunications Act was amended 15 times. As a general observation it can be concluded that the Telecommunications Act was cautious, based on little intervention on the market. Gradually the regulation has become more far-reaching, as PTS and the legislator observed that competition did not develop in the direction desired. Other general conclusions are that if a reform aims to grant new entrants access to incumbents' networks and the actors have conflicting interests, PTS must be given authority to decide on what terms this should apply. This has not always been the case. Finally, timing is of crucial importance. [257] In a report PTS (2003b) evaluated the effects of some of the major reforms, namely (1) a procedure of open invitation to apply, (2) interconnection, (3) carrier pre-selection, (4) number portability, (5) provision of network capacity, (7) national roaming, and (8) access to the local loop. It is beyond the scope of this report to probe further into these changes. However, the main conclusions from the PTS report will be presented.

Procedure of open invitation to apply. The basic underlying aim of the reform was to allow all interested *mobile* operators to apply for a license on equal terms, when the frequency space is not sufficient for everyone. Those who best satisfy the criteria prescribed should receive the license, in competition. The procedure is based on the assumption that the number of applicants is larger than the number of licenses that are to be allocated. Four such procedures have been conducted since the rule was introduced, but only one case (the UMTS licenses) was conducted in this way. The rather obvious conclusion is that licenses must have sufficient commercial interest and that the applicants themselves can specify the extent to which they are prepared to offer, for example, population coverage and rate of development.[258] It is still open to debate whether this amendment worked properly in the UMTS license case, since the

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[252] Telecommunications Act (SFS 1993:597), section 17 a

[253] Hultkrantz (2002:144)

[254] SFS 1997:400

[255] Nordin and Tavernier (1998)

[256] The concept of "significant market power" was not defined in strict terms, but will be left for PTS to ascertain. It should, however, be kept in mind that the term "dominant position" is not used, so presumably a number of operators can be embraced.

[257] PTS (2003b:12-13)

[258] PTS (2003b:8)

licensees have not been able to fulfill their promises. Possibly also the most technically competent and commercially sound application (Telia's) did not receive a license (as argued by e.g. Berggren and Laestadius 2003).

Interconnection between the operators (the joint use of networks) in the market is a fundamental precondition for subscribers being able to reach each other and a precondition for allowing new operators to enter the market. It was included in the Telecommunications Act from the start, assuming however that the parties would be able to agree on interconnection contracts. In the event of disputes, PTS was empowered to mediate between them. However, this did not lead to desired results. Therefore, the provision was made more stringent in 1997, and PTS was empowered to decide what should apply between the disputing parties. More and better interconnection contracts followed, with a manifest improvement in the competition situation, both directly as a result of PTS decisions and indirectly because the parties were faced with the prospect that PTS could otherwise decide what should apply.[259]

The *pre-selection reform* was implemented to make it easier for the consumers to select another operator than the operator owning their access network, taking away the need for the subscriber to dial a prefix to be able to call with the pre-selection operator. The reform was introduced in September 1999. Overall, it seems to have been successful in improving competition. Since the introduction, approximately one third of all private customers have chosen another pre-selection operator than Telia. The number of operators that a private consumer can choose between has increased from approximately 10 to approximately 30.[260]

Another reform that aimed to make it easier for customers to change operators was the introduction of *number portability*. This makes it possible to retain the telephone number when changing telecom operator. The aim was to remove switching costs for customers, thereby enhancing competition. The reform seems to have been a failure, though. For fixed telephony this has to do with a lack of choice for most customers. The impact in the mobile market has been marginal as well; the reform is rather unknown among users.[261]

In May 2000, an obligation was introduced for mobile network operators to lease *network capacity* to undertakings that did not have their own networks, i.e. allowing for MVNOs. Also in this case, PTS could not make decisions when the parties did not agree on the terms. Since the provision was introduced, several MVNOs have entered the Swedish market. However, the new operators basically offer the same services at the same prices as the incumbents and their market share is negligible There are no compulsory means to induce network operators to lease network capacity on terms that would seriously make real competition possible. This position of power for the network owners does not stimulate equal negotiations. The amendment appears in conclusion to have failed to meet its objectives. [262]

Similarly, the provision on *national roaming* was introduced to make it easier for new mobile operators to enter the market, but it had little effect, primarily due to the limited powers beyond mediation that were granted to PTS. The aim was that new operators would be able to provide extensive coverage without first needing to build their own network. Since the commercial interests of the incumbents work in the opposite direction, voluntary agreements

[259] PTS (2003b:9)

[260] PTS (2003b:9)

[261] PTS (2003b:10)

[262] PTS (2003b:10)

would be naïve to expect.[263] We have difficulty in understanding what thoughts of legislators were behind amendments like this one.

In December 2000, an EC Regulation was introduced regarding access to the *local loop*. The aim was to provide new operators with access to the local loop, which would improve competition primarily in the markets for local telephony, subscriptions, ISDN connections and broadband access. The regulation in Sweden has not yet had any major effects on the competition situation within the access network. In the current situation, there is an extremely small proportion of the total number of accesses that are leased by other operators within the framework of the Regulation. Instead, it is other products in Telia's range that have proved to be more interesting but which have not been covered by the current Regulation.[264]

In 2003, the Telecommunications Act was replaced by the new law of electronic communication. This new law has not been investigated further in this report.

To conclude, deregulation appears to have led to intensified competition and price reductions, more in some segments than others. Some parts of the regulation can be considered as successful, some not, viewed in traditional economic terms such as pricing and intensity of competition. For the purposes of this study, the dynamic effects on innovation have been poorly studied, however. Now we will take a step back in time and investigate how the competitive process actually unfolded in the Swedish market.

4.2.7 The emergence of competition and the rise of Tele2

The (new) competition in the Swedish telecom market started in the late 1960s with the entries into the fringe markets of mobile telephony and datacom. Actors such as General Electric Information Systems and IBM started offering private data networks to companies, while a number of smaller firms started offering mobile telephone services on a local basis, eventually consolidating into Comvik, controlled by the Kinnevik group. Comvik also obtained the second GSM license, while a third license was awarded to the NordicTel (Europolitan) consortium.[265] The further developments of these two markets are investigated in Chapters 6 and 0.

Other areas of early competition were cable TV and satellite services. Cable TV seems to have been introduced in Sweden in the mid-1980s, initially primarily by Televerket, although competition was allowed from the start. With a strategy to attack monopolies, the Kinnevik group was early to embrace the new technology. It entered the market through Finvik in 1987. It also became involved in satellite TV via the Astra satellite in 1989. The next step was to establish Kabelvision with other investors in 1987. Kabelvision was then fully acquired in 1990. By the early 1990s, Televerket held about 60% of the market and Kabelvision/Finvik AB 18%, the remaining market being divided among Stjärn TV (9%), Sweden On Line and Scandi Net (4% each).[266] In the first years, cable TV networks were exclusively used for TV, although the possibilities to provide also tele- and data services were perceived early on.

Another market of early competitive entry was satellite communications. Initially Televerket was (since 1971) the sole provider of such services through INTELSAT, and later EUTELSAT and Tele-X. The Kinnevik group started to prepare for entering this market too.

[263] PTS (2003b:11)

[264] PTS (2003b:11)

[265] See e.g. Karlsson (1998) and Johansson and Granstrand (1994)

[266] Karlsson (1998:253-255)

Comvik Skyport was established in 1985 and applied to offer international business-business services. This was a lucrative market, and in response to the threat Televerket established a separate company, STS Telecom for this purpose in 1987. STS was later taken over by Swedish Telecom International (see below). Televerket and the Government delayed the issue for a couple of years, so that Comviq Skyport could not start offering services until 1990.[267]

The Kinnevik Group intensified its activities in the telecommunications sector in the early 1990s. In line with a strategy to attack Televerket's core businesses and become a full-fledged telecommunications operator, it established Tele2 on the basis of the operations of Comviq Skyport. It closed a deal with the Swedish Railway Administration (Banverket) in 1989 to install and operate national fiber-optic backbone network (initially between Stockholm, Göteborg and Malmö) to be used by Tele 2 and Comviq GSM. The same year Cable and Wireless acquired 40% of Tele2. The strategy was to introduce Tele2 in three stages: (1) data communications on broad scale (IP through Swipnet, X.25 and leased lines), then (2) business services, and finally (3) residential customers. In April 1992, Tele2 had negotiated an interconnection deal with the same conditions as the GSM operators.[268] Tele2 launched its international service in March 1993 using the prefix 007, instead of 009. Quite rapidly the company captured a substantial share of that market (10% by the end of the year).[269]

The operator activity in 1992, i.e. just before the new regulation went into force, is summarized in Table 4-4.

Table 4-4 Operators active in the Swedish market in 1992

Company	*Domestic telephony*	*International telephony*	*VANS and datacom*	*Private networks*	*Mobile*
Televerket	X	X	X	X	X
Tele2/Comvik		X	X	X	X
Nordic Tel					X
Banverket				X	
BT		X		X	
AT&T		X		X	
GEIS			X	X	
IBM			X	X	
Others			X	X	

Source: Karlsson (1998:303)

4.2.8 The fixed telecom services market 1993-2003

Since the developments of mobile communications and Internet/datacom services are covered in other chapters, we will primarily focus here on the development of fixed telephony and, in addition, the market for network capacity.

4.2.8.1 The first years of competition (1993-1997)

When the new telecommunications act entered into force on July 1, 1993, new operators rushed into the market. Although it had been possible to enter before, this was not very attractive due to the regulatory uncertainties involved and the market power of Televerket. The rise of specialist suppliers had lowered the entry barriers, which further facilitated entry. In addition, although the Swedish prices were low in comparison, the system of subsidizing

[267] Karlsson (1998:255-265)

[268] Karlsson (1998:255-265)

[269] Karlsson (1998:255-265)

local calls through long-distance and international calls, and residential customers through business customers, meant that the margins on the latter were very high. New entrants could simply undercut Telia's tariffs and still obtain good margins. Some operators had other rationales than short-term profits for entering the market, for instance to learn how to compete in a competitive environment. As a result, new entrants attacked the international and then the long-distance market, where Tele2 took the leading position as shown in Figure 4-13 and Figure 4-14.[270]

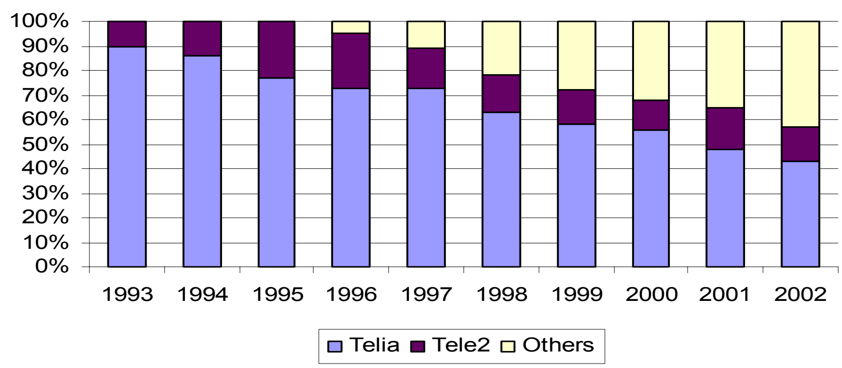

Figure 4-13: Market shares in international fixed telephony

Source: Nordin & de Tavernier (1998:100) (years 1993-1996) and PTS (2003) (years 1997-2002)

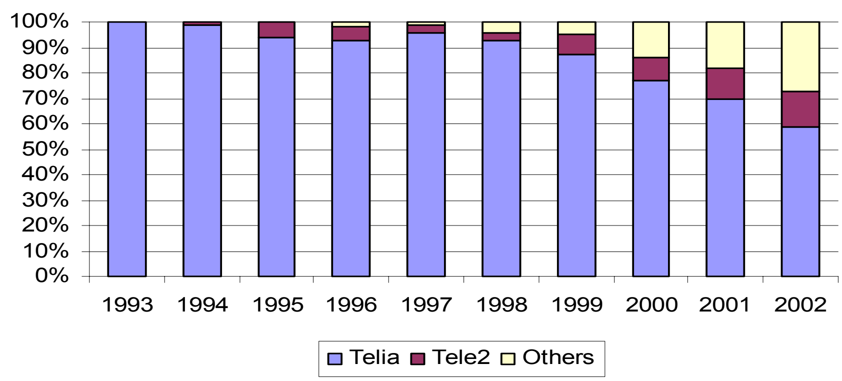

Figure 4-14: Market shares in national fixed telephony

Source: Nordin & de Tavernier (1998:100) (years 1993-1995) and PTS (2003) (years 1996-2002)

Telia responded to this price pressure through increasing prices on local calls, while lowering prices on international and long-distance ones; long-distance rates were almost halved and local rates doubled in only four years. Telia also responded with high interconnection rates. In fact these were for a long time higher than local call rates (see Figure 4-15). Since PTS had little authority to intervene, such rates made it difficult to enter some markets. However, dial-up Internet connections made the amount of traffic terminating in other operators networks increase. In relation to some operators, e.g. Tele2, the balance started to become negative, thus making it in Telia's interest to reduce the rates. The combination of higher local-call rates and lower interconnection charges made it attractive (around 1998) to enter the market of local calls, by offering low day-time charges.[271]

[270] Nordin and de Tavernier (1998:97-100)

[271] See Nordin and de Tavernier (1998:100-101) for an elaboration and further references.

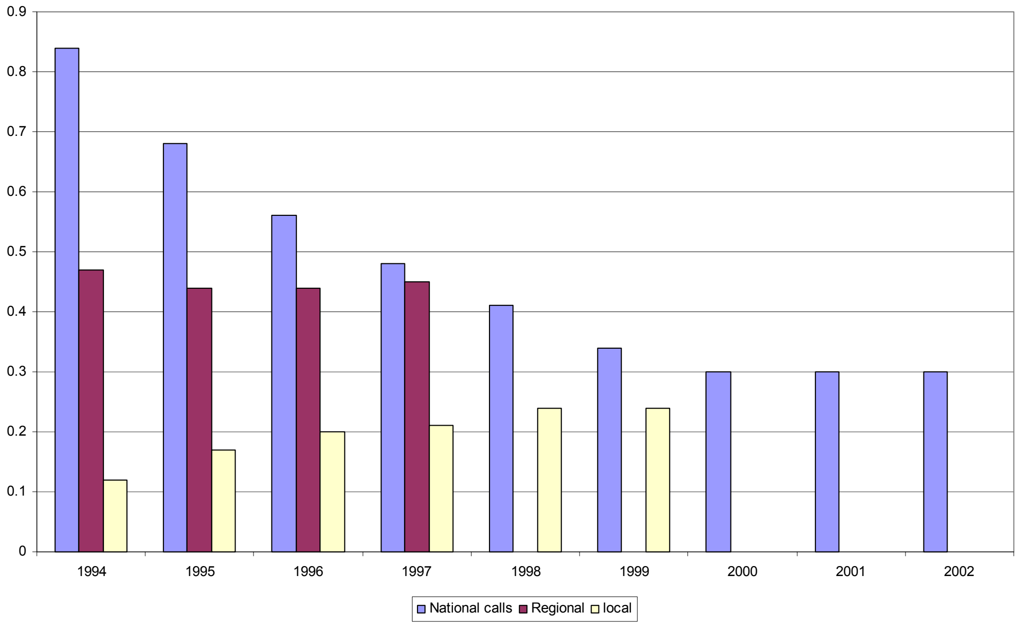

Figure 4-15: Average price of three-minute call (excl. VAT), 1994-2002

Source: PTS (2003a)

In the initial years, entry strategies were fairly regular, given the pricing and competitive structures at that time. As a rule, the entrants first attacked the datacom market, then international telephony, and eventually national telephony. They also attacked the business market before the residential customers.

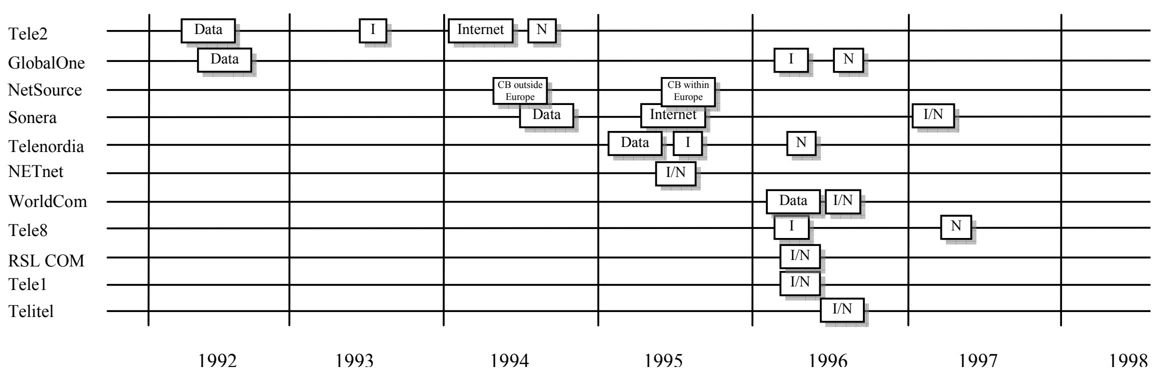

Figure 4-16 Overview of operators' service introductions (1992-1997)

Source: Nordin and de Tavernier (1998:106)

A brief overview of the entrants is given in the following paragraphs.[272] Tele2 has already been discussed, but it could be mentioned here that Tele2 was also a very early mover in Internet service provisioning. *France Telecom* entered the market by offering datacom services. A major datacom purchase from Statel established France Telecom as major player and it began to expand into other services as well. When the international alliance of FT, Deutsche Telecom and Sprint, *GlobalOne*, was formed in 1996, it took over FT's activities in Sweden. *GlobalOne* also won Statel's telephony procurement in collaboration with Vodafone. GlobalOne suffered from heavy losses though, also in its Swedish operations.

[272] This account draws on Nordin and de Tavernier (1998: 51-87). We have not been able to fully investigate how the operator market structure developed from 1998 to the present.

BT had entered the Swedish market very early. By 1995 it entered into an agreement with Telenor and Tele Denmark, and formed *TeleNordia*. TeleNordia acquired Algonet in 1996, and became the third largest Internet service provider. It also acquired a small callback operator, and the 4^{th} GSM-1800 license from Tele8, but did not act upon it. Another Nordic PTO, *Telecom Finland*, entered the market in 1995 by itself (after months of rumors of collaboration with other operators) as part of a European internationalization strategy. It entered with data services, gradually expanding the service range. Telecom Finland was then gradually privatized and renamed Sonera. When Sonera and Telia merged, Telia's activities in Finland and Sonera's in Sweden were acquired by Tele1 Europe, which thus became a major Nordic player.

WorldCom was one of the new entrants on the US market that rapidly rose into fame through a large number of mergers and acquisitions, the largest one being the acquisition of US long-distance carrier MCI for USD 30 billion, the resulting company posting sales of more than USD 30 billion in 1998. The primary strategy for entry to the Swedish market was to provide fiber-based solutions to businesses with a need for much bandwidth. Another international player that entered the Swedish market was Singapore Telecom, through the acquisition of the cable-TV operator Stjärn-TV.

Yet another category of operators, acting on arbitrage opportunities, was the callback operators. They used the fact that it sometimes was cheaper for a customer, who wanted to call from Country A to Country B, to instead call up country C (often the US), hang up, let someone in country C call up both A and B (hence callback), and connect the calls. Examples of such operators were Callback international, Unicall, Magnacom, Kallback, and GreenTel. For a few years there was a multitude of such operators, but they ceased to exist as price advantages disappeared.

A number of minor operators also entered the market in the mid-1990s. Tele8 entered the market for international business calls in Southern Sweden. It is most famous for having been awarded the fourth GSM-1800 license, not being able to finance the build-out, and eventually selling out to TeleNordia. Other examples were RSL, with a background in the cosmetics industry, entering the Swedish market through acquiring Cyberlink. Yet another one was Netsource which initially acted as a callback operator, then as telecom broker (i.e. it selects the cheapest alternative) for customers. Another telecom broker was NetNet (started by Jan Carlsson and Torsten Press). Netnet then spun off Glocalnet, an early pioneer in IP telephony (1998).

The early market for network capacity (1993-1997)

The market for network capacity (or leased lines) consists of (1) companies that own network infrastructure and sell capacity to operators (or to other organizations for private networks), and (2) companies that resell capacity. The former market was fragmented; Telia dominated, but became subject to competition primarily from Banverket, Svenska Kraftnät and Teracom.[273] Banverket had built up the largest fiber-optic network besides Telia, and had several of the other operators as customers. Svenska Kraftnät sold network capacity primarily to Tele2, while Teracom had a microwave link network. Further actors included other electricity companies, NSAB/Rymdbolaget, Stokab and municipalities. Also within this group, the players had differing objectives – many municipalities built networks for their own use or in order to attract companies to the area, but not always seeking profit.[274] The largest actor in this respect was Stokab in Stockholm. The market for network capacity of 1997 is shown in Table 4-5.

Table 4-5: **Companies which had and/or offered leased lines (1997).**

Company	*Infrastructure*	*Type of network capacity sold* *Dark fiber*	*Other*	*License*	*Turnover 1997 MSEK*
Telia	Yes	Yes	Yes	Yes	> 1,500
Banverket	Yes	No	Yes	Yes	105
Stokab	Yes	Yes	No	Yes	50
Svenska Kraftnät	Yes	Yes	No	No	30
Teracom	Yes	No	Yes	No	15
Rymdbolaget	Yes	Yes	Yes	No	15
Sydkraft	Yes	Yes - partly	Yes	No	< 10
Vattenfall	Yes	Yes	No	No	< 5
Municipalities (10)	Yes	Partly	Partly	No	< 15
Tele2	No	No	Yes	Yes	< 15
Sonera	No	No	Yes	Yes	< 10
WorldCom	No	No	Yes	Yes	< 5
GlobalOne	No	No	Yes	Yes	< 5
Telenordia	No	No	Yes	Yes	< 5

Source: Nordin and de Tavernier (1998:47) based on Stelacon (1997)

The market for leased lines sold from operators to operators mainly consisted of lines to be used as access lines, i.e. raw capacity used by operators with the intention to add value and in turn sell to end-customers. The market amounted to 350 MSEK in 1996, the prime supplier being Telia and the prime customers being Tele2 and TeleNordia.[275]

4.2.8.2 Internationalization of Swedish telecom operators

The Swedish operators' market has been characterized by both inward and outward internationalization. Most of the early new entrants were foreign operators, or involved major foreign ownership. For instance, Pacific Telesis (one of the RBOCs, later AirTouch) quite early took a majority ownership share in Nordic Tel (in addition to a large share held by Vodafone). Cable and Wireless took a 40% share in Tele2 quite early too. Table 4-6 summarizes some key data for selection of these investors.

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[273] Nordin and de Tavernier (1998:47)

[274] Nordin and de Tavernier (1998:47)

[275] Nordin and de Tavernier (1998:47)

Table 4-6: Summary of key data for a selection of new entrants (c. 1993)

Telco	*Year of entry*	*Major owners*	*Off-ices*	*Empl.*	*Turn-over*	*Nodes (Swe)*	*Tot inv. (mid-93 MUSD)*	*Entry strategy*	*Entry areas*
AT&T	1987	ATT (IOD)	1	30	n.a	1	n.a	Cooperation (leased-lines)	Int'l dataserv. calling cards
BT	1989	BT	2	40	75 (Nordic)	3	n.a	Cooperation (leased-lines)	Data services, Int'l telephony
Comvik	1981 (92)	Korsnäs (100%)	7	170	n.a	2	> 150	Investments in new network	mobile
MCI	1992	MCI	1	2	n.a	1	n.a	Cooperation (leased-lines)	Int'l telephony, data services
Nordic Tel	1991	Pacific Tel. (51%) Vodafone (19%)[276]	3	> 150	n.a	3	appr. 150	Investments in new network	mobile
Tele2	1986 (91)	Kinnevik (60%) C&W (40%)	3	130	n.a	6	appr. 70	Coop. (leased-lines), inv. in new network	Int'l data. int'l telephony
Trans-pac Sc.	1992	France Telecom (60%)	8	16	n.a	8	n.a	Acquisition	Data services

Source: Johansson and Granstrand (1994:223)

The Swedish operators also took advantage of the opportunities presented abroad through liberalization. Televerket started internationalizing quite early, but its strategy has been subjected to several changes and failures. In many respects, this has been an opportunity partly lost. Televerket was one of the most advanced operators worldwide, not least in mobile, which was the major internationalization vehicle at least in retrospect. It had the financial resources and operating competence to make a much more focused effort.

Televerket started internationalizing through its consultancy subsidiary Swedtel. It also had a long tradition of cooperation with the other Nordic telecom adminstrations (cf. NMT). Another major step was taken when Swedish Telecom International was established. Through this company Televerket started investing in cellular and other operators, with some focus on the Baltic region. However, it came to pursue another less profitable track with greater emphasis – Unisource. Unisource was established in 1991, as a joint venture with PTT Netherlands and the Swiss PTT (later including also Telefónica of Spain). It was one of several moves in line with the general logic in the telecom business of that time – on a global market in the end there would be room only for a few giant operators. The old PTTs started teaming up with each other, France Telecom with Deutsche Telecom, AT&T with major Asian carriers, BT with MCI etc. All of them were leaning towards NTT, which was not allowed to enter foreign markets at that time. However, Unisource (like most of these ventures) fell short of Telia's expectations, and the alliance was dismantled in 1998. Meanwhile much attention had been taken away from the lucrative mobile market. In fact Unisource and Telia acted as competitors from time to time.

Unisource also had the effect of breaking the Nordic collaboration; seemingly a mistake in retrospect since Telia tried to approach the other Nordic former PTOs in late 1999. By 1999 Telia had already signed an agreement on a merger with the Norwegian Telenor, but the agreement fell apart at the last minute over disputes concerning the division of power and

[276] Three other owners were Spectra-Physics, Volvo and Trelleborg who each had 10% in Nordic Tel Holding, which owns almost all shares in the operating company Nordic Tel (with the brand name Europolitan).

issues of national pride. After yet another momentum-losing failure, Telia announced a new strategy, under which it sought to extend its operations beyond the Baltic Sea region and to become a global operator. It acted with caution during the 3G licensing frenzy, but could make some cheap investments during the bust. Still, it had holdings in some 30 countries at the time of the announcement (2002) of a merger with the far more aggressive Finnish partner Sonera. Together the companies have a strong footprint in the Nordic countries, the Baltic region and former Soviet republics.

Although Tele2 was initially focusing on the Swedish market, the Kinnevik group as a whole had an international scope, in particular Millicom which focused on cellular licenses in small countries. It also held stakes in cellular and PCN operators in the UK, later divested. Millicom's strategy has not been very profitable over the years, though. In 1993 Kinnevik established Netcom System to support a strategy of Nordic expansion. In line with this, an early move was into Norway, through a major stake in the second GSM operator, Netcom GSM. In the mid-1990s Netcom also started fixed operations in Norway and Denmark. Then, in the late 1990s and early 2000s, Netcom expanded in the Baltic region, and in other parts of Europe. In 2001, Netcom activities changed their identity to Tele2, as did most of Kinnevik's telecom-related business, apart from Millicom. Tele2 invested selectively in 3G consortia. By then, the company had a strong European footprint. It has experienced strong growth in revenues and profits, primarily from the Swedish mobile telephone operations, but also in other markets.

4.2.8.3 Recent developments

In the late 1990s the access network was given increased attention, because of the legacy monopoly Telia enjoyed in the copper network subject to regulatory LLUB attempts (see above). In 2000, Telia started offering other telecom operators access to the copper network, through the "copper service" which involves access to the consumer's telephone jack at a cost of 1,500 kronor per year and customer, which was higher than a yearly subscription, and therefore very unattractive.[277]

Alternative networks were given increased attention. Apart from mobile, these were (1) cable TV, (2) fixed radio, (3) electric utility networks, and (4) optical fiber. This attention was partly a result of Telia's legacy dominance in the local loop, partly a result of the attention to and demand for "broadband" communications in the late 1990s. With more than two million households connected, many of them through telecom-related providers (Telia, Tele2, and UPC which acquired Stjärn-TV in 1999), the CATV was an obvious way to bypass Telia's local loop. Trials to provide telecom services over CATV were conducted for several years, but it was not until 1999 that true commercial broadband services were delivered over the CATV networks.[278]

Other broadband access forms have emerged since then. During 1998, much attention was paid to the use of the electricity supply network as an access network for telecommunications services.[279] However, the technology has taken longer than anticipated to develop, and is currently (late 2003) offered on a limited basis only. Fixed radio and satellite is also used only on a limited scale. Another access form emerging is Fibre LAN, since rapidly declining prices for optical fibers and increasing demand made some firms lean towards the possibility to offer optical fiber in the access network as well. ISDN is an access form in decline, while the major

[277] PTS (2000:63)

[278] PTS (2000:63)

[279] PTS (2000:63)

broadband growth area has been xDSL. See PTS (2003a:36-38) and Chapter 6 for further treatments.

4.2.8.4 Concluding observations from the operators' market

In spite of being one of the more advanced telecommunications markets in the world ten years ago, the operators' market in Sweden has grown rapidly in the last decade – it has more than doubled. It seems fair to conclude that revenue growth has been driven by both the introduction of competition and the introduction of new and improved services (i.e. innovations). Growth has occurred in all four major segments, although the mobile data growth has so far been comparatively low (in absolute terms) and fixed telephony has started to decline in recent years, presumably as a result of substitution (fixed to mobile) and price erosion. This trend is likely to continue. The big question is whether the increase in data communications (fixed and mobile) will compensate for the decline in voice.

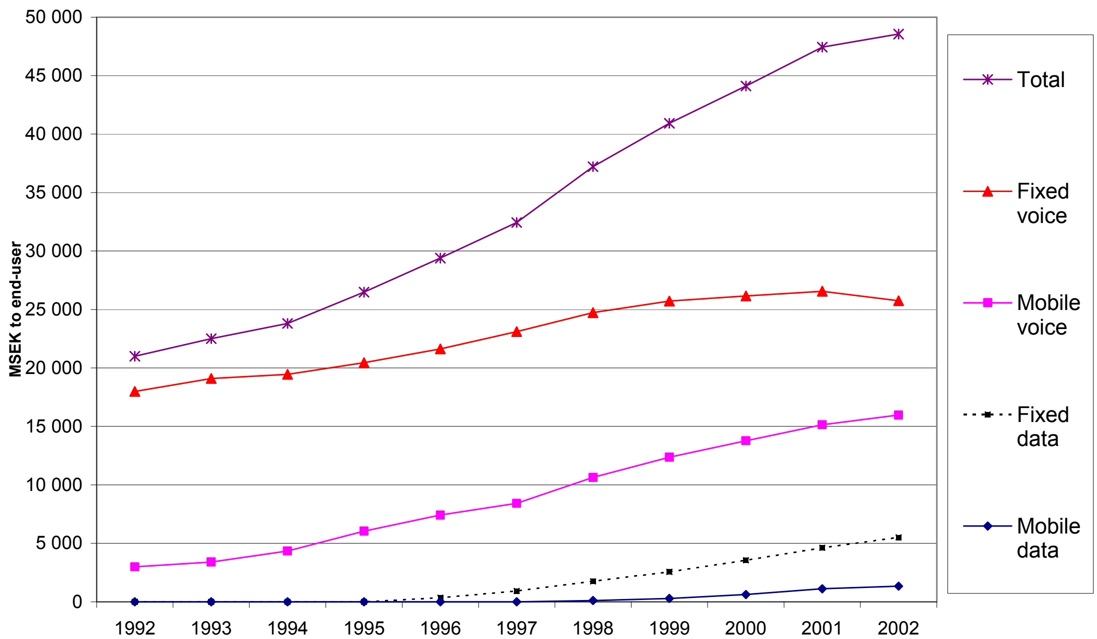

Figure 4-17 Revenue development for fixed & mobile voice and services

Source: PTS (2003a)

However, Figure 4-17 underestimates the impact of new services in several ways. First, as seen in Figure 4-18, it is obvious that revenues from both national and international voice are in decline, partly as a result of price reduction, partly as a result of Internet calls and calls to mobile networks. Further, Internet generates revenues in other parts of the value chain (content etc.). This will not be further elaborated upon here.

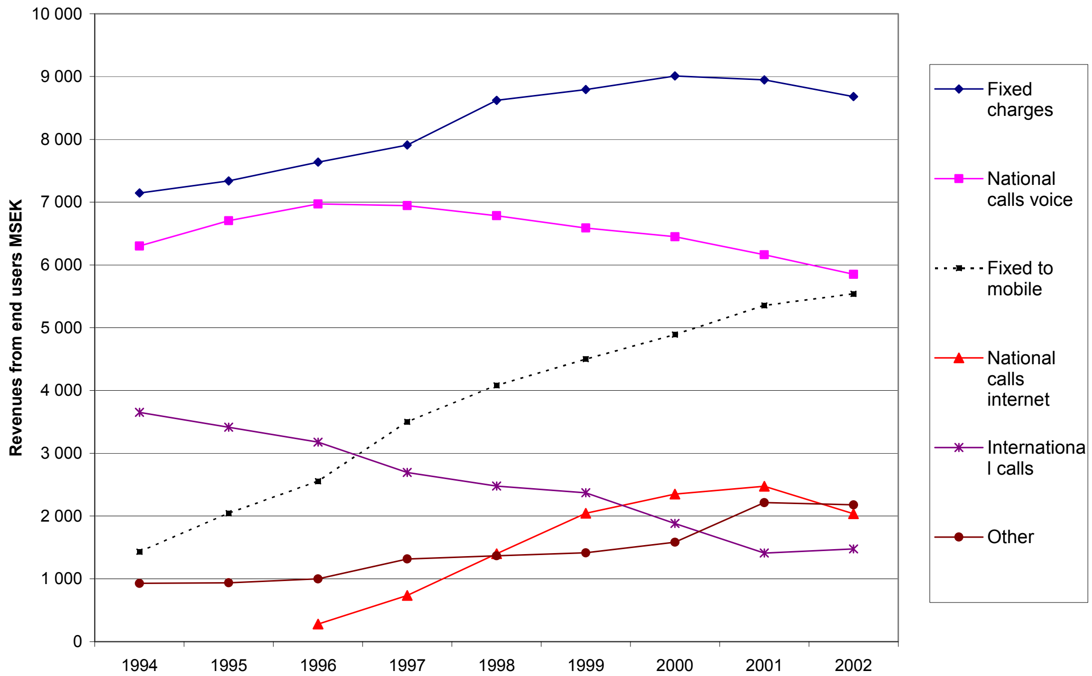

Figure 4-18 Traffic revenue development for fixed telephone services

Source: PTS (2003a)

By the end of 2002, there were 322 so-called undertakings registered with PTS, as having given notice or as license holders. This number increased the most in the late 1990s and 2000, to decline eventually. The number of undertakings with licenses was 19, some of which had licenses for several services.[280] For the two major markets, fixed telephony and mobile, Telia/TeliaSonera held a dominant position throughout the period, although the market shares have been declining (see Figure 4-19). As mentioned before, we have not been able to make a complete review of how the operators developed until the present.

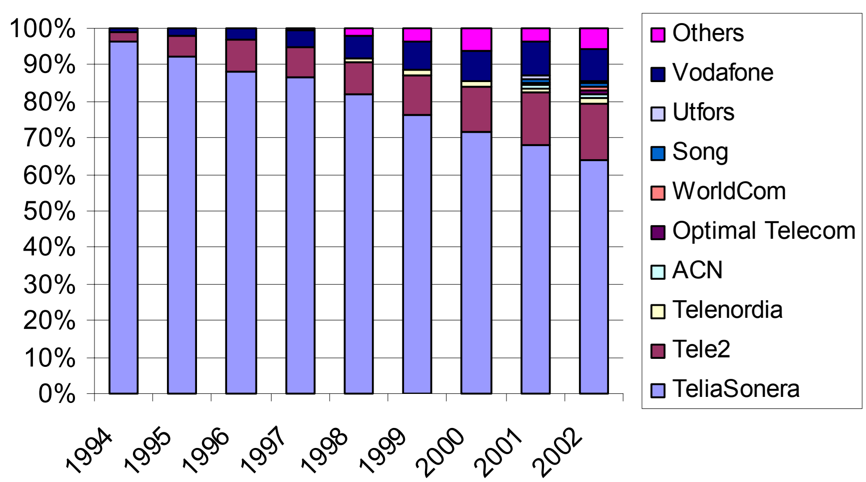

Figure 4-19 Market shares (turnover) for fixed telephony and mobile communications

Source: PTS (2003a)

[280] PTS (2003a:11)

The competitive situation differs substantially between different sectors. In the Internet sector (not elaborated on here) there is a multitude of players, and TeliaSonera's market share is below 50% (although higher for broadband). In fixed telephony, TeliaSonera's position is stronger (see Figure 4-20 and Figure 4-21).

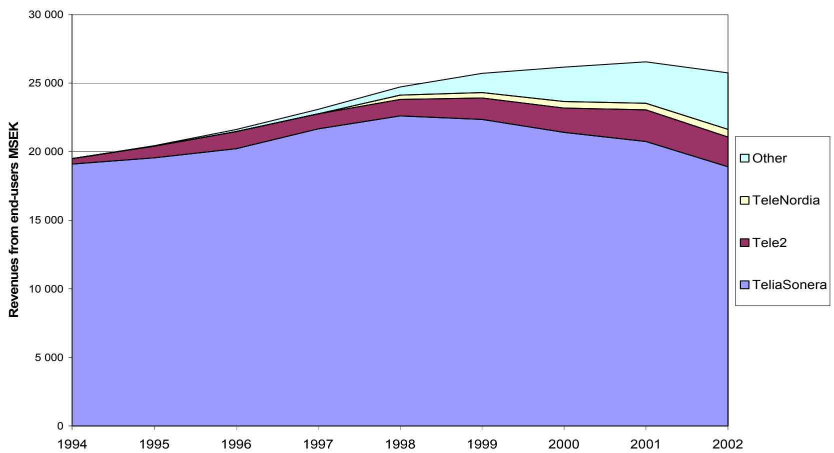

Figure 4-20 Revenues from fixed telephony (1994-2002)

Source: PTS (2003b)

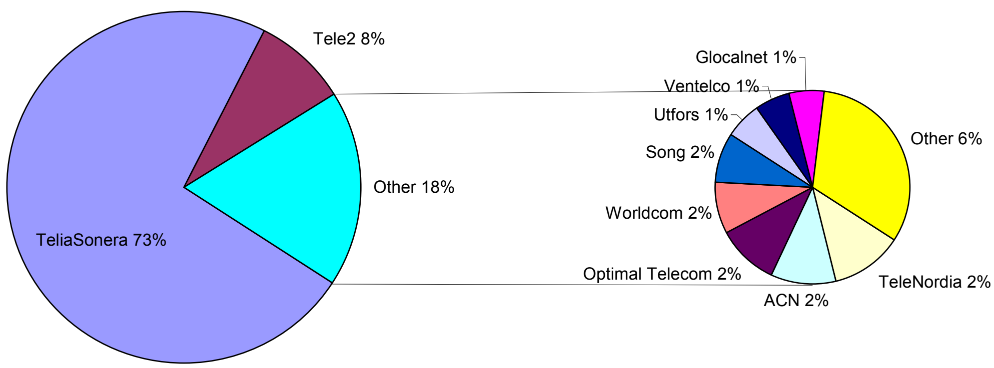

Figure 4-21 Fixed telephony market shares (2002)

Source: PTS (2003a)

In the mobile communications market TeliaSonera's share of revenues is 50% with Tele2 second (27%) and Vodafone third (21%), the remaining 2% split among service providers and the "3" company. The mobile telephony market is thus even more concentrated to the main three actors than fixed telephony (Figure 4-22). In the last few years a number of MVNO competitors have emerged, but so far their impact has been marginal. In late 2003 new actors ("3" in particular) initiated more intense price competition, but the full impact is yet to be seen.

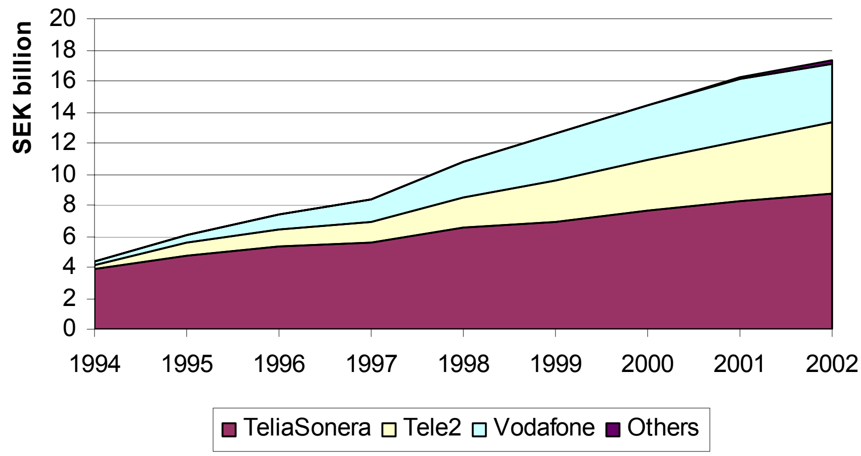

Figure 4-22: The Swedish mobile telephony market by actor, 1994-2002

Source: PTS (2003a)

4.2.9 Swedish operators' market in an international perspective

With the introduction of competition in the early 1990s, the fixed international telephony market was the first to be attacked. New entrants have gradually acquired market shares during the last decade, and in 2001 generated 57% of the international traffic minutes. In an international comparison this figure is high, indicating a well-functioning and competitive market.

Table 4-7: International market share of new entrants (% of international traffic minutes)

	1997	1998	1999	2000	2001
USA	54.6	56.9	61.8	67.5	-
Sweden	32	-	45	51	57
UK	51	51.6	54.6	47.5	53.1
Japan	40.6	-	-	47.2	-
Korea	32	32.9	38	43	51
Finland	41.4	45.3	48.5	49	50
Germany		30	40	56	50
Iceland		0	5	16	22

Source: OECD (2003:39)

In the national long-distance market, new entrants have thus far not been equally successful. In 2001, around 31% of the switched minutes were billed by new entrants, but the annual increases in market shares were strong (Table 4-8). This figure is far behind the countries which have come furthest in long-distance competition, the USA and Finland, but new entrants are rapidly gaining market share.

Table 4-8: National long-distance market share of new operators (% of switched minutes)

	1998	1999	2000	2001
USA	61.3	62.9	65.2	-
Finland	63	62	63	63
Japan	-	-	57.2	-
Germany	30	40	34	40
UK	30.7	33.4	33.5	35.6
Sweden	-	14	23	31
Korea	8.9	10	15.8	15.4
Iceland	0	4	5	8

Source: OECD (2003:38)

Although at a varying pace, competition has been introduced in most parts of the Swedish telephony market. The last strong outpost of the incumbent Telia has been the access line market, where a monopoly situation is still present in reality. In an international comparison, in particular the local loop is highly concentrated in Sweden. With only 0.1% of the access lines provided by new entrants, Sweden is well behind countries such as the USA and UK with figures in the range 10-20% (see Table 4-9). In 2003, Bredbandsbolaget has begun offering over its broadband network. In early 2004, Com Hem followed suit, indicating a potential start of competition also in this area.

Table 4-9: Access line market shares of new entrants (%), 1997-2001 (selection of countries)

	1997	1998	1999	2000	2001
USA	-	14.3	15.4	19.2	19.8
UK	1.06	3.05	4.3	7.7	10.2
Finland	0.38	0.46	5.5	4.6	4.9
Germany	-	0.5	1	1.7	3
Korea	-	0	0.3	1.52	1.5
Japan	-	-	1	1.3	-
France	-	0	0	0.5	0.5
Norway	-	0	0.4	0.14	0.28
Sweden	-	-	-	0.1	0.1
Iceland	0	0	0	0	0

Source: OECD (2003:36)

As shown above, the introduction of competition led to price pressure in the telephony market. In 1991, Swedish telecom revenues per capita in USD were second highest among the OECD countries (only Switzerland had higher). Since then, the revenue increases have been stronger in a number of other countries, with Sweden only slightly above OECD average in 2001. In fact, revenues per capita in dollar-terms have not grown during 1998-2001. These figures should be considered with caution, since the strong dollar in 2001 may have effects on e.g. the Swedish values. In terms of SEK, the Swedish figures have had a development similar to the US.

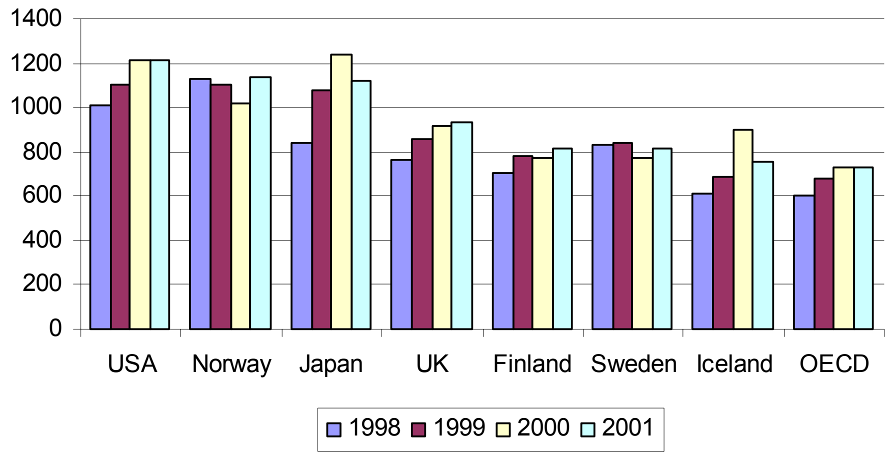

Figure 4-23: Public telecommunications revenue per capita (USD), 1998-2001

Source: OECD (2003a:75)

4.3 Ericsson and the supplier industry

Due to the extreme importance of Ericsson for the Swedish telecom sector, its evolution and status need to be investigated. The history of Ericsson has been well documented (see e.g. Attman et al. 1976, Attman and Olsson 1976, Meurling and Jeans 2000) and will therefore only briefly be summarized here[281], with some key events presented in Table 4-10 and Table 4-11.[282]

4.3.1 The early years (1876-1970)

Table 4-10: Selected key events in the early development of the Swedish supplier industry

Year/period	Event/activity
1876	Lars Magnus Ericsson and Carl Johan Andersson founded L.M. Ericsson & Co., as a telegraph repair shop. The telephone is patented but not in Sweden.
1878	Ericsson starts producing improved telephones.
1883	SAT is founded. Ericsson starts selling to and collaborating with SAT, e.g. a joint development of 'automatic' exchanges.
1888	Max Sieverts Tråd och Kabelfabrik established. SAT purchases Stockholm Bell.
1891	Televerket starts manufacturing of telephones and switchboards.
1896	Ericsson converts to a joint stock company. SAT sets up AB Telefonfabriken in competition with Ericsson.
1897	Ericsson establishes its first foreign manufacturing facility in Russia.
1918	SAT and Ericsson merge.
1921	Televerket standardizes on Ericsson's 500-point automatic switch system.
1926 (1935)	Televerket installs its first internally developed cross-bar switch (later to be produced by Ericsson).
1928	Ericsson acquires Sieverts Kabelverk.
1925-1931	Ivar Krueger takes voting control over Ericsson to eventually sell it to ITT.
1931 -	Banks take control of Ericsson.
1937	Ericsson starts manufacturing vacuum tubes.
1945-46	Ericsson starts developing cross-bar systems, delivers its first police radio and sets up Mätinstrument AB. Starts research on television.
1960	ITT sells its Ericsson shares to Swedish institutions.
1968	First SPC switch developed.
1970	Ellemtel established.

Source: Adapted from Meurling & Jeans (2000:449-455) and Åsgård & Ellgren (2000:31-185)

In 1876, Lars Magnus Ericsson started Ericsson with a partner, as a telegraph workshop. Through some reverse engineering and aided by the absence of Bell patent protection, Ericsson could soon diversify into manufacturing telephones. Quite soon, Ericsson established a close relationship with a demanding customer, SAT, formed in 1883 for the purpose of competing with the dominant Bell Company. In order to do so, SAT had to acquire equipment from some other supplier. It chose Ericsson and posed quite high demands on Ericsson's products; sometimes product development was conducted in close cooperation. Ericsson also followed SAT abroad when it established concessions, and therefore became a highly internationalized company early on.

Several other manufacturers were started in these early days. Ericsson started to outsource some component manufacturing quite early. Already in 1900 the company had 30 Swedish sub-suppliers. Eventually, SAT established its own manufacturing arm – AB Telefonfabriken – for internal supply, which led to a temporary chill in relations with Ericsson. It also meant

281 The account draws heavily on Åsgård and Ellgren (2000) and Meurling and Jeans (2000) unless stated otherwise.

282 It should be noted that only the first 100 years have been properly documented by historians. Note also that the company changed its name on several occasions. The company will be denoted Ericsson throughout this report.

that the Swedish market was more or less closed for Ericsson, which had to pursue an international expansion strategy instead. Another company, Sieverts Kabelfabrik, was established with the main business idea of supplying wires for telephone networks. In 1918 Ericsson merged with SAT, and took over manufacturing facilities. Later it acquired Sieverts as well. In the following years Ericsson both acquired and formed new firms for manufacturing telecom equipment in Sweden. Examples of acquired firms include Alpha, Svenska Elektromekaniska and Sieverts. Svenska Radio Aktiebolaget (SRA) was also established in this period, together with ASEA, AGA and Marconi.

Televerket established a manufacturing unit, the Industrial Division (ID), in 1891. This was primarily a response to the increased demand for telephone equipment, which Televerket previously had bought from Bell and Ericsson. However, the establishment of ID (later Teli) constituted a basis for Televerket to develop in-house R&D and manufacturing capabilities.[283] It grew to become a quite substantial business, since Televerket purchased about 50 per cent of the telecom equipment internally. By 1964 it had a total turnover of 146 MSEK, 3,200 employees and several factories. By then it expanded its manufacturing operations in the form of a company (Telefabrikation AB – TEFAB) in order stay more flexible for future expansion (and also to be able to keep qualified personnel). The new company commenced manufacturing in the late 1960s, but it grew slowly and remained small compared to Teli.[284]

Ericsson continued to grow and expand, apart from the crisis years of the early 1930s, when the company nearly went bankrupt as a result of the Krueger crash in 1931 (Ivar Krueger had secretly acquired the voting majority of Ericsson in the years before, and as a result ITT obtained a major share of Ericsson). Two Swedish banks (Enskilda, later SEB, and Handelsbanken) and later their related financial investment companies (Investor and Industrivärden), saved Ericsson, but it took some ten years to recover. Consequently (and also as a result of the preferential share system, where the voting difference is 1,000 between A- and B-shares) Ericsson has been completely controlled by these two interest groups. This control was further strengthened when ITT's share was acquired in 1960.

In the postwar period Ericsson strengthened its position. It had earlier established its own production of electric components, strengthened by the acquisition of Rifa in 1945. While it had been a slow mover in the shift to automatic exchanges, it regained a leading position with the introduction of crossbar technology, developed in cooperation with Televerket (both Televerket and Ericsson had developed cross-bar switches previously, but later coordinated their developments). As a result Ericsson could launch a very competitive product in the early 1950s and expand during the transition in the following two decades. Meanwhile the computer-controlled AKE switch had been developed and launched in 1968. During this time period, the Swedish production became decentralized to smaller manufacturing facilities throughout the country. R&D became internationalized to some degree, while production had been so for a long time.

4.3.2 Point of departure (1970)

Before exploring the Swedish telecom supplier industry in 1970-2003, a few observations from 1970/1971 are made here. An overview of the industry (including also some firms from related sectors, with part of their activity in telecoms, or simply firms which this study could not classify but which might have been involved in the sector) is provided in Table 4-11. The dominance of Ericsson (and Televerket, but not as a supplier) is striking already back then,

[283] Hauknes and Smith (2003:8-9) referring to Tahvanainen (1993) and Karlsson (1998)

[284] Karlsson (1998:82-86)

contributing some half of the revenues and employees. Ericsson had almost 67,000 employees in 1971 with around 23,000 of them in Sweden.[285] Ericsson's main product areas at this time were electromechanical crossbar switches and subscriber equipment. Ericsson was very dependent on foreign markets – its exports as a share of sales were 63%, and increasing. It was spending a quite large amount of its revenues on R&D (in the range of 7-8%) and was one of the largest R&D spenders in Sweden (sources differ). R&D was concentrated in Sweden and in projects concerning electronic switching. With the formation of Ellemtel, R&D was concentrated there, but some important R&D work was still at Ericsson in Sweden and in the American and Australian subsidiaries.[286]

Table 4-11 Some key data of the Swedish telecom supplier industry of 1970/1971

Firm	Revenues MSEK	Employees
Ericsson	1760	22800
Teli (Televerket total)	316 (3117)	3661 (42601)
Sieverts Kabelverk AB	206	1006
Standard Radio & Telefon AB	163	1660
LM Ericsson Telemateriel AB	157	1192
SRA	149	2025
AB Rifa	97	1446
Philips Teleindustri AB	88	684
Telub AB	54	642
Telefabrikation AB	22	476
Total value added (MSEK)[a)] – 1350, Total number Employees [a)] 33,561		
Other telecom-related firms		
IBM Svenska AB	740	3461
Svenska AB Philips	480	1430
Siemens AB	326	1460
AB Liljeholmens Kabelfabrik	238	1162
IKO Kabelfabrik AB	130	1162
Stansaab Elektronik	64	684
Luxor (?)		

Note: [a)] Teleproduktsindustri according to SOU (1972). Number of employees includes also employees outside Sweden (apart from the aggregate)

Source: SOU (1974:11), Veckans Affärer (1972) and Karlsson (1998:36)

It is also worth noting that Televerket was larger than the whole manufacturing industry taken together. Through its manufacturing arms (Teli and Telefabrikation AB) it was by far the second most important manufacturer. A few foreign firms which at least abroad had substantial telecom-related business were also established in Sweden (Siemens and Philips) as well as an ITT company (Standard Radio). Of these, Philips and Standard Radio had telecommunications-related manufacturing, geared towards the military. Siemens's activities are unclear to the authors of this report. Some cable firms are also included, although these may have predominantly supplied cables to the power supply sector. According to SOU (1974) the telecom sector was growing more rapidly than the Swedish manufacturing sector as a whole in the early 1970s.

[285] VA (1972), Sveriges 1000 största företag, Specialtidningsförlaget AB, Stockholm, 1972

[286] See e.g. Fridlund (1997:14-16)

4.3.3 Ericsson 1970-2003

In the following we will concentrate on the evolution of Ericsson, with some key events summarized in Table 4-12.

Table 4-12: Selected key events in the development of the Swedish supplier industry /Ericsson (1970-2003)

Year/period	Event/activity
1970	Ellemtel established
1970-1977	Major development period of AXE
1977	Ericsson receives major AXE contracts from e.g. Saudi Arabia
1980-1988	Ericsson acquires Datasaab, forms EIS, and divests it
1983	Ericsson launches the successful PBX MD 110
1981, 1984, 1985	First cutovers for Ericsson's NMT, AMPS and TACS cellular systems
1989, 1993	Ericsson forms JV with GE in mobile telephones, later acquiring GE's share and moving headquarters to Stockholm
1992	GSM launched
1992	EHPT joint venture set up
1994	Ericsson acquires the Teli group of companies from Telia
1995	Ericsson acquires the Telia part of Ellemtel
1995	AXE-N development discontinued
1998	ATM switch introduced
1997-2000	Ericsson acquires a range of datacom firms
2000	Ericsson shares price peaks
2001	Mobile phone business spun off to JV with Sony, SEM
2001-2003	Ericsson crisis, major cutbacks and finally return to profitability

Source: Adapted from Meurling & Jeans (2000:455-459) and Åsgård & Ellgren (2000:185-)

One key activity after 1970 was the development of the AXE – a fully digitized SPC switching system. Ericsson had some previous experience from digital switching and from SPC exchanges (e.g. AKE and ARE, which Ericsson sold as gap-fillers throughout the 1970s and beyond) and so had Televerket (the A210).[287] Adding to its telecom skills, Ericsson had built up some computing competence (in computer architecture, systems reliability, multi-processing and structured programming) internally in the 1960s. This competence build-up paved the way for the modularized, decentralized approach which later become so important. In fact, as argued by Granstrand and Sjölander (1990: 44-45), this approach may have been aided by the fact that Ericsson was not in the main line of computer development.[288]

Internally it was discussed whether Ericsson should pursue the track of AKE (which was centralized) or AXE. Development progressed in parallel, although AKE became more geared toward market adaptation. Meanwhile Ellemtel had been created (see below) as a joint venture development company (with Televerket). In 1972, a major decision was taken to pursue the development of AXE along the track of the modularized flexible concept. This would allow AXE to be implemented in different kinds of exchanges and at the same time allow for stepwise introduction of new technology, in particular digitalization of the switch (group switch and then subscriber switch set). Development was carried out in the X-division of Ellemtel, headed by Bengt-Gunnar Magnusson. Marketing efforts began already by 1974, while the first pilot exchanges went into trial in 1976. By that time some orders had been received, mainly for the analog version of AXE.[289] Total development costs have been estimated as BSEK 5-10.[290]

[287] Meurling & Jeans (2000:471-475)

[288] Granstrand and Sjölander (1990: 44-45)

[289] The history of AXE is well documented; see in particular Vedin (1992) and Meurling and Jeans (1985)

[290] Granstrand and Sjölander (1990:43)

After a breakthrough order in Saudi Arabia in 1977, AXE became a huge success. Ericsson could further increase its market shares. In fact the diffusion and substitution of AXE for older systems was much faster than anticipated by Ericsson. The technological choices made were the right ones, in particular the modularized structure, which allowed for sequential introduction of new modules and functionality. Only a few competitors had comparable products on the market (some of them failed completely), and Ericsson had an advantage in its international presence when the markets started opening up. By 1995 AXE had been installed in 110 countries serving more than 105 million lines, estimated by some to be more than 20 per cent of the installed lines of operators.[291] AXE development has continued until this writing.

Here it could be mentioned that productivity improvements in the industry were very rapid. Take the AXE as an example. When AXE was introduced it meant productivity improvements of 60% (in terms of working hours/capacity) compared to previous electro-mechanical technology. However, improvements of AXE technology went much further. In the 1990s alone, productivity improvements were in the range of 2000 percent. Quite naturally, such productivity improvement has led to a reduction in the need for manufacturing personnel.[292]

AXE also turned out to be an important asset (more or less unintended) in Ericsson's expansion into mobile communications, which will be treated further in Chapter 0. It must be briefly mentioned here as well, since Ericsson has rapidly undergone a transformation to being a mobile communications company. Figure 4-24 illustrates this transition, in which mobile communications went from less than 10% of revenues to more than 90% in 15 years. This transformation was for many years highly successful, but also made the company vulnerable.

Other and increasingly important developments at Ericsson during these years were the operations-, billing- and management-support systems, eventually (in 1992) conducted in cooperation with Hewlett Packard in a JV (EHPT). Ellemtel contributed the AZ data network and various generations of PBXs (AY), and in particular the launch of MD 110 in 1983.[293]

[291] See e.g. Meurling and Jeans (2000), Åsgård and Ellgren (2000) and Granstrand and Sjölander (1990)

[292] Figures are from Åsgård and Ellgren (2000:164-165)

[293] See e.g. Meurling and Jeans (2000)

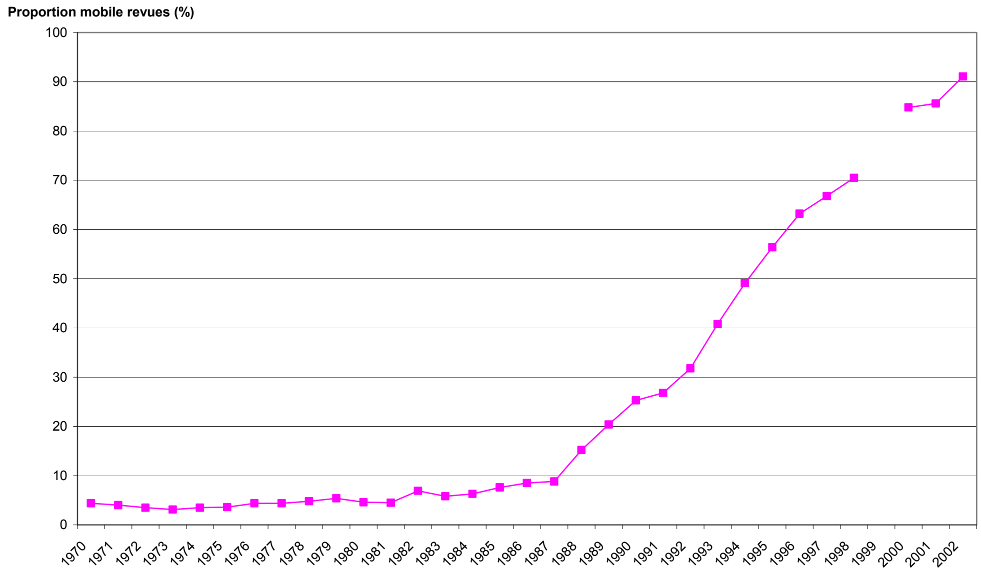

Figure 4-24 Proportion of Ericsson's revenues related to mobile communications

Note: The exact proportion is difficult to calculate. Mölleryd's method of calculation is not known: For 2000-2002, the proportion is simply calculated as "mobile systems sales"/"total systems sales", assuming that e.g. "other operations" and "inter segment sales" share the same proportions.

Source: Mölleryd (1999:147) and Ericsson Annual Report (2002:21)

Ericsson developed and produced many of the necessary components internally.[294] In the 1970s and 1980s, the development of key microelectronic circuits took place at Rifa in collaboration with AMD, for some time with contributions from the government-sponsored NMP program. In the late 1980s component supply was continued by Ericsson Components, then in cooperation with Intel. A number of key inventions were made related to power supply (the Power MOSFET, PKAs, and introducing microprocessing technology into power supply in 1985, integrated into the rest of telecom equipment in 1992).[295] According to Meurling and Jeans (2000:333) the microelectronics was transformed, from essentially a means for securing the availability of key components, into a key development activity since the design of systems at an ever-increasing rate takes place at that level, when the functionality of systems is defined in silicon.

Apart from traditional cellular mobile communications, a number of key radio-related developments emanated from Ericsson's involvement with the military and space sectors, mainly taking place within the MI division, later Ericsson Radar Electronics and eventually Ericsson Microwave. Several types of advanced radar equipment were developed for e.g. Viggen and JAS. These developments spilled over to civilian use, via advanced competence build-up in e.g. DSP and antenna technology. MI also developed advanced optical and infrared technology, later divested to SAAB Dynamics. Various components were also supplied to satellite systems, from 1992 within the frame of Saab Ericsson Space. [296]

[294] Developments related to optical communications will be treated in Chapter 5.

[295] Meurling and Jeans (2000:329-333)

[296] Meurling and Jeans (2000:251-265)

The commercially most significant products, however, were the radio links. Initially (1970s) these were not primarily used for telecoms, not even the digital MiniLink. Through a large order from the US military, Ericsson could refine production technology and quality, and the product instead became a key component in cellular systems, almost by accident turning Ericsson into the leading Radiolink supplier and radio links into a core product area for Ericsson, later also including a point-to-multipoint option for so-called LMDS access services.[297]

In the early 1980s Ericsson (like so many other companies) tried to enter also into computing. It acquired Datasaab and formed Ericsson Information Systems (EIS), acting upon a vision of convergence and the paperless office. However, the company had neither the organizational nor technological resources to be able to compete effectively, and was divested (to Nokia) in 1988. This adventure and its consequences will be further elaborated in Chapter 6.

Another major failure was the AXE-N development project. It was conducted during 1987-1995 within Ellemtel, where some BSEK 10 were spent without being able to launch a product. To the knowledge of the authors, this development failure has been poorly documented. It seems to have been some kind of ATM-based switching system/network that would be able to handle all kinds of traffic. Some of the development may have come into use later in the ATM and Engine products, but it has been difficult to assess to what extent. The ATM switch is labeled AXD 301 and can be installed on top of AXE. ENGINE is a platform for accommodating both circuit- and packet-switched and ATM-based services, or rather for handling a migration from circuit-switched to packet-switched.

In spite of the EIS and AXE-N failures, the importance of Internet became clear to everyone by the mid-1990s. With a new CEO (S.-C. Nilsson having a data background) Ericsson pursued a strategy to develop communications competence through acquisitions (see further Chapter 6). Among the products that emerged from this acquisition frenzy were a number of backbone and access routers as well as expertise in IPv6.[298] Another aspect of this strategy was to develop and manufacture products and solutions for broadband access (ADSL, LMDS and CATV solution). The efforts in these areas were emphasized in strategic decisions taken in late 1999.[299]

Among important acquisitions and collaborations, the following could be mentioned:[300]

- The collaborations with H-P, Intel and GE.
- In 1993 it acquired TELI and in 1995 Telia's shares in Ellemtel.
- It acquired the outstanding 50% in two JVs in France (with SAT and Matra).
- The JV with Microsoft to develop mobile e-mail and other mobile Internet solutions.
- The acquisition of Qualcomm's infrastructure division.
- The involvement in Symbian (with Motorola, Psion, Nokia and later Matsushita) developing OS for mobile terminals.
- Various acquisitions and Joint Ventures into Internet/Datacom-related companies (e.g. US-based Juniper, Torrent, TouchWave and Telebit in Denmark) in the areas of routing, IPv6 and voice over IP. See further Chapter 6.
- Cooperation with Symbol in the WLAN area.
- The WAP and Bluetooth initiatives.
- Initiatives to stimulate demand in m-commerce, mobile games and MMS.

[297] Meurling and Jeans (2000:251-265)

[298] See e.g. Meurling and Jeans (2000:295-396) and Ericsson's Annual Reports (1999-2002)

[299] Ericsson Annual Report (1999)

[300] Based on Meurling and Jeans (2000)

- The establishment of Ericsson Mobility World in 2001 for support of and cooperation with third-party developers.
- A JV with Electrolux to develop residential Internet products.
- The divestment of PMR activities in 1999.
- The Sony Ericsson Mobile phones joint venture, starting in 2001.

On the component side a number of important developments also took place in the 1990s. Ericsson Microelectronics (the former Ericsson Components) sold components also to other telecom suppliers. Its development is conducted in collaboration with Texas Instruments, while manufacturing is outsourced, mostly to the Far East. Among important chip developments were: SLIC (Subscriber Line Interface Circuits, where Ericsson became the leading supplier), ATM/ADSL chips, WDM chips for optical cables, various RF circuits for mobile communications and Bluetooth chips. The power supply systems were eventually divested.[301]

Outsourcing has been another important trend. To exemplify, in the late 1990s Ericsson sold its plastics factory to Nolato (in 1997), a circuit board assembly plant to Flextronics, printing circuit boards manufacturing to SCI systems and Solectron. Logistics was outsourced, as was IT support in the Nordic countries. Software development was sold to AU-system, and more manufacturing operations inside and outside Sweden were outsourced to Solectron and Flextronics, and real estate to Skanska.[302]

As opposed to outsourcing, or rather as part of a trend of moving downstream in the value chain, Ericsson has increased its involvement in customer operations. In 1999, as part of a strategy to strengthen its offering in this activity, Ericsson brought together its services and business-consulting offerings, in order to be able to offer a wide range of services to operators and business customers,[303] into the business unit now called Ericsson Global Services. This has turned out to be a substantial and growing business, with 20,000 employees in 2001, and partly growing revenues through the crisis.

On the market side, the Chinese developments are particularly relevant. Ericsson had a long presence in China. By 2000, China outgrew the US as Ericsson's largest market. Initially, the growth was fuelled by AXE and MD110, in recent years driven by a booming cellular market. Ericsson operates primarily on a joint venture basis in China.[304]

In the late 1990s and the very early 2000s, Ericsson acted on the supposedly booming mobile Internet market by extending its reach. Realizing that much of the innovative activities in Mobile Internet would be conducted by entrepreneurial start-ups, Ericsson formed Ericsson Business Innovation for developing entrepreneurial projects. Together with its controlling owners and Merrill Lynch it created the USD 300 million Ericsson Venture Partners focusing on North America and Europe. Another venture capital operation was started to focus on mobile Internet in Asia.[305]

Ericsson's focus on mobile Internet was manifested in other ways as well. The lion's share of R&D activities was geared towards mobile Internet and 3G. The future of Mobile Internet looked bright in 2000; Ericsson forecasted that by 2003 mobile Internet would overtake fixed

[301] Meurling and Jeans (2000:429-431)
[302] Meurling and Jeans (2000:397)
[303] Ericsson Annual Report (1999)
[304] See e.g. Meurling and Jeans (2000:399)
[305] Ericsson Annual Report, "Understanding our business" (2000:31)

Internet (presumably in terms of number of subscribers). Ericsson did win a large share of 3G contracts; it was involved in 22 of 33 announced contracts by year end 2000, and could on good grounds expect to take a share of more than 30% of the 3G market (in addition to the more than 50 percent market share on GPRS that Ericsson held by that time). Ericsson projected an increase in sales by 15-20% for 2001 and at least 20% for the coming five years (see Figure 4-25). In order to meet the coming demand, new production facilities were opened up.[306] Obviously, Ericsson was sizing up for continued rapid expansion.

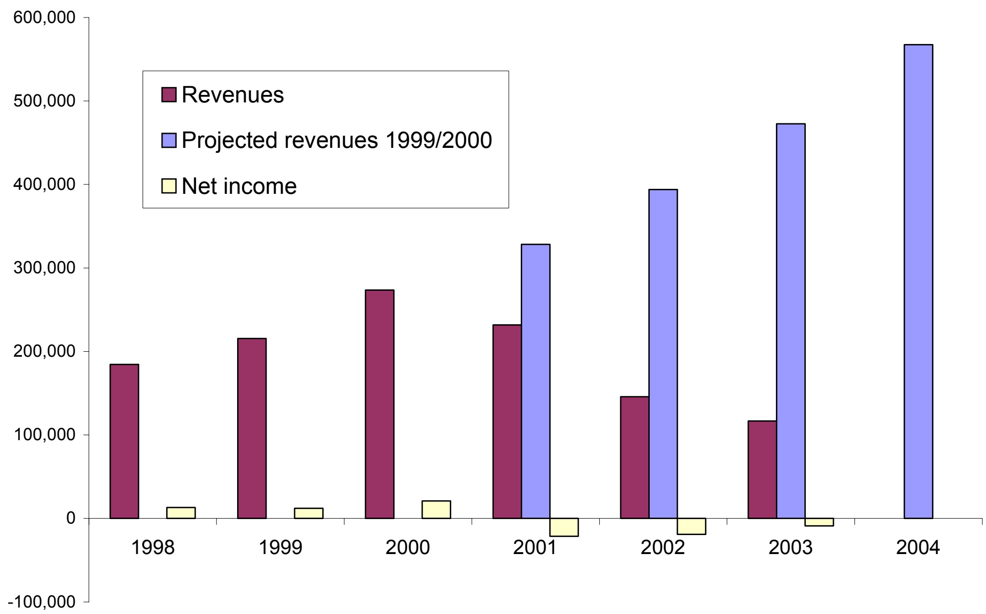

Figure 4-25 Ericsson's annual revenues (actual and projected in 2000) and net income (1998-2004)

Note: MSEK. Revenue and net income for 2003 are extrapolated from quarterly data in 2002 and 2003.

Source: Ericsson annual reports

The crisis first hit Ericsson in the mobile phone business. When it failed in the mobile phone market, this was presumably due to platform development problems, quality problems and lack of design skills. In 1997-98, Ericsson had large problems with a new platform, arriving one year later than expected, with the result that the company could not sell at the prices intended, and in addition lost market shares and suffered losses (in the range of BSEK 15 in 2000-2001). In 2000, these losses could still be covered by the highly successful systems business (net income before tax of BSEK 32.6).

When the inflated systems market collapsed in early 2001, Ericsson was (seemingly) caught by surprise. Ericsson had an organization adapted to continued rapid growth, and consequently suffered record losses. The company started restructuring in order to adapt to the new situation. A massive efficiency program was launched later in 2001, and a joint venture was formed with Sony to save the mobile phone business – Sony Ericsson Mobile (SEM). SEM also continued the process of massive cost reductions, reducing the losses to BSEK 1.3 in 2002. However, the downturn in systems continued and losses in other operations increased instead. The total losses were therefore still in the range of BSEK 20. Ericsson had to intensify the efficiency program, cut back personnel including R&D, and turn to the equity market for funding. In the summer of 2002, in a stock issue the company brought

[306] Ericsson Annual Report, "Understanding our business" (2000:31)

in almost BSEK 30 which saved it from bankruptcy.[307] At this writing, Ericsson has just turned to black figures again.

Statistics on Ericsson employees reveal some interesting facts about the development of Ericsson during the period. As seen in Figure 4-26 Ericsson has a smaller total number of employees in 2003 than in 1971, and about the same number of employees in Sweden. Just as in the early 2000s, Ericsson had to downsize during the economic downturn in the early 1990s. The following eight years show a remarkable growth, however, with the company size expanding by almost 60% before contracting in 2001. Interestingly, for Sweden the contraction started already in 1997/1998. Through outsourcing Ericsson did away with numerous production employees, making its importance as an employer in Sweden ever smaller.

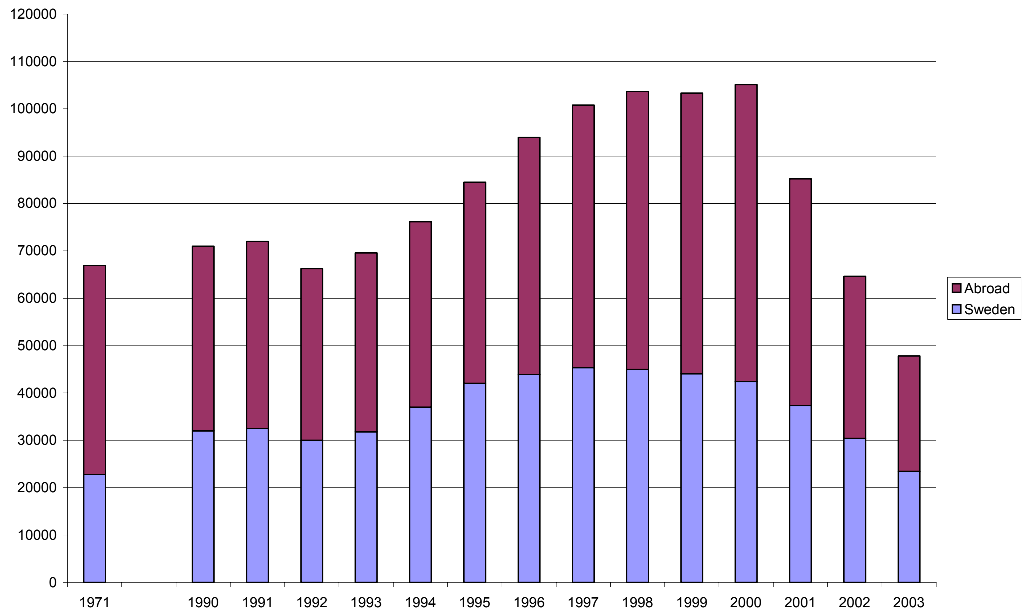

Figure 4-26 Ericsson employees inside and outside Sweden (1971 & 1990-2003)

Note: a) 2003 figures are projected on basis of 2003 Q3 Quarterly Report. b) 1990-1991 figures estimated from figure in Åsgård & Ellgren (2000:163)

Source: Ericsson Annual Reports (yrs 1992-2003), Åsgård & Ellgren 2000 (yrs 1990-1991) and VA 1972 (yr 1971)

[307] Ericsson Annual Reports and Business review (2002, 2003)

4.4 The Swedish telecom sector in the early 2000s

Due to lack of a comprehensive compilation of actors in the Swedish telecom innovation system, we have turned to the annual ranking of IT companies provided by the weekly business magazine Veckans Affärer. Based on their 2002 rankings, we have made a crude selection of companies with large parts of their turnover generated from telecom-related activities. As presented below, these are divided by actor category. For each actor category a turnover figure for 2002, taken from the VA statistics, is presented. Although by no means an exact measure, it provides an indication of the relative size of the industry segment.[308] All smaller firms are thus neglected in this chapter due to resource constraints. We simply conclude that there are a vast number of small firms active in the telecom sector, many working with mobile data solutions. Perhaps needless to say, although of minor economic importance today, some of these may become very important in the future.

Infrastructure Providers – SEK 167.8 billion in 2002

The infrastructure providers are the most important actors in the Swedish telecom innovation system in economic terms, constituting 55% of the top 500 IT companies' revenues in 2002. Within this group, Ericsson of course stands out as the dominant player, alone generating 87% of the revenues among the group of infrastructure providers. This means that Ericsson generated 28% of the IT-related revenues in the top 500 IT companies in Sweden in 2002.[309] Other important IS providers with development and manufacturing capabilities in Sweden are LGP/Allgon, Doro and Ascom Tateco.

Terminal manufacturers – SEK 43 billion in 2003[310]

As late as 1998, Ericsson was still the third largest terminal supplier, with almost 15% of the world market. For various reasons discussed above, the company lost much of its position in the following years. The terminal business was subsequently merged with Sony's terminal company, and the new company – Sony Ericsson – had a market share around 5% in 2003. In 2004, two of the remaining product development centers are located in Sweden – Kista and Lund – but the headquarters are placed in London. In 2003, Sony Ericsson sold 27.2 million terminals. Although the company was profitable in H2 2003, the annual result was a loss of SEK 1.2 billion.[311] Sony Ericsson generated a total turnover of SEK 42.3 billion in 2003.

Two other mobile terminal manufacturers have specialized on niche terminals. Sectra, based in Linköping, develops secure cellular phones for e.g. military applications. Helsingborg-based Spectronic markets a multimedia terminal for advanced users. Sectra had a total turnover of SEK 503 million in 2002/03, of which around 20% were secure communications. Doro (included in the infrastructure provider category), based in Lund, provides terminals (including cordless) for fixed telephony.

Operators – SEK 129.6 billion in 2002

Since the deregulation of the telecom service market a number of operators have established a foothold on the Swedish market. The business magazine Veckans Affärer identified 27 operators – with a total turnover of SEK 129.6 billion – among the 500 largest IT companies in Sweden in 2002 (some of these should, however, be classified as ISPs). The most important

[308] The figures for the terminal manufacturers include total Sony Ericsson figures, although the company is London-based and only partly Swedish-owned. These figures are thus partly counted twice, as they are included in the total Ericsson figures.

[309] Veckans Affärer, Sveriges 500 Största IT-företag

[310] Figures for Sony Ericsson 2003 and Sectra 2002/2003

[311] "Bättre än väntat av Sony Ericsson", DI 04-01-19 (Carl Thulin)

operators were TeliaSonera, Tele2 and Vodafone, between them generating 92% of total revenues.[312] The value of the fixed telephony market reached SEK 25.8 billion in 2002, 0.8 billion less than the year before. Mobile telephony generated revenues of SEK 17.3 billion in Sweden in 2002, up from 16.2 billion in 2001.[313]

In addition to the telecom operators, there are a number of actors providing backbone networks, selling black fiber. These include the state-owned electrical grid company Svenska Kraftnät and the rail company Banverket. E.g. Tele2 is a large customer of both Banverket and Svenska Kraftnät.

Software companies – SEK 2.1 billion in 2002
With the increasingly complex and software-dependent telecom equipment solutions, third-party software developers have become important actors. A number of software companies specializing in telecommunications are active on the Swedish market. Companies such as Telelogic, Teligent, Trio and Teleopti provide software used by telecom operators and equipment manufacturers. Consulting companies such as Teleca are also important software providers for the telecom industry. It should also be mentioned that consulting companies are moving into software "products". The Ronneby-based software company UIQ – a subsidiary of the British company Symbian – is an important developer of user-interface software for mobile terminals.

Distributors and retailers – SEK 3.7 billion in 2002
The growth of mobile telecommunications in the 1980s and 1990s caused several firms to start retail operations. GEAB (later acquired by The Phone House) and STC are prime examples. With the commoditization of mobile terminals, larger parts of terminal sales have been taken over by the traditional electronics retailers, e.g. SIBA and OnOff, which makes the total turnover figures for this industry segment underestimated.

Several distributors and retailers of telecom equipment have also emerged. The largest in 2002 was AxCom, with a total turnover of SEK 1.1 billion. Other important actors include Tele Jack and Topcom.

Contract Manufacturers – SEK 6.5 billion in 2002
Following the downturn in the sector, telecom equipment companies were forced to outsource much of their manufacturing in order to strengthen their balance sheets. For instance, Ericsson sold much of the manufacturing capabilities to the US firm Flextronics, TeliaSonera has sold parts of its service organization to the same company, and Sanmina acquired the sub-supplier Segerström och Svensson. Flextronics, Sanmina and Partnertech had a combined turnover of SEK 11.4 billion in Sweden in 2002, 6.5 billion of which were generated in the IT industry (including telecom).[314] Other, smaller contract manufacturers include Norrtälje-based Note, with 15% of sales (or SEK 1 billion) in 2003 to the telecom industry.[315]

Consultants – SEK 21.6 billion in 2002
An extensive consulting industry has formed around the telecom companies in Sweden. Most can be classified as suppliers to the large telecom companies, assisting in e.g. product development. To this category belong companies such as TietoEnator, Teleca and WM-data.

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[312] Veckans Affärer, Sveriges 500 Största IT-företag

[313] PTS (2003) Svensk Telemarknad 2002

[314] Veckans Affärer, Sveriges 500 Största IT-företag

[315] DI (2004-01-24), "Ericsson ökar sin efterfrågan"

Another kind of consultants are the professional-services firms specializing in telecommunications. Examples are Netcom Consultants and Northstream, specializing in technology and business strategies. This category contributes only around SEK 120 million of the total figures.

Component Manufacturers

The Swedish telecom innovation system also comprises a number of sub-suppliers to the telecom industry, whose products are not directly telecom-related. This group includes companies such as SAPA, making cooling elements for base stations, and Nolato, producing plastic coatings for mobile terminals. The size of this actor group is difficult to estimate, but probably of substantial importance for the Swedish economy as a whole.

4.5 Collaboration Ericsson-Televerket and the role of public procurement

Recently, attention has been paid to the role of public procurement for innovation. The importance of an advanced domestic demand (Porter 1990) and lead users (whose needs later become commonplace: von Hippel 1988) is by now well known. So is the role of public procurement, and its effects on long-term technological investments and innovation, when private industry otherwise would under-invest. However, there can be negative effects as well; e.g. stable procurement relations may also bring about inefficiencies because of a lack of competition.[316]

Recently, worries have been raised regarding the risk that something vital in innovation systems has been lost in sectors previously characterized by co-developing supplier-advanced public procurer relations, when these sectors have been deregulated.[317] Given the success of Ericsson, the relationship between Ericsson and Televerket has been put in focus by several researchers (Granstrand and Sigurdson 1985, Fridlund 1987, Berggren and Laestadius 2003; see also Edquist 2003). This relationship is also particularly relevant to this project. We will therefore briefly investigate the relationship and summarize the main findings of others in this section.

First, it should be mentioned that Ericsson's early development into a competitive international supplier was a result of the competitive situation in Sweden, and not a result of any relation with Televerket. Instead it was SAT (see above) that needed a supplier, and its role as a demanding customer and co-developer drove Ericsson forward and abroad. Then, SAT's and Televerket's establishment of their own manufacturing facilities pushed Ericsson to further internationalize. Thus it is in a highly competitive, while simultaneously collaborative, context that Ericsson established itself as a major telecom manufacturer. One may speculate, in line with Thorngren (IVA 2003), whether this regime is closer to the one of today than any other historical regime in telecoms. This situation changed, of course, when Ericsson merged with SAT and Televerket established its monopoly.

An early form of cooperation between Televerket and Ericsson was established in the early 1950s when the electronics council was formed. Ericsson and Televerket had separately started exploring the possibilities that opened up as a result of electronic technology. It was difficult to recruit engineers, however, and the electronics counsel was set up to coordinate

[316] Berggren and Laestadius (2003). See also Granstrand (1984a) and Granstrand and Sigurdson (1985) for pioneering studies of public procurement in Sweden.

[317] See e.g. IVA (2003)

the two parties' development work primarily in order to avoid duplication of development work and the misuse of scarce resources. In spite of this coordination, the two parties developed two separate SPC switches (A210 and AKE 12).[318] Obviously the coordination did not work properly.

In 1970 Ericsson and Televerket instead formed a joint R&D company – ELLEMTEL. The company had as its task to develop and construct equipment for (1) electronic switches, (2) computer networks, (3) digital transmission systems, and (4) advanced telephones. Manufacturing was to be performed by either Ericsson or Televerket. The major task was to develop the computerized electronic switching system (AX, later AXE). Until 1980, AXE development cost amounted to around 500 MSEK of which Ericsson contributed around 75%. Other projects started were the development of an office exchange, a data network and a new electronic telephone. Since Televerket had discontinued its electronic switching project, most of ELLEMTEL's initial 69 employees were recruited from there. ELLEMTEL then grew steadily, to 600 employees in 1979. During the 1980s, as Ericsson took over the further construction of products developed by ELLEMTEL, many engineers left ELLEMTEL for Ericsson.[319]

The commercialization of AXE was investigated in the previous section. Clearly, this commercialization became of tremendous importance, not only to Ericsson but also to Televerket and the Swedish users. The benefits compared to having procured a foreign system, or a system developed internally or by Ericsson in isolation, are difficult to assess. However, Televerket did, based on AXE, build one of the world's most modern telecom networks, essentially ahead of its initial plans. The other alternatives would probably have led to a later introduction. If Televerket had not chosen a Swedish system it would probably not have been able to manufacture by itself. It would also have been more difficult to have one single system. AXE also allowed Televerket to gradually introduce new and more advanced services.[320]

For Ericsson, the development of AXE meant that the company successfully managed the transition to a new technology in its main product segment, and strengthened its competitive position. The development cooperation with Televerket contributed to this. In what sense? First, Televerket contributed resources (capital and know-how). Second, Televerket provided guidance at some points in time when Ericsson hesitated. This held also for other projects such as the earlier cross-bar switch, and for electronic office exchanges. On other occasions it was Ericsson's international presence that provided influences.

Thorngren (IVA 2003) also emphasizes the particularities of the Swedish situation, i.e. Televerket's own manufacturing and R&D resources (introducing a competitive element into the relationship with Ericsson) while at the same time being distinctly separated entities (as opposed to e.g. the US and Canadian counterparts). Televerket's relative independence has also been important.

In the case of mobile telephony the role of "public" procurement by Televerket was more clear-cut. It is unlikely that Ericsson would have entered into cellular mobile telephony had it not been for Televerket's leading role. Televerket had built up a position as a competent developer, operator, standardizer and procurer of mobile telephony equipment. It increased the attention and resources spent on mobile telephony at Ericsson and in particular SRA,

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318 Fridlund (1997:16-17)

319 Fridlund (1997:17-18)

320 Fridlund (1997:47-49)

while at the same time influencing critical technological choices, in particular adapting the AXE switch for mobile use. In fact, and this is often forgotten, it may have been too competent a user, since it performed the systems planning and integration. Most other PTOs lacked these skills. When Ericsson approached those in the early 1980s, the company lacked these skills themselves, and had to source them from elsewhere.

Since then, that role has gradually declined, following the deregulation and introduction of competition. Televerket scaled down its own R&D and lost its incentives to continue financing the collaborative R&D, as the development would also benefit its competitors.[321]

Military procurements have also played an important role for the Swedish telecom manufacturing industry, in particular for radio communications (See further Eliasson 1995). This role too has declined, as a result of decreasing military expenditures and of the civilian telecommunication sector becoming more advanced than the military, at least in Sweden.

This does not mean that public procurement could not continue to be an effective policy tool in the 2000s. In mobile data communications, early public initiatives proved important for developing the Mobitex innovation system, although the commercial effects were rather insignificant. Could there be room for such efforts now? Such questions will be further treated in Chapter 9.

4.6 Education – some observations

This report does not thoroughly investigate the supply of competence through the educational system in Sweden, or its effect on the telecommunications innovation system. A few observations are provided here anyway.

There is widespread consensus that Sweden was behind the leading countries (notably USA) in the electronics and computer fields during the 1970s. Although a crude measure[322], the ratio of awarded degrees in relevant fields set in relation to the population provides an indication of the national strength in the area. As seen in Figure 4-27, the US has awarded a proportionately much higher number of degrees in electronics engineering and computer sciences until the mid-1990s than Sweden has. Until the mid-1980s, the number was even three times higher. In the 1990s the figure decreased rapidly, to be on par in 1995. The ratio decrease is due to both an increase in Swedish education and a decrease in the US ditto since the mid-1980s.

[321] IVA (2003:12)

[322] Jacobsson et al. (1999) point out that this may be an unfair comparison, given the importance of the US military in the development of US knowledge in computer science

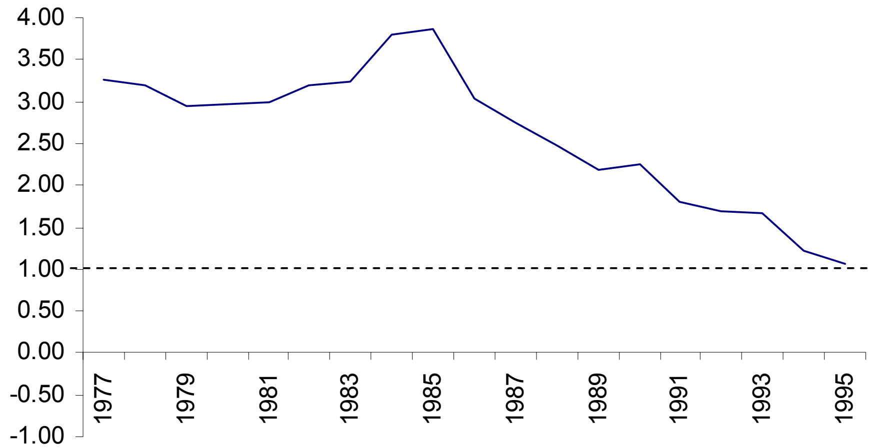

Figure 4-27: Ratio of B.Sc. and M.Sc. degrees in electrical/electronic engineering and computer science in the USA and Sweden set in relation to the total population between 15 and 64 years, 1977-1995

Source: Jacobsson *et al.* (1999:12)

During the strong market for telecommunications equipment in the late 1990s, the virtually endless demand for computer and electronics engineers outstripped the supply. Following the downturn in the early 2000s, the opposite situation has arisen.

It should also be mentioned that at least until the 1970s, the major source of telecommunications appears to have been Televerket. Throughout its history, Televerket has been important as a provider of skilled telecom personnel. Televerket was for a long period dominated by civil servants and engineers, generating a genuine engineering culture with a strong technological focus. A factor contributing to this technologically oriented organization culture was the tradition of educating own staff through the "school of telecom" (Teleskolan). Educational facilities included general introductory courses for non-skilled workers as well as higher-degree engineering studies. Consequently, not very many university graduates were employed in Televerket in the period in question, a situation that did not change until the 1980s and 90s. In this respect it is worth noting that Televerket's solution was similar to that of large Japanese corporations. In Televerket, this practice was maintained for many years and had a great impact on the character of the organization.[323]

[323] Hauknes and Smith (2003:10)

4.7 Telecom-related research and development

The telecom industry is knowledge-intensive with complex systemic products. The nature of the products calls for large R&D investments in order to stay at the frontiers of technological developments. Throughout the period large investments have been made in the field, both with public funds and with corporate R&D investments. Since the shift from electro-mechanics to electronics in the 1970s the industry has slowly but surely converged with the computing industry, often using the same basic technologies and components. Thus, it is difficult to identify public research projects purely dedicated to telecom research. Due to the importance of the telecom industry in Sweden, we make the assumption that a large share of electronics R&D has been invested in areas important for the industry.

This section compiles some of the most important national R&D initiatives in the electronics and communications fields, although no claims of a complete compilation are made.

4.7.1 Public R&D

Many of the developments in the communications industries in recent decades have been based on advances in microelectronics. In spite of signs of Swedish industry and research being behind in the rapid development in the microelectronics field during the 1970s, there were relatively small initiatives launched in the area. The public funding from the National Board for Technical Development (STU), a major financier of research at the time, even decreased in real terms during the decade. STU was created in 1968 to support technical development work in the industry. During its first decade, STU played an active role in the support for industries in crisis, notably the steel and shipbuilding industries, but less so in the electronics area.[324] In an evaluation of the Swedish microelectronics program, Glimell (1988) even calls the 1970s a lost decade in terms of technology policy in the field of microelectronics.[325] Thus, the Swedish competence in the digital field was limited at the end of the 1970s, the research in the computing area was insufficient with regard to the rapid computer technology developments, and Sweden was far behind the international leaders.[326]

In order to build up a national competence in electronics and digitalization, the framework program for electronics and electro-optical component technology was launched in 1979, running until 1984. A total of SEK 412 million of public funds was invested (besides a large amount from industry) in the period. The results of the program are manifested in e.g. an increase in the number of researchers in Sweden in these basic technologies from 90 in 1979 to around 250 in 1984.[327] The research seems to have been focused on sensors, optics, thyristors etc.

In 1980, STU started a program for development of knowledge in information processing. This program, lasting five years, led to ten new research groups, and the formation of two research institutes in 1985, SISU and SICS.[328] The Swedish Institute for System Development (SISU) was founded by a number of organizations, including NUTEK, to function as a link between national and international research institutes, universities, colleges and R&D departments of companies. In 2000, SISU had 25 researchers, with a budget of SEK 20 million. The Swedish Institute of Computer Sciences (SICS) in Kista and Uppsala is working

[324] Jamison, Andrew, in Glimell (1988)

[325] Glimell, Hans (1988)

[326] Deiaco and Arnold (2001) and Keijer (1992)

[327] STU (1991)

[328] STU (1991)

on research on future Internet technologies, large-scale network-based applications, and human-machine interaction. The institute employed around 90 researchers in 2003, a minor increase from about 85 in 2000.[329] SICS is jointly owned by industry actors and the Swedish government. The Swedish IT institute (SITI) functions as an umbrella organization coordinating and financing applied IT research. SITI was created in 1997 and is owned by the Knowledge Foundation and the Ministry for Industry, Employment and Communications and FAS, an association open to companies and public organizations in Sweden. Ericsson and Telia have large interests in SITI.[330]

Historically, a strong connection has existed between the electronics industry and the military in Sweden. The Swedish defense material administration – FMV – had launched a development project called Dator 80 (Computer 80) in the mid-1970s. The aim was to develop competitive computers for use in airborne military applications. During the work, the strong dependence on foreign suppliers was found to be a strategic problem for the future. In discussions between people from FMV and STU, possible solutions to the problem of low Swedish electronics competence were outlined. This laid the foundation for a government-funded R&D program, launched in 1983.[331] The national microelectronics program (NMP) provided SEK 373 million in public R&D funding between the years 1983/84 and 1986/87.[332] The NMP aimed at upholding the Swedish independence and competitiveness in the semiconductor field; there was a consensus that Sweden lagged the leading countries, and that government support was needed for economic as well as military strategic reasons.[333]

The NMP was followed by the National IT program (IT4), focusing on systems-oriented research and industrial production. The IT4 had a total budget of around SEK 1 billion during five years, half of which was publicly funded.[334] Telecommunication was budgeted to be around a quarter of the total IT4 program, and within the program Ericsson and Telia built a prototype GSM system.[335] In 1991, the national research program IT-2000 was launched, focusing on system technologies.[336] The total spending in large public R&D initiatives is summarized in Figure 4-28.

[329] Holst (1999) and http://www.sics.se, accessed at 03-12-04
[330] Holst (1999) and http://www.siti.se, accessed at 03-12-04
[331] Glimell (1988)
[332] VINNOVA (2002c)
[333] Jamison, Andrew, in Glimell (1988)
[334] VINNOVA (2002c)
[335] McKelvey et al. (1998)
[336] VINNOVA (2002c)

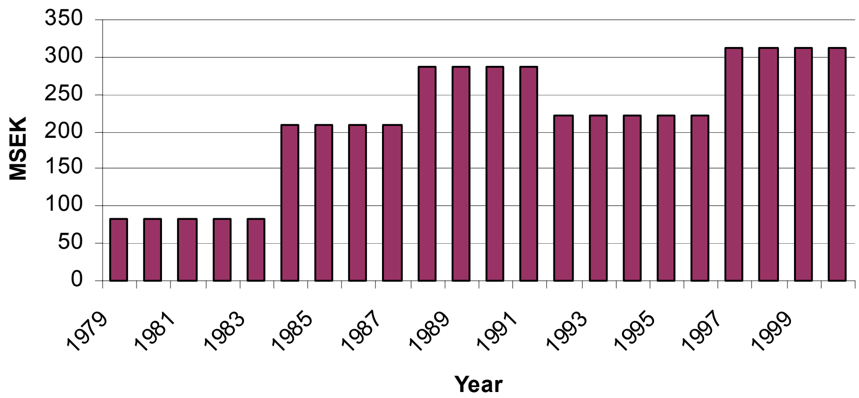

Figure 4-28: Public R&D spending on microelectronics and component technologies in Sweden

Note: The annual sums are averages of the total research program during a period.

Source: VINNOVA (2002c)

Apart from the large-scale investments in microelectronics, a number of smaller research programs have been funded during the period. In 1987, the framework program Digital communication was started, aiming at raising the level of knowledge at universities and colleges. The program, running during six years, had a budget of SEK 63.7 million, financed by STU. The background was the fast-paced transition from analog to digital technology in telecommunications. The focus of the initiative seems to have been on mobile communications, which is natural considering the strong involvement of Ericsson and Televerket. According to an evaluation of the program, it secured the supply of competence in the field for Ericsson and Televerket, and has had great impact on the development and implementation of GSM.[337] In 1987, STU also started a framework program for computerized image processing.

A number of smaller research programs were launched during the 1990s. Examples include: (1) SWAP (Swedish ATM Platform), a NUTEK-sponsored program of ca. SEK 7 million per annum for three years with the purpose of supporting the research underlying Ericsson's ATM effort[338]; (2) the PCC program on personal computing and communication, financed by the SSF (Foundation for Strategic Research) in 1996 with a total turnover of US $18 million between 1997 and 2001; and (3) a three-year SEK 190 million research program in information technology initiated by SSF in 2002.[339] Between 1993 and 1999, NUTEK had a research program on telecommunications, with yearly budget of around SEK 20 million in the early years, later lowered to around 12 million.[340]

In the early 1980s, the prioritizations of Swedish public research funding were to build up the knowledge base in information technology. At the mid-1980s, the use of IT received more attention.[341] Still, in the mid-1990s the prioritized areas of IT-related research in Sweden were generic methodology and modeling development, as well as technological development in the

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[337] Deiaco and Arnold (2001)

[338] Hedin (2004)

[339] SSF (2002) and www.pcc.lth.se accessed 031215

[340] McKelvey et al. (1998) and Hedin (2004)

[341] STU (1991)

microelectronics area. The focus of Swedish research activities was on “physical products”, whereas areas as services and applications seem to have received little interest.[342] The importance of applications seems to have been placed higher on the agenda recently. In the early 2000s, e.g. two dedicated IT universities were funded. In 2000, the Royal Institute of Technology in Stockholm started the IT University, located in Kista north of Stockholm. The university had from the start three focus areas: microelectronics, telecommunication, and distributed communication systems (including Internet). The initiative was followed by the IT University in Gothenburg, started the next year, focusing on applied IT research and education. The Viktoria Institute in Sweden was founded in 1997 to perform applied research in the IT field, and the Interactive Institute, working with innovative digital applications, in 1998.

In the light of the massive dismissals at Ericsson during recent years, VINNOVA has been active in projects aiming at retaining the Swedish telecom competence. As an example, VINNOVA and Ericsson together invested SEK 25 million to transfer people with knowledge and skills in the optical networking area to the research institute ACREO. In this project a national test bed for the development of broadband communication solutions was created.[343] In late 2002 a proposal for an IT/telecom stimulation package of SEK 3.5 billion over five years was proposed to the government. The package included a number of R&D initiatives in the telecommunications field, with references to the strong public telecom R&D in Finland, UK and Germany.[344]

As mentioned in 4.1.2, Sweden spends a large share of the GNP on R&D: over 3% during the last decade. In 1995, Sweden topped the list of R&D funding as a share of GNP in the European Union.[345] Although differences in how R&D is measured (how much of corporate R&D is included) might impact the figures, it seems that Sweden had a strong R&D infrastructure during the 1990s. The total Swedish R&D expenditures in Sweden reached 96.7 billion SEK in 2001, equivalent to 4.3% of GNP. This figure is high in international comparison and places Sweden among the top countries in the world when measuring R&D-to-GNP ratios. The public share of the total Swedish R&D expenditures has, however, gradually decreased during the last decade, with industry providing the majority of R&D funds. In 2001, industry provided 78%, or SEK 75 billion, of the total Swedish R&D funding. The telecom industry was the most active in R&D, providing 29% of the industry total, or SEK 21.7 billion in 2001. Of the 21.7 billion, around 5 % (c. 1 billion) was invested in research (rather than development).[346]

[342] Holst (1999)

[343] “Statliga VINNOVA och Ericsson gör gemensam sak!”, Vinnova Press Release 2002-07-03

[344] Vinnova (2002)

[345] Holst (1999)

[346] SCB (2003)

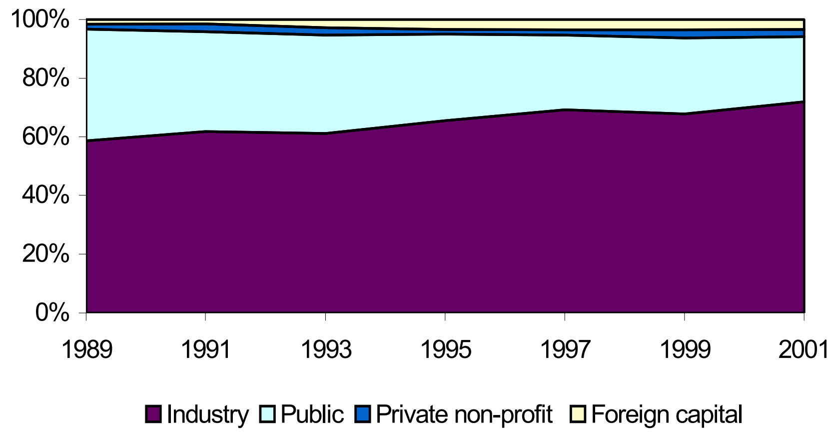

Figure 4-29: Total R&D in Sweden by source of finance, 1989-2001

Source: SCB

4.7.2 Industry R&D

As shown in Figure 4-29, industry has played an increasingly important role in R&D in recent years; perhaps more so in the IT field than in other areas. Some estimates indicate that 90% of all IT-related research was carried out in the industry in 1987, and only 3% of total university research funds in 1990 were allocated to IT-related fields.[347] In 1993, costs for ICT research were almost SEK 12 billion for industry-related R&D, compared with around 450 million available for academic R&D programs. This corresponds to around 25% of all R&D funds in the country in 1993.[348] In most large-scale public R&D programs, industry has provided up to half of the funds.

During the whole period, the telecommunications industry has had an influential role in Swedish R&D. In the late 1980s, telecommunications equipment made up 58% of the electronics production in Sweden.[349] R&D expenses in the Swedish electronics industry were also focused on the telecommunications area; of the SEK 19.9 billion invested in electronics R&D in 1999, 10.8 billion were invested by the telecom products companies.[350] In 1999, the electronics industry in Sweden had a total turnover of SEK 190 billion, with electronics products making up SEK 164 billion. Of the total electronics production, communications equipment constituted 84%.[351]

The importance of Ericsson in the Swedish R&D system is illustrated by the fact that the company spent SEK 43 billion on R&D in 2001, equivalent to half the total Swedish R&D investments.[352] Although the share spent on R&D in Sweden is only roughly half the total sum, Ericsson had great relevance for the Swedish ICT R&D. As a rough estimate, 20 of the 43 billion SEK were spent in Sweden, which would amount to more than a fifth (>20%) of the total R&D in Sweden. Obviously the well-being of this one firm and its decisions regarding R&D will have effects on the Swedish National Innovation System.

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[347] Keijer (1992)

[348] Teldok (1997)

[349] Jörgensen, Ulrik, in Glimell (1988)

[350] VINNOVA (2002c)

[351] VINNOVA (2002c)

[352] VINNOVA (2002c)

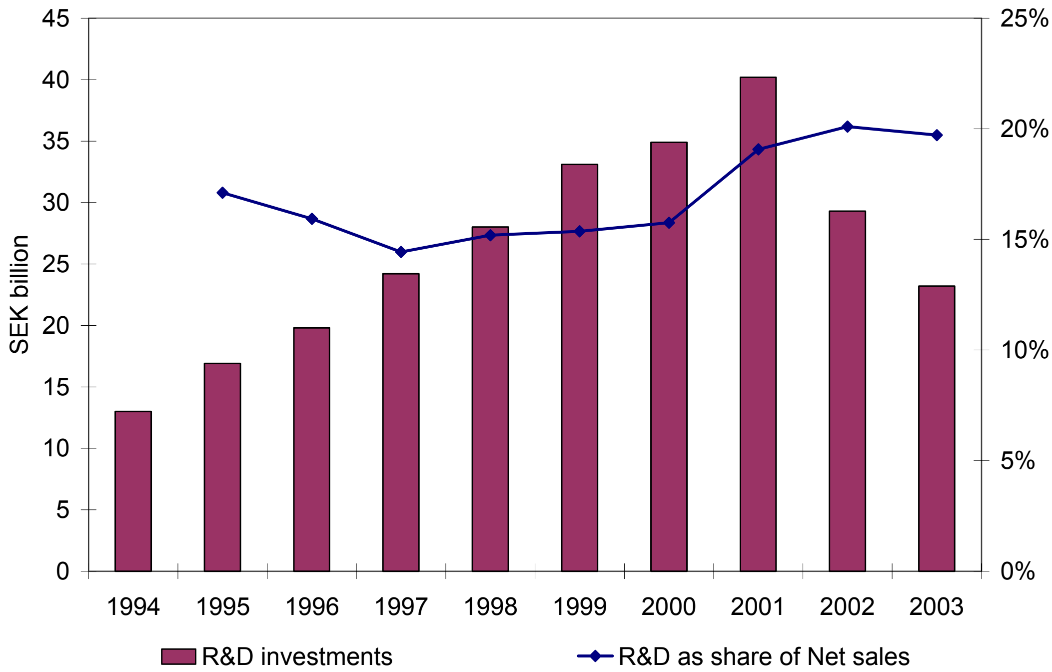

Figure 4-30: Ericsson R&D investments, 1995-2002

Note: 1) R&D investments include “Other technical expenditures”. 2) Accounting principles have been altered during the period, leading to difficulties in comparing them.

Source: Ericsson annual reports

Ericsson’s sales came to a drastic halt in 2001, following a long period of steady growth. As seen in Figure 4-30, R&D investments have also been cut, but increased as share of total sales. This implies R&D spending being cut back less than other expenditures. Still, the reliance on Ericsson as a major contributor to the Swedish R&D investments seems burdened by a great risk, considering how close the company came to bankruptcy following the drastic market slowdown.

During the 1970s and 1980s, Televerket played an important role in the Swedish telecommunications R&D system. With the monopoly situation, Televerket was commissioned by the government to perform long-term R&D. Until the de-monopolization in 1993, Telia (or Televerket) funded both research and development of telecommunication equipment. As discussed earlier, in the cooperation with Ericsson, Ellemtel, the AXE switch was jointly funded and developed. Through the production arm Teli, the operator also produced telecommunication equipment. During the last decade Telia has gradually decreased its R&D efforts. As seen in Figure 4-31, the R&D investments of Telia have not increased in line with turnover increases, and R&D as a share of net sales has steadily fallen during the last decade. In the competitive telecom services market there are no signs of reversing the falling R&D trend.

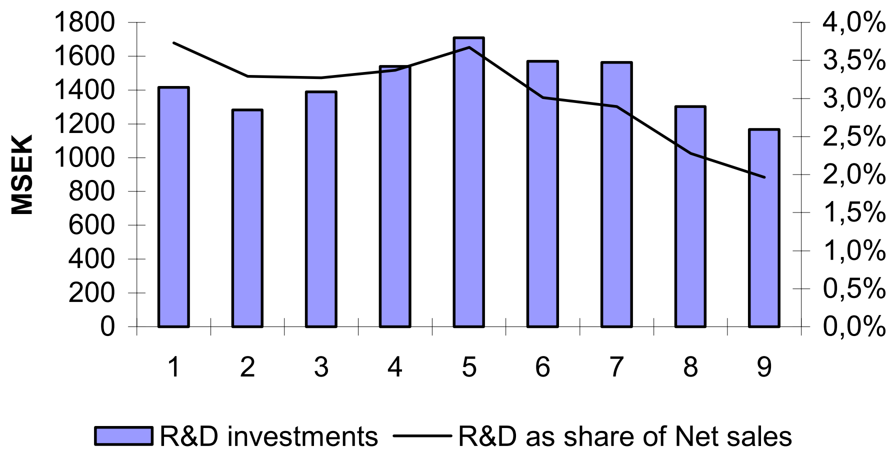

Figure 4-31: Telia R&D investments, 1994-2002

Source: Telia and TeliaSonera annual reports

With Ericsson and TeliaSonera decreasing their R&D investments, R&D in small firms often funded by venture capital could play a more important role in the Swedish innovation system. The development of the venture capital market will therefore (and for other reasons) be assessed in the following section.

4.8 Access to capital/investments

Venture capital is an important mechanism for transferring savings to industry investments. A strong venture capital industry is a crucial part of the system for helping new firms to grow through exploitation of new technologies.[353] Access to venture capital, particularly in the early phases of a company's life span, is a key factor for the creation and growth of new firms. This chapter provides a brief introduction to the developments in the Swedish private venture capital industry in recent years, followed by an overview of public capital sources.

4.8.1 Private venture capital

In the last years of the previous century, rapid technological developments in the Internet and mobile communications areas created vast amounts of opportunities for new firms to exploit. The rapid increase in entrepreneurial activities during the 1990s was assisted by an increase in available venture capital. The size of the venture capital and private equity industries grew faster in Sweden than in any other OECD country in the latter half of the 1990s. Sweden is also among the leading OECD countries in terms of private equity investments as a share of GDP.[354] The Swedish venture capital industry was born in 1973 when the company Företagskapital was started.[355] Like many of the early venture capital firms, Företagskapital was semi-private, i.e. based on cooperation between the private and public sectors. By the mid-1980s, there were around 20 venture capital funds in Sweden. Around the mid-1980s, a period of shakeouts of venture capital firms came about, and many of the private ones left the industry.[356]

During the banking crisis in the early 1990s, the government made SEK 6.5 billion available for venture investments through two new investment organizations, Atle and Bure, and state-owned venture capital organizations. This was the start of a period of new growth in the industry. According to the Swedish venture capital association (SVCA) the number of active corporate members increased from 25 in the year 1994 to 55 in 1998. Research by Karaömerlioglu and Jacobsson (2000) indicates there were 94 venture capital firms in Sweden in 1998 (see Figure 4-32). The harsh financial climate following the stock market collapse in 2000 led to a new shakeout period in the industry. Figures from SVCA indicate 155[357] member companies in 2001, and in October 2003 SVCA listed 126 companies as active members on their website, of which some have turned out to have seized operations.

[353] Karaömerlioglu and Jacobsson (2000)

[354] OECD (2003c)

[355] Hyytinen and Pajarinen (2001)

[356] Hyytinen and Pajarinen (2001)

[357] SVCA (2002)

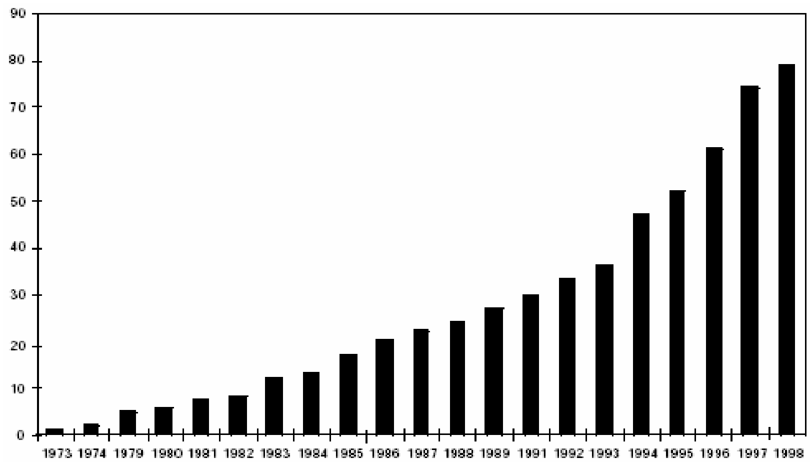

Figure 4-32: Accumulated number of venture capital firms in Sweden, 1973-1998

Source: Karaömerlioglu and Jacobsson (2000:261)

Many authors have argued that Sweden has had a relatively small venture capital industry, that the share of investments going to early phases has been too small, and that a relatively small part is invested in high-tech areas such as IT and biotech.[358] This view has been opposed by Karaömerlioglu and Jacobsson (2000), showing that Sweden at the end of the 1990s had more venture capital firms per capita than the USA, that the accumulated capital was growing more rapidly than in the USA, and that a relatively large share was invested in early phases. The authors did, however, identify lack of competence as a weakness of the Swedish venture capital industry.

In line with an increased number of venture capital firms in Sweden, the capital funds increased. As seen in Table 4-13 below, the capital under management in Swedish venture capital firms has increased rapidly since the early 1980s. The largest increases occurred in the late 1990s/early 2000, with modest increases since 2001. Although the numbers are based on surveys carried out by the Swedish venture capital association among its members, and the absolute numbers are not fully reliable, the relative increase is important.

Table 4-13: Managed and invested capital in Swedish venture capital firms, 1983-2003

(SEK billion)	1983	1987	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Managed capital	0.4	4	12	N/A	15	N/A	41	52	138	191	190	201
Invested capital	N/A	N/A	N/A	N/A	N/A	N/A	1.8	11.2	19.4	18.9	4.5	

Source: Swedish Venture Capital Association (SVCA) (except 1983 and 1987, which are from Karaömerlioglu and Jacobsson, 2000)

[358] Karaömerlioglu and Jacobsson (2000)

The downturn in the world economy and the burst of the stock market led to a decrease in the number of venture capital firms in Sweden by 10% from 2001 to 2002.[359] The venture capital industry, dependent on a vibrant public equity market for exits, halted investments when the stock markets plunged. As seen in Table 4-13 the venture capital investments increased very rapidly until 2000, with a minor decrease in 2001. The figures for 2002 imply a drastic decrease by 75% in investment volumes. According to an OECD report, particularly the amount of capital earmarked for investments in the early phases of growth decreased.[360]

The venture capital portfolios are dominated by companies in high-tech industries. Companies classified in the Computers and IT category made up 35% of the number of companies in 2003 (26% in 1999), and companies in the Electronics and Telecommunications category made up 5% in 2003 (9%).[361] The investments are concentrated in the three large Swedish city regions. As many as 47% of the portfolio companies were located in Stockholm area, followed by Västra Götaland (14.5%) and Skåne 11.6%). A comparison with the share of total number of companies indicates a disproportionately large share of VC investments in the Stockholm area.

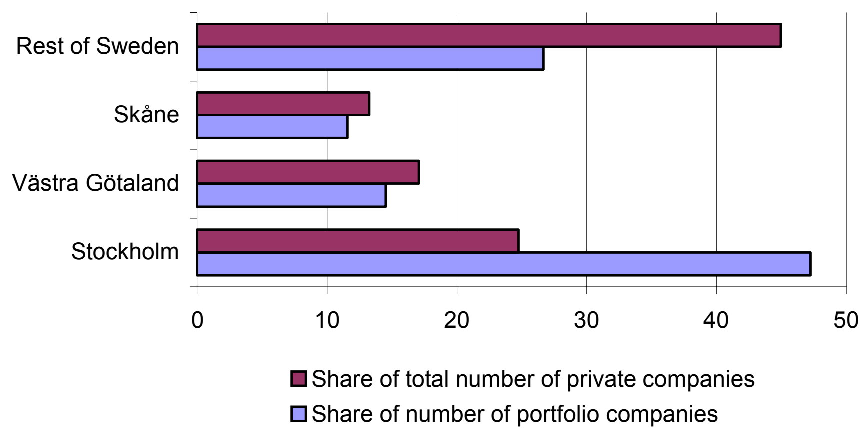

Figure 4-33: Share of private companies and VC portfolio companies by region in 2003

Source: NUTEK (2003)

In an international context, Swedish private equity/venture capital investments as a share of GDP are high, overshadowed only by the UK in 2002 (see Figure 4-34). Although the share of GDP is high, the major part of the Swedish private equity capital is targeted at later stages of investments, with the share of capital available for investments in early phases considerably lower than in the world-leading USA.

[359] http/:www.svca.se, accessed 030901

[360] OECD (2003c)

[361] NUTEK (2003)

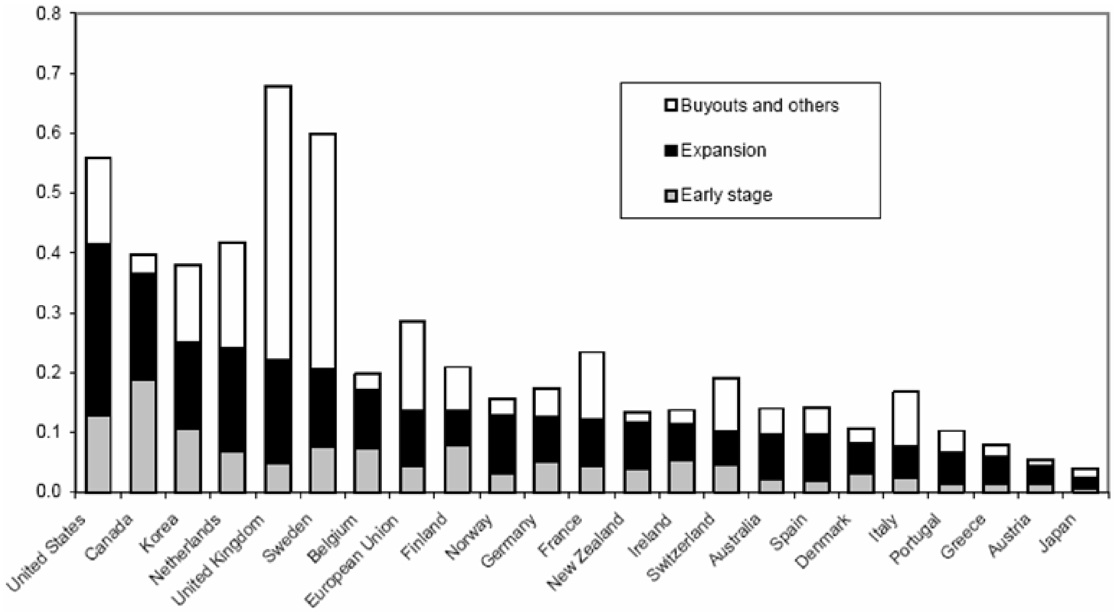

Figure 4-34: OECD venture capital investment by stage as a percentage of GDP, 1998-2001

Note: The definition of private equity/venture capital tends to vary by country
Source: OECD (2003c:8)

Since 2000, the relative share of number of investments in early phases has fallen radically. In both 2001 and 2002, the major part of the Swedish venture capital was invested in the expansion phase (Figure 4-35), probably due to the weak financial markets providing small opportunities for exits. With the smaller amounts of capital needed and the higher associated risks, it could be expected that a majority of the number of investments are made in the early phases of a firm's life.

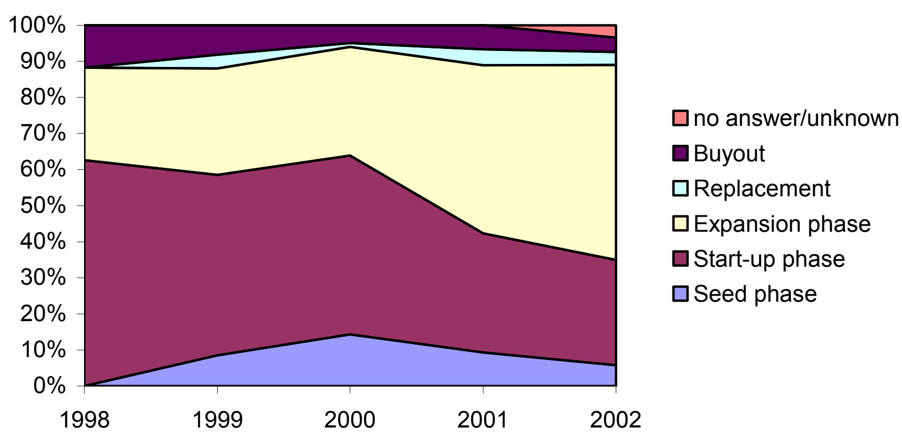

Figure 4-35: Share of number of investments by investment phase, 1998-2002

Note: The numbers are based on a survey, and might not provide a complete picture

Source: The Swedish Venture Capital Association (SVCA) membership register 2002 (for 1999-2001), OECD 2003c (for 1998), SVCA quarterly reports 2002

Apart from venture capital firms, there are so-called business angels, private investors investing their personal wealth in new companies. The business angel network SwedBan (Swedish Business Angel Network), founded in 2001, estimates that there are around 3,000 business angels in Sweden. The criterion for joining the network is a minimum capital of SEK

200,000 available to invest in early ventures. In addition to the available capital sources, advisors have gathered in seven regional CONNECT not-for-profit network organizations, providing entrepreneurs with advice and connections. The networks are loosely coordinated by CONNECT Sweden, sponsored by IVA (Royal Swedish Academy of Engineering Sciences).

4.8.2 Public capital access

The public sector has played an important role in Swedish venture capital provisioning since the early 1970s. Today, the public sector is active through bodies providing equity, scholarships and soft loans to entrepreneurs, mainly in high-tech areas. The Swedish pension funds are important sources of capital for private venture funds. In the mid-1990s Sweden introduced changes relating to the public pension funds. Previously, only small fractions of the funds could be invested in private equity. With the introduction of the sixth pension fund, focused on private equities, a large capital injection was brought to the venture capital industry. In 1999, governing rules for other public pension funds were liberalized, to allow greater venture capital investments.[362]

During the 1990s, NUTEK (the Swedish Business Development Agency) provided early-phase financing to small companies and entrepreneurs working on promising high-tech developments. In 1994, following the economic downturn, initiatives were implemented to increase new-firm creations. E.g. the government-owned ALMI was formed to provide soft loans to start-ups. NUTEK coordinated investment efforts with ALMI and other public financing bodies, e.g. Industrifonden (Swedish Industrial Development Fund) and Innovationscentrum (Sweden Innovation Center). Industrifonden, founded by the government in 1979, provides loans and/or equity capital to small and medium-sized companies. For investments in early phases, investment applications are first screened by NUTEK or ALMI, then by Industrifonden. In the first half of 2003, ALMI had issued loans of SEK 2.5 billion, and a cash reserve of SEK 2.5 billion.[363] Industrifonden has SEK 3.7 billion in assets, with investments in 288 companies.[364]

Stiftelsen Innovationscentrum (SIC) and Teknikbrostiftelserna are two other sources of financing for the early development phases. SIC, founded in 1994, provides loans (max. SEK 400,000) to companies in early phases. The seven regional Teknikbrostiftelserna (founded in 1994 and planned to operate until 2007) support technology-based spin-offs from universities, mainly through scholarships.

4.8.3 The stock market

The venture capital industry is dependent on a strong secondary capital market for exits from the investments. With the strong stock markets in the late 1990s, the public equity market option was an important exit route for venture capital investments. In 2001, the public equity finance market decreased significantly from the year before, effectively closing the IPO exit door for venture capital firms. The decrease in public equity finance cut across all industries, but the telecom industry was among the most severely affected (see figure belowFigure 4-36).

[362] OECD (2003c)

[363] Almi financial report, H1 2003

[364] Industrifonden annual report, 2002

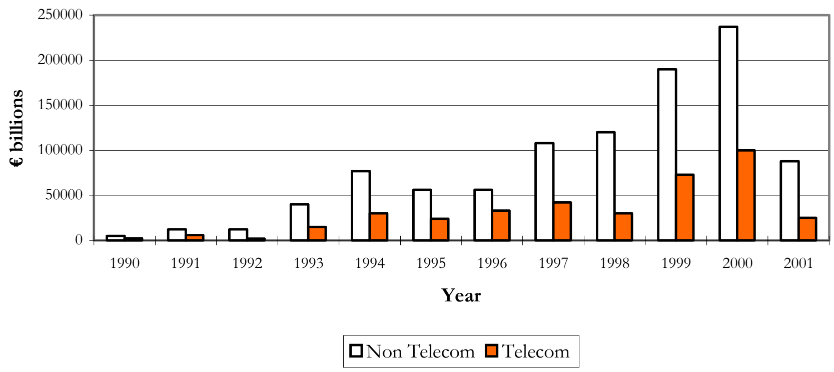

Figure 4-36: Public equity finance in Europe during 1990-2001

Source: Björkdahl et al. (2002)

4.9 Summary and discussion

The telecommunication sector is an important part of the Swedish economy, and has been increasingly so during the 1990s. The contribution to economic growth (measured as productivity improvements and value-added growth) has increased to become almost half of the contribution of the industry in 2001. The increase in value added stems mostly from the telecom-equipment part of the industry (with telecom-services contributions more marginal). Second only to Finland, Sweden is the OECD country most dependent on the telecom product sector of the ICT industry. With a lack of data for 2002-2003, no clear statement can be made about the most recent developments, other than that the telecom bust has been particularly painful for the Swedish economy.

Telecom has also been the major driver of growth in the R&D component (as is also shown by patenting statistics) of the Swedish national innovation system, while the corresponding computing part has been relatively low. (The reasons for the latter will be further investigated in Chapter 6.) It may be hypothesized that, for telecom R&D, Ericsson's growth – in particular in mobile communications – has played an important role. If so, the Swedish R&D system overly depends on the success and failure of one product area of one firm. This has been a strength for Sweden, but may equally turn out to be a threat and weakness.

The evolution of the operators' market has been elaborated on here. After a few decades of intense competition (between the local Bell company, SAT, Telegrafverket and local municipalities) a de facto monopoly was established in the late 1910s. This de facto monopoly lasted until the 1980s. Early on, Sweden became an advanced market in terms of penetration of telephony services, the state of technology implemented, and the quality of services in use. It continued to be so throughout the monopoly years. Four important features of the monopoly made it stand out in an international comparison. First, Televerket had a powerful position in relation to the government. Second, Televerket was never linked to the postal service. This meant that it did not have to worry about telephony substituting for postal services and support the postal sector. Third, Televerket was a public enterprise, a fact which contributed to its independence. Finally, it had an important division of equipment manufacturing, which meant that it could develop its own manufacturing and R&D expertise, and became a powerful purchaser. It was also (like many other PTTs) driven by a genuine engineering culture.

In the 1970s the monopoly started to adapt to changing conditions. These changes were partly driven by the opportunities created by technological change, which stimulated large users and new firms from the emerging electronics and computer industries to join forces. They were supported by liberal and conservative politicians. A general liberalization trend, with the US as a prime mover, contributed to this. Televerket management was relatively quick to react to these changes – it started to adapt the organization and actually pushed for deregulating the market in some respects.

Deregulation became a gradual process in Sweden, progressing in a few key areas. Subscriber equipment, monopolized by tradition, was set free in 1970 for mobile telephones. In the 1980s other equipment such as telex, telephones, PBXs and modems were gradually liberalized to become completely open in 1989. Infrastructure competition also started in mobile, followed by CATV in 1985, interconnection and third-party operating rights in 1991. In addition, regulatory responsibilities were gradually separated from Televerket starting in 1981 and completed with the formation of PTS in 1993. Finally, the corporatization was very much driven by Televerket in order to gain more freedom of action, respond effectively to threats, and take opportunities in e.g. other countries. The process started with creation of manufacturing companies (Telefabrikation AB and Teli AB), an investment company (Teleinvest AB), a company with the purpose of grabbing opportunities abroad (STI) and finally the establishment of Telia AB in 1993. Later in 2000 a partial share offering was made, and by this writing Telia has merged with Finnish Sonera.

A major stepping stone in the deregulation process was the establishment of the Telecommunications Act in 1993. The law was quite gentle, imposing very few restrictions on the market, although some restrictions were put in place to prevent Telia from acting upon its dominant position (in the form of bundling restriction, cross-subsidy restrictions, and temporary price-caps. The telecommunications market was partly regulated by competition and marketing laws as well. During its ten years of existence it has been amended several times, with mixed effects on competition and prices. Effects on innovation are even more ambiguous.

Competition on the (broadly defined) telecoms market started with international computing firms entering data communications and local firms entering mobile telephony in the 1960s. Other areas of early competition were cable TV and satellite services. The major attacker of Televerket's monopoly became the Swedish financier Jan Stenbeck and his Kinnevik Group. It first attacked the mobile telephone market, then satellite communications and CATV, and later received the second GSM license. In the early 1990s it established Tele 2 and closed a deal with Banverket to install a national fiber network. In 1993 it established itself in 1993 on the over-priced market for international calls. Tele2 took an early lead to become the second largest operator in Sweden. A number of others rushed into the market, partly as a result of the new Telecommunications Act, which took away much of the regulatory uncertainty.

Competition gradually intensified, but at varying degrees in different segments. International telephony and data communications were early subject to intense competition, resulting in lower prices, and then followed by long-distance telephony. Telia responded by shifting its price structure, actually raising local call tariffs and high interconnection charges. This was possible because of its legacy network in the local loop, which has remained a major barrier to competition since then. Meanwhile both Telia and Tele2 took advantage of opportunities abroad.

As a result of competition and the growth of new services, the telecom services market expanded rapidly in the last decade. However, fixed voice is declining in revenues, and the mobile voice market is maturing. If there is to be any future growth, data communication (fixed and mobile) has to compensate.

The Swedish supplier industry has been extremely dominated by one firm, Ericsson (and by domestic firms in general). Ericsson was established with the advent of the telephone and internationalized early on. A few minor suppliers have been present, including Televerket which had its own manufacturing arm. In the beginning of the time period investigated, Ericsson accounted for around three quarters of the Swedish telecom sector. The relationship with Televerket was one of collaboration and to some degree competition. The development of the AXE switching system became crucial to the future competitiveness of Ericsson and consequently the Swedish telecom sector. AXE (like a few other products and systems) was developed jointly by Televerket and Ericsson. In this respect it was very much a result of collaboration, guidance and resource-sharing with an advanced customer, but not public procurement.

While Ericsson focused its attention on the computing market, mobile communications expanded to become its major growth area. In this, the combination of public procurement, the availability of the AXE switch, and entrepreneurial spirits at its radio communications subsidiary SRA was paramount to its success. In the mid-1990s, Ericsson was predominantly a radio communications company, while it was weak in the booming data communications market, a fact that led to a rapid build-up of resources mainly through acquisitions.

In the Swedish telecom innovation system, Ericsson is by far the most important actor in terms of revenues, followed by the large operators. Around Ericsson, a vast number of companies supplying components and services have emerged. Based on statistics on the 500 most important IT companies in Sweden, the industry generated revenues of between 300 and 400 billion SEK in 2002.

The recent telecom bust hit Ericsson hard, first in the mobile phone business (although that failure was more a result of internal mistakes) and then in the infrastructure market. Drastic efficiency programs were initiated. It is an essentially halved Ericsson adapted to the smaller market that has entered the year 2004. The effects on the Swedish economy and its innovation system have been dramatic, with consequences still difficult to assess. However, effects on R&D expenditures are dramatic as well.

Although public funding of R&D has been important for the telecommunications industry, funding has become increasingly dominant, in particular at Ericsson. In 2001, Ericsson contributed more than 20% of the total R&D spending in the country. The effects of cutting almost half of this R&D spending are, perhaps needless to say, immense. Historically Telia has contributed much to the R&D spending, but as a result of the changing competitive conditions its importance has decreased significantly. With the two main actors decreasing their investments, others have to step in, provided that the sector sustains its innovativeness. We have focused our analysis on two such alternatives, public R&D funding and venture capital.

Disregarding Televerket's R&D, public R&D expenditures in the emerging microelectronics and computing fields were insufficient during the 1970s. In the 1980s a number of programs were started to build up the competence base in general, e.g. through framework programs, the NMP and IT4 programs, and the formation of research institutes such as SISU and SICS.

Targeted programs, e.g. one in digital communications, contributed to competence build-up and supply of knowledgeable personnel in times of rapid growth at Ericsson. In recent years, the importance of applications has been placed higher on the agenda. The recent crisis in telecommunications was addressed by Vinnova, requesting a major stimulation package of SEK 3.5 billion over five years from the government, with only a fraction actually being granted.

It has been hypothesized here that an increasing share of innovation in the emerging ICT industry will take place at small entrepreneurial firms. Access to venture capital, particularly in the early phases of a company's life span, is an important factor for the creation and growth of new firms. Thus access to capital through the venture capital market will be a major function in the telecom sector's innovation system.

The Swedish venture capital industry, born in 1973, was early based on cooperation between the private and public sectors. With a few minor setbacks, the industry continued to grow until the early 2000s, when the financial crisis forced many companies out of business. There has been a debate about the size and strategy of the Swedish VC industry. At the end of the 1990s Sweden had more venture capital firms per capita than the USA; the accumulated capital was growing more rapidly than in the USA, and a relatively large share was invested in early phases. However, competence was lacking. In an international context, Swedish private equity/venture capital investments as a share of GDP are high, overshadowed only by the UK in 2002. However, capital is targeted at later stages of investments. There may be a lack of functionality in the early-stage financing in the Swedish VC system.

In 2003, the venture capital portfolios are dominated by companies in high-tech industries. Companies classified in the Computers and IT category made up 35% of the number of companies in 2003 (26% in 1999), and companies in the Electronics and Telecommunications category made up 5% in 2003 (9%). The investments are concentrated in the three large Swedish city regions, with disproportionate amounts invested in the Stockholm region. In addition to venture capital, there is a number of opportunities to attract so-called soft loans and equity from public actors (e.g. ALMI, SIC, Industrifonden and Teknikbrostiftelserna). Many of these initiatives were launched in the mid-1990s, following the severe financial crisis in the early years of the decades. Some of them will run out of funding in the coming years, potentially limiting early-phase capital access.

In sum, Swedish companies seem to have an internationally competitive situation regarding access to capital. A question can be raised regarding the capital available for the earliest phases, however, and regarding the future of public seed capital initiatives.

To conclude, this chapter has given a broad overview of the evolution of the Swedish telecom sector. Still, given the size and complexity of the sector and lack of time, resources and available indicators and statistics, many questions remain unanswered and many important paths of inquiry are left open for further research. Our approach with these inherent limitations has been to focus on the three major growth segments of mobile, data, and mobile data, the first two being the major growth segments allowing for a comparative analysis, the latter having huge future potential and high policy relevance. In addition, the area of fiber optics is focused upon in depth.

5 EVOLUTION OF FIBER OPTICAL COMMUNICATIONS

The case study will investigate the area of optical communications technology[365] within communications and is structured as follows.[366] Firstly, the international scene and the development of the technology will be reviewed, whereafter the Swedish efforts in the area will be investigated. Thirdly, an analytical framework examining the development in terms of functions will be applied to the Swedish efforts. In the last section, identified strengths and weaknesses of the system of today will be discussed.

5.1 The international scene

The field of optical communications has developed in two waves, where the first concerned what might be called remote viewing, or the transmission of light and images, and the second concerned the transmission of signals. In the following, a brief presentation will be given of each wave and its development over the decades.

5.1.1 The First Wave

The first wave has its basis in the transmission of light and images. The basic principles had long been known, but the first experiments with practical applications were conducted in the late 1920s for purposes of the transmission and scanning of images. Then in the 30s, Lamm, a medical student in Germany, experimented with fibers for making a flexible endoscope. However, none of the experiments worked satisfactorily due to the inability to attain sharp and bright images, and the ideas were soon abandoned.[367]

In the early 50s, fibers were improved by adding first plastic, and then glass cladding so that cross-talk between fibers was reduced, i.e. light was prevented from leaking out when one fiber came in contact with another. The advances toward more practical realizations of the technology through experimental studies also increased theoretical understanding of the phenomena of waveguide mode propagation in small-diameter fibers. As the transparency increased and cross-talk was further reduced, more applications were considered. Among other things, the flexible endoscope was brought up again and its development pushed the technology of making high-quality glass fibers further. The first patent, covering the gastroscope, was filed in 1956, and shortly thereafter Hirschowitz tested the first prototype on himself.[368] After some problems in building machinery for industrial production, the first commercial gastroscope was tested in 1960. By that time, special fiberscopes for use in bronchoscopy, rectoscopy, and urethroscopy etc. were already being developed. It was a dramatic advance and by the late 1960s they had almost totally replaced the earlier semi-rigid lensed gastroscopes. Only recently have tiny electronic cameras begun to replace fiber bundles. Further development of applications, such as faceplates and fiber-optic illuminators in card readers that processed the punched IBM cards etc., made for a growing fiber-optic industry. However, the first wave was beginning to flatten, and from the mid-60s the second wave reached the surface.[369]

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[365] The terms optical communications, fiber optic communications, fiber optics will be used interchangeably.

[366] This chapter has been written by Mattias Johansson.

[367] Hecht (1999)

[368] Hecht (1999)

[369] Granberg (1988)

To summarize, two strands of technology stand out as relevant for the new technology. The first comprises the skills and knowledge of manufacturing high-purity glass, and the second is the technology of fiber fabrication, including drawing thin filaments of glass or glass-type materials for optical or non-optical purposes.[370]

5.1.2 The Second Wave – communicating with light

The genesis and development of the concept of optical communication, or the second wave, involves the convergence of several knowledge areas like quantum physics, semiconductor technology, communication theory, wave propagation theory, and laser technology, as well as first-wave fiber technology. The basic functions performed by an optical communication system include transmitting and receiving optical signals as well as signal analysis.

Already in the 50s, alternatives to and improvements in the existing copper network were looked for, as there was a belief in an increased need for capacity. Two trends pushed the demand for higher capacity. One was the sheer volume of traffic; the other was the shift toward carrying signals that carried more information and thus needed more capacity per signal.[371]

In a communications system it is primarily the switches and the pipes, or the medium, that determine the capacity. The alternative to copper cable was either light or radio waves. Unfortunately, when radio waves approach the millimeter spectrum needed for the higher capacities, they cannot easily pass through clouds as they are blocked by raindrops. The alternative was to send the millimeter waves through hollow pipes – millimeter waveguides – and in the early 50s, Bell Labs concluded that the only way optics could match the capacity of the millimeter waveguide was with a coherent light source. Light was by no means a new idea; Bell had experimented with it and even demonstrated a photophone operating by sunlight,[372] but it proved impractical compared to wires. When the first lasers were built, light once again became interesting.

The first laser was built in 1960, and in 1962 researchers could present light-emitting diodes (LEDs). Different groups of researchers at, among others, General Electric Research Laboratory, IBM, and Philips made substantial improvements in operating efficiency, and by the end of 1964 the best semiconductor lasers could fire a single pulse at room temperature before it had to be cooled again. With a nearly ideal generator for transmission, the question of medium became a major concern.[373] Bell Labs experimented with using lasers in air, but soon began experimenting with guiding the light through hollow pipes similar to those that guided radio waves.

At the Standard Telecommunication Laboratories (STL) of International Telegraph and Telephone Corporation, Alan Reeves assembled a small team and turned to light in the late 50s.[374] By the early 60s, STL had essentially abandoned the millimeter waveguide, instead concentrating on hollow optical waveguides with the rise of the laser. Initially, fibers were not part of the picture because, although conceptually attractive, they were still a highly loss-prone transmission medium. The discrepancy between the actual and the desired loss levels was, by any standard, enormous. However, in time, Reeves and his team also started

[370] Granberg (1988)
[371] Hecht (1999:79)
[372] Hecht (1999)
[373] Granberg (1988)
[374] Hecht (1999)

considering transparent rods. Both Bell Labs and RCA had entertained similar ideas before, but neither did anything with them, reaching the conclusion that transparent rods did not transmit light well enough. Then in 1964, Charles Kao took over management of the small optical program at STL. He believed in using fibers, and in 1965 he conducted the first systematic feasibility study together with his colleague Charles Hockham. In 1966 they published their findings in a landmark paper, proposing that optical fibers might be a suitable transmission medium if the attenuation could be kept under 20 decibels per kilometer (dB/km).[375] At the time of the proposal, optical fibers exhibited losses of 1000 dB/km or more, and communication satellites and light pipes were still in the future. But on a small scale, the race towards low-loss fibers had begun. The glass needed for longer-distance communication had to be extremely clear with a very low loss of decibels per kilometer, and in theory glass could be extremely clear. However, no one knew how to make such glass in practice, and Kao had few believers that this could be done at all.

On the other side of the Atlantic, in Corner Sullivan Park Research Center, the logic of making fibers of compound glasses was clearly understood. Corning had extensive expertise in glass technology, and had also made optical fibers for faceplates, when they decided to look at fibers for communication. They started out on a very small scale in 1967, hiring summer project graduates, and added full-time staff in 1968. By 1970 they had managed to make impressive improvements, and finally in the summer of 1972 they made a breakthrough, producing glass with an attenuation of only 16 dB/km.[376] It was the purest glass ever made. Also in Japan, Nippon Sheet Glass had started working on fibers but of a slightly different kind. They used a technique called graded-index fibers that allowed for larger cores, thus making these more manageable. By the end of 1969 they reported losses of 100 dB/km, making continuous progress. The reports on the possibilities of low attenuation and the activities of different companies also forced Bell Labs to take fibers more seriously. Also the British Post Office was in advance, managing to get a small piece of the Corning fiber and analyzing its composition. Other actors during this time were Nippon Electric Corp., AEG-Telefunken and Siemens & Halske in West Germany, as well as different universities.

Once fibers started to compete with hollow waveguides as a possible medium, other parts required for building a system gained more attention. Light detectors and electronic amplifiers were easy to build. Largely based on the theoretical heritage of other, well-established photosensitive devices, advances had been made both prior to and in the course of the 60s in the technology of photodetectors, making the development of the simple PIN diode, and next the ADP, relatively straightforward. Also in the area of electrical circuitry surrounding the system, the early 60s had brought important changes, most notably in the integrated circuit. However, the laser source was a much tougher problem. Early semiconductor lasers were as useless for practical communications as early fibers. Many researchers in numerous countries were involved in solving the problems of steady-state, room-temperature lasers. By April 1969, development had come so far that RCA announced plans to manufacture single-heterojunction lasers, and only two months later a spin-off – Laser Diode Laboratories Inc. – announced that it would too. Bell Labs succeeded with room-temperature steady-wave lasers in 1970.[377]

375 www.fiber-optics.info

376 Hecht (1999:144)

377 Hecht (1999)

5.1.3 1970-1980

By the early 70s, development had also made fibers practical: they didn't break. Corning started scaling up fiber development in 1972 by the time of the breakthrough, and later the same year they reached an attenuation of about 4 dB/km in the 800 to 850 nanometer spectrum, and near 1050 nm.[378] This was achieved through a combination of glass consisting mainly of quartz with an addition of oxides to increase the refractive index, and the use of a vapor deposition process in making the glass preform from which the fiber could be drawn. The consequences were far-reaching. R&D activities were stepped up and the early entrants were joined by actors such as Philips, Pilkington, General Electric Co. (UK), BICC, and Northern Telecom etc.[379] In Japan, Nippon Telegraph and Telephone (NTT) started to play a key role in the development efforts due to its technological corporations with other actors.

Bell Labs had for a long time been sure that glass could never be as transparent as the air in hollow optical waveguides and millimeter waveguides. Instead, fibers were believed to be used mainly for short distances as the hollow waveguides were highly impractical for that purpose. No single event made Bell Labs turn to fiber optics. Rather it was many small developments, such as impracticality and increasing metal prices, as well as the Corning breakthrough and the continuous improvements in fibers, that made them finally abandon hollow optical waveguides in 1973, and millimeter waveguides after a field trial in 1975. Shortly afterward, the British Post Office also abandoned millimeter waveguides, just before the planned trial between London and Reading. Bell finally started to make progress on fiber fabrication, and by 1974 they reduced the loss to 4 dB/km at 900 nm and to just over two decibels at 1060 nm by producing fibers through their own vapor deposition processes.[380] Progress was also made elsewhere with the same techniques. In England for example, the University of Southampton developed fibers with minimum loss of 2.7 decibels per kilometer at 830 nm. There were some variations in the processes, but Corning soon received fundamental patents that would become gatekeepers for entry into the American optical communications industry.

The early improvements in fiber attenuation were achieved when there were still markedly different opinions regarding the potential merits of various fiber types. Both single-mode and multimode, and in the latter case both liquid- and solid-core fibers, were developed. However, as the Japanese turned to the easier-to-handle graded-index fibers, Corning followed and by the mid-70s, the multimode, solid-core, graded-index fiber emerged as the standard type for use in first-generation telecommunication systems.

The inadequacies of laser lifetime and operational reliability did not, however, progress as fast as fiber development. The spring and summer of 1970 had marked breakthroughs on the semiconductor laser frontier and, by late 1972, STL could switch a narrow-stripe double-heterojunction laser on and off up to a billion times per second.[381] This meant that a laser could transmit a billion bits per second. However, the problem of lifetime was still pertinent. AT&T wanted lasers that lasted for many years routinely, but those were far away. The British Post Office, STL, RCA and Nippon Telegraph and Telephone all ran their own programs. In 1975, the small RCA spin-off, Laser Diode Laboratories, launched a new product with a predicted lifetime of 10,000 hours, even though tests were only up to 1,000 hours. By 1976, Bell Labs, which had been close to shutting down diode laser development

[378] Hecht (1999)

[379] Granberg (1988)

[380] Hecht (1999)

[381] Hecht (1999)

before turning wholly to fiber, estimated average lifetimes of 5 to 10 years. There were other important technical tasks involved as well. For instance, temporary junctions and laser-fiber couplings were also tough and worked upon, steadily improving in performance. Moreover, photodetectors and electronic circuitry had to be developed or, more typically, adaptively modified.

Field trials and real systems

Along with continuing efforts to further improve the components, the second half of the 70s witnessed an increasing concern with system design and evaluation and further improvement of system performance. Moreover, technological and practical problems associated with the factory production of components and installation, operation and maintenance of systems, and the economic, or cost-reduction, aspects of all activities and devices involved became increasing concerns.[382]

In 1976, AT&T ran its first large-scale field trial in Atlanta. On a smaller scale, STL ran its own field trials, and others like the French National Center for Telecommunications Research, Siemens in West Berlin, and Pirelli in Turin followed. From the field trials of AT&T the biggest problem was still the gallium-arsenide lifetimes. In 1977, a refined system in Atlanta sent its first test signals, and AT&T was getting ready for its first real system in Chicago. At the same time, however, another company, General Telephone and Electronics, set up a system of 6 M/bits in California, managing to get it in traffic just before AT&T had its own real system of 45 Mbit/s up and running in Chicago.[383] In Britain the Post Office started routing the first live traffic on June 16th, 1977, just two months after AT&T and GTE.

The second generation

From the mid-70s on, there is a distinct accumulation of publications, conferences and formal organizations devoted to the technology. A critical mass of researchers pushing the limits of the technology had been built up. As they approached the limits of what was possible at 850 nm, they began looking for alternatives. In 1976, in Japan, a wider range of wavelengths was measured in low-water fiber and the loss was found to be only 0.47 dB/km at 1.2 micrometers. A new window for optical communications was found. This was coupled with developments in lasers so that they would steadily emit in that spectrum. Opening the new window changed the ground rules for optical communications.[384] Systems operating at 1.3 micrometers had a whole different set of operating characteristics than 850-nanometer systems. Japanese engineers were quick to see that lower loss and pulse spreading could be the basis of a second generation of fiber technology.

Other developments in America were the realization that one fiber could simultaneously carry signals at many wavelengths, an idea called wavelength-division multiplexing. More elaborate ways of switching light into and out of fibers were also found.

5.1.4 1980-1990

At Lake Placid in 1980, the world "saw" for the first time fiber optics transmitting signals so clearly there was no sign the glass was there. Optical communications was ready, and so too was the machinery of industrial production. However, it was still for graded-index fibers. Opening the 1.3-micrometer window made the single-mode fibers look much better, due to

[382] Granberg (1988)
[383] Hecht (1999)
[384] Hecht (1999)

less “modal noise”; and by late 1977, NTT was making low-loss single-mode fibers. At the end of 1978, they had made the clearest glass in the world, with an attenuation of only 0.2 dB/km, just a little higher than the theoretical lower limit on scattering, knowing that they could not do much better. Thus, while good graded-index fiber could carry a hundred million bits per second for 10 kilometers, it only managed 20 million bits over 50 kilometers. At 1.3 micrometers, 50 kilometers became a reasonable transmission distance, and single-mode fibers could easily carry a billion bits 50 kilometers, leaving graded-index fibers in the dust.[385] Although operating characteristics were different, the system changes were relatively minor, since the new fibers fit into the same cables and used the same connectors as first-generation systems. The British Post Office and STL collaborated on a single-mode trial in 1982. The results were impressive, and in 1983 they began installing single-mode systems. NTT also moved quickly to single mode while Bell Labs was slower. Instead it was an upstart, MCI Corp, who brought single mode into the US, and overnight all the long-distance companies switched to single-mode fibers.

The early 80s also brought the first submarine cables as an AT&T cable ship laid part of a single-mode fiber on the Atlantic floor in 1982. In December 1982, an international consortium requested bids for another fiber cable running from New Jersey to a point off the European coast, where it split into separate cables to England and France. This was TAT-8, laid in 1986, and it was soon to be followed by TAT-9, TAT-10 and TAT-11. The latter had 1.55-micrometer technology, which was a third low-loss window that had been discovered.

Around 1980, it was still easy to count the number of major optical communications systems installed by telephone and cable television companies, and also the different actors although increasing in numbers. The actors could be divided into three major categories[386]: systems operators, systems houses, and component and subsystem manufacturers. The first refers to the different phone companies like AT&T etc., and within this category, major differences existed regarding the strength of in-house R&D resources and capabilities. On the manufacturing side, represented by the second and third categories, a general tendency towards integration is clearly discernible. Thus, a worldwide survey of the optical communications industry of the early and mid-80s shows “*that the majority of firms that produce fiber/cable are in fact vertically integrated. Only 18 out of 93 suppliers make/sell just one item, all the others engage in other segments of the optical communications market. All of the major suppliers (excluding Corning) are active in more than one market*”.[387] Turning to the major producer countries, the interconnectedness and integration recur at the national level, with variation due to different institutional arrangements. In the US, all main optical communications markets were highly concentrated and interconnected via vertically integrated producers. In Japan, the optical communications industry cooperated in the Optoelectronic Industry and Technology Development Association. In France, CNET coordinated and propagated national optical communications efforts, and in West Germany the so-called “Kabellkartell” including Siemens, Standard Elektrik Lorenz, Philips, AEG, and Kabelmetall had put its hands on the fiber market.[388]

In the mid-1980s optical communications took off. In the US, the deregulation of the long-distance telephone service created a market for long-distance transmission, and the telephone industry had to adapt to a new way of doing business that was faster and more competitive.[389]

385 Hecht (1999)

386 Granberg (1988)

387 Bonek et al. (1985)

388 Granberg (1988)

389 Hecht (1999:199)

Through the 80s, advances achieved in one area spurred development in other areas. For example, the associated electronics have been challenged by the increasing speed, and optical switches, modulators etc. have begun to be developed. Other fields that of course have been relevant are computer technology and digital signal processing and switching, with its contribution of such techniques as pulse code modulation, time division multiplexing, and packet switching. Others are those underlying cable television, videotex etc., especially since they are the ones that were supposed to drive the need for more capacity. In addition, the 80s brought important standardization with the international SDH in 1986 and the American equivalent SONET in 1987.

5.1.5 1990s to present

If the market for optical communications took off in the 80s, it exploded in the 90s, and especially from the mid-90s on. The reasons were several, one being the government deregulation of the long-distance telephone service mentioned above. At the same time, the emergence of the Internet in the early 90s created a new business for telecom carriers, and investors came to see telecom as a new value opportunity.[390] Thus, the millions of kilometers of fiber installed increased rapidly (see Figure 5-1). During the same period the number of companies entering the industry increased considerably, focusing either on systems or on modules and components in the systems. Toward the late 90s there were a number of acquisitions and mergers, primarily by giants like Cisco, Lucent, Nortel, ADC and JDS Uniphase.[391]

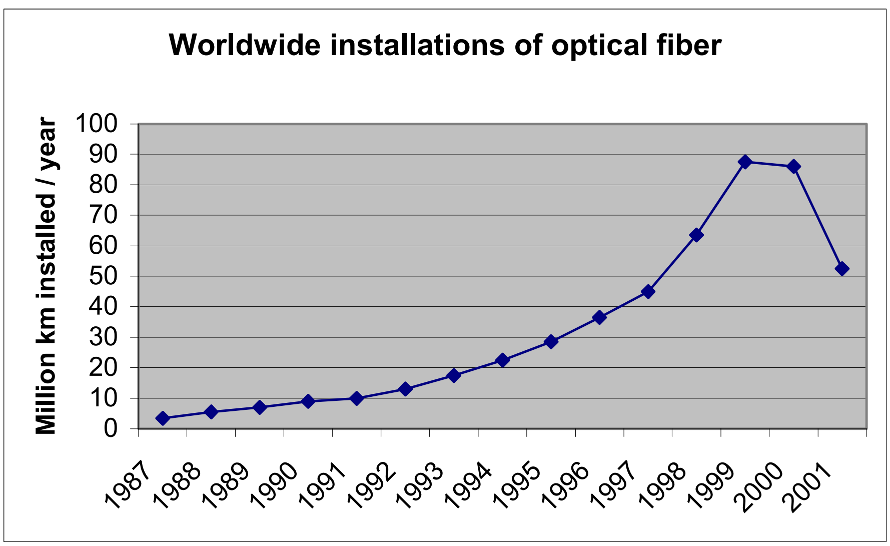

Figure 5-1: Worldwide installations of optical fiber

Source: KMI Research (2002)

[390] KMI Research (2002)

[391] Bass (2000)

However, too many networks were built to serve the same markets, at the same time as continuous advancements in technology development were made. The idea invented by Hicks in the early 80s of sending multiple wavelengths in the same fiber (wavelength division multiplexing, WDM) had reached commercial applications. Coupled with further enhancement of lasers, switches, and fibers, it rapidly enabled increasing bit rates per second in the networks (see Figure 5-2).

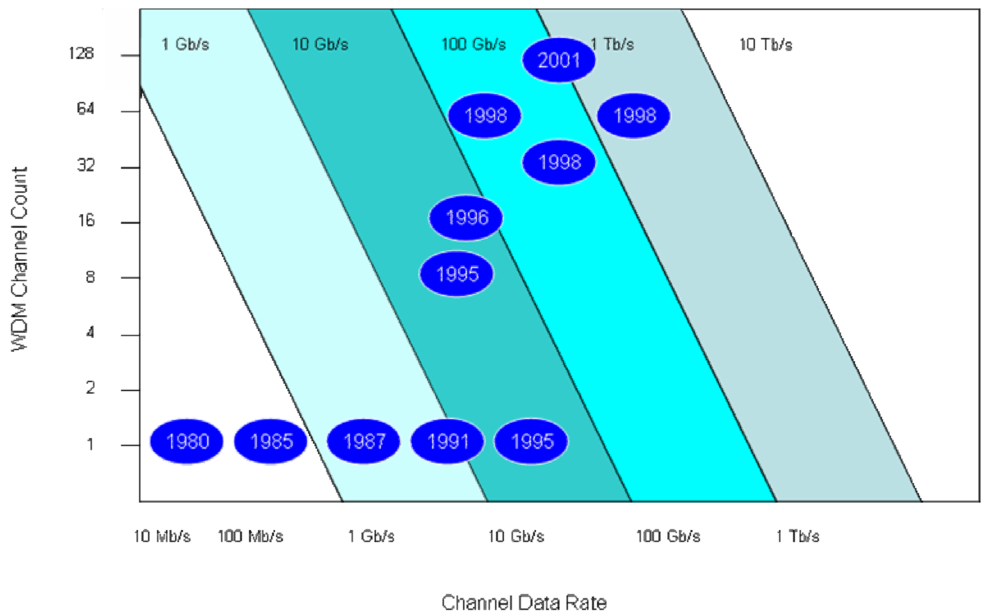

Figure 5-2: Evolution of capacity in optic systems)

Source: www.fiber-optic.info

Thus, the increased competition coupled with excess capacity on many routes, and an Internet traffic that did not increase as projected, created a huge unused capacity in the long-haul networks, which in turn caused an erosion of circuit prices. Revenues fell short of targets and failed to cover expenses, and debt burdens led to a plummeting of the market in 2000.[392] It started on the American market where the drop also was the worst, and the European market followed after 6-12 months. The Asian market was somewhat less affected. The big players exhibited enormous losses and their stocks started going down as well (see Figure 5-3). By June 2001, these five firms alone, i.e. Cisco, Lucent, Nortel, Alcatel, and Siemens, announced lay-offs amounting to over 50,000 in a six-month period.[393] This was the start of a shakeout of companies, primarily of the "new economy" firms centered on using stock options to recruit, as well as to obtain currency for acquiring innovative capabilities. A nearly halved attendance of exhibitors at, for example, the Optical Fiber Communication conference and exhibit between 2002 and 2004 may serve as an indication of the state of the industry (OFC homepage). This has, however, led to an opportunity for new players, e.g. Avanex, to enter by buying factories etc. at low prices.[394]

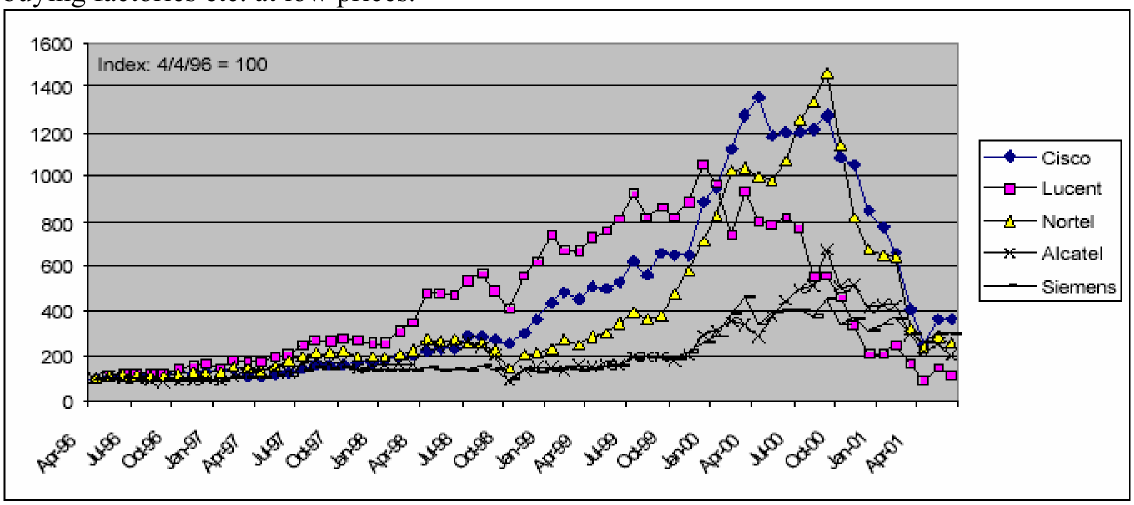

Figure 5-3: Stock price evolution for some of the major component manufacturers

Source: INSEAD (2001)

The last mile

As the long-distance routes have increasingly been replaced by optical communications networks, more attention has been paid to metro networks and the last mile. However, the last mile has been the hardest for optical communications. One reason for this may be that there is a somewhat different cost structure for bringing fibers into the home. While investments in the long-haul and metro networks have been driven primarily by an increasing need for capacity as well as obtaining a better cost per Gbit per second and kilometer, the access systems are justified by cost per subscriber and cost per premise passed (see Figure 5-4).[395] There are two ways to improve on this ratio: either through reduction of the costs of production and installation of equipment, or by improving the willingness of subscribers to pay through the services that can be generated. However, thus far, neither of these has been fulfilled satisfactorily. On the supply side there are still technical problems with, for instance, routing signals to many different points, and on the demand side there is no real need for it to

392 INSEAD (2001); KMI Research (2002)

393 INSEAD (2001)

394 CIR (2003)

395 RHK (2002)

justify the costs of building a system. That is, the services that are to fill the networks may not have developed yet to the point where they can reach a critical mass of customers.

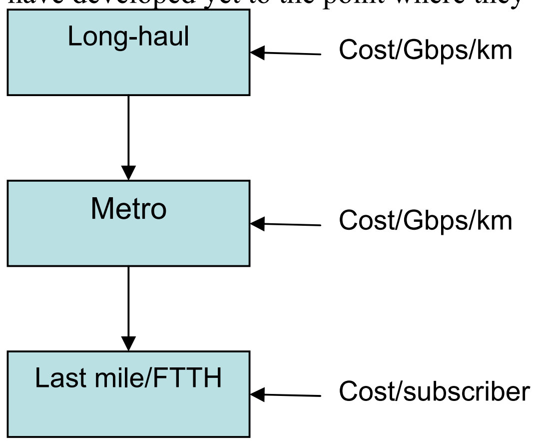

Figure 5-4: Cost structure in the networks

Source: RHK (2002)

Thus, optical fibers carry both telephone and cable television signals to towns or neighborhoods, but except for a few experimental systems, the threads of glass do not reach homes. Somewhere within a few miles from homes the fibers end in a box, which converts their optical signals into electrical form and sends them to copper wires. The trials that have been made thus far with different home-video services and the like, in the US as well as in Canada and Japan, are not much more than costly trials.[396] In Japan, NTT plans to run fibers past every home by 2010, but that has recently been revised again. France announced in 1982 that 1.5 million homes were to be connected by 1987, and 6 million by 1992. The further installation, however, was stalled in the early 90s, unofficially being a technical and economic disaster. The key is to reduce the cost of installation, and the cost of producing sufficiently good components and subsystems at a reasonable price.

[396] Hecht (1999)

5.2 The evolution of Swedish optical communications

5.2.1 The First Wave

The first wave passed relatively unnoticed in Sweden. A basic scientific competence in theoretical and applied optics was maintained at the physics departments of the universities and institutes. In 1955 the general knowledge base was reinforced through the establishment of the Institute of Optical Research (IOF), where signs of interest in the new technology appeared in the early 60s when researchers and students at IOF and the Physics Department of the Royal Institute of Technology (KTH) acquired some image-transmission fibers and carried out certain small-scale experiments and studies.[397]

The first active response from Swedish industry occurred in 1965 when engineers at ASEA came upon the idea of using optical fibers for the purpose of electrical power control, in a thyristor-control system, although this can be seen as bordering on optical communications. The contribution was the result of an engineering effort at the systems level. The LEDs were originally bought from Texas Instruments, and later supplied by ASEA Hafo.

5.2.2 The Second Wave: 1960 to the take-off

In the 60s to early 70s some competencies were built up with relevance for optical communications systems. From 1965 onwards, a particular scientific capability in optoelectronic materials was built up at the Department of Solid State Physics in Lund University. The work was particularly relevant for the complementary technologies of light sources and detectors. The Institute of Microwave Technology (IM) was founded in 1968 and became increasingly involved in the development of semiconductor components. The National Defense Research Institute (FOA) had long-standing interest in signal transmission in the military context. The activities in optical signal transmission soon came to be focused on design and evaluation of primarily short-haul links based on available components. The Institute of Semiconductor Research (Hafo), transformed into an ASEA-owned subsidiary in 1969, had competence as well. In 1971, the Institute of Optical Research (IOF), in close cooperation with KTH, also initiated studies in integrated optics, exploiting waveguide phenomena with strong potential ties to optical communications. At Chalmers University of Technology (CTH), the Institute of Electrical Measurements (IEM) enters optical communications in 1972/73, after an interest in laser applications, and constructs and evaluates laboratory systems, using commercial equipment.

The immediate industry response to the rapid international advances achieved on the front in the early 70s may be described as weak.[398] Ericsson, the company most directly exposed to the new technology, reacted primarily by sharpening its surveillance of the advancing frontline. In 1969, Gerhard Gobl at the Central Development Unit (CDU) visited the British Post Office to study its most recent development, and recommended the Chief Technology Officer (CTO), Jacobaeus, to continue monitoring both hollow waveguides and optical fibers.[399] Apart from that, ASEA-Västerås was concerned with industrial and high-voltage power applications, and Saab-Scania with avionics and military applications. However, the Swedish efforts did not match those of other comparable industrialized countries.[400]

[397] Granberg (1988:65)

[398] Granberg (1988)

[399] Hörstedt (2000)

[400] Granberg (1988)

The lack of a Swedish capability in the core technology of optical communications was discussed at an optoelectronic symposium organized by the Academy of Engineering Sciences (IVA) in 1971. The conclusion was that the needs and opportunities in optical instruments could not be specified in a way that would clearly justify fiber production in competition with the established foreign manufacturers. However, it was also considered that a possible Swedish development effort would be hampered by the lack of domestic capabilities in fiber production.

Several indicators, among others the R&D levels of foreign companies, soon pointed to optical fibers and in 1974 the Swedish optical communications effort took off. At Ericsson, Gobl recommended that Jacobaeus start research within the optics area, and Jacobaeus championed the resource allocation to optics technology at the corporate level. Gobl and Jacobaeus urged that the operations should be concentrated in only one unit, and proposed that the CDU in the Systems Research Group should be expanded with 4 researchers. Initially two transmission system applications were highlighted, which was very much in line with the other industry actors. They further suggested that Ericsson should develop knowledge of optical components, something that should be conducted together with Swedish universities to draw upon the knowledge developed there throughout the 60s.[401]

The passive stance taken by Ericsson until 1974 toward optical communications is argued by Granberg (1988:76) to be conditioned by constraints that are intimately connected with the overall technology policy pursued. The long-standing policy of Ericsson had been one of creation and maintenance of competitive strength in systems engineering and product development, while accepting weaknesses at the research end of the R&D continuum. The company, therefore, did not have the advanced research laboratories and the supporting policies and traditions that would have facilitated an early entry into the emerging field through independent front-line contributions. The stance assumed thus reflected the company's general reluctance to commit substantial resources to pioneer new science-based technologies when technical feasibility and commercial promise were still highly uncertain. With this attitiude, they implicitly accepted the risk of missing the train. When the question was no longer one of "if" but of "when", the effort was launched. This was about ten years after the emergence of the second wave – at the time when AT&T made their first field trials, the standards of the first generation had been set, and increasing attention was being paid to the issue of cost versus performance and the engineering problems of plant production.

The Cooperative Project

At the time when Ericsson was arriving at the decision to enter the field of optical communications, IM was considering a move in the same direction and proposed a mutual technology development effort. Other actors were contacted as well and the common view developed was reflected in a research program proposal, formulated jointly by Gobl and Ingelstam (IM), with reference to the other representatives' opinions. Gobl presented the research program to STU, which came to support the project financially together with Ericsson.

The project was launched in 1976, involving actors in both research and development such as IM, Ericsson with Sieverts and Rifa, IOF, FTF in Lund, and Hafo. In related organizational and technical functions it involved both formal and informal links to STU, Televerket, the ASEA group, and the defense cluster. Televerket did not have a direct need for the project, but believed that, in the long run, optics technology-based systems would to a great extent

[401] Hörstedt (2000)

spread throughout the telecom network.[402] No single organization had the role of leader or coordinator; instead a steering committee was assembled.

The development enterprise was directed largely towards fiber-optics applications in the communication area. The aim of the systems-orientated effort was to attain skills and inventiveness in system design, or the integration of components. The directions of component-oriented research were shaped together with the representatives from IM, IOR, and SSP/Lund. The ambition guiding the effort was not to leapfrog the pioneers and to assume a leading position in the further advancement of technologies, and there was thus a strong orientation toward engineering and product development. Taking into account the relatively late start of the activation process, the range covered was considerable.

For Ericsson two objectives were targeted: a platform of basic knowledge, and an in-house design and production capability in optical communications systems and key components, including fibers, fiberguard cables, light sources and detectors etc. to be able to respond to a projected growth in demand in the early 80s. The competence had to be built because acquisition of companies was not possible, as none existed at this time. In-house development of competence was also important in that the new field was not looked upon as a new product area, but as a new technology, relevant to a number of product groups within Ericsson's business domain. For the systems-oriented activities, the parent company was suitable. On the component side, fabrication and cabling of optical fibers lent itself to Sieverts Kabelverk in collaboration with the Fiber Group at Ericsson Central Material Laboratory. As regards optoelectronic components (e.g. lasers, LEDs, and photodetectors), there were only a few institutes and academic departments in which one could find individuals or small groups who had developed an active interest in optical communications technology and had acquired a certain amount of theoretical and practical knowledge. It was therefore a rather small and shallow pool to tap, and it was clearly desirable that competence in institutes and universities should be strengthened as well.

The Cooperative Project was formally completed at the end of 1978, and was by any standard a remarkable catch-up. The success was largely based on the convergence and meshing of interests pursued by primarily Ericsson and IM. The project also created a network of personal contacts and interinstitutional links that persisted far beyond the formal completion of the project. For Ericsson, the external actors were furthermore perceived as being important resources of competent personnel to be needed in the future. The only problems seem to have been slight disagreements as to the project's direction, and the sizeable demands on the limited resources of the institutes. Particularly IM had to fill gaps due to a subsequent transfer of personnel to Ericsson.

The Cooperative Project brought results notably in the fiber area, which was important in order to reduce dependence on the main supplier, Corning. At Ericsson, the Fiber Group developed a knowledge base concerning optical fibers that enabled Ericsson to act competently towards suppliers in the area. The development work was also concerned with cabling, and the seaming and connection of optical cables. Regular, non-laboratory production of fibers and cables began in 1981 at Sievert Kabelverk's so-called Opto-center, at costs significantly lower than in the market.

Advancement towards a practical design and manufacturing capability in lasers and detectors was less rapid, although there were some concrete results in laser diodes based on GaAs. The

[402] Granberg (1988:81)

reasons for this are not entirely clear, although the inherent technical complexity of the task provides part of the explanation. Further, it appears that the translation of laboratory results into full-scale processes was delayed both by persistent doubts about the economic justification of in-house manufacturing and by indecision concerning the organizational locus of such production. Not until 1981 did Rifa actively prepare for its assigned role.[403]

5.2.3 The second half of the 70s

Concurrently with Ericsson's decision to enter the field, ASEA's engagement in optics technology was broadened and intensified. More efforts were directed to industry applications, and research and development in optical sensors was initiated. FOA and FMV also showed increased activity, as did major weapon systems suppliers like SAAB-Scania and Bofors. In the academic sector, the overall picture of an expanding effort is confirmed, examples being the involvement of the Department of Electronic Measurement Technology at KTH and the Department of Electron Physics at CTH. At the latter, work was begun in the late 70s on the transmission by optical fibers of high-power laser light. The aim of this project was to develop a systems technology for such applications as surgery, spectroscopy, and chemical process initiation. IM's new orientation toward optical communications and integrated circuits in 78/79 also forced them to establish links with the department for applied electronics at KTH, with the research institute for atomic physics, and with IOF.[404]

At Ericsson, Swedberg, who succeeded Jacobaeus as CTO in 1976, reorganized the units concerned with optics technology into five strategic development projects to increase business relevance. The Systems Research Group and Glass Fiber group were transferred to the Unit for Optoelectronic Design and System Loops at the Transmission Division (T-division) where emphasis was more on systems and product development and less on general optics technology development. Two groups were formed, the Systems Design Group, and the research-oriented Technology Development Group. In 1977 a techno-economic investigation concluded that it was possible to develop and produce optical transmission systems, from both a technical and an economic viewpoint.[405] In 1978, the T-division increased to 13 researchers, and the first commercial product developed along the application lines was set up, the ZAM-2, a 2-Mbit/s system with LEDs and transmission distance of 4 km.

The first field trial

The planning of the first field trial, by Ericsson and Televerket, was in progress already in the summer of 1977. Televerket was willing to support a field trial of an optical transmission system because they wanted to learn how to purchase, install, operate and maintain the optical systems. The field trial was performed in October 1979 with fiberguide cable and terminal equipment supplied by the company. Low reliability of lasers was confirmed, and technical performance of the fiber was as good as that which could be bought. It also manifested Televerket's further interest in cooperation with Ericsson in optics technology, which meant that the optics technology could be extended.

The public support of optical communications in the 70s

The ascent of optics technology in the public domain was closely linked to the rapid expansion of business sector activity that began around 1975. Two organizations stand out: STU and Televerket. In the early 70s, STU contributed to the standby competence at institutes and universities, and from 1975 to 1978 in planning and financing the Cooperative Project.

[403] Granberg (1988)
[404] VINNOVA (2002a)
[405] Hörstedt (2000)

Although the Cooperative Project was terminated by 1978, the engagement in the field continued in the form of a number of smaller projects. Many of these were incorporated in the STU program for Electronic and Electro-Optical Component Technology initiated in 1979/80. STU thus enabled non-corporate R&D in the field in the period 1970-1980, although funding for information technology even declined in the budget of STU during the years of 1972-78.[406]

The contributions of Televerket mainly fall within two areas. The first concerns traditional informational and technical support. The second contribution was as a provider of laboratory facilities and technical expertise required for testing of optical communications components and systems. Televerket had an optics laboratory of its own with the purpose of establishing a general knowledge base in the field. Over time, they also contributed by being an increasingly knowledgeable client and user. However, there was an absence of substantial contributions in the form of in-house R&D, and of significant economic stimulus in the form of "procurement pull", although they financially supported optics technology operations at Ericsson.

The military primarily reviewed the field with regard to emerging military applications, to ensure that potential users and producers were kept informed of important developments, to conduct tests and practical evaluations of prototype and commercial equipment, and to build, in-house, the knowledge base required for procurement decisions. The military, through FMV, were also influential in areas of building component and process knowledge of integrated circuits in the late 70s and early 80s.

5.2.4 1980-1990

In the early 80s some changes in the general orientation of the institute-based optics technology activities were discernible. With the transfer of the maturing component technologies to Ericsson and the gradual loosening of the company ties, the scope for longer-term or more basic R&D at the institutes improved, and some steps were taken in that direction.

Institutes and universities

From 1978-79, the orientation of IM changed to be mainly concerned with optical communications and integrated chips technologies. For this purpose, they received lots of funding from the STU-financed program in component technology, and in four years the financial support quadrupled, leading to the institute achieving a critical mass in these areas. Because of the institute's very existence and phase of development, as well as contacts with companies like Asea and Ericsson, IM also took a key position in the National Microelectronic Program (NMP) starting in 1984.[407] Through NMP, IM could conduct a relatively offensive knowledge development in the area of optical communications. Among other research, they worked on integrated optics, doing studies of gallium arsenide (GaAs) and indium-phosphate (InP) materials. Integrated optics research was also conducted at IOF, where the main concern was lithium-neobate materials. Over time, there was a continuous transfer of personnel from IM to industry.

At the universities, basic research in semiconductors had been lagging for a long time. This started to change in the late 70s through departmental build-up in Linköping and Lund. A prominent person and a driving force was Professor Grimmeis in Lund, who was recruited to Ericsson's semiconductor subsidiary Rifa in the early 80s.[408] In the rest of Sweden, at

[406] Glimell (1988)

[407] Glimell (1988)

[408] Glimell (1988)

universities and institutes, the level of activity in the optics area increased as well. This was partly due to the STU-financed Electro and Electrooptic component program from 1979/1980 to 1983/84.[409]

All in all, the number of researchers in the base technologies of electronics and electrooptics increased from ca. 90 to ca. 250 in the period 1979-1983. According to a report by STU, about 2/3 of this was as a result of STU's financing. By 1990 the number of active researchers had increased to about 500 researchers, partly as a result of the NMP and IT programs from 1984 onwards.[410]

Ericsson

At Ericsson, the distinct development trajectory of fibers and cables in the Fiber group in collaboration with Sieverts took place at the Opto Center in Sundbyberg.[411] The multimode development had been a success; now there was a shift in the technology to the second generation. The synergies between first and second generation were substantial and, as in the late 70s, further development in the 80s was motivated for cost reasons. Development was also conducted in the areas of measurement techniques and seaming technology.

In 1980, collaboration between Televerket and Ericsson was initiated once more for a new field trial based on single-mode principles. Televerket still had no direct need of high-capacity optical systems, but supported the project to avoid a substantial reworking of their analog coaxial cable systems. They also had an interest in developing optical and optoelectronic products to be sold by the company Teli. Siverts Kabelverk was also involved in the project, and the field trial was executed in 1984.

The Y-unit

Regarding optics technology development at Ericsson, a new unit, the Y-unit, planned to last for only four years, was established in 1981 and followed by an increase in optics technology resource allocation.[412] Optics technology was well aligned with marketing and business strategies of the X- and T-divisions, and representatives from both agreed to enforce the expansion of the optics operations. The increased knowledge base in institutes and academia due to the efforts in the 70s now enabled Ericsson to expand their technology development operations by recruiting researchers and engineers from academic science in areas of e.g. fiber production and laser design. The increase in personnel was accompanied by an increase in laboratory equipment.

The responsibilities of the Y-unit covered applied research as well as market and product development in the optics area. The Y-unit consisted of the Optics Technology Section (OTS), the Section of Market and Product Development for Non-public Optics, and the Systems section geared towards traditional telecom. The unit was headed by Mattson and consisted of about ninety people. The single-mode projects got the most attention and resources at the Y-unit, as it was argued that the leading industry actors would complete such systems during the 80s. Other tasks of the Y-unit were to develop components of strategic importance to Ericsson in-house.

The technology development in the Y-unit was transferred to Televerket in a series of reports and seminars. Televerket increased its own efforts in the area in 1982, nine people being

[409] Hörstedt (2000:103)

[410] STU (1991)

[411] Hörstedt (2000)

[412] Hörstedt (2000)

engaged, but in 1983 Ericsson showed that that was not enough for efficient technology transfer to take place.

Integrated optics at OTS

Within OTS, the ambition was to conduct state-of-the-art research in some sub-technologies in the areas of e.g. electronic-optical integration, high-speed components and non-linear optics, and to assist the other sections of the Y-unit in technical matters of any kind.[413] It was emphasized that the directions of applied research should take a point of departure in the demands of future products and systems, i.e. a more long-term objective. One objective of OTS was to evaluate and develop optical and opto-electronic components, aligned to systems development; another was to act as a link between the research community and the development community. A particular purpose of the OTS was to establish an expertise within the field of integrated optics, which was expected to become a very important technology for the 90s. Technologically, integrated optics was partly related to the other developments at the Y-unit but also partly separate.

The work on integrated optics was initiated in 1982, and the first researcher in the area, Thylén, was recruited.[414] Thylén's ambition was to conduct internationally acknowledged research and thereby get access to the work of the leading research departments to further boost Ericsson's technology development. For that purpose, collaboration was needed to draw upon the knowledge in integrated optics and lasers developed at both IM and IOF. For the institutes, the main motive to participate was that Ericsson provided expensive laboratory equipment. Together with Rifa, the integrated optics group also conducted measurements and encapsulation mainly of lithium-neobate components and circuits. In 1985, when the Y-unit was dissolved, OTS was moved to the X-division where work proceeded along systems and components. In 1987, the collaboration with IM and IOF was extended to include laser amplifiers.

One particular research result in the switching area occurred in 1986, when the group managed to develop an 8*8 switch matrix, which represented a major technological breakthrough in the area at the time. The 8*8 switch matrix gave the group a strong reputation on the international scene and allowed Ericsson to participate in a joint systems-oriented project together with British Telecom. Thylén, however, encountered problems when trying to transfer the research results to the business divisions, partly due to the lack of systems strategy and lack of interest in research results among representatives of the business operations. The development work conducted on lasers and laser amplifiers triggered the development of coherent technology, i.e. the blending of the emissions from several lasers into one coherent signal. In 1987, some 5 people were involved in integrated optics at Ericsson and the monetary resources allocated were about 5 MSEK. By 1991 the group had expanded to 7 people.[415]

Public support in the 80s

Following the program on electronic and opto-electronic components technology, and being a welcomed alternative for a new industrial identity, the NMP program was accepted in late 1983. The program ran from 1984-88 and was directed at education, basic research, goal-directed research, and industrial development. The program was divided into four parts, where NMP 3 had most impact on the opto-effort, but also part of NMP 4 was important in

[413] Hörstedt (2000)

[414] Hörstedt (2000)

[415] Hörstedt (2000)

this respect. The goal of NMP 3 was development of knowledge about new production processes in new component technologies that could be expected to have a major impact on system development in the future. Within NMP 4 a large share was directed toward VLSI-production resources at Rifa.[416]

After some delays, the NMP program eventually acquired a successor in the IT programs proposed in 1987. The IT program was directed to computer systems, steering systems, and communication systems and their base technologies, and was divided into four parts in accordance with NMP.[417] Of these, it was IT4 that was most concerned with optical communications. For Sweden to have a continuously advanced position in optical communications it was important to invest in the right areas, and to make the results the base for productification. This meant that end-users should be involved at an early stage. IT4 was divided in different areas, of which one was a project in micro- and optosystem technologies. Within this part were six projects in total, accounting for 90 MSEK focused on optical communications systems and components. One of these was conducted in close cooperation with Televerket, Ericsson and IM, and concerned laser and integrated optoelectronics, gas-phase epitaxy, and integrated optics on InP.[418]

Televerket was not originially part of the NMP but worked themselves into it over time, since the enormous development costs of the fixed telecom network also placed demands on the development and use of advanced technique to be able to free investment funds through technical rationalizations. Televerket was asked for assistance in the IT program, and also agreed to provide financing together with defense authorities, which put pressure on the government to do likewise.

While Televerket had been involved in many European projects since the late 70s through an operator cooperation called COST, the question of wider participation in EC program efforts became more strategically loaded in the mid-80s. While the NMP concept had not been adjusted to connect with new elements either regionally or nationally[419], the IT program seems to have been more so. This is likely to have become more important as EC realized that Europe was lagging behind, particularly in ICT. Thus, the ESPRIT program was initiated in a first step in 1984, and in a more focused effort, the RACE[420] program was initiated the same year with a clearer emphasis on broadband networks. This program proceeded into the 90s, and probably provided important funding and international connections to Swedish actors. However, we are not clear about the exact amount of funding allocated to Swedish actors in the optical communicatons area from these European programs.

5.2.5 1990 – late 1990s

Institutes and Universities

In 1993, IM was transformed into IMC (Industriellt Mikroelektronikcentrum) and employment nearly halved from 170 to about 100. In 1995 this was reduced to 60 employees, while it again increased to 75 in 1998.[421] The IMC responsibility was to provide industry with technology and to make sure that already developed technology was commercialized. The laser technology developed at IM had obvious commercial applications, but as IMC was owned by KTH and Linköping University of Technology it could not be commercialized

[416] Glimell (1988)

[417] Glimell (1988)

[418] VINNOVA (2002a)

[419] Glimell (1988)

[420] RACE – Research and Development of Advanced Telecommunication Technologies

[421] www.ad.se

within this framework. The development group for lasers tried to arrange collaboration with Ericsson. Ericsson, however, had no interest in developing the technology further, as they chose to work on WDM systems (wavelength division multiplex) which were built out of steady-state lasers. In 1999, IMC (former IM) and IOF merged to form ACREO, with headquarters in Kista. ACREO soon came to act as something of a rescuer for many of those who had to leave Ericsson as Ericsson closed down operations in optical communications. Partly as a result of that, ACREO in 3 years, from 1999 to 2002, increased from 75 to 195 persons.[422] In recent years ACREO has also started building a testbed at which companies, both domestic and foreign, are welcome to test their products. There are also smaller efforts elsewhere, for example to develop methods for calibration and surveillance at the Swedish national institute for technical evaluation.[423]

On the university side, research directed to the area of optical communications is mainly carried out at KTH and Chalmers. Some research in related areas is also conducted at the Mid Sweden University in Sundsvall, and to some extent and more component-related also in Linköping and Lund. Given the scale of the industry and the research budget, it appears that Sweden is narrowing the scope of its thrust to specific areas such as high-speed networks, sensors, biophotonics, and quantum computation rather than targeting the whole spectrum of the domain.[424] Moreover, as there are somewhat different types of technologies underlying the different application areas of long-haul, metro- and access networks, some specialization in this regard may be discerned as well. For example, at Chalmers there is a greater focus on cheap, easy-to-manufacture components important to the access networks, while KTH is more concerned with high-speed lasers better suited for long-haul networks. There are some voices raised as to increasing difficulties in the 90s of obtaining long-term government funding and the influence and challenge of activities this may have at the universities.[425] However, it is difficult to assess to what extent this is actually the case. Lately, for example, some 3- to 5-year programs, sponsored by VINNOVA and SSF, have started with relation to optics research. As for the number of employees, this is difficult to assess. Since funding has stayed roughly the same, at the same time as it may have been slightly more difficult to obtain long-term funding in the 90s, the number of employees should have stayed roughly the same. Nonetheless, a researcher at Chalmers states that staffing today is threefold compared to the early 90s.[426]

ACREO and KTH as well as industry have also recently started a joint forum, Kista Photonics Research Centre.[427] Besides the goal of utilizing the synergies in this cluster, the centre has also initiated a master program in photonics, starting in 2003.

Reorganization and downsizing

The beginning of the 90s brought a reorganization of major parts of Ericsson's operations to more strongly reflect the various lines of business. Thus the major contents of the X-division were moved to the business area Ericsson Telecom. Within Ericsson Telecom, research was reorganized and divided between two types of units, Research Centers (RC) and Application Laboratories (AL). Funding for the RC and AL operations were to be provided by the business units, which thereby would influence the resource allocation to applied research.

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[422] www.ad.se

[423] Ny Teknik, 020830

[424] Iga (2003)

[425] Interview with Staffan Ström, KTH, in ESI, special topics, March 2003

[426] Interview with Anders Larsson, Chalmers, 20031204

[427] www.kprc.se

Apart from that, a Steering Committee for Applied Research also had authority to decide on strategic directions.

Within the field of optics technology, Fiber Optics Research Center (FORC) was formed as a RC. The operations of FORC were to a great extent based on the previous work of OTS. It was directed mainly towards optical components and particularly components that were expensive, unavailable on the market, or crucial in order to obtain important system solutions. The research intensity was 19 man-years per year. The operations of FORC were dominated by four major projects, of which one concerned components for switching in collaboration with British Telecom. An AL, Fiber To The Home (FTTH), was also established in the optics area. The operations within FTTH aimed at demonstrating an optical connection to the end-user and thereby being able to point out the possibilities, limitations and costs of the technology needed. The objective was to conduct field trials in the end of 1991, and to carry out work in-house as well as with the external partners. The research intensity was 8 man-years in 1990, with an additional two in 1991.[428]

Another business area, Ericsson Components, also established a new RC unit. It was located in Kista and included integrated optics, both in lithium-neobate and indium-phosphate materials, high-capacity optical components, process development and characterization of advanced projects. Another investment in optics technology at Ericsson included the building of an Optolab in Älvsjö, 1991. This was a process laboratory allowing research on fiber and component bonding and polymeric waveguides, and was used by several research units.

During the 80s, total R&D operations had been constantly expanding. The amount allocated to optics technology had never been questioned, partly due to its small relative size, partly because of the politically powerful support from Mattson favoring long-term research. However, FORC became more visible due to further reorganization and, more importantly, Mattsson left for a position at Ellemtel. With him, the biggest support was gone and power shifted in favor of the business unit representatives, who were under pressure to rationalize and thus emphasized short-term profitability. However, the amount of allocated resources to FORC stayed the same.

In 1993 an initiative was put forward by the head of Ericsson Components to establish an R&D unit called MEST (MicroElectronics System Technology), consisting of FORC and three other research centers. The primary motive behind MEST was to lower the risks of disturbing the company’s future key technologies by moving the units to the slightly more profitable Ericsson Components. At the same time the funding principles were changed in favor of the business unit representatives. As these were concerned with improving profit margins and cost-reduction, it implied that the level of allocation of resources to the area would decrease, and become more short-term oriented. As MEST was geographically closer to Ericsson Components than Ericsson Telecom, the aversion of the latter to funding applied research at FORC increased further.

In 1994, Ericsson Telecom established an AL for systems-oriented research, Transport Network Application Laboratory (TNAL), which partly overlapped the scopes of FORC. The possibilities for FORC to receive funding for systems research from Ericsson Telecom in 1995 were thus further reduced. However, the head of FORC, Eklund, did not alter the directions of the systems-oriented research projects, which left him with no choice but to scrap the research on optical switching. As new principles for resource allocation were

[428] Hörstedt (2000)

introduced, allowing business unit representatives further influence, allocation decreased. Since there were also diverging opinions as to the importance of this research, the amount of resources allocated to applied research activities in the organization where the integrated optics group was situated nearly halved in 1994. Ericsson had reached a state-of-the-art status within the field, but the time until integrated optics allowed commercialization of economically viable products was estimated to be too long, and in 1995 the integrated optics group was dissolved.

Thus, FORC's operations became increasingly oriented towards components and a shorter time-scope, and the resource allocation to FORC decreased significantly. The resource allocation to applied research at Ericsson Telecom as a whole was greatly reduced for the fiscal year of 1995. FORC was affected by the reductions and lost approximately half of its funding. Because of the lesser amount of resources, FORC abandoned systems-oriented projects, the development of integrated optics and some parts of the work in the switching area. The decrease in resource allocation and the stronger focus on components were counteracted by the establishment and funding of TNAL.

The remaining development within optics technology at Ericsson would be cut further. In 2002, the Systems Division exhibited a severe drop in revenues compared to the year before, and Ericsson decided to cut operations further. Thus, in late 2002 the Ericsson personnel of 15 persons at the research unit for Optical Networking were transferred to ACREO.[429] Soon after that, the development of Erion, a DWDM system that increases capacity in optical fibers, was stopped and Ericsson instead signed a contract acting as a retailer for British Marconi, which is one of the largest suppliers of WDM systems.[430]

Another reason to close down Erion was that profitability was not expected to come in the foreseeable future, and that Ericsson also regarded themselves as too small on the world market, although a couple of hundred Erion systems already had been sold. The development of Erion employed 150-200 persons. Also other units related to optics technology were close to being sold, and in 2003 Ericsson signed an agreement to sell its optoelectronics operation, Ericsson Optoelectronics, to Northlight Optronics AB. The 48 employees will be transferred to the new company. In the press release Ericsson stated that the sale was in line with an ongoing process to focus on the core business of providing systems and services for telecom operators.[431] As a result of these liquidations the government has tried to find solutions for new job opportunities, among other things to help them start up new companies.[432]

[429] Evertiq, 020808

[430] Ny Teknik 021016, Lightreading, 020516

[431] Ericsson press release 20030117

[432] Dagens Industri, 021009

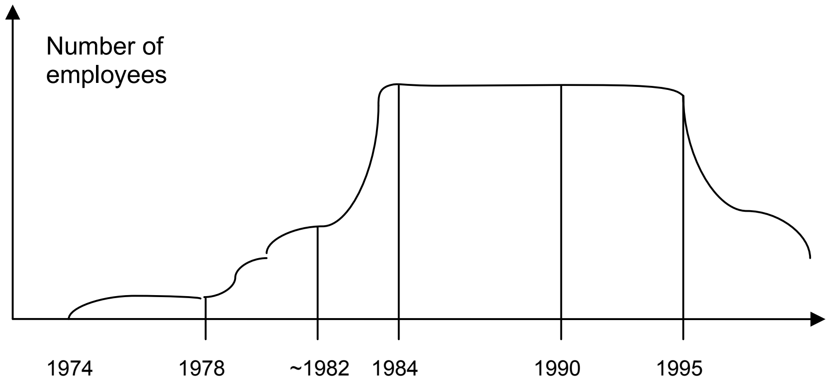

Figure 5-5: Number of employees within optics at Ericsson

Source: Hörstedt (2000).

Thus, to summarize the Ericsson efforts in optics technology in terms of number of employees from the outset until about the late 90s would leave us with a rough estimation according to Figure 5.

Fibers

As for fibers and cables, prices constantly decreased during the 80s. Ericsson Cables could not rest upon Ericsson's internal demand for fibers and cables alone, but was dependent on the demand in the open market. In 1989, a suggestion was made to redirect the operations and put higher emphasis on the area of special fiber applications including e.g. sensors and fiber amplifiers. A research center was established at Ericsson Cables, and in order to get an attractive position Ericsson Cables had to refocus its R&D and build a new laboratory. This was complemented in 1992 with a research center at Ericsson Business Communications (EBC), called ONERC, which was partly sponsored by FMV and would include optical fibers to the home, optical bonding technology and fiber amplifiers. However, reorganizations and profitability problems of EBC made further resource allocation to ONERC questionable, and it was formally dissolved in 1994. Instead Ericsson developed relations with the external supplier Sumitomo for production of prototype fibers.[433] In 1997 Ericsson closed down its fiber production due to costs; however, in 2002 the plant was reopened. The main reasons stated are to keep competence and to secure the long-term need for fibers within the company.[434]

5.2.6 Late 90s – the emergence of a new structure?

In the late 90s after the downsizing of the main actor in the area, Ericsson, new actors emerged on the scene. Many of these were spin-offs from Ericsson, Telia, the universities or ACREO, and there may be several reasons for their emergence. In some cases the downsizing of Ericsson may have triggered the spin-off; in others the booming market, and the amounts of venture capital available in the telecom sector in the late 90s, may have induced firm formation.[435] An international trend of vertical disintegration in the value chain, possibly due to standardizations, increasing technological scope and complexity, may also be partial explanations. The companies can be divided into two broad categories; those concerned with transmission systems, e.g. WDM technology, and those developing subsystems, i.e. modules

[433] Hörstedt (2000)

[434] Ny Teknik, 020315

[435] VINNOVA (2002b)

and components like cables, sensors, and switches etc. Apart from these, there were also an increasing number of operators and carriers, entering the market and building infrastructure, i.e. laying fibers. These, however, will be treated more thoroughly elsewhere.

Within the transmission systems area, three companies were founded: Qeyton, Lumentis, and Transmode. All built their business around WDM, a technology that increases capacity by transmitting more wavelengths, or "colors", at the same time through the fiber. Qeyton was sold in 2000 to Cisco System for 7.3 billion SEK, and in 2002 Cisco closed down operations.[436] Lumentis and Transmode are still up and running. In all three companies, a majority of their founders had previously worked at Ericsson in related areas. In Qeyton, for example, the largest owner was Egnell,[437] who in 1994 was responsible for the TNAL unit at Ericsson.

Within the area of opto-subsystems in Sweden, the scope and number of companies is somewhat larger. On the one hand there are older, as well as some new, companies in the more mature part or lower end of the spectrum, acting as distributors of equipment like diodes etc., and as manufacturers of parts of cables, fiber connectors, fiber splicing and welding equipment etc. Although the more mature part of spectrum, some of these are still relatively knowledge-intensive. Examples include Zarlink (former Asea Hafo), Future Instruments Fiber Optics, etc. On the other hand, several more knowledge-intensive companies were also founded, focusing on components or modules at the state-of-the-art part of the spectrum.[438] Most of the latter were founded from the mid-1990s to early 2000s, examples being: Altitun, its successor Syntune, Optillion, Comlase, Wavium, Proximion, Northlight Optronics (former Ericsson Components), PhoXtal Communications etc. Of these, some have been sold, e.g. Altitun, while others have gone bankrupt and restarted their business, e.g. Proximion and Comlase.

Apart from these, companies have also been founded in areas that border on optical communication. Examples are Switchcore, Dynarc (now bankrupt), and NetInsight. While the former deals with Asynchronous Transfer Mode (ATM), the latter two deal with Dynamic Transfer Mode (DTM), a technology connecting points with a direct line. This makes them dependent on optics technology, although they are not dealing with it themselves.

The companies, and especially some of the opto-subsystem companies, show a slight trend of becoming increasingly systems-oriented. This is in the sense that they are not only manufacturing the hardware, but also are increasingly concerned with the software governing the system and, in some cases, making it compatible with different standards etc. In that process they have also to some degree moved forward in the value chain, selling directly to operators.

As stated above, most of these companies were started by founders with previous experience from one or several of the main actors within optical communications in Sweden, i.e. Ericsson, ACREO, Telia, or the universities. According to a VINNOVA report,[439] and interviews conducted in this study, a substantial part of the original business ideas can in many cases be said to derive from the spun-off organization. According to the same report, as well as stated in interviews conducted with these firms, the relations with former colleagues are often strong, taking on an informal character with dialogues conducted on an unofficial

[436] Ny Teknik 021029

[437] Ny Teknik 021029

[438] See e.g. Ny Teknik, 020320, 020228; Elektroniktidningen, 030901, Evertiq, 020709

[439] VINNOVA (2002b)

basis. In some cases there were formal contracts to make use of the equipment of the parent organization, although often the informal contacts were equally or more important – especially in the early phases in order to get things tested, get fast access to components etc. It is also stated in the interviews that there is a great connectivity among people as the optics area is small in terms of number of people working, and as many of them have worked or heard of each other through cooperative projects etc. The view is also that this is utilized by the newly founded companies, but that interaction among them could be better utilized than today.

These companies today, together with the older players, principally make up the Swedish optical communications sector. While many of these new players initially were targets for venture capitalists in the midst of IT hype, the market for optical components and systems was turned around. Based on a survey to international suppliers of optical components, RHK (2001) reported that sales dropped 27% in Q1 2001 compared to Q4 2000. This was the first drop after more than 12 quarters of double-digit sales increase. In the 2nd and 3rd quarters, sales dropped even more. The reason was a chain reaction following the poor cash flows of operators due to overcapacity and expensive 3G licenses.[440] As these stopped purchasing more systems, system suppliers ended up with a large in-house store of components, depleting the need to buy more, which in turn affected the suppliers of these. This has resulted in harsh times for the new Swedish companies,[441] forcing many of them to cut staff, and in some cases even into bankruptcy.[442]

However, Internet usage has been increasing,[443] leading to increasing Internet traffic. This in turn leads to an increasing future need for capacity, and several market research organizations also predict a market upturn[444] although the timing differs. For the future, many analysts hope that the increasing efforts to offer broadband on a national basis, bringing fiber to the home, as well as trends of sending TV digitally through fiber networks, or multimedia services provided by mobile operators[445] will be likely to drive the system and subsystem industries.

Public support in the 90s

In 1993 the carrier monopoly of Televerket ended and Televerket was instead transformed into Telia. While this opened up for more carriers, it is not clear whether this changed the role of Telia in relation to industry. Telia continues to have cooperative projects with industry and institutes, and also continues to act as a competent buyer of equipment.

Regarding public efforts in areas related to opto-technology, funding decreased after the IT-4 program came to an end. To compensate, there was an additional effort in 1991 called IT-2000 that was mainly systems-oriented. In 1994 the Foundation for Strategic Research (SSF) was founded, and among the beneficiaries are researchers in optics technology and other areas related to communication. In 1999 VINNOVA made a final report[446] to the government concerning a national strategy for strengthening the base of IT and electronic areas, including the area of optoelectronics. A revised version came in 2002. The conclusion was that after a build-up of knowledge in the 80s, the knowledge of industrial production has been phased out

440 KMI Research (2002)

441 Ny Teknik, 20020821

442 See e.g. Evertiq, 20020829, 20021028

443 World Internet Institute (2003)

444 See e.g. KMI Research (2002); RHK (2002)

445 E.g. Ny Teknik 021023

446 VINNOVA (2002c)

at an accelerating speed during the 90s. Specifically in the area of telecommunication it is pointed out as crucial to implement new efforts in competence and resource development, as well as to develop a long-term strategy in order not to lose the position Sweden has gained. Although the IT program was not followed up like the NMP program in the 80s, this may be too harsh a statement on behalf of VINNOVA, as funding was provided to the area in the 90s and 00s (see Figures 5-6). Nonetheless, due to the recession and a plummeting stock market, the funds for directed research efforts have decreased. The Foundation for Strategic Research (SSF) was forced to cut funding for some programs related to the opto-electronic field. Examples are the microelectronics area with a cut in funding of 40 MSEK in 2003, and the program for electronic production (E-PROPER) that was terminated well before planned. They have a program running for high-speed communications, but have been forced to cut funding for other programs related to the opto-electronic field. To counteract what is regarded as a negative development for Sweden in a fast-growing area, a major long-term effort in the area is suggested. However, in late 2003 a three-year 60 MSEK program directed at optical communication was initiated,[447] and SSF is still running a program for photonics and high-speed optical communications.[448]

As mentioned earlier, there were also European efforts providing funding as well as important cooperative ties to international actors. The second phace of RACE, for example, RACE II, was pursued in the context of the Third European Framework Programme (1992-1995). However, in this study we have not been able to ascertain the amount of funding allocated to Swedish actors for efforts in the optical communication area.

Summarizing the extent of public efforts in electronics, microelectronics and related IT areas, including optoelectronics, from the late 70s to 2000 leaves us with the following picture. The period 1979/80-1983/84 is largely constituted by the program for electronic and electro-optical component technology. This was followed by the national microelectronics program (NMP) in 1983/84-1986/87, which in turn was succeeded by the IT program from 1987/88-1990/1991. Both programs, especially the latter, constituted large parts of the government's spending during their respective periods.

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[447] www.vinnova.se

[448] www.ssf.se

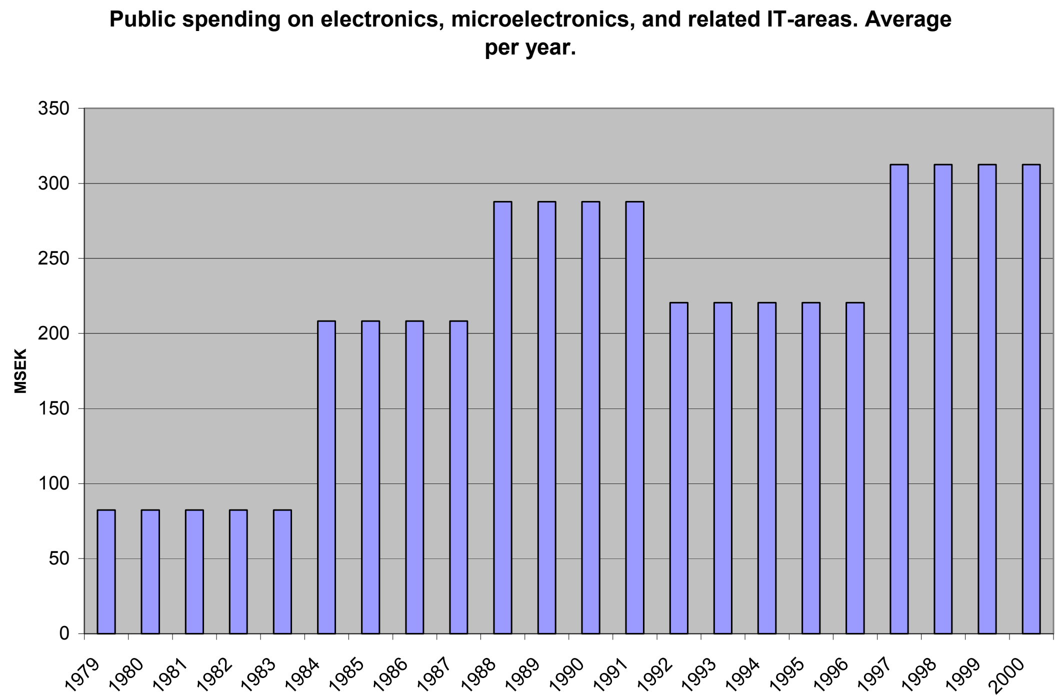

Figure 5-6 Average public spending on electronics, microelectronics and related IT areas, including optics technology

Source: VINNOVA (2002c)

In addition to the public spending presented above, industry has made substantial investments in the area. The exact order of magnitude, however, is difficult to establish. Although Ericsson has liquidated much of its in-house manufacturing capability in recent years, it is still dependent on and interested in optics technology, which is why it still sponsors many such projects in academia and institutes.

In the late 90s and early 00s, the government also adopted a rather aggressive broadband policy.[449] Apart from that, VINNOVA has also made investments in an optofiber lab[450] and a testbed[451] at ACREO with the purpose of developing and demonstrating an infrastructure that makes broadband services possible. The testbed is open to national as well as international companies.

5.3 Analysis

During the past 30 years, optical communications technology has grown into a large business. The following section analyzes the Swedish scene during this period, with references made to international events of importance.

In the analysis, the analytical framework developed in Chapter 2 will be used. Thus, focus will be on important occurrences and developments with regard to the creation and diffusion of new knowledge, guidance and direction of research, the supply of incentives, the supply of resources, the creation of networks, as well as the formation of the market. These categories

[449] SOU (1999:85)

[450] Evertiq, 20001018

[451] Elektroniktidningen, 20030123

are not mutually exclusive, and are also to various extent dependent on each other. However, here the functions primarily serve the function of categorizing the empirical data.

5.3.1 The creation of knowledge

Starting from a small knowledge base in the 70s, Swedish industry in cooperation with academia, institutes, and government, made a remarkable catch-up in the late 70s. This was due to a fruitful meshing of goals on behalf of the different participants, as well as the clear direction of the effort.

From an *industry perspective* the initial goal was to catch up on the international competence level, but in the 80s the aim was set to achieve state-of-the-art competence. Within industry, this was probably facilitated by the transfer of personnel from IM and universities that took place. Towards the late 80s and early 90s there are indications of an increased short-term orientation in the area, for instance in the form of changes in the internal funding system at Ericsson as well as in the opinions of those working there. In terms of number of people employed within the area, serving as a rough measure of the base upon which knowledge is created and diffused, there was an increase throughout the 80s. However, from the mid-90s onward there were substantial lay-offs at Ericsson, and by the early 00s a large part of operations in optics technology had in fact been liquidated or sold off. At about the same time, several new companies were founded and rapidly expanded. But in 2001-2002 these new companies were affected by the market downturn, and most had to drastically downsize their businesses.

Within *universities and institutes* a further pursuit after the Cooperative Project was eased by the national programs started in the area. This especially helped IM to expand its commitment and reach a critical mass in terms of number of employees. Toward the late 80s there was an increasing concern on the university and institute side with choosing the right areas of research for which an increased involvement of end-users was demanded. This may be an indication of an increased short-term, or applied, orientation also within universities. If so, it would follow a general trend in the public funding system.[452] In the early 90s, the transformation of IM into IMC was followed by a near-halving of staff. When IMC merged with IOF into ACREO in the late 90s the number of employees rapidly increased, partly as a result of transfers from Ericsson, to a little bit over the level of the early 90s. On the university side it is less clear; roughly the same funding levels, coupled with possibly increasing difficulties of obtaining long-term funding in the 90s, should indicate that the number of employees has not increased substantially. Nonetheless, the scope of operations at Chalmers has increased almost threefold since the early 90s. Regarding what kind of knowledge is created, this may have become somewhat more specialized, and at the same time more interdisciplinary as the underlying technologies have become increasingly complex and the scope of applications has broadened.

From a *government* perspective, Televerket supported the initial effort financially and with some staffing. The government also supported the effort through STU with both financing and planning, and did so increasingly with the efforts in the 80s. From the early 90s on, funding levels have remained roughly the same, although there have been less directed efforts and funding may have become somewhat more short-term oriented. Regarding level of employment within optics technology at Televerket, or Telia, no such numbers have been

[452] Elzinga (2002)

found. Of late there seem to have been some programs initiated by VINNOVA and SSF directed more specifically to optics technology.

Thus, from the late 70s throughout the 80s, funding increased on behalf of all actors, leading to an overall expansion in terms of number of people employed in the area. That state-of-the-art knowledge was reached is confirmed by statements from persons involved as well as by news articles stating world-class competence on behalf of Swedish actors. A further assessment could be made by investigating patents and publications in the area. Presently, however, it is likely that, in spite of an increase of personnel at ACREO and some new jobs created within the newly founded companies, the total number of people in the area has decreased during the past ten years. This, coupled with a lack of the longer-term funding programs in the 80s, may negatively affect the base upon which knowledge creation and diffusion takes place in Sweden.

5.3.2 Guidance and direction of search

At the point of departure of the Swedish optical communications effort, the direction was clear as fiber already had proved itself internationally, and standards for the first generation had been set. The aim was not to leapfrog but to catch up.

As for the technological choices, during the 80s these have primarily been directed at becoming faster and cheaper in the long-haul and metro networks, that is, improving on the cost/Gbps/km ratio. There are different ways of doing this, e.g. through improvements of lasers, fibers, or ways of packaging data. While the long-haul and metro networks have cost structures driven mainly by the cost/Gbps/km ration, the last-mile solutions that are being increasingly promoted have a slightly different cost structure, as the cost/subscriber becomes more important. This also reflects a need for different underlying technological choices. For example, instead of high-performing lasers, focus is more on lasers that are cheap and easy to manufacture and install. This may receive increasing attention, as the government in recent years has come to address a rather aggressive broadband policy which is likely to guide and direct research increasingly toward last-mile solutions.

Technological choices are to some degree also affected by standards. For packaging data, the SONET/SDH standards emerged in 1986/87 and were soon to be followed by more standards, or protocols, like ATM, and Ethernet etc. These are likely to affect especially the software solutions surveying the data transmission in the networks. Regarding the hardware, some choices are made due to physical restrictions; others emerge as standards. One recent example is CWDM compared to DWDM, where the former has been regarded as cheaper but less efficient than the latter. In 2002 a standard emerged for CWDM that set the interface for transmitter, receiver, and WDM.[453] While there is yet no standard for DWDM, the CWDM standard enables components to be made by different suppliers, thus making mass production and even lower prices possible. As the two technologies are competing in some areas, this standard and the possibilities it enables may very well tip the balance in favor of CWDM, in those areas where the technology is sufficient for the requirements.

Standards may also affect technological choices on a more aggregated level. As standards allow specialization, it becomes increasingly difficult over time to maintain expertise and cost efficiency in all areas of specialization. That this has taken place in the optical communications industry may be indicated by the vertical disintegration within industry, both internationally and nationally. Nationally, it may be one explanation for Ericsson's choice to

[453] Elektroniktidningen, 20031121

offer more system services to operators[454] rather than supplying everything from components to systems. However, it is not clear whether it may have affected choices of specialization within Swedish universities and institutes. Somewhat related, but also partly independent, is an increasing concern with the software, rather than the hardware. Increasingly, many of the new companies have become more concerned with the software governing the system than the hardware making up its base. This is also a difference between industry and universities, because as the former is more concerned with a system-to-network level, universities are more often interested in the component-to-system level.

As for the choice of market, this may have been obvious for Ericsson given its history in communications, and also for the companies spun off from Ericsson. However, for many of the companies spun off from universities and institutes, the telecommunication area was by no means an obvious or the only choice of market, as their technologies at times had a range of other application areas. Although it is unclear how many as a matter of fact did choose other industries, it is likely that those who chose the telecommunication market did so partly as a result of the booming market and venture capitalists' interest in it.

5.3.3 Supply of incentives to innovation creation and exploitation

Apart from the advancements on the international scene, which set the pace also for the Swedish actors, the interest shown by Televerket was an important reason for the escalation of the Ericsson commitment in the 70s. This interest persisted in the 80s although Televerket still had no direct need for more capacity. The basic incentive for Televerket was rather to invest in order not to renovate its old copper network. As the Swedish market is relatively small, an increasing international market in the area was probably an additional incentive for the escalating operations of Ericsson.

In the 90s Ericsson became more short-term oriented, and eventually came to liquidate or sell off a large part of its operations. This was due to a worsening economic climate and thus increasing concern with costs, and the judgment that returns on investments were too far in the future. That is, it would take too long before complementary technologies and the network itself would be developed to the degree that commercialization would be possible, to justify the investments. As mentioned above, the downsizing may also be attributed to the increasing, international trend toward specialization in the value chain, indicated for example by Ericsson considering itself too small to legitimize major efforts in manufacturing components and WDM system, instead focusing on serving operators with systems and services. An additional explanation given is that those ultimately responsible for the decisions concerning optics technology came from other areas within Ericsson, e.g. cellular phones, and thus did not have enough knowledge of the field to make the right decisions. Other areas thus became prioritized. However, as indicated by the funding of different projects, Ericsson still has a high interest in optics technology.

At about the same time as the market for optical fiber installation exploded, the Swedish venture capital industry took off. Both these occurrences, in some cases also coupled with the downsizing at Ericsson, provided incentives for new companies to form and explore new technologies within the area of telecommunication. It is difficult to say whether or not the essential lack of a Swedish venture capital market prior to 1996 made any difference to the timing of many of these start-ups.

[454] Ericsson press release, 20030117

However, as much as the market was driven by actual investments in infrastructure, these were in turn primarily driven by expectations of increases in traffic. This led to expectations of faster employment of new technologies than was actually the case. As a result, many new companies received large investments in technologies that were ahead of needed complementary technologies in the physical infrastructure, as well as ahead of actual demand.

The appropriation of value has also provided incentive as well as direction for some of these companies. As there are larger values to be appropriated the closer to the operator in the value chain, a trend among some of the new companies is to move forward to sell directly to operators. Consequently, there is also an increasing system-orientation leading to an increasing focus on the software governing the hardware developed. Another issue regarding appropriation of value is the extent to which it is possible to protect the solutions through intellectual property rights. This has probably been a prerequisite for Ericsson and Telia to develop solutions etc., and for new companies in order to attract capital. However, more important is the issue of the technologies that make up the basis of the different standards used in the industry. Despite its importance, the scope of this report does not reveal whether there are crucial patents needed to license in order to compete in this market.

As well as incentives, there may also be disincentives. For the small firms, these disincentives mainly relate to the costs of engaging in this business, i.e. the costs of getting certifications, of buying or getting access to testing equipment, and tax issues in general relating to small businesses. For Ericsson, competition from international, more specialized actors in the value chain may have been one reason for the decision not to engage as much in the optical components industry, instead focusing on providing system services for operators.

5.3.4 Supply of resources

5.3.4.1 Funding

At the outset of the Swedish optical communications industry, funding from industry was mainly provided by Ericsson. Ericsson's funding increased throughout the 80s, to decline in the 90s, although it is difficult to assess the order of magnitude. While large parts of their business operations have been liquidated or terminated today, Ericsson is still interested in optics technology and is thus still supporting different projects, for example the ACREO testbed. In the mid-90s, as noted, the Swedish venture eapital industry took off and together with a booming market this enabled the foundation of several new firms. What is clear, however, is that the Swedish venture capital market was alone not sufficient to get them going, for the vast majority have attracted international funding in later stages.

From a government perspective, funding actually decreased during the early to mid-70s. But from the late 70s and through the 80s, the government increased its funding through STU, although it is difficult to assess the exact amount dedicated to optoelectronic research. In 1994 additional funding institutions emerged, of which for example the Foundation for Strategic Research has supported projects. While the funding from NUTEK (former STU) remained on roughly the same levels, the possibilities for researchers to obtain long-term funding may have been affected somewhat, something that has been a general tendency in public funding policies.[455] Of late, however, some new programs have been started, and ACREO has also gained more funding. The state-owned company Televerket also made important funding contributions at the outset of the industry, and has continued to fund its own as well as cooperative research programs. Again, it is difficult to say anything about the order of magnitude.

[455] Elzinga (2002)

Apart from funding within the national system, funding has also been provided through joint international programs, especially those funded by the EC in which Swedish actors participated. Although we have no exact figures on the amounts, their importance is likely to have increased from the mid-80s onwards. This is partly because the national programs might have been better formulated to incorporate such elements from that point on, and partly because it was from the mid-80s onwards that the greater European efforts were initiated.

5.3.4.2 Skilled labor

At the outset of the Swedish optical communications effort, resources in the form of knowledge or educated individuals were of vital concern. Within the area of sensors, there was some knowledge within universities that could be drawn upon, but for the most part knowledge had to be built "in-house". On the research side, this was achieved through the Cooperative Project, and with subsequent increased funding through the various programs. This, among other things, led to IM reaching a critical mass in the late 70s. The increased funding through the programs is also likely to have had a positive effect on the number of PhD students in the area. On the educational side, both NMP and the IT program also address educational matters; it is however unclear to what extent optics technology was reflected in the teaching at university levels. Starting in 2003 a master program in photonics is held by the joint Kista Photonics Research Centre.

As mentioned before, the base of skilled workers may have decreased somewhat during the late 90s, mainly as a result of liquidations by the main corporate actor. The transfer of some of them to ACREO may, however, again have helped ACREO to reach something of a critical mass after its lay-offs in the early 90s. In spite of the funding climate, there may also have been an increase on the university side in the 90s.

5.3.4.3 Physical

The directed national programs in the 80s provided capital for the build-up of laboratories in universities and institutes. Laboratories were also built up within Televerket and Ericsson, and in the latter case production facilities were also built up. In the 90s further investments have been made in laboratory resources in industry as well as in universities and institutes. However, the liquidation of Ericsson's optical communications business also meant that parts of the production facilities were closed down. The extent to which this has happened is unclear, but one example was the fiber production unit in Hudiksvall which was later reopened on a smaller scale. Recently VINNOVA as well as Ericsson has sponsored a testbed at ACREO, open to national as well as international companies. This may be of great importance for the testing and further development of new technologies.

As these laboratory facilities and testing equipment are expensive, it is difficult for new companies to purchase or build them. In some cases the closeness to former organizations has been beneficial as agreements of using equipment were established, or as former colleagues helped. In other cases they have been able to buy equipment cheaply from their former organizations. With the downturn of the market, equipment has of late also been possible to obtain at low cost from liquidated companies.[456]

5.3.5 Creation of networks and its effects

The Cooperative Project formed a network of contacts that prevailed far beyond the completion of the project. This network has probably been reinforced and extended since

[456] Evertiq, 20011018

then, through continued joint efforts during the 80s and 90s where collaborative research projects sometimes involved people from the different actors working at each other's premises. The many collaborative projects throughout the industry's history, and the fact that there are few actors as well as a relatively small number of people involved in the area altogether, suggest that there is a good connectivity within the borders of Sweden. This is also confirmed in interviews with founders of some of the new companies, stating that they know on a personal basis, or know of, a large part of the people in this area. The networks also extend abroad, primarily in those settings where international collaborations are common, i.e. universities, institutes and research departments within Telia and Ericsson.

With the emergence of a slightly new industry structure, this may change. As the number of actors increases, and on the industry side they become smaller, there may not be as frequent opportunities for collaborative projects. Although there is connectivity between the newly founded companies, and in some cases they also help each other, there is an opinion that these ties could be better utilized given the similarities between many of the companies' businesses. This is not to be understated when it comes to, for example, issues of putting pressure on standardizing agencies, regulative authorities etc.

Regarding organizations and conferences, there is an emerging photonics cluster, although it is unclear whether there is any formal organization apart from KPRC to back this. On the university side there are symposiums etc. The power and ability of these to affect, for example, government policies and standardization agencies are, however, unclear.

The effects of these networks are difficult to assess. Supposedly, both Ericsson and Televerket benefited from their cooperations in that they could learn needs and possibilities, valuable for developing new products and becoming competent customers respectively. For the new companies, the connections with former colleagues etc. certainly were important in order to get access to testing equipment, to get people running tests, or to get quick access to components etc.

5.3.6 Formation of markets

When the effort started in the mid-70s there was no market yet, nationally or internationally, but rather the promise of one. In Sweden, this promise of a market was largely a result of Televerket's demonstrated interest and subsequent support. Through the 80s the market grew and took off, owing much to the capacity of the new technology and to actual as well as projected demand. The opening for competition of the US long-distance telephone service further spurred development. In Sweden this took place in 1993, bringing more carriers to the market, something which has spurred the subsequent increase of optical fiber installations here too. As there are strong technical dependencies, this in turn spurred the optics systems and components industries as a whole. Telverket has also been an important local customer to Swedish firms, and probably has continued to be one after becoming Telia. However, although providing a first step, the Swedish market alone is probably not a big enough market.

Apart from demonopolization, government policies can impact the types of networks developed, and ultimately the sales of optical components. Sweden has adopted rather aggressive national broadband policies, increasingly promoting last-mile, or fiber-to-the-home, solutions. To the extent that this differs from the long-haul and metro network markets, new markets may be forming with possibly slightly different actors.

Another aspect affecting the formation of markets is the aforementioned industry structure. In the early days, there were mainly large companies that were highly vertically integrated. Ericsson, for example, made fibers in-house as well as developing and manufacturing components. However, over time and possibly due to standards, industry maturity, increasing technological complexity etc., the different actors have become more specialized in different parts of the value chain. As the value chain becomes vertically disintegrated, this makes formerly internal markets external. Within Ericsson, this seems to have taken place around the mid-90s, and abroad a couple of years earlier, as indicated by the number of new firm formations in the area. In the wake of this, a range of new companies started.

5.4 Discussion

The previous section analyzed the situation over the years with regard to functions important for making an innovation system operate. The extent to which one operates today will be focused upon in the present section, with reference to the historical trajectory when necessary. Thus, to what extent is there a system today and to what extent are there important functions missing in that system? As the different parameters used for analysis often are strongly interdependent, the discussion will relate the different functions to each other.

There are two aspects regarding the notion of a system. Firstly, in the optical communications area, there are obvious technological systemic effects, as some technologies are dependent on others for the sake of their own commercialization. The second is the issue that will be discussed more at length here, i.e. the extent to which the actors themselves constitute something that could be labeled a system. This is contingent partly on the first issue, but also on other factors. Important to note is which parts of the system have been designed, and which parts evolved over time.

Regarding the creation of knowledge, both within industry and universities there seems to be a high level of competence. This has partly been created through deliberate efforts. Although funding in the 90s appears to have been somewhat less structured than before, this may have changed now. The numbers of employees today within universities and institutes are the same, or have increased, suggesting similar levels of knowledge production as before. In industry, however, the numbers have decreased somewhat, which may affect the extent of knowledge production. Moreover, the structure has changed somewhat as Ericsson has downsized while new companies have emerged. As these companies often are focused, at the moment at least, on getting products into the market, this may affect the total amount of research performed within industry. Regarding the types of knowledge produced, there are indications that universities focus more on component-to-system aspects, while especially Ericsson and Telia are more concerned with system-to-network aspects. Another important factor in the creation and especially diffusion of knowledge is the extent of networking and collaboration within industry as well as between industry, academia and institutes. There seems to have been a rather dense network in this industry, given the many cooperative projects and the relatively small number of actors and people engaged which probably has supported the networking. Again, however, this may change with the new, more fragmented structure. Moreover, this aspect is probably not as easily designed but rather something that evolves.

As for the direction and guidance of search, efforts seem increasingly to be guided toward the access network, which on the other hand is really nothing new. This is reflected in both industry, with the involvement of Ericsson in some projects, and universities where especially Chalmers conducts research on the low prices of components needed in order to justify future implementation. This particular direction is so far primarily supply-driven, that is, by industry and government policy. A more demand-driven development probably requires further stimulation of services to be used in these networks. As for the long-haul and metro networks, developments in their respective underlying technologies have probably been driven primarily by the cost structure, as well as by too high expectations. The resulting boom is also a likely cause of attraction of some of the new start-ups in the industry, as telecom was by no means the only application area.

Closely related to what directs search is the supply of incentives. As for the access network, these partly derive from the government broadband policy, and partly from increasing demand for capacity, although this demand has not increased as originally projected. However, there are also some disincentives present in the industry. The market is still waiting for an upturn to come; the venture capital industry is licking its wounds and is reluctant to make early-stage investments. This may hamper new investments, because although not sufficient for later-stage financing, such capital fills an important function in first-round financing. Besides, although the Swedish government has promised to help people who had to leave Ericsson to find new jobs, or found their own businesses etc., starting a new business is still costly in terms of equipment, certification etc. So while Ericsson's decision to lay off parts of its value chain may have been sound from some perspectives, in order not to lose those parts of the industry totally the situation for small-firm formation and development must be investigated more thoroughly in order to be able to support this correctly.

The present supply of resources seems to be fairly good. As mentioned above, some directed programs for 3-5 years seem to have been initiated lately with funding from VINNOVA and foundations. There is also a skilled base of labor to draw upon, and within industry there may even be an oversupply of labor. Regarding education, improvements have apparently been made recently as a new master's program has started in photonics. One may, however, ask why this has not come about earlier. In terms of facilities, government and industry have supported the building of laboratories as well as a testbed, and especially the latter is perceived to have a great potential value for firms in industry. Again, one might consider the demand for and availability of physical resources on behalf of the new entrants. Another potential resource that may be in shortage is production facilities for components. This issue is, however, not clear from the present report and thus needs to be further investigated.

As mentioned above, there is a relatively dense network within this industry. That is, there are relatively few individuals engaged and a relatively high degree of connectivity or knowledge of each other. However, while the number of actors was relatively concentrated before, the industry on the component-to-system level has become a lot more fragmented today, something that may affect this network. There are statements that it could be better utilized than it presently is. Lately an interest organization, Kista Photonics Research Centre, as well as the talk of the Photonics Cluster, may be counteracting this and facilitating further interaction. These networks have evolved over time, possibly with the help of various cooperative projects, and are moreover likely to have been valuable for the spread of knowledge, and for the increase of understanding between suppliers and distributors as well as between industry, academia and institutes etc.

Finally, the stimulation of the market for optical communications is ultimately dependent on the stimulation of demand, that is, on stimulation of traffic that will increase the need for more capacity. This could for example be promotion of broadband services, mobile data services etc., although likely to lie ahead in the future. The stimulation of the demand is further dealt with in other parts of this study. As for the new markets that have opened up as the industry has been vertically disintegrated, the stimulation of these is also dependent on the environment for creating new businesses in general in Sweden.

5.5 Conclusion

Although a more in-depth investigation of the different functions discussed here is needed, the present study suggests that the situation of today provides a good base to build upon. The industry fulfills much of what the literature would label a system, although the system seems to undergo something of a transition from one structure to another. This is apparently the result of a maturing industry that allows more specialization to be made in the value chain. However, in order not to lose the competence that has been built up, it is important to support the new industry structure in Sweden. The new companies formed, as well as the companies potentially to be formed, should be assisted so that more specialized actors can grow and possibly make up for some of the areas where Ericsson has decreased its attention.

6 EVOLUTION OF DATACOMMUNICATIONS

Sweden has been in the forefront of both telecom usage and telecom equipment manufacturing since the early days of telecommunications (see Chapter 4). But in spite of the strong position in telecom, Sweden has not secured a strong position in the Internet field (apart from Internet usage, where Sweden is one of the leading nations). This chapter aims at exploring the international and Swedish development in the data communication and Internet field, and to provide answers to why the country could not leverage its telecom competencies in the emerging and related area of data/computer communications.

6.1 The early history of data networking – US developments

In this section/chapter, a brief description of the history of the Internet is provided.[457][458] The history starts with the US developments, followed by early European computer communications activities, and the introduction of Internet/computer communications in Sweden. Although Asia has developed a strong position in the consumer electronics area, the successes within Internet technology seem to have been modest, with lower penetration than in Europe and the USA and a small share of Internet equipment sales. In the emerging field of mobile Internet, however, the picture is different, as described in Chapter **Error! Reference source not found.**.

6.1.1 The birth of Arpanet

The history of the Internet is closely interwoven with the histories of semiconductors and computers. The development of the transistor by Bell Labs (research arm of AT&T) after WWII laid the foundations for an electronics industry during the 1950s.[459] Technological development was rapid, and the integrated circuit was invented in 1958-59, paving the way for computer developments. With computing capacity being a scarce and costly resource, in combination with an increasing number of computers at physically separated locations, the need for communication capabilities between computers arose.

Around 1960 data communication over the public (and private) telephone network using modems was introduced in the US. Modem usage increased rapidly in the 1960s, in line with the introduction of more telecommunications-oriented computers.[460] The predecessor to today's Internet, ARPAnet, was born in the USA in 1969. The arms race during the Cold War had compelled the USA to develop a communications network for efficient knowledge distribution among researchers. In addition, researchers, e.g. Paul Baran at the think-tank RAND, elaborated on the idea of constructing a network able to withstand targeted attacks on the infrastructure.[461] The chosen technical solution was based on sending information in small data packages. Until then, telecommunications had been circuit-switched, meaning that during all connections there exists a closed circuit between the sender and receiver. In packet-switching technologies, small packets of data share the network lines with other packets. In this way, the use of bandwidth can be optimized.[462] In order to make use of the packet-switched solution, new network architecture was introduced. Traditional telecom networks

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457 This chapter has been written by Erik Andersson.

458 The history of the Internet is fairly well documented (see e.g. Mowery and Simcoe, 2002). Nevertheless, it is important to summarize the developments here in order to understand the context and implications for the Swedish developments.

459 See e.g. Langlois and Steinmueller (1999) for an analysis of the developments in the semiconductor industry.

460 Lernevall and Åkesson (1997:447)

461 Mowery and Simcoe (2002)

462 Edquist (2003)

had been designed as hub and spoke structures, with the intelligence placed in the switches in the hubs. The Arpanet instead connected computers in a web structure, with redundant communication channels. Each data packet has a “header” containing information about the receiver, directing the package through the routers along its way.

In order to build a packet-switched network, new types of switches able to handle packets were required. The work was carried out by the small engineering firm Bolt, Beranek and Newman (BBN), sponsored by the Defense Advanced Research Projects Act (DARPA). This was a matter of public procurement; ARPA placed an order on a technology that did not exist at the time, but which both parties thought viable to develop. The developed switch was called IMP (Interface Message Processor), and could link several computers to one another. In 1970 a packet-switched network of computers, using IMP switches, connected three American universities and a research institute.[463] The network grew quickly and, in 1972, 40 geographical sites were connected to the ARPAnet (growing to 100 in 1975). The File Transfer Protocol (FTP) was introduced for easy transfer of files between computers, of high utility in the open academic world.

The ARPAnet was not the only computer network at the time. Large companies, predominantly in the finance and insurance industries, had built computer networks connecting retail offices with their main computers. Although most computer networks were circuit-switched, there were other packet-switched networks being built. In 1973, DARPA financed an investigation called “The Internetting Project”, looking into the possibilities of connecting different packet-switched networks to each other. In 1974 the protocol TCP (Transmission Control Protocol) was developed by Vinton Cerf and Robert Kahn, sponsored by DARPA.[464] The TCP simplified routing, eliminated the need for IMPs, and allowed physically separated networks to interconnect with each other.[465] Later on, the TCP was split into two parts, TCP and IP (Internet Protocol), today de facto standards for Internet communications. Simplified, the TCP defines how data is transmitted and IP how data is addressed on the Internet. An important aspect of the explosion in usage of TCP/IP is the fact that the protocol, in contrast to the proprietary protocols existing at the time of the launch, is provided free of charge. The culture and attitude of supplying major Internet-related inventions free of charge can probably be traced to the network’s origins in the academic community. According to Mowery and Simcoe (2002) the TCP/IP becoming a de facto standard owes much to the decision by the National Science Foundation (NSF) to adopt the protocols as standards on its university network. This helped create a large installed base, resulting in considerable network externalities for future adopters.

The connection to ARPAnet was not available to all universities and institutions at the time. In 1979, actors standing at the side of the ARPAnet development started the CSnet (Computer Science Research Network) to make use of the advantages of easily sharing information electronically. In 1982, a bridge between the ARPAnet and the CSnet was developed, creating a network of networks. The following year, in 1983, the ARPAnet was divided into a civil part (ARPAnet) and a military part (MILnet). The US military wished to separate the military computers from the ever-increasing number of civil computers on the network. The same year BITNET (Because It’s Time Network) was started, backed by IBM and NSF.[466] The network

[463] The first universities connected were UCLA, UCSB, Stanford Research Institute and University of Utah

[464] Mowery and Simcoe (2002)

[465] Edquist (2003)

[466] Castells (1996)

centred on the service Listserv, a discussion forum distributed via e-mail which became a success.[467]

In 1990 the ARPANET was terminated. The traffic had by then largely transferred to NSFnet (National Science Foundation Network). This network was started in 1986 with the task of connecting the USA's six supercomputer centers. At the start, NSFnet had a strict usage policy hindering use of the network for commercial activities.[468] This usage policy served as a catalyst in the development of private Internet backbones. From 1987 to 1989, CERFnet, PSINET and Alternet UUNET became major providers of Internet connections for commercial users.[469] By the year 1995, the core network infrastructure of NSFnet was transferred into private hands when NSF handed over control of its four major Network Access Points to Sprint, Ameritech, Pacific Bell and MFS.[470]

Although more successful in the USA than elsewhere, until the early 1990s Internet usage remained a matter for academics and corporate research functions. Propelled by the high penetration of PCs in the US, Internet usage exploded in the 1990s, reaching penetration levels of 25% in 1998 and 43% in 2001.[471] In 2000 around 67% of the Americans used the Internet, increasing to 72% in 2001, and stabilizing at 71% in 2002 (a statistically insignificant reduction).[472] The figures indicate near-saturation in terms of numbers of users.

6.1.2 Value-added data networks

Value-added packet-switched data networks appeared early in the USA. In the mid-1970s the company BBN (see above) created the Telenet, the first publicly available packet-switching data network. The network was unprofitable and sold to GTE. In 1983 it connected about 2000 host computers, and in 1984 an average of 200,000 sessions daily. Another such network, Tymnet, was started by Tymshare to allow customers to time-share expensive computers. The initial time-sharing utility for customers turned out to decrease as inexpensive mini- and microcomputers were introduced. The Tymnet was acquired by McDonnell Douglas, which in turn sold it to British Telecom in 1989.[473] Both the Telenet and Tymnet later expanded their networks into Europe. Other important computer communications networks in the USA during the 1970s included PCI, Cybernet and General Electric Mark III. Although privatively owned, the large networks, including research networks, often had public characteristics.

In the late 1970s, most telecom companies in the USA provided data communication services similar to those provided by European telecom operators. US activities were, however, more open than European, with users allowed to e.g. connect privately owned equipment not always fulfilling CCITT's recommendations. The US telecom companies did not run any public data communication networks as the European operators did. The FCC (Federal Communications Commission) had decided that data traffic should be handled by computer users, computer power suppliers etc., and telecom companies were restricted to providing the communications resources: the telecommunications lines.[474] This opened up for a competitive market in the data communications field at an early stage in time. In 1986, the Computer III

[467] Sturmark et al. (1997)

[468] Sturmark et al. (1997:28)

[469] Mowery and Simcoe (2002)

[470] Mowery and Simcoe (2001)

[471] SIKA (2003)

[472] UCLA (2003)

[473] Noam (1992)

[474] SIND (1978:1)

ruling from the FCC established the network concept of Open Network Architecture (ONA). ONA is a framework for disaggregating network components to permit open access. The underlying assumption is that all central office functions consist of components or Basic Service Elements (BSEs) and that these components can and should be unbundled. Providers of communications services are allowed to use different BSEs, or different configurations of them. The open network architecture permits third parties to use the building blocks of their choice when providing services to end-users.[475]

6.1.3 On-line services and Videotex

Parallel to the academic computer network development, another, more consumer-oriented development took place. In line with the diffusion of microcomputer and, later, PC usage, the users began connecting to each other through the telephone network. Already in 1979, Compuserve launched the first commercial on-line service. Several companies followed Compuserve, connecting users to computer networks with content services using dial-up modems. In 1990, Compuserve was the leading on-line service provider, counting 620,000 subscribers, followed by Dow Jones News Service with 400,000 and GENIE with 150,000 customers. The on-line services were accessed using microcomputers and modems, often via packet-switched networks as Tymnet or Telenet. The rapid decline in costs for monitors and computers made such equipment accessible for ordinary people, and 6.5 million of the total 27 million microcomputers in the US in 1990 were equipped with modems.[476] Initially, these networks were independent of the NSFnet. During the early 1990s, a number of small players emerged, providing dial-up connection to the NSFnet. The American telecom deregulation had separated long- and short-distance telephone operations, with local telephony offered at flat rates. This provided an opportunity for providers of on-line services. Using a modem pool and a high speed Internet connection, Internet services could be offered to customers at a low fixed price.

At the end of the 1980s, computer BBSs (Bulletin Board Services) became popular in the US, following the increase in PC usage. A BBS is a computer or application set up to share information and files, and exchange of information, accessed through modems. The BBSs were often dedicated to particular subjects. According to Noam (1992), there were an estimated 25,000 BBSs in the US in 1988, each run by an individual or an organization.

Networks based on the Videotex standard developed by European PTTs (see section 6.2.1) were introduced in the US in the first half of the 1980s, without much success. A second wave of Videotex networks came in the late 1980s. The most notable was Prodigy, aiming at PC users with a user-friendly system. Prodigy had attracted around 1 million members by 1991, although many of these were inactive.[477]

Mostly companies from other industries than the telecom industries were active in the Videotex projects in the USA. Media houses and publishing companies, e.g. Time Inc., NY Times and Times Mirror, were heavily involved, and the networks were run on a commercial basis. This was markedly different from the development in Europe, where the PTT monopolies were the main actors in the Videotex field and government subsidies were plentiful (see section 6.2.1)

[475] Noam (1992)

[476] Noam (1992)

[477] Noam (1992)

6.1.4 The Ethernet

Computer networking on a smaller scale, within offices, also appeared in the 1970s. At PARC (the research arm of Xerox), the world's first laser printer was developed in the early 1970s. In order to fully utilize the fast printer, it needed to be connected to several computers inside a building.[478] In search of a solution to this problem, Robert Metcalfe, a young developer at the research center, and David Boggs, a Stanford student working at PARC during the summer, co-invented the Ethernet in 1973. The name stems from the belief that the transported data would come from all sorts of media.[479] Xerox chose to out-license the technology cheaply (a one-time USD 1000 charge), and work through the IEEE to develop product standards. The low price and the wide acceptance of the technology created through IEEE caused Ethernet to diffuse rapidly in small corporate computer networks, so-called local area networks (LANs). The widespread use of corporate and academic computer networks in turn worked catalytically for the diffusion of Internet when users wanted to interconnect separate networks. Metcalfe later co-founded 3Com, today one of the main actors in Ethernet communication equipment.

The use of Ethernet has continued to grow, and is today the de facto standard for office computer communications. The technological developments have increased communication speeds, reaching gigabits per second, so-called Gigabit Ethernet. In 2003, the cost of Ethernet equipment handling these speeds has come down to levels low enough for wider adoption. Despite the harsh economic climate, shipments of Gigabit Ethernet ports increased 38% on the previous quarter in Q3 2003. The market leader is Cisco, followed by 3Com, HP, Nortel and NETGEAR, all North American companies.[480]

6.1.5 Internet Equipment, software and content

The early development of networking technologies in the USA gave the country a head start in developing equipment for the networks. The fast-growing use of computer networks in the US caused small start-ups as well as large computer actors to innovate in the networking area. During the 1970s and 1980s, established computer firms such as IBM and DEC developed both communication equipment and proprietary computer communication protocols that diffused widely. In Sweden, as an example, DEC technology was chosen when the national university network was modernized in 1985, since all the computers to be connected were manufactured by DEC. The firms that eventually came to dominate the computer networking market were companies started in the 1980s and 1990s to exploit the opportunities of open standards, e.g. TCP/IP and Ethernet. Between them, Cisco, 3Com and Bay Networks (today a part of Canadian Nortel) have a strong grip on the market for computer communications equipment. According to Mowery and Simcoe (2002) the large domestic market in the US provided a stable ground for US firms to propel into world computer-networking market leadership, a development similar to how US packaged-software firms leveraged the US domestic PC market in the 1980s. US firms have reached dominant positions in almost all parts of the computer value network. Industry leaders in the areas of PCs (Dell, HP/Compaq), computer processors (Intel, AMD), and operating systems (Microsoft) are all US companies.

Also in the field of Internet content, US firms have climbed to world-leading positions. Amazon, ebay, MSN, Yahoo, etc. are all brand names of companies recognized globally. Google is almost synonymous with Internet search engines, helping users to browse the multitude of available information. In line with the increased Internet usage, browsers, tools

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478 CIO Magazine (1999/2000)

479 Economist (2003b)

480 Dell'Oro Group (2003)

to help structure the abundance of information available, emerged. In 1993 Marc Andreesen released the first version of Mosaic that became widely adopted, which in turn drove up the usage of HTTP (see below for an explanation of HTTP). Marc Andreesen was later to develop the widely diffused Netscape browser. Between them, Explorer (Microsoft's answer and the market leader of today) and Netscape today have a near-monopoly on the Internet browser market.

In summary, US firms today hold market-leading positions in most parts of the Internet industry, with associated software and equipment. In Figure 6-1 an overview of some important developments in the Internet history is provided.

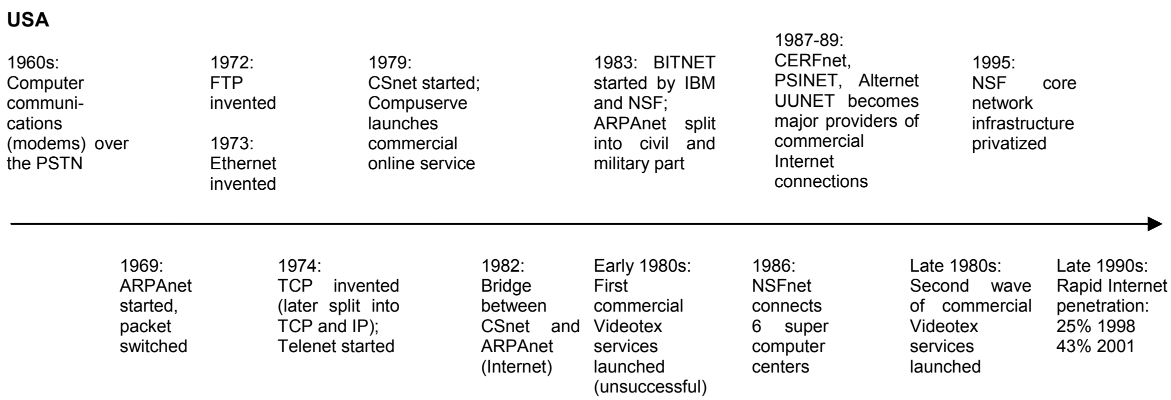

Figure 6-1: A time line of important developments in the Internet's history

6.2 Data Networking in Europe

Computer usage increased also in Europe as in the USA in the late 1960s, and the need to interconnect computers called for computer networking solutions. Although the Internet most often is regarded as an American invention, European initiatives in the early life of Internet played an important role. Mowery and Simcoe (2002) note that computer networking development from the beginning was an international effort, and that a number of European countries early on established experimental networks. Already in 1967, some years before the ARPANET was constructed, the British researcher Donald Davies developed a packet computer network, the National Physical Laboratory Data Network. The network was developed with civilian rather than military motives, perhaps the reason why funding turned out to be the network's major barrier and restricted the network to a single node.

A French initiative based on the ARPANET developments, called CYCLADES, was built in 1972, led by Louis Pouzin. The aim was to interconnect a number of French Government databases, but met with funding difficulties and was eventually shut down in 1978.[481] Although the network was no commercial success it was technologically important. One of the technical achievements was the datagram, used in the IP standard.

The fact that the European PTTs saw computer communications as a future threat and/or growth area is indicated by a large market study jointly ordered by 17 national operators in the early 1970s, examining market and technology trends. Since computing and processing capacities were scarce and costly resources, but in high demand in the 1970s, there were

481 Mowery and Simcoe (2002)

strong incentives for creating effective data communication networks. Several computer networks were taken into use during the 1970s, international as well as national. The SWIFT network connected banks worldwide, the SITA network connected airlines in Europe and the USA, the COST and STINFO systems connected research institutions in Europe, the EPSS482 network connected three British cities, and so on. According to a large market study ordered by six national PTTs (including Televerket in Sweden) in 1977, there were between 100 and 150 international private computer networks in Europe at the end of the 1970s.[483] A Swedish report on the European computer market in the late 1970s[484], showed that most computer networks built in Europe at the time were circuit-switched, although trials with packet-switching technologies were under way in several countries, notably France and the UK (see also above).

In 1982, university researchers, together with actors from the European computer industry, started the European Unix Network (EUnet), using the UUCP protocol (Unix to Unix Copy Protocol). This network is seen as the first widely available means of data communication and electronic mail between computers in Europe, and to computers in the USA. The EUnet used a dial-up connection (1200 baud), but upgraded to a SLIP (Serial Line Internet Protocol) early in 1986 and to IP at the end of the same year.[485] In 1982, the first European nodes of the ARPANET were introduced at University College in London and at the research laboratory NORSAR in Norway. Another network, the EARN (European Academic and Research Network), was started in 1983, connecting academic institutions with 9.6 kbps lines using a proprietary communication protocol (IBM's NJE, Network Job Entry) (Mowery and Simcoe, 2002). Neither the NJE nor the UUCP standards diffused widely, and the European networks grew more slowly than the TCP/IP-based Arpanet in the US[486].

The IP network EBONE (European Backbone) was started as Europe's answer to NSFnet in the USA. But in contrast to the NSFnet, EBONE was built for both academic and commercial users.[487] At the end of the 1980s, computer users from Europe began to attach to the NSFNET infrastructure in large numbers.[488] In the late 1980s, Reseaux IP Europeens (RIPE) was created with funding from the EUnet and EARN in a move towards the establishment of a large European IP network (Mowery and Simcoe, 2002). Although this was not much later than the American counterparts, the take-off was considerably slower.

One of the most important Internet innovations was published in 1991. Two researchers at CERN in Geneva, Tim Berners-Lee and Robert Caillau, released a new document format called HTML (Hyper-Text Markup Language) and a document retrieval protocol called HTTP (Hyper-Text Transfer Protocol). The inventions allowed users to include graphics in their documents, and to interconnect documents by specifying words or images as links to other documents. The two researchers called their invention the "World Wide Web" (WWW). The vastly improved ease of use brought by the WWW was a major factor contributing to the eventual growth of Internet usage.

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[482] Experimental Packet-Switched Service (EPSS)

[483] Freese (1979)

[484] SIND 1978:1

[485] Sturmark et al. (1997)

[486] Mowery and Simcoe (2001)

[487] Sturmark et al. (1997)

[488] Mowery and Simcoe (2001)

On the protocol level, Europe also developed alternatives to the US de facto standards. The IP contestant OSI (Open-Systems Interconnection) was adopted by the International Standards Organization (ISO) in 1986.[489] The OSI aimed at providing smooth interconnection of computers and networks from different manufacturers, much like the IP. The OSI model divides network architecture into seven layers, where each has defined functionalities. Higher-order levels are dependent on lower levels, but theoretically a software protocol for any level can be rewritten and replaced without having to change any other layers.[490] Much of the development work was carried out in Europe, and around 1990 it was still seen as the European alternative to protocols such as TCP/IP and IBM's Network Architecture.[491]

6.2.1 Videotex in Europe

In the mid-1970s the British Post Office (BPO) developed a computer network aiming at integrating telephones, computers and the television, later known as Videotex. The aim was to build a service where users could easily connect to central servers and access information, e.g. train timetables. BPO called this service Viewdata, and later renamed it Prestel. Standardization bodies (CCITT and CEPT) worked on an international standard for the service, establishing the name Videotex.[492] When the French Cyclades network was closed down, videotext-based network was already in the pipeline in France. In 1981 the Minitel service was launched in France, according to Castells (1996) in an effort to revitalize the French electronics industry. The Minitel system diffused broadly within France, catalyzed by the French PTT providing the terminals free of charge. The Minitel service provided users with progressive content services such as computer dating, travel reservations, government services, banking and telephone directories.[493] [494] These kinds of services are now regarded as commodities over the World Wide Web. Videotex networks appeared in many European countries in the 1970s and 1980s, including the BTX in Germany, Minitel in France, and Videotex and Teleguide in Sweden. The Videotex service raised high hopes at European PTTs, but proved difficult to make profitable. The European Videotex networks were mostly based on "dumb" terminals (often TV sets) connecting to mainframe computers over the telephone networks. The drawbacks of using this solution rather than microcomputers were evident[495], but the PTTs were afraid of having to manage large quantities of microcomputers, quickly becoming obsolete.[496] The diffusion rates of videotext services were low, reaching a total of less than 6 million in Europe in 1990 (see Table 6-1).

Table 6-1: Videotex subscribers in Europe in 1990

Country	Subscribers
France	5 million
Germany	200 000
UK	95 000
Italy	100 000
The Netherlands	28 000
Sweden	30 000 (in 1992)

[489] Noam (1992)

[490] Noam (1992)

[491] Guice (1998)

[492] Lernevall and Åkesson (1997:477)

[493] Castells (1996)

[494] By 1990 more than half of the traffic over Minitel was sex-related (Strannegård and Dobers, 2001)

[495] In the "dumb" terminal case, technological development would take place mostly in the network with new functionality being introduced there. With more intelligent terminals, technological development could be more dynamic and user-driven. Besides, if every change (e.g. editing a file) were to involve mainframe computers, this would lead to rapid increase in traffic, intead of being handled inside a computer. The data networks, limited in functionality and capacity, would have had trouble dealing with all that traffic.

[496] Noam (1992)

Source: Noam (1992), Dobers and Strannegård (2001)

Although the generic term Videotex was used in many countries, a number of different standards existed in the world: the British Prestel, French Antiope, US NAPLPS, Canadian Telidon, Japanese Captain, the European CEPT, and so on. The different standards were not fully compatible, and in the mid-1980s there were still great difficulties in communication between different networks.[497] The Videotex developments were subjects of serious industrial-policy interest, which partly explains the different standards. The possibility of building a strong domestic industry in the convergence of telecom and computing attracted much public funding, most notably in France and the UK, but also in e.g. Germany. This distinguishes the European developments from the US Videotex initiatives, which were run with strictly commercial motives.[498]

6.2.2 ISDN

According to Noam (1992), the European PTTs did not realize the true potential of data communications in the 1960s and 1970s. There was a perceived threat that standards incompatible with existing public networks would be developed, accelerating the creation of private networks. Data communication was gradually increasing, and the analog technologies used would soon become insufficient. Further, the penetration rates of telephone connections had increased sharply in the 1970s, and in many countries saturation came closer. In this setting, the CCITT decided in 1980 to study ISDN (Integrated Services Digital Network) and issue recommendations. ISDN, allowing communication rates of 144 kbps, could prove to be the growth opportunity needed by operators. Partly, the ISDN development was also defensive from the PTTs' point of view. As Noam (1992, p. 368) notes: "In a wider sense, it is a part of a contest over where the intelligence in the network resides (i.e., at the centre or the periphery), who controls it (users or network operators), who builds it (the telecommunications or the computer industry), and who runs the network (public providers or private ones)." In one sense the ISDN solution was something of a "middle way". The connection speed, 144 kbps, was more than needed for most applications, but too slow for video applications.

The ISDN development was coordinated on the European Community level in an effort to strengthen the strategically important European telecom industry.[499] According to STU, the ISDN standard was based on system solutions building on important basic technologies developed in Sweden.[500] By late 1991, ISDN commercial services had been launched in a handful of European countries, with another handful testing the technology. ISDN was introduced in Sweden in the early 1990s, but user interest was low. In spite of Sweden having the lowest ISDN prices of six OECD countries in a study by the OFTEL in 1997, there were only 30,000 basic ISDN access subscribers in early 1997.[501] The ISDN diffusion increased its pace in 1999, due to demand for higher-speed Internet connections. At this time other, often faster, technologies were available, competing with ISDN. Telia started to offer other ISPs access to the last-mile copper line in spring 2000, packaged with an ADSL service offering higher speeds than ISDN.[502] Technological competition intensified with e.g. cable TV networks modified to offer fixed broadband Internet capabilities, and new DSL technologies

[497] Ohlin (1986)

[498] Ohlin (1986)

[499] Fuchs (1993)

[500] STU (1991)

[501] Teldok Yearbook 1997

[502] Docere Intelligence (2000)

(e.g. VDSL) were introduced. The availability of superior technologies probably had an important impact on the low ISDN diffusion, and ISDN penetration reached its peak in Sweden with 133,000 active Internet ISDN subscribers in late 2001, falling to 118,000 in 2002.[503]

6.2.3 Value-added data networks in Europe

Outside the national PTTs, private actors emerged in Europe building specialized data networks. At the end of the 1970s the US company Tymshare Inc. had connected European organizations, primarily research organizations, to its US Tymnet network using packet-switched solutions.[504] The possibility to reach data bases in the USA proved important for European organizations (including some Swedish). The most widely used private data networks in Europe in 1989 were Telenet, IBM, GE Information Services and Tymnet.[505] It is interesting to note that all these networks were owned by US firms.

Figure 6-2 below illustrates important European computer communications developments.

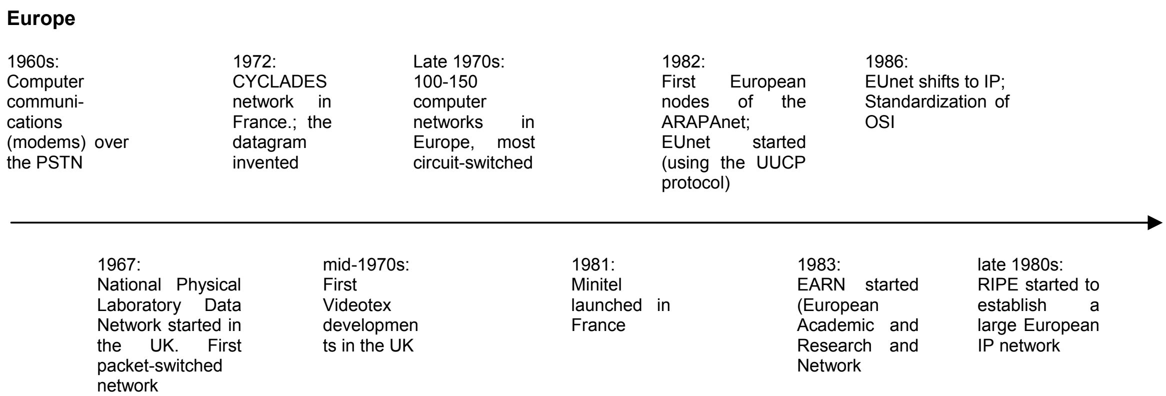

Figure 6-2: A time line of important European data networking developments

6.3 International Internet governance and regulation bodies

In the early Internet history, the US military played a leading role in Internet developments. As more academic institutions connected to the network, Internet administration and regulation shifted to civil authorities in the 1980s, mainly the NSF. In the 1990s another shift in the Internet center of gravity took place, this time to commercial activities. This shift called for new structures of regulation and governance, by independent international actors.

During the 1970s, ARPA both controlled the Internet backbone and acted as the Internet standardization body (Figure 6-3). In 1979, Vinton Cerf at DARPA created the ICCB (Internet Configuration Control Board) as an advisory body on technical issues. The ICCB was replaced by the IAB (then Internet Activities Board, later Internet Architecture Board) in 1984.[506] In 1986, the IETF (Internet Engineering Task Force) held its first meeting, attracting only 21 attendees. The IETF has since grown to a large, open international community of parties (network designers, operators, vendors, and researchers) concerned with the evolution of the Internet architecture and the smooth operation of the Internet. The work by IETF is

503 PTS (2003a)

504 Lernevall and Åkesson (1997:465)

505 Noam (1992)

506 A Brief History of the Internet Advisory/Activities/Architecture Board, available at www.iab.org

conducted in working groups, organized by topics (e.g. routing, security), often through mailing lists.[507] The working group results are published as so-called Requests For Comments (RFCs), many of which are used as Internet standardization documents. The meeting in July 1989 marked a major change in the structure of the Internet regulation bodies. The IAB, which until that time oversaw many "task forces", changed its structure to leave only two: the IETF and the IRTF.[508] Today IAB has a coordinating role and focuses on long-range planning and coordination among the various areas of IETF activity. The Internet Research Task Force (IRTF) works with long-term basic research in the Internet area.

After the Internet Society (ISOC) was formed in January 1992, the IAB's activities were placed under the ISOC. ISOC is the international organization for developing the accessibility and usability of the Internet. The society is US-based, but subdivisions, chapters, have been formed in a number of countries in line with Internet growth. The Internet Architecture board (IAB) today advises the ISOC on technical issues.

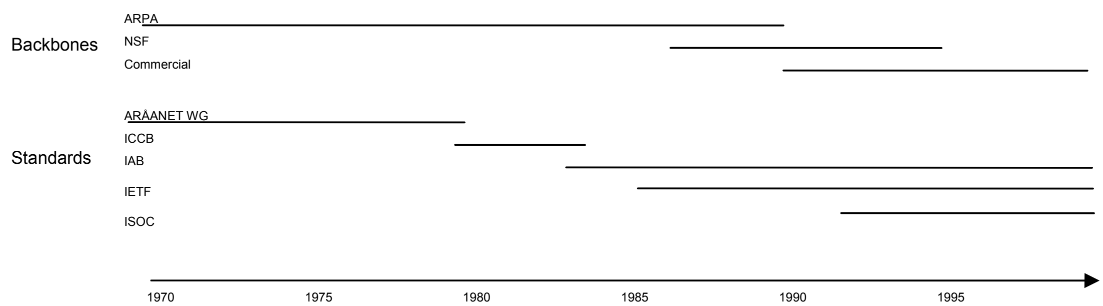

Figure 6-3: Internet governance stack

Source: http://www.telegeography.com, accessed at 2003-11-28

The increased number of Internet users created a need for a body to regulate Internet addresses. The responsibility for developing policies for allocation of IP numbers and domain names on the Internet was assigned to the Corporation for Assigned Names and Numbers (ICANN) in 1999. ICANN is governed by a board with members from different parts of the world. The Government Advisory Committee (GAC) was founded in the same year as an advisory body to the ICANN on issues concerning national governments. The GAC is open to all governments, and had 35 members in June 2003.[509]

In order to create standards for the rapidly growing use of the World Wide Web, the World Wide Web Consortium (W3C) was founded by Tim Berners-Lee in 1994. It is an international body whose purpose is to develop the WWW, hosted by three universities in Europe, USA and Japan. The W3C handles issues of protocol standardization, e.g. different versions of HTML, XML and SOAP.

[507] http://www.ietf.org, accessed at 031027

[508] http://www.ietf.org, accessed at 031027

[509] PTS (2003d)

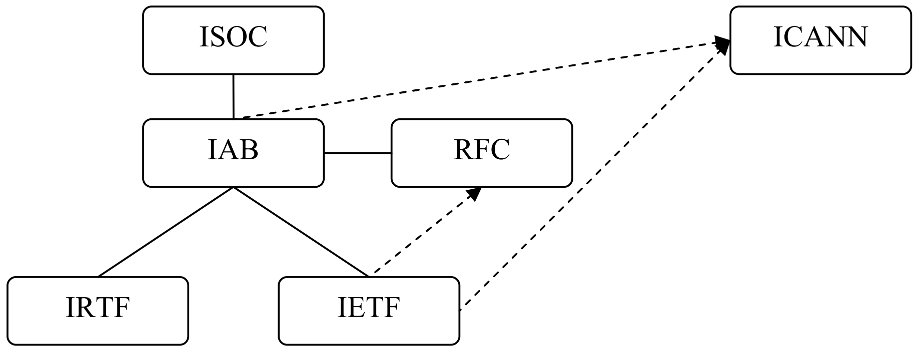

Figure 6-4: Schematic illustration of the relations of selected international Internet standardization and regulation bodies

Source: Adapted from ISOC-SE (2003, p.13)

The Internet is, as described above, mostly regulated by bodies and processes created by Internet users themselves. In line with Internet expansion, voices have been raised for regulation and transfer of ICANN responsibilities to a UN body, e.g. ITU. The reason is the increased importance of the Internet, and distrust in commercial actors' capabilities in managing the growing network.[510] In Sweden, e.g., a bill to regulate the .se top domain has been proposed. In the US a debate about regulating voice services over IP is ongoing. In August 2003, the state of Minnesota decided that the same rules apply for Vonage, a VoIP provider, as for all telephony providers, and ordered the company to start paying fees to the state's Department of Administration.[511] The FCC was to look into the matter in December 2003.

6.4 Recent Internet developments and trends

In this chapter some recent trends in the Internet developments are identified and presented. First, some usage and growth figures are presented, followed by a short elaboration on the shift towards higher bandwidths, increased QoS, and increased intelligence in the network periphery. Finally, some industry examples of industry dynamics are provided.

6.4.1 Continued usage growth and diffusion

World Internet usage is still growing at a fast pace, although the growth rates have decreased significantly. In 2002, there were around 600 million Internet users in the world, up from around 10 million in 1993. In the same period the growth rate has slowed from a hefty 105% in 1994/1993, to around 20% in 2002/2001 (see Figure 6-5). The low number of Internet users relative to the more than 1 billion fixed telephone lines and 1.1 billion cellular subscribers in the world indicates further growth potential. The growth in number of fixed telephone lines has hovered steady at 6-7% the last ten years, whereas both Internet and cellular subscribers increased by around 20%[512] in 2002 (ITU World Telecommunications Indicators, 2003). In an update of Internet trends in June 2003, investment house Morgan Stanley estimated user growth rates to be around 10% annually in the US for the next several years, with stronger growth in all other parts of the world.[513]

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[510] Economist (2003a)

[511] CNET News.com (August 21 2003)

[512] This figure is probably too low, since it is based on statistics with data lacking for a number of countries.

[513] Meeker and Pitz (n.d.)

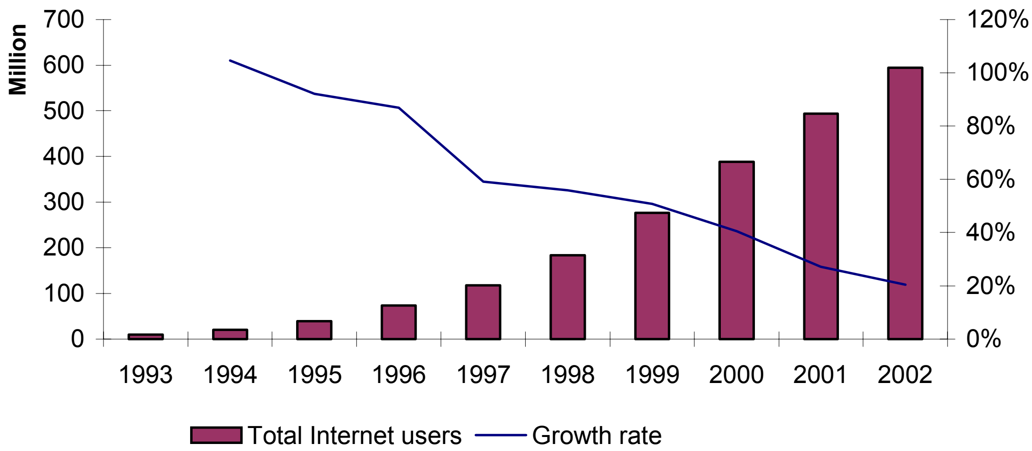

Figure 6-5: Total Internet users in the world, absolute numbers and growth rates, 1993-2002

Source: ITU World Telecommunications Indicators, 2003

Internet usage is no longer a matter only for academics and business people. With higher accessibility, higher user competence, and more widespread diffusion of more powerful terminals, the number of applications increases. The Internet has evolved from a means for sharing electronic files and messages towards an all-purpose communications network. Still, the Internet has a number of inherent limitations in comparison to the PSTN, e.g. limited QoS functionalities. Technological developments rapidly change what applications the Internet can be used for. Limitations in Internet protocol used today are about to be solved, and computer communications equipment, once state-of-the-art technology, is becoming commoditized. Below we present some of the recent Internet developments in more detail.

6.4.2 Shift to higher bandwidth connections

In addition to the increased number of Internet users, a shift towards use of higher bandwidth connections has been initiated. With the advent of xDSL and cable modem technologies, fixed Internet connections with higher bandwidths have become accessible to a larger user group, acquiring market shares at the expense of PSTN modem connections. This trend is exemplified by the Swedish case, where 13% of all Internet access customers had xDSL connections in 2002 (up from 1% in 2000) and 5% had cable modem connections in 2002 (2% in 2000). Morgan Stanley estimates there were over 44 million broadband subscribers in the world in Q4 2002, and that residential broadband has reached a critical mass.[514]

6.4.3 Voice over IP (or "Increased QoS in the data networks")

Although the Internet Protocol has become the standard for data communications, it has yet to prove its merits for extensive use in voice traffic. In recent years several companies offering equipment for Internet telephony have emerged (e.g. Cisco, Avaya), and companies providing broadband connections are trying to increase revenues by adding voice services to their customers. In Japan large companies have started seriously evaluating IP telephony. According to the research firm Yano Research, 12,000 companies in Japan will shift to Internet telephones in 2003, and the country will have 5.3 million Net phone lines at the end of the year.[515] In August 2002 Cisco announced that it had sold one million IP telephones in two years' time, and less than a year later, in July 2003 the company announced sales of

[514] Meeker and Pitz (n.d.)

[515] BusinessWeek online (October 20, 2003)

another 1 million phones.[516] The recently started Swedish company Skype[517] provides software for IP telephony through computers to be downloaded and used free of charge. With only a beta version of the software launched (late August 2003), the 3.3 million downloads in early December, and more than 1 million registered users at the end of October, are impressive.[518] All large instant messaging software providers (including Yahoo and MSN) now provide functionalities for voice over IP.

With Internet telephony, calls can be made between PCs, between PCs and IP telephones, and between IP telephones. Adding intelligence to the phones (screens, memory, processors etc.) provides new opportunities for value-added services for operators. Moving the voice traffic to IP communications can lead to new advanced communications services, tying together voice, e-mail, messaging and video conferencing in a single network. Using IP as bearer for voice traffic is a potential threat to operators providing voice services as well as traditional telecom equipment manufacturers. Figure 6-6 below indicates VoIP gaining share from PSTN traffic in recent years.

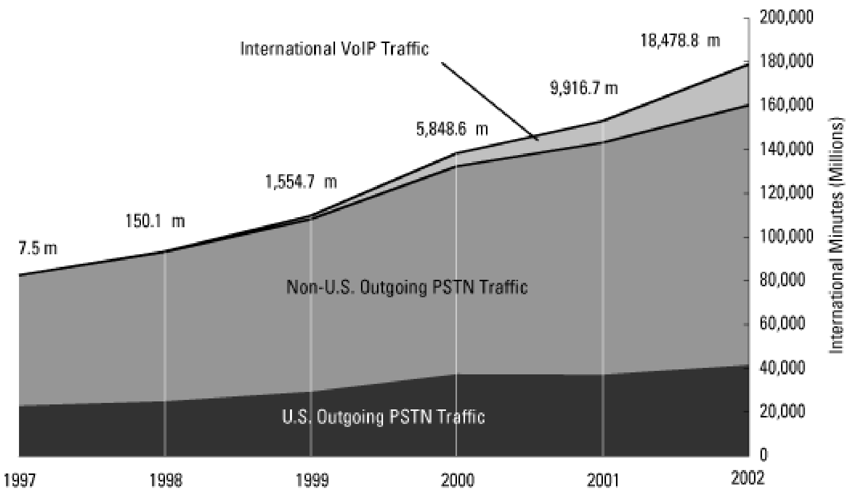

Figure 6-6: International voice traffic 1997-2002

Source: http://www.telegeography.com, accessed November 28, 2003

The IPv4 (IP version 4, established in 1981) version of the Internet protocol most widely used today has a four-byte (32 bits) address space enabling c. 4.3 billion possible addresses, a number slowly being reached. IPv4 is insufficient to meet the growing demand, which calls for a new IP standard. In 1998, the core set of protocols for the new IP version (IPv6) to replace the old protocols was established. The most important differences between IPv4 and IPv6 can be summarized in the following categories:[519] (1) improved addressing and routing capabilities, (2) simplified header format, (3) improved support for options and services, (4) improved support for differentiated services in terms of quality (QoS), (5) improved security in terms of authentication, message integrity and privacy, (6) less administrative payload due to improved auto-configuration and re-configuration, and (7) improved support for mobility.

With improved quality of service, IPv6 might function as an enabler for increased VoIP and real-time services (including streaming video) usage. The need of more addresses is strongest

[516] http://newsroom.cisco.com, accessed at 031028

[517] The company is founded by the same entrepreneurs who created the peer-to-peer file-sharing software KaZaA, today the most widely downloaded free software.

[518] Dagens Industri (2003-10-28)

[519] Bohlin and Lindmark (2002)

in parts of the world with large populations and rapidly growing Internet usage, notably in Asia. Governments and companies in Asia, having missed out on many parts of the Internet developments, now see an opportunity of catching up lost ground, and even, in some cases, surpassing Europe and the USA. With its relatively small Internet penetration, but rapid projected growth, China has a position to take advantage of the new protocol, and the government is pushing for a rapid transition to IPv6.[520] In line with an increased mobile Internet usage, where in theory every mobile terminal could have its own IP number, the need would arise also in other parts of the world. IPv6 addresses are 16 bytes long (128 bits), representing an increase by a total of 2^{96} addresses.

6.4.4 Increased intelligence in the network periphery

In Internet architecture, routers relay information to other routers on its way between the sender and recipient. No central computer tells the router where to send the information – the router itself knows to which routers information with certain addresses should be sent, and no direct connection is established between the sender and recipient. This makes computer communications networks different from telecommunications networks.

The technological developments in semiconductors lead to ever-increasing terminal intelligence. Moore's law implies that the performance/price ratio doubles every 18 to 24 months. With increased terminal intelligence, functions previously performed by central servers in the networks can now be performed by the terminals themselves. An example is the peer-to-peer (P2P) file-sharing networks that have become popular. By interconnecting the computers directly in vast ad hoc networks, users can search in and download from other terminals without the use of a central server. With more intelligence at the periphery, terminals can perform tasks previously performed in the network, such as keeping track of which terminals are connected at the moment. This opens up for a vast array of new applications, seen in e.g. the explosion of file-sharing networks in recent years.

6.4.5 Industry Dynamics

M&A activities in the communications industry were high at the turn of the millennium. Large telecom companies such as Nortel and Lucent have acquired Bay Networks and Ascend Communications, both data network equipment manufacturers, respectively. These activities were predominantly horizontal integration, with telecom companies acquiring data communications knowledge. Limited vertical integration is taking place today in the computer communications field. Examples are Intel, integrating Wi-Fi radio communication capabilities with their processors and actively working in the WiMAX field (see Chapter 8), and Cisco acquiring Linksys, a provider of Wi-Fi base stations. Computer hardware companies such as IBM and HP/Compaq are expanding into computer services, managing large corporate computer communications networks. Microsoft, traditionally a supplier of operating systems and office applications, has become the dominant actor in the browser area, and a leader in Internet messaging applications (including MSN messenger and Hotmail). Microsoft aims at transferring these strengths in the fixed Internet to the mobile Internet by becoming a strong supplier of operating systems for the mobile terminals (see Chapter 8). The AOL/Time Warner merger, approved by the FCC in January 2001, is an example of vertical integration between Internet services and Internet content. Internet broadband connection suppliers such as Yahoo Japan are providing value-adding voice communications services over IP to their customers.

[520] BusinessWeek Online (October 28, 2002)

6.5 The evolution of data communications in Sweden

In Sweden as well as in most other industrialized countries, the Internet was preceded by a range of computer networking and communication technologies. During the whole period from 1970 until the present time, competing technologies and standards have coexisted, competed and co-evolved. In order to understand the adoption and diffusion of the eventually dominant IP-based networks, the developments, technological as well as market, must be understood. In this section/chapter an overview of computer networking in Sweden is provided, and technological, industrial, governmental and usage developments are described. Due to data availability, there is a focus on the usage side, at the expense of data on the supply of networking equipment etc.

According to Corrocher (2003b, p. 229) "Sweden has the highest Internet penetration in Europe and the most advanced sectoral system of innovation in the Internet industry, both in terms of technological development and diffusion of new technology, services and applications." We believe Corrocher is right when it comes to the Swedish Internet usage, as will be shown below. Regarding the technological development in computer networking equipment, however, Sweden seems to have a less developed system of innovation. The same applies for Internet software, services and content, where Sweden, in spite of its lead-user position, has not been able to translate usage experience into leading suppliers.

6.5.1 Early data/computer communications

Televerket launched the first modems on the Swedish market in 1962 (using the international service name Datel). In 1970 there were 780 modems used in Sweden, increasing rapidly in the following years to around 5,500 in 1975 and 40,000 in 1980.[521] The main suppliers of modems were Ericsson and Standard Radio. In the 1960s there was a growing need for private data networks, mainly from banks and public authorities. Handelsbanken presented their data network plans in 1968, with other banks following suit. Centrala Bilregistret (the central car registry) switched on their network in 1972. Using fixed telephone connections and equipment (e.g. modems) rented from Televerket, customer internal data communications networks were built.[522] Televerket foresaw the need for a public data communications network and in 1969 ordered a study of how such a network should be constructed. The conclusion of the study, delivered in 1971, was that a circuit-switched data network was preferable to a packet-switched. This result was backed by close communication with the regulatory/standardization bodies CCITT and CEPT, and other European PTTs, as well as input from the SIBOL[523] project.[524] In 1973, the decision to build a test network was taken, and the commercial operations of the Datex network were started in 1981, with 500 initial customers. The network equipment was delivered by Ericsson, who won the contract in close competition with Fujitsu. The Nordic PTTs coordinated their efforts in the area, e.g. network specifications and joint procurement of equipment. Datex grew fast and reached 30,000 customers in the Nordic region in 1984, 10,000 of them in Sweden. Several data applications made use of the Datex solution, including the Bankomattjänsten (ATM banking service). The number of connections culminated at 45,000 in 1991 (decreasing to 36,000 in 1993).[525]

[521] Lernevall and Åkesson (1997)

[522] Lernevall and Åkesson (1997:471)

[523] Around 1970 the SIBOL project had been started by a consortium of Swedish banks aiming at the "cash-less society". Televerket was an active member of the different working groups, in charge of the data communication. Although the project was cancelled after some time due to disagreements within the consortium, it made Televerket aware of the opportunities in data communications (Lernevall and Åkesson, 1997)

[524] Lernevall and Åkesson (1997:459)

[525] Lernevall and Åkesson (1997)

The need to connect to databases abroad, notably in the USA, had grown in Sweden during the 1970s. A European connection to the American Tymnet had been established, but for Swedish users the closest node was placed in Amsterdam, leading to high connection charges. In 1979 Televerket acquired packet-switching equipment from the US company Tymshare Inc. and established a Swedish packet-switched node. The service was first called Databas 300 (the service purpose was to connect to various databases, and the connection speed was 300 bits per second), later renamed Telepak. In 1984 the network was further expanded and renamed again, this time to Datapak. The network was gradually connected to other networks, in 1984 numbering 50 in 40 countries. In 1988-1989 a second Datapak network was established, this time using equipment from Northern Telecom (later Nortel). Datapak I (the Tymnet network) was shut down in 1991 and all traffic was transferred to Datapak II.[526] According to Ohlin (1986), statistics from the Eurodata Foundation indicated 20 computer connections per 1000 of the Swedish workforce in 1984. This placed Sweden at the top of the European rankings and probably also among the top countries in the world, indicating Swedish computer usage to be advanced in some sense in the mid-1980s.

Leveraging the growing data/computer networks, systems for handling text messages between computers grew in popularity in the 1980s. In Sweden, the Memo system, developed at Volvo Data (later placed in Verimation, a joint venture with Ericsson), came into use in several companies, including Ericsson, Volvo and Ikea. KOM was another such system, developed by the Stockholms Datamaskincentral (computer center of Stockholm's municipality). In 1985 Televerket decided to introduce a public message handling system, TeleBox, using the American company GTE/Telemail's Telemail system. The multitude of different available systems existed as little "islands" in the computer network, unable to communicate with each other. In some cases, e.g. Televerket, organizations had multiple message-handling solutions internally, with no interconnection possibilities.[527] This was a clear sign of the drawbacks of using different protocols and standards.

In the early 1980s STU (Styrelsen för teknisk utveckling) and FRN (Forskningsrådsnämnden) made the first efforts to connect computers at universities in Sweden in a network, SUNET (Swedish University computer Network), using X.25[528] switches and terminals. The connections were made through the services Databas 300 and Telepak from Televerket. In 1985, a project to modernize SUNET's X.25 equipment was initiated. The choice fell on equipment from Digital Equipment Corporation (DEC). The reason was a survey conducted among Swedish universities, indicating a need for interconnecting a total of 65 computers, all made by DEC. From 1987 it became economically unfeasible to base the computer network on the X.25 service provided by Televerket because of the growing number of connections. In 1988 a number of fixed connections were leased from Televerket, and SUNET switched from the proprietary Digital Equipment communication architecture DecNet to the open standard TCP/IP. This switch made connections of computers from other manufacturers than DEC possible.[529]

The SUNET was connected to the European computer network EARN in 1988. In 1989 Nordic research computer networks were interconnected to form the NORDUnet (Nordic University Network). After careful evaluation of different communication protocols, the IP

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[526] Lernevall and Åkesson (1997)

[527] Lernevall and Åkesson (1997:475)

[528] Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit, http://www.itu.int/rec/recommendation.asp?type=items&lang=E&parent=T-REC-X.25-199610-I, accessed 2003-10-29

[529] http://basun.sunet.se/html_docs/info_sunet/historia.html, accessed 2003-09-01

was chosen, and connections to Amsterdam and the USA (NSFnet) were established.[530] At this point in time, fewer than 3,000 computers were connected to the SUNET in Sweden and the data transfer rates were not faster than 64 Kbit per second (Table 6-2 below). Both user figures and network speed increased rapidly in the following years. The connection speed increased to 155 Mbit/sec in 1999 and in 2001 over 200,000 computers were connected to the network.

Table 6-2: Number of computers connected to the SUNET computer network

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
computers 1000s	*2.9*	4.2	14	18	28	40	55	81	120	138	185	225	220
Speed Mbps	0.064			2		34					155		

Note: The numbers for 1989-1993 are approximate. The numbers for 1994-2001 are June statistics, except 1996 which is April statistics.

Source: http//basun.sunet.se/html_docs/info_sunet/historia.html

6.5.2 Videotex in Sweden

Following the Videotex developments in Europe, a Swedish commercial Videotex service was launched in 1982[531] (at first called Datavision, but soon renamed Videotex). The introduction was preceded by a period of inquiries and analysis of media policy effects, since the Videotex was considered a completely new medium, to be compared with television or radio.[532] Comparing Videotex with broadcasting television, the majority of the inquiring committee suggested that advertising over Videotex should be prohibited. Although the prohibition was not implemented, it mirrors the view of data communication as something new and frightening at the time. At first the service was directed at corporate users. By the beginning of 1986 the service had attracted around 7,000 subscribers.[533] Travel agencies, banks, media companies, government authorities, as well as dedicated Videotex companies offered their services over the network.

The plans for the Teleguide project, much like a Swedish version of the French Minitel, were announced in 1989. In November 1990, the first terminal prototypes were delivered and in October 1991 the Teleguide service was launched.[534] The Teleguide project was run by a consortium consisting of Televerket, IBM and the office supply manufacturer Esselte. The service made use of the existing Videotex network which had not attracted users to the extent anticipated, an obvious driver for Televerket. IBM hoped to sell computer equipment connecting PCs to the service, and Esselte considered the project strategically important for a move into electronic services. As in the Minitel case the terminals were delivered free of charge, but a monthly subscription charge as well as minute charges applied. The services available were very similar to the services of Minitel. The adoption of Teleguide, however, was slow. By the summer of 1992 it had attracted 22,000 customers, far below the expected numbers.[535] In October 1992 Televerket announced their plans to leave the Teleguide project, putting up their part for sale. Shortly after, Esselte announced their departure from the project. The three owners negotiated with Posten, the Swedish post office, to take over the project. But when these negotiations stranded, Teleguide was closed down in early 1993.

[530] http://www.nordu.net/articles/article1/text.html, accessed 2003-09-01

[531] On a smaller scale, tests had been run since 1979.

[532] Ohlin (1986)

[533] Ohlin (1986)

[534] Dobers & Strannegård (2001)

[535] Dobers & Strannegård (2001)

6.5.3 The commercial Internet in Sweden

In 1986, Björn Eriksen registered enea.se (the company he worked at) as the first name under the .se domain, in a way marking the birth of commercial Internet in Sweden.[536] Still, at the end of the 1980s, there were no commercial actors selling Internet access to companies and households. A user society called SNUS (Swedish Network User Society) developed plans for an IP network connecting universities and companies, Basnät 90.[537] The state-owned telecom operator Televerket was contacted to build the network. Televerket offered to build the network, but insisted on coordinating it with their own communication service Datapak. SNUS, wanting to build a pure IP network, then turned to the small satellite communications company Comvik Skyport (later renamed Tele2) with their specifications. Comvik agreed to build the network if SNUS ran it for three years (with an option for Comvik to take over the network operation after three years). The network, renamed Swipnet (Swedish IP Network), connected its first customers in March 1991. In total, around 30 companies purchased fixed Internet connections from SWIPnet in the first year.[538] At the end of 1991, Televerket introduced an IP network called TipNet. Later, a third commercial Internet operator, Transpac, owned by France Telecom, entered the Swedish arena.[539]

In 1994 the company Algonet, then a part of the Semic publishing company, started providing Internet access through modems for consumers/private users. Until then, all Internet providers had catered exclusively to academic and corporate users. In early 1994, Tele2/Swipnet charged SEK 1500 per month for a dial-up connection, far too much for most consumers. Algonet used a fixed connection from Tele2, who welcomed the consumer initiative since they could profit from Algonet buying capacity from Tele2 while catering to customers not included in the Tele2 strategy at the time.[540] Six months after the launch Algonet had 1,500 users, and was soon followed by a number of other ISP start-up companies.

Table 6-3: Internet access charges, 1994

ISP	Fixed initial fee	Fixed monthly fee	Variable fee
Telia	40000	10000/month	No variable charge
Swipnet	1000	800/month	90/hour
Algonet	N/A	150/month	No variable charge (apart from local telephone charges)

Note: The figures for Telia concern 64 kbit/sec fixed connection

Source: Mattson & Carrwik (1998, p.44), referring to MacWorld in August 1994

When Tele2 saw the success of Algonet, it started offering Internet access to consumers as well, and soon the telecom incumbent, Telia (Televerket was renamed Telia in 1993), followed suit. Entrepreneurial activities were high in the emerging ISP industry. In 1996 there were 75-100 Internet service providers, with a combined market share of around 1%.[541] In 2002 there were still around 100 companies providing Internet access to companies and consumers.[542] In the late 1990s, intense competition led to price reductions in Internet access. Between 1998 and 2000, access fees were reduced by two thirds, and "free" Internet subscriptions (no fixed, only variable charge) appeared in great numbers, offered by most

[536] ISOC-SE (2003)

[537] Mattsson and Carrwik (1998)

[538] Mattsson and Carrwik (1998)

[539] Sturmark et al. (1997), Statskontoret 1994:11

[540] Mattsson and Carrwik (1998)

[541] Stelacon (1997)

[542] PTS (2003a)

ISPs.[543] As seen in Table 6-4 below, the combined market shares of the largest three actors, Telia, Tele2 and Telenordia/Algonet[544], have gradually decreased in line with stronger competition from broadband Internet service providers, e.g. Utfors, Bostream, Tiscali and UPC. The market share of the three largest Internet service providers has decreased from 99% in 1996 to 72% in 2002. This implies a more intense competitive situation, leading to lower prices for end-users.

Table 6-4: Market shares, number of Internet access customers

Company	1996	1997	1998	1999	2000	2001	2002
Telia	42%	36%	33%	31%	31%	35%	36%
Tele2	43%	40%	33%	27%	26%	27%	26%
Telenordia/Algonet	14%	15%	18%	14%	11%	11%	10%
Others	1%	9%	16%	28%	32%	27%	28%

Sources: PTS, Svenska Telemarknaden (2001, 2002 and 2003)

Looking at the market shares for Internet connections with higher speeds[545], the picture is somewhat different. TeliaSonera, the incumbent and owner of the last-mile connections, has secured a 55% market share (Table 6-5). Tele2, number two in total Internet access customers, has only a three percent market share, and Telenordia 5% of the market. Considering that high-speed Internet connection is the high-growth area, the large market share of TeliaSonera could indicate competition barriers associated with the last-mile connections. On the other hand, actors other than the top three have a combined market share of 37% in high-speed Internet connections, vs. 28% in total number of Internet access customers.

Table 6-5: Market shares, customers with high-speed Internet access by company, 2002

Company	2002
TeliaSonera	55%
Tele2	3%
Telenordia	5%
B2 Bredband	13%
Bostream	9%
UPC	8%
Other	7%

Source: PTS (2003c), p. 39

543 Docere Intelligence (2000)

544 Telenordia acquired Algonet in 1996

545 There is no universal definition of what bit rates must be supplied for use of the term “broadband” or “high-speed connection”. Here, the term is loosely defined as connection offering higher speeds than dial-up modems.

6.5.4 Internet usage

In 1997, the Swedish Parliament introduced tax reductions on computers bought by companies for their employees' private usage.[546] This program quickly led to an increase in both absolute computer numbers and usage in Sweden, and Swedish PC penetration rates outpaced most other countries' in the following years (see Table 6-6). A recent study by the ITPS (Swedish Institute for Growth Policy Studies) indicates that the employee computer program has played an important role in accelerating diffusion rates of PCs in Sweden. A comparison with initiatives and diffusion rates in other Nordic countries suggests 10 percentage units lower penetration today without the program. In addition, the program has created a more even distribution of computers among income classes. The report also emphasises the decreasing effect on diffusion rates in recent times, and concurs with the recent government proposal of a reformed subsidy program.[547] As seen in Table 6-6 below, Sweden had more computers per capita in 2001 than most other countries.

Table 6-6: PCs per 100 inhabitants in ten OECD countries, 1990-2001

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
USA	22	24	25	27	30	33	37	41	46	52	59	62
Sweden	11	13	14	15	18	i.u.	29	34	40	45	51	56
Norway	13	15	16	19	23	27	32	36	41	45	49	51
Denmark	12	13	16	18	19	27	31	36	38	41	43	45
Finland	10	11	13	14	16	24	27	31	35	36	40	43
Iceland	4	8	12	13	17	21	26	30	33	36	39	42
UK	11	13	15	17	17	20	22	24	27	30	34	37
Japan	6	7	7	8	9	12	16	21	24	29	31	35
Germany	8	9	11	13	15	18	21	24	28	30	34	35
France	7	7	11	12	14	15	16	19	23	27	31	34

Source: SIKA (2003) (based on statistics from Eurostat)

In line with the Internet development, more and more of the computers came equipped with modems and networking capabilities. Thus, the diffusion of computers, in turn propelled by government tax subsidies, paved the way for diffusion of Internet usage. Commercial Internet service providers emerged later in Sweden than in e.g. the US (see section 6.5.3). An international comparison (Table 6-7) indicates Swedish Internet adoption levels lower than the most advanced Internet nations (Finland and the USA) in 1995. In 1997, however, Swedish Internet diffusion had outpaced even the USA and Finland, and has since stayed in a top position concerning Internet penetration levels in the world.

In the early 2000s Sweden is among the top three countries in Internet usage in most available analyses. Measuring and comparing Internet penetration rates is a cumbersome issue, though. Internet usage is sometimes reported as number of subscriptions reported by access providers, sometimes as number of users based on surveys, sometimes as estimations of how many users are connected to each subscription. Although the numbers are somewhat unreliable, when measured the same way, international comparisons should provide good indicators of a country's relative development.

[546] Steen (2002)

[547] ITPS (2003)

Table 6-7: Estimated Internet penetration, 1995-2001 (selection of countries)

Country	1995	1996	1997	1998	1999	2000	2001
Sweden	***5%***	***9%***	***24%***	***33%***	***41%***	***45%***	***52%***
USA	9%	16%	21%	30%	36%	44%	50%
Japan	2%	4%	9%	13%	21%	29%	45%
Finland	14%	17%	19%	25%	32%	37%	43%
Germany	2%	3%	7%	10%	17%	29%	36%

Note: Author's calculations. The 2001 population is used as base for all years

Source: ITU (2002)

According to a report prepared for PTS by PA Consulting (1995), the total market for Swedish Internet access was smaller than 5 MSEK in 1991, growing to around SEK 60 million in 1994 and steadily increasing in the following years, reaching SEK 5.5 billion in 2002 (PTS, 2003). As the numbers imply, the diffusion of Internet access was rapid in Sweden in the late 1990s (annual growth rates of around 90 % in SEK).

During 1995 the number of dial-up Internet connections reached 54,000 in Sweden, with a strong increase in 1996 (Stelacon 1996). In February 1996, Telia stopped accepting new Internet customers due to overloaded networks. Until May 1996 the company chose not to connect any new customers, rather than lowering service quality for existing customers. For the same reasons, Algonet also closed its network for new customers for a short while at the end of 1995 (in March 1996 Algonet was acquired by Telenordia)[548].[549] The rapid diffusion was aided by the service providers' heavy subsidies on modems in return for one- or two-year contracts with customers. This strategy had previously been used with good results in the mobile phone business.

Table 6-8: Active Internet access customers by access form

	1995	**1996**	**1997**	**1998**	**1999**	**2000**		**2001**		**2002**	
						Number	%	Number	%	Number	%
PSTN						2031100	89%	2232500	79%	2352900	74%
ISDN						126400	6%	133000	5%	117900	4%
xDSL						26200	1%	241500	9%	421400	13%
CATV						56300	2%	112000	4%	156400	5%
Radio						200	0%	1400	0%	2900	0%
Other						40500	2%	98600	3%	135385	4%
Total	**54000**	**236000**	**653000**	**1450000**	**1880000**	**2280700**		**2819000**		**3186885**	
Growth		*337%*	*177%*	*122%*	*30%*	*21%*		*24%*		*13%*	

Note: Small differences from PTS sums due to round-off

Source: PTS (2003a)

As seen in Table 6-8, dial-up modem (PSTN) has from the start of computer communications been the predominant access form, and still is. In recent years, a gradual shift towards higher-speed connections has been initiated. The relative PSTN usage has decreased since other access forms; primarily broadband xDSL connections have grown rapidly to a 13% market share in just three years. The table above also indicates growth in Internet access through cable TV connections, and the gradual phase-out of ISDN as an access technology. The forces towards higher bandwidth are many. Since annual growth rates of Internet access customers are decreasing, from 337% in 1996 to a more modest 13% in 2002, ISPs must find new ways

[548] Svenska Dagbladet (1996-03-12)

[549] Svenska Dagbladet (1996-03-10)

to achieve revenue growth. In a saturating market, migration of customers to premium high-bandwidth connections has been the solution. At the same time, but from a demand perspective, new applications such as video streaming and file sharing have driven consumers' interest in broadband connections.

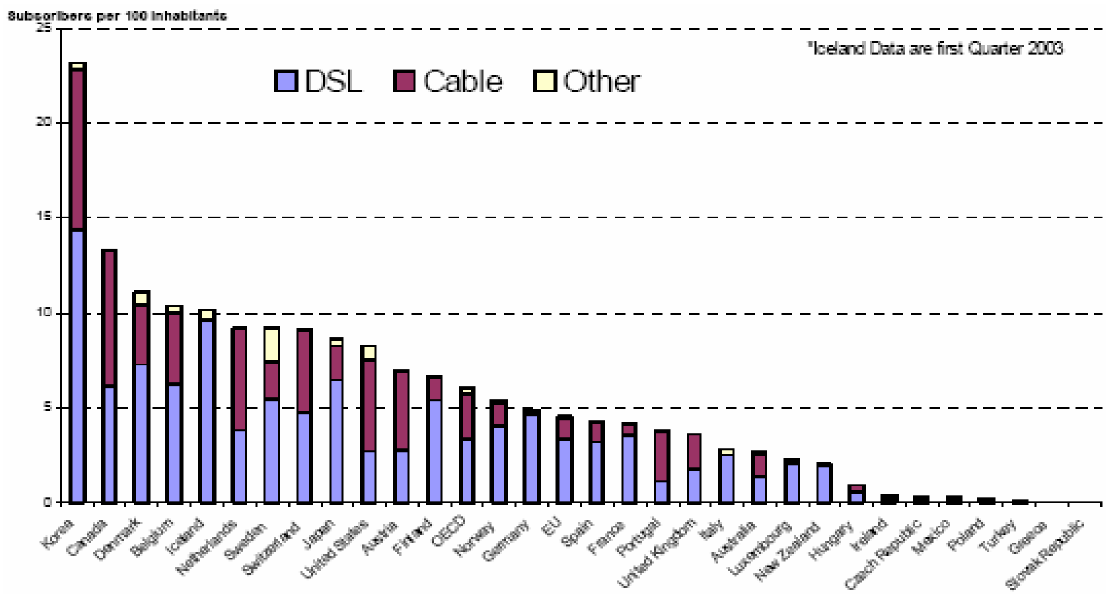

Figure 6-7: Broadband subscribers per 100 inhabitants, Q2 2003 (selection of countries)

Source: OECD (2003c)

In 2003, the diffusion of high-speed Internet connections in Sweden is high in comparison to most countries (Figure 6-7). Broadband access diffusion is seen as a vital part of Swedish IT policy, and a prerequisite for creating new services, public and private. However, Sweden is still far behind the world leader, Korea, where broadband Internet connections are the predominant access form. Figure 6-8 below indicates that Swedish Internet users in homes both access the Internet more seldom, and spend fewer minutes on-line, than their counterparts in e.g. the USA and Japan, in spite of higher broadband penetration levels. Possible explanations could be high Internet access costs, and that higher penetration levels in Sweden mean that a larger proportion of the users do not belong to early adopter categories with great interest in IT usage. The numbers are interesting, however, since they could indicate that high penetration levels do not automatically lead to qualified usage.

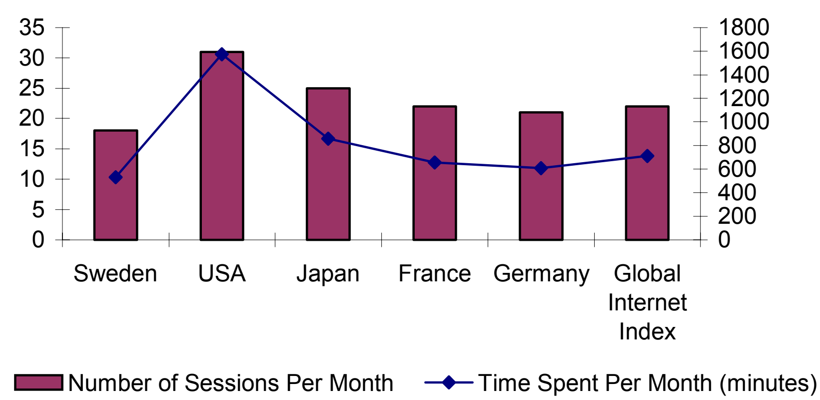

Figure 6-8: Number of Internet sessions and time spent on-line, Home Panel, September 2003

Source: http://www.nielsen-netratings.com, accessed at 031110

The number of domain names per 1000 inhabitants can be used as a proxy for total Internet usage in a country. The USA had by far the most domain names per capita in 2002 (273), followed by Finland (193). Sweden's 177 (same number as Iceland) per 1000 inhabitants are third highest in the world, and well above the EU average (71). The high number for USA can partly be explained by the difficulties in measuring domain names. Whereas the use of national domain names, e.g. .se for Sweden or .jp for Japan, the use of e.g. .edu, considered to be one of the US suffixes (including .edu, .mil, .gov, and .us), is spread outside the US. The same applies to e.g. the .net, .com and .org suffixes.

The strong Swedish position in number of domain names is not seen in number of websites (web servers) or secure servers. The number of web sites per 1000 inhabitants provides an indication of relative national content development.[550] Germany ranked first in the world in this measure in 2002, with Sweden far below, even under OECD average. The number of secure servers gives an indication of the diffusion of e-commerce (OECD, 2003a). As Figure 6-9 shows, there is no correlation to the number of web sites per capita. Iceland has the highest number of secure servers per capita, followed by the USA. Sweden is placed around the OECD average, well behind Iceland and the US. Interesting to note are the low numbers for Korea, in spite of the vast number of broadband connections.

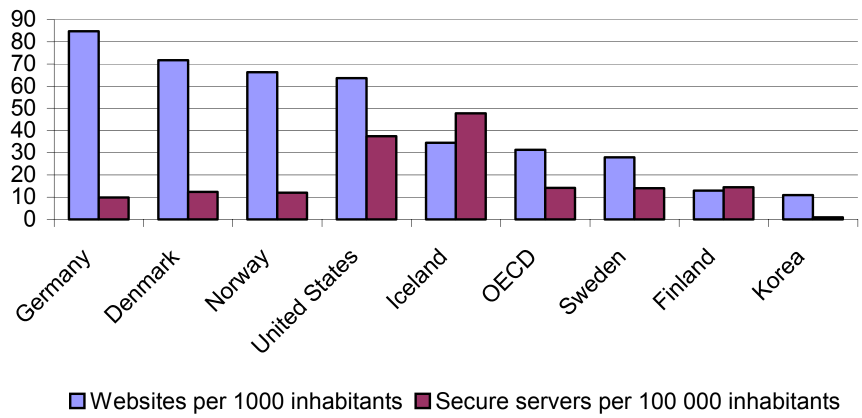

Figure 6-9: Web sites per 1000 inhabitants and secure servers per 100,000 inhabitants, 2002 (selection of countries)

Source: OECD (2003a)

High Internet penetration is not only a fact in the consumer market. According to market studies performed by SIKA, more than 90% of Swedish companies had Internet access in 2000, and based on companies' own intentions this figure was expected to reach 95% in 2001 (see Table 6-9). In mid-2003, 471,000 companies used Internet-based banking services, an increase by 30% in only six months.[551]

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[550] OECD (2003a)

[551] Dagens Industri (2003-11-07)

Table 6-9: Share of companies with Internet access in the Nordic countries, 1999-2001

Country	*1999*	*2000*	*2001*
Finland	85%	91%	95%
Sweden	**78%**	**91%**	**95%**
Denmark	78%	87%	90%
Norway	66%	74%	81%

Note: 2001 figures are estimations based on companies' stated intentions in 2000

Source: SIKA (2003)

In overall IT rankings, Sweden often receives high scores. The high level of computer diffusion in Sweden combined with high Internet and mobile phone penetration has propelled Sweden to being one of the most advanced IT nations in terms of usage. In 1999, both IDC and the magazine Forbes placed Sweden in the number two spot (behind USA) on a ranking of countries' IT development. In 2000, IDC regarded the Swedish IT society as more developed than even the USA, and placed Sweden in the number one position (Steen, 2002). As seen in Table 6-10, Sweden has held onto that position in 2001, 2002 and 2003. The table shows that in the period 1999-2003 the relative positions of nations on the list have varied significantly, but Sweden has remained in the top position. The index measures qualitative measures, e.g. installed PCs and home Internet users. For qualitative measures, e.g. how advanced the services used really are, the index is less useful. As an example, the cellular phone subscriber levels are higher for Sweden than Japan, but the advanced usage and advanced terminals in Japan are not reflected in the index.

Table 6-10: IDC Information Society Index Rankings, 1999-2003

	2003	**2002**	**2001**	**2000**	**1999**
Sweden	1	1	1	1	2
Denmark	2	5	5	5	6
Netherlands	3	6	10	7	7
Norway	4	2	2	4	5
Finland	5	8	3	3	3
New Zealand	6	-	-	-	-
Switzerland	7	3	7	8	-
United States	8	4	4	2	1
Austria	9	-	-	-	-
Canada	10	-	-	6	10
Australia	-	9	8	9	8
Japan	-	-	-	10	9

Source: IT-kommissionen 2002, http://www.idc.com

6.5.5 Internet Content

In the mid-1990s there were strong entrepreneurial activities in the Internet area. The rapid growth of Internet usage in Sweden and elsewhere caused several companies and individuals to seize opportunities. On August 25, 1994, the daily newspaper Aftonbladet became the first newspaper in Sweden to launch its Internet issue. The same year, the Internet service provider Algonet launched its services, followed by Everyday Online in early 1995.[552] Large companies, e.g. Telia and Posten, saw the Internet as a threat to their existing business and raced to establish a foothold in the emerging market. Telia, which was slow to realize the

[552] Everyday soon shifted to providing services over the Internet

potential of the Internet, aimed at creating an on-line market place when creating Passagen in 1995. Telia set out to provide the context and let other companies create the content. Posten, seeing the Internet and e-mail usage as a clear threat to its mail distribution business, had similar ideas when it launched Torget in 1996 (Mattson and Carrwik, 1998). Neither of the initiatives turned out to be successes.

Perhaps the most notable of the Internet-related companies started in the mid-1990s were the Internet consultants. First out on the Swedish market was Spray in 1995, followed by Icon Medialab and Framtidsfabriken (later Framfab). Fuelled by venture capital and high stock prices (after the IPOs), the companies rapidly expanded in Sweden and overseas. In 1999 these three companies between them had a total turnover of more than SEK 800 million. The figures for 2000 were SEK 3 billion in turnover, with total losses of around 5 billion.[553] Adding the numbers for similar companies, e.g. Adera, Cybercom and Halogen, the Internet consultancy industry was of considerable size at the turn of the century. In 2000, the total market capitalization of the Swedish IT companies[554] reached SEK 170 billion. The fall from those levels was high. Of 25 IT and Internet consultancies listed on the Stockholm stock exchange, only 5 were profitable in 2002. In the first half of 2003, 16 of the 25 had returned to black figures, but still 16 of 21 listed software companies were unprofitable.[555]

Important to note is the nature of the companies started at this period. Rather than equipment for the Internet, Swedish companies tended to focus on consulting services in web design, Internet business models, and on content services. There are a few manufacturers of computer networking hardware (e.g. Net Insight, Switchcore, Axis) but their total sales are relatively small.

Today, both the hardware (Internet access, computers etc.) and a high IT readiness are in place in Sweden. Many researchers and industry representatives see a development towards increased value in providing content services once the Internet access has become a commodity. In the light of such trends it is interesting to examine the usage habits of the Swedish Internet population. The important question for the Swedish Internet innovation system is what kinds of Internet services are used today, and what types might be used tomorrow.

In Table 6-11 below, a snapshot in time of the most widely used Internet properties in Sweden is provided. The time span, one month, in the list is by no means enough to provide a comprehensive picture of Internet usage habits, and the preferences tend to change rapidly. However, it provides interesting information about the wide use of search services such as Eniro (telephone directory, maps etc.), MSN (Microsoft), Lycos and Google. A comparison with August 2003 statistics reveals minor changes in the numbers leading to different relative positions on the list, but the companies on the list remain the same, indicating strong positions in customers' minds.

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[553] Affärsdata, Icon and Framfab annual reports

[554] The Swedish IT companies are defined according to the classification of the business magazine Affärsvärlden. No telecom companies are included in the group.

[555] Svenska Dagbladet (2003-09-30)

Table 6-11: Sweden's top properties, May 2003

Property Name	Unique Audience (1000s)	Reach	Time Per Person
Microsoft (including MSN and Hotmail)	3,269	73.58%	00:31:08
Eniro	1,794	40.39%	00:14:28
Aftonbladet Hierta	1,597	35.95%	00:49:08
TeliaSonera	1,586	35.69%	00:22:48
Bonnierförlagen	1,524	34.30%	00:26:43
FöreningsSparbanken	1,281	28.83%	00:50:23
Google	1,082	24.36%	00:13:14
Counties of Sweden	1,034	23.28%	00:11:14
Lycos Europe	1,008	22.69%	00:28:11
TV4	963	21.67%	00:25:39

Source: Nielsen/Netratings

The Swedish banks have successfully taught many of their customers to perform simple banking tasks themselves over the Internet, as exemplified by the position of FöreningsSparbanken on the list. According to research from Svenska Bankföreningen (Swedish banking association), 36% of the men and 23% of the women were customers of an Internet bank in 2001.[556] By June 2003 the number of customers of Internet banks increased to 5.1 million, up from 4.5 million in January.[557] FöreningsSparbanken is the fifth largest Internet bank in Europe, counting unique visitors in May 2003.[558]

E-commerce and Internet security

With more people using the Internet and more transactions carried out over the Internet, the lure for misuse of the network through criminal activities grows stronger. Spamming is a real and growing problem, as are viruses, trojans and worms. In recent years we have seen several attacks, causing damage worth billions of dollars. These developments have opened up opportunities for a special type of Internet software firms: Internet security companies. Establishing a secure communications infrastructure has become a major issue for both national governments (including Sweden) and international organizations (including the EU).

The notion of Internet as a disruptive, revolutionizing invention was widespread in the late 1990s, and the concept of a "new economy", with decreasing transaction costs, was widely used. Traditional industrial companies were slow to realize Internet's potential and a number of companies aiming at acting as intermediaries in Internet-based commerce were started. The crash of the stock market, combined with a raised Internet literacy in all companies, has led to the bankruptcy of most such companies. Instead, industrial companies have come to exploit e-commerce opportunities themselves, with more and more of companies' transactions being made electronically.

Sweden is relatively advanced in e-commerce activities. In the annual e-readiness rankings performed by the Economist Intelligence Unit in cooperation with IBM, Sweden topped the ranking in 2003, up from fourth position in 2002 (EIU, 2003).[559] The ranking combines more than 100 quantitative and qualitative criteria ranging from infrastructure to policy

[556] SIKA (2003:124)

[557] Dagens industri (2003-11-07)

[558] Nielsen/Netratings (2003-06-13)

[559] EIU (2003)

environment and adoption figures. Swedes are active in on-line shopping as well as using on-line government services. Conclusions from the ranking are that governments play very important roles in the advancements of Internet usage and e-business adoption. The Swedish government's activities in creating on-line services, including tax filing services for consumers at the Tax Authority (RSV), and on-line systems for registering company names, patent information and trademarks from the Patent and Registration Office (PRV). In the case of PRV, companies can be registered using electronic signatures provided by the Nordea bank, completely on-line, any time of the day.

The Internet commerce is a growing part of the total commerce in Sweden. Already in 1996, some retailers and department stores experimented with on-line sales. An example is B&W in Arninge, Stockholm, who enabled users with a certain minimum income, living within a radius of 20 kilometres, to shop from their PC at home.[560] According to research carried out by SIKA, almost one million Swedes purchased goods or services over the Internet in the period May-October 2002.[561] This corresponds to almost 25% of all Internet users in Sweden making at least one purchase. As seen in Table 6-12, the most popular goods and services include travel and event tickets, as well as small, relatively high-value but easy-to-send goods such as books and storage media (CD/DVD/Video etc.).

Table 6-12: Selection of purchased/ordered/booked goods and services among e-commerce users, May-Oct 2002

	Goods and Services	**Share (%)**
Ordered/bought	Groceries or other daily goods	3
	Books	26
	CD, DVD, Video, software or computer accessories	36
Booked/paid	Travel	41
	Hotel	18
	Event tickets	47
	Booked/purchased something else	32

Source: SIKA (2003:125)

High security is a prerequisite for e-commerce to be used by a majority of the population. The European Union is taking the IT security issues seriously and planned to set up a European Networking and Information Security Agency.[562] Sweden was mentioned as one of the candidates to host the agency. Strong opinions were raised from both the public administration and the industry in Sweden that the government should actively work for the agency being placed in Sweden. The IT security competence gathered in a European agency is expected to spill over to existing and new firms within the strategically important IT security field. However, during the finalization of this report, it was decided to place the agency in Greece.

Still, Sweden has an internationally strong physical security industry with companies such as Securitas, Assa Abloy and Gunnebo. In the 1990s traditional security companies foresaw a convergence with IT security. Already in 1997 Securitas launched a service called "IT watchman (IT-väktaren", able to e.g. take back-ups of firms' computer systems at night.

[560] Göteborgs-Posten (1996-09-16)

[561] SIKA (2003:125)

[562] EC (2003)

Securitas also previously owned the IT security company Säkdata.[563] In more recent times Pinkerton, a subsidiary of Securitas, has developed a security system integrating physical security with access security to companies' IT systems. Gunnebo has acquired a control post in the small biometrics company Fingerprint, possibly moving into access security for computers and handheld terminals. ASSA ABLOY, focusing on locks, has acquired competence in e.g. smart cards and readers, and RFID. Although slowly moving from mechanical to electronic products and solutions, none of the large companies have leveraged their strong security brands in software and Internet security.

The Internet and computer security business is growing rapidly. According to the research company IDC, the Nordic part of this market will grow 25% annually in the coming years, reaching SEK 7.4 billion in 2005.[564] A number of Swedish firms are active in the field, including Nexus (Digital IDs and security consulting, 440 employees), Proact (e.g. authentication and surveillance, 280 employees, 50% in Sweden), Protect Data (e.g. Network security, digital identities, antivirus software, 90 employees), and Cygate Måldata (security consulting). According to IDC, there is strong competition, with many large American companies present (including Symantec, Computer Associates and Network Associates). Other Nordic actors, including Norwegian Norman and Finnish F-Secure and SSH, have been more successful in internationalization than their Swedish counterparts.[565]

6.5.6 Swedish data communications equipment industry

In the 1960s-70s, when computer communications in Sweden was very much a matter for Televerket, Swedish telecom industry was a strong supplier. At the end of the 1970s, around 50% of the modems installed in Sweden were supplied by domestic producers; Teli (subsidiary of Televerket), LM Ericsson and Standard Radio & Telefon (SIND 1978:1, p. 283). The telecom equipment industry in Sweden developed alongside its customers: the network operators. There are major differences between traditional telecom network architectures (PSTN) and IP network architecture (Internet), concerning technologies as well as market structure and sets of relevant competences. Telecom network equipment vendors have traditionally sold integrated systems solutions, often with proprietary protocols (software etc.) to large telecom operators. The user (operators) – producer (equipment/systems manufacturers) relationships have been developed during large time spans, sometimes as much as 100 years. In many cases the relationships have involved joint research and development, sometimes even joint ventures (e.g. Ellemtel, of Sweden's Telia and Ericsson).

The Internet technologies have, as described above, to a large extent grown out of the computer industry. The differences in origin compared to other computer network initiatives have had impact on both the design of the network and markets. Today, the telecom and Internet communications industries are undoubtedly converging. In line with the diffusion of Internet usage, an ever larger share of the traffic over the telecom networks is IP-based. Traditional telecom equipment vendors, e.g. Lucent, Nortel and Ericsson, are building up competence and product portfolios in IP routing and switching. At the same time, computer networking companies such as Cisco and 3Com are acquiring telecom skills.

In the computer networking equipment industry, the USA has had a leading position from the beginning of computing. However, initiatives were made in Sweden in the early 1980s to

[563] Computer Sweden (2003-09-05)

[564] Computer Sweden (2002-01-11)

[565] Computer Sweden (2002-01-11)

build up a computer industry. The most notable example was Ericsson's venture into the consumer electronics market. Ericsson was early on aware of the changes through the convergence of telecom and computing. In 1980 Ericsson acquired Datasaab and formed Ericsson Information Systems (EIS). Ericsson's vision was to create the "paperless office" in the convergence of telecom and computing. The company made heavy investments in consumer electronics and entered the US market for home PCs in the mid-1980s, but with very limited success. In 1986 a new strategy was formed: EIS was to become a systems supplier to customers, delivering everything from PCs to telephone switches and word processors. This was much like the Ericsson strategy in telecom network equipment. By supplying whole systems to customers, and guaranteeing interoperability between components, Ericsson had become successful in the telecom business. In the computer area, this strategy was not as successful. EIS caused Ericsson heavy losses, and although they returned to profitability in 1987, EIS was sold to Nokia in November 1987.[566]

The failure of EIS probably delayed Ericsson's developments in the early 1990s. In the mid-1990s Ericsson developed scenarios for what the telecom world would look like in 2005, describing three different ways of organizing the value chain.[567] One of the scenarios involved a push of the intelligence in the networks further out towards the users, and easy Internet access from all terminals, with a weaker position for operators. Such a scenario could be advantageous for suppliers of intelligent terminals, and suppliers of network equipment based on open standards, e.g. IP. With Ericsson behind many data-communications firms in skills and knowledge in these areas, company acquisitions were one way forward. The end of the 1990s, with the inflated stock prices of telecom and Internet companies, saw a marked increase in mergers and acquisitions. Ericsson had formulated a strategy of acquiring firms within data communications and router technology in 1995-1996, and this strategy was put into practice in 1997 with the acquisition of Juniper.[568] In the following three years Ericsson made 11 acquisitions, predominantly within the IP and ATM areas. Interesting to note is that no companies were acquired in Sweden, and 9 out of 13 acquisitions were US companies, indicating that this competence was not available in Sweden.

In 1990 Ericsson was invited by the investment house Morgan Stanley to acquire a small upstart in datacom named Cisco on the American west coast. Ericsson did not see Cisco as a competitor at the time, and Ericsson was convinced that the AXE-N under development was the solution for future communications.[569] That Ericsson saw communications over IP as a future threat was underlined by Ericsson's acquisitions and strategic investments, starting with Juniper Networks in 1997 (see Table 6-13). Ericsson was also one of the bidders for Cisco's competitor Bay Networks, acquired by Nortel in 1998.[570]

[566] Åsgård and Ellgren (2000)
[567] Åsgård and Ellgren (2000)
[568] Dalum and Villumsen (2003), in Edquist (2003)
[569] Åsgård and Ellgren (2000)
[570] Åsgård and Ellgren (2000)

Table 6-13: Acquisitions and investments by Ericsson 1997-2000

Acquired firm	Country	Year	Capability	Empl s.	Price (US$)
Microwave Power Devices	US	2000	Design & manufacture of radio frequency microwave linear high-power amplifier for 3G	340	100 million
Part of LCC International	US	1999	Network-optimizing technologies	185	22 million
Matec S.A	Brazil	1999	Enterprise solutions	475	53% share
Saraîde	US	1999	Wireless Internet service	150	na
OZ.com	Iceland	1999	Internet applications	90	na
Qualcomm infrastructure division	US	1999	CDMA infrastructure	1300	na
Telebit	Denmark	1999	IP router software	60	30 million (75% share)
Torrent Network technologies	US	1999	Aggregation routers	80	50 million
TouchWave	US	1999	IP-based PBX, IP telephony	27	46 million
Advanced Computer Communications (ACC)	US	1998	Access equipment, routers & concentrators	200	300 million
Mariposa	US	1998	ATM service access	50	na
Juniper	US	1997	Backbone routers	270	na

Source: Adapted from Dalum and Villumsen (2003) in Edquist (2003:67)

6.5.6.1 ATM and DTM

In the 1980s Ericsson started working on the next-generation broadband telecommunications switches able to handle voice, video and data. The switches, successors of the successful AXE switches, were dubbed AXE-N. Heavy investments were made in the project, according to some sources as much as SEK ten billion.[571] The technological hurdles of integrating voice and data proved higher than anticipated, and in 1995 the project was terminated. The AXE-N switch was based on Asynchronous Transfer Mode (ATM) packet-switching technology. The aim was to replace all different data networks with ATM networks, and in the long turn even include voice traffic. In late 1995, then CEO Lars Ramqvist declared that Ericsson's focus in fixed broadband telecommunications had shifted from large handle-all switches to smaller switches and access products.[572]

The ATM technology lived on, however. In 1999 both Ericsson and Nortel introduced products for ATM-based multi-service networks.[573] Ericsson launched the Engine solution, based on an ATM switch, a telephony server and a media gateway. IP was seen as a clear threat at the time, but ATM had the advantages of offering quality of service, built-in billing mechanisms and subscriber management functions.[574] In the first versions of Ericsson's ATM switches the traffic could be billed according to level of service (16 levels), per time, per bit volume, or as single objects (e.g. a movie ticket).[575] In the first quarter of 2001, when the downturn in the mobile business had already appeared, Engine sales increased 37%, reaching SEK 8.8 billion, equivalent to 16% of the total turnover.[576] When Jan Uddenfelt in 2001 was asked to list the five most important technologies for Ericsson's future, he named 3G,

[571] Veckans affärer (1997-06-16)

[572] Veckans affärer (1997-06-16)

[573] Datateknik 3.0 (1999-12-06)

[574] Computer Sweden (2001-04-27)

[575] Nätvärlden (1998-03-20)

[576] Vision (2001-04-22)

Bluetoooth, Wap, Backbone technologies such as Engine, and streaming services in the networks.[577]

Parallel to the ATM development, Ericsson co-financed research at the Royal Institute of Technology (KTH) in Stockholm on another switching technology, dynamic synchronous transfer mode (DTM).[578] When the technology was ready for commercialization, Ericsson decided not to develop DTM products. Instead, the research resulted in two start-up companies in 1996, Dynarc and Net Insight. Dynarc focused on the IP protocol, whereas Net Insight from the start had solutions for several protocols.[579] A third company, Effnet, provided PC-based router solutions supporting among other techniques DTM, but later focused on IP header compression technologies. DTM is a circuit-switched technology, but the dynamic time-slot allocation capabilities make it suitable for bursty data transfer, including IP-based data. ATM is a standard, whereas DTM for long was a proprietary technology with patents held by Dynarc, Net Insight and the initial backer Ericsson. Evenutally DTM also became standardized.[580] The market for DTM technology proved smaller than anticipated, and in mid-2002 Dynarc filed for bankruptcy.

Another Swedish company, providing chips for use in ATM-based switches, SwitchCore, was founded in 1997 (under the name Netcore). Switchcore has later shifted its focus from ATM solutions to Gigabit Ethernet. In 2002 the total turnover reached SEK 71.5 million with around 80 employees.[581] Another company supplying networking processors for Ethernet and optical networks, Xelerated, was started by people from Net Insight and SwitchCore in 2000.

Recently, Ericsson seems to have shifted focus from ATM for access networks towards what they call “Public Ethernet”.[582] Ericsson has developed solutions for extending Ethernet-based services to the public network. The company follows a three-stage strategy from the present solutions of ATM over ADSL, to Gigabit Ethernet as access form for homes and business.[583]

6.5.7 Government initiatives/institutions

The Swedish government has played a large role in the Swedish Internet development, both directly and indirectly. As late as 1991, government-owned companies had a staggering 98% of the total telecom operations market.[584] Through the ownership of companies such as Telia, Vattenfall, Svenska Kraftnät, Banverket and Teracom, the state still controls a very large share of the total communication backbone systems in Sweden. In 2003, the state controls 78% of the high-speed network infrastructure, and municipalities and municipality-owned corporations control another 11%.[585]

The year 1994 is often regarded as an important year in the development of Internet in Sweden. This was the year when the Swedish Prime Minister, Carl Bildt, sent a now famous

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[577] Vision (2001-03-18)

[578] Datateknik 3.0 (1999-10-04)

[579] Nätverk och Kommunikation (n.d.)

[580] Hedin (2004)

[581] Switchcore 2002 annual report

[582] http://www.ericsson.com/network_operators/campaign/publicethernet/01_broadband_challenge.html accessed at 031013

[583] http://www.opticalkeyhole.com/keyhole/html/ericsson.asp?bhcd2=1068740374, accessed at 031111

[584] PA Consulting (1995)

[585] PTS (2003c)

e-mail to President Clinton.[586] In 1994 the politically conservative Bildt gave a speech on how Sweden could catch up in the development race using IT. Liberal thoughts were prevailing, which influenced the views on telecom regulations and IT policies. The conservative government set up a special IT commission in 1994. When Sweden had a shift of government after the elections in 1994, Jan Nygren (s) took over the leadership of the IT commission.[587] The political shift seemingly had an impact on the attitudes towards IT; the Social Democratic minister displayed a more skeptical attitude.[588]

As seen from the US Internet development, public procurement can be an efficient policy tool for affecting technological and industry structure development. In 1993, Stattel awarded France Télécom a contract for public data communication services. Stattel is a framework agreement for procurement of public telecom services running for five years, applicable to all state agencies. The contract, worth some SEK 800 million, was won in competition with Telia, Tele2 and British Telecom. The Stattel initiative was taken in order to reduce public costs for telecommunication services, and the FT bid was as much as 32% lower than the Telia bid, forcing Telia to lower its rates.[589] In 1996 the company GlobalOne[590] was announced the winner of another Stattel agreement, this time together with Telia. An interesting fact concerning the Stattel agreements is the use of public procurement to spur competition, leading to lower prices. The choice of awarding the contract to a non-national actor works counterproductively for using public purchasing as a means to build up a strong domestic industry. However, the Swedish market was at the time in effect an oligopoly, with limited competition and thereby limited pressure for actors to lower costs and prices. By choosing a non-national actor the level of competition was increased, leading to lower prices in the longer term.

IT has received an important place on the political agenda in Sweden in recent years. The overall goal for the Swedish IT policy is to be the first country to become an information society for everyone.[591] Three areas are prioritized in Swedish IT policy: IT trust, competence to use IT, and accessibility to IT services. In recent years, stimulating activities have been performed in all three areas.

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[586] However, it seems Clinton never replied. According to initiated sources President Clinton only sent two mails during his presidency, of which one was test-mail. http://www.aftonbladet.se/vss/nyheter/ story/0,2789,424925,00.html [Accessed 27 January 2004]

[587] In May 1996, the Swedish minister of communications and chairman of the IT commission, Ines Uusman (s), said in a newspaper interview that surfing the Internet may be a “quickly passing fad” (author’s translation), since then a widely quoted statement in Sweden. (Svenska Dagbladet, 1996-10-06)

[588] Svenska Dagbladet (1996-05-14)

[589] Dagens industri (1994-06-22)

[590] GlobalOne is a strategic alliance between Deutsche Telekom, France Télécom and the American operator Sprint

[591] Ministry of Industry, Employment and Communication (2002)

6.5.7.1 IT Trust

The reliability of the IP network has impact on the trust for IT usage and services. High trust is a prerequisite for usage of Internet for e.g. financial transactions. In an effort to improve Internet security, the administrative units RSV, PRV, RFV and Statskontoret jointly develop standards and infrastructure for electronic signatures to facilitate development of services. In July 2003 a new bill on electronic communication was ratified. The bill has a larger scope than the bills it supersedes (Telelagen and Lagen om radiokommunikation). It encompasses all types of communications and networks – television, radio, and Internet-based communication. The bill does not deal with content services, but prohibits e.g. the use of cookies for collecting information about a user without the user's knowledge.

In 2003 a bill on the Swedish top domain .se was proposed by the Swedish government.[592] The bill proposes far-reaching governmental administration and supervision of the Swedish top domain, today administered by a not-for-profit foundation. The administrative fees for a domain name should be regulated and be cost-based, and include a "supervisory fee" to cover the additional costs for the state. The bill refers to principles established by GAC (Governmental Advisory body), the inter-state organization functioning as advisory body to ICANN (Internet Corporation for Assigned Names and Numbers. The bill has raised a debate about the direction and scope of public IT policy in general, and the involvement of national governments in Internet development in particular.[593] The issue whether international regulations should be imposed on the Internet is debated in other countries as well (see Section 6.3).

6.5.7.2 Competence to use IT

The tax reductions on computers bought by organizations for their employees' personal usage were aimed at raising the competence to use IT (see above). The project ITiS (IT in the schools) was run between 1999 and 2002. In total SEK 1.7 billion was spent in the project, aiming at raising IT literacy among Swedish schoolteachers.[594] By making teachers feel comfortable with IT usage, IT is hoped to be made a natural part of school education. The program encompassed 75,000 teachers, around half of the total number of teachers in Sweden.[595]

6.5.7.3 Accessibility to IT services

In the late 1990s/early 2000s the Swedish government presented a vision of Sweden as the world-leading IT society under the slogan "broadband for everyone". A prioritized area of Swedish IT policy is to increase the accessibility of IT services through a strong infrastructure of high-speed connections. The government has set aside funds to support infrastructure investments in municipalities where the market forces, for economic reasons, do not invest.[596] Another form of support is tax reductions of up to SEK 5000 per house or apartment for certain costs associated with communication access installations.[597] To date (October 2003), only 23% of the total SEK 3.1 billion subsidy funds has been distributed to municipalities.[598] The state-owned company Svenska Kraftnät[599] was ordered to build an open backbone

[592] SOU (2003:59)

[593] See e.g. Dagens Industri (2003-11-06)

[594] http://www.itis.gov.se/om/ accessed at 031103

[595] ITPS (2003)

[596] PTS (2003c)

[597] PTS (2003c)

[598] ITPS (2003)

[599] Svenska Kraftnät is a state-owned company providing electrical grid network to electricity utilities

network through installation of opto-cable on its electrical grid infrastructure. In March 2003, 215 out of 3,000 municipalities were connected to Svenska Kraftnät's or cooperating companies' optical networks.[600] The aim is to connect all Swedish municipalities with high-speed data transmissions (see e.g. Gov. Bill 1999/2000:86). This goal was operationalized in a bill proposed on the use of state-owned infrastructure for electronic communication purposes.[601] It is suggested that the state should take a comprehensive approach on the use of public infrastructure for constructing an electronic communications network with access points to the backbone network for all Swedish municipalities. The proposal includes concentration of access to capacity (in networks owned by Svenska Kraftnät) to Teracom, and the opening up of channel space controlled by Banverket and Vägverket for private data and telecom operators. Such initiatives, if executed properly, could lead to healthier conditions for competition among operators.

In a press release from the Ministry of Justice on December 9, 1999, the government announced that it had given Statskontoret the task of developing criteria for the often-used term "24-timmarsmyndigheten". The "24/7 authorities" is the umbrella under which initiatives are aimed at developing the public administration to better meet people's needs through deployment of IT services. The aim is to increase IT usage and create services accessible for individuals and companies at any time of the day, e.g. handing in or checking status of applications. The aim is also to rationalize the operations of the public administration in order to cut costs and prepare the organization for large retirements in the coming years.[602] It is hoped that increased IT usage will lead to improved IT infrastructure, spur technological innovation and, in the long run, strengthen Sweden as an IT nation. The public administrations' websites had around 2 million unique visitors each month at the end of 2002, and the annual increase in number of users has increased by around 15% in recent years.[603]

The Swedish government has adopted a four-step approach to implementing electronic services (Figure 6-10). The Swedish plan is very similar to the EU-wide initiative eEurope Action Plan. The eEurope 2002 Action Plan was an initiative aimed at creating a foundation for a knowledge-based economy by increasing the number of Internet connections in Europe.

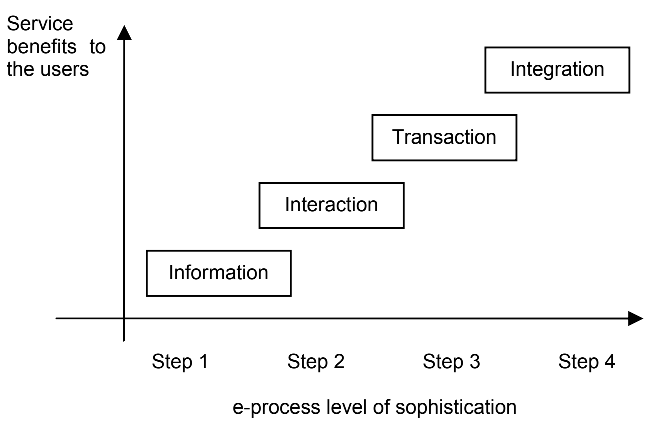


Figure 6-10: The development stages towards the 24/7 authority

Source: http://www.statens-e-forum.nu (Statskontoret)

[600] ITPS (2003)

[601] SOU (2003:78)

[602] Regeringskansliet (n.d.)

[603] Statskontoret (2002:30)

A follow-up initiative, eEurope 2005 Action Plan, focuses more on applications and services with the goal of increasing productivity.[604] In 2005, EU member states are to have implemented e.g. Internet-based public services, e-administration, services for e-learning, e-health care services, and a secure information infrastructure. Sweden aims at reaching those goals through e.g. 24/7 authorities. Today, some authorities are in Step 1, while some (e.g. PRV, RSV) have implemented solutions where the public can handle all its contacts with authorities in a given matter over the Internet.

Table 6-14: Selection of IT initiatives by public authorities

IT trust	Competency to use IT	Accessibility to IT services
- Jointly developed standards for electronic signatures by public administration authorities - New electronic communications laws, placing Internet communications alongside television and radio	- Tax reductions on company computers bought for employees' private usage - ITiS project (SEK 1.7 billion during 3 years) to raise IT literacy among schoolteachers	- Tax reductions for broadband access installations - Proposal of opening up channel space in state-owned infrastructure for telecom operators - State-owned companies obliged to build high-speed backbone infrastructure - Implementation of the "24/7 authorities"

Source: Compiled from various government reports and proposals

In a recent evaluation of the Swedish IT policy, ITPS (Swedish Institute for Growth Policy Studies) concludes that Sweden has come a long way in the work towards a broad involvement in the IT society. There are, however, a number of weaknesses in Swedish IT policy. Perhaps the most important are the lack of measurable IT targets, and that Sweden, in spite of high ambitions and numerous initiatives, lacks a clear strategy for reaching and implementing the IT goals. In addition, government IT concepts, such as IT trust, are poorly defined, leading to possible misinterpretations.[605]

6.5.8 Swedish Internet governance bodies

The Swedish part of the Internet is to a great extent governed by the international governance organizations and bodies. Some country-specific organizations have been formed. ISOC-SE, the Swedish chapter of ISOC, was founded in 1997. The organization administers the domain name allocation process in Sweden. ISOC-SE also appoints two members of the board of the II foundation (II-stiftelsen), founded in 1997 to take a long-term perspective on the development of the .se top domain. Under the II foundation the company NIC-SE was started to handle the daily operations of the domain name administration. The II foundation is financed by the annual domain name registration fees. In 2003, a government bill on state regulations and supervision of the Swedish top domain administration was proposed (see Section 6.5.8).[606] Although no decision has yet been made, the bill reflects the ongoing debate about increased regulations of the ever more important Internet.

There are 13 root name servers in the world keeping track of all domain names on the Internet. Of these servers, 10 are located in the USA, one in Tokyo, one in London, and one in Stockholm. The server placed in Stockholm is run by the company Autonomica, owned by Netnod AB, a company establishing and operating nodes between Internet operators' networks.

[604] http://europa.eu.int/information_society/eeurope/2002/news_library/documents/eeurope2005/eeurope2005_sv.pdf

[605] ITPS (2003)

[606] SOU (2003:59)

There are several societies for network users and operators. Svenska Operatörers Forum (SOF) is a non-profit society for the Swedish Internet operators connecting to the Internetional Internet nodes administered by Netnod. SOF has been run informally for several years and formally since 1999. Swedish Network User Society (SNUS) unites Swedish network users, aiming at increasing network knowledge in Sweden, thereby increasing the national competitiveness.[607] SNUS has mainly individuals as members. SSNF (Svenska Stadsnätföreningen, founded in 1998) is an industry organization for network owners and BitoS (Branschföreningen för innehålls- och tjänsteleverantörer på onlinemarknaden i Sverige, founded in 1997) is an industry organization for content and service suppliers. PTS follows the developments in accessibility of broadband Internet connections, and is the supervisor of companies issuing electronic signatures. PTS also works with protection against IT incidents by gathering information about IT security breaches.

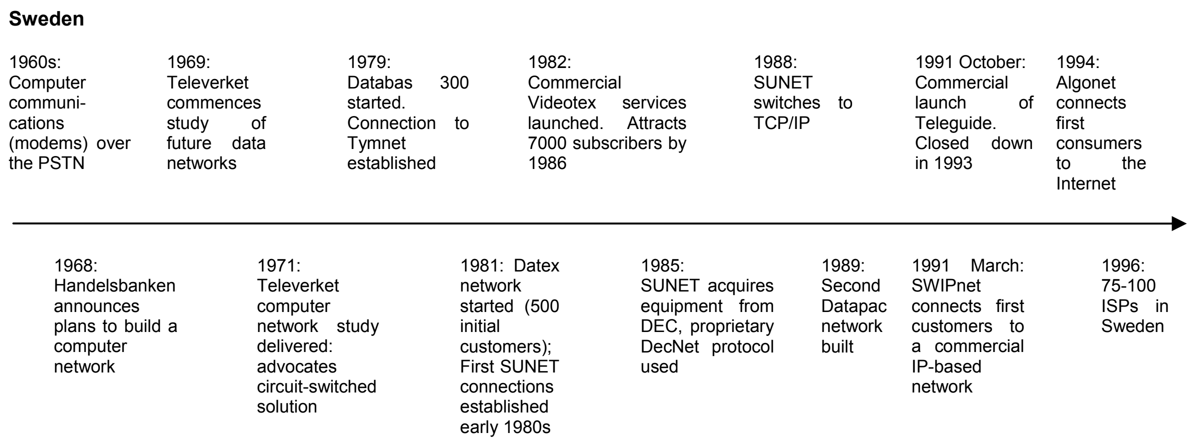


Figure 6-11: A time line of important Swedish data networking developments

6.6 Summary and conclusions

This chapter analyzes the developments of the Internet into a common international computer communications platform. The chapter starts with an analysis of US developments, with a European comparison. In the following part the Swedish developments are analyzed in more detail, structured according to the analytical framework presented in Chapter 2.

6.6.1 International developments

History is most often written about winning technologies and standards, and thus seems to follow a straight line from idea to mass market adoption. The development of Internet has never followed a straight line. From the early days there existed a multitude of competing network technologies and protocols. The development of Internet, born out of a research project commissioned by the US Department of Defense in the early 1970s, cut across complex networks of different kinds: scientific, institutional and personal. Early-involved actors included the Department of Defense, NSF, major universities and think-tanks. Still, the Internet is evolving and the complicated relationships between technologies, markets and industries make it difficult to predict what the Internet eventually will become. There is an ongoing debate about which factors have been most deciding in Internet development. Some

[607] ISOC-SE (2003)

argue that the lack of government control and strong competition of ideas and products have been most important for innovation. Others stress the importance of initial government finance, the free exchange of ideas and software, and the openness of standards.

Networked computer systems are very complex and no single firm had the ability to innovate in all parts of the system, as was the case for IBM in the mainframe computer business. As noted by Mowery and Nelson (1999), the open platforms and standard bundles permitted compatibility and connectivity between equipment of different kinds. This equipment was developed and commercialized by specialized firms in the various layers, opening up for new actors. The new entrants included spin-offs from established computer firms, science-based firms established by university scientists, and new firms with market or marketing competencies. This development was catalyzed by the availability of venture capital, and of venture capitalists knowledgeable in the computer industry. The spillovers of knowledge between universities, established firms and new firms were important in the computer networking development. The Silicon Valley area, with companies active in all layers of computer networking, benefited from strong complementarities and local knowledge externalities. During the 1980s and 1990s, several firms were founded in the area, spurred by the plentiful access to venture capital. Many of the firms emerging as leaders in networking technologies were founded at this time, e.g. Cisco, Bay Networks and 3Com. In the words of Mowery and Nelson (1999), "Intense formal and informal communication and high personnel mobility (together with the high entry and growth rates already present in the mini and micro period) allowed firms located in the United States (particularly in Silicon Valley) to be exposed early on to new experiments, knowledge, and technologies". Today, US companies are market leaders in most parts of the Internet value chain: computers, communications hardware, browser software, aggregators, content sites etc.

There are several reasons why the USA managed to secure its strong position in the Internet industry. Europe lacked many of the complementary strengths that catalyzed the diffusion of the Internet in the USA. In Europe, the academic networks were not operating on a common platform as in the US, the LAN infrastructure and the commercial on-line services industry were smaller, and Europe had no strong domestic base of computer manufacturers. There were many technical limitations for using the public telephone network as a computer network. There were also many hindering institutional factors during the 1970s. In Europe, in contrast to the USA, most telecom operators were monopolists controlled by the governments. The monopolies often included the equipment used by end-users, telephones, modems etc. According to Noam (1992), the PTTs in Europe failed to realize the full potential of data communications. Much of the equipment and technologies, e.g. packet switching, was therefore developed outside the traditional suppliers to the telephone industry. This can be explained by the monopoly situation, the integration of post and telecommunications in some countries, and the huge capital investments made in the telecom networks. Another reason for slow take-up was that data communication services were not allowed to cannibalize on telecom services. The data communication rates in the 1970s were set on the same principles as telecom rates; the charges depended on distance and time rather than transferred amounts of data.

As described above, federal US R&D funding also played an important role in the early development of the Internet. Using several different instruments, including direct funding and public procurement, the means for long-term investments in R&D were provided. Another aspect of government funding is the importance of available, highly trained and skilled, researchers caused by the heavy defense spending during the postwar arms race. This pool of talent became an important resource for companies working in the computer networking field.

The heavy lean towards the USA in computer communications can also partly be explained by the developments in supporting technologies (e.g. semiconductors and computers) in the 1950s and onwards. These developments were catalyzed by heavy defense spending during the Cold War years. The USA was also first to introduce competition among the telecommunications carriers, and open up for specialized providers of data communication services. In Europe (including Sweden), data communications was long considered a matter for the telecommunications industry. R&D initiatives were focused on large-scale, extensively standardized, and nationally coordinated, systems developments as evidenced by the Videotex and ISDN cases. The European industry policies included support for national champions and efforts to build strong positions in the electronics field, partly explaining e.g. the massive French subsidies to the Minitel system. These large, focused development projects in Europe seem to have had an inhibiting function on the process of innovation among new firms, and guided firms' development efforts in wrong directions. The firms started in the US to make use of new, standardized and open technologies emerged as the winners when the world eventually unified around universal communications protocols and technologies.

The different regulatory policies chosen in Europe and the USA can be illustrated as in Figure 6-12 below. Whereas in the US diversity in both technological solutions and companies providing them was promoted, in Europe the focus was on standardization and monopolies in the communications area.

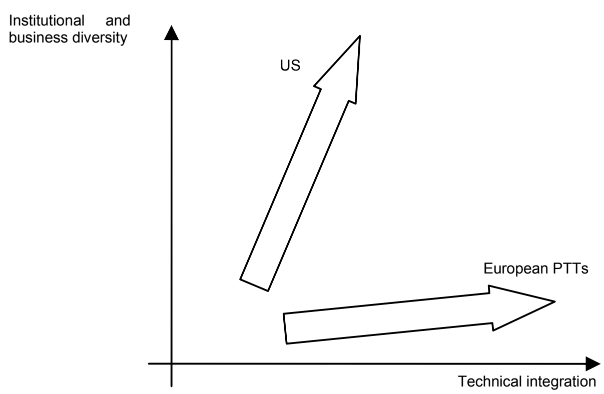


Figure 6-12: Illustration of different regulatory policies in Europe and the USA until the 1990s

Source: Adapted from Noam (1992, p. 413)

The developments of the Videotex and ISDN standards, promoted by European PTOs, are both evidence of this state. In the US the relatively more diverse atmosphere was a growing ground for multiple technologies, improved through competition with each other. Adding the fact that the developments in the computer field outpaced the developments in the telecommunications field, Europe ended up lagging the USA both in terms of computer communication usage and in relative strength of the computer communications industry.

6.6.2 Sweden

Sweden indisputably has come a long way in Internet penetration and usage. With penetration rates among the top countries and a strong growth in broadband access, the Swedish Internet population is one of the most mature in the world. The growth has been catalyzed by high PC penetration, in turn stimulated by favorable tax-cuts on computers for firms' employees. There is a strong political will to create the foundations for economic growth as well as cost-cutting in the public sector through increased IT usage. The government is promoting widespread use of broadband connections and subsidizes build-out in areas not catered to by private actors. Table 6-15 below summarizes the Swedish position in IT usage in some international comparisons.

Table 6-15: Summary of selected research/reports on Swedish IT usage

Indicator	Swedish status	Year/Source
PC penetration	World No 2	2001/OECD
Internet penetration	World No 3	2002/ITU
Broadband Internet connections	World No 7	2003/OECD
IT usage	World No 1	2002/IDC
Companies with Internet access and e-procurement	Europe No 1	2003/EITO

Source: Various reports, compiled by authors

A strong domestic demand has often proved an important factor for creating a competitive industry.[608] The early usage of computer networking in US universities and companies is regarded as one of the main factors for the build-up of a strong US networking equipment industry. Sweden long lagged the US in both computer and networking usage, and much later introduced IP as a standard and common communication protocol. Computer usage in companies was higher in Sweden than in most European countries already in the mid-1980s, but the first commercial providers of Internet services emerged in 1991 (companies) and 1994 (consumers), many years after their US counterparts. The strong Internet and computer usage in Sweden has not been transferred into a strong international Internet equipment and services supplier industry. The most probable explanation for this seems to be the lack of strong computer industry actors. Instead the strong telecommunication actors seem to have guided the data communications developments, with late adoption of IP technologies.

In the following an analysis of the Swedish datacom innovation system will be performed, using the analytical framework.

6.6.2.1 Creation of knowledge

The character of a country's industry naturally influences what knowledge is created in the innovation system. In the 1960s and 1970s, Swedish telecom suppliers provided much of the data communication equipment used in the country. Although Televerket adopted data communications early, it cannot be regarded as a lead user and innovator. A convergence with the computer industry, with use of mutual technologies and components, seems to have been clear to Televerket at the time. However, in the 1970s Sweden was far behind the leading countries in microelectronics skills and knowledge. A number of research programs were launched during the 1980s to build competence in this important field. The programs raised the national electronics competence, but the lack of a computer industry led to solutions created for telecommunications rather than computer communications.

During the last decades, data communications solutions created in the telecom industry have proved inferior to the solutions from the computer industry in many aspects. The Swedish research and development efforts in the telecommunications area have generated extensive knowledge about the digital transfer of data over long distances, both wired and wirelessly. With the focus on telecommunication in Swedish industry, a large part of R&D funding in the communication field has been allocated to telecommunications research rather than computer

[608] See e.g. Porter (1990)

communications (e.g. Telia's and Ericsson's research budgets). Based on research at universities and corporate research laboratories, solutions for data communication were developed, including ATM and DTM. However, both Ericsson and Telia seems to have been slow to adopt IP technology, indicating a gap between the telecom and computing industries.

With a move towards mobility in Internet access, Sweden, with its strong mobile communications industry, has an opportunity to catch up ground lost in the fixed data communications field. A strong knowledge base has been created, and an infrastructure for creation of knowledge in the field is in place. However, there is a threat that technological developments will follow other paths, as seen in the fixed communications developments, making existing knowledge and infrastructures non-optimal.

6.6.2.2 Guidance and direction of search

In the early 1970s, Televerket conducted a major market study of the future of data communications, similar to the important study laying the foundation for the NMT development in mobile communications. The conclusion was that Sweden should build a circuit-switched computer communications network, rather than packet-switched solutions. Although we are not fully aware of the importance of the market study, it is interesting to note that a technological solution later to be out-competed was chosen, resulting in key actors building knowledge about "wrong" technologies. Without a strong national computer industry, Televerket – monopolist in the communications field – had an important role in data communications developments. It is reasonable to believe that the choice of a circuit-switched network guided the search away from packet-switching.

Like much of Europe, Sweden invested heavily in the development of Videotex services in the early 1980s. As late as the early 1990s, Televerket made a second attempt to introduce Videotex-based on-line services with IBM and Esselte, but this attempt also failed. Although important learning about on-line communities, sales and marketing might have taken place, much of the technological learning became obsolete when the Internet was established as a common data communication network.

The Swedish telecom equipment industry has been strong since the end of the 19th century. Ericsson has one of the strongest patent portfolios in the telecommunications industry, and companies like LGP/Allgon and Telia reinforce the Swedish strength in telecommunications. The fact that winning fixed data communications solutions have grown out of the computer industry has limited Sweden's strength in the computer communications field. In the computer communications industry, the absence of a strong Swedish actor (manufacturer of operator) to guide the direction of search seems to have been important. Although there are innovative companies developing communications hardware, including Net Insight, SwitchCore and Axis, their relative size is dwarfed by the US counterparts. In the late 1990s a Swedish Internet consultancy industry grew strong with companies rapidly expanding internationally. The burst of the IT bubble all but erased these companies, which moved towards supplying more traditional IT services. Although the majority of the domains most frequently visited by Swedish users are Swedish, no Swedish content or service actor has secured a strong international position.

Early on, Swedish authorities and companies realized the coming convergence of telecommunications and computing. Sweden was active in the European development of large-scale computer network initiatives in the telecommunications sector. The country had a strong telecom industry, but a weak position in the computer field. Swedish companies tried to diversify into the computer industry, but the efforts were largely unsuccessful. With technological solutions from the computer industry winning the standards race, the Swedish communications industry received the role of bystanders when the Internet equipment industry took off.

6.6.2.3 Incentives for innovation creation and exploitation

The rapid growth of the PC industry provided incentives for companies to innovate in data communications. Ericsson tried to diversify into the personal computer business in the 1980s, but the efforts were largely a failure. This failure may have lowered Ericsson's incentives to engage in datacom, in particular at a time (early 90s) when most attention and resources were directed to mobile communications.

During the late 1990s, with the high valuations of high-tech companies on the world's stock markets, possibilities for IPOs provided financial incentives for many entrepreneurs to commercialize inventions. Several companies were founded in the Internet area during this period. However, the backside of easy access to capital is the possibility of dubious business ideas and models being funded, which many argue to have been the case in the late 1990s.

An important function for inventions to be commercialized is a strong and well-functioning IPR system, allowing innovators a time-restricted monopoly. The Swedish IPR system is rigid and complies with international standards and regulations. A difference between Sweden (and Europe in general) and the US is the propensity to allow patents for software innovations. This difference in patenting policy might have an impact on the willingness to innovate in the field. With software constituting a larger share of the value in communication systems, this could be a factor that lowers incentives for innovation. However, we have not analyzed this issue further.

Finally, through public procurement and subsidies of broadband communications build-out, incentives for innovation in high-speed data communications networks have been provided (and still are); however, the effects on the innovation system have been difficult to assess.

6.6.2.4 Supply of resources

The available supply of resources, financial as well as human, is of highest importance for the establishment of a strong industry. In the case of data communications, Silicon Valley leveraged the pool of skilled people from the semiconductor and computing industries, and much available venture capital provided the means for company expansions. The absence of strong computing and semiconductor industries made the telecom industry and universities the main sources of competence, thus probably lacking some important computer knowledge.

Data communications is a complex and research-intensive business where access to capital is important for breakthroughs to be made. The Swedish venture capital industry was born in the early 1970s, and grew slowly during its first decades. Swedish VC industry was larger than even its US counterpart measured per capita in the late 1990s, and a relatively large part was invested in firms' early stages. During the 1970s and 1980s, when many of the leading computer communications firms were started, the VC industry seems to have been rather weak. Perhaps more importantly, Sweden venture capitalists have not been as competent as e.g. their US counterparts (see e.g. Karaömerlioglu and Jacobsson). Judging from the nature of the nation's industry, this has probably been the case in computer communications. The VC industry grew strong in the late 1990s, resulting in a large number of companies being created, also in computer communications.

With corporate R&D playing an important role in the provisioning of R&D funds, the nature of a country's industry is important for allocation of funds to different technological areas. Given the focus on telecommunications in Swedish high-tech industry during the recent decades, it is reasonable to assume that technologies targeted at telecommunications solutions have received a much larger proportion of funding than data communications.

6.6.2.5 Creation of networks and its effects

In complex technological systems such as computer communications, no single firm can innovate in all parts of the value chain. Firms must specialize in small parts of the technological systems, as Cisco grew strong in the router business. In order to utilize the technological advances from one area in other areas, networks of companies active in many parts of the technology system must coexist. These networks should also include other actors, as university research departments and qualified users.

In Sweden, strong networks exist between telecom equipment companies, telecom operators and universities. The weak national computer industry makes it natural for innovations in the data communications field to originate in the telecom world. Strong telecom networks established consensus regarding failing technologies.

The network of users of SUNET, the university computer network and first major Swedish network to start using IP, has probably played an important role in the diffusion of Internet. With university students used to the Internet, companies hiring graduates learned about the Internet and its utilities. The importance of strong networks, not least on the user side, is illustrated by the fact that a group of data communications users, SNUS, was active in establishing the first commercial IP network in Sweden. Again, the absence of a strong computer company, like Ericsson and Televerket in telecommunications, seems to have been an important factor for slow adoption of Internet.

6.6.2.6 Formation and stimulation of market/demand

The formation of markets and stimulation of demand can be made by governments and companies. As in the French Minitel case, Swedish Televerket subsidized TeleGuide terminals to stimulate demand for data communications in the early 1990s. The efforts were largely fruitless, as the project was launched when the Internet was already evolving into a consumer technology.

In Internet usage Sweden has secured a world-leading position, comparable to the position in cellular phone usage. An internationally high proportion of the population uses the Internet, increasingly over broadband connections, and e-commerce is rapidly growing. The Swedish government is, and has been, active in stimulating IT usage. A high degree of literacy in IT usage is believed to be important for future growth also in other sectors of the economy.

The Swedish government's will to raise IT literacy in order to make full use of IT in all parts of the economy has materialized in a number of stimulating initiatives in recent years. The employee computer program in the late 1990s, with tax reductions on computers bought by companies for their employees' private usage, had a positive impact on the computer diffusion and usage. Tax reductions had earlier been used to successfully stimulate the market for mobile phones, resulting in high penetration levels. Although it is difficult to quantify the effects of such programs, estimations and comparisons with neighboring countries indicate that PC penetration would be as much as 10 percentage units lower had the initiative not been launched. Widespread computer diffusion, and competence to use computers, have made way for rapid Internet penetration. If the employee computer program had a positive effect on the number of Internet users, broadband initiatives could have a similar effect on the usage levels. Through subsidies, and by using government-controlled companies, the government aims at building a network of high-speed data communication available in all municipalities. The goal is to provide broadband Internet access to all Swedish citizens. This would provide the basis for new types of services and applications, opening up for a more qualified IT usage.

During the latter half of the 1990s, a number of companies offering Internet subscriptions at no fixed charge emerged. These companies tried to build a market, and collect revenues from users once they had started to use their Internet connections. Although overall data communications usage was stimulated, many firms failed in the competitive situation.

6.6.3 Concluding observations

The Internet (being a data communications network) is a generic technology (see e.g. Bresnahan and Trajtenberg 1995), in some respects even comparable to e.g. electricity. As such, Internet comprises the "pipes of the plumbing", allowing smooth, standardized communication between terminals of different brands and capacities, using different operating systems. As a generic technology, Internet can be used for a multitude of purposes, impossible to foresee in the early stages of development. In fact, it can be argued that even today we have not seen more than a small share of what the Internet will eventually be utilized for.

The coming improvements in the Internet protocol are vital steps toward possibilities of using IP as the dominant bearer for voice telephony traffic and other real-time applications. Perhaps they alone do not solve the problems associated with using the Internet for voice traffic; the QoS will probably not be comparable to today's telephony networks in the near term, and there are no standards in equipment – which makes equipment from different vendors unable to interoperate. Prime targets for vendors of IP telephony solutions today are companies. However, many companies have made extensive investments in existing telecom solutions, and might be unwilling to invest in new IP-based equipment. The regulatory situation is also diffuse. In most countries IP telephony is still unregulated, but authorities are closely following the developments. Nevertheless, protocol improvements are important steps in the development towards converged telecom and datacom networks. If the technological hindrances to wide diffusion of VoIP are removed, in which the new IP version seems to be an important piece of the puzzle, far-reaching changes in the communications industry could be brought about. For Sweden, with a strong telecommunications industry, these developments must be closely followed.

With continued telecom-datacom convergence through ever-increasing usage of IP as the information bearer in telecommunications, actors from the telecom and datacom worlds are increasingly becoming direct competitors. Much as the proprietary computer communications systems developed by the likes of DEC and IBM were incompatible in many ways, the existing solutions in the telecommunications area are often not fully interoperable. Creating switching costs through the use of proprietary technologies has long been a successful strategy used by telecommunications equipment and computer manufacturers. Although increased standardization has partly solved interoperability problems and lowered switching costs for operators, the standards are often based on pooling of important patents by leading equipment vendors, effectively creating high barriers to entry for new actors. With an increase in usage of open standards, e.g. IP, IEEE WLAN, etc., the entry barriers will gradually be lowered, putting new demands on the communications equipment industry. An increased standardization could possibly lead to increased component focus at the expense of system knowledge and skills. If all components in a system work more seamlessly together, there is a possibility that extensive system knowledge, traditionally strong skills of telecom actors such as Ericsson, will decrease in importance. This trend would force today's telecommunications actors to organize sales and marketing functions differently, and have a strong impact on their innovation strategies.

An interesting question to explore further is why American firms made use of the open standards IP and Ethernet to a larger extent than others. With the continuing convergence of telecommunications and computer communications, open standards will probably play an increasing role in the future. The border lines between computer communications and telecommunications will eventually be blurred, with a multipurpose communications industry emerging. Thus far, it seems that firms originating in the computer industry have been the most successful in making use of the convergence.

7 EVOLUTION OF MOBILE TELEPHONY

As identified in Chapter 3, mobile telephony has been the main telecom growth market in recent decades.[609] The purpose of this chapter is to describe and analyze the evolution of this sector. In Section 7.1 the international development including its salient features and trends are described. The development of the Swedish sector is investigated in more detail in Section 7.2. The Swedish mobile telephony industry, particularly Ericsson, has been regarded – at least until the recent downfall – as a true success story, substantially contributing to growth in the Swedish economy. This success will be qualified and tentative explanatory factors identified.

7.1 International outlook

7.1.1 Overview

The development of mobile telephony could be described as a fairly orderly series of generational shifts illustrated in Figure 7-1. The most recent of those shifts (from 2G to 3G) is treated in Chapter 8. The first non-cellular land mobile telephone systems emerged in the late 1940s. Cellular systems had to wait until around 1980 before implementation, quite independently, in the US, Japan, Germany and the Nordic countries. A second generation (2G) of cellular systems, this time digital, was launched in the early 1990s. At this writing a third generation (3G) is under launch.

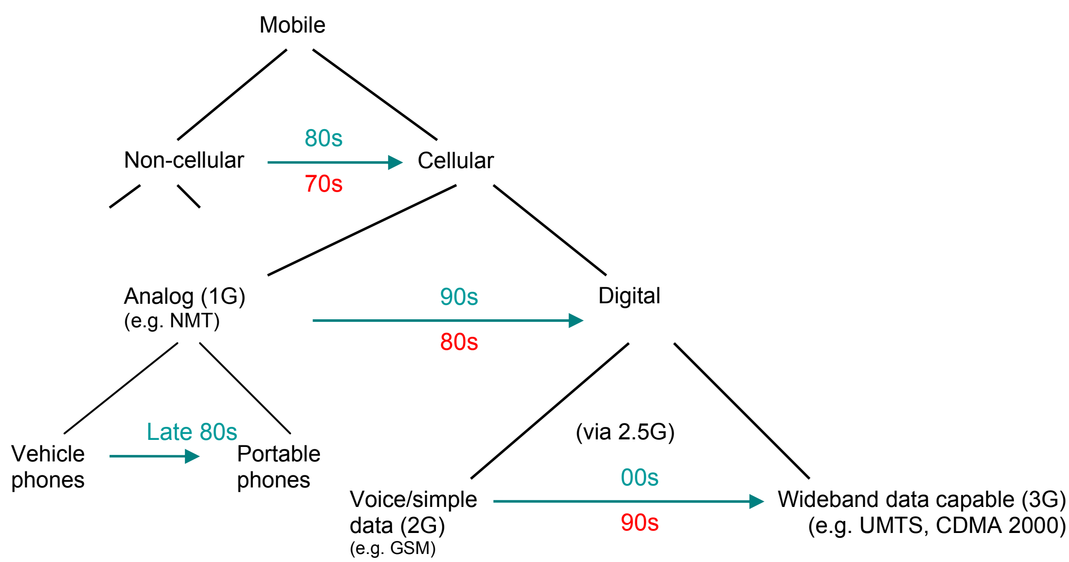


Figure 7-1 Transitions in mobile communications

Note: Arrows represent transitions. Years above arrow represent commercial migration. Years below represent main time period for R&D and standardization.

7.1.2 Pre-cellular mobile telephony

The first land mobile telephone systems were implemented soon after World War II. The war had the effect of improving radio technology, production capabilities, public awareness and user competence, and accordingly allowed new services to be offered to the public. The United States had gained a lead in radio communications, the dominant manufacturers being

[609] This chapter has been written by Sven Lindmark. It draws partly on Lindmark (2002), with original references used.

Motorola General Electric, RCA and F.M. Link. Accordingly, following some testing during the war, the first public land mobile telephony system was implemented by Southwestern Bell in St. Louis in 1946.[610] The following year similar services were launched in 25 US cities, including also a highway system between New York and Boston. These systems used FM transmission and wide-area architecture, i.e. one single transmitter (with a range of approximately 50 miles) which covered a whole city. In the 1950s mobile telephone systems were implemented in a few countries also in Europe, most of them developed by the PTTs in cooperation with their preferred national suppliers. Manual systems remained the dominant form of land mobile telephony until the mid-1960s (although a few automatic systems were developed in the US and elsewhere).[611] National monopoly operators (e.g. AT&T and Televerket) normally provided the service and developed the systems, often in collaboration with the radio industry. However, competing operators were also present, for instance the so-called Radio Common Carriers (RCCs) in the US and independent operators in Sweden.

These early mobile telephony systems suffered from a number of limitations, notably congestion, bulky equipment, poor service and high costs. Still demand outstripped supply. Demand for more spectrum became alarming in many countries and not least in the US, whose FCC was reluctant to set aside more frequencies for mobile telephony. Instead, most of the frequency spectrum was allocated to the military and frequency-hungry broadcasting services. As a result, mobile telephony would suffer from spectrum shortage for many years to come.

Since then, the mobile telephony industry (i.e. the PTTs and mobile radio suppliers) has focused engineering efforts on improvements of terminal size, signal/noise ratio, spectrum utilization, cost and reliability. One technological breakthrough of major importance to mobile telephony (and mobile radio in general) was automatic trunking. Automatic trunking requires the mobile unit to be able to tune in efficiently to a variety of frequencies. In early terminals, crystals were used for this purpose. In the 1960s different frequencies became synthesized electronically: a tone was placed on the idle channels, and idle mobile units searched automatically for these. Other important technological improvements in these early years included implementation of transistors and automatic switching.[612]

In 1964, AT&T incorporated these and other improvements into the Improved Mobile Telephony Service (IMTS). Similar developments took place in e.g. Germany, France, Italy, Switzerland, Norway and Finland. In the early 1980s there were around 300,000 pre-cellular subscribers in the world, fairly evenly split between the US and Europe (see Table 7-1).[613] A typical terminal was priced around USD 2000, with monthly fee of some USD 100, both varying considerably between countries.[614]

[610] Bell Laboratories (1946).

[611] The first two paragraphs draw on Noble (1962), Young (1979), Calhoun (1988); Garrard (1998) and Zysman et al. (2000).

[612] See e.g. Noble (1962) and Young (1979).

[613] Young (1979), Spindler (1982), Garrard (1998) and GSM (12/82 app. 9).

[614] See Steinbock (2003: 91-93)

Table 7-1: Pre-cellular mobile telephone systems in selected countries

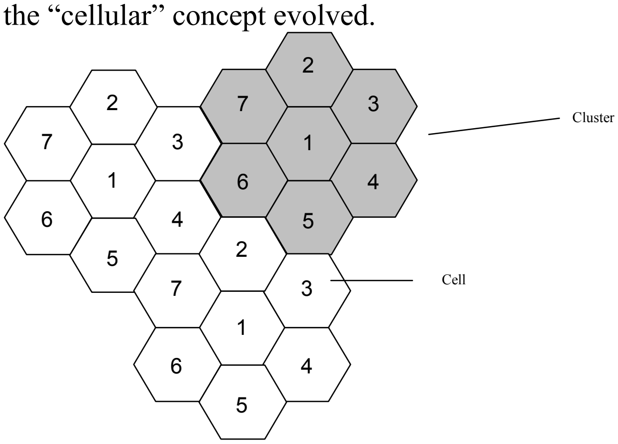
Country	Introduction (year)	Comment	Subscribers (c. 1981)
United States	1946	Various local and highway systems in the 40, 150 and 450 MHz bands. Automatic systems were introduced in the 1960s in the 150 and 450 MHz bands.	150,000
The Netherlands	1948/49	German system B was implemented in 1972.	5,000
Switzerland	1949	Subsequent systems launched in 1978 and 1981/82.	4,600
Germany	1950	Automatic system B introduced in 1972.	18,500
Sweden	1955	MTA automatic. Improved system launched in 1965. Manual system MTD launched in 1971.	20,000
France	1956	Automatic local Paris system in the 150 MHz band launched in 1973.	6,500
United Kingdom	1959	Improved manual system 3 launched in 1972. Automatic system 4 launched in 1981.	7,300
Denmark	1962	MTD (see above) launched in 1974.	15,000
Norway	1967	MTD (launched in early 1970s).	33,000
Finland	1971	Manual system launched in 1971.	30,000
Spain	1972	Automatic Motorola system launched in 1981.	1,000
Austria	1972	German system B.	1,200
Italy	1973/74		3,000/6,000

Sources: Noble (1962), Televerket internal (6708), Young (1979) Calhoun (1988), Spindler (1982), GSM (12/82 app. 9), Gerdes (1991), Harrison and Bishop (1995), Garrard (1998), Bekkers (2001, p. 308) and personal communication with P. Dupuis (1995). Note that sources differ somewhat. For instance, Garrard (1998) claims 10,000 subscribers in Austria by 1982.

7.1.3 Analog cellular systems

7.1.3.1 The cellular concept[615]

In spite of these improvements, costs of mobile telephony were high, service poor and capacity of the systems low. As a response to these limitations, mainly the capacity limitation, the "cellular" concept evolved.



Explanation:
The essence of the cellular idea is to use low-powered transmitters, covering small geographical areas with a dedicated assignment of frequencies to each cell. Different frequencies should be used in neighboring cells, permitting a pattern for systematically reusing the frequencies. Another key idea was to start with large-radius cells which later could be divided into small-radius cells, making the system flexible in terms of capacity .The numbers correspond to a set of channels (corresponding to a set of frequencies).

Figure 7-2: The cellular principle

[615] This section draws mainly on Young (1979), Noble (1962), Calhoun (1988) and Garrard (1998).

Cellular is a quite simple idea, usually credited to AT&T Bell Labs (see Figure 7-2).[616] The idea was presented in the late 1940s, but was not implemented before the late 1970s/early 1980s. This gestation time was due to technological, economic and regulatory (in the US) constraints. First, in order to reuse frequencies, low-power transmitters operating at higher frequencies than was commercially feasible at that time had to be developed. Moreover, dividing the area of coverage into cells requires additional functionalities such as (1) *handover,* (2) the *roaming* (or locating) function. These functions required intelligence in the system, mainly located at the switch. It took until SPC (Stored Program Control) switching developed (in turn enabled by implementation of transistors and integrated circuits) in the late 1970s for these intelligent functions to be implemented in the system. Finally, semiconductor technology had to advance far enough for complex terminals to be built.[617]

Table 7-2: Summary of analog cellular systems

System	AMPS	TACS	NMT 450	NMT 900	C-450	NAMTS	RTMS	RC2000
Home market	US	UK	Nordic countries	Nordic countries	Germany	Japan	Italy	France
Development period	1960s and 1970s	1983	1971-1980	1983-1985	mid-1970s - 1984	1972 -1979	1980 - 1984	1981 -1984
Year of intro.	1983	1984	1981	1986	1986	1979	1985	1985
Frequency band (MHz)	800	900	450	900	450	800	450	200, 450, 900
Roaming	limited	national	internat.	internat.	national	limited	national	limited
Main developers	Bell and Motorola		NMT group	Ditto	Siemens	NTT	SIP and Telettra	Matra
System suppl. (1991)	8	4		5 (total NMT)	2	1(?)	1	1 (?)
Main system suppliers	Motorola AT&T Ericsson NorTel	Ericsson / Radio-system Motorola	Ericsson / Radio-system Nokia Mitsubishi	Ericsson / Radio-system Nokia	Siemens	NEC	Telettra.	Matra
Terminal suppliers (1991)	30	28	15	25	7	n.a.	3	5-10
Main terminal manufacturers	Motorola, Nokia / Mobira, NEC + Japanese	Nokia / Mobira,MotorolaNEC	Ericsson, Nokia / Mobira, Motorola, Benefon	ditto	Siemens, Philips, Storno, Bosch, AEG	Japanese	Italtel, OTE, Telettra	Matra (later others)
Price of terminals c. 1988-89 (USD)	700 (mob.) 1200 (hp)	800 (mob.) 1500 (hp)	1400 (mob.)	2000 (hp)	3800	leased	leased	n.a.
Subscribers (000)								
1985	258	51	233	-	-	60	-	-
1990	6,527	1,668	857	649	287	320	97	230
1995	41,500	13,600	1750	2,950	650	c. 1500	8	140
1999	99,600	16,100	1,850	2,600	500	600	-	96
Max. (000) (year)	c. 90 (1999)	c. 17 (1998)	c. 1.8 (1995)	c. 3.0 (1996)	c.0.85 (1994)	n.a. (c. 2)	c. 0.1(1996)	0.33 (1993)
Foreign entry year	1984	1985	1981	1987	1986	-	-	-
Countries (end 1996)	73	32	37	12	3	-	-	-
Main regions	NA, LA, C, AP, S	WE, AP	WE, AP, EE, S	WE, AP		-	-	-

Legend: NA=North America, LA=Latin America, C=Caribbean, WE=Western Europe, EE=Eastern Europe, S=former Soviet Union republics, ME=Middle East, AP=Asia Pacific, mob=mobile, h.=hand-portable

Sources: Various compiled by the author

[616] See e.g. Young (1979), Millman (1984:235) and Zysman et al. (2000). See also Chapter 4.

[617] See Menich (1993:49) for an elaboration of these technologies.

The US had an early lead in developing cellular systems, and technology for cellular systems seems to have been available in the US in the 1970s, but regulatory obstacles delayed their introduction. Instead, it was Japan and the Nordic countries that pioneered the commercial introduction of such systems, in 1979 and 1981 respectively. The first US system was launched in 1983, followed by a few other cellular and quasi-cellular standards in Britain, Germany, France and Italy in the mid-1980s. The analog cellular systems are summarized in Table 7-2 and briefly described below. The US market will be elaborated more, due to its relative importance,.

7.1.3.2 United States – AMPS

The United States, mainly represented by the Bell System and manufacturers such as Motorola, had a lead in mobile communications for several decades. Entering the 1990s this lead was lost to the Europeans, partly as a result of regulatory obstacles which delayed introduction of cellular in the US.[618] This was in turn partly because frequencies were set aside for broadcasting radio and television as well as for military purposes, but also due to the FCC's seemingly hesitant actions in reserving frequencies and issuing licenses.[619] In 1956, the Justice Department decided that Bell had to leave radio and computer manufacturing, which paved the way for Motorola to become the dominant US radio equipment supplier and opened up for competition from the Radio Common Carriers (RCCs) in service provisioning. These eventually acquired roughly half the market of subscribers.

Motorola and the RCCs later teamed up to counter Bell's aims to dominate the cellular market. AT&T/Bell aimed at being the sole provider of cellular services. Cellular was a complicated and costly concept, and AT&T appeared natural as the operator for such a system. The RCCs became better positioned to oppose this view as they grew larger, strengthened their financial positions and gained experience in managing and operating mobile communications networks. The development of digital SPC switches (from other companies than Bell) also reduced the technical hurdles of building a cellular system. In addition, the support from Motorola put them in a more favorable situation.

In 1982 FCC issued a docket which set the rules for cellular in the form of AMPS. The country was divided into small areas (MSAs and RSAs), in which there would be two licenses; one for wireline carrier (a Bell company or an independent exchange carrier such as GTE) and one for non-wireline carrier. First using a competitive hearing, then in 1984 switching to a lottery procedure led to the approval of ever more speculators; cellular licenses became traded among the carriers. By this time (in 1983) the Bell System was divested. The giant company had been split into (1) seven Regional Bell Operating Companies (RBOCs responsible for local traffic) and (2) AT&T, responsible for e.g. long-distance traffic and manufacturing. The RBOCs obtained most of the wireline licenses and most of them chose AT&T as their supplier. GTE obtained most of the remaining wireline licenses (about 15%) and chose Motorola. Ericsson was contracted to deliver several of the non-wireline systems, e.g. in Chicago and Buffalo, due to fast and adaptive product development based on its experience from NMT and some skilled businessmen.[620] Northern Telecom/General Electric also took a substantial part of the remaining contracts. Some minor contracts went to NEC,

[618] This section constitutes a synthesis of the following sources: Porter (1971), Staras and Schiff (1971), Lane (1973), Kamman (1975), Fisher (1977), Huff (1978), Nadel et al. (1978), Blackstone and Ware (1978), Young (1979), Weinberg (1980), Floodas (1982), Erlich (1983), Lumsden (1984), US Department of Commerce International Trade Administration (1987), Davis (1988), Calhoun (1988), CTIA (1993), Menich (1993), Garrard (1998), Zysman et al. (2000), and interviews.

[619] For an elaboration of this story see e.g. Calhoun (1988:48-50).

[620] For a more detailed description of how Ericsson made its entry into the American market, see Meurling and Jeans (1994:63-85).

Harris and E.F. Johnson (an ITT company), the latter two exiting the cellular industry shortly thereafter.

As the cellular licenses were traded, larger operators consolidated ownership, especially in major markets. Among these most aggressive buyers were some RBOCs[621] and some RCCs (e.g. McCaw, later to be acquired by AT&T for USD 12.6 billion). Operators tended to build larger coherent areas of coverage, in which users could roam more easily.[622].

At the terminal side, domestic suppliers had dominated the land mobile radio and non-cellular mobile telephony markets. Initially, they (e.g. Motorola, E.F. Johnsson and GTE) grabbed a large share of the cellular market as well. However, soon foreign suppliers crowded the cellular terminal market. Japanese consumer electronics manufacturers such as OKI, NEC, Panasonic, Mitsubishi, Toshiba and Hitachi, together with the Finnish manufacturer Mobira, together took a lion's share of the American market. Motorola remained the market leader, but with a dramatically reduced market share.

Although it was clear that AMPS would eventually support hand-portables, the first terminals were simply mobile, as the IMTS terminals had been since the mid-1970s.[623] They were priced at some USD 3,000 and weighed a few kg. Together with TACS (which was very similar to AMPS), AMPS came to dominate the analog cellular market. This marked dominance allowed scale economies, learning and early introductions of a large variety of brands and new models, and considerably faster price reductions than in NMT for instance. Thus, phones were cheaper and more advanced than elsewhere. Indeed, most manufacturers first released their new models in AMPS versions, only later adjusted to other standards. Motorola released the first hand-portable (the 8000 model) in 1986, and the first MicroTac (350g) in AMPS in 1989. This also marked the beginning of Motorola increasing its market shares, eventually to completely dominate the US AMPS, largely at the expense of Japanese manufacturers. According to Oskarsson and Sjöberg (1995), this success was mainly due to its ability to master, and innovate in, performance- as well as cost-driving technological fields.

In terms of market penetration, the US cellular market has been very successful in spite of the regulatory and roaming problems since Ameritech (the Chicago-based RBOC) launched the first AMPS system in December 1983. Compared to Europe at an aggregate level, the US was for many years far ahead in terms of cellular penetration.[624]

This successful development soon led to capacity problems in densely populated areas, which called for development of a new digital AMPS standard (see below). Manufacturers and service providers also found solutions to cope with congestion. One example is Motorola's Narrowband AMPS system (N-AMPS, which is a modification of the Narrowband TACS system that Motorola developed for the Japanese market).

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621 Read BellSouth, SouthWestern Bell and PacTel. The RBOCs were allowed to acquire licenses outside their home markets.

622 See e.g. Lindmark & Wilkinson (1992). To promote cellular, and to exchange information, the operators also formed the Cellular Telecommunications Association (CTIA) in 1984. The association became a strong force when it came to lobbying and to development of roaming specifications.

623 Motorola had launched the first mobile phone, DynaTac, in 1973 (CTIA 1993).

624 Observers from the Nordic countries may be under the impression that the US has lagged behind Europe when it comes to adoption of cellular services. This is not the case.

7.1.3.3 Europe – a plethora of standards
In Europe a number of different standards were implemented: NMT in the Nordic countries, TACS in the UK, C-Netz in Germany, RTMS in Italy and RC 2000 in France. This was partly a result of the old protectionist PTT structure. For Europe as a whole this fragmentation was a disadvantage. Users could not roam between countries, and manufacturers had difficulties in achieving economies of scale. These developments are summarized in the following.

7.1.3.4 The UK and TACS
By 1981, the British and French PTTs agreed on introducing an NMT system (at 900 MHz) that would include roaming between the two countries.[625] However, this cooperation was never finalized, due to British government intervention and deregulation of the British telecom market, initiated by the government of Margaret Thatcher – including privatization of BT, introduction of competition (or rather duopoly), and separation of regulatory authority (OFTEL). The British mobile communications market became a test-bed for competition, liberalization and experiments in a vast number of areas (mobile data, Telepoint, PCN, paging etc.). It was decided that also the cellular market was to become a duopoly with (1) a BT-dominated operator and (2) one privately owned company. Among the five applications for the latter, Racal-Vodafone (including a small Swedish ownership through the Stenbeck-controlled Millicom) was somewhat surprisingly chosen in a non-transparent process.[626]

In a mutual agreement, the operators decided upon a modified AMPS variant labeled Total Access Communications System (TACS). There was no British manufacturer capable of supplying a full system. Instead BT chose Motorola as system supplier, and Racal-Vodafone chose Thorn-Ericsson. In the late 1980s, as TACS began to prove itself a potent cellular system standard (regarded as the best analog standard by some industry experts), it became the internationally preferred alterative in the 900 MHz band. Its similarity to AMPS enabled manufacturers to reap economies of scale and scope as intended. Accordingly TACS terminals were priced much lower than, and launched ahead of, NMT terminals.

7.1.3.5 Germany and C-Net
In the late 1970s in response to congestion in the so-called B-Netz, DBP commissioned Siemens to develop a cellular system in the 450 MHz band. This system was called "C-Netz" (C-network), and was launched in the mid-1980s.[627] C-Netz became technically advanced, but turned out to be a commercially mediocre system. C-Netz never reached more than some 800,000 subscribers (in late 1993). Siemens actively promoted the C-Netz outside Germany, but only Portugal and South Africa adopted the system. The service and terminals (supplied by Siemens, AEG and PKI (the local Philips subsidiary) later to be joined by SEL, Storno and Mobira) were expensive and marketed as status symbols to e.g. managers, a fact that hampered the commercial success of the system.

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625 This section is based on Northcott (1983), Appleby (1984), Custance (1984), Swain (1985), Gillick (1989), Bradley (1992), Beddoes and Easteal (1993), Meurling and Jeans (1994:89-97), Harrison and Bishop (1995), Valetti and Cave (1996a,b), Garrard (1998), GSM (18/82 and 51/83), and interviews.

626 In order to stimulate further competition at the retail level, a new distribution system was introduced, where operators sold air-time in bulk to service providers and in addition bonuses, which were used at a next level (retailers), allowed to sell both air-time and terminals. This system has been debated over the years. Especially the service providers ended up in a very unfavorable position, with low profitability, leading to consolidation.

627 This section is mainly based on Spindler (1982) and Garrard (1998).

7.1.3.5.1 France – RC 2000

In France, industrial policy shaped the choice of cellular systems. The French telecom market as a whole lagged behind its European counterparts until the 1970s when a large modernization program commenced.[628] Meanwhile, the French telecom manufacturing industry was restructured in the mid-1970s, concentrated in Alcatel, which became one of the dominant telecom manufacturers in 1986 when it took over the telecommunication activities of ITT. Meanwhile, in the late 1970s, DGT (the French telecom administration) selected Thomson (a French company cultivated by DGT to become a major competitor in telecommunications) to develop a cellular system. But this development did not progress as planned, since Thomson was heavily involved in developing a digital switch and did not prioritize mobile telephony. A cooperative effort with the UK failed when the British chose TACS. Then France turned to Germany instead (see below, on GSM). Meanwhile, Alcatel had developed a cellular system concept (MATS-E) jointly with Philips, later teaming up with Siemens. They proposed a very advanced system, economically unacceptable to the French authorities. Thus, MATS-E was never implemented, and Alcatel and Philips as well as the French and German authorities refocused their efforts on the coming pan-European digital cellular standard – GSM.

Lacking an acceptable alternative (turning to Motorola or Ericsson for TACS or NMT would not have been politically acceptable), France chose to adapt a trunked private mobile radio system (RC 200) developed by Matra to a hybrid quasi-cellular mobile telephone system (RC 2000). The RC 2000 service was expensive and suffered from congestion. Coverage was only slowly built out; service and terminals were priced fairly high. Dissatisfaction with mobile telephony offerings in France led the government to introduce yet another solution in 1989, when a new private operator (Ligne SFR) launched services based on NMT 900 technology (designed by Nokia, with Alcatel as a complementary supplier). However, capacity was limited and SFR had to pay high interconnection charges; and the choice to implement yet another standard limited the possibilities for economies of scale in terminal manufacturing. At the end of 1991, introductory penetration was not even near one percent. Analog cellular had failed in France and participants of the French cellular industry prepared themselves for GSM.

7.1.3.5.2 Italy: RTMS and the TACS explosion

In 1985 (Società Idroelettrica Piemonte), the state-owned operator, now called Telecom Italia) introduced a cellular system called RTMS. Italtel, the major Italian manufacturer working for SIP (both companies were owned by STET), designed and made major parts of the system, while three Italian electronics manufacturers – Italtel, OTE, and Telettra – supplied the terminals. Network parameters limited the capacity to 70-100,000 subscribers, and it was quite easy to manipulate the system, which led to fraud. Furthermore, terminals had to be leased from SIP. Therefore the need for an enhanced cellular service in Italy was high and accordingly SIP decided to implement TACS in 1990.

[628] This section draws mainly on personal communication with P. Dupuis (1995) and in addition on GSM (18/82), GSM (24/84), Meurling and Jeans (1994), Fransman (1995) and Garrard (1998).

7.1.3.6 Japan

While the US and the Nordic countries made many pioneering efforts in cellular telephony, Japan became the first country to launch a cellular system in 1979, with no previous commercial experience in land-mobile telephone systems.[629] The postwar period included a great catching-up effort, which resulted in a very advanced mobile communications market in the late 1970s, in most respects except for land-mobile telephony. NTT's Electrical Communications Laboratories (ECL) had commenced R&D on mobile telephone systems already in 1953, with a system ready in 1967. It was never commercialized due to a lack of frequencies. R&D was instead redirected towards an 800 MHz system with technology similar to Bell's proposed cellular system. In December 1979, NTT launched the first cellular system in the world. The system was then extended to other cities. Still, cellular telephony diffused slowly in comparison to other countries. As late as 1988, there were still less than 100,000 subscribers in Japan. NTT introduced nationwide roaming in 1984, but it was made automatic only in 1988. Prices were high, and a limited number of terminal models were available for rental only (priced at roughly USD 100 per month).

The Japanese terminal manufacturers were fairly competitive during the 1980s. They had grown strong partly as a result of NTT's (and the Japanese government's) policy of using a family of domestic suppliers (NEC, Fujitsu, Hitachi and OKI, and to a lesser extent Mitsubishi and Toshiba; the rise of Sony and Matsushita was, however, more a part of the classic consumer electronics catch-up of Japan). NTT usually performed most R&D and testing in its own laboratories, and then supplied the domestic manufacturing industry with very detailed specifications as well as assistance. Then, the market was divided into fairly equal parts. For cellular systems, NEC was more involved in development than was usually the case. NEC supplied switches and radio base stations to NTT, whereas the terminal market was split among several suppliers. This game of order was not acceptable to e.g. the US government, which lobbied to open up the market, in particular to open it up for Motorola.

In the mid-1980s the Japanese government pursued a program of liberalizing the telecommunications service market. It privatized NTT and allowed two new regional operators to enter the market: Daini Denden Inc. (DDI) and Japan Idou Tsushin (IDO), both eventually choosing a derivative of TACS. Still, diffusion of cellular telephony in Japan was hampered by the fact that cellular terminals had to be leased until as late as 1993. In addition, the NTT system was never implemented outside Japan, a fact that may also have had a negative effect on the domestic diffusion (and vice versa).

Nonetheless, using their skills in consumer electronics, Japanese manufacturers grabbed a large market share of the AMPS and TACS markets – as opposed to cellular infrastructure supply, where Japanese suppliers largely failed internationally.

[629] This section is based on: Ikegami (1972), Watanabe and Miyauchi (1977), Ito and Matsuzaka (1977), Pempel (1978), Izumi et al. (1980), Takeushi et al. (1981), Murakami (1982), Matsushita (1982), Kuwabara (1985), Chiba (1985), EMC (1993), Fransman (1995) and KDDI (2001).

7.1.4 Development of digital cellular – 2G

By the early 1990s the wireless industry was ready to implement digital cellular systems. Driving forces differed in the triad. While US developments were driven by expected congestion in analog AMPS, GSM was developed in response to the fragmented European market and in order to achieve economies of scale and strengthen the European manufacturing industry, at the same time improving service for end-users. Japan took yet another route. The developments of digital cellular systems, with an emphasis on GSM (which stands out in terms of successful standardization), are investigated in the following.

7.1.4.1 Europe and the success of GSM

GSM was developed in response to the fragmentation of the European mobile communications market, and the opportunity arising from the reservation (by WARC in 1979, and by CEPT in 1982) of frequencies in the 900 MHz frequency band. A special working group (Groupe Special Mobile) was created within the setting of CEPT, the cooperative body of telecom and postal administrations in Europe. The Nordic PTTs were active in this formation, and the group got a Swedish chairman as well as secretary. In the early phases, neither the manufacturers nor the European Commission were very active.

The basic requirements of the system were decided upon quite early on. Still, a number of technical choices had to be made. Some of these choices became contagious, notably the choice of multiple access scheme (and, related to it, channel spacing), but also modulation schemes and speech codecs. Since several actors had built up competence, property rights and prestige along different tracks, these choices were believed to have important commercial impact. As a result, these choices nearly stalled the standardization process.

In parallel with the official system standardization activities in CEPT, applied R&D was conducted in Germany, France, the UK, Italy, Holland, and the Nordic countries. Ericsson and Televerket in Sweden had been conducting research in the field of digital radiotelephony for several years (see the section on Sweden), and a similar program was started in Finland.[630] In the UK a joint research group was set up. The groupings had developed somewhat different solutions, and they propagated and lobbied for these.

Especially a number of Franco-German consortia had invested considerable funds and prestige in this development. By autumn 1984, France and Germany decided to redirect an already ongoing cooperation in mobile telephony towards digital cellular, in order to give France and Germany a power position in the GSM work and possibly to accelerate its development pace. The two countries agreed to invest in an R&D program on the development of experimental radio subsystems as parts of a digital cellular system, and to fund several demonstrators by the manufacturers.[631] The objective of this action was to push for and support the GSM work, but more importantly to get a strong and early market entry with funded, coordinated R&D and early equipment orders, in order to strengthen the domestic industries, breaking the dominance of Ericsson and Motorola.[632] After an evaluation in March 1985, four proposals were chosen for construction of demonstrators. These were (1) the "CD 900" proposal from AEG/SEL/ATR/SAT (often referred to as the SEL/Alcatel

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[630] GSM (83/84).

[631] European Commission (1992); GSM (28/84); GSM (76/84); GSM (6/85), personal correspondence with P. Dupuis (1995) and Dupuis (2001a:25).

[632] Bekkers (2001:316), based on an Ericsson source (Meurling and Jeans 1994). This is the prevailing view in Sweden, confirmed by several interviews conducted. Although plausible, it has not yet been confirmed by French and German sources.

consortium after DGT/Alcatel acquisition of SEL in 1986), (2) the "S 900-D" proposal from ANT/Bosch/Matra, (3) the "MATS-D" proposal from TeKaDe/TRT (Philips subsidiaries) and (4) the "SFH 900" proposal from LCT/TRT.[633] The Franco-German cooperation later extended to Italy (June 1985) and the United Kingdom (April 1986) to become known as the "Quadripartite Agreement".

In all, eight different systems were evaluated at the end of 1986 in tests arranged at CNET in Paris under the supervision of the Permanent Nucleus. These are summarized in Table 7-3. The tests became known as the "Paris Trials".

Table 7-3: Contender systems of the "Paris Trials" in December 1986

System	Developers	Access Type	Trans. Bit Rate (kBit/s)	Carrier Spacing (kHz)	Mod. Type	Channels /Carrier
CD-900	ART, SAT, SEL, AEG, Italtel	Wideband TD/CDMA	7980	6000	QPSK	63
MATS-D/w [a)]	Philips, TRT	Wideband CDMA/TDMA	19968	1250	QAM	64
MATS-D/N [a)]	Philips, TRT	FDMA	19.5	25	GTFM	1
ADPM	Elab	TDMA	256-4096	200-4000	DPM	10-160
DMS-90	Ericsson	Narrowband TDMA	340	340	GMSK	10
MOBIRA	Mobira	Narrowband TDMA	252	252	GMSK	9
SFH-900	LCT	Narrowband TDMA	201	150	GMSK	3
S-900-D	ANT, Bosch, Telettra	Narrowband TDMA	256	250	QFSK	10
MAX II	Televerket	Narrowband TDMA	302	300	GMSK	11

[a)] The MATS-D proposal included different solutions for the uplink and the downlink.

Sources: Hanzo & Stefanov (1992), Finnie (1986), BIS Mackintosh (1986) and Bekkers (2001, Appendix B). Note that sources differ somewhat.

In essence the choice was between two camps: (1) those of the Franco-German consortia that worked with wideband solutions, (2) the Finnish-Swedish manufacturers and operators that had developed narrowband solutions. Systems were tested in field trials and with a propagation simulator and assessed according to a number of criteria. All in all, the narrowband proposals performed as well as or better than the wideband ones according to all criteria. Thus, the choice was obvious from a techno-economic perspective but not from an industry-political one. In order to circumvent the possibility that none of the proposals were selected, a solution resembling the Nordic ones in most respects was decided upon with the reservation of the French and German representatives. Eventually, after it had become a matter at ministerial level, the Germans and French gave in, having negotiated a change in modulation technique. Then GSM standardization could progress along the so-called "broad avenue", seemingly a compromise but, according to most observers, favoring the Nordic manufacturers Ericsson and Nokia.

However, the future of the standard was not completely assured. Some other actions needed to be taken. First, the manufacturing industry (i.e. infrastructure suppliers, terminal suppliers and the semiconductor industry) needed some reassurance that GSM was actually to become

[633] GSM (64/85). Sources differ somewhat here. See e.g. GSM (64/85), Bekkers (2001:326) and Dupuis (2001a:27). Presumably participants changed during the course of the projects, since the telecommunications and electronics industries were undergoing many ownership changes at this time. For instance, CGE/Alcatel acquired the former ITT subsidiary SEL. These ownership changes also led to tensions. Officials in the French government favored Alcatel instead of LCT, a nationalized ITT subsidiary, to be acquired by Matra. (Dupuis 2001a:27.)

implemented on a broad scale, not least since CEPT had a track record of producing standards that were not necessarily implemented by its members. Thus, a MoU (Memorandum of Understanding) was signed by the relevant operators and regulators, in which they agreed to implement GSM by 1 July 1991.[634] This MoU later developed into a forum for collaboration among operators (to be named GSM MoU, and later the GSM Associations)

Second the support of the European Commission was decisive. Bekkers (2001, pp. 339-340) summarizes the EEC arguments to support GSM as: (1) GSM provided an opportunity to introduce liberalization, without too many vested interests; (2) GSM could stimulate manufacturers to become more pan-European in their operations, thereby achieving greater efficiency and economies of scale; (3) GSM would allow a truly pan-European service; (4) GSM would prove that the internal market was effective in boosting competitiveness and performance; (5) GSM would provide a benchmark for further European standardization; (6) GSM would open up the closed national markets; (7) the pan-European nature and hi-tech charisma of GSM would make it attractive for European integration.[635] Based on the policy framework of the "Green Paper on the Development of Common Market Telecommunication Services and Equipment"[636] the Council issued a recommendation on the coordinated introduction of public pan-European cellular digital land-based mobile communications (with features similar to those of GSM), plus a directive on the frequency bands to be reserved for the coordinated introduction of GSM (where it was stated that 2*9 MHz in the 900 MHz should be released for that service)[637]. As a result this directive was widely debated, and later somewhat relaxed "according to commercial demand".[638] Nevertheless, these recommendations and directives gave GSM further credibility; there was an official document which the EEC telecom administrations were obliged to follow.[639]

Another important result of the new policy was the creation of a new standardization institute – ETSI – to which the standardization activities of GSM were transferred in 1989. This also meant that equipment suppliers became officially involved in the standardization activities. They had been gradually more and more involved anyway, on an unofficial basis (as observers). This trend of increasing influence of manufacturers vis-à-vis other operators has continued since.

The GSM group decided to take an evolutionary specifications approach in order to circumvent the problem of "how much to standardize". In late 1989 the GSM group decided to "freeze"[640] the specifications, the actual freezing taking place in January 1990. To facilitate future improvements of the standard, specifications should be divided into certain phases (Phase 1, Phase 2, Phase 2+), where the later phases would include more features.[641] The burden of standardization also became increasingly demanding, although manufacturers were also involved now. The complexity of the specifications and the resulting software

[634] European Commission (1992) and Temple (2001). For further details see GSM (121/87) "Memorandum of Understanding on the implementation of a pan-European cellular mobile telecommunications service by 1991".

[635] See e.g. GSM (1/85), GSM (3/85), Garrard (1998:130), Haug (2001b:19), Dupuis (2001b) and Bekkers (2001:339-345) for the relation between EEC and the GSM.

[636] European Commission (1987)

[637] European Commission (1992), EEC (1987/371; 1987/372) and Garrard (1998:130).

[638] According to Bekkers (2001:342).

[639] The importance of the directive has been confirmed by most sources; see for instance Dupris (2001b).

[640] Freezing is a somewhat misleading term. As standardization progressed, the recommendations had to be changed when errors and ambiguities were discovered (Garrard 1998).

[641] For more details of the scope of phases, see Twingler et al. (1994).

development inspired a re-christening of the system as “GSM – the Great Software Monster”.[642]

Patents and standardization have conflicting objectives, and these trigger conflicts. GSM became an early source of such conflicts.[643] As it turned out, a number other companies possessed patents that were essential to and overlapping the specifications of the system: so-called *essential or standard blocking patents*. The European manufacturers claimed that they had agreed to solve the problems with cross-licensing agreements, and the GSM group had not themselves filed any patent applications for their solutions, so the issue was somewhat neglected until it was very late. The MoU group[644] suggested procurement contracts where the manufacturers would be awarded contracts only if they (1) were prepared to indemnify the operators against any patent infringements, and (2) allow worldwide use of their IPRs.[645] Manufacturers reluctantly accepted the first terms, but the second clause was unacceptable to many manufacturers, since it would favor companies that had not invested anything in R&D.

It was to be Motorola, coming from a tradition of aggressive patenting in the US radio industry, that took a stand and refused to adhere to a policy of allowing worldwide use of their IPRs. The conflicts went on for two years, some European actors claiming that Motorola acted in an obstructive manner.[646] Finally the matter was solved by cross-licensing agreements, an outcome that favored companies with large patent portfolios, and disfavored companies without them – notably some of the terminal manufacturers.[647] Meanwhile ETSI spent considerable effort in trying to solve the conflicts and outline an IPR policy in order to circumvent similar problems in the future. Still, IPR issues became a problem again in the 3G standardization process. That time, the telecommunications companies were better prepared since the IPR conflicts in GSM triggered a change in the IPR strategy of most companies in the industry, for better or for worse. However, IPR and standardization still present an unresolved dilemma.

The technological choices made in 1987 made it possible both for standardization to progress and for manufacturers to start developing products.[648] Only existing manufacturers of digital SPC switches could enter the switching part of the market. These were Alcatel, Ericsson, Nokia and Siemens, and somewhat later Lucent and Nortel. Base station products were somewhat easier to develop (the BSC includes switching elements, though) and, in addition to the switching companies, Italtel, Motorola, Philips, Matra and Orbitel developed products for these.[649] By 1988, manufacturers teamed up in consortia to compete for contracts. The reasons were (1) specialization (some firms only had the resources to develop either switches or base stations), (2) cost considerations (see above), (3) initial compatibilities (lack of testing

[642] Garrard (1998:133) and Bekkers (2001:351).

[643] See e.g. Granstrand (1993), Nicholson and Miselbach (1993), GSM (11/86; 31/87; 82/87; 101/87; 149/87; 168/87; and 16/88); Garrard (1998:139-141), Bekkers (2001) and contributions to Hillebrand (2001) (e.g. Haug 2001a:20; Temple 2001:45).

[644] The procurement of validation systems by the MoU PG Group brought out the conflict.

[645] These clauses originated from the Franco-German cooperation, where government had funded contracts under the condition that any IPR generated from the program had to be licensed to partners on a royalty-free basis. This was done in order to circumvent imbalances where French and German companies had licensed out for free, whereas other companies could charge for their licenses. (Temple 2001:45.)

[646] Bekkers (2001:360-364) elaborates on this, and on Motorola’s objectives.

[647] Later another company, InterDigital Technology Corporation (IDC), claimed that its patents were infringed in every TDMA system. Although the US Federal Court ruled these claims invalid, IDC is believed to collect substantial amounts on royalties for the GSM-related patents it holds (Bekkers 2001:363).

[648] In line with Bekkers (2001:351).

[649] Bekkers (2001:351-352).

regimes on the infrastructure side and insufficient standardization in some cases forced manufacturers to team up in order to ensure compatibility), and (4) market access (teaming up with local partners increased the possibilities to get a contract). Later many operators complemented their initial supplier with a second one for radio base stations. Some operators were forced into multiple source supply. Others awarded contracts to their preferred national suppliers (the PTTs in Italy and Germany for instance). Operators with a TACS or NMT network in place often chose the same supplier as before, or a consortium headed by such a supplier. New entrant operators chose their suppliers according to other commercial grounds.[650] Ericsson and Nokia proved to be successful in securing these contracts.[651]

Not until mid-1992 were commercial terminals launched, still mainly consisting of test terminals and some bulky models. There were many reasons for this delay. The specifications were so complex and comprehensive that faults and inconsistencies were inevitable, calling for specification revisions. However, the most important problem was to develop GSM terminals and have them tested on time. To quote G. Schmitt, "Everybody thought that the market would generate a broad supply automatically".[652] The main reasons for this not happening were development of customized VLSI for signal processing and testing and type-approving the terminals. Operators that had rolled out their networks very rapidly (read Mannesmann Mobilfunk) suffered heavily from having no terminals to sell, which led George Schmitt, chief executive at Mannesmann Mobilfunk, to cry out his famous interpretation of GSM at the IBC GSM World Congress in Berlin in 1992:

> "God Send Mobiles"!

Eventually terminals arrived on the market. Mainly due to the complexity of the software, these were heavier and more expensive than the analog ones, and remained so until late 1994.[653] Initially only larger manufacturers, who had also been involved in systems development, were able to launch terminals, since these were very complex and required considerable resources to develop. It is estimated that first-generation models cost about USD 8-16 million to develop. Ericsson and Nokia dominated the market for a few years by releasing models with better performance than their rivals. In 1996 the GSM phone market shares as reported in Bekkers (2001, p. 371) were as follows: Ericsson 25%, Nokia 24%, Motorola 20%, Siemens 9%, Panasonic and Alcatel both 6%. Ericsson eventually lost out in this race[654], leaving the market leader position unchallenged to Nokia. Some analog terminal manufacturers did not make the transition to GSM. The failure of the Japanese manufacturers (with the exception of Panasonic) is also notable.[655] Table 7-4 shows the market share in three

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[650] Not in Sweden, though, where Televerket had rights to the AXE switch (see Section 6.7).

[651] Bekkers (2001:354-356).

[652] Schmitt (2001:492).

[653] Orbitel, Motorola and Nokia had mobile terminals ready in the summer of 1991. Ericsson, Motorola and Nokia released the first hand-portables in October 1992. These phones weighed between 375 and 500 g, priced at roughly USD 1500. By 1994 there were 18 hand-portable models available from 11 manufacturers (excluding OEM models). Average size and weight declined rapidly; by 1996, 200 grams, 4 hours of talk-time and 100 hours of standby time in terminals had become standard. Thus, size and volume had become on par with analog telephones, while battery life was already superior in GSM due to the built-in power-saving feature of the standard. By 1997, top-of-line models weighed about 100 g. Initially GSM terminals were sold for USD 1,600 (in Germany which was cheaper than C-Netz); by the end of 1994, ex-factory prices were down to USD 400-500, which was comparable to the TACS prices. (Garrard 1998: 141-143, 151.)

[654] One often-quoted reason is technical problems in developing a whole platform generation (around 1997) making the entire Ericsson product line obsolete. Other reasons are unattractive design and lack of consumer electronic market skill general.

[655] Garrard (1998:141-143, 151). There are many plausible reasons. The complexity of terminals, in combination with not having participated in standardization work, not having the synergy effects involved with supplying infrastructure, and high licensing costs are sometimes quoted to explain Japanese companies' failure to enter the early GSM market. See e.g. Bekkers (2001:367-376), who discusses in detail (but somewhat inconclusively) IPR as barrier to entry in the GSM terminal market.

GSM sub-markets in 1996. Figure 7-3 illustrates that, on an aggregate level, in terms of market shares, Ericsson was at its height around 1996/97. Then the decline started.

Table 7-4 Market shares on three major GSM sub-markets in 1996.

Supplier	*Switching*	*Base stations*	*Terminals*	*Rank*
Ericsson	48%	37%	25%	1
Nokia	14%	22%	24%	2
Siemens	21%	2%	9%	3
Motorola	1%	13%	20%	4
Alcatel	10%	10%	6%	5
Lucent	2%	4%		6
Matra	2%	3%		7
Italtel	0%	5%		8
Nortel	1%	0%	3%	9
Philips	0%	2%		10
Orbitel	0%	2%		11

Source: Bekkers, R. (2003) Presentation to the CIP Forum 2003, October 8th 2003.

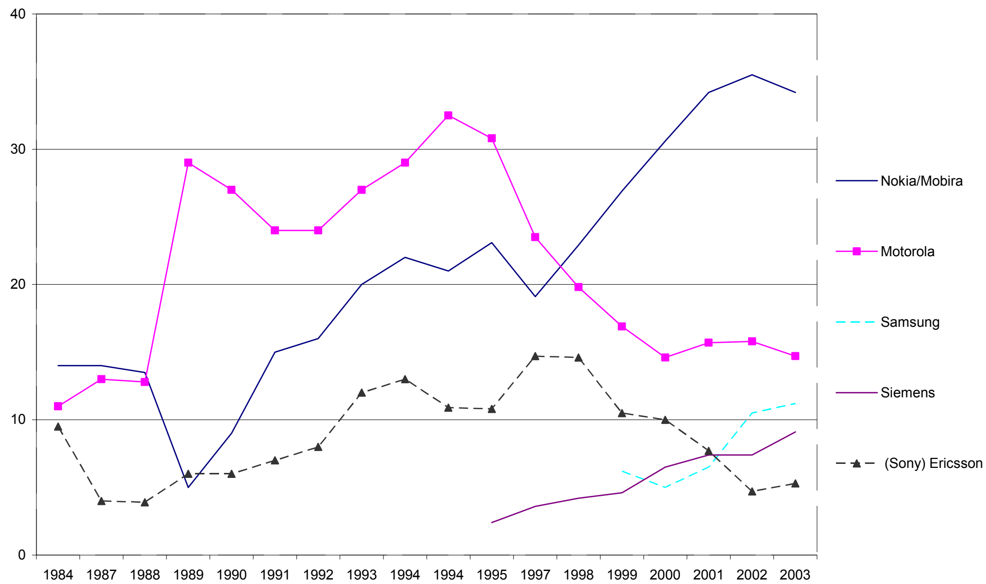

Figure 7-3: Market shares for selected terminal suppliers (1984-2003)

Source: Various compiled by the authors

Introduction of competition speeded up the introduction of GSM, just as the converse happened (GSM provided an impetus to introduce competition). The European Commission encouraged the member countries to introduce competition, but could initially not enforce this aspiration.[656]. Anyway, starting in Germany, several European countries issued second licenses, early on in Denmark, Norway, Sweden[657] and Finland, and later in e.g. the Netherlands, Belgium, Italy and Spain. Implementing competition turned out to be a complex procedure, however. Most often, regulatory authorities had to be created and broken out from the PTTs. Then the PTTs often had to establish mobile services divisions in order to keep track of interconnection charges. To the new operators, the incumbents became both competitors and suppliers of interconnecting and leased lines, which brought up a number of

[656] Garrard (1998:219-221). Formal decisions were limited to customer premises equipment and value-added services at that time.

[657] In Sweden a third license was awarded to NordicTel (see below).

economic, technical, and other issues due to further regulation.[658] Thus, introducing competition involved a number of complicated regulatory issues, not yet fully solved.[659]

Many European GSM operators launched their systems in 1992. The introduction of second licenses clearly speeded up the transition from analog cellular to GSM, also since incumbents were forced to respond to competitive pressures. Somewhat depending upon the saturation and quality of the analog networks, the majority of the PTOs were probably aiming for an introduction around 1994-1995, when most of the analog systems were expected to become saturated. Accordingly, the transition progressed at a slower pace in those countries with an initial absence of new entrants, as in the UK, Spain and Italy.[660]

Figure 7-4 shows that on an aggregated European level, the growth of GSM (including DCS-1800) surpassed the analog growth (with a small margin) in 1994. This year gave record growth rates for both analog and digital as a result of an increased awareness of cellular in general, competitive pricing and an upturn in the European economy. The growth in analog cellular was largely maintained by the fast-growing TACS markets of the UK and Italy (and, to a lesser degree, of Spain and some NMT 900 markets). In 1996, TACS growth stopped in Italy and the analog subscriber base started to decline. GSM had won the battle of Europe, but that was only part of the story.

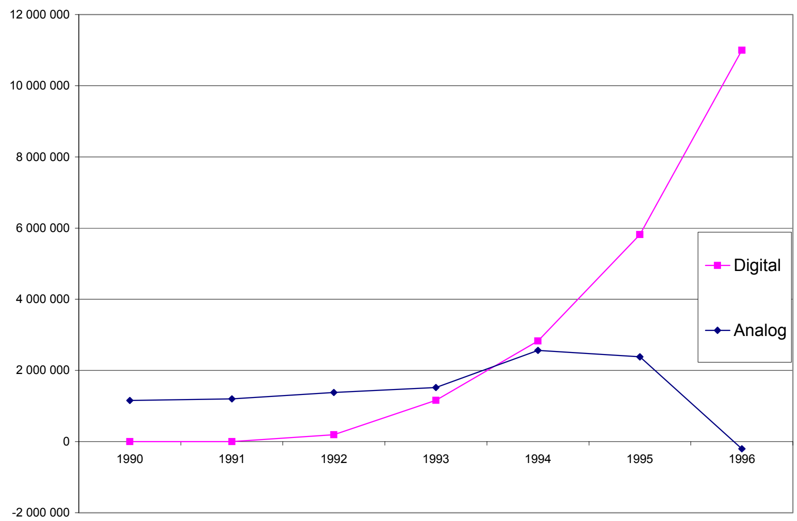

Figure 7-4: Yearly net change of analog and digital subscribers in Western Europe

Source: Various issues of Financial Times Newsletters, Mobile Communications and Mobile Communications International, compiled by the authors.

The introduction of GSM, especially the German D2 license, triggered and became a key process in internationalization of the telecom market. Foreign operators, initially mostly US ones, entered consortia applying for second licenses, since experiences from analog cellular had shown vast profit opportunities.[661] Usually these licenses were awarded to one out of

[658] Garrard (1998:225-231).

[659] As mentioned before, these deregulating events took place without any explicit directive from the Commission, which was instead engaged in outlining a policy for mobile communications between 1990 and 1994. This resulted in a Green Paper on Mobile Communications in 1994 (Higman 1994; European Commission 1994) which became widely opposed. The final outcome was a directive in 1996 by which every country should introduce competition in mobile services with at least two GSM operators and one DCS 1800 operator. Further, mobile operators should be allowed to build their own fixed links. However, a perhaps more important role of the Commission was to influence the competitive environment in specific national markets (Garrard 1998:243-244)

[660] For an in-depth discussion of the speed of transition from analog to digital cellular, see Lindmark and Granstrand (1995).

[661] Mobile telephony was (rightfully) regarded by many as a “license to print money” as some interviewees put it.

several applying consortia, typically consisting of at least one large domestic firm (e.g. Mannesmann A.G. in Germany), at least one experienced foreign cellular operator (e.g. the RBOCs, a European PTO, or a specialized mobile operator such as Vodafone) and a few other domestic investors.[662]

In response to market needs, GSM became standardized in the 1800, 1900, and 800 MHz bands, in particular to be able to penetrate markets outside Europe. The main promoters of GSM were the globally active manufacturers (especially those with a strong position in GSM) and network operators with international aspirations, as well as the GSM group and MoU association. In the early 1990s GSM began to diffuse rapidly outside Western Europe. The Europeans' obvious commitment to introducing it, and the increasing probability that the system would be implemented in time and the availability of products, made it a viable alternative also outside (Western) Europe. This was valid both for countries introducing their first cellular systems and for countries implementing a second (or third) cellular system. Reflecting this, GSM was renamed *Global System for Mobile Communications*, in order to relate to the expansion outside Europe. GSM became a commercial trademark with its own logotype. As of May 2001, some 400 networks had been commercialized in 169 countries, serving more than 500 million subscribers. This number corresponded to some 65% of the total cellular market. Meanwhile, European penetration figures had surpassed US ones, and the European manufacturing industry has gained large market shares mainly as a result of GSM. Some European operators could also use GSM as a vehicle for internationalizing their activities,[663] Vodafone being the prime example. GSM was a true success story!

7.1.4.2 Digital cellular in the US

Two digital standards emerged in the US: (1) D-AMPS/TDMA/IS-54/IS-136 and (2) CDMA/IS-95/cdmaOne.[664] The development started in late 1980, when the need for more capacity in cellular systems was conceived. It was decided that a dual-mode concept should be used, minimizing investments in infrastructure upgrading and allowing for terminals to be used in both analog and digital environments. No new licenses had to be granted. TIA was to specify the standards.

A number of conflicts regarding technical choices emerged. The first one concerned the choice between FDMA and TDMA as access method. When TIA requested proposals from its member companies, Ericsson (later joined by among others Northern Telecom) proposed a TDMA solution, while AT&T joined by Motorola proposed a FDMA solution. In January 1989 TIA chose TDMA by ballot. Another choice concerned the speech codec. By mid-1990, the so-called IS-54 standard was published, sometimes referred to as D-AMPS (Digital AMPS), a much less complicated standard than GSM. It was actually not fully digital, since the signaling channel was analog. A fully digital standard IS-136 was completed in 1994. Operators started installing systems in 1992, with dual-mode phones becoming widely available by 1994, although accounting for less than 10% of handset sales at that time. The transition to digital became much slower in the US, contributing to the US losing the lead in cellular.

Meanwhile another technology emerged – CDMA, the main sponsor being San Diego-based Qualcomm. After a persuasion and trial period, TIA embraced CDMA in 1992. Qualcomm, which did not have the international presence or manufacturing capabilities, licensed the

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[662] For a detailed investigation see Lindmark & Wilkinson (1992) and Garrard (1998:233-242).

[663] See Lindmark & Wilkinson (1992) and Azoulay (1996)

[664] This section draws on Lindmark (2002:235-242)

technology to systems and handset manufacturers, among them Motorola. A number of significant operators showed interest in the new technology, e.g. Pactel. Ericsson, the leading GSM and TDMA proponent did not embrace CDMA, however, and together with the GSM community it started opposing the technology. This started a contentious debate, conducted at a low level of objectivity. The first CDMA systems were launched in the US in 1996 and about the same time in South Korea, where CDMA was promoted as a vehicle to catch up and strengthen the manufacturing industry. CDMA also became the base for the 3G system CDMA 2000.

By 1995 and 1996, the US held auctions in the so-called PCS bands (1850-2000 MHz). This provided an opportunity for new players, in particular Sprint and other long-distance carriers, to enter the lucrative cellular market. All in all, the total bid value amounted to some USD 20 billion. The FCC did not mandate any specific standards, which opened the US market for ever more technology competition. Soon, however, the cellular standards TDMA, CDMA, and GSM turned out the preferred alternatives. The first PCS operators launched services by 1995.

7.1.4.3 Japanese digital cellular

The Japanese authorities decided upon a Japanese TDMA standard, soon after the US decision.[665] The development of a Japanese standard (eventually to be labeled PDC) progressed fairly quickly with most work conducted by NTT in the early 1990s. Meanwhile, a major event for Japanese mobile communications was the separation of NTT DoCoMo from NTT in 1992. The new company was still owned by NTT, but with significant managerial freedom, while at the same time exercising considerable control over manufacturers and standards. DoCoMo subcontracted minor parts of the infrastructure supply to some major infrastructure manufacturers (Ericsson, AT&T and Motorola). The existing operators were granted licenses in the 800 MHz band. In addition three licenses in the 1500 MHz band were given to DoCoMo and to new entrants TUKA and the Digital Phone group. The newcomers contracted most of their infrastructure orders to foreign manufacturers. For instance the Digital Phone group chose Ericsson as their main supplier.

Thus there were five operators on the Japanese cellular market. DoCoMo launched services in 1993, with the other operators following in 1994. Rapidly falling tariffs, the liberalization of the terminal market, and the introduction of PHS services further stimulated the Japanese market which more or less exploded in the mid-1990s, becoming the most competitive in the world, with high-technology terminals and innovative services. The operators' market consolidated in the late 1990s and early 2000s into three major players: DoCoMo, KDDI and J-Phone (eventually Vodafone). Still, DoCoMo exercised control over the PDC standard, and was claimed to be withholding the latest features from competitors. KDDI, not entirely pleased with this situation, decided to replace its PDC network with CDMA.

Subsequent introduction of better networks (1988), introduction of competition (1988), digital services (1993), further competition in the 1500 MHz band (1994), liberalization of the terminal market (1994), introduction of three competing PHS operators (1995), the DDI and IDO switch to cdmaOne in 1998, with concomitant price reduction and improvements in terminal and service functionality, made the Japanese market take off into rapid growth in the mid- and late 1990s.

[665] This section draws on Lindmark (2002:242-245)

7.1.5 Cordless and satellite

Although cellular telephony, entering the new millennium, emerged as the winner in the battle for providing mobile telephony, this was never the self-evident outcome. It was not until the 1990s, a decade or so after the introduction of the cellular technique, that mobile telephony surpassed other mobile communications services and became the dominant means for wireless communications. As late as in the early 1990s, attention was drawn to cordless and satellite systems, which were expected to compete and merge with cellular for providing personal communications services. To some degree, cordless has managed to converge with cellular in terms of functionality, applications and markets, but has essentially not acquired footholds in applications other than public mobile telephony (mainly office and residential applications). Mobile satellite communications have remained a niche market, where multi-billion dollar investments of LEO and MEO systems have flopped so far. We will briefly describe the development here.

7.1.5.1 Cordless

Traditional cordless telephones (dominating until the early 1990s) were analog devices bought in two pieces – a base station hooked up to the telephone jacket, with which a cordless telephone could communicate. Such residential devices have a longer tradition and have been much more widely used in the United States and Japan than in Europe (similar to paging). In the mid-1990s there was an installed base of roughly 60 million cordless phones in the US. Total sales amounted to 15 million units a year, priced at USD 50-100. In Japan, the installed base was estimated as 20 million, with total annual sales of 3-4 million units.[666]

In Europe early cordless phones were illegally imported from the US or the Far East; penetration was 6% of households (compared to 35% in the US).[667] To circumvent this problem, a number of standards were developed (CT0, CT1) with limited success apart from in the UK. The deficiencies of the UK CT0 standard stimulated the development of what later became the CT2/Common Air Interface standard as well as the "Telepoint" concept (i.e. a sort of wireless pay-phone service, in which outgoing calls could be made in the vicinity of base stations named Telepoints). Meanwhile Ericsson had developed a cordless technology labeled DCT900 (sometimes also labeled CT3) aiming for the business cordless market. Industry became divided between these two proposals for some years. Both systems were proposed to CEPT to become endorsed as European standards. CT2 eventually became accepted as an interim standard while DCT900 became recognized as a standard in Sweden only. However, it provided the technical base for much of what later became DECT.[668]

Telepoint based on CT2 services was launched in the early 1990s first in the UK and later in elsewhere in Europe (Finland, France and the Netherlands) and Southeast Asia (e.g. Hong Kong and Singapore). The service became a flop in England and most other countries.[669] All in all, the Telepoint concept must be regarded as a fiasco. Later in the 1990s more sophisticated digital cordless systems were launched in the triad in Europe (DECT), Japan (PHS) and the US (PACS). DECT (Digital European Cordless Telephony, later Digital Enhanced Cordless Telephony) was specified by ETSI in the late 1980s and early 1990s, with a first set of specifications ready in 1992.[670] The first DECT products appeared in 1993. The

[666] Padgett et al. (1997).

[667] Garrard (1998:447).

[668] See Garrard (1998:450), Bekkers and Smits (1998:291-304) and Gessler (2000).

[669] Padgett et al. (1997).

[670] See Gessler (2000) for an overview of the standardization process.

initial interest came from the wireless PABX market, the leading manufacturer being Ericsson, followed by Alcatel.[671]

Although trials were conducted with public service and "hot-spot" coverage, these services did not take off commercially.[672] [673] Instead, residential local loop became a steadily growing niche market for DECT, with 10,000 installed lines in 1996 and over a million in 1999, the main manufacturers being Siemens, Alcatel and Ericsson. Eventually around 1998, residential consumer devices were price-competitive vis-à-vis analog cordless phones (priced at roughly USD 100), and DECT could start overtaking that market. DECT also made inroads to market in the Americas, Africa and Asia, and was adopted as one of several air interfaces for the IMT 2000 standard.[674]

It is also worthwhile pointing out, considering the competition between WLAN and 3G of today (2004), that similar thoughts existed in the early 1990s. The Telepoint flop has already been described above. Another possibility was the interworking between cellular and cordless. In the mid-1990s several operators undertook trials to assess this potential as an extension of their cellular networks, in some cases using dual-mode telephones. BT Cellnet launched the world's first commercial dual-mode DECT/GSM service – Onephone – by 1999, with what appears to be limited interest from the market.[675]

In Japan, a somewhat more consumer-oriented approach was adopted. In 1995, NTT and three other operators launched public services based on the Personal Handyphone system (PHS). This standard was simpler than DECT, in order to facilitate rapid low-cost implementation and small and cheap handsets. Initially, the Japanese quickly adopted PHS, offered as an alternative to cellular with lower costs, smaller energy-efficient handsets and better voice quality.[676] PHS made several inroads subsequently, first in Asia, later in other parts of the world.

However, growth rates for PHS peaked already in 1996, adding some half a million subscribers each month. The Japanese cellular operators and terminal manufacturers had been spurred to provide better service, lower prices, and smaller and cheaper handsets, and the service could no longer compete with the superior coverage of PDC. PHS began to be perceived as a "poor man's cellular". As a result, the subscriber base of PHS started to level off and even decline.

In the US, Bellcore (the joint development center of the RBOCs) had developed an air-interface called WARC (Wireless Access Communication System) intended to provide wireless connectivity for local exchange carriers. With the advent of the PCS auctions in the US, features of WACS and PHS were combined into the industry standard PACS (P = Personal).[677] PACS was one of the proposed standards for PCS services; the status of the standard is not clear to the author, since attention has been overshadowed by the standards war between different cellular technologies.

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[671] The leading country in terms of adopting DECT was Germany by far (Trivett 1998).

[672] Although in 1998 another application of DECT was launched commercially in Italy – CTM, Cordless Terminal Mobility. Branded "FIDO" in Italy, CTM is a public access service, based on DECT, whereby a cordless handset, as well as operating as a cordless phone at home, can also be used in city centers to access public DECT base stations (DECTweb 2001b).

[673] Trivett (1998).

[674] Garrard (1998:457) and DECT Forum (1997, 2001).

[675] DECTweb (2001a).

[676] Mobile Communications International (1995) and Padgett et al. (1997).

[677] Padgett et al. (1997).

7.1.5.2 Satellite

Communication satellites have been around since the 1960s. Traditional applications include television and radio broadcasting; fixed communications for sparsely populated areas; mobile communication for maritime use and aeronautical as well as land-based vehicles; long-distance transmission links for e.g. intercontinental traffic, and rapid fixed installations with so-called VSATs and data communications.[678] The main provider of mobile satellite service throughout the 1980s and 1990s was Inmarsat, formed in 1979.[679] In Sweden, Inmarsat services are provided by Telia (holding a stake in Inmarsat). Inmarsat has launched a number of systems and services (voice and data), also providing land mobile and aeronautical communications. The first portable phones was launched in 1996 when Inmarsat launched a service called Inmarsat mini-M, with transportable phones typically weighing 2 kg, at the size of a laptop computer (priced at c. USD 3,000).[680] On April 15, 1999, Inmarsat became the first intergovernmental organization to privatize.[681]

Satellite communications entered a new phase in 1990, when Motorola announced a concept for mobile communications – Iridium – intended to revolutionize the use of satellites for mobile communications.[682] Iridium uses 66 low-orbiting satellites[683] and cellular-like technology in order to obtain global coverage, with much smaller satellites, shorter communication delays and less power output required than traditional geostationary satellites.[684] Motorola's announcement also spurred several other consortia to form, with the aim of launching similar systems. The main ones were ICO (Inmarsat and partners), Globalstar (Loral, Qualcomm and partners), and Odyssey (TRW, Teleglobe Canada and partners). These systems planned to use GSM or narrowband CDMA-based technology, with commercial launches around the millennium shift. Services were aimed for business travelers and for areas where there was no cellular coverage. Terminals were to be hand-portable dual-mode, able to connect to cellular as well as satellite systems. Data speeds were typically to be 2.4 kbps.[685] Even more spectacular was Bill Gates' and Craig McCaw's Teledesic project, initially proposing 1000 low-orbiting satellites that would give high-capacity bandwidth on a global scale. In addition to these global systems, several regional projects were about to be launched, most of them also based on GSM technology.[686]

So far, the commercial outcome of these projects has been a complete failure. Iridium went operational in the fall of 1998 but, with expensive service and a limited availability of high-cost GSM dual-mode terminals, it was able to attract very few subscribers. Iridium went bankrupt in the spring of 2000 and closed down service, but the company obtained new financing and service started up again in 2001. Meanwhile Odyssey had merged with ICO, but this company also ran into financial problems and was saved by Craig McCaw. Then Inmarsat withdrew from the venture and ICO and Teledesic merged their operations. Meanwhile, Globalstar went operational, but was struggling to attract customers. The authors

[678] Nilsson (1996).

[679] IMCO (1976).

[680] Tipple (1999).

[681] Inmarsat (1999).

[682] Industry folklore has it that the concept was conceived in 1985 when the wife of a Motorola executive could not use her brick-sized mobile phone on vacation in the Caribbean, and convinced her husband that a global wireless system would be a good thing. (Communications International 1999.)

[683] Originally planned for 77 satellites, the number of iridium in the periodic table.

[684] Nilsson (1996).

[685] Nilsson (1996).

[686] Interview S. Reinefjord (1997).

of this report are not fully updated on the most recent developments, but all consortia seem to be struggling with financial difficulties. Around a million subscribers were estimated to be needed for each system to recoup investments, but none of the systems is anywhere near such figures (if operational at all).

7.1.6 Operators' market

As investigated in Chapter 3, liberalization of the mobile telephone market and the introduction of new technologies, in particular digital cellular, provided an opportunity for regulators to introduce competition and for operators to internationalize.

Starting in the US, with the break-up of the Bell system and the cellular licenses, the operators started searching for revenue opportunities outside their home market. Essentially the internationalization was driven by deregulation, providing an opportunity for new entrants, and a threat as well as an opportunity for the incumbents. Figure 7-5 illustrates this trend of intensified competition in the OECD countries. Entering the 1990s, a majority of the markets were still operated by monopolies. When that decade was over there was no monopoly left, and a majority of the countries had instead three or more operators.

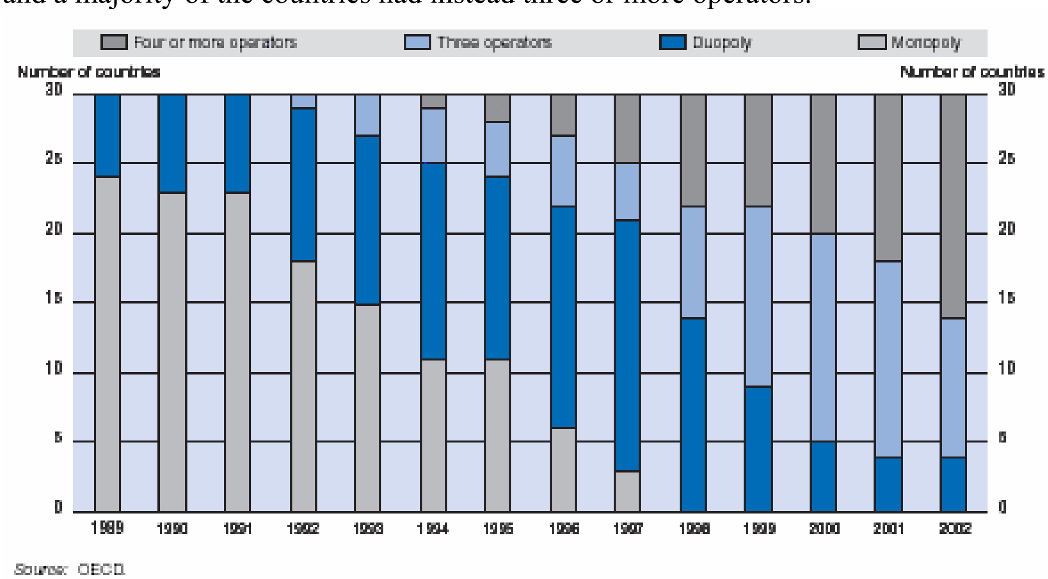

Figure 7-5 Competition in mobile operations

Source: OECD (2003:14)

The most internationally active operators were the RBOCs (Bell South and Pacific Telesis in particular), some European former PTTs, Cable and Wireless and Millicom, and some of the new entrants such as Racal Vodafone and Mannesmann Mobilfunk. The introduction of digital cellular was often coupled with the introduction of more licenses and thus further opportunities for internationalization. Some operators with strong home market revenue generators (e.g. Vodafone, Bell South and Airtouch) were able to pursue an aggressive internationalization strategy. We cannot dwell on all the developments of all these, but on one them – Vodafone – since it has strong interest in the Swedish market, and has developed into *the* major international operator.

Vodafone started out as a consortium applying for the second UK TACS license. Its major shareholder was the British electronics firm Racal. In 1986 Racal bought out its partners, in a deal where the company was valued at £80 million. Then, in 1988, Racal floated Vodafone on the British stock market. After a few years Vodafone was generally believed to be worth more than market cap of its parent company. In 1991, Racal and Vodafone de-merged fully. In the early 1990s the company acquired shares in cellular operators and formed consortia in a number of countries. However, it was in the late 1990s, under the leadership of Christopher Gent, that Vodafone took the No. One position through a number of spectacular deals: the mergers with Bell Atlantic/Verizon Wireless and Airtouch and the hostile take-over of Mannesmann Mobilfunk.

So there are two trends working simultaneously: (1) lowering entry barriers and (2) internationalization. Introduction of new licenses and new technologies have provided opportunities for new firms to enter. In addition, technological barriers have decreased as infrastructure suppliers such as Ericsson are able and willing to take over more and more of operations. Adding to this, more and more markets have opened up for service providers without infrastructure.

Counteracting this trend are the economies of scale (in operations, procurement, innovation, marketing etc.) and synergies involved in being large operators. It could be difficult for local operators to compete on an increasingly international market, and Vodafone just might be one prominent sign of the long anticipated consolidation of the operators' market.

7.2 The evolution of Swedish mobile telephony

This section investigates the development of the Swedish mobile telephony sector. Two actors came to dominate the Swedish mobile innovation system – Televerket and Ericsson. It was the pioneering development of Televerket, starting already in the late 1940s, that paved the way, through cultivating the innovation system, for the rapid expansion of the Swedish mobile telecom in the 1980s and 1990s. Later it was Ericsson, through pulling together the necessary resources inside and outside the firm, that managed to achieve a world-leading position in a fast-growing mobile market. This strong position has significantly contributed to economic growth in Sweden. On the other hand, the great recent downturn may have hit the Swedish economy harder due to the great dependence on this one firm. Nevertheless, seen in a long-term perspective, the evolution of mobile telephony has been very successful for Swedish firms. These developments will be investigated here, providing some tentative explanations as well.

The development of mobile telephony in Sweden can be divided into four phases. The first phase was centered on Televerket's innovative development of MTA and MTB in the 1950s and 60s. In the second phase, in the 1970s, NMT was developed while MTD was introduced as a gap-filling innovation system builder. In the 1980s, NMT diffused rapidly while GSM was developed, and Ericsson replaced Televerket as main actor in the innovation system (the third phase). The fourth phase in the 1990s was harvesting time, when GSM took off and competition was introduced. The diffusion of these systems is shown in Figure 7-6. The sections in the following are divided slightly differently, since we follow also the pre-commercialization development of the different generations.

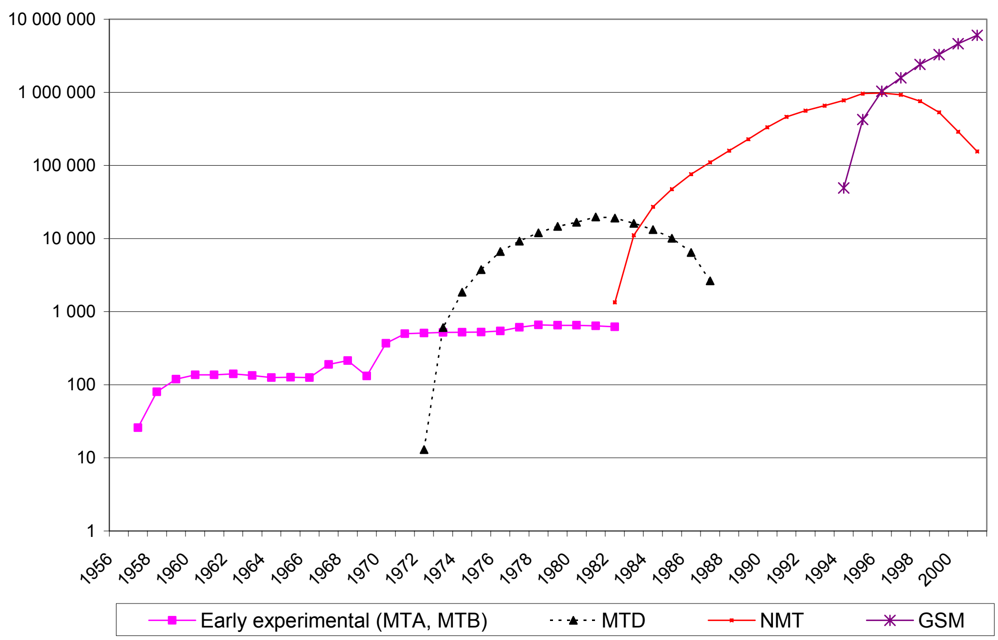

Figure 7-6: Subscribers in Swedish mobile telephone networks (log-scale)

Source: Adapted from Lindmark (2002)

7.2.1 Pre-1970s

After WWII, Ericsson, as investigated in Chapter 4, was an internationally established telecom manufacturer and the dominant supplier to the Swedish market. By the mid-1970s Ericsson and Televerket had jointly developed a digital stored program control switch – AXE. Almost by accident this switch became an essential part of Ericsson's cellular system offering, and one key factor in how the company emerged as the leading cellular system supplier in the 1980s and 1990s. However, Ericsson's success was equally dependent on its radio competence, which emanated from a company called SRA.

SRA (Svenska Radio AB) was formed in 1919 by ASEA, AGA and L.M. Ericsson and three financial institutions. In 1921 Marconi became a part-owner. By 1960, SRA was a fairly typical radio supplier involved in land mobile, military and broadcasting radio, focusing on the Swedish market. In the 1960s and 1970s Marconi's share was reduced, while SRA focused on land mobile and military radio and started to internationalize.[687]

Televerket gradually assumed a role as the dominant and pioneering actor in radio service provision in Sweden, as both a commercial operator and regulator. In 1916 "Radiobyrån" was established as a separate unit within Televerket. Initially the users were almost exclusively military, but in 1919 Televerket started delivering commercial radio services.[688] In the mid-1920s, radio (and later television) broadcasting became the dominant line of business for Televerket's radio unit, and remained so until the commercial breakthrough of mobile telephony. After World War II, it began establishing itself as one of the leading operators in the field of radio communications, launching a wide range of services including mobile telephony.[689] Televerket also assumed a regulatory role during this period, since radio frequencies had to be managed and licenses issued. The need for frequency planning activities was triggered by the development of broadcasting and land mobile radio. In 1954, Televerket became responsible for issuing licenses. These activities were grouped into a special line of business: the frequency board.

As World War II stimulated progress in radio communications, new market segments, e.g. fire departments, ambulances, taxis, public utilities and transport companies, began to use mobile radio.[690] Still, land mobile radio was a rather small and infant business opportunity.[691] As the telephone network expanded, access to the PSTN became recognized as an important functionality especially for small businesses and private users. In the late 1940s, Telestyrelsen assigned to Sture Lauhrén of Televerket's "Tekniska byrå" and Ragnar Berglund of Televerket's "Radiobyrå" the development of an automatic land mobile telephone system (eventually named MTA – Mobile Telephone system A).[692] In cooperation with representatives from SRA and Ericsson, Televerket put up a test system in 1950 in Stockholm, and launched commercial systems in Stockholm and Göteborg in 1956.[693] Among

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687 Cederquist (1994). See also Mölleryd (1999) for an elaboration of Swedish industrial history in mobile telephony.

688 See e.g. Televerket Radio (1980), Tahvanainen (1993) and Esping and Hesse (n.d.).

689 While maritime radio remained the most important mobile radio activity, contributions were made to aeronautical radio services. Televerket also developed an advanced navigation system, and in 1969 an aeronautical telephony service was put into operation. Radio was also used for fixed applications that expanded in the 1940s, and microwave links were implemented in 1953. (Heimbürger and Tahvanainen (1989), Tahvanainen (1993), Esping and Hesse (n.d.)).

690 Heimbürger and Tahvanainen (1989) and Gerdes (1991).

691 In the mid-1940s there were approximately 40 users. In 1965 there were 1,553 users (Heimbürger and Tahvanainen, 1989).

692 Besides Lauhrén and Berglund, some important contributions were made by Ivar Ahlgren of SRA (Lauhrén 1955).

693 The same phones worked in both Stockholm and Göteborg. In addition, a private network was provided to the Stockholm city municipalities and operated by Stockholms Elektricitetsverk (Lauhrén 1955).

the users were medical doctors, mobile bank buses, corporate top management, transport companies and other service organizations.[694]

Berglund worked with improvements of the radio equipment (tone code signaling and crystal elements) that eventually led to the introduction of an improved system (labeled "system Berglund" or MTB). Televerket started testing the system in 1961 and launched it in 1965 in Stockholm and Göteborg, and in 1967 in Malmö.[695] Compared with the MTA, the system was improved with regard to signaling and faster switching, and terminals (supplied by SRA, AGA and AB Nordisk Teleproduktion, ANT Swedish representatives for Motorola and British Pye) were cheaper. These improvements led to an increase in demand, and soon after its introduction MTB became crowded, i.e. capacity problems occurred.[696] As a result, the MTA and MTB systems had a very limited number of subscribers. The main market segments were banks, medical services, transportation companies, small businesses, service engineers, managers and public institutions.[697] Distribution was handled through Televerket's sales offices, with marketing limited to the telephone directory and sales offices.

A few firms that constituted the Swedish supplier industry were partly involved also in the innovation process. These were Ericsson, SRA, ANT, and AGA. The Swedish mobile telephony innovation system around 1970 is summarized in Table 7-5.

Table 7-5 The Swedish mobile telephony innovation system around 1970.

Category	*Actors*
operators	Televerket, plus 15 private operators
manufacturers	Ericsson, SRA, ANT, AGA
distributors	Televerket sales office
regulator	Televerket's frequency board
standard body	Not relevant, internal Televerket standard
users	Circa 700-800 (500 of which in Televerket's systems). Banks, medical, transports, executives, technicians, radio/TV authorities, customs, locksmiths, reporters.
Total domestic market size (adjusted for inflation)	10-20 millions.

694 Lauhrén (1951, 1955), Berglund (1951, n.d.), Övergaard and Berglund (1953), Televerket internal (1955), Tele (1960), Televerket internal (6708), Heimbürger and Tahvanainen (1989), Gerdes (1991) and Mölleryd (1999).

695 Gerdes (1991) and Mölleryd (1999).

696 Televerket internal (6708).

697 Mölleryd (1999)

Table 7-6: Some facts and features of early mobile telephone systems in Sweden

	MTA	MTB
Manual/automatic	Automatic	Automatic
Domestic coverage	Stockholm, Göteborg areas (25-30 km radius)	Stockholm, Göteborg, Malmö
International	-	-
Development period	late 1940s-1956	mid-1950s to 1965
Test system introduction	1950	1961
Commercial period	1956-1969	1965-1983
Mode of terminal distribution	Leased from Televerket	Leased from Televerket
Frequency band	160-170 MHz	80 MHz
Number of speech channels	4	n.a.
Main developers	Televerket (tekniska byrån and radiobyrån) in cooperation with SRA and Ericsson	Televerket, Radiobyrån
Investment for Televerket cost (million)	1.2	3
- in 1998 years prices (million)	11	
Suppliers		
of switches	Ericsson	Ericsson
of radio base stations	SRA	SRA, ANT
of terminals	SRA	AGA, ANT, SRA
Users	Banks, medical doctors and veterinaries, transport companies, taxis, boats, managers, service technicians, radio/TV authorities, customs, locksmiths, photographers, journalists	
Weight of terminal	c. 40 kg	c. 10 kg
Price of terminal		
Peak number of subscribers (year)	125 (1962)	650 (1980)

Sources: Various compiled by the author, e.g. Heimbürger and Tahvanainen (1989), Mölleryd (1993, 1999), Gerdes (1991) and archival documents.

Besides Televerket, a number of local operators of varying size operated mobile telephone systems from 1963 onward. In 1970 there were 13 such operators, a total of 45 base stations and more than 500 subscribers. To exemplify, one of these companies, Wikanders Ur & Optik, operated a PMR network in Jönköping from 1965. In 1966 it changed name to Telelarm Mobiltelefon AB and was allowed, from 1968 onward, to interconnect to the telephone network at 12 locations, leasing equipment from Televerket.[698]

[698] Karlsson (1998:225 ff.).

7.2.2 1970s: developing NMT and cultivating the innovation system

If any development has been a key to the Swedish success in mobile telephony it was NMT – the Nordic Mobile Telephone system. The concepts behind NMT were formed inside Televerket during the 1960s. In 1962 Telestyrelsen appointed a working group for investigating new mobile radio services, which submitted its report in 1967. Many students of the development of mobile telephony in Sweden (Gerdes 1991; Granstrand 1993; Mölleryd 1999; Lindmark 2002) have emphasized the importance of this investigation. The report suggested that Televerket should provide three nationwide services (1) MS – paging, (2) MRG – a public mobile radio service, and (3) MT – a nationwide mobile telephone service to be provided by Televerket. Among other topics, the group had studied mobile telephone systems internationally and stated that neither those nor Lauhrén's or Berglund's systems were feasible for this purpose without several modifications. The report also outlined a number of system features that in many respects guided what later would become NMT.[699]

Telestyrelsen approved of the general ideas of the recommendations in 1967. It was decided that Televerket should initiate and conduct most of the development, since the manufacturing industry was not expected to have the incentives to do so, given limited expected size of the market. The report also concluded that Televerket was the natural operator, as part of its government-mandated responsibility to offer universal service. Therefore, in 1968 Televerket's newly created radio development section (part of the R&D department) started investigating and developing parts of the system, by then labeled MTC. However, it was concluded that substantial technical progress had to be made before a fully automatic mobile telephone system with the functionality outlined by the "Åsdal investigation" could be delivered. Faced with these obstacles, Televerket decided to opt for international cooperation.[700]

Therefore, in 1969, Åsdal approached the other Nordic telecom administrations at the Nordic Telecom conference (an already established structure for cooperation). They responded positively since they realized the benefits of economies of scale and cooperation in development. A Nordic system would create a large enough market for the industry to develop products (including the user benefits of Nordic roaming). The Nordic telecom administrations appointed a working group, labeled the Nordic Mobile Telephone Group or the "NMT group"[701] for short, and tasked it with investigating future compatible Nordic mobile telephone systems.[702]

The group concluded that an automatic nationwide system could not be expected to be technically feasible before the end of the 1970s, while demand for mobile was perceived to be high. Therefore the initial work of the NMT group concentrated on developing an interim manual system and coordinating frequencies for the interim system as well as the future system.[703] Thus an interim system was quickly developed in Sweden, Denmark and Norway, based on available technology. In Sweden the system was labeled MTD, since the name MTC

[699] Televerket internal (6708), Lernevall and Åkesson (1997). For the importance of this investigation see also Gerdes (1991), Granstrand (1993) and Mölleryd (1999).

[700] Gerdes (1991), Lernevall and Åkesson (1997:559, 685), Mölleryd (1999), Manufacturers such as STORNO (in 1968) were also consulted at an early stage (Gerdes, 1991)

[701] "Nordiska Mobiltelefongruppen" in Swedish, officially NTR 69-5.

[702] Nordiske Telekonferensen protokoll (6906), interview with T. Haug (1995) interview with C-G. Åsdal conducted by O. Granstrand (1992).

[703] NMT (7001). In addition, regulations had to be changed so that terminals could circulate across the borders (NMT 7101 and Haug 1991).

was reserved for what later became NMT. Many still consider this to have been a step backwards, which it indeed was technically, but it proved to be very positive commercially. MTD (see Table 7-7) was quickly developed and commercialized in 1971, and fully built up in 1973. The system was manual since an automatic system with adequate capacity was not technically feasible.

Table 7-7: Some facts and features of MTD

	MTD
Manual/automatic	Manual
Domestic coverage	Gradually built up to cover most of Sweden
International	Norway and Denmark
Development period	1970-1971
Test system introduction	1970 (1)
Commercial period	1971-1987
Mode of terminal distribution	Free purchasing from independent terminal suppliers
Frequency band	450 MHz
Number of speech channels	n.a.
Main developers	Televerket, various departments connected to the radio labs
Suppliers	
of switches	Not relevant
of radio base stations	Magnetic, SRA, Mitsubishi
of terminals	AP, Handic, Mitsubishi, Salora, Sonab, Storno, SRA
Weight of terminal	2-4 kg
Peak number of subscribers (year)	19,687 (1981)

Sources: Compiled from e.g. Heimbürger and Tahvanainen (1989), Mölleryd (1993, 1999), Gerdes (1991) and archival documents.

One very important decision was that the terminal market was liberalized, which meant that customers could purchase terminals directly from the manufacturers (via retailers). This was a radical break from established practice among PTOs to own also customer equipment. The decision was taken for a number of reasons: (1) to reduce the necessary investment for Televerket, (2) to stimulate competition and thereby development of a wide variety of terminals, and (3) to stimulate marketing of terminals.[704] It also had the effect of developing the distribution system. Thus, although the growing number of manual operators created excess cost and other problems, being unprofitable in the short term, MTD had important dynamic effects, preparing the whole innovation system.

When the manual system had been developed, the NMT group could start seriously investigating, developing and specifying NMT. The work included detailed analyses of e.g. operational requirements, numbering, pricing, radio signaling, dimensioning of the radio base stations, cell planning, specification of the air interface, functional description, and routing principles. The NMT group also informed the manufacturing industry and invited about 40 potential suppliers to a meeting in the autumn of 1971. Among the participants were L.M. Ericsson and Svenska Radio AB (SRA). Thereafter the industry was consulted on a regular basis (regarding technical as well as cost-assessing matters) and some projects were outsourced. The dominant radio companies in the Nordic countries were SRA, Storno, Motorola and AP. However, these companies, which had a long tradition from land mobile radio, were reluctant to pursue work under the NMT concept, since an open standard might threaten their dominant position and market shares. Japanese companies were more flexible and provided input regarding the feasibility of placing microprocessors in the terminals, and

[704] Åsdal (1977).

duplex filters.[705] From 1973 onward, much work was spent on the air interface and signaling issues. The manual signaling intelligence of man-to-man communication (i.e. user to central office) had to be replaced by computers, whose development was time-consuming. The network structure and cell-planning issues were finished in late 1973. A system testing procedure was also developed.[706]

The basic functional features, commitment to implementation and cost-sharing structure were decided upon in 1975. The NMT group could now begin to plan the system tests in detail, and to specify the mobile telephone switch (MTV or MTX). The NMT group also concluded that it would be beneficial to let the subscribers purchase or lease terminals from suppliers, since the administrations would then not have to invest in equipment, distribution and service. In addition (just as in the MTD case) competition would be stimulated, leading to better terminals and related service.[707]

Much of the development was carried out in the development labs of Televerket, by a group consisting of roughly 10-15 people. At this time Televerket forecasted the subscriber development of NMT to reach 39,800 in 1991, although admitting that the service could become more popular than expected, so that the system had to be dimensioned to accommodate 80,000 subscribers.[708] In 1977-1978 Televerket conducted system tests in Stockholm, in order to verify that the chosen specifications were realistic from an economic as well as technical point of view. The test system design, construction and actual operation were mainly conducted in Televerket's Radio Labs, headed by Östen Mäkitalo; some parts were developed in Oslo.[709] Four separate tenders inviting the manufacturers to submit final proposals for base stations and exchanges (MTXs). In 1978 Televerket chose Magnetic and Mitsubishi to supply the base stations,[710] and out of a shortlist of three manufacturers Ericsson was chosen to deliver the MTX. Within Ericsson a smaller AKE-13 switch was initially preferred, but Televerket persuaded Ericsson that the more capable AXE switch would be more suitable.[711] As in so many other R&D projects (cf. AXE, GSM), in December 1978 not only the project group but also the system was officially referred to as NMT – Nordisk MobilTelefon (Swedish for Nordic Mobile Telephone) – for the first time. Televerket successfully tested an Ericsson MTX in 1981. Mobile unit specifications were ready in 1980 and testing of mobile units began in 1981. Finally on October 1, 1981, the Swedish NMT system was inaugurated.[712]

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705 Televerket internal (7712), NMT (7506), Gerdes (1991) and Mölleryd (1999).

706 Televerket internal (7712) and Gerdes (1991).

707 NMT (7506) and Televerket internal (7712).

708 NMT (7506), Televerket internal (7507) and Televerket internal (7712).

709 Televerket internal (7712) and Gerdes (1991).

710 SRA delivered the control unit of the base station to Magnetic. SRA at that time primarily focused on terminals, mainly for dispatch radio, and later fully diversified into the radio base station business.

711 Meurling and Jeans (1994), Lernevall and Åkesson (1997:564) and interview with Lundqvist (1994).

712 Gerdes (1991) and Lernevall and Åkesson (1997:564).

7.2.2.1 Competition on the operators' market

As mentioned above, by 1970 there were some 13 operators (the major ones being Telelarm, Nordiska Biltelefonväxeln, Svenska Sambandscentralen and Nordiska Radio centralen, together operating 45 base stations. These were a mix of local and regional operators, mostly small companies many of which had mobile telephony as a side-business. The private operator market went through a consolidation phase in the 1970s, mainly due to financial difficulties and because of Telestyrelsen's restrictive policy[713] in granting licenses and interconnection to the telephone network.

Eventually in 1981 a company named Företagstelefon was singled out as the only remaining operator.[714] Using a variety of networks and frequencies, Företagstelefon had a base of roughly 1,900 subscribers. During 1980 and 1981 this private company had a controversy with Televerket on whether it should be allowed to automatically connect to the telephone network. Företagstelefon agreed to build out a manual system instead. Later in 1981 the Industriförvaltnings AB Kinnevik (holding company for the Swedish financier Jan Stenbeck) acquired Företagstelefon, and restructured it into "Comvik". Kinnevik had been involved in mobile telephony in the United States through its daughter company Millicom, and saw the Swedish mobile telephone market as a promising business opportunity.[715] In August 1981, one month before Televerket, Comvik launched a new automatic system based on the available frequencies and transferred the old customers (about 2,500 at that time) to the new system. Televerket opposed this (with the argument that they should not be allowed to automatically connect to the telephone network). After appealing, later in 1981 the Swedish Government decided in favor of Comvik (on an exemption basis).[716]

7.2.3 1980s: Commercializing NMT and Ericsson internalizing the IS

The Comvik system was neither fully cellular nor fully automatic at that time. E.F. Johnsson, and later Technophone (a UK-based company started by a Swede), NEC and Toyo, manufactured the terminals that were sold under the Comvik brand name. E.F. Johnsson (and later Radiosystem) also delivered base stations, and Rydax supplied switches (Televerket had a monopoly on AXE on the Swedish market). The system gradually expanded during 1981-1989 when the last Comvik telephone model was introduced. As the system expanded, Comvik applied for more frequencies. Although opposed by Televerket, the Government twice allocated more frequencies to Comvik, although not enough to enable the company to compete effectively, at least according to Comvik.[717]

From 1982 onward for a few years, there was fierce competition between Comvik and Televerket, with NMT quite soon outstripping Comvik in terms of subscriptions. A number of other controversies occurred, the most important ones regarding: (1) interconnection of the automatic Rydax exchanges, (2) abolition of interconnection fees, (3) frequencies, (4) marketing and (5) prices of fixed telephone lines. Comvik also applied for frequencies in the

[713] In 1979 Televerket presented a new and even more restrictive policy which among other things did not permit automatic systems, and a charge of SEK 240 per year per subscriber.

[714] Karlsson (1998:225-238).

[715] Millicom also entered the UK market having a share in Vodafone, which was gradually divested in order to finance investments in mobile telephone systems in developing countries. (Mölleryd 1999:102)

[716] Lindmark (2002 based on Karlsson (1998:225-238), Lernevall and Åkesson (1997:564-656), and Mölleryd (1999:97-105). For more detailed accounts of the competition with Comvik, see Karlsson (1998) and Mölleryd (1999).

[717] Lindmark (2002)

900 MHz band, but eventually the window of opportunity to compete in analog cellular was perceived to be lost. In 1987 Comvik turned its attention to GSM instead.[718]

After some initial problems, such as type approval of terminals and roaming problems between the Nordic countries, NMT sales began to grow rapidly in 1982. Televerket Radio improved its marketing skills, partly as a result of the threat from Comvik's aggressive competition and marketing campaigns.[719] Relatively early, it became obvious that Comvik could not attract nearly as many subscribers as NMT (never more than 20,000), since the service of the system was slightly inferior and the number and performance of telephone models was insufficient. In addition, a lack of frequencies limited Comvik's possibilities to compete. If given more frequencies, Comvik might have more seriously dealt with the competition from Televerket, by building up a fully cellular system such as TACS, a strategy that was in fact considered by Comvik.[720] However, Comvik and Kinnevik had acquired a foothold on the Swedish market and this proved to be very important later, when GSM licenses were to be awarded.[721] Kinnevik was also, through Comvik International and Milllicom International, a very active player in the international arena with a strategy to provide mobile communications to several minor markets.[722] Further, the independent terminal suppliers and retailers indirectly marketed NMT.[723] A large number (10+) of independent local, Nordic, European, Japanese and US suppliers entered the market with a number of NMT models that indirectly marketed NMT.[724] Prices were lowered rapidly and performance improved.

Distribution of products and services had also developed considerably since 1971 when the terminal market was opened up. Initially, terminals were provided via companies specializing in radio equipment. Those companies were the core of what eventually became specialized mobile telephone distributors. When NMT was introduced, there were some 250 to 300 retailers of mobile phones.[725] During the 1980s, automobile and office equipment retailers were added to the distributor base (reflecting the activation of new market segments). Also terminal equipment manufacturers entered the retail business. In 1989 the number of retailers had grown to some 1,500.[726] Many companies had to withdraw from the retail market due to financial problems and other reasons; however, a few prospered and expanded rapidly, such as GEAB.[727]

Quite soon demand exceeded forecasts.[728] Initial growth of NMT was supported by Televerket stimulating a rapid migration of MTD users to NMT.[729] In October 1982, roaming between the Nordic countries began to work effectively. The build-out of NMT was accelerated. In 1983,

718 Karlsson (1998:238-247).

719 Lindmark (2002) based on Lernevall and Åkesson (1997:565) and interviews.

720 Mölleryd (1999:105) and Lindmark (2002) based on interviews.

721 Lindmark (2002) based on interviews.

722 Lindmark (2002) and Lindmark and Wilkinson (1992).

723 Lernevall and Åkesson (1997:565).

724 Lernevall and Åkesson (1997:565).

725 250 in 1982 according to Lernevall and Åkesson (1997:565); 292 in 1980 according Mölleryd (1999).

726 Televerket Radio (1989).

727 Mölleryd (1999:121-124) based on Anderson and Mölleryd (1994).

728 Televerket had forecasted that there would be 45,000 subscribers ten years after introduction (i.e. 1991), and it dimensioned capacity as well as prices according to these figures. After only three years (late in 1984) these figures were already exceeded. (See Lindmark 2002:167-168) and Mölleryd (1999:

729 Operators (telephonists) were gradually transferred to a manual answering service introduced in NMT. In 1989, Televerket introduced the automatic answering service "Mobilsvar". (Lernevall and Åkesson 1997:568.)

NMT surpassed the MTD system in terms of subscribers, and lack of capacity was soon expected to be a serious problem, especially in densely populated areas during peak hours. In 1985, a temporary solution was to implement a so-called small-cell structure (with more base stations and directed antennas) that had been developed by Televerket's Radio Laboratories which increased the estimated capacity of NMT to about 250,000.[730] Additional frequencies, in combination with a new system having higher capacity, were clearly needed. There was an opening in the 900 MHz band which had been reserved for mobile telephony by WARC and later by CEPT (see above). Thus, already in late 1982, the NMT group started to specify a NMT in the 900 MHz band.[731] NMT 900 mainly used and adapted NMT 450 technology, including some improved features such as battery-saving functionality for hand-portables, improved speech quality by using compander/expanders, and faster handover.[732] Televerket launched NMT 900 in 1986, but in Sweden adoption was slow initially. NMT 900 gave the operators the benefit of larger capacity – a benefit that the end-user could not really appreciate. Televerket had anticipated this. Therefore, although some manufacturers (e.g. Philips and Mobira) had developed hand-portables for NMT 450, Televerket did not allow these to be commercialized, since introduction of hand-portables was to be saved as a competitive advantage for NMT 900. Still, manufacturers were slow in launching terminals for NMT 900. So it was not until hand-portables were introduced and, probably most importantly, coverage of NMT 900 extended outside urban areas that the subscriber base started to grow rapidly.[733]

7.2.3.1 Internationalization of NMT and Televerket's international activities

During the first years after introduction, the Nordic telecom administrations actively promoted NMT outside the Nordic countries in order to create a larger subscriber base, to improve the benefits of roaming, attract more suppliers and lower the prices of equipment. Although not implemented to any great extent in the major European countries, benefiting from being the first Western cellular system NMT made entries into e.g. the Benelux countries, Spain and Austria, and also into the Middle East and Southeast Asia. Compared to other cellular systems, NMT 450 had the advantage of being a low-cost alternative, offering quick wide-area coverage and not occupying frequency spectrum in the 900 MHz band (often reserved for GSM systems or for the military as in Eastern Europe). This explains some of the diffusion of the NMT 450 system in the early 1990s, when it was implemented in most countries in Eastern Europe and the former Soviet Union. This renewed diffusion of NMT 450 and resulted in an increased interest among suppliers and in the introduction of hand-portable phones.[734] As can be seen in Figure 7-7, compared with NMT 450, the diffusion of NMT 900 in terms of number of adopting countries has been very modest, the main reason being more intense competition from other system standards.

[730] Televerket internal (850215).

[731] Televerket internal (850215), GSM (23/83), Lernevall and Åkesson (1997:566) and interview with B. Magnusson (1995). Actually, already in 1975 the NMT group stated that the 450 MHz band might not suffice for future demand (NMT 7506).

[732] Lernevall and Åkesson (1997:566).

[733] Lernevall and Åkesson (1997:566-567).

[734] See Lindmark (2002: 170-172)

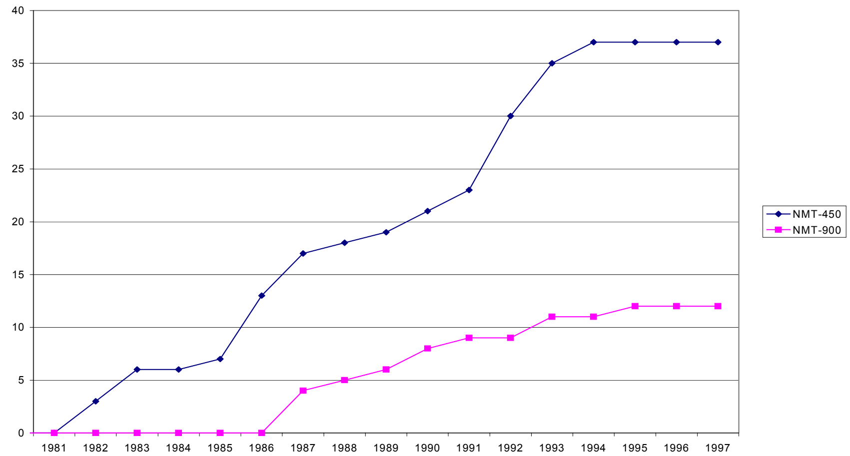

Figure 7-7: Number of countries where NMT has been adopted (1981-1997)

Source: Adapted and complemented from Lindmark and Granstrand (1995)

The internationalization of NMT provided opportunities for internationalization of firms. Initially, this opportunity was grasped by the supplier industry only. It was not until the late 1980s and early 1990s that Televerket, through Swedish Telecom International (STI), began applying for licenses in other countries. Focus was then on the countries around the Baltic Sea (Estonia, Lithuania, Latvia, Poland, St. Petersburg in Russia etc.), but later STI looked for and obtained licenses further abroad, as in Italy, India, Namibia and Ecuador. The early efforts were often made in partnership with the Nordic neighbors. However, when Televerket, PTT Netherlands and the Swiss PTT formed the Unisource partnership, the Nordic cooperation ended abruptly. Televerket also put itself in a position of internal competition when Unisource formed a daughter company for mobile services, Unisource Mobile. Since then, Televerket has revised its international strategy on a number of occasions.[735] Obviously such a lack of strategy and focus has led to lost business opportunities.

7.2.3.2 NMT in the 1990 and beyond

At the time when NMT 900 was introduced, Televerket had obtained a near-monopoly position on the Swedish cellular market. For some years Televerket could enjoy harvesting investments in NMT. Approaching the 1990s, however, first Comvik and then NordicTel obtained licenses to operate GSM networks in competition with Televerket – a competition on more equal terms than the earlier limited competition from Comvik. Televerket realized that it had to position itself and its monopoly NMT systems in order to face this competition and to harvest. In the early 1990s it launched several marketing campaigns and new pricing alternatives.[736] Televerket also invested in better-performing equipment, mainly base stations, to substantially increase performance and capacity, new functionalities, lower operating costs, and allow enhanced services in the NMT 900 system.

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[735] Lindmark and Wilkinson (1992), Johansson (1994, based on data collected by the author). See also above.

[736] Such as “NMT-RÖD”, “NMT Combi”, “NMT PRO”. NMT-RÖD, specifically for the 450 system (“röd” is Swedish for red, echoing low-priced “red departures” for trains), had very low tariffs at non-business hours, while “NMT PRO” aimed for heavy business users and “NMT Privat”, aiming for the private market.

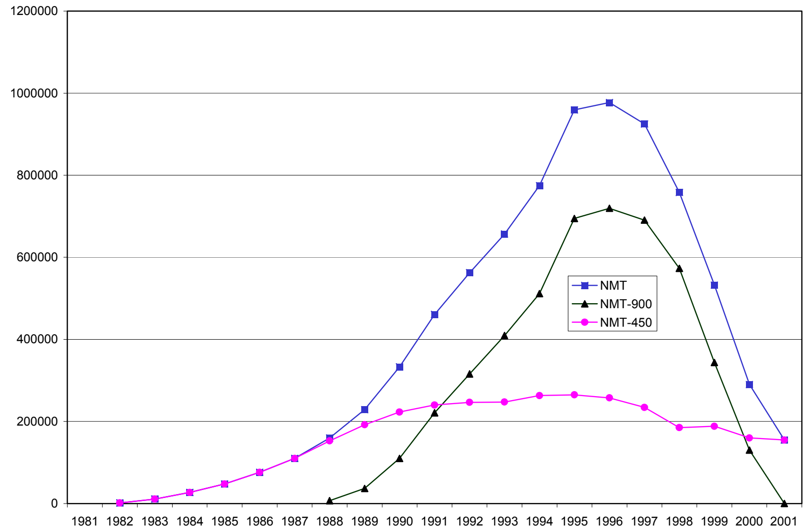

Figure 7-8: NMT subscribers in Sweden 1981-2001

Note: Beginning of years. Note also that a large portion of NMT subscriptions are not actively used.

Source: Televerket annual reports, Mobile Communications International various issues

As a result the influx of subscribers continued to grow in 1993-1994. It was not until spring 1994 that GSM subscribers grew more rapidly than NMT 900. In the long run Telia could not keep up its NMT 900 momentum. As GSM coverage expanded, better terminals and services were introduced and price wars began. NMT 900 stopped growing (see Figure 7-8). Since NMT 900 (and TACS in other countries) occupied 10 MHz of the 25 MHz reserved for GSM, Telia had to gradually give up frequencies used by NMT 900 and phase out the service. Finally, on December 31, 2001, NMT 900 was closed down.

NMT 450, on the other hand, was standardized in a new and better version: NMT 450i (NMT 450improved). This version was partly initiated by the late-coming diffusion in the Baltic states, Eastern Europe, and former Soviet Republics. The new standard offered better functionality[737] and allowed for hand-portables produced by 2-3 manufacturers. Besides being first, NMT 450 may very well be the analog cellular standard that will survive the longest.[738]

[737] For instance, shorter handover time and battery-saving function (NMT 450, 6/92)

[738] In the late 1990s digital GSM as well as CDMA became adapted to the 450 MHz band, and it seems likely that a number of countries eventually will switch to these digital standards instead.

Table 7-8 : Overview of the "Nordic" systems MTD and NMT

	MTD	NMT 450	NMT 900
Manual/automatic	Manual	Automatic	Automatic
Domestic coverage	Gradually built up to cover most of Sweden	Ditto	Ditto although less than 450.
International	Norway and Denmark	Nordic countries and several (30+) countries in Europe and worldwide	Nordic countries and some countries in Europe and worldwide
Development period	1970-1971		
Test system introduction	1970 (1)	1971-1980	1983-1985
Commercial period	1971-1987	1981-	1986-2001 (in Sweden)
Mode of terminal distribution	Free purchasing from independent terminal suppliers		
Retailers	n/a	Radio specialists, car dealers, later office equipment retailers, radio and TV shops	Ditto
Frequency band	450 MHz	450 MHz	900 MHz
Main developers	Televerket, various departments connected to the radio labs	NMT group, radio labs of PTTs – mainly Televerket	Ditto
Suppliers			
infrastructure	Magnetic, SRA, Mitsubishi	Ericsson, Nokia, Mitsubishi, Motorola, Magnetic, Radiosystem	Ericsson, Nokia, Mitsubishi, Philips
terminals	AP, Handic, Mitsubishi, Salora, Sonab, Storno, SRA	AP, Benefon, Bosch, Cetelco, Dancall, Ericsson (SRA), Mitsubishi, Mobira, Motorola, NEC, Panasonic, Siemens, Simonsen, Storno, Cetelco	Alcatel, Bosch, Cetelco, Dancall, Ericsson (SRA), Mitsubishi, Mobira, Motorola, NEC, Panasonic, Siemens, Simonsen, Spectronic, Storno, Technophone
Weight of terminal	2.4	4 kg	0.3 kg
Peak number of subscribers (in Sweden) (year)	19,687 (1981)	260,000 (1995)	750,000 (1996)

Sources: Various compiled by the authors, e.g. Heimbürger and Tahvanainen (1989), Mölleryd (1993, 1999), Gerdes (1991) and archival documents.

7.2.3.3 Supplier industry

Infrastructure

NMT became extremely important for the development of Swedish mobile telephony industry. The time period starting with the development of NMT and introduction of MTD, and ending with digital systems overtaking the market, could be described as a period of growth and expansion of the innovation system, with Ericsson internalizing it.

As mentioned above, the supplier industry was fairly reluctant to NMT, preferring proprietary systems locking the users. As mentioned above, Magnetic was chosen for base stations and Magnetic and Mitsubishi to supply the base stations,[739] and out of a shortlist of three

[739] SRA delivered the control unit of the base station to Magnetic. SRA at that time primarily focused on terminals, mainly for dispatch radio, and later fully diversified into the radio base station business.

manufacturers Ericsson was chosen to deliver the MTX. Within Ericsson a smaller AKE-13 switch was initially preferred, but Televerket persuaded Ericsson that the more capable AXE switch would be more suitable.[740] Stories differ here, however (see e.g. McKelvey et al. 1998:26-27). Ericsson's reluctance was partly due to the fact that they did not perceive mobile telephony as an important business opportunity. Thus the vision of Televerket instead guided their actions. The orders from the Nordic PTOs and others (e.g. Saudi Arabia) demonstrated the market potential, and pulled the company into mobile telephony. The choice to use AXE proved to be an important strength for Ericsson later on when the market expanded rapidly, since it could handle many subscribers and was flexible enough to include new functionality demanded by e.g. digital systems. Ericsson could then also use its complementary assets in the form of established relationships with foreign PTOs and its international presence in general to establish itself as the leading supplier. However, this required not only switching competence but also radio and system competence, the former already residing inside the firm, the latter having to be acquired.

As opposed to switching firms, the early history of firms in radio communications is largely a story of small firms, sometimes competing, sometimes collaborating, and sometimes sourcing in components from each other in a quite complicated pattern. As mentioned above, the Swedish mobile radio consisted mainly of SRA, Sonab, AGA, Magnetic and ANT[741]. In the 1960s, Ericsson gradually increased its share to become the majority owner in SRA, and the company was streamlined to mainly include communication radio for commercial and military use. In the mid-1960s SRA shifted its focus from military to civilian radio communications. It was out of this focus shift that Ericsson's mobile telephony business was born.[742] Much of the technology used in base stations at SRA was, initially at least, based on technology used for the military.[743] SRA aspired to AGA's mobile radio business (AGA Mobilradio) with 475 employees and revenues of SEK 30 million. However, instead it was Sonab, founded in 1966, that acquired AGA mobile radio, turning Sonab into the second largest Swedish mobile radio supplier.

Sonab run into financial problems and was acquired (including 400 employees) by SRA in 1978. This deal was part of a strategy of SRA's managing director Åke Lundquist to acquire companies with the resources that Ericsson needed to become a major competitor in mobile radio and mobile telephony. Clearly SRA had lacked these competences. In the early 1970s, SRA had failed to receive base station orders for MTD, because its technology was not sophisticated enough. The orders instead went to Magnetic.[744] Also, when the Nordic PTTs called in bids for RBS for NMT, several firms responded, including SRA, Magnetic, Mitsubishi, Philips and Nokia. However, SRA only had the competence to deliver the control unit. According to McKelvey et al. (1998:31) one reason was that the company had diverted its attention to the US market, thus failing to gain knowledge about Nordic technical specifications. A second reason was that they were focused on the terminal business. However, SRA managed to secure a position as sub-supplier of control units.[745]

Magnetic was perhaps the leading base station supplier in the 1970s. It received its first order for radio base stations to MTD. Under Torbjörn Johnsson's management Magnetic developed radio base stations also for NMT. For the first procurement order, they had to share the order

[740] Meurling and Jeans (1994), Lernevall and Åkesson (1997:564) and interviews.
[741] The fate of ANT is not clear to these authors.
[742] Åke Lundqvist as quoted in McKelvey et al. (1998:20)
[743] McKelvey et al. (1998:20).
[744] Mölleryd (1999:108-109)
[745] McKelvey et al (1998:31-32)

with Mitsubishi, which according to Johnsson had copied Magnetic's technology. Magnetic received orders also from Denmark and Norway. Due to a royalty dispute, Johnsson left Magnetic in the late 1970s, and the company was bought by Ericsson/SRA in 1983, in order to further strengthen its radio base station officering. However, with its main inventor no longer in the firm, Magnetic's technological development and products stagnated.[746]

With a strong belief in the future of mobile telephony, Johnsson and two partners established Radiosystem in 1978 based on personal loans of the founders. Radiosystem started supplying filters, combiners and full radio base stations to a number of systems including NMT, RC 2000, Comvik and Mobitex. It pioneered production technologies such as surface mounting, engaging around 30 subcontractors and 500 component suppliers. Early crucial orders included subsystems for the radio base stations to Ericsson in Saudi Arabia in 1981 and to NMT in Sweden. Radiosystem expanded into becoming a full-fledged radio base station supplier, expanding first in the Nordic countries, then in Europe. Due to financing provided by e.g. Anders Tuvenhjelm, the company started developing GSM base stations in the mid-1980s. By 1986 it was listed on the Stockholm stock exchange, with an annual turnover of circa SEK 100 million and 100 employees. By then, Radiosystem had become a major competitor to Ericsson. Still, it was questionable whether or not Radiosystem would manage the transition to GSM. Then in 1988 Ericsson acquired the Radiosystem company for SEK 465 million, with Johnsson continuing to work for Ericsson Radiosystem for a number of years.[747]

Allgon was another major company using the soaring mobile telephone market as vehicle for growth. By the 1970s, Allgon (owned by the Kämpe family) focused on aerials primarily for the defense industry. Recognizing the growth potential of mobile telephony, in 1982, the company turned its attention to delivering antennas and other components to radio base stations and terminals. Allgon's specialization forced it to expand abroad. By the late 1990s, Allgon employed some 1000 employees and had almost SEK 2 billion in turnover. It held 10-15% of the combiner market and 40% of the market for mobile phone antennas.

Returning to SRA/Ericsson, with Sonab's competence, it could now deliver base stations and AXE switches to NMT in e.g. Saudi Arabia. Triggered by an NMT contract in the Netherlands in 1982, Ericsson acquired also the systems integration competence. The reason for Ericsson not having this competence was that the Nordic PTTs held this competence in house. The Dutch PTT preferred to buy switches from Ericsson and base stations from Motorola. Ericsson objected to this and persuaded them to buy also SRA base stations. The Dutch required, however, that Ericsson supply a system with small-cell technology, which Ericsson sourced in from US consultants. The company was thus developing into a full-fledged communications supplier, and managed to secure strategically extremely important orders for other system standards in the US and the UK in 1983. This internationalization was driven by deregulation of the market in these two countries. On the US market Ericsson could partly free-ride on an offensive campaign of EIS equipment there.[748] Them, following the acquisition of Radiosystem, Ericsson became the major base station supplier with a 40% market share.

It should be pointed out here that the success of Ericsson could to a large extent also be explained by factors internal to the company, in particular the entrepreneurship of Åke Lundqvist at SRA (pushing for mobile telephony), the use of AXE, securing the Saudi deal,

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[746] Mölleryd (1999:110-112)

[747] Mölleryd (1999:112-114)

[748] McKelvey et al. (1998:41)

and integrating the divergent competences inside the company, turning Ericsson into a full-fledged supplier.

Terminals

As mentioned earlier, the land mobile investigation of 1967 recommended the opening up of the terminal market. The decision was taken for a number of reasons: (1) to reduce the necessary investment for Televerket, (2) to stimulate competition and thereby development of a wide variety of terminals, and (3) to stimulate marketing of terminals.[749] It also had the effect of developing the distribution system. This decision was implemented with the introduction of MTD in 1971. All the intended effects came true. Similar experiences from Denmark and Norway were both inspiring and positive. A number of manufacturers from the mobile telephone market entered the MTD market. These were AP, Handic, Mitsubishi, (Gadelius), Salora, Storno, Sonab and SRA. Competition also led to improved performance of terminals in the form of e.g. frequency synthesizers and "portable" telephones. Therefore it was natural for the NMT group to recommend the same model for NMT.[750]

All in all, a large number (10+) of local, Nordic, European, Japanese and US suppliers entered the Swedish market with a number of NMT models (see Table 7-8). Although NMT terminals were priced higher than e.g. AMPS and TACS (see above), prices lowered rapidly and performance improved. Among the Swedish suppliers, AGA was the leading one well into the 1970s. When Sonab acquired AGA Mobilradio in 1974, it overtook that position, presumably with SRA as number two.

Comvik's system led to the Swede Nils Mårtensson starting up the terminal manufacturer Technophone – not in Sweden though, but in the UK, possibly to take advantage of the opening up of the British telecom market, possibly because of access to capital. Technophone was acquired by Nokia in 1991.[751]

Spectronic, established in Helsingborg in 1972, supported by NUTEK and Utvecklingsfonden i Malmöhus län, began developing mobile phones in the mid-1980s. The first phone was launched in 1989. Simultaneously the company began cooperating with Siemens, and developed and manufactured an NMT phone called Marathon for them. This cooperation was very profitable and financed the development of the new terminal model TS 220. When Siemens ended the cooperation in 1992, Spectronic launched an advanced mobile data terminal.[752] Through the latter part of the 1990s, Spectronic was heavily engaged in developing a multimedia GSM terminal (TS 2200 SIDETOUCH), launched in 2000, with innovative advanced datacom capabilities, and a newly developed user interface, designed to facilitate for simpler input of data.[753]

Following the introduction of NMT 900, hand-portables were released on the Swedish market (somewhat later than e.g. in the US). As performance (terminal weight and volume; stand-by and talk-time) improved and hand-portables' price decreased rapidly and approached that of mobiles, hand-portables took an increasing share of the total cellular market, as shown in Figure 7-9.

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[749] Åsdal (1977).

[750] Mölleryd (1999: 116-117)

[751] Mölleryd (1999:118)

[752] Mölleryd (1999:118-119)

[753] Or possibly 2001.

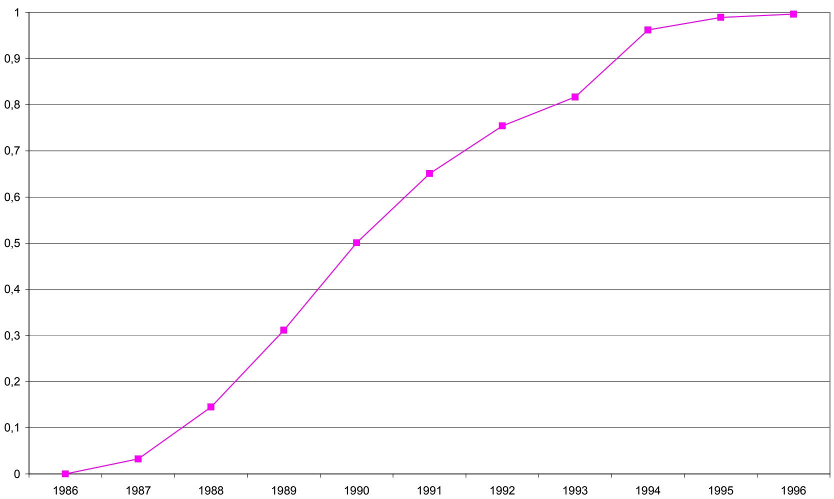

Figure 7-9: Share of hand-portables of the total cellular phones in Sweden

Source: Mobiltelebranschen as reported in Mölleryd (1999)

Production in Sweden, in particular of mobile phones, has experienced both an upswing and downturn. Ericsson's NMT phones were initially manufactured in a small part of Ericsson's production facilities in Kumla. During the early expansion years, production was almost exclusively made there, eventually employing 3,500 persons. Another plant was started in Linköping (at Datasaab's old facilities) when it was considered to be too risky to have all production in one place. Production was also placed in the UK, US and in China, and contract manufacturing in Malaysia. The number of production employees peaked at 5,000 in 1999 (corresponding to 11% of Ericsson's employees in Sweden).[754]

Early in 2003 the last Ericsson (by then Sony Ericsson) phone was manufactured in Sweden, when Flextronics's production in Linköping was moved to Sony's production facilities in France.[755] The only terminal production left in Sweden is Spectronic's <100,000 terminals and Spectra's few thousands for the military.[756] Since the mid-1980s most of Ericsson's terminal development has taken place in Lund, employing up to 1000 persons. After the merger with Sony, Lund remains an important development center, with some of the more advanced terminals being developed in Stockholm. Ericsson has also started a separate company based in Lund licensing mobile platforms to terminal manufacturers (including Sony Ericsson).

[754] Nilsson (2003)

[755] Nilsson (2003)

[756] Nilsson (2003)

7.2.3.4 Distribution

Distribution of products and services had developed considerably since 1971 when the terminal market was opened up. Initially, terminals were provided via companies specializing in radio equipment. Those companies were the core of what eventually became specialized mobile telephone distributors. When NMT was introduced, there were some 250 to 300 retailers of mobile phones.[757] During the 1980s, automobile and office equipment retailers were added to the distributor base (reflecting the activation of new market segments). Also terminal equipment manufacturers entered the retail business, though not very successfully. In 1989 the number of retailers had grown to some 1,500.[758] Many companies had to withdraw from the retail market due to financial problems and other reasons; however, a few prospered and expanded rapidly, such as GEAB.[759]

7.2.3.5 Users

During the 1970s mobile telephony was still confined to small and medium-sized companies. With the introduction of NMT 450 new market segments were activated, such as building and construction firms, repair and service firms and wholesale traders. In the mid-1980s, mobile telephony spread beyond these core segments, for instance to sales and service personnel in larger firms. The introduction of hand-portables opened up the market for executives and yuppies. Beneficial taxation rules contributed to penetration of these segments, the mobile could be bought and paid for by the firm, while used to a substantial degree for personal purposes.

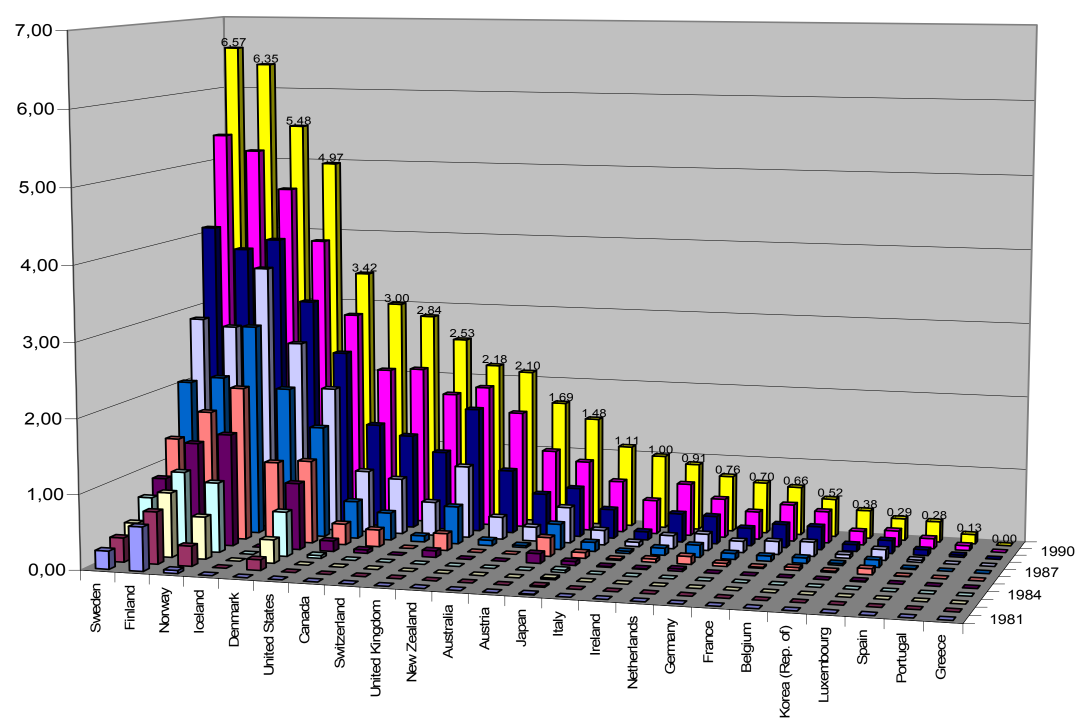

Figure 7-10: Cellular penetration (%) in the OECD countries in the analog era (1981-92)

Source: ITU telecommunications data base

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757 250 in 1982 according to Lernevall and Åkesson (1997:565); 292 in 1980 according Mölleryd (1999).

[758] Lindmark based on Televerket Radio (1989).

[759] Mölleryd (1999:121-124) based on Anderson and Mölleryd (1994).

Although not the most advanced market when it came to terminals used, the Swedish mobile market (and Nordic markets) in general was extremely advanced when it came to penetration of mobile services (see Figure 7-10), far beyond other OECD countries (notably the large economies of Japan, France, Germany and Italy). Second to the Nordic market came the North American ones, followed by e.g. the UK and New Zealand where competition had been introduced early on.

7.2.3.6 Others

Apart from the main players, the NMT group, Ericsson and Televerket, the radio industry, and the competing operators, other actors only played a minor role. Universities and institutes did not contribute substantially to development of technology. Few firms were started in the early phases. Some foreign influences were affecting the development, which was dependent on a number of enabling technologies, in particular semi-conductor technology supplied from abroad. No government-sponsored research other than Televerket research has been identified as having been important. The role of military R&D was limited to being important for the development of radio supplier industry. This came to change for the next generation.

7.2.4 Digitalization

7.2.4.1 Competence build-up

The Swedish manufacturing industry gained from pioneering efforts by Televerket and SRA, who initiated research in the field of digital cellular already in the 1970s. This research came to progress along the same lines, and influenced the choices made in GSM standardization, a fact that largely benefited Swedish actors.

Managing the transition to GSM required innovation and development of competences in a number of technological fields (see e.g. Granstrand et al. 1992; Eliasson 1995; Palmberg and Martikainen 2003). Depending on the method for classification, these were e.g. digital radio circuitry, frequency hopping, digital signal processing, modulation, speech coding, data communications, etc. According to Eliasson (1995:100-112) SRA's involvement in military technology played an important role, since competences gained from that involvement could be adapted to mobile telephony. Examples of such fields were: certain antenna technologies, frequency hopping, coding, error correction, and the use of high frequencies in general (also important in the previous shift).[760]

Sven-Olof Öhrvik, head of R&D at SRA, clearly influenced by military radio technology, encouraged the company's activities in digital mobile telephony. He also stimulated research on national and international (Nordic) level. In the mid-1970s SRA started discussions with STU to initiate academic research in the field of digital radio. In 1977, Öhrvik initiated a joint R&D network, including Ericsson/SRA and Televerket, the military, and the principal technical universities: Chalmers (Göteborg), Lund, Stockholm and Linköping. Research mainly focused on digital ASIC design and digital signal processing, i.e. modulation, channel coding and speech coding).[761] There was also an exchange of competence within the Nordic countries.[762]

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[760] It is important to note that nowadays civilian use of radio technology is more advanced than military use, at least in Sweden.

[761] Televerket internal (870401), GSM (73/86), Meurling & Jeans (1994), STU (1991:14), Keijer (1992:3-6)

[762] McKelvey et al. (1998:46)

Televerket's Radio Laboratories, then headed by Östen Mäkitalo, started a research project on digital mobile telephony in the late 1970s, initially focusing on modulation techniques.[763] The first efforts were concentrated on FDMA, including development of an FDMA demonstrator in 1983. Eventually the FDMA technology track was abandoned, as TDMA proved to be more feasible.[764] Therefore, in 1984 development efforts were redirected to TDMA, first within Televerket, then at Ericsson. They cooperated in several technical areas but, in 1985 and 1986, chose to develop two separate TDMA demonstrators for the Paris Trials (see above), based on narrowband TDMA. Still, these demonstrators as well as the Finnish one were quite similar in many respects, probably as a result of the networking taking place.[765]

These efforts enabled the choice of narrowband TDMA in the GSM standardization work, a decision which clearly helped Ericsson to reinforce its position as dominant infrastructure supplier and temporarily strengthen its position also as mobile telephone supplier. When the decisions were taken, standard specifications and product development could start more seriously. Both these efforts were resource-consuming. The general opinion was that the Swedish competence in digital radio communications was state-of-the-art, but that it was thin with only 25 individuals working with applied research at Ericsson and Televerket, being the main players. Therefore a number of fully or partly government-funded research programs were initiated, most importantly the STU framework program in digital communication (1987-1993)[766] and the IT-4 program[767]. The IT-4 program, in total roughly SEK 1 billion, half of which came from the government agencies partly applied to digital communications, had the importance of e.g. developing testing systems and components as well as enabling participation in international research programs.[768]

The STU program (64 million SEK in total) was important in developing competence at the technical universities. It strengthened the network of R&D in digital technologies and created a pool of competent individuals that was critical for Ericsson's development of GSM[769] and later other digital standards (PDC and TDMA) in particular. To some degree it also helped Radiosystem in developing GSM, the competence being transferred to Ericsson as a result of the acquisition.

Ericsson's strong position enabled the company to influence the US and Japanese choices regarding digital technology, thus aligning their choices to Ericsson's technological strengths. However, to develop products for all three standards was extremely resource-demanding. The company had to increasingly rely on international R&D centers, sourcing of component technology, alliances and collaboration. It also involved substantially increasing R&D investments at a time of recession, a quite brave strategy initiated by Lars Ramqvist when he became CEO in 1990.[770] Ericsson also managed to essentially strengthen its position in the terminal business.[771]

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763 Lindmark (2002:228) based on interviews.

764 Some benefits were better capacity, possibility of using microcells, frequency hopping and mobile-assisted handover. (Although there were technical problems in the beginning, such as speech coding and time dispersion.)

765 Lindmark (2002: 228) based on interviews and Meurling & Jeans (1994).

766 Deiaco and Arnold (2001)

767 See e.g. McKelvey et al (1998: 49-50) and Lernevall and Åkesson (1997:693-694)

768 McKelvey et al. (1998: 49-50) and Lernevall and Åkesson (1997:693-694

769 Deiaco and Arnold (2001) and McKelvey et al. (1994)

770 See e.g. McKelvey et al. (1998:51-52)

771 The later developments of the mobile phone business (the platform development failure, start of mobile platforms, merger with Sony) were treated in Chapter 4. The investigation could have been pursued more, but must be left for further research.

7.2.4.2 Operators' market

The introduction of GSM provided an opportunity to seriously intensify competition. Instead of two operators, which was the normal case in Europe, there were three operators on the Swedish market: Televerket/Telia, Comviq and Europolitan. Televerket was in a favorable position to become the first GSM operator in Sweden, due to competence and infrastructure build-up in NMT (including billing) and its involvement in GSM digital radio development, the available resources in the form of capital and masts for the GSM radio base stations, etc. However, Televerket had no commercial incentives to introduce GSM so early, and would probably have waited until 1995 or so before actively launching GSM, had it not been for competitive pressure.

Comvik, Televerket's quasi-competitor, decided not to implement a TACS system (see above) in competition with NMT, and pursued a strategy to become a GSM operator instead. Initially, Televerket opposed this, claiming technical and economic inefficiencies of introducing a second GSM operator. However, Comvik's presence on the mobile telephony market, and the general liberalization and deregulation regime emerging in Europe at this time, made it natural for the Swedish Frequency Board (still being a part of Televerket) to grant licenses to both Comvik and Televerket. The operators were granted 5 MHz each, with options for another 2*2.4 MHz provided that certain demands in terms of e.g. coverage were fulfilled. Within Comvik a new company – Comviq GSM – was created for providing GSM services.[772]

A third operator soon entered the arena. In 1989, Ulf J. Johansson and later Mats Ljunggren, at that time managers at Ericsson Radio Systems, perceived the opportunities of operating GSM in Sweden. They founded NordicTel Holdings AB in early 1990. In 1990, four major Swedish companies, Custodia, SAS, Spectra Physics and Volvo, each invested SEK 4 million in the capitalization of NordicTel. The same year, NordicTel applied for a license to operate a nationwide GSM network in Sweden. In December, following a debate whether or not this was beneficial, the Swedish government issued a third license, to the consortium.[773] In 1991, the Vodafone group became a part-owner (10%) of NordicTel's Swedish operations. Vodafone had successfully operated a mobile telephone network in the UK since 1985, and pursued an aggressive international expansion strategy by applying for GSM licenses abroad (the company had earlier unsuccessfully applied for a GSM license in Sweden). Vodafone's share of the company later changed to become 20% (of the holding company). In 1991, SAS sold its shares to the other joint owners, and in 1993 the other Swedish owners sold 51% of the shares to the US mobile telephone operator AirTouch[774] for SEK 1.2 billion.[775]

Soon after obtaining the license, NordicTel tried to expand internationally and applied for licenses in Denmark, Norway and Poland (together with Televerket). The application in Denmark was successful (where NordicTel had a 20% share in the winning consortium).[776] In 1994 NordicTel was listed on the Stockholm stock market and the joint Swedish owners sold the remaining parts of their respective share holdings (23%) in the company. Then, in 1999, owners AirTouch and Vodafone merged to form the world's largest mobile telephone operator, having ownership interest in operating companies in some 20 countries, including a

[772] Lindmark (2002:229) based on interviews

[773] Lindmark (2002:229-230). See Mölleryd (1999:140-142).for an elaboration.

[774] At that time named PacTel and also expanding rapidly outside the US.

[775] Mölleryd (1999:143)

[776] Lindmark (2002:230) based on interviews

majority share in NordicTel/Europolitan.[777] Vodafone later further increased its holdings in order to take full control of the company.

Since Comvik and NordicTel were restrained from buying Ericsson equipment, because of the agreement between Ericsson and Televerket which gave Televerket a monopoly on AXE switches in Sweden, they had to search for other system suppliers. Comvik chose Motorola (base stations) and Siemens (switches) while NordicTel chose Nokia.[778] Both Comvik and NordicTel launched their systems in September 1992 under the names of Comviq GSM and Europolitan, Televerket launching in November the same year. As mentioned before, Telia took advantage of its unique position on the NMT market. In the autumn of 1993, Telia Mobitel (the name was changed from Televerket Radio to Telia Mobitel on July 1, 1993) launched a new pricing package for NMT, named "NMT-Privat", thus harvesting on its successful analog system and at the same time successfully competing with Comvik for the private users.

During the first years (late 1992 and 1993) growth rates in GSM systems were low, due to limited coverage and lack of type-approved terminals. Terminals were short in supply and the lion's share went to Mannesmann Mobilfunk in Germany, which led to an even worse shortage of supply in other countries.[779] In addition, terminals were large and heavy. In the words of the local press:

> "Thinking of buying the new European mobile phone – GSM? Don't do it"
>
> *Translated from local Göteborg newspaper iDAG, 920829, p. 23.*

Instead, NMT-Privat became a success for Telia Mobitel. NMT grew faster than ever before in 1993. Telia Mobitel also concentrated its marketing on NMT and claimed that GSM was not yet as functional as NMT (in terms of capacity, speech quality, coverage, terminal performance etc.). As a result Comvik obtained a majority of the GSM customers. However, in the spring of 1994, Telia began to market its GSM system, introducing new pricing packages and new functionalities such as GSM Data and Fax.[780] .

[777] Lindmark (2002:230) based on interviews

[778] Lindmark (2002:230-231) based on interviews

[779] For a discussion on the slow start of GSM in Sweden, see Hultén and Mölleryd (1993).

[780] Telia Mobitel to distributors (940502).

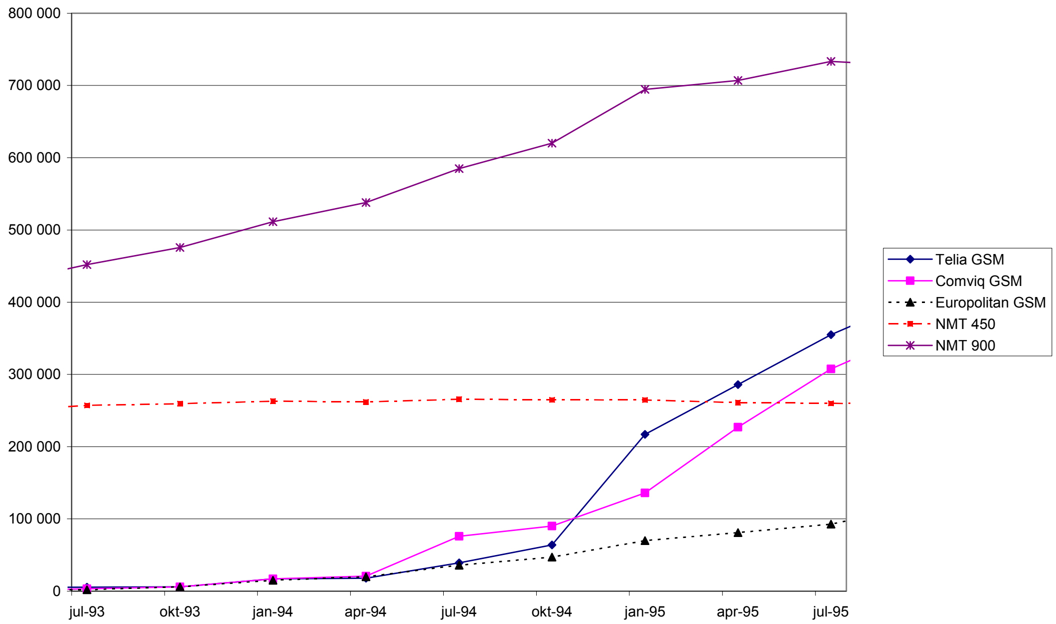

Figure 7-11: Mobile telephony subscribers in Sweden (mid-1993 – mid-1995)

Source: Various issues of Financial Times Mobile Communications and Mobile Communications International.

In the summer of 1994 Comviq and Telia got involved in fierce and prestigious competition to become the largest operator and obtain more than 50% of the subscribers. They started to pay large commissions and other compensations to retailers in order to attract these. Europolitan, not having the financial muscles to engage too heavily in such price wars, had to adapt to a different and less costly strategy, namely to aim for the high-end market segment.[781] Coverage build-up strategies also differed somewhat between the operators; while Comviq aimed for strategic areas, Europolitan and Telia aimed for large area coverage.[782]

In the autumn of 1994 and particularly around Christmas, GSM sales virtually exploded – a result of better terminals, increased coverage, and fierce competition among the operators, resulting in extensive bonuses to the dealers and distributors of subscriptions (several thousand SEK per subscription sold). These bonuses made GSM phones so cheap (to the end customer) that they were sold for almost nothing from time to time (e.g. 1 SEK by Comviq in January 1995). As a result, nearly half a million new subscribers signed up for GSM in 1994. Telia Mobitel, having a market and distribution presence that the other competitors had difficulties in matching, was the operator that benefited most from this boom, capturing almost half the market, although closely followed by Comvik (see Figure 7-11). Europolitan, with a larger percentage of the commercial customers (who use the telephone much more intensively), had a larger share of calling time and revenues than subscriber figures show.

As a result of this boom, frequencies were already beginning to get crowded in 1995. Comviq and Europolitan requested that Telia should give up some of its NMT 900 frequencies to the GSM operators, referring to an EEC directive of 1987. In an initial ruling, the Swedish Frequency Board decided that Telia should gradually transfer 1.8 MHz of the 9 MHz available for NMT 900 to GSM. (Of course, none of the operators were satisfied with this solution.) This was not the first time Comviq (and Europolitan, although with a much lower

[781] Lindmark (2002:231-234) based on personal communication with U. Johansson (1999).

[782] Affärsvälden (931013:35-39).

profile) attacked Telia's monopoly position on the NMT market and the advantages it could obtain by using them in the GSM competition. Earlier complaints were filed against Telia, because of e.g. (1) its non-public registers of NMT customers and (2) a coordinated billing procedure for Telia's NMT and GSM customers. Telia suggested that the GSM expansion should be taken care of by (a) half-rate coding (which would double the capacity) and (b) letting the GSM (900) operators expand their networks to the 1800 MHz band by building parallel DCS-1800 MHz systems in critical areas such as city centers, airports, etc. The other operators, having more restrained financial resources than Telia, seemed hesitant to adopt this solution since it would require immense investments in new infrastructure.

As it turned out, the answer to the question of releasing more frequencies in the 1800 MHz band or Telia handing over NMT 900 frequencies became both. As of May 1995, seven applying consortia had indicated their interest in licenses to operate a mobile telephony network in the 1800 MHz band. In January 1997, PTS decided that the three existing GSM operators obtained 1800 licenses, and later in March a fourth license was granted to Tele 8, later taken over by TeleNordia. But this license was never acted upon. In late 1997, as the first operator worldwide, Telia launched its GSM 1800 network. However, availability of dual-mode terminals was very limited. Later the other operators launched their networks, and as manufacturers launched more and more attractive telephone models, traffic volumes in 1800 networks increased steadily.

Meanwhile, PTS decided that Telia Mobile had to reallocate all frequencies in the 900 MHz band from the NMT 900 system to GSM by the end of 2000. Preparing to shut down the network, Telia encouraged its NMT 900 customers to switch to the GSM network, and as a result the number of NMT subscribers began decreasing rapidly, amounting to 395,000 in September 1998,[783] and finally shut down in December 2000.

Coverage became a main competitive differentiator between operators, a fact that led to a rapid build-out of the networks. Already by 1996, all three operators had achieved coverage obligations stipulated in the licenses (all towns with more than 10,000 inhabitants and all major roads should be covered).[784] In order to reach more market segments, operators started to differentiate themselves by other means also, e.g. by using different brands and subscription packages. Both Telia and Comviq chose to market their services by using several brands. Telia used the brand DOF (Department of the Future) for advanced value-added services. Kinnevik used the Comviq brand to consumers and Tele2 Mobile to business users for a while.[785] In 1998 Comviq/Tele2 offered 11 forms of subscriptions, while Telia and Europolitan used fewer.

Approaching the turn of the century, the Swedish market continued to expand rapidly. Some important events worth pointing out are: (1) the launch of pre-paid subscriptions, (2) the entrance of operators without their own infrastructure and (3) the emergence and take-up of data services (especially SMS) and licensing of UMTS (the latter returned to in Chapter **Error! Reference source not found.**.

Comviq launched pre-paid SIM-cards in March 1997, soon followed by the other operators. This innovation further boosted the GSM market by activating new market segments. Over one million cards were sold in 1998, of which more than 60% were Comviq/Tele2 Mobil.

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[783] Telia (1998)

[784] Öhrlings PWC (1999:

[785] Öhrlings PWC (1999: 41-42)

From that year onward, pre-paid cards accounted for the main share of subscriber growth. Pre-paid subscriptions generate less revenue per subscriber (ARPU) than traditional post-paid ones. In 1998 pre-paid cards to business users were also offered. In general, advanced services were offered later to pre-paid customers. Voice mail and SMS, for instance, were introduced in 1998 over pre-paid cards, the latter being important for the take-up of SMS. Since then, the number of active pre-paid cards has persistently increased to reach some 55% at the end of 2002, the share of revenues still being much lower (ca 16%).[786]

In 1998 a new market for operators without infrastructure emerged, which further stimulated competition. Such operators have been labeled service providers and later mobile virtual network operators (MVNO). The trend was started by Norwegian Sense, which applied to rent capacity over Telia's GSM network; however, there was no regulation in place that forced Telia to comply. PTS suggested that regulation should be changed and recommended that operators accept such proposals. The operators objected to this, arguing that it would change the rules of the game in retrospect. They also argued that operators would invest less in new services and new technology, given the case that they would have to offer these services to other operators. Still, in 1999, Telia and Tele1Europe closed a deal, where Tele1Europe was allowed to use Telia's network to provide services using their own SIM cards and numbers.[787] Starting by May 1, 2000, a new resolution went into force, demanding that all mobile operators sell excess capacity on commercial terms.[788] Later in 1999, Wireless Maingate also established itself, and in April 2000, Sense reappeared on the market. These entries were welcomed by the Swedish authorities, which held the view that competition was not working properly on the Swedish mobile market. Studies showed that prices essentially had not been lowered since 1995. This was especially so for SMS, where prices in Sweden were several times higher than in many other European countries. When Sense entered the market, they did so by offering lower SMS prices, which forced the incumbents to follow.[789]

In 2001, the number of service providers increased dramatically from two to around 10, increasing further to 18 in 2002. Some of these were owned by the established operators (Tango/Tele2, Halebop/Telia and Lunar/Europolitan Vodafone). With the exception of Djuice (owned by Telenor) and the ones owned by network operators, service providers only offered post-paid subscriptions. By the end of 2001, these operators had taken a 1.1% market share of subscriptions and 6% of the growth that year, increasing to 2% and 9% respectively in 2002.[790]

At this writing (December 2003), the operators' market for mobile telephony has matured. Some 90% of the Swedish population had a subscription (including prepaid). Growth in number of subscriptions had slowed down to 11% in 2002, and revenue growth to 6%. In an international comparison this meant that other countries, in particular European, were catching up (Figure 7-12). Telia/TeliaSonera still leads the market both in terms of subscribers and revenues, with Tele2 as number up. Tele 2's share of the consumer market and pre-paid cards is much higher, while Vodafone's customers spend more on an average.

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786 PTS (2001a:36-37: 2003a:63-67)

787 Öhrlings PWC (1999: 48-49)

788 Stelacon (1999:37)

789 Stelacon (2000:45-46)

790 PTS (2002a:23-25; 2003a:24)

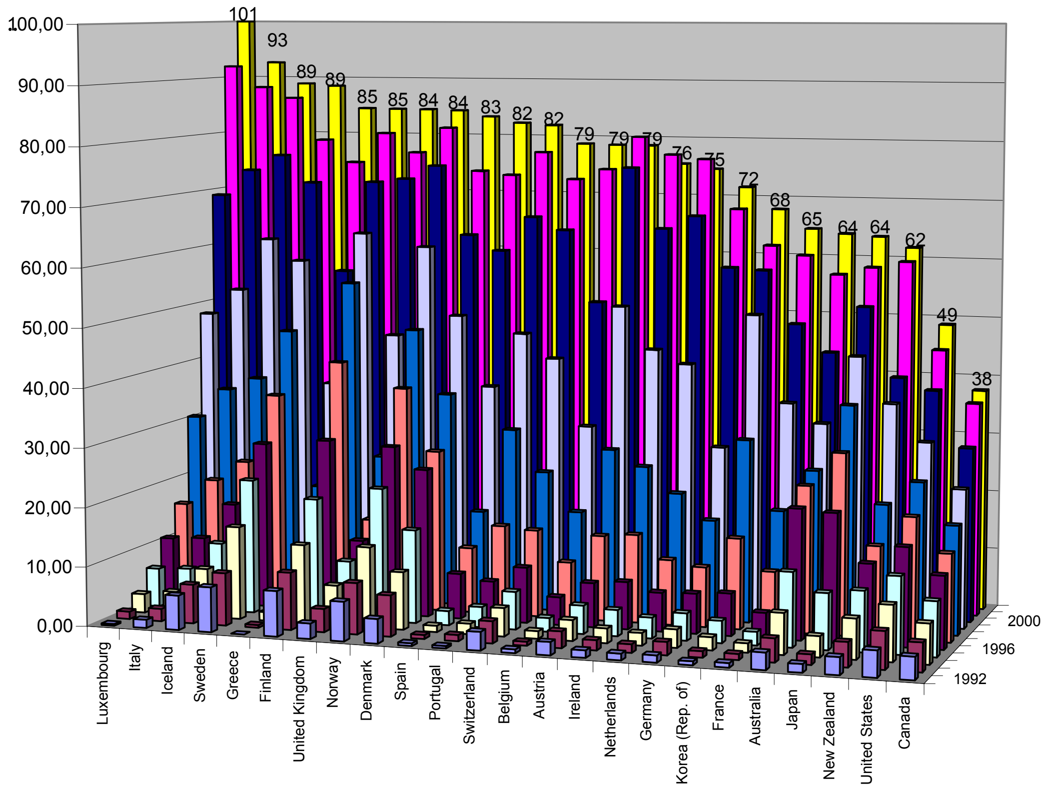

Figure 7-12: Cellular penetration (%) in the OECD countries in the analog era (1992-02)

Source: ITU telecommunications data base

7.2.4.3 Suppliers

By the late 1990s mobile telephony had developed into a major industry in Sweden. It is difficult to delimit the mobile telephone sector from official statistics. According to investigations made by Ny Teknik (1998/21, 2000/8), in 1998 there were more than 100 firms in Sweden employing more than 35,000, with total revenue of more than SEK 100 billion (excluding retailers, all sub-suppliers and wholesalers). The number of employees had increased to 45,000 by late 1999. These firms are listed in Appendix A. It should be emphasized that the companies listed have not been investigated in detail in this project. Therefore it may contain errors of different sorts. Nevertheless, one could observe that although the Swedish mobile sector is heavily dependent on Ericsson, a large number of other firms exist, several of them acting as sub-suppliers to Ericsson. Approaching the turn of the millennium a number of foreign firms established development centers, primarily in Kista. Complementary to a general expansion of the Swedish VC industry, specialized venture capital firms also emerged. Further, a number of mobile Internet-related start-ups were founded during this time period (see Chapter **Error! Reference source not found.**). A few of the newly started forms will be highlighted in the following.

One apparently particularly strong cluster emerged around antenna-related technologies. Torbjörn Johnsson, who had founded Radiosystem, left Ericsson in 1995 to found *Radio Design*. Radio design developed a new antenna technique for the NMT 450 system. It incorporated Antech, formerly Antel, focusing on antennas and antenna-based products.[791] Radio Design's business idea was not viable, however. It changed focus on several occasions,

[791] Mölleryd (1999: 149-150)

under different owners and management, and finally closed down. Other firms in this cluster include Allgon, LG and Carant. Later LG and Allgon merged and were finally acquired by foreign interests in 2003.

7.2.4.4 Distribution

The emergence of a mass market for mobile telephony was facilitated by the fact that the operators started to subsidize the GSM phones, by paying retailers when they signed up new subscribers. Mobile telephones started to become an interesting market for Radio and TV retailers, such as OnOff, Ljud & Bild, SIBA and City Stormarknad. This further stimulated the market since these retailers were accustomed to large volumes and low margins. Alternative distribution channels were specialist retail chains (such as GEAB, STC) networks operators shops (e.g. Telia and Europolitan Stores). Computer vendors and office equipment suppliers also started to offer mobile phones. Specialist mobile telephone suppliers lost market shares as a consequence. They experienced a first serious shake-out in 1991. The mobile phone suppliers responded by cutting down the number of contacts while at the same time intensifying the remaining contacts. In addition, a number of wholesalers were active in Sweden in the late 1990s, including APE Telecom, Brightpoint, Scribona and GEAB.[792] Through its international branch, Unisource Mobile, Telia acquired the major retailer and wholesaler GEAB in 1994, but divested it again in 1998. Some foreign investments were made in the retail business, for instance Talkline, British retailer and service provider, which established itself in Sweden in 1990.[793]

7.2.4.5 End-users

The mobile telephone started to become a consumer product in the mid-1990s, as GSM tookoff. Declining manufacturing costs, combined with the subsidies, enabled this development. These price decreases are illustrated in Figure 7-13. Prices for service have also decreased, but not as fast as for terminals, and not in recent years.

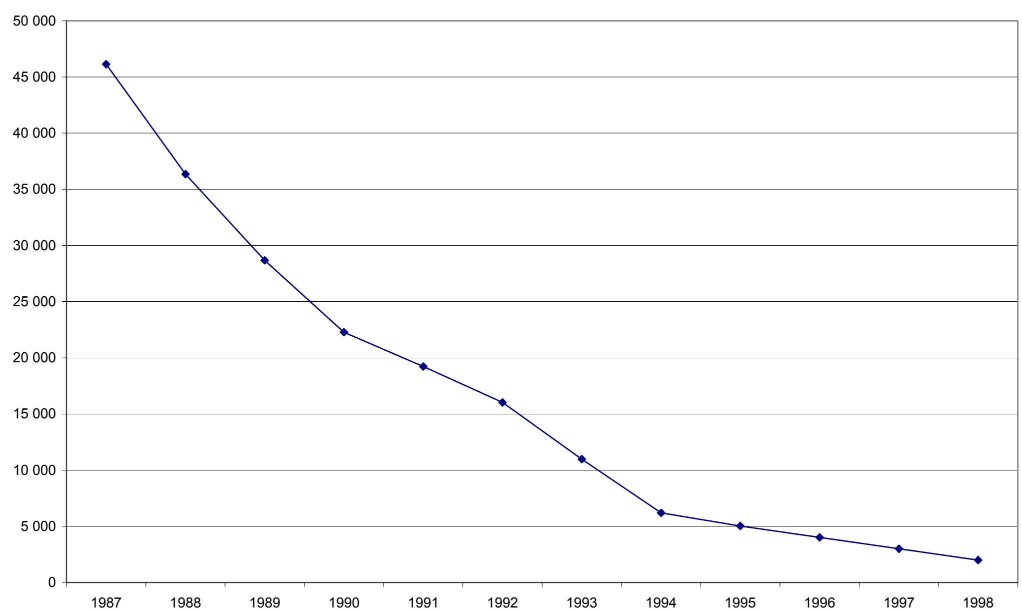

Figure 7-13: Price reduction of hand-portable mobile phones in Sweden (SEK) 1987-1998

Note: 1998 year's prices

[792] Mölleryd (1999:155-156)

[793] See e.g. Mölleryd (1999:156-157)

Source: Adapted from Mölleryd (1999: 159)

Meanwhile, mobile telephony continued to further penetrate the business and public organizations market. However, as late as in the late 1990s, strategies for mobile telecommunications were not well thought out among the business users, with only a minor part of the opportunities being utilized.[794] This was (and still is) a weakness and opportunity for the Swedish sector.

7.2.4.6 Cordless and satellite

The Swedish innovation systems around cordless and satellite have not been investigated in this project. A few observations are worth pointing out anyway. Telia in Sweden undertook an extended series of DECT/GSM interworking trials with Ericsson, using separate handsets as well as the first dual-mode prototypes (at the time sticking standard GSM and DECT designs together in a single case, with little optimization of the reuse of the design). However, faced with changes in the commercial telecom environment in the country, the dual-mode service was not prioritized.[795]

7.3 Summary and Conclusions

This section summarizes and analyses the evolution of mobile telephony, first internationally and then for the Swedish development. It is not explicitly structured according to the framework. Instead, observations relating to the innovation systems functions are made when appropriate.

7.3.1 International developments

The origins of land mobile telephony date further back in history than the main time period under investigation in the report. Induced by WW II and its ending, land mobile telephone systems emerged in the late 1940s, first in the US and a few years later in Europe. National monopoly operators (e.g. AT&T and Televerket) normally provided the service and developed the systems, often in collaboration with the radio industry. In some countries there were private operators as well.

These early systems suffered from many limitations, the most serious ones being low capacity (due to lack of frequencies and poor spectral efficiency), poor service quality and bulky terminal equipment. Those bottlenecks, reverse salients or focusing devices, to use the terminology of Hughes (1987) and Rosenberg (1976), have been attacked and improved by engineers ever since, at least until the late 1990s. For instance, the capacity of systems has multiplied greatly since then, roughly by one order of magnitude every decade. Performance and cost parameters in one complementary technical system – the terminal – progressed perhaps even more rapidly, enabling mobile telephony to be released from the vehicle. This progress was partly due to pervasive technological change in key technologies (microprocessors etc.), but also as a result of learning in the industry. Availability of frequency spectrum has been, and still is, another bottleneck, which needs to be addressed by the regulators.

The cellular concept arose (in the late 1940s) as a response to the problem of low capacity, the solution being to reuse frequencies at a certain geographical distance. However, putting the cellular idea into practice required advances in a number of other enabling technologies, such as microprocessing and switching. It had to wait until around 1980 before implementation, quite independently, in the US, Japan, Germany and the Nordic countries (such long gestation

[794] Mölleryd (1999: 158-159)

[795] DECTweb (2001a).

times are not uncommon in the history of technology). It should be pointed out that the cellular principle did not solve the problem free of charge, but at the cost of a dramatic increase in the number of radio base stations and the complexity of switching equipment.

Clearly, regulation played a key role in the history of mobile telephony. For instance, the United States had developed a technological and commercial lead in radio communications, especially after WW II. Still, regulatory obstacles (in the US) made it possible for NTT of Japan to pioneer the introduction of cellular systems in 1979, although with moderate commercial success. Although the Japanese succeeded in catching up technology-wise, they failed to leverage this to a strong position in 1G and 2G cellular systems. The UK, with a policy of introducing market competition, fared much better – while seemingly misdirected French industrial policy aimed at strengthening the French position in mobile failed to do so, on the user side as well as supplier side.

Another institutional factor that played a major role was standards. Before the introduction of cellular, mobile telephone standards had been more or less national in scope. As the mobile telephone industry internationalized, competition between different standards emerged as an important phenomenon in the early 1980s. When finally commercialized in 1983, US AMPS also turned out to be an immediate success, domestically as well as internationally. AMPS dominated the world market in terms of number of subscribers. Competition between standards is clearly a key feature in the evolution of mobile telephony. This issue has been underemphasized in innovation systems literature and policy research. This international diffusion has been influenced by a large set of political, technical and economic factors, working in favor of three standards, NMT, AMPS and TACS. Suppliers sponsoring these standards, e.g. Ericsson, clearly benefited from their success.

Another salient feature in the evolution of mobile telephony (as for telecommunications in general) was the introduction of competition. In the pre-cellular era, national monopolies operated mobile telephony as a rule, although in some countries there were smaller, often local, private operators. With the advent of cellular in most countries (apart from the US) national licenses were awarded, most often to the PTT. This made it difficult for the other actors to enter and stay in the market. One early exception to this rule is the United Kingdom, where cellular service was provided by a duopoly and supported by an adaptation of the American AMPS standard – TACS – which became a success on its home market as well as internationally. Although Britain failed to produce any significant supplier, the leading international operator (Vodafone) emerged from this pioneering market liberalization.

Of particular importance to the European mobile communications sector was GSM. The system was developed in response to the fragmentation in the European mobile communications market, and the opportunity arising from the reservation of frequencies in the 900 MHz frequency band, a special working group (Groupe Special Mobile) was created within the setting of CEPT, the cooperative body of telecom and postal administrations in Europe with the purpose to obtain economies of scale, and to provide a better service for the users.

Although there were European integrative R&D efforts before 1987 (e.g. COST, Eureka) these were not significant for the development of GSM. Instead, national efforts were more important for developing the competence in relevant technologies. Research and development in digital cellular took place along different technological trajectories, mainly in two camps, the Franco-German and the Nordic. These interests clashed in late 1986 at the Paris Trials, where different proposals were evaluated and compared. Eventually, a settlement was reached and GSM standardization could progress along "the broad avenue", seemingly a compromise, but clearly favoring manufacturers such as Ericsson and Nokia. This GSM example yields a number of implications – for instance, the importance of being able to influence standardization processes, in order to align them with a firm's and national technological bases and strategies. In order to be able to influence the standardization process, firms need to bring into the standardization process some development, requiring technological capabilities.

The importance of credibility of technological choice and standards is another key lesson from GSM. Early on, market demand for analog standards provided this credibility, facilitating for the GSM group to move forward. The commitment shown by operators through the MoU, and the endorsement by the European Commission, were crucial in the product development stage.

However, the increasing importance of standards put the regime increasingly under strain. The standardization processes are becoming increasingly complex and time-consuming, while at the same time demands on short time to market are in conflict with this trend. Also, as the industry changed, manufacturers internationalizing – and operators losing their monopoly status – changed the incentives to engage in standardization activities. In the GSM context, the conflicting objectives of standardization and patenting emerged as a serious problem. This conflict is not yet resolved.

The transition from analog to digital cellular was rapid, in spite of being perceived as slow for some of the key actors. One reason for the initial delays was lack of terminals, in turn due to difficulties in developing terminals and having them tested and type-approved. This was not the first time the availability of terminals became a problem for network operators and diffusion of a new service – and certainly not the last time, as will be shown in the next chapter. Such delays are the result of more general problems of coordination in the emergence of complex technical systems.

More generally, the following factors worked for and against the transition. New entrants stimulated the transition to GSM. Factors working against diffusion include: (1) difficulties in developing terminals and having them tested and "type-approved", (2) lack of commercial incentives for incumbent analog operators, (3) the time and efforts involved to build out sufficient geographical coverage, (4) and large and expensive terminals. On the other hand, the introduction of GSM was often coupled with the introduction of market competition on the operator side, a fact that speeded up implementation of GSM.

During the 1980s and early 1990s digital cellular systems developed also in the United States and Japan, the driving forces being quite different there. Since GSM could reach the market before the other standards, it was able to exploit early mover advantages in the international market, which is one explanation for the rapid international diffusion of GSM and its dominance on the world market. As a result, the European manufacturing industry (especially Nokia and Ericsson) has come out much stronger than the US and especially the Japanese, and has a lead in the systems as well as terminal markets. However, the battle between the GSM and CDMA camps continued into the 3G, as will be investigated in the next chapter.

Competition not only between standards, but between different technological solutions, has been an important feature in the evolution of mobile communication. As late as the early 1990s, much attention was drawn to cordless and satellite systems, which were expected to compete and merge with cellular for providing personal communications services. Cellular technology won this bottle for technological dominance. Early successes generated positive feedback loops through increased R&D spending, economies of scale etc. To some degree, this has happened for cordless, which has converged with cellular in terms of functionality, applications and markets. Essentially the technique has established itself in applications other than public mobile telephony (mainly office and residential applications). Mobile satellite communications have remained a niche market, where multi-billion dollar investments of LEO and MEO systems have flopped so far.

7.3.2 The Swedish innovation system for mobile telephony

The development of the Swedish mobile telephony innovation system cannot be fully understood without taking some development before 1970 into consideration. During the postwar period Televerket established itself as a leading innovator, contributing to knowledge creation and formation of markets. In the process, other important functions in the innovation systems were also developed. Assuming that such functional development takes time, this is an important observation in itself.

The pioneering development of MTA and MTB developed the competences inside Televerket. The experiences gained by commercializing the system also guided future search. Without this knowledge it would have been difficult to publish the influential Åsdal investigation in 1967. Some knowledge may have been developed in the domestic supplier industry as well. The role of government and universities seem to have been negligible at this time.

The year 1970 is a hallmark, for two reasons: (1) the start of the NMT development and (2) the decision to implement MTD. Established network relations with the Nordic telecom administrations facilitated the rapid start of standardizing NMT and launching MTD in three of the countries. The connections with the radio industry seem to have been rather weak by then, however. One could also speculate that without the prior build-up of knowledge from previous, Televerket just might have chosen a different route.

The launch of MTD was technologically a step backwards, but for achieving dynamic systemic effects it was crucial. MTD nurtured and cultivated the innovation system by increasing, not least, its capacity to deliver and absorb the expansion to come. All functions in the innovation were improved during the 1970s, in particular those that aided the formation of markets. When NMT was introduced, there were more than 20,000 subscribers using mobile telephony, and many more aware of the service. Compared to other countries, the Swedish mobile penetration was very high at this time. The concurrent liberalization of the terminal market (whatever the reasons) further stimulated demand (and supply) in the form of independent distributors and terminal manufacturers. In addition, although unprofitable in the short-term perspective, it prepared Televerket market-wise for the launch of NMT. These developments could be contrasted with Japan, which introduced a cellular system in 1979, earlier than Sweden, but with no previous systems and limited success, presumably since the innovation system was less developed than the one in Sweden.

The competence that had been developed at Televerket's radio labs enabled it to take a leading role in the development of NMT (although its Nordic counterparts also contributed to some extent). From the point of view of the supplier industry, Televerket and the NMT group assumed the dual role of being a lead innovator and user. It is fairly safe to assume that the firms in the radio industry would never have developed a similar system by themselves. Not only did they lack the necessary competence; their expectations of the future market were pessimistic. Furthermore, open systems like NMT would not be compatible with existing business models, i.e. to deliver proprietary systems to which they could lock in their customers. The choice of Ericsson as switch supplier (and Magnetic for base stations), and persuading it to deliver AXE instead of AKE, were also crucial. In the terminology of Bergek (2002), Televerket counteracted the resistance to change at a time when change was necessary.

It should be emphasized, however, that Televerket's expectations of the mobile telephone market were not correct either; instead they grossly underestimated demand. In addition, not all parts of Ericsson were reluctant to NMT. Åke Lundqvist, the manager of SRA, early on had the vision of mobile telephony as a potential growth market.

Competition from Comvik made Televerket more market-oriented, while at the same time exerting its regulatory power to keep safe from serious competition. Thus the regulatory framework stifled competition. The effects of this on the Swedish innovation system are difficult to speculate on counterfactually, however.

Why then did Sweden (and Finland), but not Norway and Denmark, develop a strong cellular infrastructure supply industry? The answer probably lies in the supply side of the innovation system. While all four countries appear to have had fairly developed land mobile radio industries, only Sweden and to some extent Finland had a strong switch supplier. In the long run, both these legs were needed (and in addition the systems competence). By 1982-83, Ericsson had acquired all these three competences. A few years later Nokia managed to do the same. In addition, Ericsson managed to internalize the Swedish innovation system through acquisitions.

To sum up the analog era, the prime mover was Televerket. Its development of mobile telephony, and key decisions taken, shaped the innovation system with respect to several of the functions of the innovation system. It built up the competence base, and guided the direction of search through technological choices, and through its activities in standardization and in procurement. It was instrumental in forming and stimulating the market, and to some degree through investing in innovation. Ericsson increasingly became a key player, while the role of other actors was marginal. Universities and institutes did not contribute substantially to the development of technology. Few firms were started in the early phases. Some foreign influences were affecting the development, which was dependent on a number of enabling technologies, in particular semiconductor technology supplied from abroad. No government-sponsored research (apart from Televerket's research) has been identified as having been important. The role of military R&D was limited to being important for the development of the radio supplier industry. All this came to change for the next generation.

The transition from analog to digital telephony was, in the terminology of Henderson and Clark (1990), a modular innovation. The general architecture as well as customers were essentially kept, although expanded. Some technological fields had to be built up in the innovation system, an innovation system that became increasingly dominated by Ericsson. The key to Ericsson's success was a combination of building on the existing analog success, being able to develop the necessary digital technologies, and influencing the choices made in standardization. Public procurement from the military lead-user was important for developing digital technologies. The close ties with Televerket influenced the guidance of search in the proper direction, i.e. towards narrowband TDMA, which was the best choice in techno-economic terms. This relationship and the alliance created with other Nordic actors helped to influence the choice in the standardization process. After that, the technological choice in GSM legitimized Ericsson's pushing for similar solutions in the US and Japan.

While these successes in the formation of the market benefited Ericsson, they seriously challenged the companies' abilities to develop products, due to lack of resources. When the important choices were made, the Swedish innovation system's (read Ericsson's) competence needed strengthening. Government funding through STU's framework program and the IT4 program was crucial for product development, not least for the inflow of competent personnel. Eventually, Sweden could not supply the rapidly growing company with the necessary resources, and Ericsson was forced (also for other reasons) to internationalize its R&D activities. Thus the corporate innovation system (see Granstrand 2002) became internationalized.

The extremely rapid growth of mobile telephony provided opportunities for other actors to establish themselves, sub-suppliers (parts of base stations, and mobile telephones), distributors, competing operators etc. Still, this build-out could possibly have been even greater, had the supply of capital and personnel been higher. It was not until the late 1990s that start-up activity really gained pace (see the next chapter).

The Swedish case also points at the importance of designing institutions (regulations) while bearing the proper goals and economic incentives in mind. For instance, introduction of competition, i.e. allowing for two full-fledged operators to enter the GSM, speeded up the transition, thus maintaining the Swedish leading position in terms of usage of the new technology.

8 EVOLUTION OF MOBILE DATA

The purpose of this chapter is to investigate the evolution of mobile data communications.[796] The first three sections investigate the international development along three identified development tracks, all emerging in the 1980s. These are:

1.) The radio track: Private mobile radio (PMR) systems including data communications (e.g. ARDIS, MPT 1237, TETRA).
2.) The telecom track : Cellular systems becoming more data-capable (1G, 2G, 3G)
3.) The Internet track: Wireless LANs and their development.

Mobile data communications are not possible without improved terminal features. Such recent terminal developments are given particular attention in Section 8.4 [797] The emergence of mobile data communications has also led to a break-up of traditional actor systems, which is investigated in Section 8.5. Sections 8.7-8.11 investigate the Swedish sector along similar tracks. A summarizing discussion concludes the chapter.

8.1 The radio trajectory

8.1.1 The emergence and evolution of mobile radio communications

It was the radio industry that first started to experiment with mobile data in the late 1970s.[798] Data could therefore be regarded as one the more recent emerging communications applications of radio technology. For an overview of radio communications applications, see Figure 8-1.

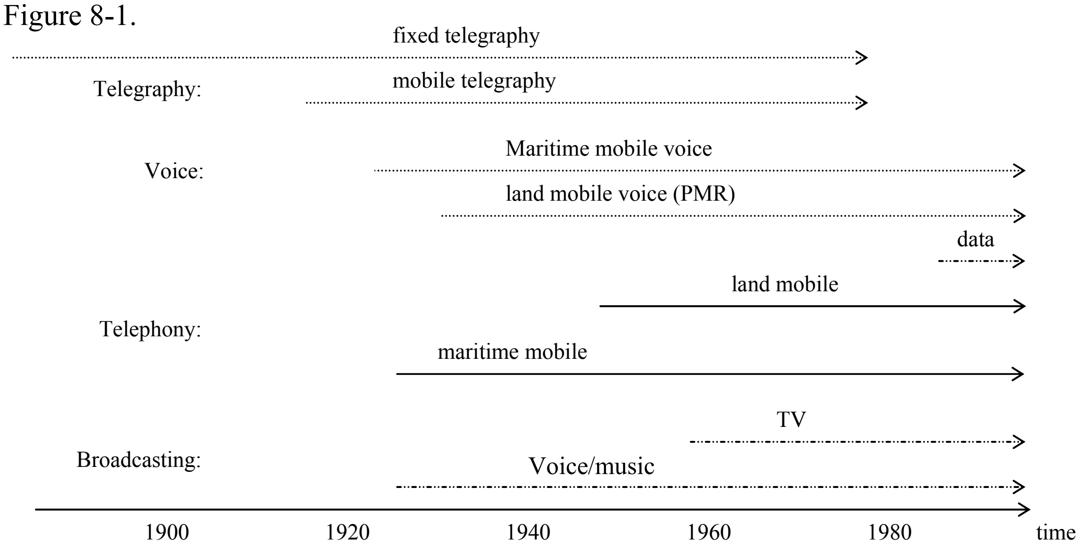

Figure 8-1: Overview of radio communication applications

Source: Lindmark (2002: 398)

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796 This chapter has been written by Sven Lindmark and Erik Andersson. Part of the chapter draws heavily on, and summarizes, Lindmark (2002), with original references kept as far as possible. It should be emphasized, though, that much research has been conducted specifically for the purposes of the present study.

797 These are not the only development tracks. In addition, satellite systems (such as Iridium) and cordless systems (such as DECT and PHS) are data-capable. However, their impact has been marginal. Moreover, they are treated in Chapter 7 and will not be further investigated here.

798 This section and the next one draw on Lindmark (2002: 135-140), based on synthesis of secondary sources, in particular the historical overviews given in: Noble (1962), Freeman (1974), Kargman (1978), Tucker (1978), Jagoda and de Villepin (1993), Calhoun (1988), Garrard (1998) and Levintahl (1998).

Radio communications emerged in the late 19th century, commercialized on a larger scale by Marconi, and used mainly for communications with remote locations, such as transatlantic communications. US, UK and German firms came to dominate the radio industry for a number of years. The major manufacturers were Marconi, Telefunken (a merger between the radio interests of Siemens and AEG), General Electric and RCA. Out of their R&D labs came a number of radio-related inventions. Such inventions, in combination with the rapid improvement induced by World War I (where radio communications were used mainly by sea and air forces), made radio voice communications ready for commercialization in the 1920s. Yet the real take-off did not happen in two-way communications, but in the field of broadcasting – higher than 50% household penetration was achieved in less than 10 years.

The increased use of private, public and military radio, broadcasting, fixed transmission and mobile applications called for regulation (see Chapter 3), since suitable frequencies were a scarce resource that had to be managed. The radio industry established an international regulatory body, CCIR (similar to the ITU, which had been established in 1865) as well as national bodies such as the US FRC (Federal Radio Commission, later inaugurated as FCC which had been established somewhat earlier to coordinate frequency allocation).

The first mobile applications (communications where at least one unit is mobile) were in the maritime market: ships that could carry the bulky equipment and high costs. The sinking of the Titanic in 1912 increased public awareness of the utility, and accordingly catalyzed the diffusion of radio communications. Mobile radio *voice* communications started out in the 1920s. Fishing fleets were the first to adopt, since they could not afford skilled telegraphy operators. Later, other maritime segments (e.g. ocean liners) and aviation and train applications proliferated. These early services used expensive, large and power-consuming equipment. Cost reduction, and reduction of size and power consumption, have been of utmost importance for mobile radio applications ever since, as mobile radio terminals moved from maritime to vehicular, portable to handheld, and possibly wearable applications.

Innovative users, such as the military and police forces, fire departments and power companies, made pioneering developments in land mobile radio in the 1920s. A number of technical problems remained to be solved before commercially viable public services and products could be introduced. Despite the above problems, the mobile radio industry expanded. New user groups, such as water, gas and electricity utilities, railroads, buses and taxis, adopted mobile radio during the following years. Among the first suppliers of receivers was Bosch (1931). RCA, General Electric and Motorola entered the mobile radio industry in 1936 and 1937.

World War II had an enormous impact on the development of radio technology and the radio innovation system. Hundreds of thousands of mobile radios were manufactured, resulting in considerable learning effects both on the supplier and on the user sides. Frequency Modulation (FM), invented in the 1930s, also developed further. After the war, technology had improved enough to offer new and improved services to the public. So had production capabilities and user awareness and competence in handling radio equipment. Manufacturers adapted military technology to civilian use and soon companies such as General Electric, RCA, Motorola and AT&T were on the US market with various mobile radio communications products, for instance the walkie-talkie. Spurred by improved products and a liberal regulatory regime, the number of US mobile radio users increased from 1,000 in 1940 to 86,000 by 1948, to 695,000 in 1958 and 1,395,000 in 1963.[799]

[799] In 1945, FCC recommended spectrum allocation for a wide range of mobile radio services: police, fire departments, forestry services, electric, gas and water utilities, transportation services, railroads, buses, cars, trucks and taxis. In 1949

Private mobile radio (PMR, i.e. closed communications networks where a group of users stay in contact with a central controller/dispatcher) emerged in the 1930s to become an important application of radio. Conventional PMR was usually operated on a local or regional basis. Taxis were the first commercial users. Many user segments, such as the transportation industry, were slow to adopt, partly because of opposition from the chauffeurs and labor unions. The advances in semiconductor technologies reduced the size and increased reliability, which enabled further diffusion of PMR, although at greatly varying rates in different countries. PMR became most widely adopted in the US, and in the Nordic countries.

Increased popularity and limited frequency availability and capacity led to congestion problems in PMR networks. Trunking was gradually implemented in PMR networks since the late 1960s to alleviate these problems. By the early 1980s PMR had matured; most sales were replacement sales. Distribution was handled either directly by manufacturers or via distributors that installed, engineered, planned and maintained such systems. Suppliers active in Europe included (in 1990) AEG, Alcatel, Autophon, Bosch, Philips, Ericsson, Nokia, Motorola and some Japanese manufacturers.

8.1.2 Data over PMR

In the late 1970s and early 1980s a number of PMR vendors began developing mobile data solutions. In the late 1980s Motorola assumed the role of the leading vendor of data over PMR, followed by, among others, Ericsson/SRA and Philips. Major customer segments included field service organizations, couriers, taxi operations and public safety. In 1990 the world base in service was estimated to be 200,000 units, half of which were in the US.[800]

Some of these systems were made public, the most prominent being ARDIS[801] (Advanced Radio Data Information Service developed by Motorola/IBM) and Mobitex (developed by Televerket/Ericsson; see further below). In 1983, Motorola developed ARDIS as a private mobile digital data network for IBM's national service division. This system had the purpose of facilitating computer-aided dispatching, parts ordering and tracking, as well as service contract entitlement checking for IBM field service engineers. In 1986, some 12,000 IBM engineers used it,[802] a figure that rose to 25,000 in 1990, when it was expanded to cover about 400 cities. ARDIS became an effective tool for improving IBM's service, in spite of limitations in the functionality of terminals and in roaming.

Like all private data communications systems, ARDIS was heavily underutilized. In response to this underutilization and to the Mobitex introduction in the US, IBM and Motorola launched ARDIS as a public network in May 1990.[803] The take-up of the ARDIS service suffered from barriers similar to those observed in the Mobitex case, i.e. lack of applications, terminals etc. By the end of 1998 there were only 65,000 subscribers.[804] These were mainly in the segments of field service, transportation and telemetry. Internationally ARDIS has been implemented in around ten countries under the brand name of DataTAC, In 1998, American Mobile Satellite Corporation, a company involved in satellite communications, acquired ARDIS. The company was renamed Motient in 2000. Motient's subscriber base grew from

mobile radio was officially recognized as a new type of service. The same year, FCC created the Citizen Band service (a broadcast party-line), which exploded in popularity during the 1970s.

800 CIT Research (1993).

801 ARDIS refers to US service. Internationally the system was branded DataTac.

802 Dhawan (1997).

803 See e.g. Garrard (1998:430).

804 Garrard (1998:430) and Pineda (1998).

140,000 subscribers in 1999, to 206,000 by year-end 2000. The main growth areas were in transportation and a wireless e-mail service.[805]

As will be elaborated below, Swedish Televerket and Ericsson developed a system similar to ARDIS/DataTAC, namely Mobitex. Mobitex and DataTAC addressed roughly the same applications and market segments. Together these two systems dominated the world market for public packet mobile data. A few other systems emerged, such as the CDI system in the US, and hybrid systems such as MPT 1237 in the UK (see below) and RC-2000 in France (see Chapter 7). These systems allow public access data communications, yet were not specially designed for this purpose, but for PMR.

As mentioned above, already in the 1970s the market for PMR was maturing due to a saturation of demand. In addition, frequency spectrum was congested in the United States as well as in many countries in Europe. In order to reduce and circumvent inefficient use of frequencies, and to avoid large initial investments for customers, authorities began to introduce public access mobile radio where users could share the infrastructure. The systems were run by an operator. In the US, these services were labeled SMR/ESMR – in Europe, PAMR. SMR (Special Mobile radio) launched in the 1970s had about two million users by 1995. Enhanced SMR (ESMR) had digital services first launched by the operator Fleetcall (a major SMR operator with 150,000 subscribers)[806] based on Motorola's iDEN technology, enhancing the capacity several times. Under the name of Nextel, the company acquired other SMR operators and managed to cover most of the US population. By the end of 1996, Nextel had 900,000 subscribers, being the largest ESMR operator.[807]

In Europe, similar services evolved in the 1980s, with (as for so many other mobile communications services) Britain providing the impetus with the reallocation of frequencies to PAMR (Public Access Mobile Radio) with the standard MPT 1327 (which allows data communications) specifically developed by DTI for this purpose. MPT 1237 became a *de facto* European standard for PAMR (and PMR since the standard was also used for closed systems).[808] By the early 1990s, these systems were almost exclusively used for voice, however.[809] Major manufacturers included Motorola, AEG, Rohde & Schwartz, Ericsson, Ascom, Nokia and Bosch.[810]

Meanwhile, the leading PMR manufacturers developed new generations of digital PMR systems, the main advantages being increased capacity and security. These systems more readily allowed data communications. For example, Ericsson's EDACS system was a digital PMR system supporting analog voice and 9.6-kbps data communication.[811] Motorola, Matra and Rohde & Schwartz offered a range of analog and digital PMR systems, including TETRA and US APCO (the Association of Public Safety Communications Officials) Project 25 compliant solutions.[812]

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805 American Mobile (1998) and Motient (1998, 2000, 2001).

806 A transition to digital would enhance capacity to 5 million in Fleetcall's licensed areas.

807 Garrard (1998:418-419).

808 Additional data services were developed by a group of equipment suppliers under the name MAP-27 (Bekkers 2001:397).

809 Bekkers and Smits (1998:216-222) and Garrard (1998:420-424).

810 Bekkers (2001:397). Although they were designed as an open standard, manufacturers built in proprietary features.

811 Ericsson recently spun off its PMR activities to Com-Net, which is now marketing EDACS and other PMR products under the name Com-Net Ericsson.

812 Armstrong (1995); Bekkers and Smits (1998:215 –237) and Bekkers (2001:397-398).

In the late 1980s, the PMR in Europe was still underdeveloped in numerous respects such as spectral efficiency, diffusion and industrial competitiveness, especially compared to the US. In response to these deficiencies, and following the successful standardization of GSM the idea of TETRA[813] emerged, starting in ETSI in the late 1980s.[814] The development of TETRA became a slow and winding process, however, due to divergent and changing demands on e.g. coverage and features, interests and difficulties of harmonizing frequency bands.[815] Conflicts and technological choices drove several suppliers led by Matra (soon followed by Siemens) to launch an alternative system based on Matracom-9600 (later re-branded Tetrapol).

TETRA became a fully digital standard specified in two variants – one for voice and data, and one for data only. It supports private as well as public mobile radio services, voice and circuit-switched and data up to 28.8 kbps, in two frequency bands (400 MHz and 800/900 MHz bands). The main target groups of TETRA are traditional professional PMR users.[816] For many years, the future of TETRA appeared uncertain. The system turned out to be complex and quite expensive. Customers and manufacturers were reluctant to dedicate themselves to the standard. Few actors were therefore willing to take the risk of investing in a national system.[817] As of 2001, a number of TETRA networks had been launched in Europe and the standard seems to be gaining acceptance in other continents as well. The dominant suppliers have been Motorola, Nokia, and Simoco[818]. Nationwide public safety networks and public service networks were deployed in e.g. Finland, the UK, Belgium and the Netherlands.[819] Dolphin, a subsidiary of Canadian Telesystem International Wireless, which had established itself by acquisitions as a leading European analog PAMR operator, became the leading operator. Dolphin launched commercial networks in the UK and France, and deployed networks in Germany and Belgium, having interests also in Spain and Portugal.[820]

Throughout the spectacular growth period of cellular mobile telephony, there have been niches left for a modestly growing PMR market. Due to cost functionality advantages (mainly group calling), PMR has been fairly well protected from the cellular threat. This situation may be changing, as cellular terminals have become less expensive (in spite of being more complex) due to economies of scale. In addition, cellular systems are beginning to offer quasi-PMR services such as those developed under the GSM 2+ programme. These services include group calls, reduced set-up times and PMR-like terminals. Ericsson is driving this development, introducing a product offering labeled GSM Pro in 1999.[821] In some applications such as public safety, TETRA customers seem fairly dedicated to implementing TETRA and other PMR systems, due to e.g. safety and security considerations.

Today, functionalities of PMR networks are being included in mobile telephony networks, so-called push-to-talk functions. These enable mobile phones to be used as a communication radio, allowing users to perform e.g. group calls. Manufacturers such as Ericsson and Nokia are driving these developments, and operators have shown great interest.

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813 "TErrestrial Trunked RAdio system".

814 Jagoda and de Villepin (1993).

815 See Bekkers and Smits (1998:223) and Bekkers (2001:390-391, 399-404, 416-418).

816 Mackie (1996).

817 E.g. SOU (1998), TETRA News (4/2001:7), Clemens (1998). If TETRA were built up with national coverage, it would cost roughly SEK 3 billion in a medium-sized European country.

818 Motorola and Nokia dominate the infrastructure market. These two, together with Simoco and Marconi, supply terminals.

819 In early 1998, the Helsinki City Energy Company launched the first TETRA network. In the UK, DTI issued TETRA licenses early on.

820 E.g. SOU (1998), TETRA News (4/2001:7) and Clemens (1998).

821 See e.g. Bekkers (2001:414), Gratorp et al. (1999) and Chapter 8.

8.1.3 Paging

Paging was, in fact until the mid-1990s, the most widely diffused mobile communications service. Compared to other mobile communications services, it offered benefits in the form of higher capacity, lower costs (in infrastructure and terminals), better in-building penetration, longer battery lifetime and smaller terminal size.[822] The first systems (developed shortly after WWII) were crude (large pagers, non-selective addressing etc.). In the 1960s some of these deficiencies were overcome. Hospitals and manufacturing firms implemented privately owned paging systems at on-site premises. A few wide-area networks were also built up at this time. In the 1960s and 1970s, PTTs started introducing (most often proprietary) national paging services, e.g. the Franco-German "Eurosignal'" system. These systems were all analog.[823]

In the 1970s digital paging systems emerged. In the US, the radio common carriers (RCCs) built local and regional paging networks in every city of importance. Users of these early networks were professionals, and they were particularly important for emergency situations. Later, more types of professionals started using paging, such as service engineers, couriers and truck drivers.[824]

The most important digital paging system was POCSAG (named from the Post Office Coding Standardization Group), developed by Philips in the 1970s on the initiative of the UK Post Office. The standard introduced improved capacity, transmission speed, signaling protocols and battery lifetime, and allowed for full-text messages.[825] POCSAG was installed in most European countries. Large volumes enabled manufacturers to produce cheap and small terminals (below USD 100). A majority of paging manufacturers offered POCSAG infrastructure and/or terminals. These included Motorola, Glenayre (US), Ericsson, Tecnomen (Finland), Philips, Rohde & Schwarz, Multitone (UK) and NEC.[826]

Despite an early start, the European paging market was dwarfed in comparison to the US and Asia-Pacific ones. By the end of 1996, there were 40 million subscribers in the Asia-Pacific region and 25 million in the US,[827] compared to only 4 million in Europe. The US market was highly competitive, with substantially lower prices than in Europe. The tariff structure of cellular (receiving party pays) made the pager a viable substitute (and complement). In Asia, leading countries in terms of market penetration were China, Japan, Taiwan, Hong Kong and Singapore.[828] European penetration and growth rates differed greatly between the national markets.[829] The Benelux countries, Sweden, Norway and Switzerland stood out with higher penetration figures. Many markets had already matured and were even declining at that time, outcompeted by cellular services.[830] PTTs operated these paging networks as a rule. The UK pioneered the introducing competition in service provision, issuing followed by France. When competitive licenses were issued on a broader scale in Europe in the late 1990s, they received lukewarm interest due to the booming cellular market.

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[822] Bekkers (2001:439-440).

[823] Kamman (1975); Garrard (1998:432-433); Bekkers and Smits (1998:311-314); and Bekkers (2001:440).

[824] Kamman (1975); Garrard (1998:432-433); Bekkers and Smits (1998:311-314); Lernevall and Åkesson (1997:549-550) and Bekkers (2001:440, 444-445).

[825] Bekkers (2001:442).

[826] Bekkers (2001:443).

[827] 35 million by year-end 1995, according to Garrard (1998:439).

[828] See e.g. Bekkers and Smits (1998:311-338) and Garrard (1998:432-446).

[829] Garrard (1998, 437-439).

[830] See Garrard (1998:434-439); Lernevall and Åkesson (1997:549-553).

In the 1980s, Europe recognized that it was lagging behind in paging. Also, inspired by GSM CEPT started standardizing a pan-European standard for paging – ERMES, later taken over by ETSI. The standard was finalized in 1994 and the first networks launched the same year. Adoption of ERMES was disappointing due to difficulties in releasing frequencies, and to interference with other radio services. More importantly, however, few actors were interested in the technology. Network infrastructure and terminals were complex and expensive, and benefits compared to POCSAG were not obvious for the end-users, especially not for the growing low-end market. In many countries, POCSAG had overcapacity and was preferred by operators. Absence of commitment among operators and end-user benefits caused manufacturers to hesitate, and many of the dominant paging manufacturers withdrew from producing ERMES equipment. This in turn further undermined the confidence of operators. In this vicious circle, growth of ERMES has been very modest inside and outside Europe.[831]

The ERMES failure was not only due to success of cellular and POCSAG; other competing standards also emerged, mainly Philips's APOC and Motorola's FLEX. Philips developed APOC as an upgrade of POCSAG. Including essentially the same level of technological sophistication, but commercially far more successful, was Motorola's FLEX system, introduced in 1995. Compared to ERMES, it offered many advantages such as backward compatibility with POCSAG, smaller and cheaper terminals, voice messaging and two-way paging functionality. Motorola has made the technology available to a number of suppliers through licensing agreements. Ericsson, for instance, decided to license FLEX in 1996, and Philips, facing limited success with APOC, followed later in the same year.[832] Due to its techno-economically far more sound design, FLEX became the preferred standard of the mid- and late 1990s. By January 1997, there were already 130 networks in use worldwide. It had been chosen as standard in the Americas and Asia, including China. More than 35 million FLEX pagers had been shipped by early 1999. FLEX also made inroads on the European market, and several operators declared their preference to FLEX instead of ERMES.[833]

In the 1990s, the traditional demarcations of paging versus other mobile communication systems became increasingly blurred. Paging is indeed a simple form of messaging, and messaging is one of the major uses of most telecommunications networks. Other systems started providing paging functionality, e.g. cellular systems which provided notification and messaging functionality through the SMS service, booming in the late 1990s and early 2000s (see Section 8.2.3). The size advantage of pagers over cellular phones disappeared with rapidly decreasing terminal sizes. In the late 1990s, two-way paging services were provided over, for instance, the Mobitex network.

Paging systems also became increasingly sophisticated, e.g. by introducing two-way paging functionality, e-mail notification and other new datacom functionalities. Initially, two-way paging allowed users to acknowledge, and to send receipt messages. Later the systems allowed for richer messages to be sent in both directions. However, upward link data rates have to be traded with power of terminals and density of base stations. These trade-offs limit the capabilities of paging systems in terms of data rates from terminals. The infrastructure for such systems is also more expensive to build, compared to one-way systems, and pagers are more expensive with shorter battery lifetime. Still, two-paging systems have been commercialized in the US.[834]

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[831] See Bekkers and Smits (1998:321-328), Garrard (1998:442-445), and especially Bekkers (2001:435-471) for information on ERMES.

[832] Bekkers and Smits (1998:330-334); Garrard (1998:445-446) and Bekkers (2001:453-454).

[833] Bekkers (2001:465-466).

[834] Dhawan (1997), Bekkers (2001:454-455) and interview with G. Rydberg (1997).

8.2 The telecom trajectory 2.5G and 3G

8.2.1 Data over cellular analog ("1.5G")

Similar to how computers were connected to the fixed telephone networks, a notebook or other mobile (or fixed) unit could be equipped with a modem, and sending data over analog cellular systems has been possible since the 1980s. Connection quality was low, however, and data rates slow (typically 9.6 kbps/s were possible to achieve, with effective data rates lower than 5 kbps). Because of these problems of low quality and high costs, which were commensurate with a perceived lack of utility among customers, the use of data communication over analog cellular systems was very limited. CIT Research (1993) estimated that in 1992 roughly 50,000 subscribers (1 percent of all cellular subscribers) in Europe used a data modem.[835] Corresponding figures in the US were 100,000 (1.25% percent).[836] According to the same source, most of this limited demand came from service and transport operations. To exemplify, applications from UK included (1) lighthouse and lightship service, (2) parcel operation, (3) credit card transactions, (4) computer service engineers and (5) construction and building (fax).[837]

A radical step towards better datacom abilities in cellular systems was taken in the US by the large cellular operators and IBM, partly in response to the emergence of packet-switched dedicated data systems (Mobitex and ARDIS), through the development of CDPD (Cellular Digital Packet Data).[838] CDPD was designed as a digital packet overlay network to the AMPS (and later digital AMPS) infrastructure, thus constituting a considerably smaller investment than a new infrastructure. Data was sent over dedicated channels providing raw data rates of 19.2 kbps. In addition, CDPD offered several advantages relative to data over analog cellular: set-up time much shorter, secrecy better and quality of communication higher. This solution made AMPS (D-AMPS) the first cellular system to support both voice and packet data.[839]

The first draft specifications were ready by 1993, and expectations were raised. Perceived applications included (1) credit card authorization, (2) fax and e-mail, (3) messaging and paging, (4) file transfer, (5) alarm, (6) fixed applications and (7) dispatching.[840] CDPD gathered interest from a vast number of participants. In 1997, the CDPD Forum, the cooperative body, included some 100 terminal, equipment and application suppliers, operators, and software developers.[841] Formal standards were specified by the TIA (as IS-732 and its addenda).[842] Large vendors had products ready by late 1996 or early 1997 (e.g. Ericsson which made its CDPD solution ready by January 1997). Commercial services started in 1996, initially targeting vertical segments, awaiting more general packaged CDPD access products such as modems to target the horizontal business market.[843]

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[835] Even this modest estimate can be argued to be exaggerated.

[836] The installed base of data terminals using analog cellular networks is poorly documented.

[837] CIT Research (1993). See also Harris (1993) for similar estimations and a detailed technical description of data communication over analog cellular.

[838] Lindmark (2002: 329).

[839] Ericsson (1997) and Vetterborg (1996).

[840] Hedström and Ryd (1996).

[841] Lindmark (2002).

[842] TIA (98021).

[843] Ericsson (1997) and Washburn (1996).

Like other mobile data services, CDPD did not take off as expected.[844] By year's end 1997 there were only 10,000 subscribers,[845] growing to roughly 20,000 in 1998.[846] Lack of coverage and applications, difficulties in signing up and starting to use the services, poor performance of terminals, and high costs were some explanations given for this slow take-up.[847] AT&T Wireless, which by then was CDPD's most dedicated sponsor, put pressure on manufacturers to launch multi-mode terminals and, in late 1999, it re-launched its struggling CDPD operation, named PocketNet, by offering a quadruple-mode (AMPS/TDMA800/TDMA1900/CDPD) Mitsubishi terminal in close cooperation with mobile portal operator Omnisky.[848] In spite of these measures, the uptake of CDPD was low.

8.2.2 Data over digital cellular (2.5G)

8.2.2.1 GSM evolution

As mentioned in Chapter 7, the GSM standardization process gradually moved towards an evolutionary approach to standardization, i.e. allowing gradual implementation of more advanced technology and successively including more and better data services. An evolutionary approach also allowed GSM to evolve (and in combination with IS-136, to converge) into third-generation (3G) cellular services.[849] The core of the evolutionary concept is that the system must be designed so that new functionalities can be introduced without jeopardizing the functioning of equipment already in use. GSM Phase 1 (frozen in 1990) did not entirely fulfill this goal; instead GSM Phase 2 (frozen in 1995) was fully ready for gradual evolution.[850]

Further enhancements in GSM go under the notation of "GSM Phase 2+", stressing that it is not a new phase, but a continuous program of enhancements to GSM Phase 2. Phase 2+ is organized as a set of independent items, which can be introduced with little influence on the others. This allows for independent introduction of new features adapted to timing of market needs and technological difficulty.[851] Its objective was to allow GSM to adapt to new market requirements and technological opportunities. In 1993 Nokia suggested that GSM, in order to be competitive, should evolve to include many of the items that were intended for UMTS at that time. First opposed, this proposal gained considerable support after a while.[852] In 1996 it was decided that Phase 2+ would be issued in yearly releases, where version 5.x.y corresponds to release 96, release 6.x.y to release 97 etc.[853]

8.2.2.2 Improved datacom in GSM

Making the systems digital had an inherent implication for providing better data communications, since digital systems offer: (1) improved secrecy (better coding), (2) fewer

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844 For instance in 1997, Ericsson estimated that CDPD would have 28 percent of the total wireless data market (Ericsson 1997).

845 Interview with S. Johansson (1997).

846 Pineda (1998).

847 Lindmark (2002) based on Ericsson (1997) and interview with L. Vetterborg (1997). Ericsson joined the forum in 1994 (Ericsson 1997). Subscriber statistics have been notoriously difficult to obtain (probably because they are so low).

848 Parker (2000a).

849 Dupuis (1995).

850 Mouly and Pautet (1995), Garrard (1998:135-136), Dupuis and Bergman (1996) and Dupuis (2001c,d).

851 Mouly and Pautet (1995).

852 SMG 234/93. See Dupuis (2001d:74-75) for an elaboration.

853 Dupuis (2001d) and Redl et al. (1998). This was valid until release 2000, after which releases were renamed again, to Release 4, 5 etc. For an overview of GSM Releases 96-99, see Hillebrand (2001a:82).

errors due to protocols for non-transparent communication, (3) guaranteed data transmission rates for transparent transmission, (4) better handover mechanisms, (5) possibilities to implement more sophisticated services, and (5) since signals are digital, no modem is needed at the terminal end.[854]

Although the GSM group had data communications from the start, in the early years the issue was almost forgotten, partly due to a lack of data communication expertise in the group, partly due to the focus on telephony.[855] The issue reappeared several times, but it was not until 1987 that data services were seriously specified in a new working party (WP 4).[856] From 1989 onward, facsimile service was given much attention: as late as in 1995, WP 4 worked under the assumption that facsimile was the most important non-voice communication application.[857] It was not until GSM Phase 2 was finished in 1995 that fax and other data communications were properly standardized.[858] Still, some operators could launch data services in 1994.

The first generation of data services over GSM suffered from some basic limitations. Maximum data rates were low (9.6 kbps and actual data rates even lower[859]) which meant time for establishing a connection was too long for many applications. These drawbacks led to unacceptably long times for performing even simple tasks. Adding to this, since the services were (and still often are) billed per minute, costs of service became too high. These limitations were anticipated early on and subjected to performance-enhancing standardization. The most important items were "14.4", "High Speed" and GPRS.

There are two possible data rate-enhancing solutions consistent with the existing air interface: (1) to spread the transmission over several time slots and (2) to improve the user data rate of each time slot. The former solution was addressed in a Phase 2+ item called HSCSD (High Speed Circuit Switched Data, or High Speed for short). High Speed uses between two and four of these time slots (typically one for the uplink and two or three for the downlink), thus extending the data rates to 19.2-38.4 kbps (all else being equal).[860] Specifications for High Speed were frozen in 1996 and the first operators launched this feature in their networks in the second half of 1999. As of 2001, the commercial interest in High Speed was quite low. Only a few operators had implemented it in networks, not all vendors were supplying infrastructure, and there was very little interest in supplying terminals.[861] The other data rate enhancement, "14.4", was to increase data rates on one traffic channel (i.e. one time slot).[862]

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[854] Hedström and Ryd (1996).

[855] Hillebrand (2001d:407-408). During these years, ISDN was intensively promoted in the telecommunication industry. Therefore the GSM group actually had to avoid making GSM into a "mobile ISDN", for instance by rejecting the possibility to provide full capacity B- and D-ISDN channels.

[856] Hillebrand (2001d:408-409). The group was chaired by F. Hillebrand, who was one of the few persons with experience in data communications. The group was actually dominated by industry representatives. This reflects the low priority given to data communication among the PTOs.

[857] Holley (2001:418-419) and interview with G. Ericsson & S. Ouvrier (1997). Regarding facsimile there was a debate on whether to prioritize throughput or quality (Holley 2001:418-419). See also Hämäläinen (1994).

[858] Bergmann (2001a). Also facsimile services and the half-rate were moved to Phase 2 as a result of technical difficulties.

[859] Maximum data rates (raw bandwidth) apply to perfect radio conditions, which are rare. A typical data rate is 40-50 percent of the maximum ones.

[860] In principle more time slots can be used, but are difficult to implement in the terminal. In addition, the interface between BSS and MSC is limited to 64 kbps (which equals one ISDN channel). Thus higher data rates would require further changes in the network. Besides, the more time slots are used, the more are required by the digital signal processors.

[861] Channing (2000).

[862] Redl et al. (1998:204). This feature was generally referred to as "14.4" and has been driven by the needs of US operators. These data rates affect all other data services, for instance HSCSD, which can achieve 28.8 (14.4*2) kbps by using two time slots.

The most radical Phase 2+ enhancement in GSM was perhaps *GPRS* (General Packet Radio Service), but finalization has been a slow and reluctant process. Around 1988, IBM and Motorola proposed that GSM should include packet data services, but the idea was rejected then.[863] The needs and ideas for a packet-switched service came up again around 1992, this time from the European Commission (which had a special interest in road transport telematics) and UIC (a railway organization). In addition, the introduction of CDPD in the US put competitive pressure on GSM to introduce packet switching.[864] Notable is that anticipated applications were: (1) road traffic informatics, (2) connection to X.25, and (3) traditional mobile data applications such as field service, fleet management, remote telematics, commodity/supply logistics and EFT-POS,[865] but also the "mobile office".[866] Only later did connection to the Internet become an objective. While network operators believed that there was a need for packet-switched radio, manufacturers, especially those in the business of dedicated packet radio, had (quite understandably given their disappointing experiences) their doubts.[867]

In 1993, SMG started drafting the GPRS specifications. At that time it was suggested that specifications would be completed in 1994[868], so that GPRS could be commercially introduced around 1996/1997. As so often happens in communications standardization, this turned out to be very optimistic since GPRS proved much more complex than was anticipated from the start. In the core network, an overlay network had to be developed. In addition, substantial changes were required in the radio subsystem.[869] The GPRS specifications also had to be split into several phases. GPRS Phase 1 was included in Release 97. This was a mistake, however. Manufacturers who tried to implement GPRS discovered numerous flaws that were fed back in the standardization process in the form of change requests. Phase 2, which had been planned for Release 98, had to be postponed to Release 99, in order to make Phase 1 stable first.[870]

Besides providing better data rates (somewhat depending on which coding schemes are used),[871] GPRS allows significantly lower set-up times than before. However, data rates for GPRS have been much hyped by the industry. Data rates over 171.2 (8*21.4) kbps were promised early on, later dropping to 115 kbps. Since 8-time-slot data is not feasible to implement in the terminal, and since channel-coding schemes require extensive upgrading of the infrastructure, 53.6 kbps (4*13.4 kbps) is the more realistic maximum raw data bit rate (in the downlink), which corresponds to 20-30 kbps in practice.[872] Reports from early implementations stated that actual data rates were around 20 kbps with some delays (more than one second) in delivering data.[873] Still, GPRS is much better suited for short and bursty applications than circuit-switched GSM. More than other existing bearers (apart from 3G),

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863 Dupuis (2001d:77).

864 Dupuis (2001d:77-78).

865 Gilchrist and Günther (1994) and interview with G. Ericsson & S. Ouvrier (1997).

866 Roth and Baumann (2001).

867 See e.g. Roth and Baumann (2001:425).

868 Dupuis (2001d:78). Hillebrand (2001a, p.90) claims that work started in 1994 and the standard was expected to be completed by 1995.

869 Hillebrand (2001a, p.90). Roth and Baumann (2001) elaborate further on the causes of these delays.

870 Hillebrand (2001a, p.90). See also Roth & Baumann (2001) and Färber (2001:325-327) for descriptions of the cumbersome GPRS standardization process and some plausible delay explanations.

871 GPRS defines four coding schemes with different levels of error protection: 9.2, 13.2, 15.6 and 21.2 kbps.

872 Byttner (2000).

873 Mobile Streams (010201a).

GPRS is suited for e-mail, information services, dispatch, remote LAN access, Web browsing, still images, short video clips, chat, audio clips and gaming.[874]

In mid-1999, some 10 operators had placed equipment contracts, going predominantly to their existing suppliers.[875] Some operators offered trial or quasi-commercial services in 2000. Delays were partly due to late arrival of handsets, complex product development, testing and type-approval. In 2000, there was only one model available in volumes (Motorola's Timeport P73891). Although networks were available, they were still not fully stable and incompatibilities were reported. Fully commercial services and products became available only as late as 2001.[876] By then operators were still experimenting with tariffing schemes,[877] some offering GPRS at a flat monthly fee in order to stimulate demand, thus lowering tariffs for heavy users, and provide "always-on" functionality. At this writing (November 2003), GPRS was vastly deployed. Services were available on 147 networks in 58 countries and more than 160 terminal models were available, but rather few users actually had GPRS subscriptions (6.8 million) and even fewer used the service.[878]

The alleged final stage for GSM data evolution will be *EDGE* (Enhanced Data for GSM Evolution). EDGE builds on GPRS and offers substantial speed improvements by upgrading the radio protocol. By deploying high-level modulating schemes and new error-protecting mechanisms, EDGE quadruples the nominal bit rate in one time slot to 48 kbps, which offers a theoretical maximum of 384 kbps.[879] Ericsson proposed EDGE to ETSI in 1997.[880] ETSI and UWCC, the standard body responsible for IS-136 TDMA, succeeded in harmonizing their proposals for high-speed data (i.e. EDGE).[881] Backed by the TDMA community, ITU accepted EDGE as part of the IMT-2000 umbrella of 3G standards (see below). One month later, 3GPP decided to include EDGE as part of the 3G standards development.[882]

By August 2002, EDGE commitment from European operators is weak, while among TDMA and GSM operators in the Americas public commitment seemed strong. Few operators outside the USA had commercialized EDGE services (see Table 8-1). Not surprisingly, the terminal industry was also slow in delivering EDGE handsets. By mid-2003, there were only two models available, one from Motorola and one from Nokia.[883]

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[874] Mobile Streams (010201a).

[875] Yankee Group (1999). Yankee Group estimated that 85% of GPRS infrastructure equipment orders had been awarded to operators' existing GSM suppliers.

[876] See e.g. Dennis (2000), Channing (2001) and Baker (2001).

[877] GPRS introduces new demands on billing systems.

[878] http://www.gsmworld.com

[879] Some sources claim 474 kbps (e.g. Northstream 2001a). Given experience from promises of other networks, EDGE initial data rates are likely to be in the range of 60-70 kbps. This estimate can be compared with Northstream (2001a) which predicts that ambitious network planning would give "actual downlink data rates of 150 kbps". Given that these figures apply to perfect conditions, actual user data rates would be some 60-70 kbps.

[880] Furuskär et al. (1999).

[881] Bekkers (2001:382). See also Färber (2001).

[882] Parker (2000a).

[883] http://www.gsmworld.com

Table 8-1: EDGE networks worldwide (deployed and planned as of November 2003)

	Operator	Status	Country	Operator	Status
Anguilla	Cable & Wireless	Planned	Israel	Cellcom	Planned
Antigua & Barbuda	Cable & Wireless	Planned	Italy	TIM	2H 2003
Argentina	Telecom Personal	Planned	Jamaica	Cable & Wireless	Planned
Australia	Telstra	12/2004	Kuwait	Wataniya Telecom (NMTC)	Q1 2004
Australia	Optus	Planned	Lithuania	Bite GSM	In deployment
Bahrain	Batelco	Planned	Malaysia	DiGi	In deployment
Bahrain	MTC Vodafone	Q1 2004	Mexico	Telcel	Planned
Barbados	Cable & Wireless	Planned	Singapore	StarHub	Planned
Bermuda	Telecom	Q1-Q2/2003	Montserrat	Cable & Wireless	Planned
Bermuda	The Bermuda Telephone Company	Planned	Philippines	SMART Communications	In deployment
Bermuda	Telecom/AT&T Wireless	Q1/2 2003	Philippines	Globe	In deployment
Brazil	Telecom Américas	In deployment	St Kitts & Nevis	Cable & Wireless	Planned
Brunei	DST	Q1 - 2004	St Lucia	Cable & Wireless	Planned
Canada	Microcell	Planned	St Vincent & The Grenadines	Cable & Wireless	Planned
Canada	Rogers AT&T Wireless	03/2004	Turks & Caicos Islands	Cable & Wireless	Planned
Cayman Islands	Cable & Wireless Cayman Islands	Planned	Thailand	AIS	In deployment
Columbia (East)	Comcel	Planned	Thailand	DTAC	In deployment
Columbia (West)	Occel	Planned	Thailand	Orange	Q1 2004
Columbia	Columbia Móvil	Oct 2003	Singapore	StarHub	In Trial
Dominica	Cable & Wireless Dominica	Planned	UK	Orange	Deployed
Ecuador	Conecel	Planned	USA	AT&T Wireless Group	Deployed
France	Bouygues Telecom	Planned 04-05	USA	Cingular Wireless	Deployed
Grenada	Cable & Wireless Grenada	Planned	USA	Dobson Communications	Deployed
Hong Kong	Peoples Telephone	Trial Q3 2003	USA	Cellular One	Planned
Hong Kong	Hong Kong CSL	In Trial	USA	EDGE Wireless	Planned
Hong Kong	Sunday	In Trial	USA	T-Mobile USA	Deployed
Hungary	Pannon GSM Telecommunications	Trial Q3 2003			

Source: http://www.gsmworld.com/technology Accessed on November 17, 2003.

8.2.2.3 Data in other digital cellular standards

In the US, development of data over digital cellular progressed along two lines: (1) from IS-95/CDMA to CDMA2000, and (2) from IS-54 via IS-136 to UWC-136. CDMA IS-95 networks supported 14.4 kbps packet- and circuit-switched data services from the start. This was one of the main benefits of the IS-95 network design; operators did not have to make significant investments to add further data services. In a second step commercialized around 2000, sometimes labeled IS-95b, data rates were increased to 64 kbps.[884] In later phases, IS-95 networks were specified to allow higher data rates, following an evolutionary path towards 3G labeled CDMA2000 (see further below).

While the establishment of the CDMA2000 road to 3G has been fairly straightforward, influenced by a competitive relation vis-à-vis GSM/WCDMA, the TDMA roadmap became somewhat more complicated. Initially, TDMA IS-54 offered no support for data communications. The evolved TDMA standard for both cellular and PCS (IS-136) offered support for 9.6 kbps circuit-switched data transmission. By using two or three time slots, data rates could be increased to 19.6 and 28.8 kbps.[885] Later the TDMA upgrading path merged with GSM (see below).

In Japan, NTT launched a circuit-switched data service with data rates of 2.4 kbps on their PDC network in 1993. In 1995, data rates were enhanced to 9.6 kbps.[886] In addition, NTT specified a packet-switched variant of PDC-P, which was implemented in 1997. Ericsson Mobile Data Design was contracted to develop the radio part of this system. The same year, NTT DoCoMo introduced a packet-switched service, "DoPa", which peaked at 640,000 subscribers. PDC-P, with modest data rates of 9.6 kbps only later in 2003 upgraded, is the network behind DoCoMo's immensely popular service: i-mode (see below).[887]

8.2.3 Messaging – the first killer application – SMS, EMS, MMS

The commercially most important data communication service of the late 1990s and early 2000s became the Short Message Service (SMS). SMS is a low-speed (c. 600 bps), low-capacity (1120 bits or 160 Latin alphabet characters) data service for two-way text messaging, which uses the signaling channel of GSM.

The bulk of SMS traffic today is mobile-to-mobile messaging and voice mail notification. In early 2003, of the "charged-for" traffic, mobile-to-mobile messaging represented circa 90 percent of the traffic.[888] Every SMS has to pass through an SMS center by any of the following vendors: CMG Telecommunications, Comverse Network Systems, Logica, ADC Newnet, Nokia, Ericsson, Motorola and the Sema Group.[889]

GSM operators started introducing mobile-originated SMS by 1994, with initially slow take-up. Fueled by interoperability enhancements, interconnect agreements, pre-paid cards and the introduction of new services, more capacity in networks, better terminal displays, inbox browsing and message reply, predictive text input, chat boards, WAP over SMS etc., the market started to grow very rapidly in late 1999 and early 2000 (see Figure 8-2). The number

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884 Helme (1999) and Langer and Larsson (2001).
885 Wirelessready.org (2001).
886 NTT (1997).
887 Nakamura (2001).
888 Netsize (2003).
889 Buckingham (2000).

of transmitted messages doubled every six months in many countries. In June 2001, some 20 billion SMSs were sent in GSM networks worldwide, compared to 4 billion in January 2000.[890] SMS had turned out to be a popular means especially for young people to communicate, but was also used in a range of other applications. SMS started to account for a major share of operators' revenues – some 10 percent in the OECD area).[891] In 2003, more than six out ten Europeans use SMS as a way to keep in touch.[892] Messaging is perhaps adequate to be labeled the first "killer app" of mobile data, just as e-mail was the first killer app of the Internet.[893]

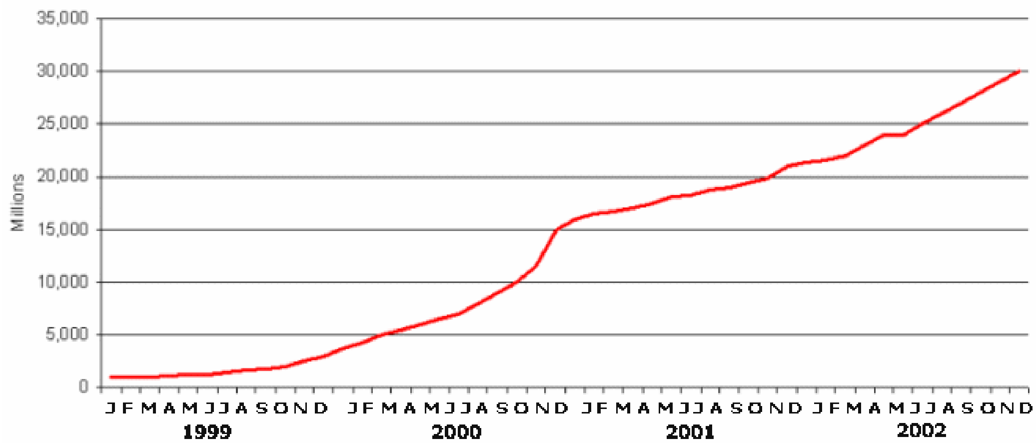

Figure 8-2 Monthly SMS messages (million)

Source: EMC Research as presented on http://www.gsmworkd.com [accessed 10 November 2003]

The remaining 10% of SMS traffic (besides mobile-to-mobile messaging) originates from value-added services, including fax notification, unified messaging, e-mail alerting, downloading logotypes, ring-signals and simple graphics, polls, chat, and information alerts. Many of these services started to appear in the late 1990s, partly enabled by the possibility to use premium SMS, launched first in the UK in 1999. According to Netsize (2003) the consumer traffic distribution was (in April 2002): information (15%), customization (20%), entertainment (30%) and discussion (20%). Estimates are that the ring tone and logo download market alone amounts to more than € 1 billion per year.[894] Corporate applications are relatively sluggish, estimated as some 2.5% of the SMS traffic. Applications include e-mail, mobile marketing, affinity programs, customer service, vehicle positioning,[895] dispatch, point-of-sale, telemetry and different m-commerce solutions (such as buying tickets, prepaid cards refill, parking, vending machines, and pay-per-view web).[896] The European premium SMS market varies widely among countries and operators, with respect to tariffing, technical specifications, terms and conditions.

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890 GSM World (2001); see also Northstream (2001b).

891 Simply assuming € 0.1 per SMS gives annual revenue worldwide of over € 3 billion per month globally.

892 Netsize (2003).

893 MobileSMS (2001). Since its inclusion in the GSM standard, SMS has also been incorporated into many other mobile phone network standards, including NMT, CDMA IS-95 and PDC. Each of these standards implements SMS in slightly different ways, and message lengths do vary.

894 Netsize (2003).

895 GPS position information is typically about 60 characters in length (Buckingham 2001).

896 Buckingham (2001) and Netsize (2003).

Table 8-2: Premium SMS launches in Europe

Country	Launch	Country	Launch
UK	1999	Denmark	August 2001
Finland	2000	Sweden	Autumn 2001
Norway	April 2000	France	June 2002
Austria	April – October 2002	Germany	April – October 2002
Italy	March 2001	Ireland	2002
Spain	April 2001	Switzerland	February 2002
Netherlands	Spring 2001 / Spring 2002	Portugal	March 2002
Belgium	Summer 2001		

Source: Adapted from Netsize (2003)

Mobile messaging is currently going beyond text messaging by taking a development path from SMS (Short Message Service) to MMS (Multimedia Messaging Service).[897] The Multimedia Messaging Service (MMS) is, as its name suggests, the ability to send and receive messages comprising a combination of text, sounds, images and video to MMS-capable handsets. New mobile network infrastructure is needed for Multimedia Messaging (MMS) – in addition to implementing the new bearer services such as 3G, new network elements such as Multimedia Messaging Relays and Stores will be needed. MMS is standardized by 3GPP (and WAP Forum), and seems so far to be supported by a united community of handset manufacturers.[898]

Most European operators launched MMS in their networks during 2002 accompanied by a few terminal models supporting MMS, with a wide range of models following during 2003. MMS has been regarded by many as one important platform for new services and operator revenues, and the "saviour of 3G". In June 2003, a total of 176 operators in the world had deployed MMS, with 148 actually launching services (see Table 8-3). The launches have often been accompanied by a 2-3 month free trial period to reduce adoption barriers. These periods have in many cases been prolonged. In Norway, the first country to launch MMS services, the operators gradually have postponed the date for starting charging the customers, the latest indication being December 2003.[899] In the same period the expected price of an MMS has eroded from NOK 10 to NOK 2.50. According to the research firm ARC Group the average price of a 30 KB MMS is USD 0.35, 3.86 times the price of an SMS.[900]

[897] Some actors supported an intermediate step – EMS – the Enhanced Messaging Service. EMS is the ability to send a combination of simple melodies, pictures, sounds, animations, and text as an integrated message for display on an EMS-compliant handset. A simple black-and-white image could be displayed along with some text and sound effect. Presented by Ericsson, and supported by most major handset vendors, EMS was standardized as part of the 3GPP technical specifications. Nokia argued that the implementation of MMS, technically superior to EMS, was close at hand, and would quickly supersede EMS. In 2002, few operators had launched major EMS initiatives, and even initially supporting vendors such as Ericsson and Comverse showed lukewarm interest (Mobile Streams 011112, Mobile Streams 010901).

[898] Mobile Streams (011112) and Novak & Svensson (2001).

[899] TeliaSonera (2003b).

[900] Walsh (2003).

Table 8-3: Commercial MMS Deployments, June 2003

Region	MMS deployments	In service
Africa	6	3
Americas	21	16
Asia-Pacific	42	35
Europe: Eastern	27	22
Europe: Western	70	66
Middle East	7	4
USA/Canada	3	2
Total	176	148

Source: Walsh (2003)

8.2.4 Mobile Internet to the phones: WAP, i-mode, EZ-Web, Vodafone Live, etc.

WAP – the Wireless Application Protocol – emerged in 1997 as a major effort to reduce and overcome the limitations of terminals and networks.[901] Terminals had small, monochrome displays and limited input interfaces, processing and storage capabilities. In addition, the connections suffered latency, poor security low data rates and were subject to lost connections. Although terminals improved during the 1990s to be increasingly capable of accommodating data, there were still problems in presenting Internet information to the mobile user.

Behind this WAP lay the independent efforts conducted by Unwired Planet (later to be renamed Phone.com, and more recently Openwave), Ericsson and Nokia, which, if pursued, could have led to at least three independent standards, a scenario which was in no one's interest. The three companies, joined by Motorola, announced their WAP plans at a Mobile Data Initiative (a forum driven by Intel) meeting in June 1997. The goal of this effort was to produce a refined, license-free protocol that was independent of the underlying air link standard. Another aim was to encourage growth in the market for intelligent mobile phones and services. WAP should therefore inherit the main characteristics and functionality from HDML (Handheld Device Markup Language)[902] and HDTP (Handheld Device Transport Protocol) developed by Unwired Planet; the Smart Messaging specification and Tagged Text Markup Language (TTML) developed by Nokia; and the ITTP (Intelligent Terminal Transfer Protocol) specification developed by Ericsson. In December 1997, the four companies formed the WAP Forum Ltd (a non-profit company that administered the worldwide WAP specification process and facilitated for new companies contributing to WAP specifications) and began specifying a first release of the standard. In order to speed up the process, the WAP Forum did not open its doors to other members until a first version of the standard was drafted in spring 1998.

The WAP standard is a re-expression of Internet protocols adapted to suit mobile communications, at different layers in the OSI model. It includes a micro-browser, WML (the WAP equivalent of HTML, a telephony application interface, different content formats (business cards, calendar events etc.), and a layered communications stack which isolates

[901] This paragraphs on WAP draws on and synthesizes a large number sources such as Larsson (1998); Erlandson and Ocklind (1998); Channing (2000); Hibberd (2000); Law (2000); Parker (2000b); Persson (2000); WAP Forum (1998, 2000, 2001); Mobile Communications International (2000); Parker (2000c); PricewaterhouseCoopers (2001:778-785); Mobile Streams (010201b); Northstream (2001b); Goldman (2001); and Bekkers (2001:383).

[902] It should be noted that since then Unwired Planet has continued to supply, maintain and issue new releases of HDML. See e.g. Parker (2000b).

variances in the bearer technologies and provides security, reliability and caching. Of particular importance is the WAP Gateway, which takes on responsibility for mediating between users and content providers. For the end-users, WAP would permit access to applications and functions such as: (1) management of personal telephone profiles; (2) handling of voice, fax, and e-mail, i.e. unified messaging; (3) information services – taxi, restaurants, hotels, stock trading; (4) banking, directory services, etc.; (4) Internet services; (5) improved user interface to existing, and addition of more advanced, telephony-related services.

In 1999 operators began implementing WAP gateways, pioneered by Unwired Planet but also marketed by e.g. Ericsson, Nokia and CMG. The first operator to launch a WAP service was Finnish Sonera, in August 1999, before WAP phones were commercially available. During the autumn of 1999, WAP became *the* buzzword of the industry. Unrealistic expectations of the usefulness of WAP, fueled by analysts, so-called industry experts, media and others, contributed to the hype, with dramatically rising stock prices for companies involved in WAP development. Not surprisingly (not even ex-ante), WAP services did not take off as expected, due to limited usefulness, limited performance networks, services and a lack of terminals.

The first WAP phones were available a few months later, but only in limited numbers. Delays were due to interoperability testing, incompatibilities between different versions of the standard (1.0 and 1.1, and later 1.2 which some claim was the first really stable version of WAP), and incompatibilities between phones and gateways from different vendors. A few services, mainly financial services and e-mail, were launched at about this time, but some of them worked only for specific phone models. Although after a while a quite large proportion of terminal sales supported WAP (ca. 50 million accumulated shipments by early 2001), few users actually made use of WAP services as late as in 2001, a majority being in Japan. Instead, industry hopes were clinging to the introduction of GPRS.

Meanwhile, the WAP Forum continued to improve and adapt the WAP protocol to changes in terminals and networks, in close cooperation with the Internet community. When WAP was conceived and launched, the Internet community reacted with skepticism. Moreover, WAP was affected by and overlapped with improvements undertaken by other standardization efforts. Therefore, the WAP Forum established close cooperation with ETSI (SMG 4 and MExE subgroup), CTIA, W3C, TIA, IETF, 3GPP, and GSM Association's M-services initiative. In autumn 2001, a new WAP specification was launched – WAP 2.0. WAP 2.0 would be more consistent with Internet standards (TCP/IP and XHTML) and take advantage of improvements in bearer services and more powerful terminals. When the Open Mobile Alliance was formed in 2002, it took over the WAP specifications.

The failure of WAP could in part be explained by limitations in complementary technologies (bearers). Improvements in those complementary technologies reduce the need for WAP, which poses a dilemma for WAP proponents. It is also significant that the perceived failure of WAP was not only about technology, but was to a large extent dependent on unrealistic expectations – hype. In addition, the perceptions of failure of WAP are due to the unexpected relative success of a somewhat similar venture: i-mode.

In February 1999, NTT DoCoMo launched i-mode[903] – a wireless Internet service. In contrast to WAP, which is a set of specifications, i-mode is a full service concept. Traffic runs over DoCoMo's packet-switched PDC-P network, which allows for always on-line functionality.

[903] The account of i-mode draws on Lindmark (2003), unless otherwise stated.

The i-mode server is a gateway between the packet network and the content providers.[904] I-mode phones are manufactured according to DoCoMo specifications, and include large color screens and polyphonic ring-tones. This network uses protocols more closely related to Internet protocols than WAP equivalents. For instance, the mark-up is a subset of HTML 3.0, compact HTML (cHTML or iHTML), with some additional tags.

DoCoMo controls the entire actor system, by setting the specifications, dictating terminal development, running the main portal and controlling what content providers are present on its website. Content providers can either hook up to DoCoMo's i-mode portal (I-menu), where they can make use of DoCoMo's billing system. In addition, the customer can access unofficial websites by typing in their URLs. I-mode uses a simple business model where customers are billed by only one company (DoCoMo). The bill comprises a monthly charge, a packet transmission charge and information charges. DoCoMo then pays the information charges to the content providers, who in turn pay a commission fee to DoCoMo. DoCoMo successively improves i-mode, for instance by introducing color content, polyphonic sound, camera phones, picture-sending services, JAVA-enabled services (called i-αppli) and location-based services.

Table 8-4: Key facts of i-mode over time

	3/99	3/00	3/01	3/02	3/03
Cellular subscribers	23,897	29,356	36,026	40,783	45760
DoCoMo's market share (%)	57.5	57.4	59.1	59.0	58.0
i-mode subscribers	N/A	5,603	21,695	32,156	37,758
Churn Rate (%)	1.75	1.61	1.39	1.18	1.22
Aggregate ARPU (JPY/month)	9,270	8,740	8,650	8,480	8,120
Voice ARPU (JPY/month)	9,270	8,620	7,770	6,940	6,370
i-mode data ARPU (JPY/month)		120	880	1,540	1,750
Official sites	67	600	1500	3000	c.3450
Unofficial sites	< 500	8000	42000	54000	c. 64000

Note: ARPU figures are yearly averages.

Source: DoCoMo homepage, dates as provided in Table

I-mode proved almost an immediate success. In only 9 months, it had won about 2 million subscribers; 227 content providers used the NTT portal, and some 2000 "un-official sites" were accessible via i-mode phones via the Internet. By 2003 these number were circa 3,500 and 65,000 (see Table 8-4). By October 2003, i-mode had grown to about 40 million subscribers. NTT DoCoMo reported that data traffic generated 10 percent of revenues already in fiscal 2001, up from 1 percent the year before.[905] This growth compensated for the rapidly falling ARPU of voice services. This share of data traffic continued to grow and is more than 25% at this writing.[906]

In response to i-mode, cellular operator rivals KDDI and J-phone launched similar services on their CDMA and PDC networks. KDDI named its mobile Internet service "EZ web" and J-Phone named theirs J-Sky. Although using different technological solutions, similar levels of success were reached.

[904] PricewaterhouseCoopers (2001:785-786).

[905] NTT DoCoMo (2001).

[906] Bohlin et al. (2003a).

Attempts to identify the important lessons here have been made by a number of students of the mobile communications industry. These range from consultants (e.g. Northstream 2001 and PricewaterhouseCoopers 2001) to industry participants (e.g. Natsuno 2003) to academics (e.g. Sigurdson 2001, Funk 2001, Fransman 2002, Kärrberg and Marnung 2001, Gawer and Cusumano 2002). These analyses have emphasized explanatory factors ranging from technological and socio-cultural factors to a low degree of fixed Internet penetration. However, as pointed out by e.g. Lindmark (2003), the main explanatory factors concern DoCoMo's balance between coordination and control.

Clearly, by 2001 Japan had taken the lead in mobile data communications in many respects, e.g. deployment and diffusion of advanced wireless Internet services, and in addition in technical sophistication of terminals.[907] Whether or not this advantage could be leveraged overseas remained to be seen. DoCoMo was actively pursuing an internationalization strategy where it tried to capitalize on early i-mode success and FOMA 3G experience (see below). Starting in 2002, i-mode was launched in a number of European countries including the Netherlands and Germany. KDDI has a strong international profile in fixed communications, and might, if CDMA2000 should turn out to be successful, start building an international mobile presence as well.[908] Handset manufacturers, and possibly infrastructure and applications suppliers, will most certainly also try to increase their international presence.

In an effort to replicate the success of i-mode in Japan, Vodafone launched its Live! concept in eight countries simultaneously on October 24, 2002. The service package included content and MMS services, and was sold with preconfigured phones, often with the Vodafone brand on the terminals. In 2003, a further seven countries were added to the list (until end of November, 2003), and Vodafone announced over 1 million Live! customers in Europe and over 3 million Live! customers in the world.[909] The Live! service has boosted mobile data usage, increasing to 15.5% of total service revenues, up from 14.6% for the year ended March 2003.

Locally oriented operators imitated the Live! concept. To exemplify with Sweden, Telia launched a service package similar to Vodafone's, named Telia Go!, in June 2003, with around 20 services included from the start. The service was sold with preconfigured phones, at first two models from Nokia and Sony Ericsson.[910] Tele2/Comviq announced their initiative, similar to Telia's and Vodafone's, in November 2003, named Comviq Go Live!.

8.2.5 Collaborations and the standardization

Partly as a result of the infancy, convergence and increased complexity, a number of cross-industry initiatives were created to stimulate the growth of mobile data communications. These initiatives, although not a new phenomenon in general, can be said to have started in 1996 with the creation of the Mobile Data Initiative. This initiative was launched by Intel, which perceived a huge potential mobile market for its microprocessors but also a number of hurdles for that market to be realized. Intel noted that data communications represented only 0.5% of traffic over GSM networks (1% of revenues) compared to 46% in landline networks. In order to stimulate a take-up of data services, Intel took the initiative to form a cross-industry cooperation aimed at promoting data services among GSM users – the Mobile Data

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907 Haskin (2000).

908 The Vodaphone group, the largest cellular operator, dominates J-Phone.

909 Vodafone (2003a,b).

910 TeliaSonera (2003a).

Initiative. Intel gathered key players from the laptop computing, software and mobile communications industries, with the aim of providing laptop and notebook users with GSM access to corporate networks and the Internet, making it easier to send messages, faxes and e-mail, handle databases, monitor news events etc. MDI was also a response to a lack of bodies to handle cross-industry standards efforts.[911] Since then an increasing number of similar initiatives have been launched and forums created, as illustrated in Figure 8-3, which shows the number of cooperative forums formed each year.

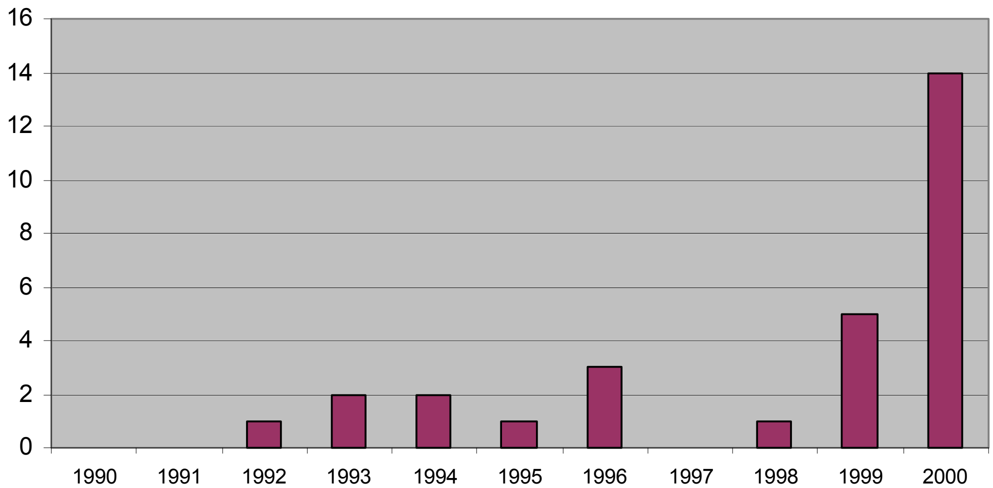

Figure 8-3 Yearly formed mobile Internet consortia

Source: Adapted from information available at e.g. http://www.etsi.org

Several of these fora include not only technological and market development efforts, but also standard-setting. The convergence of technical systems implies, quite logically, also a convergence in standards. For instance, standardization processes of the next generation Internet Protocol (IPv6 – Internet Protocol version 6) and 3G, notably UMTS, are increasingly interdependent. This means that, for example, IETF (the Internet Engineering Task Force) and 3GPP have to cooperate more intensively than before. This cooperation can be problematic since standardization procedures in mobile communication and the Internet are quite dissimilar.[912]

8.2.6 3G

8.2.6.1 Development and standardization

By the turn of the century, the first so-called 3G systems were commercialized. Much hyped in the late 1990s, the transition into 3G has so far been a huge failure for many industry actors. This section briefly investigates this development.

The efforts started in 1985 within ITU, and with early research in Europe and Japan a few years later. The work within ITU was triggered by concerns raised by the rapid development of incompatible analog cellular mobile telephone standards, and the need for collaboration in the development of harmonized standards for the future. In 1986, ITU created a formal

[911] Mobile Communications International (1996) and interviews. In 2000, MDI was followed by Mobile Data Initiative Next Generation (MDI-ng) with the purpose of making wireless Internet/Intranet access as simple and as commonplace as data over fixed wires (Intel 2000).

[912] There are several other problems related to this convergence, for instance a need to accelerate IPv6 deployment, in order to circumvent that 3G system run out of IP-addresses. These issues are addressed in Bohlin and Lindmark (2002).

working group – CCIR task group 8/1.[913] Initial studies were aimed at defining objectives for a system named Future Public Land Mobile Telephone System (FPLMTS) and inferring radio spectrum requirements as part of ITU-R (ex-CCIR) input for WARC. The initial vision for FPLMTS was mainly a pocket-sized mobile telephone that could be used anywhere in the world. However, it did not take long until the concept became far more complex.[914]

The FPLMTS program was dominated by three regional groupings: Europe, the United States and Japan, guided by different incentives and industry-political interests. Although instrumental in setting up the CCIRgroup to start with, Europeans devoted most resources to GSM standardization efforts and waited for the needs and results of improvements in that system. Instead it was the Japanese who came to lead the FPLMTS work. Japanese industry had been losing market shares due to the GSM success. Japan's actions were guided by MPT, and its interests were aimed at regaining its position in mobile communications.

A major step was taken in 1992 when WARC (World Administrative Radio Conference) allocated spectrum for third-generation (FPLMTS) services. In spite of this measure, many observers would agree that until 1996, the work on FPLMTS in the various working groups of ITU could be characterized as a policy-driven, slow-pace theoretical exploration of scenarios conducted by ITU delegates, researchers and university professors. All this changed during 1996, mainly because of the actions taken in Europe and Japan.[915]

In Europe, efforts with 3G systems had a number of antecedents, e.g. the research conducted within the RACE (Research and development in Advanced Communication technologies in Europe) and ACTS (Advanced Communications Technologies and Services) programs, the PCN concept, and of course GSM.[916] RACE I involved some 20-25 organizations, including operators, equipment suppliers, universities and research institutes. The project identified two main classes of mobile communication services: UMTS (wide-area speech and low to medium data rate services) and MBS (local-area high data rate services).[917] It targeted radio interface definition, signaling issues and fixed network impact, identification of required frequency spectrum and submission of contributions to both ETSI and ITU.[918] In 1991, focus shifted towards system definition; a system definition group was formed, which spent the next 1.5 years outlining a system concept to be known as UMTS.[919]

The European Commission welcomed the idea of UMTS, initially viewing it as a continuation of the convergence of European standards for PMR/data, paging, cellular and cordless (i.e. the next step after GSM, ERMES, TETRA and DECT). UMTS would then replace those, as a single standard that would satisfy all conceivable user needs. Still at this time, European personal communication efforts were rather voice- (telephony-) centric and concerned matters such as convergence between cellular and cordless (partly as a result of the UK PCN initiative).[920] In response to the progress in RACE, ETSI established a UMTS group.

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[913] Lindmark (2002) based on interviews.

[914] Garrard (1998:476-477) and Lindmark (2002) referring to interview with T. Beijer (1997).

[915] Donegan (1996) and Lindmark (2002) referring to interviews with T. Beijer (1997), P.:Bliksrud (1997) and E. Ljungberg (1998).

[916] Chapter 7 touched upon the PCN concept in the UK, and also the involvement of the European Commission and the "green paper". As described earlier, the UK PCN concept resulted in DCS 1800, a variant of 2G GSM. However, when the concept was launched it was quite similar to other visions of 3G.

[917] Schwartz da Silva (2001:116).

[918] Schwartz da Silva (2001:116) and RACE (1994).

[919] Tuttlebee (1993) and RACE (1994). Swedish organizations (Televerket and Ericsson) participated in the project, partly funded by the IT 4 program. (Lernevall and Åkesson 1997:694.)

[920] Garrard (1998:477-478).

In the second phase of RACE – RACE II[921] – issues of mobility were given increased attention. During the period 1992-1995, a number of mobile projects were conducted under the RACE II Mobile Project Line. Since RACE I had concluded that technologies other than advanced TDMA could be feasible and possibly outperform it, researchers started looking in other directions including CDMA, OFDMA, multi-carrier systems and hybrid systems. In RACE II one project (CODIT CODe DIvision multiple Testbed) specifically focused on CDMA, while another (ATDMA) continued the TDMA path.[922]

The ACTS (Advanced Communications Technologies and Services, lasting from 1995-1998) framework continued and further expanded RACE II research in telecommunications. In terms of resources and projects, the mobile communications part of ACTS was far more ambitious than in RACE. In ACTS more than 100 out of 630 million ECU (Euro) in funding were allocated to mobile communications. Some 37 projects were related to mobile communications, the most influential being Future Radio Wideband Multiple Access Systems, in which the conflict between TD-CDMA and WCDMA emerged.[923]

Around 1994, the vision and concept of third-generation cellular started to change, following the tremendous success of GSM, the emergence of global satellite LEO concepts, the rapid diffusion of Internet, and the emergence of multi-mode handsets. Global telephony access was no longer a primary feature either in Europe or on a global scale. GSM was well on its way to providing all functionalities defined in UMTS. Therefore, the need for a new standard along the lines of integrating existing 2G systems was reduced. Therefore, the work and vision changed towards a system that should be able to carry mobile multimedia, broadband and packet-switched data.[924] In addition, due to vested interests among GSM operators, UMTS had to be backward-compatible with GSM.[925]

The European Commission set up the UMTS Task Force,[926] with the mission to propose a UMTS strategy for Europe.[927] It laid down a preliminary program for developing and introducing UMTS by 2002, including the formation of a new policy-creating forum.[928] This was a response to the slow pace of 3G development, the new emerging need, and following the recommendations of the "Bangemann Report" (on the development of the information society) which pointed to the necessity of pro-active European moves in the field of mobile communications. Based on the recommendations, the UMTS Forum was set up to provide strategic guidance to policy- and standard-making bodies and to create a momentum behind UMTS.[929]

One of the first conclusions from the UMTS Forum, published in June 1997, was an urgent need to allocate more spectrum for UMTS and begin the process of harmonized UMTS licensing.[930] The UK DTI issued a document covering a framework for licensing operators to provide 3G services. About the same time Alcatel, Siemens, Ericsson and Nokia issued a joint

[921] In the context of the Third European Framework Programme.

[922] Bekkers (2001:482).

[923] Garrard (1998:477) and ACTS (1999). Bekkers (2001:483) and Berruto et al. (1998).

[924] White and Fuller (1992), Hillebrand (1997).

[925] Mitts (1995).

[926] Donegan (1996), UMTS Task Force (1996) and Fernandes (2001).

[927] Donegan (1996), Fernandes (2001) and Beijer (2001).

[928] Donegan (1996).

[929] Beijer (2001).

[930] UMTS Forum (1997) and Channing (1997).

declaration of their commitment to a timely standardization of 3G systems based on a GSM core network.[931]

ETSI decided to take a phased approach to UMTS, where the UMTS Radio Access Network (UTRAN) and an evolution of the GSM Core Network would be developed in a first phase, including a TCP/IP component. This approach would allow the introduction of UMTS in both new and pre-existing networks. In a second phase, a UMTS core network could be specified to focus more on broadband multimedia. Such an approach preserved investments in GSM technology, while simultaneously moving forward in both radio and network technology.[932] By February 1997, ETSI had established a strategic consensus on this approach.[933] Still, in Europe, it was becoming clear that radio air interface choices would become contentious. The European time-plans and decisions were to become increasingly affected by what was happening elsewhere – in Japan.

Around 1997, most parties realized that there was practically no chance of agreeing on a single radio interface and single network protocol at a global level; instead the concept of a "family of standards" was advocated.[934]

The Japanese (NTT, ARIB) had been studying CDMA since the late 1980s, and by the mid-1990s it had become clear that Japan would support some sort of wideband CDMA proposal. In 1995 and 1996 extensive research efforts were put into the various CDMA proposals which, after a field test at NTT, were merged into a common wideband CDMA platform, essentially based on R&D conducted at NTT.[935] Having made those technical choices the Japanese could concentrate on formulating their contribution to ITU and start lobbying for their solutions.[936] Two factors guided the Japanese actions: (1) In 2G Japan was stuck with its own digital standard, while the rest of the world was split between GSM and US standards. Japanese manufacturers had lost market shares, and (2) many Japanese operators were running out of frequencies and needed to use the frequencies that WARC had reserved for FPLMTS. Therefore, the Japanese estimated that a new standard had to be implemented already by the year 2000.[937]

NTT DoCoMo, the dominant mobile operator, largely drove Japanese actions and exercised control over technological choices. In the spring of 1997, the company announced plans to work with the Japanese standardization organization ARIB (under the guidance of MITI and MPT) to develop a 3G interface based on Wideband CDMA, largely identical to the FMA-2 proposal developed within the ACTS FRAMES program (see below).[938] According to Bekkers (2001, pp. 487-488) this order proved decisive for Ericsson's and Nokia's support of WCDMA. Ericsson (supported by Nokia and of course ETSI) preferred, though, a smooth

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[931] Channing (1997)

[932] Dupuis (2001e:182-183). The importance of GMM is stressed by both SMG chairmen (P. Dupuis, and F. Hillebrand) in (Dupuis, 2001e) and Hillebrand (2001b).

[933] Hillebrand (2001b:187-196).

[934] Donegan (1997b) and Hillebrand (1997).

[935] Gessler (2002:145-147).

[936] Already in the early and mid-1990s Japanese delegates had dominated ITU's work on FPLMTS.

[937] MPT (1997).

[938] It is not entirely clear who influenced whom. Clearly, Ericsson and NTT DoCoMo had a close relationship. According to Meurling and Jeans (2000:416) Ericsson convinced NTT of the viability of WCDMA. Funk and Methe (2001) imply that it might have been the other way around, but that Ericsson and Nokia convinced NTT DoCoMo of the viability of building on GSM. According to Gessler (2002:150) the Japanese were allowed to participate in ETSI's evaluation procedure, and were thereby able to adjust their proposal accordingly.

migration based on the GSM Core Network and managed to convince the Japanese to abandon their PDC-based solution.[939]

Not all Japanese companies were content with the old structure of NTT dominance, and two of the competing operators DDI and IDO (supported by MPT) decided to begin migrating their customers to IS-95. This was a welcome move for the IS-95/CDMA community headed by Qualcomm,[940] since it increased the momentum behind efforts to make third-generation design backward-compatible with IS-95 as a first step in providing an evolutionary route to 3G.[941] In response to NTT initiatives, in the summer of 1997 the CDMA development group (CDG) revealed its own plans to develop a 3G air interface based on an evolution of IS-95 CDMA technology. It was named "CDMA2000".[942] IS-95 CDMA was concurrently re-branded "cdmaOne" in order to have a common name for CDMA around the world. A three-step approach to developing cdmaOne into CDMA2000 was developed, gradually increasing data rates to 384 kbps.

Despite these moves, the United States was trailing behind, since most of the spectrum set aside for FPLMTS had already been made available for second-generation PCS, and the operators had few commercial incentives to invest in 3G systems. Instead, the US was likely to implement three different 3G standards – based on evolutions of second-generation standards IS-95 CDMA, IS-136 TDMA and GSM. The TDMA camp (Universal Wireless Communications Consortium (UWCC) headed by the leading vendor Ericsson[943] and major carriers (such as AT&T Wireless, BellSouth Mobility and Southwestern Bell Mobile Systems), also specified an upgrade path to 3G. However, being the commercially weaker of the 2G standards and the similarities with GSM, the development path was eventually merged with GSM/UMTS.

By 1997, it was quite clear that there would be several third-generation systems at a global level. The momentum behind the second-generation standards was too strong to design an all-embracing 3G system backward-compatible with them all. Instead the best-case scenario envisaged at this point in time was a core of global standards around which there could be variations.

In Europe, the most important issue became the technology choice for the air interface (TDMA, different variants of CDMA, or combinations).[944] In 1998 SMG was to make this major technical choice for UMTS (and others). In the end of 1997 two favored solutions emerged, dividing manufacturers in two camps: the Alpha and the Delta proposals. The Alpha proposal was based on FRAMES FMA-2 and similar to technology selected by ARIB and NTT DoCoMo. Ericsson and Nokia, backed by Lucent and Japanese suppliers, were the main proponents. Many European operators (most notably Telecom Italia Mobile) and a majority of non-European operators supported the concept. This included also NTT DoCoMo, which realized the importance of ETSI choosing WCDMA, therefore compromising and aligning its 3G standard to also be based on the GSM core network.[945]

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[939] Bekkers (2001:487).

[940] Mobile Communications International (1996) and Mobile Communications International (1997). DDI and IDO eventually merged their operations. By April 1999 they had established a nationwide IS-95 network with roaming. By early 2000 they launched PacketOne, supporting up to 64 kbps data rates (KDDI 2001).

[941] Dawson (1997).

[942] Channing (1997).

[943] Including also Lucent, Nokia, Nortel, Alcatel, Motorola and Hughes (Bekkers 2001:491).

[944] Donegan (1997a).

[945] Channing (1998b) and Bekkers (2001:495-496).

Table 8-5: The two main UTRA concept proposals

Proposal (also known as)	Technology	Main proponents [a.)]	Claimed advantages (of alpha vs. delta)
Alpha (α) (W-CDMA, FMA-2)	Direct Sequence Wideband CDMA, FDD, asynchronous operation	Ericsson, Nokia, Lucent, NTT DoCoMo, ARIB plus Fujitsu, NEC, Mitsubishi, BT	- Less investment in base stations. - Better possibilities to use existing frequency bands. - The Japanese factor leading to economies of scale and roaming.
Delta (δ) (TD/CDMA, FMA-1 with spreading)	Wideband TDMA/CDMA, FDD and TDD modes, 8 time slots; one time slot can support eight subscribers by use of CDMA spreading	Siemens, Alcatel, Nortel, Italtel, Motorola, Bosch, Sony and France Telecom	- Better technical integration with existing GSM networks, with resultant lower roll-out costs and more effective dual-mode (GSM/UMTS) terminals. - The inherent TDD solution. - Less critical IPR situation.

a.) The groupings were to some extent fluid and subject to change due to lobbying.
Note: There were three other proposals, beta, gamma, and epsilon.

Sources: Lindmark (2002) based on SMG (480/97), Channing (1998b), Bekkers (2001, p. 494) and Hillebrand (2001d, p. 201)

Several other manufacturers, headed by Alcatel and Siemens, favored the Delta concept, a hybrid solution that combined TDMA and CDMA (TD-CDMA) and was based on FRAMES' FMA-1 spreading variant. Sony and Bosch later joined this grouping. Motorola seemed to back both concepts.[946] Decisions would certainly influence the competitive positions within the industry. The general perception was that if W-CDMA was to be chosen, Ericsson and Nokia would probably have a technological lead (again) which the others might have difficulties in catching up with.

The different camps geared up their lobbying efforts in the end of 1997. ETSI prepared for an inconclusive outcome with two interfaces. The controversy reached a point where it threatened to jeopardize Europe's leading position in mobile communications, if the different camps could not come to terms. In Madrid in December 1997, a so-called indicative voting was held, which gave Alpha 58.45% of the weighted votes, most of the remainder going to Delta, none of them achieving the 71 percent that would have been required if a formal vote had been held. In a second meeting on January 28, 1998, Alpha received 61.1 percent, while Delta received 38.7 percent and both solutions thus fell short of the required 71% majority. After 11 hours of intense overnight negotiations, a compromise solution was reached where Alpha W-CDMA would be used for FDD operation in the paired spectrum intended for wide-area coverage and Delta TD/CDMA would be used for TDD operation in the unpaired band, intended for low-mobility coverage.[947]

When SMG had taken its decision the next conflict emerged, mainly between two camps representing W-CDMA and CDMA2000. Once ETSI had chosen W-CDMA for UTRA, the CDMA2000 camp started working against this solution.[948] Qualcomm also used its IPR positions in order to influence the outcome.[949] Headed by Alcatel, which had a weak patent position in WCDMA, a large number of manufacturers and network operators issued an IPR declaration stating that they were prepared to grant irrevocable licenses on fair, reasonable and non-discriminatory terms and conditions; but Qualcomm, stating that it held 130 CDMA

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946 Ibid.

947 ETSI (32/98); Mobile Communications International (1998); Bekkers (2001:498) and Hillebrand (2001c:202-203). The consensus proposal also included, as a third point, a statement that in selecting the technical parameters it should be guided by the objectives of low-cost terminals, harmonization with GSM, and FDD/TDD dual-mode operation, and fit into 2*5 MHz spectrum allocation (*ibid.*).

948 Channing (1998a).

949 Bekkers (2001:523-527).

patents with many more patent applications pending worldwide, refused to sign the agreement.[950] Formally, ETSI would then have to abandon the CDMA trap and look for other technical solutions, which of course it did not do. Ericsson and other major manufacturers claimed that (1) Qualcomm's patents were not essential to W-CDMA (a statement that most observers found hard to believe), and that (2) they had essential patents of their own which could block use by Qualcomm or other actors (which most observers believed to hold). On the industrial side, the technological debate was increasingly becoming one of non-GSM vendor Qualcomm (backed by the US government) against non-IS-95 vendor Ericsson (backed by e.g. ETSI), with a number of players in between.[951] Qualcomm announced that it required the W-CDMA to be modified so as to become backward-compatible also with cdmaOne, for instance by modifying the chip rate.[952] Finally, the conflict was solved on March 25, 1999, when Ericsson and Qualcomm announced that Ericsson would acquire Qualcomm's loss-making infrastructure and associated R&D operations. By doing so, Ericsson gained access to Qualcomm's IS-95 CDMA competence and, perhaps more importantly, its IPR portfolio.[953]

Meanwhile, most participants in the industry seem to have accepted a concept of a "family of standards". Following the Qualcomm–Ericsson agreement, ITU presented a "single" IMT-2000 terrestrial air interface standard encompassing five optional modes: (1) UTRA FDD (WCDMA), (2) CDMA2000, (3) UTRA TDD & TD-SCDMA, (4) UWC-136 and (5) DECT.[954] Much of this harmonizing work was accomplished outside ITU, but as a result of an operator-driven initiative – the Operators Harmonizing Group (OHG) – which sorted out some IPR issues and, more importantly, achieved some level of harmonization with four radio access interfaces (including a harmonization of UTRA TDD and the Chinese TD-SCDMA proposal)[955] and two core networks (evolved GSM/MAP and evolved IS-41). Among the decisions taken in order to achieve harmonization was to lower the W-CDMA chip rate to 3.84 Mcps. ITU then formally approved the IMT 2000 standard in November 1999.[956]

These decisions led to some synchronizing of 3G standardization, in the form of partnership projects.[957] In December 1998 a number of standards organizations and other related bodies from Europe, the US, and Asia (ARIB, ETSI, CWTS, T1, TTA and TTC) entered an agreement to cooperate for the establishment of a complete set of globally applicable Technical Specifications for a 3rd Generation Mobile System, based on the evolved GSM core networks and the radio access technologies (i.e. UTRA, both FDD and TDD modes). The project was entitled the Third Generation Partnership Project (3GPP). UMTS standardization was transferred from ETSI to 3GPP, which produced a first set of technical specifications (Release 99) in December 1999. These specifications, frozen in March 2000, were essentially a consolidation of the underlying GSM specifications and the development of the new radio access network, and were released in order for 3G services to be launched in Japan in spring

950 Channing (1998a).

951 Channing (1998a) and Bekkers (2001:523-527).

952 SMG (471/98, 482/98).

953 Daniels (1999a,b) and Hibberd (1999a,b). See also Bekkers (2001:523-527).

954 Daniels (1999c).

955 By then, the Chinese TD-SCDMA proposal had emerged as possible 3G contender. TD-SCDMA (Time Division – Synchronous Code Division Multiple Access, also known as TDD Low Chip Rate) just might become a serious contender to established 3G technologies. The chief proponents of TD-SCDMA are Siemens and China's Datang (the manufacturing arm of CATT, China Academy of Telecommunications Technology). (Dennis 2001.)

956 Nilsson (1999); Barberis (1999a); Operators Harmonizing Group (1999); Bekkers (2001:510-512) and Hillebrand (2001c:211-212).

957 During 1997, the Japanese had given up their core network position and had accepted UMTS being based on GSM. In early 1998 contacts between ETSI, the leading grouping in Japan (ARIB/TTC) and the GSM community in the US showed that a common UMTS concept based on UTRA and an evolved GSM core network would be possible.

2001.[958] A mirroring organization, 3GPP2, was born out of the turbulent period in 1998-99 (described in the previous section) with two clashing camps. 3GPP2 was formally created in January 1999, including TIA from the US, ARIB and TTC from Japan, TTA from Korea and CWTS from China.[959] According to Bekkers (2001, p. 503), the standardization work of 3GPP2 is more loosely defined than in other bodies.

8.2.6.2 3G Evolution: 3.5G

The 3G standards are evolving beyond their initial specifications. CDMA2000 was to be available in two variants: (1) "1x" which uses the same 1.25 MHz channel bandwidth as IS-95, and (2) "3x" which uses 3.75 MHz. In turn, "1x" was to be offered in two variants: (a) a data-only 1x variant under specification "1xEV-DO" (1x Evolution Data Only), and (b) a data plus voice variant "1xEV-DV" (1x Evolution Data/Voice). The cdma2000 1xRTT offers theoretical data rates of 144 kbps and 1xEV-DO best-effort packet-switched 2.4 Mbps. CDMA 1xEV-DV, as yet under development, will provide integrated voice and data, including real-time service at peak rates of 3.1 Mbps. The first 1xRTT networks services were launched (in Korea) in October 2000. CDMA2000 1xEV-DO was launched in 2002 by SK Telecom and KT Freetel. At the time of writing there are 63 CDMA2000 1X and 8 1xEV-DO commercial networks across Asia, the Americas and Europe, with a total of more than 60 million subscribers.[960] Table 8-6 summarizes the CDMA2000 evolution.

Table 8-6: CDMA 2000 Evolution

	CDMA 2000 1x RTT	**CDMA 2000 1x EV-DO**	**CDMA 2000 1x EV-DV**	**CDMA 2000 3X**
Main features	Backward compatibility with cdmaOne 2*voice capacity of cdmaOne 144 kbps data rate	Separate data carrier 2.4 Mbps best-effort downlink data	Integrated voice and data Real-time data 3.1 Mbps peak data rates	n/a
Introduced	October 2000	2002	n/a	n/a

Sources: Compiled from CDG (2002), Kasargod et al. (2002) and Lindmark (2002).

CDMA2000 could possibly establish itself as the preferred technology in another niche – coverage of a large area with few base stations. Qualcomm has implemented its CDMA2000 1X-system in the 450 MHz spectrum for covering large areas in Romania.[961] Possibly, large areas could be provided with Internet-connectivity at a relatively low cost with such an approach. Some European countries, e.g. Sweden, are likely to release spectrum in the 450 MHz band for digital cellular services.[962] CDMA2000 is a strong candidate for delivering such services.

Although arriving later on the market, the WCDMA/UMTS technology is also evolving beyond its initial launch status (see Table 8-7). Its future development can best be projected by following the standardization activities. UMTS is standardized by 3GPP. 3GPP UMTS

[958] 3GPP (1998; 2001a,b). For an elaboration on the creation of 3GPP see Rosenbrock (2001). Since then, the release numbering system has changed. Release 2000 (frozen in March 2001) was renamed Release 4.

[959] See e.g. Bekkers (2001:503) and information from http://www.3gpp2.org [accessed November 21, 2001]

[960] Compiled from CDG (2002), Kasargod et al. (2002) and Lindmark (2002).

[961] Hanganu (2002)

[962] See http://www.pts.se/Nyheter/pressmeddelande.asp?ItemID=2455 (in Swedish) [Accessed August 29, 2003]

specifications are continuations of GSM specifications. GSM specifications were released in two phases (Phase1 and Phase 2), after which additions (labelled GSM 2+) to the standard were specified in yearly releases (Release 1996-1999). The initial UMTS specifications were included in Release 99. In September 2000, the concept of yearly releases was abandoned in favour of content-based releases offering defined added functionality. Thus, Release 2000 was split into Release 4 and Release 5 with target freeze dates of March 2001 and June 2002 respectively.[963]

Two of the most important features of Release 5 are High Speed Download Packet Access (HSDPA) and IP Multimedia System (IMS). HSDPA, high-speed data delivery to 3G terminals, ensures that users requiring effective multimedia capabilities benefit from data rates previously unavailable because of limitations in the radio access network (the link between the user's terminal and the base station). Using packet technology, HSDPA delivers[964] dramatically increased data rates, meeting the needs of the most demanding multimedia users.

Table 8-7: UMTS/WCDMA Evolution

Release	R99	Rel-4	Rel-5	Rel-6	Beyond Rel-6
Freeze date	March 2000	March 2001	June 2002	c. 2004	n/a
Main features (examples)	- Basic UMTS e.g. - UTRA in FDD and TTD modes - New codec	- Low chip rates TDD -	- IMS (all IP) - HSDPA(> 3MBps in downlink)	- WLAN interworking - DRM - Broadcast service - Speech recognition	- New modulation techniques? - New spectrum arrangements?
Commercialization	Oct. 2001	2003	2005?	n/a	n/a

Sources: Compiled from http://www.3gpp.org/specs/releases.htm, ETSI (011024), 3GPP (2003), UMTS Forum (2003), ETSI (2003).

The IP Multimedia System (IMS) will enable the UMTS to benefit from the use of Internet Protocols (IPs) and, as a result, to offer users, operators and service providers the sorts of service capabilities that IP is designed to provide. These include access to Internet and multimedia content. IP offers a number of attractions over traditional telecommunications protocols: in addition to representing a bridge between the telecommunications and Internet worlds, it also offers a "seamlessness" of communication over many different types of networks. This facilitates a wide diversity of communications scenarios, including various combinations of fixed and mobile, wired and wireless networks, the specific characteristics of which are of no interest to customers. As a result, customers will experience extremely flexible telecommunications, irrespective of the various networks over which their calls may pass. IMS will use the emerging IP version 6 (IPv6), considered by many to be substantially superior to the current, widely deployed version 4 (IPv4). The use of IMS in 3G systems will be optional, but is expected to be seen by operators as an attractive choice for enhancing 3G packet mode operation.[965] [966]

[963] http://www.3gpp.org/specs/releases.htm [Accessed October 19, 2003]

[964] See e.g. Nokia (2003).

[965] See e.g. ETSI (011024), 3GPP (2003), UMTS Forum (2003), ETSI (2003).

[966] The TDD TD-CDMA development is not entirely clear to the authors at this writing.

Clearly, cellular 3G systems are evolving beyond their initial releases, e.g. in the direction of providing increasingly high data rates. The costs for achieving these data rates will be dealt with in the following chapter on the commercialization issues connected with 3G.

8.2.6.3 Commercialization of 3G

In 1999, the licensing procedures for 3G started. In Europe, the regulatory framework stipulated by the Commission urged member states to take the necessary actions to introduce UMTS[967] and to establish a licensing framework no later than January 1, 2000.[968] However, the licensing procedure was left open to the member countries, which led to highly debated variations in mechanisms for awarding the licenses (in terms of e.g. auction vs. beauty contests, bidding procedures, number of licensees, duration of licenses, fees, spectrum assignment approaches, conditions for access to 2G networks, see e.g.Table 8-8).

In March 1999, Finland started the process by licensing four UMTS operators by means of a so-called beauty contest (i.e. a comparative bidding procedure). The UK conducted an auction procedure in the spring of 2000 yielding total value of 30 billion pounds. Similar auctioning occurred in a number of countries, e.g. Germany, while other countries such as Sweden were conducting beauty contests.[969]

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[967] In response to pressure from the US, the Commission did not mandate UMTS as 3G technology; other IMT-2000 standards could be implemented as long as at least one licensee used UMTS. (Bekkers 2001:493.)

[968] Bekkers (2001:493).

[969] See e.g. Bekkers [2001:514], European Commission (2001), UMTS Forum (2001), Björkdahl & Byström (2001) and Cellular News (2001).

Table 8-8: 3G licenses in selected European countries (as of autumn 2001)

Country	Date	Licensing mech.	# lic	Yield (bill. €)	Yield/ cap. (€)	Licensees	Notes
Finland	March 1999	Beauty contest	4	0	0.001	Sonera, Soumen 3G, Radiolinja, Telia	No specific obligation
Spain	March 2000	Beauty contest + payment	4	0.5	13	Telefónica, Airtel, Amena plus Xfera.	Due to start August 2001, but delayed
United Kingdom	April 2000	Auction	5	39.6	649	Four incumbents plus Hutchinson 3G.	80% of pop. cov. by end of 2007
Isle of Man	n.a. (spring 2000?)	No contest	1	0	0	Manx telecom (BT subsidiary)	Announced 1st launch in May 2001. Delayed.
Netherlands	July 2000	Auction	5	2.8	170	4 incumbents plus 3G-Blue	
Germany	Aug. 2000	Auction	6	51.3	618	4 incumbents plus Group 3G and MobilCom	25% by the end of 2003; 50% by the end of 2005
Italy	Oct. 2000	Auction	5	11.3	256	3 incumbents plus H3G, Ipse	
Portugal	Nov. 2000	Beauty contest	4	0.4	44	Telecel, Optimus, TMN, OniWay	20%>1yr; 40%<3 yrs; 60%>5yrs
Austria	Nov. 2000	Auction	6	0.8	101	Connect Austria, H3G, max.mobil, Mannesmann 3G, Mobilkom Austria, Telefonica 3G	12 packages of 2x5 MHz and 5 packages of 1x5 MHz
Norway	Nov. 2000	Beauty contest	4	0.05	14	Telenor, Netcom, Tele2 Norge	One licensee withdrew
Poland	Dec. 2000	Auction	4	0.8	23	Incumbents	3 applicants, 4 lic. Postponed.
Switzerland	Dec. 2000	Auction	4	0.15	22	3 incumbents + Team 3G	
Sweden	Dec. 2000	Beauty contest + payment	4	0.05	Dep. on market	Europolitan, Tele2, HI3G and Orange	Annual percentage fee. Full coverage by end 2003.
Belgium	Feb. 2001	Auction	4	0.5	44	Incumbents	A 4th license to be issued later.
France	July 2001	Beauty contest + payment	4	9.8	166	Incumbent: Itineris (France Telecom) and SFR (Cegetel).	Conditions n.y.d. two further licenses
Greece	July 2001	Auction	4+	varies	varies	3 incumbents (only 3 participants)	Fixed + variable (5% of turnover) fee
Denmark	Sept. 2001	Auction	4-6	0.1	c. 120		Sealed bid, winner pays for lowest bid

Sources: European Commission (2001), UMTS Forum (2001), Björkdahl and Byström (2001), Cellular News (2001).[970]

The high sums paid for licenses, in combination with high costs for building up infrastructure (and the market), worried many observers, who claimed it would have a potentially negative impact on the take-up of 3G services in Europe. In order to raise capital, operators had to enter into expensive loans, emit shares or use vendor financing. Indeed, by 2002 the telecom sector was facing a crisis, with operators and suppliers reporting huge losses and debts, and as a result stock prices were plunging. This crisis was partly caused by the 3G licensing procedures.[971]

As a result of the 3G auctions, operators found their debt burden increasing tremendously, while at the same time their market caps slumped. Financial markets reacted with skepticism, in particular concerning operators' ability to perform in accordance with expectations set forth

[970] Updated information available at e.g. http://www.umts-forum.org/servlet/dycon/ztumts/umts/Live/en/umts/Resources_Licensing_index.

[971] See e.g. the Economist (2002).

in business plans and other reports, and due to the bad balance sheets and high debt burdens. As a result, credit ratings were downgraded drastically (as shown in Figure 8-4) at a time when operators needed funding to ensure 3G network and service rollout.[972]

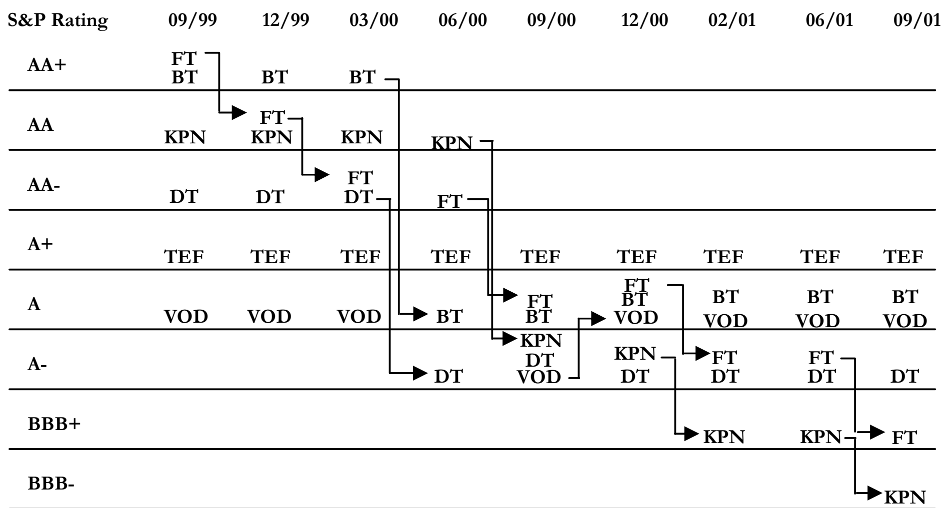

Figure 8-4 Comparative credit ratings of major European telecommunications operators, 1999-2001.

Source: Björkdahl et al. (2002) based on Standard & Poor's.

Most operators had to change their strategies to focus on reducing debt burdens, secure profitability and to consolidate, rather than to expand. Operators had to:[973]

- give priority to strengthening their balance sheets
- divest non-core businesses
- find new revenue sources
- seek Capex reduction for 3G investments, for instance through network sharing, delay investments and roll-out plans
- abandon plans for international expansion

The changed strategies of the operators turned the market upside down. Infrastructure suppliers found their order books shrinking dramatically. Faced with a cost structure suitable for a market in exponential expansion, suppliers' profits were turned into huge losses.

Service and application developers were also affected by the financial market and the delayed 2.5G and 3G markets. The market delays affected their revenue streams in business cases. When the financial market stopped investing in ICT, most mobile Internet start-ups, involved in developing new services, found no capital to cover their operations and many went bankrupt.

Meanwhile 3G commercialization was further delayed not only as a result of operators' changed strategies, but also due to technical problems (software stability in network nodes, interoperability between network node in case of different suppliers, interoperability between networks and terminals and handover and cell reselection between 2G and 3G), general

[972] Northstream (2002) and Björkdahl et al. (2002).

[973] Northstream (2002). See also Björkdahl et al. (2002) for an elaboration.

uncertainty regarding terminal availability, site acquisition, and availability of services distinguishing 3G from 2G.[974]

Only one European operator, "3" controlled by Hutchison, pushed forward with an aggressive 3G roll-out and operation – see Table 8-9 – initially focusing on video services including three rather heavy terminals (two NEC models and one Motorola, later adding one more of each brand). Since then, 3 seems to have experimented with differing offerings, new pricing schemes, terminal subsidies etc.[975]

Table 8-9: 3G introduction in Europe (as of Oct. 2003)

Country	3G Operator	Date	Subscribers (Late 2003)
UK	3	May 2003	210'
Italy	3	March 2003	340'
Austria	mobilkom austria	April 2003	n/a
Austria	3	May 2003	15'
Sweden	3	May 2003	15'-20'
Denmark	3	October 2003	n/a

Source: http://www.umts-forum.org, http://www.3gtoday.com/operators, and http://www.3gnewsroom.com/html/stats/index.shtml, NyTeknik 2004-01-21

In the US, PCS operators occupy most of the IMT-2000 frequency spectrum. The US Department of Commerce aimed to finalize spectrum options by autumn 2001, in order to begin licensing by late 2002, but these auctions were postponed. Some further spectrum may be allocated specifically for 3G services, in either the 1.7 GHz or 2.6 GHz band. The US 3G situation is not entirely clear to the authors at this writing. However, it seemed plausible that PCS operators would have the option to introduce 3G services based on standards of their choice, presumably CDMA2000, UMTS and EDGE. Meanwhile, several US operators had begun implementing and offering 2.5 generation services.

However, it was not Europe but Japan that moved first. NTT DoCoMo was the first operator to launch its FOMA 3G services based on W-CDMA. The commercial launch was delayed, perhaps not surprisingly, because of an immature network and lack of terminals. In October 2001, FOMA was commercially launched in high-population areas with moderate success. In the spring of 2002, KDDI launched 3G services based on cdma2000 1X, an upgrade of cdmaOne, having less expensive roll-out costs, a larger number of cheaper terminals, and roaming with cdmaOne. Accordingly KDDI's services took off much more rapidly than FOMA (see Figure 8-5). J-Phone launched 3G services in December 2002.[976] In November 2003, DoCoMo revised its FOMA forecast upwards for the first time since launch,[977] a sign as good as any of an upturn in the market. Other signs include coverage approaching acceptable levels, better terminals, new attractive services and features.

[974] Northstream (2002).

[975] See e.g. http://www.3gtoday.com

[976] See Bohlin et al. (2003a) for an elaboration.

[977] http://www.3gnewsroom.com/3g_news/nov_03/news_3899.shtml

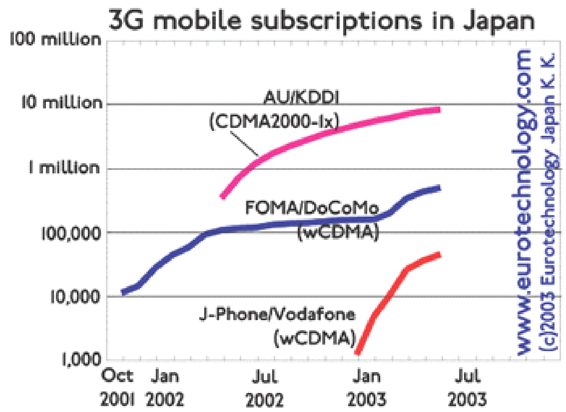

Figure 8-5: **3G subscribers in Japan**

Source: Eurotechnology.com.

In October 2000, South Korea launched the world's first commercial IMT-2000 3G network using CDMA2000 1X, and on January 28, 2002 it launched the world's first commercial CDMA2000 1xEV-DO service. Somewhat depending on the definition of a 3G service, CDMA2000 had taken the lead in terms of subscribers. By October 2003 there were 63 CDMA2000 1X and 8 1xEV-DO commercial networks mainly in the Americas and Asia, serving more than 60 million subscribers, of which more that 20 million in Korea and 10 million in Japan.[978]

Table 8-10: 3G technologies status (as of October 2003)

Network technology	Launch date	Subscribers (millions)	Operators	Terminal models launched
CDMA 2000	1 October 2000	60.5	51	299
CDMA 2000 1x EV-DO	28 January 2002	2.98	4	34
WCDMA/UMTS	1 October 2001	1.75	9	24

Source: Adapted from http://www.3gtoday.com/ [accessed 8 November 2003]

In the rest of the world, the adoption situation remains somewhat scattered and unclear. The Asian tigers, Australia and New Zealand, were well on their way towards commercialization and deployment of WCDMA/UMTS and CDMA2000 services. The situation in China remained unclear, also in respect to what technology to use. India has not made any commitments yet. African, Middle Eastern, Latin American and East European countries were also in varying stages of licensing procedures, deployment and commercialization of 3G systems. Although their commercial viability remains to be seen, 3G systems will very probably be commercialized in most parts of the world.

3G services offered vary greatly between operators. CDMA 2000 operators seem to focus on upgraded versions of their 2G services, while WCDMA/UMTS operators such as NTT DoCoMo and 3 initially marketed services that 2.5G networks could not deliver – mainly video telephony. While European 3G terminal models were still limited in numbers, NTT DoCoMo offered a wider and better performing range of terminals, not to mention the CDMA 2000 community, where terminal functionality and availability are on par with e.g.

[978] Bohlin et al. (2003b), http://www.cdg.org [accessed 8 November 2003] and http://www.3gtoday.com/subscribers/ [accessed 8 November 2003]

GPRS/GSM and other 2.5 technologies (we are aware that it is questionable to label CDMA 2000 1X a 3G technology, but the fact remains). Table 8-11 (see also Table 8-10) below shows the number of terminal models launched by manufacture in the different networks. Interesting to note are the absence of Nokia, the world market share leader in mobile handsets, and the overrepresentation of Asian manufacturers.

Table 8-11: Terminal models launched according to network and supplier

Supplier	WCDMA/UMTS	CDMA 2000 1X DV
Fujitsu	3	
GTRAN		2
Hyundai		2
KTF		1
LG		4
Mitsubishi	1	
Motorola	2	3
NEC	10	
Panasonic	4	
Samsung		18
Sanyo	2	
Sharp	1	
Sierra Wireless		1
SK Teletech		3
Toshiba	1	

Note: CDMA 2000 1x terminals are too manifold to count. Suppliers with many models are Samsung (86), LG (66), Motorola (18), Sanyo (16), Kyocera (15), Hyundai (10), Nokia (8), SK Teletech (7) and Toshiba (6). Sony Ericsson has launched four models.

Source: http://www.3gtoday.com/

8.3 Wireless Internet – the computer industry perspective

The term "wireless Internet" has received many meanings. It is often used to describe new services available over 3G networks, but also to denote the connection to Internet cordlessly over LANs (Local Area Networks). LANs connect end-user devices, such as PCs and work stations, to shared resources such as file servers, printers and application servers. The use of LANs is widespread in corporations and universities around the world, and is growing in home usage. In wireless LAN solutions, end-users communicate wirelessly between terminals and access points (base stations). Wireless LANs often perform worse than their wired counterparts when it comes to data rates and other performance parameters (e.g. error rate), while installation costs are lower and flexibility is higher.[979] This section describes the developments of wireless LAN, PAN (personal area networks) and WAN (wide area networks) markets and technologies.

8.3.1 Wireless LANs

In recent years short-range wireless data communications, such as wireless local area networks (WLANs) and even shorter range communication (sometimes labeled wireless personal area networks – PANs), have become increasingly popular.[980] The first experimental WLANs were created in the mid-1980s in the US, encouraged by FCC's opening up of three unlicensed frequency bands. In order not to interfere with industrial, scientific and medical (ISM) equipment operating at these frequencies, only low-powered spread-spectrum communication techniques were allowed. One of the pioneering solutions was NCR's WaveLAN, later acquired by AT&T/Lucent. A number of other firms (including Aironet

[979] Dhawan (1997, pp. 149-166) and Frost and Sullivan (1999).

[980] This section draws on Lindmark (2002), in turn based on Dhawan (1997), Padgett et al. (1995) and Pahlavan and Levesque (1994) unless otherwise stated.

Wireless Communications, Proxim, IBM and DEC) entered the market for these so-called ISM-band systems. At that time, WLANs were mainly conceived as a replacement for cables, applied under circumstances when cabling was impractical or expensive. In 1992, Europe opened up the 2.4 GHz band for wireless LANs. The same year, PCMCIA developed a standard interface for portable computers, facilitating production of WLAN adapters, which could then be made compatible with a range of computers. Still, air-interface standards were lacking at this time.[981]

Spurred by the rapid take-up of laptops in the early 1990s, Wireless LANs were increasingly deployed to provide *mobility* to LANs, often when cabling was impractical and costly. Mobile applications included providing connectivity for laptops, PDAs and other handheld devices in e.g. the health-care sector (hospitals, access to patient information), the hospitality sector, manufacturing plants and stock trading floors.[982]

In the mid-1990s, data rates of radio WLAN technologies were limited to some 1-2 Mbps. With infrared (IR) technology, higher data rates could be achieved. Hewlett-Packard, for instance, experimented with IR in its so-called ChipNet project during the early 1980s, but eventually abandoned this track. Commercial high-speed IR *networks* emerged in the late 1980s and early 1990s. By 1992, InfraLAN Acton could supply line-of-sight IR Ethernet (10 Mbps) and Token Ring (16 Mbps) systems, for single-room applications. Infrared had earlier been used for shorter-distance applications, for instance HP's calculator-printer applications in the mid-1980s. In the 1990s, IR ports became commonplace for notebooks and cellular phones. Industry experts postulated that IR ports would become commonplace for any electronics device, such as scanners, palmtops, cellular phones, pagers, printers, scanners etc., enabling point-to-point ad-hoc networks to be created anywhere. One limitation of traditional IR techniques, however, was that they had difficulties handling multiple simultaneous users. In the 1990s "flooding room diffuse" IR techniques were developed by e.g. IBM and Spectric Corp., which were claimed to overcome this limitation, thus allowing infrared WLAN networks. However, these systems were delivered at high costs (USD 5,000 for an access point in 1995).[983]

In the mid-1990s, IEEE started to specify standards for WLAN. These standards were dubbed IEEE 802.11 and were specified for the 2.4 GHZ band. About the same time, ETSI (European Telecommunications Standards Institute) started to work with HiperLAN standards for the 5.1 GHz band, promising much higher data rates. In parallel, a number of companies formed a wireless ATM working group, set up to establish standards for wireless ATM systems.[984] In early 2001, two major standards were under development: (1) HiperLAN2 and (2) IEEE 802.11a. HiperLAN2 was developed by ETSI/RES10 and backed by Ericsson, telecom operators (e.g. Telia) and the consumer electronics industry (e.g. Philips, Sony and Thomson). IEEE 802.11a was backed by the US computer industry and data communications companies, including also Nokia and Lucent (the dominant WLAN supplier). Using OFDM (Orthogonal Frequency Division Multiplexing) and operating in the 5 GHz band, both standards offer data rates as high as 54 Mbps. HiperLAN2 was designed to support real-time video and audio applications, aimed at residential applications. IEEE 802.11a was aimed at corporate IP-based services. HiperLAN2 has some technical advantages compared to 802.11a, including support for QoS, dynamic frequency and power control, and authentication and encryption support. The development of HiperLAN products was slow, however, with very few products

[981] Wickelgren (1996).

[982] Dhawan (1997:149-166).

[983] Wickelgren (1996).

[984] Wickelgren (1996).

launched in 2003. Today (2003), it seems as if IEEE 802.11a, originated in the computer industry, has out-competed the technically somewhat superior HiperLAN2 with roots in the telecom world.

A third IEEE 802.11 standard, 802.11g, can be seen as an enhancement of 802.11b. Operating in the same frequency band, and backward-compatible with 802.11b, but offering much higher data rates, it is a strong contestant to become the next step in the WLAN developments. The developments of the IEEE 802.11 standards continue. The new 802.11e standard, backward-compatible with 802.11b and g, will provide increased QoS functionality.[985] The standard is important for the possibility of providing delay-sensitive applications, such as Voice over Wireless IP and streaming voice and video applications. It seems that some of the HiperLAN solution was included in the IEE standards.

According to the market research firm Dell'Oro Group, the total WLAN market realized revenues of US$ 457, and the market revenues for WLAN enterprise-class access points/bridges reached US$ 121 million in the third quarter 2003.[986] The market research firm Synergy Research Group awards Cisco a 44.5% revenue market share in the Enterprise WLAN market worldwide in Q3 2003, followed by Symbol (15.3%), Proxim (6.8%), and 3Com (6.7%). In the SOHO (Small offices and homes) WLAN market, Linksys (acquired by Cisco) has a 21.3% market share, followed by D-Link (16.6%), NETGEAR (14.8%) and Buffalo (14.7%).[987] All of these companies are US-based, except D-Link (Taiwan) and Buffalo (Japan).

8.3.2 Personal Area Networks (PANs)

PANs are used to connect devices at even shorter distances than LANs.[988] Short-range data connections have often been handled using infrared links. In the late 1990s, infrared links were about to get competition from radio, most notably the Bluetooth standard. Bluetooth emanated from an internal project within Ericsson – the MC (Multi-communicator). The MC was eventually discontinued, but a sub-project, the "MC-link", was continued. Ericsson teamed up with Intel, and later Nokia, IBM and Toshiba, to form a Bluetooth Special Interest Group (SIG) in 1998. Bluetooth SIG had the purpose of establishing a worldwide *de facto* standard for short-range wireless communications. The proposed Bluetooth solutions (hardware- and software-based) would automatically synchronize mobile devices when end-users enter their offices or home. Bluetooth was designed to allow slightly less than 1 Mbps at ranges up to 10 meters. Since the start of this initiative in 1998, interest in Bluetooth has grown tremendously – in October 2003, some 2,900 companies had joined SIG.[989] In February 2001, Bluetooth Special Interest Group (SIG) released version 1.1 of the standard. This version was recognized as the first commercially viable release, and consequently more and more products were becoming available. According to a recent report from Frost & Sullivan, 70 million Bluetooth units will be shipped in 2003, up from 35 million in 2002, and 10 million in 2001.[990] This indicates that Bluetooth still has a huge potential, although not to the degree that was predicted by e.g. Ericsson.[991]

[985] http://www.nwfusion.com/news/tech/2001/0312tech.html, accessed on 031016.
[986] http://www.delloro.com/ accessed at 2003-11-17.
[987] http://www.srgresearch.com accessed at 2003-11-17.
[988] This section draws heavily on Lindmark (2002: 322-323).
[989] http://www.bluetooth.com, accessed at 2003-10-17.
[990] Frost & Sullivan (2003).
[991] Ritsell (2001), Nobelius (2000) and Sytoff (2001).

8.3.3 Public WLAN networks

An early version of a public computer network was the Metricom Ricochet network based in the San Francisco Bay Area. [992] Ricochet was a wide-area wireless radio network with a nationwide US wired backbone. The network, which operated within a license-free part of the 900 MHz band, consisted of small-sized radio transceivers, mounted to streetlights or utility poles. The micro cells require only a small amount of power from the streetlights themselves.

Metricom, founded in 1985, provided its Ricochet with modems, e-mail and Internet applications, and access to a regional mobile data system at a flat rate.[993] In 1997, the Ricochet service was available in San Francisco, Seattle, Washington D.C., and at a number of university campuses, airports and corporate campuses across the US. In the spring of 2001, the network had been expanded to more than ten cities across the continent, and 15 airports nationwide. A new high-capacity version (128 kbps instead of 28.8 kbps) of Ricochet was under deployment during 2000 and 2001. As for most mobile data services, take-up was slow. Ricochet grew from 17,000 subscribers in 1997, to 30,000 in late 1999 and 34,000 in late 2000, with the company reporting operating losses. In 2001 Metricom filed for bankruptcy, and the network was shut down.[994]

Around the turn of the millennium a number of actors emerged trying to build public WLAN networks, i.e. networks of hot spots – small areas with base station coverage in e.g. hotels, airports or cafes. A wave of start-up companies as well as established infrastructure suppliers and service providers began focusing their efforts into this market. In the US and parts of Northern Europe, service providers have rolled out public area wireless network access. The telecom operators, being threatened by new actors moving in to provide wireless access, started building their own networks of hot spots using IEEE 802.11b technology. The Swedish operator Telia, for example, has set up base station at 663 locations[995] under the name Telia HomeRun, and the British operator BT has launched the BT Openzone service, with 400 hotspots in the UK in June 2003, projected to increase to 4,000 by 2005.[996] The largest public hot spot operator is the Korean operator KT with 8,000 deployed hot spots in March 2003.[997] The German operator T-mobile is second largest with over 3,000 installations in the USA at airports and hotels, and in Starbucks coffeehouses and Border's Book & Music stores.[998] As seen in Table 8-12 below, TeliaSonera was the first operator in Europe to launch a public WLAN network in 1999. In spite of the economic downturn in recent years, operators have continued to invest in WLAN, and many networks were deployed in late 2002/early 2003.

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992 This section on Ricochet draws heavily on Lindmark (2002:319-320), in turn drawing on information as available on Ricochet's and Metricom's home-pages http://www.ricochet.net/ and http://www.metricom.com/ [accessed 12 December 1997, 6 May 2000 and 7 June 2001].

993 Lindmark (2002). The Ricochet modem (it weighed 13 ounces) plugged directly into a desktop, Laptop or PDA standard serial port. Subscribers to the Ricochet service can make modem connections anywhere within a coverage area. Ricochet modems can also communicate with other Ricochet modems on a peer-to-peer basis outside the service area. Modems are compatible with most software and hardware platforms and most communications software – eliminating the need for additional middleware.

994 http://www.phoneplusmag.com/articles/1a1whole3.html, accessed at 031015.

995 http://www.homerun.telia.com/eng/about/about_howitworks_coverage.asp, accessed at 031016.

996 http://www.bt.com, accessed at 031016.

997 Björkdahl and Bohlin (2003).

998 http://locations.hotspot.t-mobile.com/, accessed at 031016.

Table 8-12: European operators that have launched public WLAN

Operator and service	Country	Launch Date
Swisscom Eurospot	Europe-wide	March 2003
O2 Ireland	Ireland	February 2003
France Telecom/Orange	France (will spread across all subsidiary units)	February 2003
O2 Germany	Germany	February 2003
Westel Mobile	Hungary	December 2002
T-Mobile	Germany	November 2002
D2 Vodafone	Germany	November 2002
Connex Romania	Romania	November 2002
TDC Denmark	Denmark	July 2002
BT Openzone	UK	April 2002
Telefonica Moviles	Spain	February 2002
T-Mobile	Austria	November 2001
One / Ewave	Austria	October 2001
Telenor Mobil	Norway	February 2001
TeliaSonera Homerun	Sweden/Finland	Oct. 1999/June 2000

Source: Björkdahl and Bohlin (2003)

Some analysts and industry representatives have regarded public WLAN networks as a threat to the new third-generation cellular telecom networks. The take-up of public WLAN services usage has been slow, however. There are many possible explanations for this. One example is the prices; in Sweden Telia charged their customers a monthly flat rate of SEK 1500, too much for all but the most advanced users. Today, available subscriptions include a monthly flat rate of SEK 1744 (SEK 1869 for non-Telia GSM subscribers), or a monthly subscription fee of SEK 50 (SEK 188) with a variable SEK 2.50 per minute charge (SEK 3 per minute).[999] Another barrier to wider diffusion is the lack of standards in billing solutions. With actors using proprietary, non-compatible solutions, roaming is difficult and users are confined to a single operator. With the underlying idea of WLAN access being high-speed Internet connections at convenient locations, the small number of access points provided by each operator severely impedes user utility.

An initiative to bring a solution to interconnection problems is StockholmOpen.net. The WLAN network StockholmOpen.net was created by the IT University, the city of Stockholm, Stokab and Svenska Bostäder in 2001 (Sundelin, 2001). The network is an effort to create an open communication environment in the Stockholm area. The vision is to provide wireless access for everyone in the area to use, and for all ISPs to connect to. In October 2003, the network comprised 82 access points.[1000]

Another kind of public WLAN networks has been built by consumers themselves in recent years. Movements of people setting up hot spots in their homes and making them accessible to a wider public have appeared. By reporting the locations to membership sites on the Internet, WLAN connection is provided free of charge at a vast number of locations around the world.

8.3.4 Wireless Metropolitan Area Networks – expanding the reach

The computer industry is now moving further into the territory traditionally occupied by actors in the telecom industry. Accenting this trend is the fact that as much as one third of the

999 http://www.homerun.telia.com/eng/about/about_howitworks_pricelist.asp, accessed at 031016

1000 http://www.wan.it.kth.se/sysMonitor/ap-status.php, accessed at 031029

R&D staff at the semiconductor company Intel work with wireless communication technologies.[1001] The advances in semiconductor and computing technologies lead to more intelligent devices, longer reach from base stations, higher bandwidths, and ability to allow more users to share the existing bandwidth.

New standards in the broadband wireless access area were published in April 2002, called IEEE 802.16, or WiMAX (with a second version, 802.16e, in April 2003).[1002] [1003] The WiMAX standard allows for megabit speed connections for hundreds of simultaneous users per cell over large distances, up to tens of kilometres. The main aim is to provide a low-cost alternative to DSL and cable TV modems. In addition, the technology could be a solution for backbone networks for so-called hot spots using other wireless communications standards. In a couple of years' time, however, mobility functionalities could be added to the standard, making it an option for broadband mobile communications. This explains the great interest from Nokia in the standard developments.

WiMAX products are expected to reach the market in 2004, and connection speeds of up to 128 Mbps over distances of up to 50 kilometres are expected.[1004] WiMAX has received heavy industry backing, with Nokia and Intel among the supporters. A competing wireless MAN standard, BRAN HA (Broadband Radio Access Network HiperAccess) or HiperMAN, is standardized by the ETSI. In July 2003, unified specifications for the two standards were presented, and some industry analysts believe WiMAX will eventually become the dominant force.[1005]

The IEEE 802.20, or Mobile-Fi, is another new wireless MAN standard. This standard is positioned as the solution for broadband data mobility. With support for terminal devices moving at high speeds, the technology poses a potential threat to today's mobile operators. According to ARC Associates, this is the reason why a power struggle in the 802.20 standardization group took place in June 2003. Executives from NTT DoCoMo and Lucent replaced people from smaller firms such as Flarion and Navini as heads in the working groups. It has been claimed that the shift of power ensures 802.20 does not gain ground against 3G or WiMAX.[1006] 802.20 is not anticipated to be ratified as a standard until late 2004. At that time, some of the limitations (e.g. mobility support) of WiMAX are expected to be solved, effectively making WiMAX and Mobile-Fi competitors rather than complements. Table 8-13 below provides a short comparison of different wireless PAN, LAN and WAN technologies available.

[1001] "Intel strävar mot en trådlös värld", Ny Teknik 031015, Niklas Dahlin.

[1002] "WiMAX: The Critical Wireless Standard". Monthly research report October 2003, ARCchart Ltd., Caroline Gabriel.

[1003] http://grouper.ieee.org/groups/802/16/pub/backgrounder.html, accessed at 031015.

[1004] "WiMAX: The Critical Wireless Standard". Monthly research report October 2003, ARCchart Ltd., Caroline Gabriel.

[1005] See e.g. ARC, October 2003.

[1006] "WiMAX: The Critical Wireless Standard". Monthly research report October 2003, ARCchart Ltd., Caroline Gabriel.

Table 8-13: Comparison of wireless LAN, PAN and WAN technologies

	PAN			*LAN*		*WAN*	
	Bluetooth	**802.11b**	**802.11g**	**802.11a**	**HiperLAN/2**	**802.16**	**802.20**
Frequency band	2.4 GHz	2.4 GHz	2.4 GHz	5 GHz	5 GHz	2-11 GHz, 10-66 GHz	Below 3.5 GHz
Max. data rate	1 Mbps	11 Mbps	54 Mbps	54Mps	54Mps	120Mbps	16 Mbps
Approx. range	10 m	100 m	Up to 100 m	100 m	100 m	50 km	15+ km
Portability /mobility	Portable	Portable	Portable	Portable	Portable	Fixed (later mobile)	High-speed mobile

Source: Pyramid Research, www.wi-fiplanet.com, ARCchart October 2003

8.4 Intelligent terminals – PDAs and Smart phones

The handset market is perhaps the most visible sign of the convergence between mobile phones, Internet and computers. Distinctions between products and groups of products become increasingly blurred and difficult to classify. While mobile phone companies such as Nokia and SonyEricsson are building phones with PDA[1007] capabilities, PDA manufacturers increasingly add communication capabilities to their products. Handspring, for instance, in 2003 has products based on the Microsoft Windows Mobile 2003 platform, with built-in triple band phone. This makes the products and companies, originating in two different industries, head-on competitors. This chapter investigates the early developments of PDAs and smart phones, and presents some of the issues lying ahead for the industry.

8.4.1 PDAs

The first PDAs emerged around 1993. The predecessors of PDAs were electronic organizers, pioneered by Psion, Sharp and Casio. These gadgets appeared in the mid-1980s, with functions including calendars and address directories. Apple broke new ground in 1993 when it launched the Newton MessagePad (the first product labeled PDA). Newton was a handheld computer with advanced features such as handwriting recognition and possibilities to exchange data with PCs and Macintosh. Apple wanted to create a standard, and licensed out hardware and software to competitors. However, the Newton and other PDAs largely failed to meet customer expectations, largely due to poor handwriting recognition and high price.[1008] Only some 100,000 PDAs were sold in 1993, and sales were dropping.[1009] Still, firms such as General Magic, Sharp, Motorola, Casio and IBM/Bell South entered this new market in 1994. In addition, electronic organizers improved their functionalities so that the distinctions between the products became blurred.[1010]

The breakthrough of the PDA market came instead in 1996, when Palm launched its Palm Pilot. The Palm Pilot was small and easy to use with a simple data-entry system. Just 18 months after introduction, Palm had sold more than one million devices and the PDA market changed from being perceived as a giant failure to a success.[1011] In 1999, 9 million PDAs were

[1007] Personal Digital Assistant (PDA).

[1008] McGahan et al. (1997) and PricewaterhouseCoopers (2001:310).

[1009] Apple withdrew from the market in 1998.

[1010] McGahan et al. (1997).

[1011] CNET (2000).

sold worldwide (of which 6 million in the US), Palm dominating with more than half the market. Palm also licensed out its software to e.g. IBM, Handspring (a Palm spin-off), Kyocera, Sony, Symbol, and TRG.[1012]

The soaring PDA market and increasing data communication capabilities of cellular phones and systems created a new industry for software. Because of its dominance in the device market, Palm's OS dominated the PDA OS market, but there were alternatives. In 1998, the dominant cellular phone manufacturers (Nokia, Motorola and Ericsson) teamed up with Psion in a joint venture labelled Symbian. This venture had the purpose of developing software standards for wireless smart phones and terminals, notably EPOC, an operating system based on earlier Psion versions. In 1996 Microsoft launched Windows CE for a wide range of small non-PC devices, including pocket versions of its major applications. Windows CE was reported to be ill-suited for use in handhelds, however, because of an overly complicated interface, slow performance and poor power management. In 2000, Microsoft launched a new version of Windows CE, the PocketPC operating system, adapted to small handhelds, and sponsored a range of products, e.g. HP's Joranda PocketPC, Casio's Cassiopeia and most successfully Compaq's iPaq. Microsoft also coined the term Handheld PC (HPC), typically with a clamshell design and a keyboard, with more features than palm derivatives. By 2000, Palm OS controlled some 66% of the market, with PocketPC at 20% and EPOC 6%. In addition, some products came with embedded Linux.[1013] In 2003, Microsoft's OS has become the dominant OS in the PDA market, with Palm as the runner-up. Between them the two companies held a 90% market share in the EMEA region in 2003 (see Table 8-14 below).

In the late 1990s and early 2000s, PDAs were launched with built-in wide-range communication capabilities. In 1999, Palm launched its Palm VII with built-in communications via Bell South's Mobitex network. In the following years most other competitors followed suit, adding communication capabilities to their products.

8.4.2 Smart Phones

Mobile telephones evolved from expensive, large, power-consuming vehicle-mounted devices to lightweight, cheap pocket telephones in the late 1990s and early 2000s. While the trend towards less expensive, smaller and easy-to-use devices continued, other trends were becoming visible. As a result of the convergence with data communications, mobile telephones became increasingly able to perform computing functions and communicate data. Screens were becoming larger and switched from black and white to colors. Input functionality became more adapted to data, by means of touch screens and word recognition programs. In 1996/1997 AT&T Wireless launched PocketNet data phones from Samsung and Mitsubishi.[1014] These phones could be classified as "smart phones". Smart phones was a term emerging about this time referring (roughly) to mobile phones with some added PDA, personal information management, data communications, e-mail or messaging capabilities, typically at this size of traditional phone, with a comparatively large screen. Concurrently, a product launched that attracted much attention was Nokia's 9000 Communicator, a hybrid between a cellular phone and a laptop. Other products that could be classified as smart phones were Alcatel's "One Touch" launched in 1998 and Qualcomm's pdQ launched in 1999.[1015]

[1012] PricewaterhouseCoopers (2001:325-326). Kyocera acquired Qualcomm's wireless hand-set business in early 2000, including its pdQ smart phone. Kyocera improved and re-branded it as Kyocera Smart Phone QCP 6035, combining a Palm OS handheld with communication (over CDMA and AMPS) and e.g. browsing capabilities. (PricewaterhouseCoopers 2001:325.)

[1013] PricewaterhouseCoopers (2001:318-392).

[1014] AT&T (1996a) and AT&T (1996b).

[1015] Yankee Group (1998).

Motorola announced a smart-phone model (MP) in 1998, but it never made the market. Ericsson launched a long-awaited smart phone, R380, in late 2000. Following the introduction of WAP, i-mode, GPRS and other standards and platforms, most large manufacturers had high-end products available that could qualify as smart phones.[1016] In 2003, most handset makers have introduced terminals with built-in cameras, color screens, organizers, advanced messaging functions, large memories etc.

The growth of the PDA market more or less came to a halt after 1999, with total PDA sales reaching around 11 million devices in 2003.[1017] The market for smart phones, with the same capabilities as PDAs, is still growing rapidly. According to the research firm In-Stat/MDR, less than 4 million smart phones were sold in the world in 2002, but more than 12 million will be sold in 2003, overtaking PDA sales for the first time.[1018] In Sweden, sales of smart phones increased almost 100% year-on-year in the third quarter of 2003 according to the company IT Research. Sales of handheld computers increased by 8.5 % in the same period.[1019]

In conjunction with the development of more intelligent terminals, the terminal value chain has been disintegrated. Ericsson, for example, produced its own phones and developed its own operating systems until the early 2000s. Today, Ericsson has placed the terminal business in a joint venture with Sony, with much of the production carried out by contract manufacturers. The company uses the Symbian operating system for its smart phones, with the user interface platform developed by UIQ, a Symbian-owned company located in Ronneby in southern Sweden. In some of the newer Nokia models, the media player from Real Networks is pre-installed, as are the visualization tools from the Swedish company Mediabricks. With increased computing power in the terminals a higher number of, and more diverse, applications can be added. This increases the product complexity, and terminal manufacturers have neither the skills nor resources to innovate in all parts. In this setting the operating system is becoming a more important part of terminals and a platform for external software developers, a development previously seen in the computer industry.

8.4.3 The battle for handheld OS positions

When phones were used mostly for making phone calls, and PDAs for calendar functions, there were a number of proprietary operating systems on the market. With increased convergence, and more complex applications, OS competition is intensifying in the handheld terminals industry. Microsoft, dominant in the PC OS arena, is trying heavily to establish a dominant position for its phone-enabled Windows Mobile OS. In addition, Linux-based OS is developed by some actors, catalyzed by political expressions of will to establish a system able to compete with Microsoft from e.g. China, Japan and South Korea.[1020] UIQ, Nokia and Microsoft are all developing graphical user interface platforms, licensed to phone manufacturers. According to figures from the market research company Canalys, Windows CE was the leading OS for data-centric handheld terminals in the EMEA (Europe, Middle East and Africa) region in the first quarter 2003, closely followed by Palm (see Table 8-14). Windows has gained in market share since Q1 2002 at the expense of Palm and other competitors. For voice-centric devices, Symbian has a whopping 91% market share in the region, with Microsoft as number two with only 7%. Since the market for voice-centric devices is growing much faster than the market for data-centric devices, it could be argued

[1016] See e.g. PricewaterhouseCoopers (2001:332-338).

[1017] "PDA, RIP – The next big thing that wasn't – or was it?" The Economist, October 16, 2003.

[1018] "PDA, RIP – The next big thing that wasn't – or was it?" The Economist, October 16, 2003.

[1019] "SonyEricsson växer inom handdatorer", Dagens Industri, 2003-11-04.

[1020] Asahi Shimbun (September 1, 2003).

that Microsoft has effectively been out-competed in the handheld arena. However, in September 2003 the world no. 2 handset manufacturer Motorola announced it would sell its shares in Symbian, and at the same time announced a partnership with Microsoft. The world no. 3 handset maker Samsung has also chosen to develop products using Microsoft OS. In addition, Microsoft has developed terminals together with OEM manufacturers, sold under 8 operators' brand names in 2003.[1021] All combined, these are strong indications for severe competition in the OS area in the coming years.

Table 8-14: Handheld terminal operating system market shares in the EMEA region 2002-2003

Operating System	Q1 2003 Shipments	% share	Q1 2002 shipments	% share
All devices[1022]	*1524630*	*100%*	*678580*	*100%*
Symbian	807270	53%	77810	11%
Windows CE	370530	24%	228810	34%
Palm OS	284840	19%	295170	43%
Others	61990	4%	76790	11%
Data-centric	*638650*	*100%*	*579650*	*100%*
Windows CE	308360	48%	228810	39%
Palm OS	270740	42%	284200	49%
Others	59550	9%	66640	11%
Voice-centric	*885980*	*100%*	*98930*	*100%*
Symbian	807270	91%	77810	79%
Windows CE	62170	7%	-	-
Palm OS	14100	2%	10970	11%
Others	2440	0%	10150	10%

Source: http://www.canalys.com/pr/r2003041.htm, accessed at 2003-11-04.

8.4.4 Asian manufacturers building strong positions

The launch of i-mode with sophisticated service possibilities has spurred Japanese handset makers to innovate and improve their products. Already in 2000 and 2001, Japanese handsets were more technologically complex than handsets in Europe and Sweden.[1023] Advanced features such as colour screens, data capabilities, JAVA capabilities etc. diffused more rapidly in Japan than elsewhere, since services making use of these improvements were introduced. Improved music and camera capabilities in handsets have directed mobile handset terminals on a road possibly leading to competition with home electronics manufacturers.

The technological lead of Japanese handset makers has only recently been challenged by European counterparts. Still, handsets released on the Swedish market in late 2003 are much less advanced than Japanese handsets. The screens and cameras have lower resolution, the music-playing quality is lower, and memory capabilities seem less developed. Although the European handset makers still hold a large part of the world terminal market, mainly 2G, the Japanese and Koreans have already gained valuable experience in building products for the third-generation mobile systems, and two Korean manufacturers are now among the top five handset vendors. As seen in Table 8-11, Japanese and Korean terminal manufacturers dominate the 3G market so far. The convergence with computing and home electronics,

[1021] BusinessWeek Online (October 15, 2003).

[1022] Data-centric devices: handhelds (non-wireless and wireless) positioned primarily for data. Voice-centric devices: pocket-sized devices positioned primarily for voice, with capabilities of adding OS-based applications.

[1023] See e.g. Northstream (2001c).

demanding new technological and marketing capabilities, will probably lead to further changes in the mobile handset actor system.

Table 8-15: Comparison of handset models launched on the Swedish and Japanese markets in 2003

Feature\series	505i (typical performance)	Sony Ericsson Z600
launch	May 2003	Q3 2003
colors	262,144 (main); 65,536 (sub)	65,536 (main); B&W (sub)
chords	64	32
screen size, inches	2.2	128x160 pixles
weight (g)	110	110
size	N/A	90x48x27
stand-by time	520h	200h
talk time	2h 15 min	6h
JAVA capabilities	Y	Y
camera	Y (up to 1.3M pixels)	Y (352x288 pixels)
data rates	28.8	N/A

Source: NTT DoCoMo homepage, Sony Ericsson homepage, www.gsmarena.com

8.5 The emerging actor system

Only a few years back, mobile communication services were mostly about connecting people through voice conversations. With the advent of more intelligent terminals, higher transmission capacity in the network, and new applications, focus has gradually shifted towards the provisioning of data services. This shift is similar to the shift that took place in the fixed communications business in the 1980s and 1990s, pushed through by the increased data communication in general and Internet usage in particular. Today, data traffic makes up the major part of traffic in fixed networks, and data usage in mobile networks is steadily increasing. Since there is much higher complexity involved in data-based service development and provisioning, the telecom operators can only be active in parts of the service value chain. This has made room for a number of new roles and actors, both occupying new spaces and performing tasks previously performed by operators.

A number of attempts have been made to analyze and visualize the roles and actors in emerging mobile value networks. The UMTS Forum (2002) has specified a number of generic roles for 3G service provisioning (see Table 8-16).

Table 8-16: Generic roles for 3G service provisioning

Role	Function
Network Operator	Provides access and transport services. A network operator is typically a 3G licence holder.
Content Aggregator	Performs the function recognized today as mobile portal. The key function of the content aggregator is to package and offer services from one or several content providers.
Content Provider	Provides services ("content" or applications) that add value to access and transport services. Value-added services can be produced by the content provider itself or purchased from others.
Billing and Collections Provider	A billing and collections provider issues bills (or the equivalent) and arranges for collection of payments from customers. In most cases this provider will also handle authentication, authorization and credit reservation.
Financial Institution	Handles financial transactions such as payments on behalf of other organizations. In most countries these institutions must hold a banking license.
Clearing House	A clearing house communicates the roaming records and/or settlements between visited and home domain "parties".
Authentication, Authorization and Credit Reservation role	This role is usually included in the billing and collections provider role, but it may be a separate role in some particular roaming scenarios.
Resellers	These perform the function of an agent between the network operator and end customers.
Advertisers	Offer advertisements or sponsored services.
Content Owners	Provide content providers with original content (do not interact directly in providing services).

Source: Adapted from Bohlin et al. (2003b)

These roles are expected to be present in all 3G networks, and combinations of the roles can be found in any 3G service offering. Some firms may perform many of the roles, and different companies can perform the same role for different services. The linear sequential dependencies seen in traditional mobile telecom networks are replaced by a number of parallel and interlinked value chains and systems, establishing a complex actor system.[1024] Table 8-17 presents seven parallel value chains, four concerning applications/service provisioning and three concerning enabling technologies, products and systems.

Table 8-17: Value chains in 3G service provisioning

Application/service value chains	
Network Transport	Network operators have traditionally integrated the whole network operating value chain, consisting of spectrum brokerage, mobile network transport, and mobile service provisioning. With advent of mobile virtual network operators (MVNOs), the transportation value chain has been disintegrated.
Applications Operation	The application environment includes application developers, systems integrators, and applications operators.
Content Provisioning	The content value chain consists of content owner, content providers and content aggregators (including portals).
Payment Processing	With the possible advent of mobile commerce, requiring a number of mobile financial services, other parties than network operators, such as banks, specialized billing companies, and mobile commerce platform vendors, may perform this activity.
Enabler value chains	
Network Equipment Provisioning	Infrastructure vendors such as Ericsson, Nokia and Motorola increasingly provide new applications and middleware (see next bullet) to complement their relatively standardized network equipment.
Middleware/Platform Provisioning	Middleware and platforms (e.g. WAP gateways, SMS gateways, mobile portal platforms, mobile commerce platforms) are becoming more important parts of the wireless value system.
Device Solution Provisioning	Terminal manufacturers try to establish end-user relationships, with built-in functions connecting users directly to their sites.

Source: Adapted from Bohlin et al. (2003b), in turn based on Yankee Group

[1024] Bohlin et al. (2003b)

According to Bohlin et al. (2003b), operators will still have an important “gate-keeping” role in the future, controlling both the underlying technological infrastructure and relationships with the users. However, the authors’ (Bohlin et al. 2003b) compilation of recent research in the field (Ballon et al. (2002); Fransman (2002); Wehn de Montalvo et al. (2003)) indicates that a number of trends and changes are becoming visible:

- Increased importance of handset and network vendors in the core value network, since these actors provide more platform and middleware functionalities.
- Although the operator still largely controls the billing relationship, it is no longer restricted to this role.
- Actors are still experimenting with business models for content provisioning, although the I-mode model (and the messaging model in e.g. Europe) have emerged as the most successful ones so far.
- Continued shift of R&D investments and activities from operators to terminal and equipment manufacturers. As operators keep decreasing R&D budgets, the relative importance of terminal and equipment manufacturers in R&D increases.
- Users are increasingly considered of importance in the value creation process.

8.6 A note on 4G

Although perhaps prematurely, the concept of 4G is gaining attention. However, it means different things to different actors. The 3G sponsors, in particular the European manufacturers and the European Commission, envision 4G as something replacing or building on 3G, perhaps 10 years into the future. A number of initiatives were taken (e.g. the WSI, WWRF) already within the 5th Framework Programme, continuing into the sixth.

Asian countries take a more aggressive industrial policy-driven stance, aiming to take over leadership. Japan and Korea have announced on several occasions that they will launch 4G earlier than 2010. China has publicly announced that it aims to take a leading position in 4G – and these countries cooperate. They also drive the process forward in international cooperative bodies (e.g. ITU and WWRF). Meanwhile, mainly in the US, the 4G vision is something different. It involves the organic growth of WPAN, WLANs, WMANs, the establishment of ad-hoc networks etc., made interoperable, also with cellular networks. This vision is driven by the computer, datacom and microelectronics industry, including firms such as Intel and Cisco as well as start-ups.

Inside firms, at universities, institutes, government-sponsored initiatives and forums, research progresses along a multitude of lines. To mention a few: deviceless communications (invisible devices); new user interfaces; personalized services and profiles; application adaptivity and service discovery to ensure continuous service; integrated micro-payment systems; ubiquitous communication; location- and orientation-dependent applications and services; new radio interfaces that increase the data rates, new modulation techniques; multiple antenna concepts; advanced signal processing; ad-hoc and multi-hop wireless access; software re-configurable radio; IP evolution driven by wireless; interoperability; roaming and handover between different access technologies via a seamless network architecture; satellites and other high-altitude platforms; layered structure of different access technologies; system support for privacy and security; energy efficiency; and a variety of spectrum issues including identification of the spectrum needs and the requirements for spectrum management, dynamic allocation, co-farming with military use and broadcasters, coexistence in unlicensed and licensed spectrum, etc. It is, however, far beyond this report to dwell further on these developments.[1025] Nonetheless, they need to be closely monitored.

8.7 Mobitex – The Swedish radio data industry

8.7.1 Background

The Swedish telecom monopolist Televerket developed Mobitex during the early and mid-1980s. It became the world's first *public* mobile data communications system. The following background factors were important for the start of the Mobitex development. (1) There was a substantial and growing private mobile radio (PMR) base in Sweden. Users of PMR systems suffered from several limitations such as poor frequency use, poor quality and coverage. (2) Coordinated efforts were conducted (e.g. the SARK investigation) with the purpose of improving this situation. (3) Televerket and some other PMR users, notably SOS Alarm AB (SOSAB, a support organization for emergency services), had a need of improving their internal PMR system for dispatching field personnel – MRT. (4) There was internal demand for developing alarm functionality for solitary field workers inside Televerket. These four areas eventually resulted in one project – Mobitex – to be developed in Göteborg.[1026]

8.7.2 Development of Mobitex

In 1980-1986, Televerket's Radio Division (Televerket Radio) developed Mobitex, mainly in the Göteborg area. The initiation of Mobitex could be described as a demand-pull. More general needs to provide mobile data communications and to make more efficient use of radio frequencies were other important driving forces. The project then grew as more applications were perceived and new functionality added. Soon Mobitex developed into a general public system for data communications. Until launch, Televerket had spent in the range of 200 man-years on the project. [1027]

While Televerket continued its development of the Mobitex system, other solutions for mobile data communications were developed elsewhere, in Sweden and internationally (see above). These were mainly customer-specific data over PMR and over cellular networks. In Sweden, SRA/Ericsson began developing such solutions based on its MRS 4000 system (a PMR system) e.g. for taxi operations. Volvo Transport Systems (VTS) had also developed a Taxi dispatch application called TAXI 80, partly in cooperation with SRA. In order to be able to compete with those systems (which addressed similar market segments), Mobitex was designed to include also dispatch speech, quick access, broadcasting functionality and low cost. Televerket approached potential suppliers, application suppliers and user groups, although with a lukewarm response, partly because of fear of cannibalization, low computing competence, and lock-in effects.[1028]

Televerket launched Mobitex in Sweden in 1986; however, take-up was slow due to a number of barriers. For example, technically the system was not quite ready for commercialization at that time. In addition, equipment manufacturers had no type-approved terminals available, applications were not yet developed and sales processes were complicated. An elaboration of these barriers can be found in Box 8-1. Therefore, Mobitex was not adopted as had been anticipated. The market development of Mobitex was disappointing to most of the parties involved. In the beginning of 1990, there were not more than 2,000 subscriptions in the

[1025] See instead Bohlin et al. (2003b).

[1026] Lindmark (2002: 260-264).

[1027] Lindmark (2002: 264-268).

[1028] Lindmark (2002: 268-269).

Swedish Mobitex network. Of these, most were test subscriptions or for Televerket's internal use – in fact there were almost no paying customers.[1029] Figure 8-6 shows the development of the number of subscribers in Sweden over time.

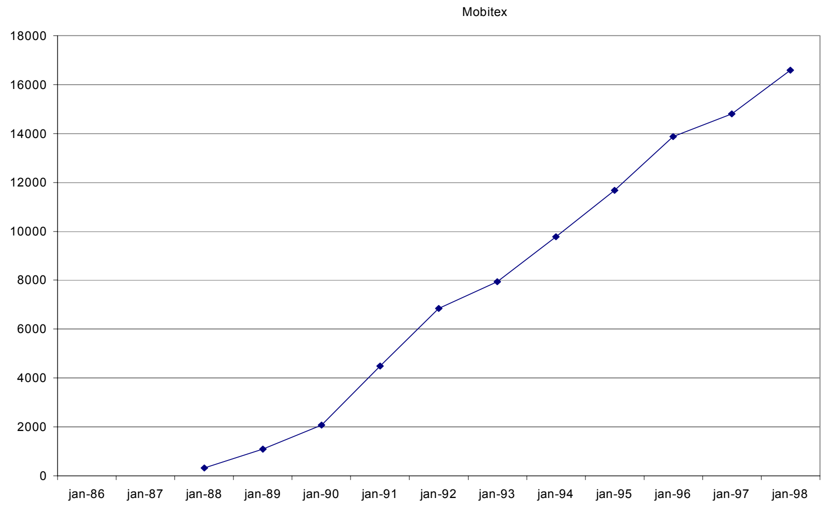


Figure 8-6: Number of subscribers in Televerket's Mobitex network

Source: Lindmark (2002: 280) based on statistics supplied by Bengt Sjölander, Telia Mobile

These figures were far lower than the overly optimistic forecasts. For instance, one forecast made in 1986 predicted more than 10,000 subscribers in 1990. All in all, the adoption of Mobitex has been a disappointment. There are several reasons for the slow diffusion; the most important are presented in Box 8-1: Main barriers to Mobitex diffusion.[1030]

[1029] On 1988-09-30 there were 1,057 mobile terminals, with another 2,245 signed up in contracts. (Televerket internal 881027.)

[1030] For a comprehensive analysis of barriers to Mobitex adoption, see Lindmark (2002).

Box 8-1: Main barriers to Mobitex diffusion

1) Lack of complementarities
   a) A lack of type-approved terminals
   b) A lack of applications
   c) A lack of competencies (including systems integration skills and Marketing skills and experience)

2) Limited demand for wireless access to fixed data communications (General computing competence among buyers and users was low)

3) The purchasing process:
   a) A lack of purchasing experience among potential customers.
   b) Unclear roles in purchasing process among potential customers.
   c) Lack of personal incentives, and sometimes even resistance, among potential users (truck drivers for instance).
   d) A Mobitex application often required large investment decisions and business process re-engineering.

4) Strength of substitutes
   a) An initial preference for PMR among most actor groups (customers and suppliers).
   b) Later, many actors halted investments and waited for future systems (e.g. GSM and TETRA)

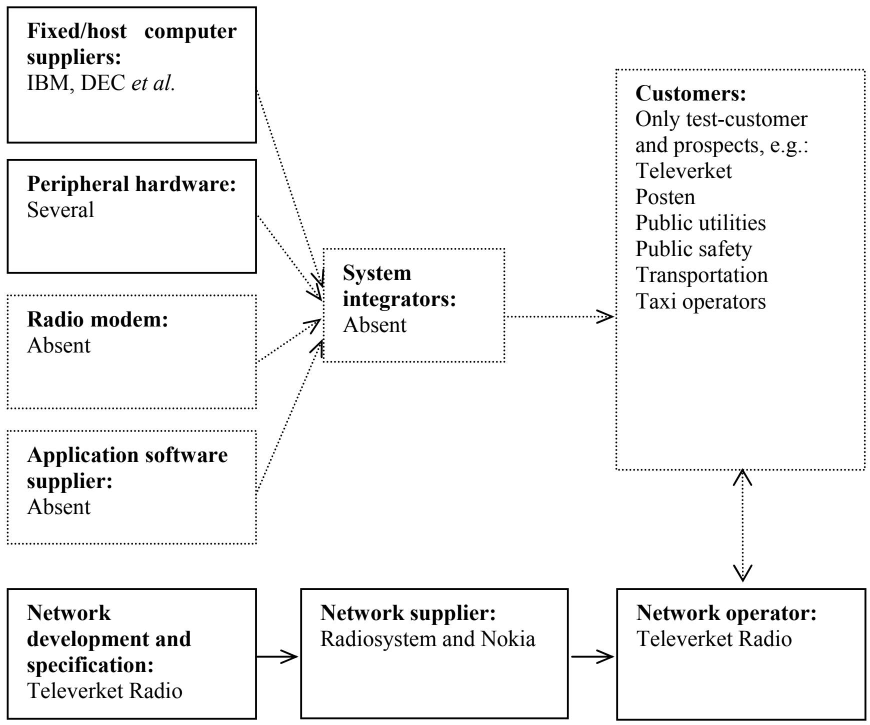
Source: Lindmark (2002: 420) based on a synthesis of interviews and documents

8.7.3 The Swedish Mobitex "innovation system"

Several of the explanatory factors for the seemingly slow diffusion of mobile data communications lay partly in the absence of complementary technical systems and actors in the actor system.[1031] Having identified the importance of complementary systems and the lack of commercial incentives to develop such systems for Mobitex, it follows that few actors were interested in engaging in complementary systems development. As opposed to the NMT case, the actor system linked to the Mobitex system was weak, if not incomplete when it came to certain actor categories and relations (especially application developers and system integrators). The market was slow to organize complementary developments, and the Mobitex sponsors did not fully realize how slow. One implication is that innovators need to have an innovation-system view, and try to manage the development of such innovation systems. We do not claim that the Mobitex sponsors were not aware of the problems – they were – but the difficulties in forming the actor system were clearly underestimated. The weak actor system and slowness of diffusion are in sharp contrast to one of the few success cases in mobile data communications: i-mode in Japan.

The varying roles of the most important actor groups of Mobitex, in 1990, can be categorized into: (1) network operators; (2) network suppliers; (3) mobile radio modem suppliers; (4) peripheral hardware suppliers; (5) fixed equipment suppliers; (6) application suppliers; (7) system integrators; and (8) end-customers. Figure 8-7 illustrates the actor network (and the holes in it as of the 1980s). These are briefly described below:

[1031] This section is based on Lindmark (2002) unless otherwise stated.



Legend:
Boxes contain sets of actors.
Dashed boxes and arrows indicate absence or weak (test) set of actors or relations.
Arrows indicate deliveries of goods, services or specifications.

Figure 8-7: The (incomplete) Swedish Mobitex actor system of the 1980s

The *network operator* constructs and operates the network, and sells services either directly to the user or via service providers. The network operator is often either a PTT or a new entrant. Televerket Radio, with its successors Telia Mobitel and Telia Mobile, was for many years the sole operator of Mobitex in Sweden.

The *network suppliers* develop, produce and sell network systems or components. Before Eritel was formed, Radiosystem supplied Mobitex base stations and Nokia Mobitex switches. Later, Ericsson was responsible for supplying the whole network, thus being network component as well as network system supplier.

The radio modem consists of the radio unit and necessary software and hardware enabling terminals/computers of the end-user to communicate with the network. *Radio modem suppliers* for Mobitex in Sweden have been Mobira (Autocom), Mitsubishi (Gadelius), Ericsson and Philips. Motorola delivered modems for the Mobitex network in the US. However, these were not ready until 1990.

Peripheral terminal equipment could be computers and all equipment interfacing with the end-users, such as computer keyboards, printers or screens, but also complementary equipment interfacing with other systems such as GPS terminals. For Mobitex, there have been several terminal equipment manufacturers, e.g. Microscribe, Symbol MSI, Ericsson, Autocom, Philips, VTS E-mail, Telxon, MCC and Gandalf.

Fixed equipment suppliers. In some applications, there has to be a host, or fixed computer. DEC, IBM mainframes or PCs have been those most commonly used. Moreover, someone has to supply interfaces including hardware and software.

Application suppliers develop and provide the software and hardware needed for application provisioning. Very few suppliers were interested in developing applications, as hints. All in all, roughly 30 application suppliers have been more or less involved in Mobitex, of which roughly 10 were active in the late 1990s.

Table 8-18: Mobitex applications and application developers in 1990

Company	**Product**	**Description**
AU-System Network AB	AVITEX	Software enabling a PC to be used as a fixed or mobile terminal connected to Mobitex
HT-Data	n.a.	Software for directing containers in harbors
TaxiTel and Mobitel [a.)]	Taxi 80 M	Taxi dispatch system
VTS (Volvo Transportation Systems)	Profleet	Transport planning system
Golfdata	n.a.	Result reporting from golf tournaments
Hego System AB	n.a.	Result reporting from horse racing
Teli	MOBIKEX	Tool for salesmen
Ingenjörsfirma Finn Frogge	n.a.	Application software for taxi
Hogia Data	Mobimail	PC program for traffic control
STS and Telelogic Uppsala AB	Mobimed	Remote diagnostics
Mobitel [a.)]	Planet	Planning system for personal transport
Mobitel [a.)]	CoordCom	SOS Alarm. System for rescue services, police civil defense, and security companies
Mobitel [a.)]	Best	Small taxi system
Orust Data	Orumob	Program for IBM S/3X, AS/Entry and AS/400

Notes: [a.)] Mobitel was a unit of Televerket that started out developing the CordCom application. Eventually the unit had some development responsibility for other applications, partly as a result of acquiring applications developed by Volvo Transport Systems

Source: Lindmark (2002)

The *system integrator* is responsible for delivering a fully functioning application to the customer. The system integrator could come from a variety of the actor groups above, most notably application suppliers such as Hogia, Transwere and PlanIT, but also units within Telia and even customers themselves have historically acted as system integrators.

Customers are companies and other actors involved which purchase and use of mobile data solutions based on Mobitex. Customers are not always the same as the end-user, but are not distinguished from the latter in this account. Leading customers as of 1997 are listed in Table 8-19. It can be noted that initial target groups such as rescue services, the police force, and transport companies did not adopt Mobitex to the degree expected.

Table 8-19 Mobitex customers and segments

Customer/segment	Applications	Users (1997)
Televerket	MOBIFLEX (dispatch, accessing databases, status reports, alarm)	2500
Posten	Dispatch, status report	2000
Public local transportation	Mainly GLAB's traffic control system	2100
Military	Dispatch	2000
Taxi	Dispatch, transport planning	1600
Police and rescue services	Dispatch, remote diagnostics, database access	2100
Transport companies/road carriers	Transport control, dispatch	3300
Energy	Dispatch, telemetry	450
Forestry	Goods tracking	600

Sources: Lindmark (2002: 299) based on Engvall and Svensson (1992) and statistics provided by Telia Mobile

8.7.4 Internationalization of Mobitex

Televerket perceived a need to develop the system further and to aim for the international market in order to reap economies of scale and recoup investments. For this purpose, Ericsson was contacted and somewhat reluctantly engaged. In 1988, Televerket and Ericsson formed the joint development company Eritel for further developing the system, and Ericsson took over the commercial responsibility (apart from operations in Sweden). Ericsson succeeded in marketing the system internationally, in competition with e.g. the similar DataTac system from Motorola. Especially important was a contract from RAM Communications (c. 1990) in the US. RAM (later acquired by BellSouth) became a lead-user and sponsor of Mobitex. It demanded a better-performing system (8 kbps) and has since been active in promoting the system internationally. In the mid-1990s, Mobitex was well on its way to becoming a Europe-wide *de facto* standard for mobile data communications. However, facing low-profitability business cases and competition from cellular and other systems, including false expectations on future enhanced versions of GSM (i.e. GPRS), some European operators closed down their systems.

BellSouth/RAM continued to pursue the Mobitex operations. In close cooperation, BellSouth and Ericsson developed a third generation of Mobitex, released in 1998, which allowed better coverage, longer battery lifetimes and faster radio access establishment, thus being more cost-effective and increasing the competitiveness with PMR and paging networks.[1032] These enhancements have been accompanied by and enabled new products such as RIM (Research in Motion) interactive pager and a Palm model (VII) with a built-in Mobitex modem. Similar devices and services were later launched over Cantel's Canadian network and also over other technologies.[1033] A similar device has also been successfully launched by Korean CNI, first on the Korean market.[1034] These developments have enabled Mobitex to grow substantially around the turn of the millennium (see Figure 8-8). The main growth can be attributed to RAM/BellSouth's network (recently renamed Cingular Wireless) as a result of a merger of BellSouth's and SouthWestern Bell's wireless operations. Cingular continued to enhance the network and launched Web-based platforms and application development tools. Palm

[1032] It should be noted that the Mobitex standard, since the launch of the system, has been under continuous development.

[1033] See e.g. PricewaterhouseCoopers (2001).

[1034] Kim (2001).

introduced the technology in new PDA models, as did RIM. By early 2002, there were more than 800,000 subscribers in Cingular's rapidly growing Mobitex network.[1035]

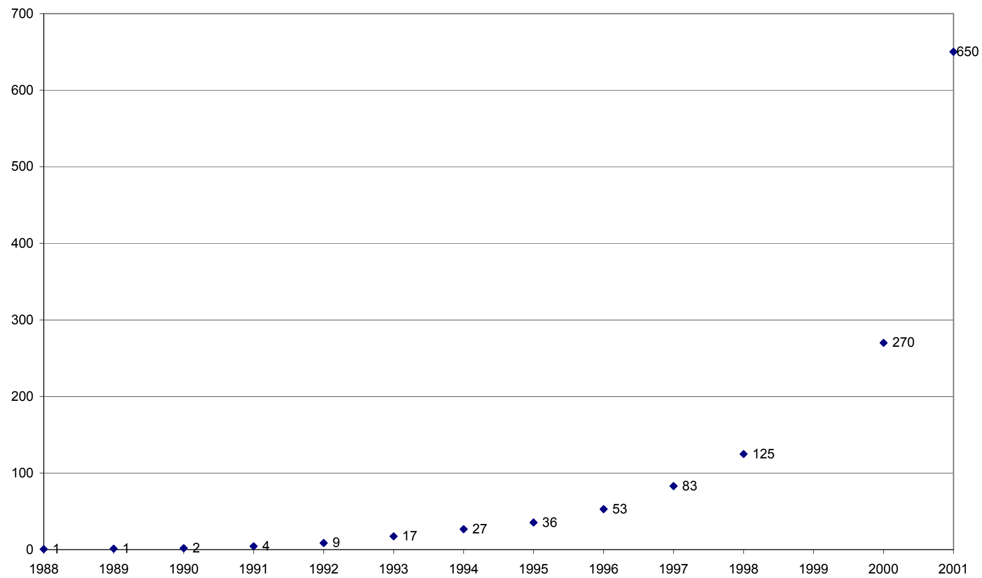


Figure 8-8: Total number of Mobitex subscribers (1,000 installed radio modems) in all Mobitex networks (beginning of years)

Source: Statistics provided by Ericsson. Note that some figures are the author's estimates based on graphs provided by Ericsson.

New markets and applications emerged, in particular private systems (for cost-efficiency and security reasons). Although not the idea behind Mobitex from the start, semi-private network features were launched in the new PMD 8000 standard. Also horizontal applications experienced a revival. New gadgets such as Palm, RIM, and CNI's products aimed for the horizontal market. In Hong Kong, Telecom Digital Limited (TDL) launched the first Mobitex 800 MHz network in late 2001. Key applications included e-mail, mobile Internet, stock trading, and sales force applications. Perhaps more importantly, China's MPT opened up the 800 MHz band for Mobitex in 2001. The same year, Ericsson signed with Chinese operator Sky Network to install a Mobitex network with a capacity for 500,000 subscribers initially, thus being the second largest Mobitex network in the world.[1036] Clearly, Mobitex has experienced a revival in the late 1990s and early 2000s.

Another trend was in the operators' profiles. In the early and mid-1990s, normal operators were established telecom operators or consortia dominated by telcos. These operators put forward business plans based on rapid expansion similar to that of mobile telephony. Later operators had to revise their expectations and business strategies, and focused more on vertical market segments and modest growth. New companies, not necessarily telcos, entered the market in somewhat new applications.[1037]

1035 Mobile Data Magazine (2/2002:7-8).

1036 Westfeldt (2001) and Larsson (2001b).

1037 Mobile Data Magazine (2/1998:20-22).

8.7.5 Domestic development 1990 – 2003

In order to obtain a positive operating margin, Televerket (1) concentrated its Mobitex operations to Göteborg, (2) halved the sales force in 1991, and (3) formed alliances with some partners (system integrators and application suppliers such as Hogia and HT-data) and supported them with advice, knowledge transfer and financial help. Partly as a result of these measures, partly as a result of the arrival of fully functioning applications, type-approved terminals, semi-generic applications, smaller terminals (Minitex) and increasing use of data communications among customers, Telia's Mobitex operations finally generated a positive operating margin in 1995.[1038] In 2003 Telia's Mobitex operations were transferred to the Swedish communications solution provider Multicom Security, 49% owned by TeliaSonera.[1039]

In Sweden, a company named Mowic established itself as a mobile data operator in 1997. Mowic used PMD 8000 technology in the 400 MHz Euroband. Often combined with GPS and GIS (geographic information systems), Mowic initially targeted traditional vertical markets such as building and surveillance, logistics and transport, governmental authorities and municipalities in the Stockholm and Göteborg regions. When Korean CNI launched a handheld computer for the 400 MHz band in 2001, Mowic started targeting office applications as well. The company faced funding problems during 2001,[1040] but was still active in 2003, when it e.g. received an order from Skånetrafiken.[1041]

The early packet-switching Mobitex developments laid the foundation for Ericsson's strong position in mobile data equipment today. Today's GPRS switching solutions, as well as WCDMA base stations for the Japanese market, are developed by Ericsson Mobile Data Design in Göteborg, the company responsible for the Mobitex developments. The importance of the mobile data knowledge and skills extracted from the Mobitex development was underlined in the recent Ericsson downsizing activities. In 2002, Ericsson closed down around 50 development centers worldwide, keeping 15 main and 15 supporting center, where Göteborg is one center responsible for 3G BTS for Japan, Minilink, Mobitex and Packet switches.[1042]

8.8 Mobile data over cellular systems in Sweden

8.8.1 Data in NMT

In Sweden, data over NMT was used in a few limited niche applications such as facsimile at Sweden-Finland passenger ferries. Televerket did not actively market data over NMT, and manufacturers were not very active in developing supporting products. In 1994 only a few terminal suppliers had accompanying modems on the market, among them Ericsson for its model NH-99. Such modems were priced at roughly SEK 6,500.[1043]

There was another means of using the NMT network for data communications. Signaling internal to the network took place in a separate channel, the signaling channel. Helsingborg-

[1038] Lindmark (2002: 287-288).

[1039] Telecom online (2003).

[1040] Sabel (2000) and Larsson (2001a).

[1041] Lewan (2003).

[1042] Sjögren, Sten (2002), "Göteborg utvalt för forskning – Ericsson skrotar ett femtiotal utvecklingsavdelningar världen över", Göteborgs-Posten 2002-06-11.

[1043] Lindmark (2002).

based Spectronic used this idea to develop mobile data communication products in the late 1980s.[1044] By 1992, Spectronic launched one of the first mobile terminals with built-in data communications and some computing functionalities. This terminal supported data communications at a rate of 600 bps in both directions (without having to use modems), by using the signaling channel of NMT. This signaling function in NMT was labeled DMS, and Spectronic's technique was accordingly labeled DMS 1200. The DMS service had some drawbacks; e.g. both communicating parties had to be equipped with a DMS-adapted terminal. Furthermore, the low data rates allowed only for short messaging, sending alarms and positioning information.[1045]

8.8.2 Early data in GSM

Data services over GSM were launched in Sweden simultaneously as in the rest of Europe. Telia of Sweden, for instance, launched its first mobile-originated fax/data services in May 1994. Europolitan introduced SMS[1046] in May 1994, and claims to have been the first operator to offer Internet access via the GSM network through its "europolitan@internet" service in early 1996.

Take-up of these data services was very low. This was hardly surprising since (1) there were few available applications, (2) public data communications diffusion was still fairly limited, (3) there was an initial lack of communications software, communications drivers and other necessary equipment, (4) services were difficult to use, (5) software and hardware were badly adapted to mobile radio conditions, (6) software and hardware were expensive, (7) performance of networks (data rates, set-up times, cost) was inadequate, (8) competence was low among users and distributors, and (9) promises of future systems led to waiting decisions among potential buyers.[1047]

8.8.3 SMS in Sweden

Also SMS diffusion was slow initially, for the reasons stated in Section 8.2.3, and started to increase significantly in the late 1990s. Figure 8-9 indicates this strong growth but also a maturing market. During 2002 each Swedish subscriber sent an average of 15 SMS in a month, of which 88% were sent by private customers.[1048] In 2002, SMS accounted for 8% of operators' ARPU; for private customers the corresponding figure was 12%.[1049]

[1044] Other sources claim that Sonera developed this solution. See http://194.251.250.241/telegalleria/english/historia/dms1.html [Accessed August 5, 2002]

[1045] Lindmark (2002: 329) based on interviews.

[1046] SMS – Short Message Service.

[1047] Lindmark (2002: 421).

[1048] PTS (2003a).

[1049] PTS (2003a).

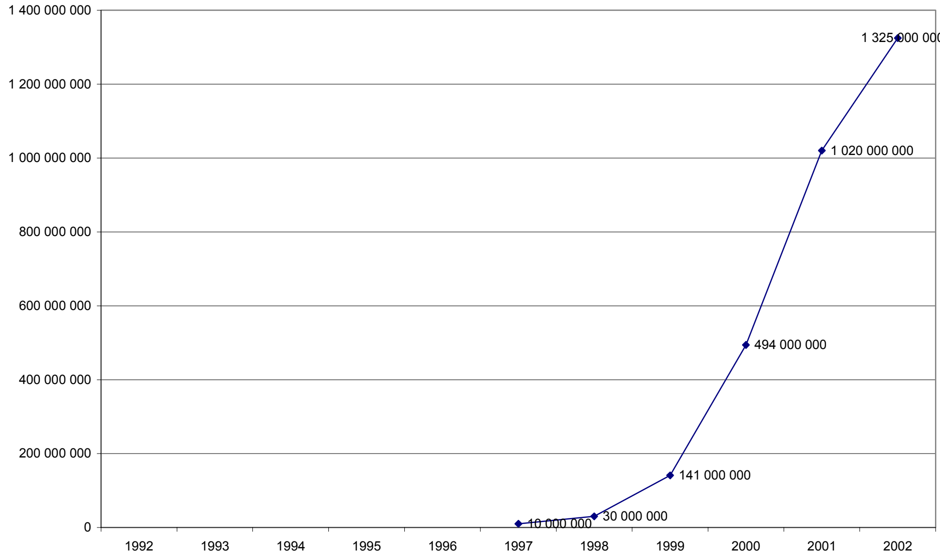


Figure 8-9 Yearly sent SMS in Sweden

Source: PTS and estimations based on Telia figures

These figures may at a first glance look impressive. However, in an international comparison they are not. While the Swedish SMS market appears to be approaching upper limits, it is still substantially lower than in e.g. Norway and Denmark (see Figure 8-10).

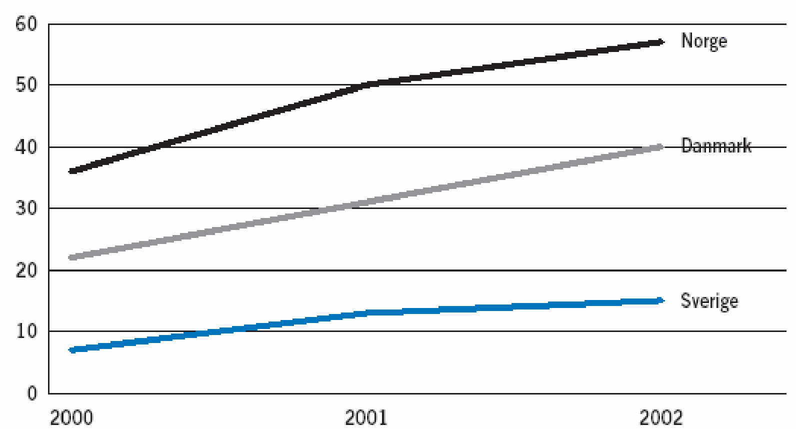


Figure 8-10: Average number of sent SMS in Sweden, Norway and Denmark

Source: PTS (2003a:31)

The price of sending an SMS went down from SEK 2.50 to 1.50 (on average) in early 2000 but has not changed since then, despite repeated complaints from PTS. In 2002, the normal price ranges from SEK 1.25 to 1.50 among the major operators, with some minor actors offering lower rates, for example Spray Smart Mobile and Universal Smart at SEK 0.95. Halebop offers a special subscription for SMS for SEK 49 per month that allows the subscriber to send as many SMS as he/she wants. By 2002, the average revenue per SMS (reflecting the price) was exactly SEK 1.[1050]

[1050] PTS (2003a) and Bohlin *et al.* (2003a) based on the contribution of S. Huthén.

Table 8-20: Costs of sending SMS in 2002

Operator	Cost per SMS in SEK
Telia	1.50
Tele2	1.25
Vodafone	1.50
Spray	0.95
Halebop	49 regardless of number SMS sent
Average revenue per SMS in 2000	1.31
Average revenue per SMS in 2001	1.09
Average revenue per SMS in 2002	1.00

Source: Bohlin et al. (2003a) (based on operators' web sites and PTS 2002a) and PTS 2003.

To some extent the lower usage in Sweden can be explained by higher prices. For instance, TeliaSonera charged SEK 1.50 in late 2002 in Sweden, ca. 1.15 in Norway (lowering to ca. 0.80 during spring 2003) and 0.60 in Denmark. At the same time prices are higher in Norway than in Denmark, but still usage is much higher, suggesting that other factors come into play. Northstream (2002b) analyzed the Norwegian SMS market and concluded that four factors contributed to high P2P usage in Norway (compared to Sweden). These were: (1) P2P was offered free of charge during first 6-12 months after launch, (2) the operators continuously marketed SMS services, (3) prices have been lower throughout the period, in particular in early stages, and (4) early interworking between operators.[1051] Notable is that Norwegian SMS revenues on average are three times higher than Swedish ones. Thus, not only is the user market less advanced; operators presumably trying to profit-maximize have failed to do so in Sweden. Important for this study is whether this fact leads to comparably negative dynamic consequences for growth and innovation. According to Northstream (2002b), and quite plausibly, the usage of P2P SMS will affect the use of SMS for delivery of value-added services – premium SMS.

Premium SMS and corresponding short numbers have been (2001-2003) a main vehicle for delivering content services. The three main operators launched premium SMS in autumn 2001.[1052] According to PTS (2002b), barriers to entry are too high for a content industry to develop. Content providers have been forced to pay relatively high entry fees and monthly fees. In addition, operators kept 30-60% of revenues. Operators also had an upper limit of SEK 30 on the price of premium SMS, excluding many possible services.[1053] PTS (2002b) concludes that these structures act as barriers to variety and use of mobile Internet service, and that these barriers may translate into barriers for the introduction of more advanced mobile data services, such as those delivered over 3G.

8.8.4 GPRS

GPRS was introduced by Europolitan/Vodafone in late November 2000[1054], followed by Telia and Tele2 in the fall of 2001. Different payment models were being tested; Telia started with two subscriptions: one with a high charge of SEK 300 per month that allowed 25 megabytes of communication, and one with a smaller charge of 100 SEK for 5 megabytes. Later Telia added a third service with a charge of 30 SEK per month and 0.5 megabyte. Halebop, a subsidiary of Telia, offered a rate of 0.05 SEK per kilobyte. Vodafone used subscriptions where it charged 12.50–20 SEK per megabyte. Tele2 charged 21 SEK per megabyte in its subscription Max, but the first three megabytes in a month are free. The operators'

[1051] Northstream (2002b).

[1052] Netsize (2003).

[1053] PTS (2002b).

[1054] Augustsson, Tomas, "Trög start för omtalad mobilteknik", Svenska Dagbladet 2001-01-18.

subscriptions with GPRS are more expensive than the basic mobile telephone subscription.[1055] In November 2001, Telia and Tele2 offered GPRS for free during some months to increase the number of subscriptions. In February 2002 Telia started to offer its subscribers GPRS roaming in the Nordic markets. Europolitan/Vodafone launched, in the spring in Sweden, a service with European roaming in the biggest European markets for the GPRS service.

Uptake of GPRS appears to have been slow. In Sweden, the total GPRS traffic amounted to 997 Gbyte in 2002, and total HCSD traffic reached 43 million minutes in 2002.[1056] In the first half of 2003 the figures were 1009 Gbytes and 19.7 million minutes respectively, indicating a doubling in GPRS usage, and stagnation in HSCSD usage.[1057] Although most new terminals were GPRS-capable, by Q4 2002 there were only 105,000 active users (reaching 199,900 in Q2 2003)[1058]. The percentage of active users was thus 1.3% (4.7% in the business segment, 0.6% in the consumer segment).[1059] No exact figures of GPRS revenues are provided. Assuming an average price of SEK 35/MB (this price is probably too high since a couple of MB/month is included in most subscriptions, and prices per MB in corporate subscriptions often are lower), GPRS traffic would have generated SEK 35 million in 2002. This corresponds to only 2.6% of total SMS revenues (1.3 billion) in 2002, indicating that mobile data revenues and SMS revenues were almost synonymous. The launch of data service packages such as Telia Go has led to an increase in GPRS usage, albeit from low levels. In Q3 2003 alone, the number of GPRS users in the Telia network increased from 100,000 to 150,000, with usage increasing even more.[1060] Drastic GPRS price reductions in late 2003 are expected to further catalyze usage. This could be compared with Japan where a majority of subscribers are actively using packet-switched services.

8.8.5 Mobile data service packages and portals

Although mobile data has long been considered an important growth area for Swedish operators, service take-up has been slow. The first packaged mobile data services on the Swedish market were launched by Telia in February 1998 under the name Telia DOF (Department of the Future).[1061] The DOF service introduction was aided by a large marketing campaign (SEK 21 million the first six months)[1062] targeting corporate customers.[1063] The package included many of Telia's existing services, but some were specifically developed for the DOF launch. The most notable were the unified messaging service developed in cooperation with Oracle, and the voice-controlled dial-up service where the phone book was placed on the network instead of in the terminals. The unified messaging service combined voice mail, fax, e-mail and GSM-text in one service. The users could choose which messages should be relayed to the terminals and which should be read through the web interface, and the phone number was used as e-mail address.[1064]

In 1999, Telia launched what it called the world's first public WAP portal, Mydof. The portal included services such as news from the daily Aftonbladet, TV4 and CNN, banking services

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[1055] S. Hulthén in Bohlin et al. (2003a).

[1056] PTS (2003), Svensk telemarknad 2002.

[1057] PTS (2003b).

[1058] PTS (2003b).

[1059] PTS (2003).

[1060] "Antalet gprs-kunder hos TeliaSonera upp 50 procent", Nyhetsbrevet Telekom, 2003-11-19.

[1061] Österlind 1998, Dof – och så försvann 21 miljoner, Vision, 1998-11-25.

[1062] Österlind 1998, Dof – och så försvann 21 miljoner, Vision, 1998-11-25.

[1063] Steneberg, Kristoffer (1998), "Telia miljoninvesterar på mobiltjänst", FinansTidningen 1998-10-15.

[1064] Karlberg, Lars Anders (1998), "DOF ska ge Telia tuffare image", Dagens IT 1998-02-04; and Sandred, Jan (1999), "Analytiker gör tummen ner men på Telias DOF är det glada miner", Datateknik 3.0, 1999-01-28.

from Föreningssparbanken, hotel booking, stock trading, horoscope and weather services, train and bus timetables, etc. The portal was developed by Telia and Oracle, utilizing the jointly developed software PANAMA, filtering web information to make it presentable on a mobile terminal.[1065] The technically advanced DOF service ran into quality problems, and in January and February 2000 Telia denied new customers, and instead focused on making the service stable.[1066] According to Computer Sweden (2003-05-26) the sale of DOF subscriptions targeting companies was cancelled in early 2003, when around SEK 1 billion had been invested in the project since the launch in 1998.[1067] The Mydof portal lived on, however. Table 8-21 below shows the most popular SMS and WAP services on Telia's portal MyDOF in October 2002.

Table 8-21: The most popular services on Telia's portal MyDOF

Rank	Type	SMS or WAP
1.	Weather	SMS
2.	Passagen Aktiekurser (Shares)	WAP
3.	My e-mail	WAP
4.	Aktiekurser (Share prices)	SMS
5.	Gula Sidorna Nära Dig (Yellow Pages)	WAP
6.	TT-Nyheterna (News)	SMS
7.	Föreningssparbanken (Bank)	WAP
8.	SF Cinema	WAP
9.	Find a Friend	WAP
10.	Bostad Nära Dig	WAP

Source: Telia as presented by S. Hultén in Bohlin et al. (2003a).

The DOF project mainly aimed at providing value-added telecom services to advanced users. In a move into mobile data services, Telia and Oracle launched the Halebop mobile portal in mid-2000. Halebop announced around 80 services available from the start, and the company had expansive plans with rapid internationalization.[1068] In August 2000 the company reported 100,000 users, although the ARPU was very low.[1069] The portal was acquired fully by Telia in September 2001, when the company previously operating the portal, Drutt, was transformed into a portal technology development company.[1070] In mid,September 2001, Halebop announced it would start operating as a virtual operator in the Telia network, selling mobile telecom services.[1071] Halebop reached 14,000 mobile prepaid customers in February 2002, and the number of members of the Halebop portal increased to 670,000 the same month.[1072]

In November 2000, Telia announced the launch of a new mobile portal project, Speedy Tomato. Through Speedy Tomato, Telia aimed at reaching customers in markets where the company did not yet have customer relations. The portal, built on the Wise technology provided by Ericsson, was to be launched on most European markets outside the Nordic countries, beginning with the UK.[1073] The portal was later launched in Italy, Denmark and Finland. In the fall of 2001, Telia coordinated work on its mobile portals in one organization, using a common technical platform. At the same time the Speedy Tomato operations in Italy

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[1065] Rittsell, Per (1999), "Världens första wap-portal öppen", Computer Sweden, 1999-09-20.

[1066] Holmström, Patrik (2000), "Nya problem för Telias prestigetjänst", FinansTidningen, 2000-05-16.

[1067] Danielson, Peter (2003), "Telia säljer Microsoftmobil – Efter fiaskot med Dof ställs hoppet till Microsoft", Computer Sweden, 2003-05-26.

[1068] Augustsson, Tomas (2000), "Mobil portal ska bli ny svensk exportprodukt", Svenska Dagbladet Näringsliv, 2000-05-10.

[1069] Söderlund, Peter (2000), "Halebop växer snabbare än planerat", Computer Sweden 2000-08-28.

[1070] Sjögren, Sten (2001), "Telia tar over Drutts mobile portal Halebop", Göteborgs-Posten, 2001-09-01.

[1071] "Därför ska Halebop sälja egna mobilabonnemang", Nyhetsbrevet Telekom, 2001-09-19.

[1072] "Halebop har 14 000 mobila kontantkortskunder", source unknown (VILKEN KÄLLA??)

[1073] Augustsson, Tomas (2000), "Telia i riskfylld mobilsatsning", Svenska Dagbladet Näringsliv, 2000-11-30.

and the UK were terminated.[1074] In June 2002, the operations in Denmark and Finland were also terminated, ending Telia's European mobile portal venture.[1075]

Europolitan (later renamed Vodafone) launched a WAP portal in late 1999, where customers had access to a number of information services. The portal was not a walled garden structure, but users could access any WAP site by simply typing the URL. The portal was accessible from both mobile terminals and the company website, where customers could configure which services they wished to have access to in order to present the information as easily as possible.[1076]

Following the advent of more capable terminals, with cameras, colour screens and MMS capabilities, new mobile data packages were launched by the operators. First out on the Swedish market was Vodafone, launching its mobile data package Vodafone Live! in late 2002, at the same time as in seven other countries. With the Live! introduction, the first terminals with operator preconfigured settings appeared on the Swedish market. Two camera-equipped mobile phones were branded Live! at the launch, with more terminals added gradually. The terminals used an icon-based user interface, ensuring ease of use for customers. Among the first services were MMS, news from Aftonbladet, sports news, ring tones and games.[1077] The preconfigured phones, with easy-to-use menus, marked the emphasis on usability; a customer with little mobile experience should be able to buy a phone, and directly start using it. The Vodafone Live! introduction was aided by a massive advertisement campaign in cinemas, magazines, TV commercials and billboards.

Telia launched its answer to Vodafone Live!, the Telia Go service package, in June 2003. The service targeted consumers and around 20 services were included from the start. In essence, it was a repackaging of the Mydof service package, and very few (if any) services were new at the Go launch. The service was sold with preconfigured phones, initially two models from Nokia and Sony Ericsson.[1078] In contrast to Vodafone, Telia did not put its brand on preconfigured phones; Telia's small size would simply make this too costly. While launching Go, Telia kept its Mydof service package, which was directed at more advanced users.[1079]

Following the branded service packages launches by Telia and Vodafone, Tele2/Comviq announced their mobile data service initiative in November 2003. The package was similar to Telia's and Vodafone's and, with a reference to its competitors, named Comviq Go Live!. Two preconfigured terminal models from Nokia and Sony Ericsson were sold with the service settings at the launch, and settings were available for download from the website for users with GPRS- and MMS-capable phones. Among the available services were weather from SMHI, news from Metro and Aftonbladet, horoscopes and games.

All three operators, Telia, Comviq and Vodafone, have announced their plans for migrating customers into their new 3G networks through the use of branded mobile data service packages. When the new networks are turned on, customers already using 2.5G services should be familiar with the 3G environment.

1074 "Telias mobila portaler får samma plattform", Computer Sweden 2001-09-19.

1075 Zirn, Tomas (2002), "Miljardrullning i den havererade jättesatsningen", Computer Sweden, 2002-06-05.

1076 "Europolitan lanserar öppen WAP-portal", Press Release, Europolitan, 1999-12-01.

1077 "Nya koncept från Vodafone gör det mobila livet enklare och roligare", Press Release, Vodafone Sverige AB, 2002-10-24.

1078 "Telia Go! ska göra det ännu enklare att använda mobila tjänster", TeliaSonera Press Release 2003-06-03.

1079 "Ahlbom, Helen (2003), Telia Sonera går live med Go", Ny Teknik, 2003-06-11.

8.8.6 MMS

Building on the success of SMS, the industry developed a messaging standard, MMS (Multimedia Messaging Service) integrating text, sound and images in messages. The Norwegian operator Telenor was the first in the world to launch commercial MMS services in March 2002. MMS services were launched in Sweden by Vodafone and Tele2/Comviq in October 2002, followed by Telia in December the same year. The operators Tele2 and Vodafone reached MMS interconnection agreements for their networks in the end of March 2003, with Telia included in the cooperation since April 2003.[1080]

Table 8-22: MMS offerings by Swedish operators

	MMS Launch	***Price (Nov. 2003)***	***Content-based services***
Telia	December 2002	SEK 3.80	Weather, Music Hitlist, Karaoke MMS
Tele2/ Comviq	October 2002	SEK 3.25	Post cards, Polyphonic ring signals, Champions League goal service, MMS Creator, Photo Album
Vodafone	October 2002	SEK 3.50 (1-30 KB), SEK 5.50 31-100 KB	Screen savers, Post cards, Fashion pictures, Polyphonic ring signals
3	May 2003	SEK 3.80	Images, Soccer Goal service

Source: Company websites

MMS was, and still is, widely seen as the application that would help operators to increase mobile data-usage ARPU figures. The price in Sweden was first set to around SEK 5, but to stimulate the use of MMS services, Telia offered the MMS service free of charge until June 2003[1081], Tele2/Comviq until August 2003, and Vodafone charged only SEK 1.50, roughly the equivalent of an SMS.

Apart from P2P MMS, content MMS services have emerged (see Table 8-22). In line with the diffusion of handsets with e.g. color screens, larger memory capabilities, JAVA functionalities and cameras, MMS-based services will become more sophisticated. This makes MMS an important part of operators' strategies to migrate customers onto 3G services. According to the magazine Computer Sweden, both TeliaSonera and Tele2/Comviq also introduced barriers in their networks, blocking MMS messages from independent providers from being delivered to their customers, in order to protect their investments. Both TeliaSonera and Tele2 state that the barriers are not a result of strategic considerations, but rather a question of caution before agreements on relations with independent MMS providers have been struck. Vodafone Sweden has not implemented any barriers in its network, but states that this too is not a result of strategic considerations; it has not yet taken any decisions in the matter.[1082] New independent MMS providers, such as the Swedish company Zidango, circumvent the barrier by sending their own MMS settings via SMS to users with TeliaSonera or Tele2/Comviq subscriptions, which hinders users from using the operators' MMS services.[1083]

[1080] Press release, 2003-04-15, TeliaSonera's mobile customers in Sweden can now send MMS messages to Tele2/Comviq customers, http://han16ns.telia.se/telia/thk/thkpre70.nsf/vNyhetEfocusEng/C6DFA22D13B6563441256D080036F8D6

[1081] Press release, 2003-04-15, TeliaSonera's mobile customers in Sweden can now send MMS messages to Tele2/Comviq customers, http://han16ns.telia.se/telia/thk/thkpre70.nsf/vNyhetEfocusEng/ C6DFA22D13B6563441256D080036F8D6

[1082] "Operatörerna dröjer med MMS beslut", Computer Sweden, 030416.

[1083] http://www.zidango.com accessed at 030729.

Little data on the usage of MMS services have been released by the actors, but the prolonged periods of free usage and MMS-capable terminals only recently becoming a mass market product indicate low usage in comparison with SMS.

8.8.7 Operators' data revenues

Considering the expectations on data as the future revenue driver, mobile operators' share of revenues generated from data traffic has become an important indicator. It can be used as a proxy of how far operators have come in moving their customers towards usage of data services, thus preparing them for the shift to a new data-based network generation (3G). Many operators have looked with envy on the successes of Japanese operators, with increased data usage in recent years, resulting in the ARPU decreases levelling off. As seen in Figure 8-11, Japanese operators are placed high up on the list of data as share of ARPU among operators (although Globe and Smart have considerably higher shares, but at low total ARPU level). When adding an average of Swedish operators to the figure (the red line), it is evident that Swedish operators have a considerably lower data usage than e.g. German, UK and Norwegian counterparts. Figure 8-12 shows similar figures specifically for Vodafone companies.

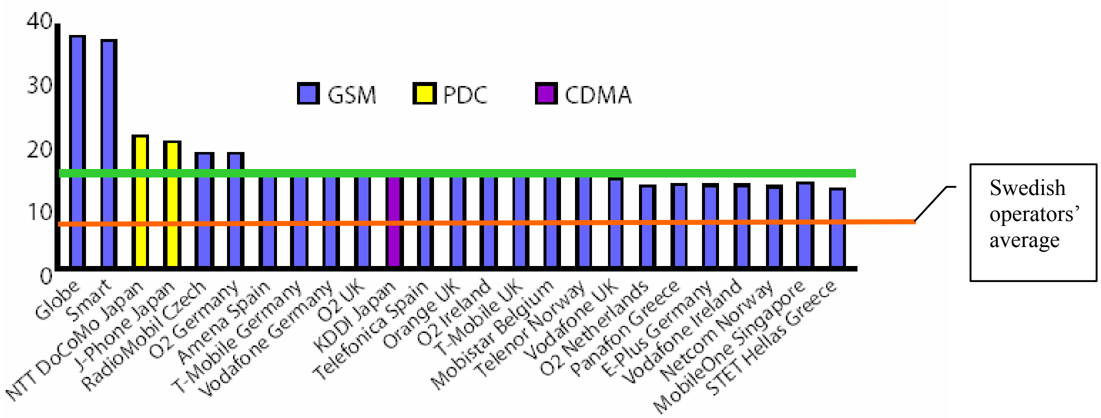

Figure 8-11: Data as percentage of operator ARPU (2002)

Source: Nokia (2003)

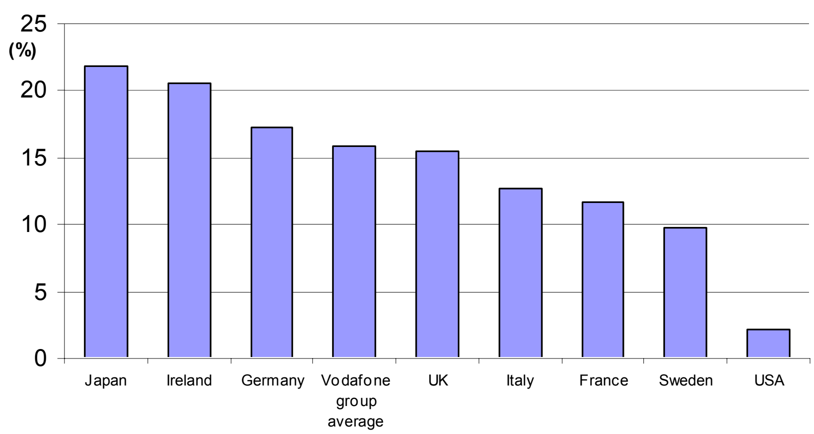

Figure 8-12: Data as percentage of operator ARPU (Vodafone and Orange 2003)

Note: France is Orange. Data for Sweden is estimated from data Vodafone "Northern Europe" and PTS data.

Source: Vodafone KPI Q4 2003 available at www.vodafone.com, and France Telecom website.

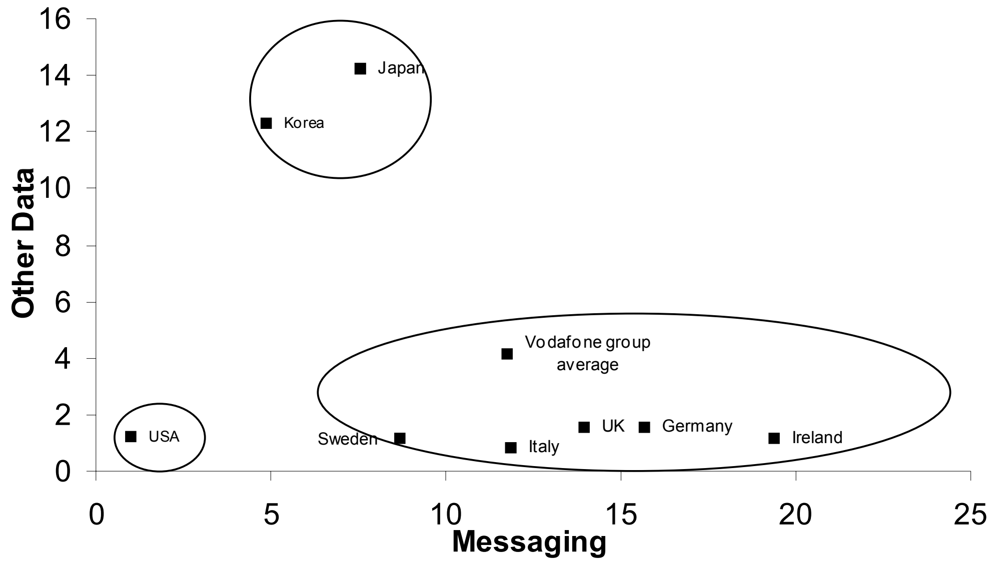

Figure 8-13: Breakdown of data revenues (as share of total revenues)

Note: Data for Korea relate to SK Telecom.

Source: Vodafone KPI Q4 2003 and SK Telecom website.

Figure 8-13 indicates that operators/nations can be divided into three groups: (1) those with almost no data revenues (e.g. US); (2) those with considerable messaging revenues, but small "other data" revenues (value-added data, e.g. downloads, WAP browsing) (Europe); and (3) those with high revenues in both dimensions (Japan, Korea). Sweden belongs to the second group. It is notable that within this group Sweden generates comparatively low revenues from messaging.

If the trend towards higher data usage continues, which seems likely, the low Swedish mobile data usage indicates that Sweden is not a lead market in mobile communications. Where data usage is high, as in Japan, both new and established companies are attracted to develop and launch new services, creating a positive spiral of increased data service usage and innovative services. The learning that takes place in these companies, both technology- and market-wise, may be leveraged to launch services in other countries. Low Swedish data usage hinders this learning from taking place, potentially leading to Swedish companies missing out on future growth opportunities.

One plausible explanation for low Swedish data usage is high prices. With take-up of GPRS usage being slow all over Europe, SMS usage makes up the bulk of European mobile data usage. Compared to the neighboring countries Norway and Denmark, Sweden has had considerably higher SMS prices and much lower SMS usage (about 50% higher prices than e.g. Norway in 2001[1084], with the number of sent SMS per user as low as one third of the Norwegian 55+ (see Section 8.8.3) in 2002. The high prices are sometimes attributed to low competition. The competitive situation in Sweden, with three strong operators, seems however comparable to or better than the Norwegian situation with a near duopoly. Instead, Norwegian operators seem to have taken a longer-term perspective on mobile data than their Swedish counterparts, with earlier introduction of e.g. both reverse billing capabilities for

[1084] Northstream (2002b)

premium SMS[1085] and MMS, long periods of free SMS (and MMS) usage at the introduction, and continued marketing of the service.

With the gate-keeping position of operators, a strong operator initiative (like that of NTT DoCoMo's i-mode) seems to be needed in order to markedly increase data usage. On the Swedish market, such initiatives seem to have arrived during the last year with introductions of packaged data services from Vodafone, Telia, Comviq and 3.

8.9 3G in Sweden

The third generation (3G) of mobile telephony is often regarded as the potential saviour for the beaten telecom industry. Once the operators start investing in new networks, the manufacturing industry will return to profits and revenue growth. Although the technology has been much hyped, economic and technological realities have led to delays in the introduction of 3G throughout the world. With late introductions in Europe and the US, Asia – particularly Japan and South Korea – has taken the lead in 3G implementations. This chapter describes the 3G developments in Sweden. The chapter is divided into two parts, pre- and post-licensing events, with a table summarizing the most important developments until late 2003.

8.9.1 Pre-licensing events

On 12 May 2000, PTS issued an invitation to all parties interested in providing network capacity for UMTS services (and in some cases GSM). Four licenses were to be issued, and apply until 2015-12-31 with the option of prolongation. The selection should be based on a beauty contest in two steps. This announcement was preceded by a number of events and decisions of which some are listed in Table 8-24.

The most controversial choice was perhaps the one of a beauty contest and the rules for that contest. The PTS decision on a beauty contest was in fact an interpretation of the Swedish law, stating that licenses should be issued on grounds of fact, in relation to aims of the telecommunications law. Auctions or lottery processes could not be squeezed into such an interpretation. In addition, industry-political goals supported this choice. A rapid implementation of 3G was considered to be an essential part of the development of Sweden as an IT nation. In accordance with policy, expressed by among others minister Mona Sahlin, PTS came to focus on the beauty aspects of rapid roll-out and coverage, and on allowing infrastructure sharing (70%).[1086] The frequency band was divided into four 2x15 MHz (FDD) + 5 MHz (TDD) to ensure the quality of the services and in order not to give competitive advantages to any of the licensees.[1087]

The selection was carried out in two phases. The first phase evaluated four parts: (1) Financial capacity of the applicant; (2) Technical plan for the UMTS network; (3) Business and market plan; and (4) Experience and knowledge of fixed and mobile networks. The applicants that passed phase 1 then continued to Phase 2. In Phase 2 the applicants scored certain points proportionately to how the application fulfilled the criteria that PTS evaluated. In this phase PTS focused on two criteria: (1) the promised geographical coverage regarding surface area,

[1085] Northstream (2002b)

[1086] Hultén (2001). See also Björkdahl et al. (2002).

[1087] Björkdahl et al. (2002).

population and diffusion in the country, (2) the promises of when the rollout will be completed and when the services will be available.[1088]

Table 8-23: Applicants for 3G licenses in Sweden

Applicant	# base stations end 2003	Estimated costs(billion SEK)	Area coverage (km^2) % of pop. (end 2003)	Rollout start	Participating firms	Outcome
Europolitan AB	20000	27.5	165 259 100 %	January 2001		awarded license
Hi3G Access AB	20184	36.9	224 724 100 %	Jan. 2002	Investor (40 %) Hutchison (60%)	awarded license
Orange Sweden AB	8635	19.7	364 528 100 %	Aug. 2001	Orange PCS Bredband Mobil AB Skanska AB NTL Ltd Schibsted	awarded license
Tele2 AB	10186	17.7	112 666 100 %	Oct. 2001		awarded license
Telenordia Mobil AB	7200	14.0	181 346 98 %	Jan. 2002	BT (90%) Telenor (10%)	Passed Phase 1
Mobility4-Sweden AB	8760	15.3	395 520 100 %	Jan. 2002	T-Mobil International AG Utfors AB ABB	Failed in financial capability
Telia AB	4100	6.8	308 661 100 %	Jan. 2002		Failed Phase 1 in technical quality (data rates)
Reach Out Mobile AB	5238	15.8	259 944 100 %	April 2001	Sonera (45%) Industri Kapital (35%) Telefónica (20%)	Failed Phase 1 in project organization and technical quality (data rates)
Broadwave Communications AB	4700	14.7	32750 81 % 90% end of 2009	Sept. 2002	Tele1 Europe Western Wireless International 2G/3P Group etc.	Failed Phase 1 according to all criteria
Tenora Networks AB	7550	11.2	290 038 100%	January 2002	Ratos (25%) Nomura (55.1%) Teracom (19.9%)	Failed according to all criteria (?)

Source: Adapted from Bohlin et al. (2003a) and Björkdahl et al. (2002)

In total, ten consortia or operators applied. Five of these failed to pass on to Phase 2. The most surprising result was perhaps that Telia did not pass phase 1. Telia considered itself to have filed the technically smartest and commercially soundest proposal, but failed according to PTS because the low number of base stations gave too low transmission speeds compared to the proposed business model, and less coverage than promised.[1089] Three of the rejected applicants contested the decision in court. In June 2001, the county administrative court rejected the complaints, while at the same time criticizing PTS on some aspects of the licensing procedure. In our opinion, the most problematic aspect of the PTS procedure is that they rewarded unrealistic roll-out and business plans. For example, Europolitan and Hi3G roll out 700 base stations per month, and Hi3G planned to invest SEK 36.9 billion. This would create problems in what followed.

[1088] Björkdahl et al. (2002)

[1089] Hultén (2001).

8.9.2 Post-licensing events

The license decision triggered frenetic activity among the licensees to establish suitable network-sharing agreements (since the operators only have to build 30 per cent of the network by themselves). First, shortly after the license was issued, Tele2 and Telia announced that they would establish a company that will build and run the network (later named 3G Infrastructure Services AB). The agreement with Tele2 did not involve any charges for Telia to take part of the license, and the companies will compete on the services market. This meant that Telia and Tele2 would split the infrastructure cost on a 50% basis. Later in January, Europolitan and HI3G also declared that they would establish a joint venture to build and run the network. In this case the companies are bound to fulfill the engagements separately, i.e. each company has to build at least 30 per cent of the network. However, the companies will save a substantial part of the investments. Finally, in May it was announced that Orange Sverige would join HI3G/Europolitan in cooperating in the roll-out (later named 3GIS). 3GIS would cover Sweden outside Stockholm, Göteborg, Malmö and Karlskrona.[1090]

As it turned out, existing radio masts became an attractive asset while building permits became a serious obstacle, delaying build-out. Thus, firms controlling already existing, attractive infrastructures have become interesting partners (like the state-owned Teracom, controlling around 1000 radio masts) especially for green-fielders Hi3G and Orange. Negotiations with local municipalities and property owners had to be initiated. Here, the Telia/Tele2 alliance has a big advantage from the point of view of radio masts because the Telia and Tele2 networks have better area coverage than Europolitan/Vodafone, which led to conflicts and discussions regarding fair prices for sharing masts etc. This has also resulted in long waiting times to obtain building permits, which may have an impact on the dates when the networks will be ready to go into service.[1091]

Orange, whose main owner is France Telecom, came into severe financial troubles. In August 2002, it became the first winner of a 3G license to demand a delay in the construction of the network and a reduced population coverage. The operator would like to complete the network by 2006 instead of 2003 and to reach 8.3 instead of 8.85 million inhabitants, which was rejected by PTS. Orange then started cutting on commitments and finally withdrew. It has been estimated that infrastructure costs will be in the range of SEK 6 billion for each of the remaining four operators.[1092]

The operator 3, a joint venture between Hutchison and Investor, was first on the Swedish market to launch 3G services. The launch plans were announced in May 2003, with the first terminals delivered in June. The introduction of 3's services was aided by a massive marketing campaign. Still, in September 2003 the company had only attracted around 10,000 customers. In January 2003, 3's CEO Chris Bannister announced that 3 would neither subsidize handsets nor lower prices of voice telephony in order to acquire customers.[1093] However, the slow adoption led the company to shift its marketing focus from advanced video services to cheap voice communication.[1094] In November, the company had introduced a subscription without fixed monthly subscription fee, in an effort to attract customers used to prepaid cards. 3 will also launch a prepaid subscription form in the future.[1095]

[1090] Björkdahl et al. (2002).

[1091] Hultén (2001).

[1092] Björkdahl and Bohlin (2003).

[1093] "Genborg, Kenny (2003), Ny 3G-försening i Göteborg", Göteborgs-Posten 2003-01-16.

[1094] Danielson, Per (2003), "3G-bolag startar priskrig", Computer Sweden, 2003-09-17.

[1095] "3 lanserar abonnemang utan månadskostnad", Telekom Online, 2003-11-21.

At first, 3 sold its terminals in dedicated retail stores on prime locations in the three largest cities. Phone retailers have since been added as sales channels, and in October 2003 phones were also sold in five bank offices of the SEB (controlled by the investor group). The early marketing campaigns targeted consumers, but solutions were also developed for corporate customers. Of the 10,000 customers announced at the end of the summer 2003, half were corporate customers. In October a large television marketing campaign was launched focusing on corporate customers, and system integrators as Accenture, Cybercom, and Teleca had been contracted as marketing partners.[1096] The Swedish 3G developments are summarized in Table 8-24 below.

Table 8-24 3G milestones in Sweden

Date	*Event*
1 October 1997	ERC (European Radio Communications Committee) takes decision on UMTS core band.
30 November 1997	Suggestion for UMTS regulatory framework from the EC.
31 December 1997	Identification of candidates for additional UMTS frequency spectrum (extended band, approximately 160 MHz). Regulatory framework for UMTS defined, including spectrum licenses for Phase 1.
14 December 1998	Decision on 128/1999/EC regarding introduction of 3G.
17 December 1999	PTS proposal regarding surplus of network capacity.
27 January 2000	Government bill regarding national roaming in Sweden.
21 March 2000	Decision on changes in the Swedish Telecommunications Act.
14 April 2000	PTS decides the Swedish framework for UMTS/IMT-2000, PTSFS 2000:5.
1 May 2000	The decision on excess network capacity entered into force.
1 July 2000	The decision on national roaming entered into force.
1 September 2000	Deadline for the applications to be handed over to PTS.
16 December 2000	The licenses were distributed.
8 January 2001	Tele2 and Telia (incumbent without a license) announce the first alliance concerning the construction of a 3G network (later named Svenska UMTS-nät AB).
January 2001 (late)	Hi3G and Europolitan announce that an agreement has been signed to cooperate on the construction of 3G networks (later named 3G Infrastructure Services AB).
May 2001	It is announced that also Orange will be included in Hi3G and Europolitan's 3G alliance.
March and May 2002:	The Swedish Competition Authority permits the cooperative ventures Svenska UMTS-nät AB and 3G Infrastructure Services AB.
December 2002	Orange announces the withdrawal from the Swedish 3G market.
June 2003	3 launches the first 3G services in Sweden (subscriptions sold since May, first phones delivered in June).
November 2003	Telia Sonera Sweden announces launch of 3G services in March 2004.
December 2003	Tele2 and TeliaSonera purchase Orange's 3G license through the company Svenska UMTS-nät AB (pending approval from PTS during H1 2004).

Source: Björkdahl et al. (2002) and Bohlin et al. (2003a) adapted and updated.

No other operator has launched 3G services on the Swedish market as of November 2003. TeliaSonera has announced the launch of its 3G services in March 2003, and Tele2 states it will launch at the same time if there are enough handsets available on the market.[1097] As of November 2003, Vodafone has not announced when it will launch 3G services on the Swedish market.[1098] In December 2003, Tele2 and TeliaSonera announced a joint bid (through the joint venture Svenska UMTS-nät) for the license held by Orange, provided PTS approves. PTS is investigating what effects this would have on the Swedish 3G market, and a decision is expected during the first half of 2004.

[1096] "3:s nya företagstjänster ska ge ett lyft för det mobila kontoret", Nyhetsbrevet Telekom, 2003-11-19

[1097] Danielson, Per (2003), "Tele2 går i Telias fotspår", Computer Sweden, 2003-11-19

[1098] Huldschiner, Henrik (2003), "…och även Vodafone avvaktar med 3G", Dagens Industri, 2003-11-19

8.10 Swedish activities in wireless PAN, LAN and MAN

The importance of WLAN technology in the future of datacom (and, perhaps, even telecom) is indicated by the massive investments made in the technology by industry actors as Cisco and Intel. In 2003, Cisco acquired the Wi-Fi equipment maker Linksys for US$ 500 million, and the company is spending US$ 300 million on marketing of its Centrino computer chips with integrated Wi-Fi capabilities.[1099] According to Thomson Venture Economics, Intel Capital, the venture capital arm of Intel is one of the most active investors in the WLAN area.[1100]

Although the Swedish telecom equipment maker Ericsson develops WLAN products (solutions for seamless connection between WLAN and GPRS, solutions for backhaul to WLAN hot spots, and WLAN firewall units), it is not a main actor in the WLAN/Wi-Fi field. The absence of strong WLAN products in the portfolio has led Ericsson to form partnerships. In October 2002, Ericsson announced partnerships with Proxim and Agere for public WLAN access.[1101] Ericsson can thereby offer operators complete end-to-end solutions, with access point from Proximion and WLAN modules, software and SIM technology from Agere. The partnerships seem to have paid off. In March 2003, Ericsson announced a contract with the British company Inspired Broadcast Network to supply DSL routers and Wi-Fi access points for deployment of 5000 public W-Fi hot spots.[1102] As a part of its "Always best connected" concept, Ericsson makes use of its knowledge and skills in the systems integration area to build WLAN networks. Using standard mobile phone SIM technology, Ericsson hopes to gain market share by bringing security, billing and control functions from the telecom networks to public WLAN networks.

There are several Swedish firms working with WLAN technologies. The venture capital company Brainheart Capital, focusing on the wireless technology sector, has four investments in the Wi-Fi area, two of which are based in Sweden: Service Factory (offers carrier grade systems for Wi-Fi service provisioning), and Possio (developer of wireless fax, GRPS PC cards and wireless gateway product families). Other Swedish companies active in the Wi-Fi area include Spirea (initially focused on Bluetooth technology, but now offering IEEE 802.11a/b/g transceivers), Icomera (multi-technology solutions, including WLAN, for wireless access in trains), Aptilo (provider of solutions for public hotspots and managed services), IPunplugged (authentication solutions for hotspots), Appear Networks (software platform for application delivery over WLAN or Bluetooth), Axis (WLAN access points), Servicefactory (Internet service production and administration platform, including WLAN services), and Åkerströms Nowire (WLAN products and consulting services for WISPs).[1103]

Ericsson is the inventor and a main supporter of the Bluetooth technology. The company Ericsson Technology Licensing (based in Lund) was formed in 2000 to exploit the head start in Bluetooth technology developments and license the technology to manufacturers. The company has secured contracts with most volume manufacturers, including Infineon, Intel, Phillips, ST Microelectronics and Samsung. According to Ericsson Technology Licensing, mobile phones and handheld computers make up 42.5% of the around 60 million Bluetooth chips delivered in 2003.[1104] The rapidly increasing volumes provide scale economies in

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[1099] "Wi-Fi Means Business", BusinessWeek Online, April 28, 2003

[1100] http://www.ventureeconomics.com/pew/protected/articles/dealnews/1055428820938.html, accessed at 031017.

[1101] http://www.ericsson.com/press/archive/2002Q4/20021024-100456.html accessed at 2003-11-17.

[1102] http://www.ericsson.com/press/archive/2003Q1/20030306-1431.html accessed at 2003-11-17.

[1103] Company homepages.

[1104] "Boom för Blåtandchips", Dagens Industri 2003-11-15, by Kristofer Steneberg.

production, leading to falling prices. In November 2003, the price of a Bluetooth module is around SEK 25, a number expected to keep falling in 2004, when Ericsson expects the market to reach 120 million Bluetooth modules.[1105]

Swedish-Japanese SonyEricsson has implemented Bluetooth technology in a number of handset models, and sells peripheral devices for mobile phones, including wireless headsets, under their own brand name. Several Swedish companies develop products and services based on Bluetooth technology, including Bluecell, connectBlue (Bluetooth serial port adapters and web enablers, products and OEM equipment), Free2move (provider of industry solutions for wireless communications), Bluetronics (Bluetooth class 1 USB-dongle and modules for embedded solutions), Anoto Group (system connecting digital pens with terminals via Bluetooth), IAR Systems (Bluetooth Protocol Stacks and USB drivers), and Axis communications (providers of e.g. Bluetooth wireless access points).[1106]

8.11 Mobile Internet startups

Around the turn of the millennium, a boom in entrepreneurial activities in the telecom sector was recorded. Hopes were high for the WAP protocols, and packet data services were being implemented. Mobile Internet was seen as a major future growth area, and the Stockholm area (with the strong telecom competencies built up around Ericsson and Telia) was considered a strong cluster area. The availability of strong telecom actors in Sweden, mainly Ericsson, has generated a large supply of personnel resources. In the late 1990s, many left the company to found their own firms, often in the mobile data field.

A number of articles were written in foreign press, calling the area the "wireless valley" with comparisons to Silicon Valley. With the strong economic climate, venture capital was available to many start-up firms, especially in the mobile Internet field, leading to a wave of company creations. A mapping of the emerging mobile Internet actor system in the Nordic countries indicates that the majority of the companies were active in the development of enabling technologies (mainly middleware and service platforms), and a large number of companies engaged in service and application development (Table 8-25 below).

Table 8-25: Number and type of Mobile Internet companies in the Nordic region in 2000

Type of company	*Number of companies*
Application developers	28
Consultants	12
Enabling technologies	89
Applications and services	38
Network Access Providers	8

Source: Ariad (2000)

In another mapping of the Swedish wireless communications companies from 2002, 297 companies were identified in Sweden (Table 8-26). A vast majority of these companies are located in the Stockholm area, followed by Göteborg and Malmö/Lund. The mapping also shows differences in company foci between the regions. These differences in focus have logical explanations. It is in Stockholm that many of the large companies' head offices and research facilities (including Ericsson, TeliaSonera and Nokia) are located, as well as venture capital firms and consultancies. The three large vehicle manufacturers in the Gothenburg region (Volvo, Volvo Cars, SAAB Automotive), have attracted knowledge in the telematics field. Sony Ericsson mobile terminal product development is located in Lund, attracting

[1105] "Boom för Blåtandchips", Dagens Industri 2003-11-15, by Kristofer Steneberg.

[1106] Company homepages.

component manufacturers to the region. The software company UIQ, a subsidiary of Symbian developing mobile phone interface software, is located in Ronneby, and the head office of Vodafone Sweden is located in Karlskrona nearby.

Table 8-26: Swedish telecom companies by region (2002)

Region	Number of companies	Focus
Stockholm	193	Network technologies, services
Göteborg	24	Telematics
Malmö/Lund	23	Communication products
Karlskrona/Ronneby	8	Software
Rest of Sweden	36	

Source: Svenska Dagbladet Näringsliv, 2002-04-15, p. 14.

The number of companies identified in the study has decreased significantly in the last year. Mobile Internet services have failed to gain momentum in Sweden and, this being combined with a cut in available venture capital funding, many firms failed financially. Although no thorough analysis has been performed, and therefore no magnitude of decrease can be provided, a quick search shows many of the companies presented in the study having terminated operations in the autumn of 2003.[1107]

Table 8-27: Foreign investments in wireless communications in Sweden after 1998

Company	Country	Nature of investment
Accenture	US	Global center for WAP applications and services
Cambridge Technology Partners	US	Global wireless competence center
Cap Gemini Ernst & Young	France/US	Joint competence center for 3G mobile systems
Compaq	US	Wireless competence center and e-commerce knowledge center
EDS	US	Mobile center of excellence
HP	US	Wireless research and a joint project with Ericsson and Telia
IBM	US	Wireless Internet center
Intel	US	Wireless competence center and e-business solution center
Microsoft	US	Acquired Swedish Sendit and created the Mobile Solutions Center and also formed a strategic partnership with Ericsson to develop and market end-to-end solutions for the wireless Internet
Motorola	US	Development centers for wireless applications and services
Nokia	Finland	R&D in mobile communication infrastructure
Nortel Networks	US	R&D center for datacom, telecom and wireless communication
Oracle	US	Center of excellence for wireless product development. Also established a joint company with Telia for wireless services (Halebop)
RSA Security	US	Development of secure wireless communications
Siemens	Germany	R&D center for mobile applications
Sun Microsystems	US	Wireless center of excellence
Sybase	US	Test center for mobile business applications and a strategic alliance with Ericsson around mobile banking solutions

Source: Hultén (2001)

[1107] By the time of the finalization of this report, Northstream published a report that included a recent mapping of the Swedish wireless sectors – too late, however, for including their results to any considerable extent in this report.

The developments of these investments have not been investigated further here. With the slow mobile Internet usage development in Sweden compared to many other markets, it is however questionable if Sweden in general and Stockholm in particular today are considered attractive for large-scale mobile Internet investments.

The strong telecom competency available in Sweden attracted a number of foreign companies to invest in the country during the latter part of the 1990s. Many established so-called centers of excellence relating to wireless communications and mobile Internet. In a compilation of foreign wireless communications investments in Sweden between 1998 and 2001, Hultén (2001) identifies 17 large multinational firms, mainly US-based, investing in Sweden.

8.12 A note on Swedish 4G

Since it is not clear what 4G is, it is difficult to pinpoint what Swedish actors have done in this area. One early initiative was taken in the late 1990s, when the PCC national research program was started, financed (USD 18 million) by the Foundation for Strategic Research. PCC performs research in areas of strategic importance for Swedish industry. The vision of PCC was "Personal multimedia communication to all at the same cost as fixed telephony today". PCC research work was pursued primarily in seven projects: (1) active documents and ubiquitous computing and communication; (2) adaptive antennas in wideband radio access networks; (3) algorithm/hardware co-design for mobile communications; (4) generic technologies; (5) mobile wireless access to fixed networks; (6) overall design of 4th-generation wireless infrastructures; and (7) wireless IP. PCC is a collaboration between Chalmers University of Technology (CTH), Royal Institute of Technology (KTH) and Lund Institute of Technology (LTH). Other universities participating in the program are Uppsala University and Luleå University of Technology, including industrial collaboration.[1108] A more thorough assessment of Swedish 4G development may be called for, however.

8.13 Summary and conclusions

The evolution of mobile data communications has been investigated in this chapter along a number of development paths. In fact, until now (2004), most mobile data systems have experienced a perceived slow diffusion, much slower than expected in initial optimistic forecasts. We specifically investigated the diffusion (and barriers to diffusion) of Mobitex in Sweden. However, these barriers to diffusion seem to be valid for a wide range of markets and technologies. It seems that generic technical systems such as mobile data need complementary developments in order to provide any value to users. As Rosenberg (1972; 1995) notes, this is a common phenomenon. Technologies often enter the market in an immature form, with a need for complementary innovation. Such developments are indeed complex and lengthy processes, as shown by the examples investigated. In essence, the innovation systems seemed to lack a few vital complementary parts (technical and actor-wise) and were therefore slow to develop.

In the following chapter a brief summary of international and Swedish mobile data developments is provided, followed by an analysis of the Swedish developments.

[1108] See http://www.pcc.lth.se/ and various sub-pages.

8.13.1 International developments

Wireless data communications was initially provided over PMR, and paging networks PMR has historically been the dominant form of land mobile communications, and is still a fairly large business. Lead-users (von Hippel 1976), e.g. police forces, played an important role for land mobile radio to develop in the 1920s and 1930s, but it was not until the introduction of frequency modulation (FM) and the rapid techno-economic progress induced by WW II that land mobile radio really became commercially feasible and activated new market segments. Technological progress in e.g. transistors and trunking enabled land mobile radio to diffuse rapidly during the 1950s to 1970s, at varying rates in different countries (most rapidly in the US and the Nordic countries). Mobile data over PMR emerged in the early 1980s. Some public-access mobile data communications systems were launched as well, notably Mobitex and DataTac, with mixed results. In the late 1990s market growth was somewhat rejuvenated by the introduction of new generations of digital trunked systems such as iDEN and TETRA. These were designed to carry data traffic as well as voice.

Due to low costs and small terminals, paging was for many years the dominant mobile communications service, at least in the US and Asia, where paging was far more diffused than in Europe. By the introduction of a new ETSI standard – ERMES – Europeans tried to gain ground, but failed since it arrived too late and was too complex to the market. In the late 1990s the paging concept was undergoing rapid change. Paging networks were improved to provide extended functionality, such as two-way messaging, news and e-mail services. Paging functionality was being built into other devices, such as wristwatches, cellular phones, PDAs, personal communicators, notebooks etc. To put it another way, messaging was clearly the first "killer" application of mobile data, and competing technical systems were battling over which networks these messages are to be sent over.

Some data functionalities were available in first-generation mobile telephony networks (e.g. NMT), but they did not reach any notable usage levels. Data capabilities were improved in the second-generation networks (e.g. GSM) launched in the early 1990s. Making the mobile telephony systems digital had an inherent implication for providing better data communications. Although the GSM group had data communication in mind from the start, the issue was almost forgotten in the early years, partly due to a lack of data communication expertise in the group, partly due to the focus on telephony, and it was not until 1995 that data communication was properly standardized. Still, the first generation of data services over GSM suffered from some basic limitations. Maximum data rates were low (9.6 kbps) leading to unacceptably long times for performing even simple tasks. Adding to this, costs of service were too high. These limitations were anticipated early on and subjected to performance-enhancing standardization.

The most radical GSM improvement was perhaps GPRS (General Packet Radio Service). The idea of a packet data service for GSM was introduced by IBM and Motorola in 1988, but the idea was rejected then. The needs and ideas for a packet-switched service came up again around 1992, this time from the European Commission. In addition, the introduction of CDPD in the US put competitive pressure on GSM to introduce packet switching. GPRS functionality has been implemented in most GSM networks during the early 2000s, but usage is lower than envisioned.

Instead, the commercially most important data communication service of the late 1990s and early 2000s became the Short Message Service (SMS). The bulk of SMS traffic today is mobile-to-mobile messaging and voice mail notification. In early 2003, of the "charged-for" traffic, mobile-to-mobile messaging represented circa 90 percent of the traffic. GSM operators started introducing mobile-originated SMS by 1994, with initially slow take-up. Fuelled by interoperability enhancements, interconnect agreements, pre-paid cards and the introduction of SMS, new services, more capacity in networks, better terminal displays, inbox browsing and message reply, predictive text input, chat boards, WAP over SMS etc., the market started to grow very rapidly in late 1999 and early 2000.

WAP – the Wireless Application Protocol – emerged in 1997 as a major effort to reduce and overcome the limitations of terminals and networks for mobile Internet usage. Terminals had small, monochrome displays and limited input interfaces, processing and storage capabilities. In addition, the connections suffered latency and poor security low data rates, and were subject to lost connections. Although terminals improved during the 1990s to be increasingly capable of accommodating data, there were still problems in presenting Internet information to the mobile user. Unrealistic expectations of the usefulness of WAP created hype in the late 1990s, with dramatically rising stock prices for companies involved in WAP development. Not surprisingly (not even ex-ante), WAP services did not take off as expected, due to limited usefulness, limited performance networks, services and a lack of terminals.

The belief that mobile data services were a future growth area proved right through Japanese developments. In February 1999, NTT DoCoMo launched i-mode – a wireless Internet service. In contrast to WAP, which is a set of specifications, i-mode is a full service concept. Traffic runs over DoCoMo's packet-switched network, which allows for always on-line functionality. DoCoMo controls the entire actor system, by setting the specifications, dictating terminal development, running the main portal and controlling what content providers are present on its portal. I-mode uses a simple business model where customers are billed by only one company (DoCoMo). Content providers can either hook up to DoCoMo's i-mode portal (I-menu), where they can make use of DoCoMo's billing system or launch as an unofficial site which customer by typing in their URLs. I-mode proved an almost immediate success. By 2003 there were circa 3,500 official and 65,000 unofficial sites with more than 30 million users. In response to i-mode, cellular operator rivals KDDI and J-phone launched similar services on their CDMA and PDC networks. KDDI named its mobile Internet service "EZ web" and J-Phone named theirs J-Sky. Although using different technological solutions, similar levels of success were reached.

Clearly, by 2001 Japan had taken the lead in mobile data communications in many respects, e.g. deployment and diffusion of advanced wireless Internet services, and technical sophistication of terminals. Whether or not this advantage could be leveraged overseas remained to be seen. DoCoMo was actively pursuing an internationalization strategy where it tries to capitalize on early i-mode success and FOMA 3G experiences. The strengthened position of Japanese terminal manufacturers in 2.5G can probably also be attributed to the early introduction of i-mode.

Frequencies for the third generation (3G) of mobile communications services were set aside in 1992, but it was not until the mid-1990s that the standardization efforts started to gain pace. The vision changed from "global telephony" towards a system that should be able to carry mobile multimedia, broadband and packet-switched data. In addition, operators' huge investments in a second generation made backward (and forward) compatibility with these a central issue. Japan (mainly NTT DoCoMo) came to play an active role, driven by industrial-political interests and a lack of frequencies. In 1997 European operators and suppliers were dedicated to the UMTS solution based on a GSM core network, with a new radio interface (UTRA). The choice of that radio interface became the first of two contagious conflicts settled in 1998 – the second one, concerning IPR and backward compatibility with 2G systems, settled only in 1999. By this time ITU could formally approve of a new global 3G standard (now labelled IMT-2000 instead), in reality being an umbrella of standards comprising five optional air interfaces and two core networks. The most important standards are WCDMA (backed by e.g. NTT, Nokia and Ericsson), and CDMA2000 (backed by e.g. Qualcomm and other North American suppliers).

In many countries the frequency spectrum was auctioned out, or distributed through so-called beauty contests (where operators competed on intended coverage and build-out pace). The high sums paid for licenses, in combination with high costs for building up infrastructure, created a need for operators to raise capital through loans, emitted shares or vendor financing. Financial markets reacted with skepticism, in particular concerning operators' ability to perform in accordance with expectations set forth in business plans and other reports, and due to the bad balance sheets and high debt burdens. As a result, credit ratings were downgraded drastically (as shown in Figure 8-4) at a time when operators needed funding to ensure 3G network and service rollout.

Japan moved first in 3G implementation. NTT DoCoMo was the first operator to launch its FOMA 3G services based on W-CDMA. The commercial launch was delayed, perhaps not surprisingly, because of an immature network and lack of terminals. In October 2001, FOMA was commercially launched in high-population areas with moderate success. In the spring of 2002, KDDI launched 3G services based on cdma2000 1X, followed by J-phone in December 2002. KDDI's services took off much more rapidly than FOMA due to less expensive roll-out costs, a larger number of cheaper terminals, and roaming with cdmaOne.

Through a long-term commitment, Korea has established itself as a leading nation in the mobile data field. In October 2000, South Korea launched the world's first commercial IMT-2000 3G network using CDMA2000 1X and in January 2002 it launched the world's first commercial CDMA2000 1xEV-DO service. The early launches seem to have provided Korean and Japanese terminal manufacturers with a head start, and companies from these countries have developed the bulk of the 3G models introduced on the market.

In Europe, only one operator, "3" controlled by Hutchison, pushed forward with an aggressive 3G roll-out and operation, covering six European countries between May and October 2003. Outside Europe and Asia, no commercial 3G implementations have been made.

Somewhat depending on the definition of a 3G service, CDMA 2000 had taken the lead in terms of subscribers. By October 2003 there were 63 CDMA2000 1X and 8 1xEV-DO commercial networks mainly in the Americas and Asia, serving more than 60 million subscribers, of which more than 20 million in Korea and 10 million in Japan. Although their commercial viability remains to be seen, 3G systems will very probably be commercialized in most parts of the world.

A separate mobile data development track has emerged outside the traditional telecom industry, mainly from US manufacturers. Wireless LAN technologies (WLANs) have emerged as competitors and complements to existing and future mobile communications solutions. This far, they have targeted other applications than cellular networks. While WLAN has targeted *wireless* access, cellular networks provide *mobile* access, allowing for mobility during the access session. Whereas WLAN is a means to cutting the cord for Internet access at fixed locations, cellular technologies provide users the possibility of accessing Internet content from their mobile terminals regardless of location. Thus WLANs can be compared to cordless phones. As cordless phones, they use an unlicensed frequency spectrum open for all to use. In addition, they lack the sophisticated billing, security and subscriber management capabilities of cellular networks. A main feature of mobile networks is also the roaming ability, allowing users to switch base station without losing their network connections.

For networks built on wireless LANs and MANs (Metropolitan Area Networks, covering a larger area than LANs) to pose a threat to the traditional telecom industry, the challenge lies in turning a wide array of stand-alone connection locations into a dependable network. This calls for extensive billing systems and roaming agreements to be developed and implemented, in turn probably feasible only through some kind of standardization. If voice over IP usage increases and the barriers presented above find their solutions, wireless LANs and MANs may have an important role to play in the telecom industry.

In addition, the formerly tight actor system is breaking up, as a result of the new service opportunities opening up. New entrants are rushing into the industry in a multitude of roles (content aggregators, content providers, portal providers, etc.). This emerging actor-chain complexity creates uncertainty for the sector.

Finally, the concept of 4G is gaining attention, along different tracks. The 3G sponsors, in particular the European manufacturers and the European Commission, envision 4G as something replacing or building on 3G, perhaps 10 years into the future. A number of initiatives were taken (e.g. the WSI, WWRF) already within the 5th Framework Programme, continuing into the 6th. Asian countries take a more aggressive industrial policy-driven stance, aiming to take over leadership. Japan and Korea have announced on several occasions that they will launch 4G earlier than 2010. China has publicly announced that it aims to take a leading position in 4G – and these countries cooperate. They also drive the process forward in international cooperative bodies (e.g. ITU and WWRF). Meanwhile, mainly in the US, the 4G vision is something different. It involves the organic growth of WPAN, WLANs, WMANs, the establishment of ad-hoc networks etc. made interoperable, also with cellular networks. This vision is driven by the computer, datacom and microelectronics industry, including firms such as Intel and Cisco as well as start-ups.

8.13.2 Swedish developments

Although mobile data has long been considered an important growth area for Swedish operators, service take-up has been limited. The first data solutions were launched already in the NMT networks, but the limited data capabilities were only used in a few limited niche applications. Televerket did not actively market data over NMT, and manufacturers were not very active in developing supporting products. During the early and mid-1980s, Televerket developed the Mobitex system, the first important mobile data system in Sweden and the world's first public mobile data system. The developments started because of a number of anticipated needs, both internal and external. Other actors including Ericsson and Volvo developed other, partly overlapping systems. Mobitex was launched in 1986, but due to a number of discrepancies in the innovation system, uptake was slow. In 1988 Televerket and Ericsson formed a joint venture for internationalization of the system. In the mid-1990s the system was on its way to becoming a *de facto* European standard, but false expectations on future systems caused operators to delay investments, and even to close down networks.

In 1994, data services were launched over the GSM networks in Sweden, but take-up of these services was very low. This was hardly surprising since (1) there were few available applications, (2) public data communications diffusion was still fairly limited, (3) there was an initial lack of communications software, communications drivers and other necessary equipment, (4) services were difficult to use, (5) software and hardware were badly adapted to mobile radio conditions, (6) software and hardware were expensive, (7) performance of networks (data rates, set-up times, cost) was inadequate, (8) competence among users and distributors was low, and (9) promises of future systems led to waiting decisions among potential buyers.

Also Swedish SMS diffusion was slow initially for the reasons stated in Section 8.8.3, but started to increase significantly in the late 1990s. During 2002 each Swedish subscriber sent an average of 15 SMS in a month, of which 88% were sent by private customers. In 2002, SMS accounted for 8% of Swedish operators' ARPU; for private customers the corresponding figure was 12%. This places Sweden far behind the leaders in an international comparison. With the advent of third-generation services, believed to be based on data services to a large extent, the slow Swedish data usage developments indicate that the Swedish market has lost its status as a lead market.

The first packaged mobile data services on the Swedish market were launched by Telia in February 1998 under the name Telia DOF (Department of the Future), but never reached wide market acceptance. In November 2000, Telia announced the launch of a new mobile portal project, Speedy Tomato. Through Speedy Tomato, Telia aimed at reaching customers in markets where the company did not yet have customer relations, but the project was soon terminated.

The packet data service GPRS was first introduced by Europolitan/Vodafone in late November 2000, followed by Telia and Tele2 in the fall of 2001. Uptake of GPRS appears to have been slow. Although most new terminals were GPRS-capable, there were less than 200,000 active users by mid-2003). The percentage of active users was thus 1.3% (4.7% in the business segment, 0.6% in the consumer segment)

In the late 1990s a boom of entrepreneurial activities was recorded, not least in Sweden. Fueled by high expectations, unlimited venture capital, a strong competence base, and an advanced user market, Sweden (in particular Kista) attracted also much foreign capital and R&D investments. Start-ups were created in the areas of e.g. application development, consulting, enabling technologies, service provision etc. Much of this growth came to an end with the bust of the early 2000s.

Following the advent of more capable terminals, with cameras, color screens and MMS capabilities, new mobile data packages were launched by the operators. First out on the Swedish market was Vodafone, launching its mobile data package Vodafone Live! in late 2002. In 2003, both the remaining strong operators, Telia and Tele2/Comviq, launched similar packaged data services. In May 2003 they also received competition from 3, introducing the first third-generation network on the Swedish market. In 2004, the other 3G license owners are expected to launch their services.

In short, Swedish mobile data usage has not increased as anticipated by many industry actors and observers. Although this could probably be said about a number of other countries, Sweden stands out in e.g. a Nordic comparison as the country with lowest mobile data usage.

8.13.3 Analysis

This section discusses the evolution of mobile data communications, in terms of the innovation systems functions identified in Chapter 2

8.13.3.1 Creation of knowledge

Televerket had developed knowledge about radio communication during the previous decades, and some key people had acquired some embryonic data communications knowledge through the Maritex development. The data communications skills were later strengthened internally; the universities provided skilled engineers, but Televerket had to teach them about telecom and data communications. This has been the case for Ericsson in later stages.

Through the design and development of Mobitex systems, both Ericsson and Telia gained important experience in mobile data, in particular packet-switched mobile data. The mobile data knowledge generated through the Mobitex solutions later contributed to Ericsson's development of both GPRS and WCDMA data solutions.

Knowledge about customer management, marketing and applications provides other important skills for a telecom innovation system to function properly. The provisioning of mobile data services differs markedly from traditional telecom services. Whereas the former often must be tailored and targeted at small market segments, the latter are more or less similar for all customers. The poor and late take-up of mobile data services has probably hindered these skills from being developed within the innovation system. The system thus loses a dynamic effect, and the positive spin of innovative applications and increased usage (seen in e.g. Japan) is not started. In a sense, the Swedish mobile data industry can be said to be still in a formative phase, almost 20 years after introduction.

8.13.3.2 Guidance and direction of search

Televerket and Ericsson have acted as a so-called development pair[1109], with Televerket functioning as both a demanding customer and a development partner. In the Mobitex case, Televerket initiated the development, and later sold the Mobitex arm to Ericsson. Acting on a perceived external and internal need, Televerket thus guided the search and created knowledge later to be used by Ericsson. Ericsson was initially reluctant, preferring other solutions, but eventually switched over to Mobitex. Later, foreign operators (RAM) assumed this role of being a demanding customer.

Still, as seen in the case of GPRS developments, it seems that packet switching had low priority in the Swedish mobile telecom industry, and delusions existed of which applications would be important (still in 1995, mobile fax was considered the most important application). It was not until the Internet "take-off" in the mid-90s that packet switching became a key priority in the mobile telecom industry.

In more recent years the Swedish (and European) mobile data service industry seems to have lacked a strong coordinator, a role taken by e.g. NTT DoCoMo on the Japanese market. Packaged mobile data services, to some extent comparable to i-mode, were launched only in late 2002 and during 2003, almost four years later than the Japanese counterparts. In earlier phases of the mobile telecom development, Televerket (Telia) has functioned as the natural coordinator. After deregulation, with Telia spending less on R&D, it seems no actor has taken on this role.

[1109] See e.g. Fridlund (1999) for an elaboration of the importance of long-term collaborations between an industrial company and a state-owned customer.

The structures of operators' service offerings have often been so-called walled gardens, restricting subscribers to services supplied by the operator. The operator has thus held a gate-keeping position, controlling the content and holding the billing relationships with its customers. This has placed a large responsibility on operators to identify, develop, package and market the services that provide utility to end-users. Without the possibility to learn through experimentation, service-developing companies have had limited opportunities to identify profitable service offerings. It can be argued that the operators have failed in guiding the search for successful mobile data applications, and consequently the build-up of a market.

8.13.3.3 Incentives for innovation

The success of mobile telephony spilled over to exaggerated expectations of growth in mobile data, providing the incentives for Televerket to develop Mobitex. Other incentives included internal providing efficiency and the sector responsibility.

Expectations (failed) on future growth have provided strong incentives to invest in mobile data R&D throughout the time period. For each new generation, data capabilities have been improved. In third-generation networks, data is expected to constitute a much larger share of revenues than in earlier generations, making mobile data innovations of great importance. Maturing voice markets have added to this, making actors search for other revenue sources.

In more recent years, the revenue-sharing models utilized by operators have been stricter than e.g. in Japan. At the service level, the protecting positions of operators left limited incentives for innovation in small firms. Non-dynamic business models made it difficult for service developers to adapt their service offerings to meet customers' needs and wants profitably. When the source of venture capital dried out following the stock market crash, many of these firms had to seize operations.

Ever since the introduction of NMT, operators have maintained high profit margins in their mobile businesses. Although competition has gradually increased, drastic price reductions did not occur until late 2003. Instead of engaging in activities to increase market shares through aggressive price or service competition, operators have enjoyed their protected positions by only maintaining their existing businesses. This situation may have hampered the operators' incentives for service innovations.

There has been a fear of launching too simple products too early. Instead of launching an unfinished service on the market and refining it according to the learning that takes place, there has been a tendency to wait until the services/products/technologies are fully developed. This has been the case in data solutions such as GPRS, and in packaged mobile data services.

An interesting observation is a tendency of decreasing innovativeness in Swedish operators. Until the end of the 1990s, Telia was generally among the first operators to implement new technologies, often even driving the developments. The innovating operators on the Swedish market in recent years are mostly foreign-owned. Vodafone, pioneering packaged data services and picture messaging, has, together with 3, launched the largest mobile data service innovations. Although the Swedish operators TeliaSonera and Tele2/Comviq have followed, they have not been leaders in innovation. This is a natural effect of Tele2's strategy, but for Telia it means a new order.

8.13.3.4 Supply of resources

The availability of strong telecom actors in Sweden, mainly Ericsson, has generated a large supply of telecom-skilled personnel resources. In the late 1990s, a number of employees left the company to found their own firms, often in the mobile data field. At this time, the advent of WAP was surrounded by hype and overestimations of the economic potential. Combined with plentiful access to venture capital, companies working with mobile data solutions had easy access to capital. In this setting, mobile data innovations were numerous, ranging from consulting services to middleware and applications and services.

During the bonanza years at the end of the last millennium, the high profit margins at Ericsson made a virtually endless stream of capital available for R&D. The R&D investments at Ericsson increased sharply every year, only to come to a brutal halt in 2001. Ericsson's R&D budgets spilled over to finance some university R&D, and in some cases financing of start-up firms through the venture capital arm.

In the late 1990s, a number of venture capital firms specializing in communications and mobile data emerged. The high stock market valuations made capital readily available for venture investments. Although the quantity of venture capital was large, it can be debated whether the quality matched the quantity. Some researchers point out a general lack of competence in the Swedish venture capital industry.

Platforms for innovation are another area where Sweden has been lagging the leading countries. Here the comparison with Norway is most relevant, since Norwegians were much quicker in launching third-party content developer platforms, for developing premium SMS and MMS services, than were their Swedish counterparts.

8.13.3.5 Creation of networks and its effects

With the terminal and equipment arms of Ericsson and the operator and equipment arm of Televerket, a strong nucleus in an innovation system was in place for mobile data development. In e.g. the Swedish Mobitex mobile data developments, there were "holes" in the innovation system. As opposed to the NMT case, the actor system linked to the Mobitex system was weak, if not incomplete when it came to certain actor categories and relations. Notably, there was a lack of application developers and system integrators, making mobile data solutions co-function with companies' existing IT systems. In spite of proven utilities and often high ROI, since the birth of mobile data communications it has proven a difficult task to sell services to corporate customers. At large, this can be attributed to a lack of competence regarding how to use mobile datacom in companies. At the same time, the mobile telecom industry has not had the needed access or credibility in corporate IT departments. This problem seems to exist still in 2004. Today, for instance, the operator 3 works with established system integrators such as Accenture in order to convince customer companies to implement its solutions.

Around Ericsson, a number of mobile data sub-suppliers have appeared, delivering e.g. positioning and application hosting middleware, and services and applications. In recent years, Ericsson has tried to inject interest in mobile data services through a number of initiatives. One example is Ericsson Mobility World, an initiative to spread knowledge and understanding about successful mobile data services among operators and service-developing companies.

It could be argued that the recurrent failures in the mobile data field, e.g. Mobitex and WAP, have led to a lack of legitimacy of sorts. This could in turn possibly lead to decreased innovation activities, and restrictions in access to capital.

Around Ericsson and Telia in the Stockholm region, a mobile telecom cluster has appeared. During the late 1990s, the Kista area was touted as the world's mobile Internet center of gravity. During the telecom boom a number of foreign companies invested in the area, reinforcing the strength of the cluster. However, as other regions have become more advanced in mobile data usage, the attractiveness of Kista may have become somewhat lower.

8.13.3.6 Formation and stimulation of market/demand

Throughout the studied period, it has proven a difficult task to convince customers of the utility of mobile data services and solutions. In the case of Mobitex, an incomplete value actor system was a contributing factor in unsuccessful market creation. In the more consumer-oriented mobile data service market in recent years, terminal limitations and low general service utility have turned out to be strong barriers.

The development of the first major Swedish mobile data solution, Mobitex, was initiated by Televerket, acting on external and internal needs. The diffusion of Mobitex was much slower than anticipated. By 1990, there were only around 2,000 subscribers in Sweden, most of them Televerket-internal.

The low usage of mobile data services in public administrations has hampered demand and development. Televerket claims it saved substantial sums yearly, but still adoption in other administrations was low. E.g. the police force has discussed and investigated purchase of a new communication system for almost 30 years, without actually buying. Perhaps an active procurement policy could have been an important part in forming and stimulating a market for data services. After the telecom downturn in the early 2000s, voices have been raised in Sweden about the responsibility of the public sector in stimulating usage of mobile data services. By ordering data service solutions to be used in e.g. the health care sector, it is believed that the industry could be stimulated.

The mobile data industry has experienced a kind of waiting game among potential customers in response to unclear technology situations. In spite of improved Mobitex systems offering 8 kbps, enough for a large number of applications, purchase decisions were delayed waiting for GPRS. Also operators and suppliers waited for the future systems. When GPRS finally has been implemented on a large scale, 3G is around the corner, and both customers and application developers are again acting with caution.

The service price is an important parameter for the creation of a market. Mobile data has been priced high in Sweden. Still in 2003, SMS prices are sometimes two to three times higher in Sweden than in neighboring countries. This is believed to be an important explanation for why e.g. Swedish SMS usage is lower than one third of Norwegian figures. With SMS being the commercially most important mobile data service so far, this severely hampers Swedish mobile data usage.

In Chapter **Error! Reference source not found.**, this analysis will be taken one step further by identifying major strengths, weaknesses, opportunities and threats for STIS, and the relevant implications for policy and further research.

9 SUMMARY AND CONCLUSIONS

This chapter summarizes the main observations from the previous chapters, and identifies key implications for STIS. Section 9.1 summarizes Chapters 2-4 and 6-8. In Section 9.2, the case of fiber optics is summarized and analyzed. The evolution of mobile telephony and data communications (Section 9.3) is compared, trying to answer the question of why Sweden has strong mobile telephony IS but a weak datacom IS. Section 9.4 analyzes the emerging mobile data sector. Section 9.5 identifies main trends, and Section 9.6 elaborates on a tentative SWOT for STIS. Finally, in Section 9.7 implications for policy and further research are identified.

9.1 Summary of observations

9.1.1 Innovation systems

9.1.1.1 Literature review

Systems-of-innovation theory has been investigated for two purposes: (1) to identify weaknesses and promising areas for further research, and (2) to establish a framework for analysis of the evolution of the Swedish telecom innovation system (STIS).

Systems-of-innovation approaches were developed in the 1980s and 1990s, by academics and policy-makers in cooperation. This was a response to the inadequacy of simplistic linear models, not taking learning, relations, and systemic aspects into account. Still, it is not possible to describe the current state of research as a coherent theory. Therefore received literature was divided into four broad categories: (1) national innovation systems, (2) Triple Helix, (3) technological/sectoral systems of innovation, and (4) regional/local systems of innovation. Most approaches have the concepts of "innovation" and "system" in common, although their interpretations differ. Regarding innovation, the difference refers to whether only technical innovations are considered, or also organizational and institutional innovations. There is also a difference as to whether it is only the generation, or also the subsequent diffusion, adoption, and utilization that is focused upon. Regarding systems, the approaches primarily differ in what is meant by a system, and what the included components are. Usually, the term "system" denotes that there are strong interdependencies between the components, thus making it important to look at the whole and not only the parts to find the determinants of innovation. The degree to which the system is regarded as consciously designed or spontaneously evolved also differs. As for the components included, these are often institutions, networks, markets, and actors like firms, universities etc. with emphasis differing among the approaches.

The level of aggregation on which studies are made differs among the approaches. In the National Innovation Systems approaches, the emphasis is often on firms, and they are, as the name implies, concerned with higher levels of aggregation. The Triple Helix model is more concerned with "the new knowledge economy", and thus focuses on universities. The level of aggregation is not specified, but it often relates to regional economies. Technological Systems and Sectoral Innovation Systems emphasizes knowledge bases, technologies, and sectors, which also set the boundary of the system. The levels of aggregation studied are often below national levels, sometimes coming down to departments or individuals. Regional Innovation Systems and Networks, finally, is not a homogeneous set of approaches. Nonetheless, these approaches tend generally to put greater emphasis on networks and sociological aspects than the other approaches do, and studies are often conducted on somewhat lower levels of aggregation.

The IS approaches are not free from criticism and problems. They are often vague in definitions and concepts, and some key parts of important processes like learning and diffusion are weakly treated. In addition, they have an overly strong focus on high-tech sectors, and thus neglect the low-tech and service sectors. There are also some problems in operationalizing, for example, the shaping of the dynamics in systems, leading at times to a reliance on old measures and a tendency to recreate linearity. The most pertinent problem, however, is to align IS with growth theory, as it presently is more of a conceptual framework.

Although there are some problems with the conceptual frameworks, they still serve as useful analytical frameworks in order to generate a greater understanding of what drives innovation, and thus growth. Further research could however improve on the detailed understanding as well as linking the different, complementary approaches to each other.

9.1.1.2 Our approach

In this study a sectoral/technological systems approach is proposed, including also a national dimension. This is natural given our focus on the telecommunications sector. Still, drawing the boundaries is fraught with difficulties. It is not self-evident what a sector is; its boundaries are partly arbitrary and partly a theoretical construction. Neither is it evident what constitutes the national aspect. Thus we have to be pragmatic, using definitions made in other studies in classification of systems and databases.

Innovation is defined as inventions with some economic significance (e.g. that they have been produced and commercialized). The inventions dealt with here are primarily technical, if not stated otherwise. Important components in the systems include, in general terms, technical systems, actors/organizations, knowledge, institutions, and relations.

As a starting point we define the overall function of the innovation system as being to develop/generate, diffuse and use innovations. This functionality is deemed to be too broad and vague. Therefore an analytical framework is proposed. It is adapted from and draws heavily on the works of Staffan Jacobsson and Anna Bergek.[1110] Six basic interdependent functions need to be served in a technological system. These are:

1.) The creation and diffusion of *"new" knowledge*. Possible sources may be R&D, identification of problems, search and experimentation, learning-by-doing/using and imitation.
2.) The *guidance of the direction of search* among users and suppliers of technology. This function includes guidance with respect both to the growth potential of a new technology and to the choice of the specific design approaches (e.g. standards).
3.) It is necessary to *supply incentives* for the actors to engage in innovative activity. I.e. companies must feel that they get a reasonable return on investments, otherwise they will not engage in innovative activity and entrepreneurial experimentation. These incentives could be financial (e.g. tax reductions, loans), or relate to appropriability conditions (IPR, revenue sharing among actors etc.). Future revenue expectations are also important incentives for innovative activity.
4.) *Supply of resources*, such as capital and competencies, is obviously critical to the innovation process.
5.) The *creation of networks and other sources of positive external economies*. These could be both market- and non-market-mediated. It involves the facilitation of

[1110] E.g. Jacobsson and Bergek (forthcoming), Bergek (2002).

information and knowledge exchange, and is aided by connectivity between different actors in the system and the feedback loops between them.

6.) The *creation of markets*. Since innovations rarely find ready-made markets, these may need to be stimulated or even created. This process may be affected by governmental actions to clear legislative obstacles, by various organizations' measures to legitimize the technology, and by incentives.

For a new technology to be developed and diffused, and for a supporting industry to evolve, all functions need to be served to some degree. Whether or not this happens depends on inducement and blocking mechanisms. Studied literature suggests that such an approach is most useful in early stages of the evolution of innovation systems, i.e. the formative and growth phases. Four features of that process have been emphasized: (1) market formation, (2) entry of organizations, (3) institutional change and (4) the formation of technology-specific advocacy coalitions.

This choice of analytical framework was made quite late in the course of the project, after most of the empirical material had been gathered. This fact limits the applicability of the framework in this study. Still, a number of observations could be made pertaining to three areas of the study: (1) the fiber-optic communications case; (2) to shed light on why STIS developed a successful mobile but not data communications industry; and (3) how STIS has been and is positioned in the future growth market of mobile data communications.

9.1.2 The evolution of telecommunications

The telecommunications sector is composed of actors embarking on economic activity related to telecommunication systems. Telecommunication is in turn defined as communicating at a distance, between two or more parties, using electromagnetic waves. Telecommunications systems are composed of nodes (switches, routers etc.), links (cables, radio links, etc.) and terminals (telephones, data terminals, etc.) connected to the network, which were described in this chapter. At the heart of the sector lie the organizations that develop, produce, sell, distribute, provide services over (and content for), as well as standardize and regulate, these systems. Common industry denotations for such organizations include infrastructure and terminal suppliers, operators, retailers, subscribers and end-users, standard bodies, regulators etc.

Four "segments" of the telecom sector were identified: (1) one dominant but maturing segment (fixed telephony); (2) one revenue growth-generating segment where Sweden has been very successful (mobile telephony); (3) another growth generator (in particular in terms of traffic) with a potentially disruptive effect, where Sweden has been less successful (Datacom/Internet); and (4) a potential future growth segment (mobile data). Thus the relative importance of these segments for economic growth has changed over time, and is expected to continuously do so. This change has primarily been driven by innovation.

The structure of the telecom sector of the 1970s, here labeled the PTT regime, was established early in the 20th century. It was characterized by national monopolies (in the US private local monopolies, of which some 80% made up the Bell system), often merged with postal and telegraphy, including also a regulatory function. After the Second World War a system of primarily domestic systems developed, with resulting mutual dependence of operators and manufacturers.

The developments from 1970 to 2003 were investigated as a number of interrelated pervasive trends. These have been (1) growth of markets, (2) technological progress, (3) digitalization and the resulting (4) convergence and divergence, (5) the changing role of standardization, (6) the changing R&D regime, (7) liberalization and the resulting (8) changing industrial structure.

In the high-income countries, telecommunications has become an important and growing part of the economy, i.e. telecommunications has grown faster than the economy as a whole. According to most measured aspects, telecommunications services have expanded throughout the time-period, including the first years of the crisis. POTS (Plain Old Telephony Services) are mature and probably even declining (in terms of revenues and number of users). Instead there are two pervasive growth trends in telecommunications: (1) the increasing mobility enabled by cellular radio communications and (2) the increasing share of data communications induced by developments in computing. Cellular mobile communication has contributed the lion's share of subscriber and revenue growth, but is also maturing, at least in the high-income countries. There is still a lot of untapped potential in Asia, notably in China (with India lagging a few years). Data communications, in particular Internet data communications, is the other major source of growth, especially in terms of capacity and traffic. The growth has been less significant in terms of revenue, and more difficult to measure. As a result of these trends, the number of fixed line connections is decreasing in a number of countries, while demand for capacity is increasing. The combination of those two growing segments into mobile data is likely to become a third growth area.

Technological change in telecommunications has been dramatic, with rapidly improving functionality, performance improvements and cost reductions, opening up possibilities for new services and products as a result. The technical systems are also becoming increasingly complex, with a diversity of terminal, transmission, switching and access technologies and standards, which in turn pose demands on development, not least in software.

Digitalization has played an important role for shaping and reshaping the telecommunications industry. In sum, in the 1960s digital techniques were applied to long-distance transmission. Digitization started in the core of the networks (the interoffice transmission links, the digital switches) in the 1960s to expand towards the terminals in a stepwise manner, at an accelerating rate in the 1980s and early 1990s. The local loop is still mainly analog. The importance of digitalization is twofold. First, and this was the initial driving force, the performance of networks is improved. Second and more importantly in the long run, it provides a platform for introducing computer software capabilities into the network. This factor is of dynamic nature, generating new types of services. Thus digitalization drives a process of convergence between computing and telecommunications.

Convergence, although conceptually vague, means that technologies and actors are becoming more similar or even merging, calling for institutional change as well. This convergence was perceived quite early by the industry, starting a largely failing process of telecom firms entering into computing and vice versa. In recent years, the convergence of datacom and telecom spurred renewed activity. The effects of digitization have been even more dramatic in the sense that it has opened up possibilities for a wide (*divergent*) range of new services and new layers that could be entered by new actors, to be serviced by a wide range of technologies.

The importance and complexity of *standardization* processes have increased since the 1970s. Quite naturally, the need for international standardization (and coordination in general) emerged early, and with it a number of standard bodies (ITU, CEPT etc.). The processes of liberalization and internationalization in the sector have made standards more international and open, while at the same time competing standards have clashed on the market. Following this, aligning standards to the technological competence bases of firm and nations has become an important part of corporate strategies and industrial policies. One result has been the formation of regional and national telecom standard-developing organizations (SDOs). The complexity of technologies, with multiple interdependencies between and in the networks, has made the activities of SDOs very dependent on each other – and time-consuming. Combined with rapid technological change and convergence, the formal standardization bodies became more and more complemented with more flexible ad-hoc consortia. Finally, the inclusion of as recent technology as possible into standards has led standards to come increasingly into conflict with another institutional regime – patents.

The *R&D* intensity appears to have increased in telecommunications, spurred by higher incentives to innovate and new generations of technology being more costly to develop. This trend was broken with the crises, however, when several of the suppliers cut back their R&D. The character of R&D has also changed greatly since the PTT era. Back then, the locus of R&D activities was in the research labs of the PTTs. Gradually the equipment suppliers became more capable of development, a competence they could leverage to a larger customer base because of liberalization. A new breed of operators emerged, flexible and with little or no R&D, since technology could be readily acquired from the manufacturers. The character of R&D further changed with emergence of the Internet regime, creating new layers of actors with lower barriers to entry and to innovation, open standards, higher incentives to innovate, and presumably more emphasis on services innovation and innovation in start-ups, such innovations being more difficult to capture with currently available indicators. The changing regime has also meant that patents have become more of a competitive tool than before. As part of industrial policy, governments have been spending more on targeted research programs, instead of financing R&D through the PTTs.

One of the most important trends in the telecommunication sector in recent decades is that of the break-up of the PTT system and introduction of competition. A number of terms (often vaguely defined) have come to signify this change process, e.g. *deregulation* and *liberalization*. There were a number of technological, political and economic factors, interacting in a complex manner. For instance, when networks started reaching maturity, the cross-subsidies created incentives for some user groups to look for alternatives (large organizations with increasing communication costs). New technologies allowed for other means of providing those users with telecommunications, and also made the cost structure less dependent on distance. Therefore a new market opened up for the equipment industry (who previously protected the PTT regime since they benefited from it). The convergence further contributed to this trend, since it provided incentives for new types of suppliers (the computer industry) to enter telecommunications. The PTTs responded by entering new types of services, and incentives were created from inside the PTTs, where management realized that, in order to cope with the inevitable competition, the PTTs had to be transformed into more flexible and independent structures. In addition to these factors, there was a general liberalization trend, of which telecommunications was part, with the US as prime mover.

The transition of the PTT regime started in the 1960s in the US domestic market, where AT&T's monopoly was challenged by MCI. In 1984 AT&T was broken up into a long-distance operator and seven regional operating companies. Early deregulation followed in Japan and the UK in the early and mid-1980s, while continental Europe followed a cautious path to reform, mainly pushed by the European Commission, the introduction of GSM being a major opportunity to start the process. The process went into full swing in the 1990s. By now, most high-income countries have more or less deregulated markets, with developing countries still lagging. Having liberalized the market, the governments had to redesign regulatory frameworks in order to sustain and stimulate competition, lower barriers to entry and hinder dominant operators from abusing their market power. A number of complementary reforms (e.g. interconnection, carrier pre-selection, number portability) have been introduced since then for these purposes. Internet remains an issue to solve for regulators.

Coinciding with the digitalization of the telephone network and deregulation, the telecom operators' *market structure* started to break up in the 1980s. Telecom operators encountered competition on their home markets and began to internationalize, not least in the field of mobile telephony. Large numbers of new entries, mergers and acquisitions have taken place since then. This process accelerated in the 1990s, when the market was further fragmented by the increasing importance of data communications over the telephone network, notably in the form of the Internet. Compared to the operators' market, the supplier structure has been fairly stable, with a few mergers in the 1980s, and the rise of mobile and datacom specialists and Asian suppliers. The large suppliers have grown larger and more R&D-intensive.

Finally, the remarkable collapse of the telecommunications industry around the millennium shift must be understood by first explaining the boom of the late 1990s. This boom was partly driven by unrealistic expectations of market growth and an overheated financial market, a maturing mobile market in need for renewed growth, and fueled by an unfortunate 3G licensing regime. This led to overinvestment, in particular in 3G licenses, but also in network capacity and in acquisitions raising debt to levels that could not be sustained, leading to write-downs, divestments, bankruptcies and halted investments. Faced with cost structures adapted to false market expectations, equipment suppliers' profits were rapidly turned into huge losses. Downsizing among suppliers has enabled some to regain profitability. However, although faced with continued growth prospects in emerging markets and in new services and products, the industry was still licking its wounds (early 2004). Financial markets for instance seem to be overly cautious. When the market eventually enters a growth phase again, the main actors and national innovation systems are likely to differ in their capabilities to capture shares of that growth.

9.1.3 The evolution of the Swedish telecom sector

The telecommunication sector is an important part of the Swedish economy and has been increasingly so during the 1990s. The contribution to economic growth (measured as productivity improvements and value-added growth) has increased to become almost half of the contribution of the industry in 2001. The increase in value added stems mostly from the telecom equipment part of the industry (with telecom-services contributions more marginal). Second only to Finland, Sweden is the OECD country most dependent on the telecom product sector of the ICT industry. With a lack of data for 2002-2003, no clear statement can be made about the most recent developments, other than that the telecom bust has been particularly painful for the Swedish economy.

Telecom has also been the major driver of growth in the R&D component (as is also shown in patenting statistics) of the Swedish national innovation system, while the corresponding computing part has been relatively low. It may be hypothesized that, for telecom R&D, Ericsson's growth, in particular in mobile communications, has played an imperative role. If so, the Swedish R&D system overly depends on the success and failure of one product area of one firm. This has been a strength for Sweden, but may equally turn out to be a threat and weakness.

After a few decades of intense competition, a *de facto* monopoly was established in the Swedish *operators' market* in the late 1910s. This monopoly of Televerket's lasted until the 1980s. In terms of penetration of telephony services, the state of technology implemented and quality of services, Sweden has been an advanced market since the late 19th century. Compared to many other "PTTs", a number of features rendered the position of Televerket unique. Some important features of the monopoly made it stand out in an international comparison. Being a public enterprise and not linked to the post monopoly contributed to a relatively independent position vis-à-vis the government. It also had a division of equipment manufacturing, which meant that it could develop its own manufacturing and R&D expertise, driven by a genuine engineering culture, and became a powerful purchaser.

In the 1970s the monopoly started to adapt to changing conditions, driven by the opportunities created by technological change and a general liberalization trend, which triggered large users, the emerging electronics and computer industries, and liberal politicians to act. Televerket began to adapt. Although manifested in the new Telecommunications Act of 1993, Swedish deregulation was a gradual process starting in the 1970s, gaining pace in the 1980s when subscriber equipment was gradually liberalized and infrastructure competition was introduced in selected areas (Cellular and CATV). Regulatory responsibilities were gradually separated from Televerket, starting in 1981 and completed with the formation of PTS in 1993. Corporatization was primarily driven by Televerket itself, in order to respond more effectively to threats and seize opportunities in e.g. other countries. The process started with the creation of manufacturing and investment companies and was finalized with the establishment of Telia AB in 1993. Privatization started in 2000 with a partial share offering. By this writing, Telia has merged with Finnish Sonera. The Telecommunications Act of 1993 imposed very few restrictions on the market. During its ten years of existence it has been amended several times, with mixed effects on competition and prices. Effects on innovation are even more ambiguous.

Starting with international computing firms entering the data communications market and local firms entering mobile telephony in the 1960s, followed by cable TV and satellite services in the 1980s, the major monopoly attacker became the Kinnevik Group, making inroads into mobile telephony, CATV and satellite communications in 1980s, developing into a full-fledged competitor (Tele2) in the 1990s – second only to Telia in most segments. Starting with international telephony and data communications, followed by long-distance telephony, competition gradually intensified, resulting in lower prices. Telia responded by shifting its pricing structure, possibly because of its dominance in the local loop. Meanwhile both Telia and Tele2 took advantages of opportunities abroad, with mixed success. As a result of competition and the growth of new services, the telecom services market expanded rapidly in the last decade. However, fixed voice is declining in revenues, and the mobile voice market is maturing. If there is going to be any future growth, data communications (fixed and mobile) have to compensate.

The Swedish *supplier industry* has been heavily dominated by one firm: Ericsson. In 1970, there were a few minor suppliers, including Teli. By the start of the time period investigated, Ericsson accounted for around three quarters of the Swedish telecom manufacturing sector. The relationship with Televerket was one of collaboration and to some degree competition. The development of the AXE switching system (developed jointly by Televerket and Ericsson) became crucial to the future competitiveness of Ericsson. In this respect it was very much a result of collaboration, guidance and resource-sharing with an advanced customer, but not of public procurement. In the 1980s, although Ericsson tried to diversify into the computing market, mobile communications grew to become its major growth area. It took until the late 1990s before it tried again to enter the booming data communications market, a fact that led to a rapid build-up of resources mainly through acquisitions. After failure in the mobile phone market, the telecom bust hit Ericsson's core business – mobile systems. Drastic cut-backs allowed Ericsson to survive the crises, but it is a smaller Ericsson today. The effects on the Swedish economy and its innovation system have been dramatic, the consequences still difficult to assess.

In the Swedish telecom innovation system, Ericsson is in 2004 by far the most important actor in terms of revenues, followed by the large operators. Around Ericsson, a vast number of companies supplying components and services have emerged. Based on statistics on the 500 most important IT companies in Sweden, it was estimated that the telecom industry generated revenues of between 300 and 400 billion SEK in 2002.

Industry has come to increasingly dominate the sector's R&D funding, in particular Ericsson. Following the downturn, effects on R&D spendings have been dramatic. In 2001, Ericsson contributed more than 20% of the total R&D spending in the country. The effects of cutting almost half those R&D expenditures are significant. Also Televerket/Telia has downgraded its spendings. With the two main actors decreasing their investments, others have to step in, provided that the sector is to sustain its innovativeness. Telecom-related public R&D was increased in the early 1980s, and seems to have made a difference in a number of areas. However, if deemed necessary to compensate for Ericsson's cutbacks in recent years, current levels seem to be low.

An increasing share of innovation in the emerging ICT industry can be hypothesized to be conducted by small entrepreneurial firms. Access to capital through the venture capital market will therefore be a major function in the telecom sector's innovation system. With a few minor setbacks, the Swedish VC industry grew from the early 1970s until the early 2000s, when the financial crisis forced many companies out of business. At the end of the 1990s, Sweden had a relatively large venture capital sector, investing a relatively large share in early phases and in telecom-related start-ups. It has, though, been found to lack competence. Sweden still invests much venture capital in an international comparison. However, capital is targeted at later stages of investments. There may be a lack of functionality in the function of early-stage financing in the Swedish VC system, but absolute levels are difficult to assess.

To conclude, given the size and complexity of the sector and lack of time, resources and available indicators and statistics, this report leaves many questions unanswered, and many important paths of inquiry remain open for further research. Our approach to these inherent limitations has been to focus on the three major growth segments of mobile, data, and mobile data, the first two being the major growth segments allowing comparative analysis, the third having huge future potential and high policy relevance. In addition, the area of fiber optics is focused upon in depth.

9.1.4 Evolution of data communications/Internet

9.1.4.1 International developments

Data communications evolved along several tracks, with the Internet eventually emerging as the major one. This was not a self-evident outcome, not even ten years ago, as shown e.g. by Microsoft's pursuit of a strategy along a different, proprietary track. However, the developments in the early period did shape the industry as we know it by now. Therefore it is important to trace developments back to those early days.

Data communication over the telephone network using modems was introduced in the US around 1960. Modem usage increased rapidly in the 1960s, in line with the introduction of more telecommunications-oriented computers. The predecessor to today's Internet, ARPANET, was born in the USA in 1969. The arms race during the Cold War had compelled the US to develop a communications network for efficient knowledge distribution among researchers. In addition, researchers, e.g. at the think-tank RAND, elaborated on the idea of constructing a network able to withstand targeted attacks on the infrastructure. The chosen technical solution was based on sending information in small data packages. A number of packet-switched networks followed, and in 1973 DARPA financed an investigation called "The Internetting Project", looking into the possibilities of connecting different packet-switched networks to each other. The introduction of the protocol TCP (Transmission Control Protocol) in 1974 made this task easier. Several data communications networks were created in the following decades, many in academia, using this common protocol.

Already in 1979, Compuserve launched the first commercial on-line service. Several companies followed, connecting users to computer networks with content services using dial-up modems. In 1990, Compuserve was the leading on-line service provider, counting 620,000 subscribers. The on-line services were accessed using microcomputers and modems, often via packet-switched networks such as Tymnet or Telnet.

Computer networking on a smaller scale, within offices, also grew in the US in the 1970s. PARC (the research arm of Xerox) developed the communication protocol Ethernet in 1973, in order to fully utilize the world's first laser printer also developed there (it needed to be connected to several computers inside a building). A low license fee and the wide acceptance of the technology created through IEEE caused Ethernet to diffuse rapidly in small corporate computer networks, so-called local area networks (LANs). Today Ethernet is the most widespread LAN technology.

The early development of networking technologies in the US gave the country a head-start in developing equipment for the networks. The fast-growing use of computer networks in the US caused small start-ups as well as large computer actors to innovate in the networking area. During the 1970s and 1980s, established computer firms such as IBM and DEC developed both communication equipment and proprietary computer communication protocols that diffused widely. The firms that eventually came to dominate the computer networking market were companies started in the 1980s and 1990s to exploit the opportunities of open standards, e.g. TCP/IP and Ethernet. Between them, Cisco, 3Com and Bay Networks (today a part of Canadian Nortel) have a strong grip on the market for computer communications equipment. The large domestic market in the US provided a stable ground for US firms to propel into world computer networking market leadership, a development similar to how US packaged software firms leveraged the US domestic PC market in the 1980s.

European countries were also early in establishing experimental computer networks. Already in 1967, some years before the ARPANET was constructed, a packet computer network was developed in the UK. An early French initiative based on the ARPANET developments, called CYCLADES, was built in 1972. Although the network was no commercial success, it was technologically important. One of the technical achievements was the datagram, used in the IP standard.

Videotex networks – mainly developed by European PTTs – appeared in many European countries in the 1970s and 1980s, including the BTX in Germany, Minitel in France, and Videotex and Teleguide in Sweden. The Videotex service raised high hopes at European

PTTs and in European electronics industries, but proved difficult to make profitable. Networks based on the Videotex standard were introduced also in the US in the first half of the 1980s, without much success. A second wave of Videotex networks came in the late 1980s.

In Europe, there was a perceived threat that standards incompatible with existing public networks would be developed outside the telecom industry, accelerating the creation of private networks. Data communication usage was gradually increasing, and the analog technologies used would soon become insufficient. Further, the penetration rates of telephone connections had increased sharply in the 1970s, and in many countries saturation came closer. In this setting, the development of ISDN (Integrated Services Digital Network) was initiated. ISDN could prove to be the growth opportunity needed by operators. Partly, the ISDN development was also defensive from the PTTs' point of view. The ISDN development was coordinated on the European Community level in an effort to strengthen the strategically important European telecom industry. The ISDN diffusion lately increased pace in 1999, due to demand for higher-speed Internet connections. At this time other, often faster, technologies were available and eventually out-competed ISDN.

The Internet continues to diffuse, both in number of users and in usage. In 2002, there were around 600 million Internet users in the world, up from around 10 million in 1993. In the same period the growth rate has slowed from over 100% in 1994/1993, to around 20% in 2002/2001. A shift towards higher-bandwidth connections, often of always-on type, has been evident in many parts of the world, notably in South Korea and Europe. With ever-increasing processing power and storage capabilities in PCs, the intelligence increases in the network periphery. This opens up for a number of new applications, e.g. file sharing in P2P networks. There is also a continued convergence trend, where the Internet is used for voice transfer, a traditional telecom task.

9.1.4.2 Swedish Internet development activities

In Sweden as well as in most other industrialized countries, the Internet was preceded by a range of computer networking and communication technologies. The first modems on the Swedish market were launched in 1962. Televerket foresaw the need for a public data communications network and in 1969 ordered a study of how such a network should be constructed. An important conclusion of the study, delivered in 1971, was that a circuit-switched data network was preferable to a packet-switched one. This result was backed by close communication with regulatory/standardization bodies and other European PTTs. The commercial operations of the network – named Datex – were started in 1981 with network equipment delivered by Ericsson. The Nordic PTTs coordinated their efforts in the area, e.g. network specifications and joint procurement of equipment.

The need to connect to databases abroad, notably in the US, grew in Sweden during the 1970s. A European connection to the American Tymnet had been established, but for Swedish users the closest node was placed in Amsterdam, leading to high connection charges. In 1979 Televerket acquired packet-switching equipment from the US company Tymshare Inc. and established a Swedish packet-switched node. The network was gradually expanded and connected to other networks, in 1984 numbering 50 nodes in 40 countries.

Following the Videotex developments in Europe, a Swedish commercial Videotex service was launched in 1982, but adoption was rather slow. In a renewed effort, the Teleguide project, much like a Swedish version of the French Minitel, was launched by Televerket, IBM and Esselte in 1991. The adoption of Teleguide, however, was also slow. In the summer of 1992 it had attracted 22,000 customers, far below the expected numbers. In October 1992

Televerket announced a plan to leave the project, and Teleguide was closed down in early 1993.

In the early 1980s STU and FRN made the first efforts to connect computers at universities in Sweden in a network, SUNET. From 1987 it became economically unfeasible to base the computer network on the X.25 service provided by Televerket because of the growing number of connections. In 1988 a number of fixed connections were leased from Televerket, and SUNET switched from the proprietary DecNet architecture to the open standard TCP/IP, in a way marking the birth of the Internet in Sweden.

Still, at the end of the 1980s, there were no commercial actors selling Internet access to companies and households. Influenced by an active user group, Comvik Skyport (later Tele2) connected the first customers to an IP network in March 1991. At the end of 1991, Televerket opened a competing IP network, both companies catering exclusively to corporate users. Starting in 1994 a number of companies providing Internet access through modems for consumers/private users emerged. In 1996 there were 75-100 Internet service providers.

In 1997, the Swedish Parliament introduced tax reductions on computers bought by companies for their employees' private usage. This program quickly led to an increase in both absolute computer numbers and usage in Sweden. In line with the Internet development, more and more of the computers came equipped with modems and networking capabilities. Thus, the diffusion of computers, in turn propelled by government tax subsidies, paved the way for diffusion of Internet usage.

In the period 1995-2002 the number of dial-up Internet connections increased from 54,000 to 3.2 million. In recent years, a gradual shift towards higher-speed connections has been initiated. The relative modem usage has decreased since other access forms, primarily broadband xDSL connections, have grown rapidly. In 2003, the diffusion of high-speed Internet connections in Sweden is high in comparison to most other countries.

In the middle and late 1990s there were strong entrepreneurial activities in the Internet area. The technological breakthroughs and rapid growth of Internet usage in Sweden and elsewhere caused several companies and individuals to seize business opportunities. With established companies being slow Internet starters, a number of new firms acted on opportunities of intermediary functions, reducing transaction costs. In time, the established firms learned about the opportunities brought about by the emerging technology, and the Internet was introduced as a tool in companies' daily operations. Many of the firms started in the late 1990s were acquired by established firms, or seized operations.

9.1.4.3 Swedish data networking equipment activities

In the 1960s-70s, when computer communications in Sweden was very much a matter for Televerket, the Swedish telecom industry was a strong supplier. At the end of the 1970s around 50% of the modems installed in Sweden were supplied by domestic producers. Since then, US firms – often with connections to the computer industry – have secured a very dominant position in the equipment industry, with the importance of domestic suppliers rapidly diminishing.

A strong computer industry has proven to be of great importance for the US in the formation of a strong computer *networking* industry. Initiatives were made in Sweden in the early 1980s to build up a computer industry. The most notable example was Ericsson's largely unsuccessful venture into the consumer electronics market (EIS). The failure of EIS may have had a hampering effect on Ericsson's Internet developments in the early 1990s, when the company fell behind new competitors.

In the 1980s Ericsson started working on broadband telecommunications switches able to handle voice, video and data. Heavy investments were made in the project, dubbed AXE-N, according to some sources as much as SEK ten billion. The technological hurdles of integrating voice and data proved higher than anticipated, and in 1995 the project was terminated. In 1999 Ericsson introduced products for ATM-based multi-service networks. IP was seen as a clear threat at the time, but ATM had the advantages of offering quality of service, built-in billing mechanisms and subscriber management functions.

Parallel to the ATM development, Ericsson co-financed university research on another switching technology, dynamic synchronous transfer mode (DTM). When the technology was ready for commercialization, Ericsson decided not to develop DTM products. Instead, the research resulted in two start-up networking equipment companies in 1996, Dynarc and Net Insight. The market for DTM technology proved smaller than anticipated, and in mid-2002 Dynarc filed for bankruptcy.

Today, both the hardware (Internet access, computers etc.) and a high IT readiness are in place in Sweden. Overall, Sweden has reached a world-leading position in Internet usage and is also relatively advanced in e-commerce activities. In the equipment and content industries, Sweden has been less successful. The lack of a computer industry for learning and guidance of search for technological solutions seems to be an important explanation for why this is the case. Somewhat contradictorily, the strength of the telecom industry also seems to be an important factor since this probably has guided research towards less successful solutions for data communications.

9.1.5 The evolution of mobile telephony

9.1.5.1 International developments

Induced by WW II and its ending, land mobile telephone systems emerged in the late 1940s, first in the US and a few years later in Europe. National monopoly operators (e.g. AT&T and Televerket) normally provided the service and developed the systems, often in collaboration with the radio industry. In some countries there were private operators as well. These early systems suffered from many limitations, the most serious ones being low capacity (due to lack of frequencies and poor spectral efficiency), poor service quality and bulky terminal equipment. Those bottlenecks have been attacked and improved by engineers ever since. Cellular systems (conceived and developed in response to the above limitations) had to wait until around 1980 before implementation, quite independently, in the US, Japan, Germany and the Nordic countries. A second generation of cellular systems, this time digital, was launched in the early 1990s. At this writing a third generation (3G) is being launched.

Regulation played a key role in the history of mobile telephony. The United States had developed a technological and commercial lead in radio communications, especially after WW II. Regulatory obstacles delayed the introduction of cellular in the US. This made it possible for other countries and firms to catch up. The Nordic countries, and the firms Ericsson and later Nokia, were particularly successful. NTT of Japan pioneered the introduction of cellular systems in 1979, although with moderate commercial success. Although the Japanese succeeded in catching up technology-wise, they failed to leverage this to a strong position in 1G and 2G cellular systems. The UK, with a policy of introducing market competition, fared much better, while seemingly misdirected French industrial policy aimed at strengthening the French position in mobile failed to do so, on the user side as well as the supplier side.

Standards have been a key factor in the development. When cellular systems were launched in the early 1980s, it was in the form of a number of national or regional standards (AMPS; TACS; NMT; C-Netz etc.), some of which spread to other countries as well, often followed by the main suppliers. This international diffusion has been influenced by a large set of political, technical and economic factors, working in favor of three standards, NMT, AMPS and TACS. Suppliers sponsoring these standards, e.g. Ericsson, clearly benefited from their success.

Liberalization was another salient feature in the evolution of mobile telephony (as for telecommunications in general). In the pre-cellular and analog era, national monopolies operated mobile telephony as a rule. Early exceptions were the US and the UK. Although Britain failed to produce any significant supplier, the leading international operator (Vodafone) emerged from this pioneering market liberalization.

Of particular importance to the European mobile communications sector was GSM, developed by a special working group (Groupe Special Mobile) in response to the fragmentation in the European mobile communications market. Research and development in digital cellular took place along different technological trajectories, mainly in two camps, the Franco-German and the Nordic. These interests clashed in late 1986, a settlement was reached, and GSM standardization could progress along a technological trajectory clearly favoring the Nordic suppliers Ericsson and Nokia.

This GSM case yields a number of implications. The first is the importance of being able to influence standardization processes. The importance of credibility of technological choice and standards is another key lesson. Early on, market demand for analog standards provided this credibility, facilitating for the GSM group to move forward. The commitment shown by operators through the MoU and the endorsement by the European Commission were crucial in the product development stage. However, the increasing importance of standards put the regime increasingly under strain. The standardization processes are becoming increasingly complex and time-consuming, while at the same time demands on short time to market are in conflict with this trend. Also, as the industry changed, with manufacturers internationalizing and operators losing their monopoly status, the incentives to engage in standardization activities changed. In the GSM context, the conflicting objectives of standardization and patenting emerged as a serious problem. This conflict is not yet resolved.

The transition from analog to digital cellular was rapid, in spite of being perceived as slow for some of the key actors. While new entrants stimulated the transition to GSM, factors working against a rapid transition were (a) difficulties in developing terminals and having them tested and “type-approved”, (b) incumbent operators’ lack of incentives, and (3) initially inferior systems and terminals.

Digital cellular systems developed also in the United States (FDMA and CDMA) and Japan. However, GSM could exploit early-mover advantages in the international market and establish dominance on the world market. As a result, the European manufacturing industry (especially Nokia and Ericsson) has come out much stronger than the US and especially the Japanese, and has a lead in the systems as well as terminal markets.

9.1.5.2 Evolution of the Swedish mobile telephone innovation system

The development of mobile telephony in Sweden can be divided into four phases. The first phase was centered on Televerket's innovative development of MTA and MTB in the 50s and 60s. In the second phase, during the 1970s, NMT was developed while MTD was introduced as a gap-filling innovation-system builder. In the 1980s NMT diffused rapidly while GSM was developed and Ericsson replaced Televerket as main actor in the innovation system (the third phase). The fourth phase in the 1990s was harvesting time, when GSM took off and competition was introduced.

Thus, development of the Swedish mobile telephony innovation system cannot be fully understood without taking some development before 1970 into consideration. During the postwar period Televerket established itself as a leading innovator in mobile telephony. In doing so, important functions in the innovation systems were developed, which was vital since such build-up processes take time. The pioneering development of MTA and MTB developed the competences inside Televerket. The experiences gained by commercializing the system also guided future search. Without this knowledge it would have been difficult to publish the influential Åsdal investigation in 1967. Some knowledge may have been developed in the domestic supplier industry as well. The roles of government and universities seem to have been negligible at this time.

The 1970s became important for two reasons: (1) the start of the NMT development, and (2) the decision to implement MTD. Established network relations with the Nordic telecom administrations facilitated the rapid start of standardizing NMT and launching MTD in three of the countries. The connections with the radio industry seem to have been rather weak by then, however. MTD nurtured and cultivated the innovation system, increasing its capacity to deliver and absorb the expansion to come. All functions in the innovation system were improved during the 1970s, in particular those that aided the formation of markets. When NMT was introduced, Sweden had an advanced user market, developed distribution channels, and a competitive supplier industry.

The competence that had been developed at Televerket's radio labs enabled it to take a leading role in the development of NMT (although its Nordic counterparts also contributed to some extent). It became a leading innovator as well as lead user, guiding the efforts of the supplier industry in a direction it would never have taken if left to its own decisions, e.g. the choice of the AXE switch. Thus Televerket counteracted the resistance to change, at a time when change was necessary.

Also the supply side of the innovation system mattered for the Swedish success. There were three broad technological competences necessary to become a strong mobile systems supplier: (1) radio, (2) switching and (3) systems competence. By 1982-83, Ericsson had acquired all these three competences, partly through internalizing much of the Swedish innovation system through acquisitions.

To sum up the analog era, the prime mover was Televerket. Its development of mobile telephony, and key decisions taken, shaped the innovation system with respect to several of the functions of the analytical framework. It built up the competence base, and guided the direction of search through technological choices and through its activities in standardization and in procurement. It was instrumental in forming and stimulating the market, and to some degree through investing in innovation. Ericsson increasingly became a key player, while the role of other actors was marginal. Universities and institutes did not contribute substantially to the development of technology. Few firms were started in the early phases. Some foreign influences were affecting the development, mostly regarding a number of enabling technologies. No government-sponsored research (apart from Televerket research) has been identified as having been important. The role of military R&D was limited to being important for the development of a radio supplier industry. All this came to change for the next generation.

In the transition from analog to digital, some technological fields had to be built up by the innovation system, an innovation system that became increasingly dominated by Ericsson. The key to Ericsson's success was a combination of building on the existing analog success, being able to develop the necessary digital technologies, and influencing the choices made in standardization. Public procurement from the military lead-user was important for developing digital technologies. The close ties with Televerket influenced the guidance of search in the proper direction, i.e. towards narrowband TDMA, which was the best choice in techno-economic terms. This relationship and the alliance created with other Nordic actors helped to influence the choice in the standardization process. After that, the technological choice in GSM legitimized Ericsson's pushing for similar solutions in the US and Japan.

While these successes in the formation of the market benefited Ericsson, they seriously challenged the company's abilities to develop products due to a lack of resources. When the important choices were made, the Swedish innovation system's (read Ericsson's) competence needed strengthening. Government funding was important for product development, not least for the inflow of competent personnel. Eventually, Sweden could not supply the rapidly growing company with the necessary resources, and Ericsson was forced (also for other reasons) to internationalize its R&D activities. Thus the corporate innovation system (see Granstrand 2002) became internationalized.

The extremely rapid growth of mobile telephony provided opportunities for other actors to establish themselves as sub-suppliers (parts of base stations, and mobile telephones), distributors, competing operators etc. Still, this build-out could possibly have been even higher, had the supply of capital and personnel been greater. It was not until the late 1990s that start-up activity really gained pace (see the next chapter).

The Swedish case also points at the importance of designing institutions (regulations) bearing the proper goals and economic incentives in mind. For instance, introduction of competition, i.e. allowing for two full-fledged operators to enter the GSM, speeded up the transition, thus maintaining the Swedish leading position in terms of usage of the new technology.

9.1.6 The evolution of mobile data communications

9.1.6.1 International developments

Wireless data communications was initially provided over private mobile radio (PMR) and paging networks. PMR was historically the dominant form of land mobile communications, and is still a fairly large business. Mobile data over PMR emerged in the early 1980s. Some public access mobile data communications systems were launched as well, notably Mobitex and DataTac, with mixed results. In the late 1990s market growth was somewhat rejuvenated by the introduction of new generations of digital trunked systems such as iDEN and TETRA. These were designed to carry data traffic as well as voice.

Due to low costs and small terminals, paging took over from PMR as the dominant mobile communications service, at least in the US and Asia where paging was far more diffused than in Europe. By the introduction of a new ETSI standard – ERMES – Europeans tried to gain ground, but failed since it arrived too late and too complex on the market. In the late 1990s the paging concept was undergoing rapid change. Paging networks were improved to provide extended functionality, such as two-way messaging, news and e-mail services.

Some data functionalities were available in first-generation mobile telephony networks (e.g. NMT), but they did not reach any notable usage levels. Data capabilities were improved in the second-generation networks (e.g. GSM) launched in the early 1990s. The first generation of data services over GSM suffered from some basic limitations. Maximum data rates were low (9.6 kbps) leading to unacceptably long times for performing even simple tasks. Adding to this, costs of service were too high. These limitations were anticipated early on and subjected to performance-enhancing standardization. The most radical GSM improvement was perhaps GPRS (General Packet Radio Service). After an unduly long standardization process, GPRS functionality was implemented in most GSM networks during the early 2000s, but usage is lower than envisioned.

Instead, the commercially most important data communication service of the late 1990s and early 2000s became the Short Message Service (SMS). GSM operators started introducing mobile-originated SMS by 1994, with initial slow take-up. Fueled by a large number of improvements and inventions (e.g. interoperability enhancements, interconnect agreements, better terminal displays, etc.) the market started to grow very rapidly in late 1999 and early 2000. In early 2003, of the “charged-for” traffic, mobile-to-mobile messaging represented circa 90 percent of the SMS traffic, which in turn represents more than ten percent of many operators’ revenues.

WAP – the Wireless Application Protocol – emerged in 1997 as a major effort to reduce and overcome the limitations of terminals and networks for mobile Internet usage. Fueled by the Dotcom bubble, unrealistic expectations of the usefulness of WAP created hype in the late 1990s, with dramatically rising stock prices for companies involved in WAP development. Not surprisingly (not even ex-ante), WAP services did not take off as expected, due to limited usefulness, limited performance of networks and services, and a lack of terminals.

In February 1999, NTT DoCoMo launched i-mode – a wireless Internet service that finally proved right the belief that mobile data services were a future growth area. In contrast to WAP, which is a set of specifications, i-mode is a full service concept. I-mode proved an almost immediate success. By 2003 there were circa 3,500 official and 65,000 unofficial sites, and more than 30 million users. The Japanese competitors imitated i-mode successfully. As a result, by 2001 Japan had taken the lead in mobile data communications, with DoCoMo as well as domestic terminal suppliers also starting to leverage that lead abroad.

In the mid-1990s, third-generation (3G) standardization efforts gained pace. After major choices had been made in 1998, two contesting solutions emerged: WCDMA/UMTS (backward-compatible with GSM) and CDMA 2000 (backward-compatible with cdmaOne). In many countries frequency spectrum was auctioned out, in others distributed through beauty contests (where operators competed on intended coverage and build-out pace). The high sums paid for licenses, in combination with high costs for building up infrastructure, led to high debts for operators, reduced investment rates, and thus contributed to the severe telecom crisis. In Europe, 3G introduction was delayed. Instead it was Japan that moved first in 3G implementation. So far it has been the softer upgrade to CDMA 2000 that has been most successful, in Japan and not least in South Korea.

Through long-term commitments, Korea has established itself as a leading nation in the mobile data field. In 2000, it launched the first commercial CDMA2000 network. The early launches seem to have provided Korean and Japanese terminal manufacturers with a head-start and companies from these countries have developed the bulk of the 3G models introduced on the market. In Europe, only one operator, "3" controlled by Hutchison, pushed forward with an aggressive 3G roll-out and operation, covering six European countries in 2003.

A separate mobile data development track has emerged outside the traditional telecom industry, mainly from US manufacturers, and mainly in the form of Wireless LAN technologies (WLANs). Thus far, they have targeted other applications than cellular networks (i.e. wireless to the Internet rather than mobile messaging and dedicated mobile services). As cordless phones, they use an unlicensed frequency spectrum open for all to use. WLAN and its WMAN (or WWAN) derivatives pose a potential threat to the traditional telecom industry; the challenge lies in turning a wide array of stand-alone connection locations into a dependable network. This calls for extensive billing mechanisms and roaming agreements to be developed and implemented, which is probably only feasible through some kind of standardization. If voice over IP usage increases and the barriers presented above find their solutions, wireless LANs and MANs may have an important role to play in the telecom industry.

In parallel to these developments the terminal business has undergone major changes. Cellular terminals are becoming more data-capable, with Asian manufacturers strengthening their position. The computing industry is attacking from a previously separate track of personal digital assistants (PDAs), not very successfully so far. In line with more data-potent terminals, software of different kinds is becoming increasingly important, with a looming handheld Operating Systems (OS) software war (e.g. Microsoft vs. Nokia/Symbian). The terminal being an important platform also, operators try to take control of it.

In addition, the formerly tight actor system is breaking up, as a result of the new service opportunities opening up. New entrants are rushing into the industry, in a multitude of roles (content aggregators, content providers, portal providers, etc.). This emerging actor-chain complexity creates uncertainty for the sector.

Finally, although perhaps prematurely, the concept of 4G is gaining attention along different tracks. The 3G sponsors, in particular the European manufacturers and the European Commission, envision 4G as something replacing or building on 3G, perhaps 10 years into the future. A number of initiatives were taken (e.g. the WSI, WWRF) already within the 5th Framework Programme, continuing into the 6th.

Asian countries take a more aggressive industrial policy-driven stance, aiming to take over leadership. Japan and Korea have announced on several occasions that they will launch 4G earlier than 2010. China has publicly announced that it aims to take a leading position in 4G – and these countries cooperate. They also drive the process forward in international cooperative bodies (e.g. ITU and WWRF). Meanwhile, mainly in the US, the 4G vision is something different. It involves the organic growth of WPAN, WLANs, WMANs, the establishment of ad-hoc networks etc., made interoperable, also with cellular networks. This vision is driven by the computer, datacom and microelectronics industry, including firms such as Intel and Cisco as well as start-ups.

9.1.6.2 Swedish developments

Although mobile data has long been considered an important growth area for Swedish operators, service take-up has been limited. During the early and mid-1980s, Televerket developed Mobitex, a pioneering packet-switched mobile data system. The developments started because of a number of anticipated needs, both internal and external. Other actors including Ericsson and Volvo developed other, private alternative systems. Mobitex was launched in 1986, but due to a number of discrepancies in the innovation system, uptake was slow. In 1988 Televerket and Ericsson formed a joint venture for internationalization of the system. In the mid-1990s the system was on its way to becoming a *de facto* European standard, but false expectations on future systems caused operators to delay investments, and even to close down networks.

The first data solutions for cellular telephony were launched already in the NMT networks, but the limited data capabilities were only used in a few niche applications. In 1994, data services were launched over the GSM networks in Sweden, but take-up of these services was very low. Also Swedish SMS diffusion was slow initially for similar reasons as in other countries, but started to increase significantly in the late 1990s. Still, SMS usage in Sweden was low compared to other advanced markets (8% of operators' revenues in 2002), indicating that Sweden had lost its status as a lead market.

Operators tried to launch more advanced data services from the late 1990s onward. The first packaged mobile data services were launched by Telia in February 1998 (DOF) but never reached wide market acceptance. In November 2000, Telia launched another mobile portal project (Speedy Tomato) but the project was soon terminated. The packet data service GPRS was first introduced by Europolitan/Vodafone in late November 2000, followed by Telia and Tele2 in the fall of 2001. Uptake of GPRS appears to have been slow. Although most new terminals were GPRS-capable, there were less than 200,000 active users by mid-2003.

Following the advent of more capable terminals, with cameras, color screens and MMS capabilities, new mobile data packages were launched by the operators. First out on the Swedish market was Vodafone, launching its mobile data package Vodafone Live! in late 2002. In 2003, both the remaining strong operators, Telia and Tele2/Comviq, launched similar packaged data services. In May 2003 they also received competition from 3, introducing the first third-generation network on the Swedish market. In spring 2004, the remaining 3G license owners are expected to launch their services.

In the late 1990s a boom of entrepreneurial activities was recorded, not least in Sweden. Fueled by high expectations, unlimited venture capital, a strong competence base, and an advanced user market, Sweden (in particular Kista) attracted also much foreign capital and R&D investment. Start-ups were created in the areas of e.g. application development, consulting, enabling technologies, service provision etc. Much of this growth came to an end with the bust of the early 2000s.

In short, Swedish mobile data usage has not increased as anticipated by many industry actors and observers. Although this could probably be said about a number of other countries, Sweden stands out in e.g. a Nordic comparison as the country with lowest mobile data usage. A number of initiatives to start the market have been made, but so far they have been too isolated, without the system approach taken by e.g. Japanese actors.

9.2 Analyzing the case of fiber-optic communications

9.2.1 Summary of developments

In Sweden, research on fiber optics for communications took off in 1974 as Ericsson decided to enter the industry. This was about the same time as standards for the first generation were being set internationally and the first field trials were about to be conducted by AT&T in the US. The Institute for Microwave Technology (IM) was considering a move in the same direction and proposed a mutual technology development effort. Other actors were contacted, and the common view developed formed the Cooperative Project that lasted until the end of 1978. It was by any standard a remarkable catch-up, and already in 1979 the first Swedish field trials were being performed.

In the 1980s the goal became more ambitious, to reach state-of-the-art competence. In industry this was facilitated by transfer of personnel primarily from IM and universities. On the university and institute side a further build-up of competence and physical facilities was eased by the national programs directed to the area, the first one starting in 1979. Internationally the market for fiber optics took off in the 1980s, in the US partly as a result of deregulations of long-haul telephone services. In Sweden, funding as well as the number of people employed in the area increased on behalf of all actors throughout the 80s.

In the early 90s the dominant Swedish actor, Ericsson, became more short-term oriented and also started to cut funding. By the late 90s, Ericsson had liquidated or sold off large parts of its fiber-optics operations, instead focusing on becoming more of a system service provider for operators. The liquidations were caused partly by financial problems, partly by the fact that standardization etc. had brought specialization into the value-chain, increasing the need to focus. At IM, staffing was nearly halved in the early 90s but, as IM merged with the Institute for Optical Research into ACREO in the late 90s, the number of employees and funding increased again. On the university side, funding remained at roughly the same levels as before. However, the lack of directed national programs as in the 80s made it somewhat more difficult to obtain long-term funding.

In the late 90s the market for fiber optics exploded. At about the same time a range of new firms were formed, many of which were spun off from the established actors in the area. However, the increased competition, coupled with Internet traffic which did not increase as projected, created a huge unused capacity in the long-haul networks, which in turn caused an erosion of circuit prices. Revenues fell short of targets and failed to cover expenses and debt burdens, leading to a plummeting of the market in 2001. This created a shakeout in the industry, internationally as well as nationally, forcing the new companies to slim their organizations while awaiting a projected market upturn in 2004.

The industry trend over the years has been to move from long-haul networks to metro networks, and the aim is set on the access network. While the first two are driven primarily by the cost/Gbps/km ratio, the latter is driven by cost/subscriber, suggesting a somewhat different set of underlying technologies. This trend is likely to continue, bringing fiber closer and closer to the home, although the rate at which this is done is also likely to be contingent on the demand that can be created and how competing technologies will develop.

9.2.2 Functional analysis

The analytical framework developed in Chapter 2 was applied most thoroughly in the fiber-optics case of Chapter **Error! Reference source not found.**. This analysis is summarized in Box 9-1, still being quite extensive due to the long time period analyzed.

Box 9-1: Summary functional analysis of the fiber-optics SIS

Creation of knowledge

Industry:

- Remarkable catch-up in the 70s of Swedish industry in cooperation with academia, institutes, and government, due to meshing of goals and clear direction.
- State-of-the-art competence achieved in the 80s, through transfer of personnel.
- Late 80s and mid-90s: increased short-term orientation in the area due to internal funding principles at Ericsson.
- Mid-90s to early 00s: knowledge base transferred from Ericsson to start-ups induced by Ericsson´s downsizing and with plentiful capital and expectations.
- 2001-2002 shrinking base due to market downturn.

Universities and institutes:

- The Cooperative Project and national programs started in the area helped IM reach critical mass in terms of number of employees in the 70s.
- Indications of increased short-term, or applied, orientation within universities in the 80s.
- Downsizing in the early 90s following the transformation of IM into IMC.
- Up-scaling again in the late 90s following formation of ACREO and transfers from Ericsson.
- University less clear, indication of no significant increase in the last decade. More specialization and cross-disciplinarity due to increased complexity and broadened scope of applications.

Government (including the quasi-governmental Televerket):

- Initial funding from Televerket supported the initial effort financially and with some staffing.
- STU contributed increasingly with both financing and planning in the 80s, and so did EC funding.
- Early 90s on, funding levels relatively constant, more short-term oriented.

Guidance and direction of search

- 80s: technological development more directed at faster and cheaper long-haul and metro networks (lowering cost/Gbps/km). Now there is a trend to last-mile solutions, where cost/subscriber is more important. This trend affects the underlying technological choices. The aggressive national broadband policy is to guide and direct research increasingly toward last-mile solutions.
- Standards affect technological choices (in particular software solutions surveying data transmission), and allow for specialization. Regarding the hardware, some choices are made due to physical restrictions, others emerge as standards. More in-depth investigation regarding the role of standards is, however, needed.
- Increasing concern with the software, and a difference between industry and universities, where the former are more active at the system-to-network level and the latter are more active at the component-to-system level.
- Path-dependency and the size and growth of market and VC interest have made telecommunications networks the obvious choice for Ericsson as well as the start-ups, although other alternative uses have been pursued.

Incentives for innovation creation and exploitation

- Televerket's interest combined with an increasing international market was important for Ericsson's escalating commitment in the 70s and 80s.
- Concerns with costs and beliefs that return on investments were too far in the future made Ericsson more short-term oriented in the 90s.
- Trend towards value-chain specialization and internal radio management focus made Ericsson view itself as too small to legitimize major efforts in manufacturing components and WDM systems, instead focusing on serving operators with systems and services in the late 90s.
- In the late 90s the optical fiber market exploded and Swedish venture capital industry took off. Coupled with downsizing at Ericsson, incentives grew for new companies to form and explore FO technologies.
- Investments driven by expectations of increases in traffic led to investments ahead of real demand and complementary technologies.
- There are indications of the importance of value-chain downstream appropriation, leading to direct contracts with operators, system-orientation, and focus on the governing software.
- Patents and standards are becoming increasingly important, to attract capital and to exploit technologies, but these issues have not been fully covered here.
- Disincentives. For the small firms these are mainly: costs of engaging in business (i.e. the costs of certifications, access to testing equipment, and tax issues in general relating to small businesses). For Ericsson: competition from international, specialized actors for downsizing and refocusing.

Continued on next page

Supply of resources

Funding:

- Government funding actually decreased in early to mid-70s. From the late 70s and through the 80s it increased (including Televerket funding). In 1994 additional support emerged (e.g. Foundation for Strategic Research). However, no directed research programs were visible and long-term funding may have declined. Of late, however, some new programs have been started, and ACREO has also gained more funding. EC framework funding gained in importance starting in the 80s.
- Initially much funding came from Ericsson. This funding increased throughout the 80s and declined in the 90s, although funding is still supplied e.g. to ACREO's test-bed.
- In the mid-90s, Swedish venture capital together with a booming market and international funding in later stages contributed to the foundation of firms.

Skilled labor:

- Educated individuals were of vital concern throughout the development. Most knowledge had to be built "in-house" (apart from some university knowledge, for example of sensors). On the research side, this was achieved through the Cooperative Project, and subsequently increased funding through various programs. This among other things led to IM reaching a critical mass in the late 70s, and is also likely to have increased the number of PhD students in the area. It is unclear to what extent optics technology was reflected in the teaching at university levels. Starting in 2003 a master program in photonics is held by the joint Kista Photonics Research Centre.
- The base of skilled labor may have decreased somewhat during the late 90s. ACREO may have reached a critical mass lately. In spite of the funding climate, there may also have been an increase on the university side in the 90s.

Physical:

- Directed national programs in the 80s provided capital for labs in universities and institutes. Labs were also built at Televerket and Ericsson, and production facilities at Ericsson. In the 90s further investments have been made in industry, university and institute labs. However, some production facilities have been closed down.
- VINNOVA and Ericsson have sponsored a test bed at ACREO, which may be of great importance for the testing and further development of new technologies.
- Laboratory facilities and equipment testing are expensive; it is difficult for new companies to purchase or build them. Close networks have to some degree facilitated the use of other organizations' facilities. Recently, cheap equipment has been acquired from liquidated companies.

Creation of networks and its effects

- The Cooperative Project formed a network of contacts that prevailed and has been reinforced and extended since through continued joint efforts during the 80s and 90s. Combined with a relatively small number of actors and people involved in the area altogether, there is good connectivity in Sweden and the networks also extend abroad.
- The new industry structure may change this, with less frequent opportunities for collaborative projects. Although there are connections and collaborative projects between the newly founded companies, these ties could be strengthened e.g. for influencing standardizing agencies, regulative authorities etc.
- There is an emerging photonics cluster, although it is unclear whether there is any formal organization apart from KPRC to back this and its strength is unclear.
- It seems that both Ericsson and Televerket benefited from their cooperation in that they could learn needs and possibilities valuable for developing new products and becoming competent customers respectively. This may not apply to the same extent for the new companies. For the new companies, the connections to former colleagues etc. were important in order to get access to testing equipment, to get people running tests, or to get quick access to components etc.

Formation and stimulation of market/demand

- The efforts in FO in Sweden started with a promise of a huge market, largely owing to Televerket's interest. Through the 80s the market grew and took off, largely as a result of the capacity of the new technology and actual as well as projected demand. Deregulation further spurred the market, with the opening up of the long-distance market in the US and in 1993 also in Sweden, bringing more carriers to the market. Strong technical dependencies spurred the optics systems and components industries as a whole. Televerket has been an important local customer, but the Swedish market alone is small for most if not all actors.
- Rather aggressive national broadband policies, increasingly promoting last-mile, or fiber-to-the-home, solutions.
- Disintegration (Ericsson made fibers in-house and manufactured components) making formerly internal markets external. Within Ericsson this seems to have taken place around the mid-90s, and abroad a couple of years earlier, as indicated by the number of new firm formations in the area. In the wake of this, a range of new companies started.

Source: Adapted from Chapter 5.

In conclusion, the case of fiber optics is a case of competence catch-up, from almost nothing to an innovation system capable of producing state-of-art innovation. This was made with Ericsson as prime mover, in fruitful collaboration with government, academia and institutes, where also strong networks were established, which benefited all actors. The needs of the telecommunications market (with a recent shift towards last-mile solutions) have guided both the direction and extent of innovative activity throughout the whole time period.

The last decade has been characterized by major changes including: Ericsson downsizing fiber-optics activities; increasing role of government (for resource supply but also aggressive broadband policies); the disintegration of markets, a boom and bust. These changes, taken together, make the current situation uncertain, as is preliminarily assessed in the next section.

9.2.3 SWOT – fiber optics

The current functionality in the Swedish innovation system was analyzed in Chapter 5 and will be briefly summarized here. Clearly, fiber optics displays strong technological systemic effects in the form of technological complementarities. Are there also systemic effects in the actor system? This depends partly on technological factors, but also on other factors.

Both within industry and university/institutes there seems to be a high level of competence able to create new knowledge, partly deliberately created through focused efforts. The number of employees within universities/institutes is in effect unchanged, but funding in the 90s appears less structured. In industry, the number has decreased somewhat, affecting the industry's capability to produce new knowledge. The changed structure (more new companies, less Ericsson), with new companies more focused on commercializing technology, may have the effect of further decreasing longer-term R&D. The new, more fragmented structure may also lead to less dense networks than before (from a state of very strong networks).

Search may come to be increasingly guided toward the access network, with focus on low-price components needed in order to justify future implementation. So far, this development is primarily supply-driven. Further stimulation of development of services (to be used in these networks) is needed for demand to actually materialize. As for the long-haul and metro networks, technological development has plausibly been driven primarily by the cost structure and by high expectations, attracting new entrant start-ups (not only in telecoms).

Incentives for the access network partly derive from the government broadband policy, and partly from increasing demand for capacity, although this demand has not increased as originally projected. Disincentives exist in terms of low demand and a venture capital industry reluctant to make early-stage investments. This may hamper new investments, since the start of a new business is associated with high costs (equipment, certification cost etc.). In order not to lose the competence divested from Ericsson totally (but preferably guide it into new and existing optics firms), the situation for small firm formation and development needs to be investigated more thoroughly.

The present supply of resources seems to be fairly good. There is also a skilled base of labor to draw upon; within industry there may even be an oversupply of labor. Somewhat late, new master's programs have been started in photonics, improving the educational supply. In terms of facilities, government and industry have supported the building of laboratories as well as a test bed, where especially the latter is perceived to have a great potential value for firms in the industry. The demand for and availability of physical resources for the new entrants and production facilities of components may be in shortage, but this needs further assessment.

The network is relatively dense within this industry, but may gradually become less so. Relatively few individuals are involved, with a relatively high degree of connectivity or knowledge of each other. The interest organization, Kista Photonics Research Centre, as well as the Photonics Cluster may counteract this and facilitate further interaction.

Finally, the market for fiber optics is ultimately dependent on the stimulation of demand, that is, on stimulation of traffic that will increase the need for more capacity. This could for example be promotion of broadband services, mobile data services etc. although this is likely to lie ahead in the future. As for the new markets that have opened up as the industry has been vertically disintegrated, the stimulation of these is also dependent on the environment for creating new businesses in general in Sweden.

The current functionality of the Swedish fiber optics innovation system can now be summarized in a SWOT matrix (Table 9-1).

Table 9-1: SWOT of the Swedish fiber optics IS

Strengths	**Weaknesses**
▪ State-of-the-art competence within both fiber-optics components and systems. ▪ A good resource base in terms of educated labor, physical resources etc., and possibly also government support. ▪ A competent local customer in Telia.	▪ The Swedish venture capital industry is reluctant to invest in early stages, and also short of the amounts of money needed in this capital-intense industry. ▪ Matters of taxation etc. that may act as potential disincentives for new companies to form. ▪ A possible lack of manufacturing capabilities.
Opportunities	**Threats**
▪ With the test bed at ACREO there is a great opportunity for companies to test equipment in "real" systems, and it may also provide great opportunities to test equipment to be used for the next generation of access network components and systems, i.e. fiber to the home solutions. ▪ A new industry structure with smaller and more specialized players may entail opportunities for some of these companies to grow.	▪ The newly started companies are still small players in an industry with some very large players like Marconi, Cisco, Alcatel, etc. Given overlapping markets and scale advantages, Swedish firms may find it difficult to compete, to influence standards etc. ▪ Increased fragmentation within the Swedish industry may endanger the networks created over the years and the effects of these. ▪ Ericsson has been a "prime mover" in the area in Sweden, and has had the capacity and strength to be one. Today Ericsson's scope of operations is smaller, and none of the new actors are capable of taking its role, which may result in a lack of such a "prime mover" in Sweden. ▪ Demand for large-capacity access connections will not increase as hoped for, thus delaying developments and return on investments in this area.

9.2.4 Implications

Although a more in-depth investigation of the different functions studied here is needed, the present study suggests that the situation of today provides a good base to build upon. The industry fulfills much of what the literature would label a system, although the system seems to undergo something of a transition from one structure to another. This seems to be the result of a maturing industry that allows for more specializations to be made in the value-chain. However, in order not to lose the competence that has been built up it is important to support the new industry structure in Sweden. That is, it is important to support the new companies formed, as well as the companies potentially to be formed, so that more specialized actors can grow and possibly make up for some of the areas where Ericsson has decreased its attention.

Also, as mentioned above, the stimulation of the market for fiber optics is ultimately dependent on the stimulation of demand, that is, on stimulation of traffic that will increase the need for more capacity. This could for example be promotion of broadband services, mobile data services etc., although this is likely to lie ahead in the future

A number of issues were left open in the case study of fiber optics, and these call for further research. For instance, patents and standards in FO are becoming increasingly important, to attract capital and to exploit technologies, but these issues have not been fully covered. A more in-depth assessment could also be made of the activities in the field of the universities, institutes and Telia. A further assessment could also be made on how international developments have interacted with the domestic ones.

Lastly, but not least important, the situation for small firm formation and development needs to be investigated more thoroughly. For instance, the demand for and availability of physical resources on behalf of the new entrants should be assessed. Another issue that is not clear from this report and thus needs to be further investigated is the importance of having a domestic component industry.

9.3 Comparing mobile telephony and datacom

Two main recent growth areas have been identified: mobile telephony and data communications. In terms of the competitiveness of the supplier industries, STIS differs greatly between the two segments. Swedish industry is leading in the one, largely insignificant in the other. Ericsson is the leading and dominant supplier in mobile communication, and its success has contributed much to the growth of the sector in Sweden and to the Swedish economy as a whole. The Swedish datacom equipment supply industry on the other hand is insignificant, and so is the service sector. Although the majority of the domains most frequently visited by Swedish users are Swedish, no Swedish content or service actor has secured a strong international position. In the late 1990s a Swedish Internet consultancy industry grew strong with companies rapidly expanding internationally, but these were more or less erased by the burst of the IT bubble. A few innovative companies developing communications hardware have been created, including Net Insight, SwitchCore and Axis, although their relative sizes are dwarfed by the US counterparts. In conclusion, we have one success case (mobile) and one failure case (data).

A fruitful analytical venture is therefore to apply the analytical framework of Chapter 2 to compare the two cases, in order to find out if explanations lie in the functional evolution of the innovations systems. A first attempt is summarized in Table 9-2. Then a number of key observations are discussed.

Table 9-2: Selected IS functions in the cases of datacom and mobile telephony

Datacom	***Mobile telephony***
Creation of knowledge	
▪ Convergence between telecom and datacom was perceived early by e.g. Televerket. However, Sweden was far behind the leading countries in microelectronics skills and knowledge. ▪ Although Televerket adopted data com fairly early, it cannot be regarded as a lead user and innovator. ▪ Several research programs were launched during the 1980s to build competence. The programs raised the national electronics competence, but the lack of a computer industry led to telecommunications solutions rather than computer communications.	▪ Through Televerket's early investments (50s and 60s) in mobile telephony, competence could be built up internally, partly spilled over to other parts of the innovation system. Universities were largely irrelevant at this stage. ▪ Televerket became a leading innovator as well as lead user. However, the US had a technological lead until the 70s. ▪ During the 70s key competences in (1) radio, (2) switching and (3) cellular systems were developed in the STIS. Later internalized by Ericsson.
Guidance and direction of search	
▪ Throughout most of the period Televerket (and the telecom industry) made decisions and investments and guided search in the wrong direction, e.g.: - In the early 1970s, Televerket conducted a major market study with the conclusion that Sweden should build a circuit-switched computer communications network, rather than packet-switched solutions. - Another telecom-driven European approach was Videotex services in the early 1980s. As late as the early 1990s, Televerket made a second failed attempt. Although some competence was gained, much was rendered obsolete when the Internet became the dominant solution. ▪ The absence of advanced customers (as opposed to the US) guided the Swedish industry away from initially small-scale private networks.	▪ Early investments in 50s and 60s guided future search, and laid the foundation for the important land mobile investigation and NMT (MTC). ▪ Televerket, positioned as a leading innovator, took a leading role in the NMT development and to guide the innovative activities of the supplier industry, which plausibly would have been directed elsewhere otherwise. Thus Televerket counteracted the resistance to change, at a time when change was necessary. ▪ Military procurement strengthened the Swedish radio industry in the analog era, and was particularly important for developing digital radio skills. ▪ To some degree Televerket influenced Ericsson's technological choices in digital cellular.
Incentives for innovation creation and exploitation	
▪ The failure of diversifying into the computer industry may have lowered Ericsson's incentives to engage in datacom, in particular at the time (early 90s) when most attention was paid to mobile. ▪ In the late 90s, high valuations on stock markets and possibilities for IPOs provided financial incentives for entrepreneurs to commercialize Internet-related inventions. Several companies were founded during this period, many with non-viable business models. ▪ Through public procurement and subsidies of broadband communications, build-out incentives for innovation in high-speed data communication networks have been provided, although the effects on the innovation system have been difficult to assess.	▪ The engineering culture and obligation to provide good services provided Televerket with the necessary incentives to innovate. The possibility to take out monopoly rents provided additional incentives. ▪ Semi-autonomous units at Televerket and Ericsson had the managerial freedom and visions of a future growth market to engage in innovative activity. ▪ Persistent market growth drove expectations of further market growth and consequently incentives to innovate. ▪ The early liberalization in the US and UK provided opportunities for Ericsson to enter and develop solutions for these markets.
Supply of resources	
▪ Silicon Valley leveraged the pool of skilled people from the semiconductor and computing industries, and much available venture capital provided the means for company expansions. In Sweden, the	▪ Due to its sector responsibility, Televerket had no problem in dedicating the necessary resources for systems development. The contributions of other Nordic countries helped by sharing

Datacom	*Mobile telephony*
absence of strong computing and semiconductor industries made the telecom industry and universities the main sources of competence, thus probably lacking some important computer knowledge. ▪ In the 70s and 80s, when many of the leading computer communications firms were started, the Swedish VC industry seems to have been rather weak and incompetent. The VC industry grew strong in the late 90s, resulting in a large number of companies being created, also in computer communications. ▪ Possibly, telecom has received resources at the expense of datacom.	development costs. ▪ Government funding was particularly important for expanding the competence base and securing inflow of personnel for Ericsson's needs in the development of digital systems in the early 90s. Eventually Ericsson had to source abroad. ▪ Since mobile telephony was primarily developed in large firms, access to venture capital was strong.
Creation of networks and its effects	
▪ Networks are particularly important in large technical systems such as datacom. The absence of a strong computer actor taking a coordinating role has probably hampered the formation of networks. ▪ Strong telecom networks established a consensus regarding failing technologies. ▪ The network of users of SUNET, the university computer network and first major Swedish network to start using IP, has probably played an important role in the diffusion of Internet. With university students used to the Internet, companies hiring graduates learned about the Internet and its utilities. The importance of strong user-side networks is illustrated by SNUS, active in establishing the first commercial IP network in Sweden.	▪ The MTA/B developments in the 50s/60s created some networks and spillover effects. ▪ Established Nordic network facilitated the establishment of the NMT development and development of the standard. ▪ The close ties between Televerket and Ericsson and with other Nordic actors helped to influence choices in the GSM standardization process. ▪ Technological choices in GSM legitimized similar choices in other digital standards. ▪ Government-funded projects strengthened the Swedish network in digital radio communication.
Formation and stimulation of market/demand	
▪ As in the French Minitel case, Swedish Televerket subsidized TeleGuide terminals to stimulate demand for data communications in the early 1990s. The efforts were largely without results as the project was launched when the Internet was already evolving into a consumer technology. In addition, no free terminal market was created, stifling market-driven terminal innovation. ▪ The Swedish government's will to raise IT literacy in order to make full use of IT in all parts of the economy has materialized in a number of stimulating initiatives in recent years, raising PC penetration and Internet usage. ▪ In Internet usage Sweden has since secured a world-leading position, comparable to the position in cellular phone usage. ▪ During the latter half of the 1990s, a number of companies offering Internet subscriptions at no fixed charge emerged. These companies tried to build a market, and collect revenues from users once they had started to use their Internet connections. While overall data communications usage was stimulated, many firms failed in the competitive situation.	▪ The establishment of a Nordic market created the necessary scale for some suppliers to engage in R&D. ▪ The decision to let the terminal market free in the early 70s created a new market for mobile telephones, leading to increased innovative activity (and marketing, etc.). ▪ MTD in general built up a market, and cultivated the innovation affecting all functions in the system, preparing and bridging the market until broader segments were targeted with NMT. ▪ Absence of regulatory obstacles made the market develop faster in Sweden (than e.g. in the US), which gave Ericsson the possibility to develop first-mover advantages. ▪ The ability to influence standardization bodies and to make a standard the dominant one has been a key to the success of Ericsson in digital e.g. GSM and the commitment among suppliers, operators and the European Commission. ▪ Liberalization speeded transition into digital and expanded the market.

Source: Adapted from Chapter 6 & 7

The long time periods involved make it difficult to systematically compare the two sub-sectors. However, early developments clearly mattered. The initial, relatively slow growth period with knowledgeable users in academia and research institutions, with a history of sharing results on discoveries and improvements, has played an important role in developing the Internet into the consumer technology it is regarded as today.[1111] This is the period when the US secured the lead that the country has since then held on to. Similarly the foundation of success of mobile telephony was in many respects laid already around 1970, with the initiated developments of NMT.

It must also be pointed out that the "failure" of the Swedish sector in datacom should be seen in the light of the few (one) innovation systems (Silicon Valley) that have been successful in generating a competitive datacom supplier industry. Thus, had we analyzed STIS in an isolated manner, not taking competitive relations with other innovation systems into consideration, the analysis would have been flawed. This observation is in line with the identified weak treatment of competitive relations in IS literature (see Chapter 2).

A key observation is that innovating "in the right direction" is crucial. No matter how strong the other functions of the innovation system are, if guided in the wrong direction the whole system will fail. In fact the stronger and more systemic the system, e.g. in terms of networks, the harder it will fall. The strong telecom equipment sector, and networks with and between operators, did indeed have visions of data communication, differing from what eventually became dominant. Their visions were based on protecting existing investments and structures and responding to the needs of leading customers. This is a common management failure when incumbent firms neglect disruptive technologies,[1112] which seems to hold also for innovation systems.[1113]

Another network-related aspect concerns the proximity to standard-setting organizations. Being close to these provides opportunities both to influence standards, and to be early in developing technology adhering to the standards. The locus of standardization for Internet was far away from STIS, as opposed to the case of mobile telephony.

Now, also in the US, there were large actors (Bell) guiding search in the same directions as Televerket and the European PTTs. The difference was that in the US there was a fertile ground for another innovation system to grow up, outside the telecom sector. In particular, Silicon Valley leveraged the pool of skilled people from the semiconductor and computing industries, and much available venture capital provided the means for entrepreneurial activity and company expansions. These resources were not available in Sweden.[1114]

Another major difference lies in the creation of markets, and of incentives to innovation. In the telecom world's approach (Videotex) to datacom, dumb terminals were subsidized, given or rented to customers. As a result there were only small incentives to compete and innovate in the terminal business. This is in stark contrast to Internet, and even more strikingly to NMT, where the terminal market was free, which in turn stimulated innovation and the growth in the supplier industry. Further, the size of the home market matters. For the Internet,

[1111] Mowery and Simcoe (2002).

[1112] See e.g. Christensen (1997) and Utterback (1994).

[1113] This is not surprising and has been pointed out by others (e.g. Ehrnberg and Jacobsson 1997).

[1114] A more liberal regulatory framework in the US (than elsewhere) may have stimulated an earlier entry in datacom service provision.

the US market provided an important platform for later exports. For mobile telephony, expanding from a national to a Nordic market, made the technology more attractive to suppliers, and could in a similar manner function as a platform for exports.

Yet another difference may be in the character of the datacom and cellular mobile technological systems and markets. Although interfaces were standardized, it was still necessary to excel in radio, in switching and in systems "integration" (cell planning, frequency planning, etc.). In data communications it was easier for small firms (like Cisco) to enter small markets with less need for large systems competence.

9.4 The emerging mobile data sector

9.4.1.1 Introductory comments

The evolution of mobile data communications was investigated along a number of development trajectories. Perhaps somewhat surprisingly, mobile data is not as recent a development as one may expect from observations during the much-hyped mobile Internet development in the late 1990s. Mobile data has been around for at least two decades and much can be learned from that development. In fact, until now (2004), most mobile data systems have experienced a perceived slow diffusion, much slower than expected in initial optimistic forecasts. Observations from the case of Mobitex have indicated a number of largely generic barriers to diffusion. These barriers were (1) a lack of terminal equipment and (2) applications; (3) complex systems in need of systems integration; (4) large investment decisions, often including business process re-engineering, coupled with very few personal incentives for users; (5) absence of complementary fixed networks, maturity and experience from data communications; (6) competition (real and perceived) from other existing and future system technologies.

9.4.1.2 Summary of analysis of functions

Clearly the development of generic technical systems (such as mobile data) needs complementary developments in order to provide any value to users. Such developments are complex and lengthy processes where functionality only slowly develops. Presumably the development of innovation system functions has also been a lengthy process. The role played by functions in the evolution of mobile data innovation systems is summarized in Table 9-3.

In functional terms, it can be concluded that mobile data communications is still in a formative phase. At no point during its two decades of evolution have all functions been strong, not even during the boom years (since there was no end-user demand). Seen from a slightly different perspective, this failure could be attributed to the character of the technical systems, being generic, requiring complementary innovations; their complexity requiring coordination; and the uncertainty of demand requiring experimentation.

These are general features of mobile data, which are difficult but not impossible to resolve (as proven elsewhere). The STIS has failed to solve these in spite of proven strength in mobile communications supply, its leading position in mobile telephony and Internet usage, and for some years almost unlimited access to capital and technical competence. This failure has put Sweden at a disadvantage compared to "competing" innovation systems, e.g. in the sense that mobile data usage is low, and incentives for innovation, primarily service innovations, seem to be lower here than elsewhere. Can this disadvantage be addressed by policy? We will return to this question in Section 9.7.

Table 9-3: IS functions in the emerging mobile data innovation system – observations

Creation of knowledge

- Televerket had developed knowledge about radio communication during the previous decades, and some embryonic radio data communications knowledge through the Maritex development.
- It was Televerket and later Ericsson that created much of the knowledge needed in the development of mobile data.
- Through Televerket's development of Mobitex systems, packet-switched mobile data competence was built, which later contributed to Ericsson's development of both GPRS and WCDMA data solutions.
- Knowledge about customer management, marketing and applications provides other important skills for a mobile telecom innovation system to function properly. In mobile data, services have to be tailored and targeted at small market segments. The poor and late take-up of mobile data services has probably hindered these skills from being developed within the innovation system. The system thus loses dynamic features and positive feedback effects as seen in e.g. Japan are not started. In a sense, the Swedish mobile data industry can be said to still be in a formative phase, almost 20 years after introduction.

Guidance and direction of search

- Televerket initiated the mobile data development, acting on perceived external and internal needs. Ericsson initially searched in other directions. Eventually, Televerket's dedication and procurement decisions made Ericsson invest in R&D. Later foreign customers took the lead, i.e. RAM in the US, pushing for development of more capable generations of Mobitex.
- Still, it seems that packet switching had low priority in the Swedish mobile telecom industry. As late as 1995, packet-switched mobile data was not a key priority in mobile communications; therefore few resources were spent, and technology was delayed. It was the breakthrough of Internet that refocused attention.
- In earlier phases of the mobile telecom development, Televerket functioned as the natural coordinator (cf. NMT). After deregulation, the incentives and power to take on this role disappeared. In more recent years, the Swedish (and European) mobile data industry seems to have lacked a strong coordinator (cf. DoCoMo). As a result, packaged mobile data services were launched four years later than by Japanese counterparts.
- The walled-garden approach to operators' service offerings, restricting subscribers to services supplied by the operator, placed a large responsibility on operators to identify, develop, package and market the services that provide utility to end-users. Without the possibility to learn through experimentation, service-developing companies have had limited opportunities to identify profitable service offerings. It can be argued that the operators have failed in guiding the search for successful mobile data applications, and consequently the build-up of a market.

Incentives for innovation

- The success of mobile telephony spilled over to exaggerated expectations of growth in mobile data, providing incentives for Televerket to develop Mobitex.
- Other incentives included internal efficiency and the sector responsibility
- With data services long considered an important future revenue source for mobile telecom actors, strong incentives have existed to invest in mobile data R&D. For each new generation, data capabilities have been improved. In third-generation networks, data is expected to constitute a much larger share of revenues than in earlier generations, making mobile data innovations of great economic importance. Maturing voice markets have added to this, making actors search for other revenue sources.
- Still, network innovation is not enough. Applications and service development must also be stimulated. The revenue-sharing models and walled-garden approach utilized by operators have been stricter than e.g. in Japan. This left limited incentives for innovation in small firms. Non-dynamic business models made it difficult for service developers to adapt their service offerings to meet customers' needs and wants profitably. When the source of venture capital dried out following the stock market crash, many of these firms had to seize operations. This has limited the function of entrepreneurial experimentation.
- Operators have enjoyed their protected positions, retained by only maintaining their existing businesses. This situation may have hampered the operators' incentives for service innovations.
- There seems to be a tendency of decreasing innovativeness in Swedish operators. Telia's role as a lead innovator (or at least early mover) lasted to the late 90s. Now foreign operators, e.g. Vodafone and lately 3, have taken this role, pioneering packaged data services, picture messaging, video telephony etc.

Supply of resources

- Ericsson and Telia have generated a large supply of telecom-skilled personnel resources. In the late 1990s, some left to found their own firms, often in the mobile data field. Coinciding with WAP introduction, hype and overestimations, and plentiful access to venture capital, mobile data innovations were numerous, ranging from consulting services to middleware and applications and services. In the boom years a virtually endless stream of capital was available for R&D, increasing every year to come to a brutal halt in 2001.

- Ericsson's R&D budgets spilled over to finance some university R&D, and in some cases financing of start-up firms through the venture capital arm.
- In the late 1990s, a number of venture capital firms specializing in communications and mobile data emerged. High stock market valuations made capital readily available for venture investments. Quality did not match quantity, and competence was low among VC firms.
- Platforms for innovation are another area where Sweden has been lagging the leading countries. Here the comparison with Norway is most relevant, since Norwegians were much quicker in launching third-party content developer platforms, for developing premium SMS and MMS services, than were their Swedish counterparts.

Creation of networks

- Although there was a nucleus of the IS in place for mobile data development (terminal and equipment arms of Ericsson and the operator and equipment arm of Televerket), certain actor categories and relations were missing (application developers and system integrators). As a whole, the Mobitex actor system linked to the technical system was weak or incomplete.
- Around Ericsson, a number of mobile data sub-suppliers have appeared, delivering e.g. positioning and application-hosting middleware, and services and applications. In recent years, Ericsson has tried to inject interest into mobile data services through a number of initiatives. One example is Ericsson Mobility World, an initiative to spread knowledge and understanding about successful mobile data services among operators and service-developing companies.
- It could be argued that the recurrent failures in the mobile data field, e.g. Mobitex and WAP, have led to a lack of legitimacy of sorts. This in turn could lead to decreased innovation activities, and restrictions in access to capital.
- Around Ericsson and Telia in the Stockholm region, a mobile telecom cluster has appeared. During the late 1990s, the Kista area was touted as the world's mobile Internet centre of gravity. During the telecom boom a number of foreign companies invested in the area, reinforcing the strength of the cluster. However, as other regions have become more advanced in mobile data usage, the attractiveness of Kista may have become somewhat lower.

Formation and stimulation of market/demand

- The diffusion of mobile data service has been slower than anticipated throughout the study period.
- In the case of Mobitex, an incomplete value/actor system was an inhibiting factor in the market creation. In the more consumer-oriented mobile data services market in recent years, terminal limitations and low general service utility have turned out to be strong barriers.
- Low usage of mobile data services in public administrations has hampered demand and development. After the telecom downturn in the early 2000s, the responsibility of the public sector in stimulating usage of mobile data services has been suggested.
- Waiting games in response to unclear technology situations have slowed down growth. (GPRS for Mobitex, 3G for GPRS etc.)
- Prices have been high in Sweden, in particular for SMS. Short-term oligopolistic pricing has proved to hamper long-term revenues and, perhaps more seriously, innovation.
- There has been a fear of launching too simple products too early. Instead of launching an unfinished service on the market and refining it according to the learning that takes place, there has been a tendency to wait until the services/products/technologies are fully developed. This has been the case in data solutions such as GPRS, and in packaged mobile data services.
- In spite of proven utilities and often high ROI, since the birth of mobile data communications it has been a difficult task to sell services to corporate customers. At large, this can be attributed to a lack of competence regarding how to use mobile datacom in companies. At the same time, the mobile telecom industry has not had the needed access or credibility in corporate IT departments. This problem seems to exist still in 2004. Today, for example, the operator 3 works with established system integrators such as Accenture in order to convince customer companies to implement their solutions.

Source: Adapted from Chapter 8.

9.5 Key trends and uncertainties

This section lists a number of key trends and uncertainties that the authors of this report believe will have a major impact on the telecom sector. It must be emphasized that not all of them have been fully covered in previous chapters. The trends are summarized in Box 9-2 and uncertainties in Box 9-3. Observe also that several of the trends are interdependent.

Box 9-2: Selected important trends in telecommunications

Technical trends

- Improving functionality and performance of Internet (including a better IP– IPv6, VPN, compression),
    - facilitating for a range of new services and higher acceptance of existing ones
- Increase in the network periphery intelligence and functionality
    - opening up for new applications (e.g. P2P and ad-hoc networks)
- Miniaturization of computer products (including portable devices)
- Improving input (e.g. speech recognition) and output (e.g. screen) capabilities of terminals
- Higher bandwidth in fixed and mobile networks
- Mobile radio network technologies are becoming more data-potent and intelligent
- IP integration with wireless networks
- Technological convergence, e.g.:
    - networks and terminals becoming increasingly multi-capable
    - mobile fixed integration
- Increasing numbers of competing and complementing technologies (in turn providing incentives for making these technologies compatible)
- Some complementary technologies (e.g. sensors) are improving rapidly
- Complexity in networks is increasing
- Software is increasingly important

Demand trends

- Continued persistent growth in terms of number of Internet users, diffusing into new segments and regions
- Growing number of applications & services
- Fixed voice revenues are declining, and mobile voice revenues are maturing (in advanced markets)
- Substitution (but also convergence) of fixed-mobile services (and terminals)
- Demand shift to higher-bandwidth connections (fixed and mobile)
- IP telephony will grow and increasingly substitute for circuit-switched telephony
- Growth of mobile data/Internet
- Future dominance of China and India markets
- E-Security and personal integrity grow in importance
- Looming standardization war for a number of markets including mobile terminal software

Structural trends

- Consolidation of operators
- Movement downstream (nearer the customer) in value-chain
- Industrial convergence
- Actor system complexity increase
- A mobile software market is growing fast (OS software, applications software, games etc.)
- Continued strong importance of standardization

Economic trends

- Economies of scale becoming increasingly important
- Price pressure (service and equipment)
- ARPU decline
- Cost cutting among operators and suppliers

We have not pursued the analysis of the trends fully. Instead the trends have guided the search for threats and opportunities, for policy implications and future research, as presented in the following sections. We do, however, recognize a need to systematically match trends and uncertainties with strengths and weaknesses in the STIS. In addition, they could serve as a basis for a thorough scenario analysis.

Box 9-3: Key uncertainties in telecommunications

Technological uncertainty
- Dominant technologies/standards for mobile/fixed, voice/data, terminals/software
- Possibilities and rate of integration of different technologies and standards
- Uncertainties regarding what technological regime will govern 4G, the next generation

Demand uncertainty
- Size and composition of ICT-related spendings
- Growth rate and potential of (mobile) data
- Major applications of (mobile) data
- Wireless fatigue/gadget burnout (how many new, rapidly aging gadgets will the market accept?)

Structural uncertainty
- Actor system/value-chain uncertainty
- Balance between open/standardized and proprietary solutions

Economic uncertainty
- Growth of general economy (impacting capital market/ capital availability)

Side-effect uncertainty
- Possible negative health consequences of wireless communication
- Security and privacy concerns

9.6 SWOT analysis

With the functional analysis of the two past growth areas of fixed data communications and mobile telephony, followed by a functional analysis of the future growth area of mobile data, the scene is set for a SWOT analysis of the Swedish telecom innovation system.

Historically, the Swedish sector has been in the forefront of development in the promising mobile data market, but how are we positioned now? Since mobile data as a field is perceived to be a major growth generator in the future, this last section will briefly identify a few strengths, weaknesses, threats and opportunities of the Swedish innovation system with respect to this future growth market. The analysis is summarized Table 9-4.

9.6.1 Strengths

Swedish actors have developed substantial experience in mobile data technologies during the last 20 years. With mobile data expected to increase in importance in the foreseeable future, this long experience can be leveraged to secure a strong future position. Ericsson was one of the main developers and backers of the WCDMA solution. With WCDMA expected to become the most important 3G technology, the Swedish telecom innovation system has a technologically strong position.

One strength in the Swedish datacom IS is that the Swedish Internet usage is among the highest in the world, and has been so for a number of years. Swedish companies have come far in implementing Internet-based solutions as part of their daily business, and the public administration is pushing hard to cut costs and increase accessibility through Internet solutions. With extensive usage, important learning takes place and knowledge and skills are accumulated. Combined with a very high cellular penetration, this Internet-literate population is a strength for Sweden if it can be leveraged in a mobile setting, provided that there are strong complementarities between the two.

Swedish companies have come far in implementing e-commerce solutions, and Swedish banks are leading in Internet activities. This strength could be leveraged in a mobile environment, stimulating mobile commerce. The high penetration of broadband could reinforce such activities by further making electronic services and transactions a part of daily life.

In addition, as a result of the beauty contest and the build-up of 3G network infrastructure, the Swedish is relatively well established. This may hold also for public WLAN as a result of Telia's early build-out of Homerun service. This could have a positive effect on domestic service innovation and early launches in Sweden. At present, other factors (lack of platforms etc.) counteract this strength.

The Swedish innovation system seems to be strong also when it comes to Bluetooth-related products. The many firms working with Bluetooth probably owe to the fact that Bluetooth originated in Sweden, and that the strong telecommunications industry has spilled over competence into start-ups. The market for Bluetooth products has so far been slow to take off. A market uptake could prove beneficial for the STIS, with relatively strong Bluetooth skills.

The Swedish innovation system also seems to be strong when it comes to complex systems and their integration.

9.6.2 Weaknesses

There is at least one major exception to the high ICT usage in Sweden, and that is the low usage of mobile data (compared to leading nations). With the slow take-up of mobile data services, and late introduction of packaged services over the GPRS network, Swedish operators have not had the opportunity to build application and market knowledge and skills. These skills are of great importance in the provisioning of mobile data services, often targeting small user segments. Thus, compared to most advanced markets, Sweden is at a disadvantage, and may be slower in the process of taking the innovation system from a formative to a growth phase.

This weakness pertains in particular to the service (or application) developing companies. With few users to test new services on, there are small incentives for entrepreneurial experimentation, which is extremely important in development with an endless number of possible applications.

The above can probably be linked to the fact that the Swedish operator market lacks a strong coordinator, able to take the lead in mobile data developments. In complex systems, like mobile data, this function seems to be crucial in early phases, to start the processes of positive feedbacks. Now, large international actors have taken the lead, possibly favoring solutions already introduced elsewhere.

A factor closely connected with the above is the relatively low quality of usage in Sweden (in terms of service sophistication). Although international statistics indicate that Sweden is a strong nation in cellular usage, the comparisons mostly measure numbers and fail to assess quality of use. With the increased data revenue generation, quality of usage in terms of how sophisticated and innovative services are used is expected to become important.

The lack of a strong coordinating actor seems to have been and still is a weakness also in the Swedish datacom innovation system. With no actor to drive development and guide the search of other companies and research institutes, there is a possibility that research and development initiatives might be too diverse, with no strong momentum being reached. This leads to low levels of competence in the area being generated, and a lack of technological learning taking place.

With a base in the computer industry, WLAN and WMAN activities seem to be strongest in the USA. In Sweden, there are no strong international WLAN equipment, software or service actors apart from TeliaSonera with its HomeRun network. Innovation seems to take place mainly in small companies, although some large and medium-sized actors such as Ericsson and Axis Communications are active in the area. According to ARC Associates, neither Ericsson nor any other Swedish companies are participating e.g. in WiMAX standardization groups, indicating a lack of interest in the technology.

9.6.3 Opportunities

Mobile datacom in general is a vast opportunity for STIS and the sector as a whole. With the technological strength in mobile communications, and the vast Internet user experience and competence, this field is an opportunity to exploit for Swedish actors.

There are several indications that the usage of mobile data business solutions (in Sweden and elsewhere) is far below the potential that value-added and cost savings would imply. There are several barriers to adoption, including technological and organizational uncertainty, low awareness among potential customers, costs of customizing solutions, etc.[1115] Most of these barriers can be addressed, some of them by policy actions. This is a major opportunity for STIS.

The mobile data industry is still immature, with actor systems constantly changing. The supplier industry which has emerged around Ericsson, developing enabling platforms and applications/services, is a potential growth generator. Platforms of different kinds can both create larger markets and provide opportunities for the actors innovating in platforms.

Mobile data systems are technologically very complex. Swedish actors have developed system integration skills during the last decades, which may prove important also in mobile data systems, regardless of which technologies come out as winners.

Utilizing the customer base, developing broadband services and applications for advanced users, is an opportunity. Although not specifically related to mobile data, developments are likely to spill over also to that field.

Given a trend of increasing diversity of technological solutions and standards, there will be opportunities for any actor that can realize the economic benefits that lie in the integration of incompatible systems.

9.6.4 Threats

Ericsson has successfully managed at an early stage to direct its R&D efforts towards the solutions later to be implemented as the most widely diffused standards (GSM, and seemingly WCDMA). With Ericsson being a large contributor to the development of the underlying technologies, it is likely that Ericsson had a temporary advantage compared to other equipment manufacturers. With the continued delays of 3G implementations around the

[1115] Andersson and Reimfelt (2000). Holmén (2001), Lindmark (2002) and PTS (2003e).

world, this early-mover advantage might have gradually been lost. Thus, the Swedish telecom innovation system will weaken in comparison to other systems in the event of further delays.

Parallel to the mobile telecom developments, a number of standards for radio access to computer networks exist (technological competition). Some of these are built for the purpose of access to IP networks, and developments are backed by both computer and telecom industry heavyweights. In recent years, experiments with public networks built on these technologies have been carried out, but so far with little success. However, disregarding these solutions as inferior seems premature. If the technological barriers are overcome (e.g. regarding billing, roaming and handover capabilities) these kinds of solutions are candidates for access networks to the mobile Internet, in competition with the solutions where the Swedish industry has its stronghold.

The telecom recession in recent years has led to massive lay-offs in the industry. For instance, and most importantly, Ericsson decreased its workforce by more than 50%, many of these jobs being in Sweden. There is a possibility that important skills and knowledge have been lost in the process, which could prove devastating in the future.

There seems to be a trend towards increased size of operators (e.g. Vodafone) due to economies of scale and bargaining power against suppliers and complementors. These suppliers seem to be at an advantage in service innovation, due to their size. If so, they may invest more in service innovation than their smaller counterparts, and the supporting service-developing companies may become stronger in their home markets. At present Sweden has no such large innovative operator, and this may have a weakening influence on the innovation system vis-à-vis other innovation systems.

Asian actors have emerged as strong competitors in the mobile data field. The early large-scale introduction of data services in e.g. Japan and Korea has provided operators, equipment suppliers and terminal manufacturers with advantages. The impact can already be seen in 2.5G in Europe, and the advent of 3G may catalyze this development further. Long-term Asian initiatives (not least the Chinese) to establish a strong foothold in the fourth generation (4G) may also turn out to threaten the Swedish position, and should be watched closely.

9.6.5 Summarizing the SWOT

Table 9-4: SWOT of the Swedish mobile datacom/Internet IS

Strengths	***Weaknesses***
▪ Long and broad experience in mobile data technologies during the last 20 years which can be leveraged to secure a strong future position. This position is particularly strong in WCDMA/UMTS. ▪ Widespread Swedish mobile telephony usage. ▪ The Swedish Internet usage is among the highest in the world, which could be leveraged to develop services and applications that later can be exported. ▪ Relatively rapid build-out of broadband could spur service innovation, leveraged also in the mobile field. ▪ Relatively rapid 3G build-out. ▪ Seemingly strong position in peripheral radio standards such as Bluetooth-related products. ▪ Seemingly strong complex systems (integration) competence. ▪ Swedish companies have come far in implementing e-commerce solutions, and Swedish banks are leading in Internet activities. This strength could be leveraged in a mobile environment.	▪ Relatively low application and market knowledge and skills, compared to the most advanced markets. Sweden may be slower in the process of taking the innovation system from formative to growth phase. ▪ Few users to test new services on, giving small incentives for entrepreneurial experimentation, which is very important in development with an endless number of applications. ▪ No strong coordinator (i.e. operator) to guide the search for technological and service/applications solutions. ▪ No strong international WLAN equipment, software or service actors in Sweden apart from TeliaSonera with its HomeRun network. Innovation takes place mainly in small companies. ▪ No strong computer actor guiding the search, leading to low supply of competent personnel in computer communications.
Opportunities	***Threats***
▪ Mobile datacom. With the technological strength in mobile communications, and the vast Internet user experience and competence, this field is an opportunity to exploit for Swedish actors. ▪ Platforms of different kinds can both create larger markets, and provide opportunities for the actors innovating in platforms. ▪ The supplier industry evolved around Ericsson, in particular those developing enabling platforms and applications/services. ▪ Complexity of mobile data. The Swedish system integration skills may prove important also in mobile data systems (regardless of which technologies come out as winners). ▪ Broadband services and applications to advanced users constitute an opportunity which could be leveraged. ▪ Professional business applications. ▪ Interoperability solutions.	▪ 3G delays can lead to lost early-mover advantages for STIS. ▪ Technological competition. WLAN and WMAN. If these improve regarding billing, roaming and handover capabilities they may outcompete 3G, and STIS is weaker with respect to those. ▪ The massive lay-offs in the industry, with possible risk that important skills and knowledge have been lost in the process, which could prove devastating in the future. ▪ Concentration of operator industry, with large foreign operators being more innovative. Supporting service development may become stronger in their home markets. With no such large innovative operator, STIS may become less competitive. ▪ 4G technologies, with Asian actors (including policy actors) having strategy of gaining the lead in 4G solutions.

This analysis of the Swedish innovation system may seem overly pessimistic for some observers. To exemplify the contrary, mobile data usage is far beyond the poor usage in the US. Moreover, we have not emphasized Sony Ericsson's position as a strength or weakness. The weakened position of Sony Ericsson must be seen in the light of Sweden still holding 50% of one of the world's largest terminal manufacturers, a remarkable achievement for a small country. This negative bias is based on the methodological choice to search for "holes" in the innovation system, since such holes can be targeted by policy initiatives, rather than defining the strengths. Also in global economies characterized by innovation-driven growth and first-mover advantages, it is increasingly important to lead in innovation. Thus only comparisons with the best are relevant.

So, where does all this take us? It seems an established fact that STIS still has a strong technological position in the mobile data field. The knowledge and skills built up at Ericsson and Televerket/Telia during two decades, diffusing to start-up companies and suppliers, and presumably spilling over into and co-evolving with the educational system, are sophisticated and competitive. In the coming 3G implementations, Swedish actors are expected to play an important role.

Overall, however, the strength of the Swedish innovation system in this important field is far from its internationally leading position in the late 1990s. Since then, other countries have moved more rapidly into data usage. The most notable and cited examples are Japan and Korea, but closer at hand Norway and some other European countries have been more successful in implementing data services. Multinational Vodafone reported a total 17% of revenues stemming from mobile data in December 2003, a figure higher than any Swedish operator's. Without a strong home market to use for tests and experimentation, the possibilities for Swedish companies to identify viable service offerings are small, reinforcing a vicious circle (or rather losing ground to foreign IS characterized by strong virtuous circles).

In addition, threats from new competitors are emerging. The computer industry, with its strong base in fixed data communications, is also racing for shares of the mobile data market. Although systemic and reliable products comparable with cellular systems have not yet appeared, developments are well under way and the competitive pressure is increasing. At the same time Asian actors, with strong government backing, are investing large resources to gain positions in the communications systems to replace 3G. In some respects these investments are comparable with early Swedish investments and initiatives in NMT and the Japanese automotive investments in the 1970s-80s. These eager initiatives must be taken seriously.

A change in the national attitude, from being a content leader to becoming a hungry attacker in mobile data innovation, could be called for. Much of this work must be conducted within industry. But what can be done from a policy perspective to influence the Swedish position? Section 9.7 below elaborates on a number of policy measures available.

9.7 IMPLICATIONS

9.7.1 Preliminary policy implications

Before attempting to recommend any policy, let us first identify what general policy measures are suitable. Edquist (2003:5) identifies a number of such general policy implications, which may serve as sign-posts for policy actions. These are:

- Organizational actors might need to be created, redesigned or abolished.
- Institutional rules might need to be created, redesigned or abolished.
- Innovation policy needs to focus not only on elements but also (and perhaps primarily) on relations.
- Negative lock-in situations should be avoided.
- Changes in production structure should be facilitated.
- Structural changes in sectors dominated by product innovations should be supported.
- Policy should be proactive, supporting the emergence of new product areas and new sectors.
- Focus should be on early stages.

In addition, Jacobsson and Carlsson (2003b) point at the use of functional analysis as a device for focusing policy actions. Thus, the removal of bottlenecks and stimulation of inducement mechanisms are obvious targets for policy if they can be identified, with the aim of strengthening weak functions and the innovation system's functionality as a whole. To stimulate the transition from one phase to another (e.g. from formative to growth phase), and thereby support technological transitions, seems particularly fruitful.

Also on a general level, policy measures should be directed at creating the foundations for innovation to take place, rather than guiding the innovation in certain directions. Investments (and initiatives) should be made in areas where the market can be expected to under-invest, and where only long-term effects can be expected.[1116]

Given those general guidelines, what are the most important issues for policy-makers concerning the development of STIS? First, future growth is likely to come primarily in mobile (and broadband) data communications, especially in services and applications based on them. Therefore the *stimulation of innovation and diffusion of such services* is crucial to development of the innovation system, both globally and in Sweden.

In view of the uncertainty regarding which applications will prevail, it is important to foster *an innovation system that creates diversity and stimulates entrepreneurial experimentation*. Currently there seem to be a number of weaknesses in the innovation system for such entrepreneurial experimentation to take place. It seems that *financing in early phases is too weak*. It also seems that *diffusion is hampered primarily by weaknesses in platforms* (in the sense of semi-generic solutions on which a range of services can be delivered – e.g. payment systems, advertising platforms, DRM platforms, content adaptation solutions, test beds), and by *lack of coordination and short-term profit-maximization business models*. If financing is a problem, policy implications are rather obvious.

Diffusion mechanisms are more difficult to address at policy level. Coordination and cooperation seem to be important lessons to learn from the i-mode case and the Norwegian

[1116] Mowery and Nelson (1999).

SMS market. Thus strengthening of networks, transfer of *knowledge about success factors and mechanisms that drive diffusion* should be encouraged. These factors need *further research* to identify, though (see below). Provision of platforms as identified above is another implication.

Regulatory uncertainty, delays and unpredictable changes in the regulatory framework should be avoided. The delay in deciding upon the licensing schemes for AMPS, in the late 70s and early 80s, just may have been the decisive factor for the US manufacturing industry to lose the infrastructure industry to the Europeans (i.e. Ericsson). Similarly during the 3G licensing process, mistakes and adjustments have impacted the development of the 3G market. Uncertainty hampers investments, and must be removed. In the evolution of regulatory policy for mobile markets (and telecommunications more generally), there is a complex interplay between the need for stability (predictability) and flexibility. On the one hand, regulatory frameworks need to reduce uncertainty, but on the other hand they must adapt to changing technologies and possible regulatory mistakes. In a wider and long-term context, a dynamic regulatory policy that is supportive to innovation and technology change is important to develop. However, tools, instruments and theory to support such policy are not well-developed. In the short term, it is then necessary to increase understanding of the role of innovation in telecommunications markets, and the impact of regulation on investments and innovation. As a first step, the regulator should be given a role to monitor the state of innovation and investments in the mobile sector.

It seems that the *provisioning of seed capital* is a function not performing well enough in the Swedish national innovation system. This is evidently recognized to be a market failure, but the reasons for it are unclear. Nevertheless, the availability of seed capital is of utmost importance for a company in the early stages of its existence. The great risks associated with providing capital for such early phases are not always acceptable for private actors. Here the public has a role to play. With plentiful access to seed capital, experimentation can take place, with sustainable solutions evolving. Another possible measure is the construction and operation of test beds, open for application developers at low charges. This development seems to be under way, and ensuring its survival appears important.

Although it is difficult to say whether too few resources are spent on research and development for mobile applications and services, this may be the case. We do agree with the VINNITEL proposal[1117] that public *spending on development of mobile applications and services* needs to be essentially intensified.

The 3G *market in general needs to be stimulated* (like any mobile data market) but this stimulation should be demand-driven rather than supply-pushed. Hence there is a need to develop demand-led strategies, and government policies to support demand uptake. One path is for the state to take various initiatives in e-government applications. Also the concerns regarding risks and side effects that may come from the use of mobile communications should be taken seriously, be researched and, perhaps most importantly, be addressed by innovative activities.

It should also be pointed out that it is very difficult and risky to “design” innovation systems with a top-down approach, in particular if it involves “picking the right” technologies or applications. The successful cases of NMT, GSM and i-mode may have blindfolded the mobile communications industry. In fact most standardization efforts in Europe seem to have

[1117] Ericsson and Sjödin (2002).

been failures (ERMES, TETRA, etc.). In addition, the French Minitel example, although seemingly successful in the short run, made France lose ground when the competing Internet succeeded. Instead *diversity needs to be fostered*.

Following e.g. the success of i-mode, the focus has been placed on consumer applications of mobile Internet. Consumer expenditures are, however, unlikely to fully cover e.g. the 3G investments. Instead there are indications, and this is important, that the *industry segment and public authorities underutilize mobile data and ICT in general.* The use of mobile data could then be stimulated through different means – such as raising awareness, to mention a simple example.

An often quoted policy measure is that public organizations and institutions should act as competent customers, invest in ICT solutions and thereby stimulate the market. This is fine, but will generate positive *dynamic effects only insofar as they really are lead users*, i.e. users who truly benefit from the solutions provided and whose needs will anticipate those of others.[1118] If so, the suppliers to these users may gain a head-start (first-mover advantages) that can be leveraged on a broader (international) market.

Finally, and to repeat, *a change in the national attitude*, from being a content leader to becoming a hungry attacker in mobile data innovation, is called for.

9.7.2 Suggestions for further research

The scope of this study in terms of the time span covered and the size and complexity of the sector, given the allocated resources, naturally means that important aspects of the state and evolution of the STIS have not been possible to analyze in depth. Some issues have only been covered on the surface and others not at all. In addition, during the course of the project a number of promising research avenues have been identified, but left for further research. In this section a selection of such issues is presented.

The major opportunity and threat for STIS is in mobile data communications. Although an extensive overview of mobile data communications has been provided in this report, further research is needed in a number of areas:

First, the *state of the Swedish Mobile Internet Innovation System needs to be further investigated*. There are several investigations of the Swedish mobile Internet industry, including a major one conducted by ARIAD in cooperation with the Dept. of Innovation Engineering and Management at Chalmers. The latter covers mobile Internet startups founded in 1997-2001, collected in a database. However, the investigation was conducted with other research questions in mind (entrepreneurship issues), covers only start-ups, and most importantly has not been updated since. This database should be updated including also large firms, since their diversifying into new areas is an equally important contributor to innovation. It could specifically address functions in innovation systems (e.g. supply of resources, service and application categories, investments in development, technological choices, market segments, business models, perceived barriers to innovation) and a more thorough assessment of mobile data can be made. Observe that not only the aggregate system should be investigated, but also the functionality at micro-level.

[1118] von Hippel (1988).

In addition, a more thorough understanding of the Swedish position in mobile data developments in an international context is needed. A systematic comparison of the mobile data markets in terms of application supply, terminal sophistication, usage levels, revenue generation, etc. should be carried out, at least for a selection of countries including advanced ones (e.g. Japan, Korea, Norway, Italy).

Second, *diffusion mechanisms must be better understood*. Factors driving diffusion are poorly covered in the Innovation System literature. Although it is identified as a key function in innovation systems, the mechanisms underlying that function are almost neglected, somewhat surprisingly since it is the main process generating economic value. For mobile data communications, and for STIS, it is crucial to unlock the barriers to diffusion. In order to clarify it, a thorough understanding of the mechanisms driving diffusion in general, and applied to the specific situation, is needed. In order to develop such an understanding, a framework based on earlier research is first needed. However, there is no useful theory available for those purposes. Instead a synthesis of relevant theoretical disciplines is required, including e.g. diffusion theory, economics of innovation, innovation system approaches, marketing literature, industry and value system analysis etc. Lessons from historical cases (video telephony etc.) can then be brought into the analysis. Finally, the specific situation for e.g. mobile data service needs to be investigated, both at macro-level and at micro-level (not only firm level, but *innovation level*, i.e. specific products/services – a number of them). After this venture, barriers and drivers of diffusion can identified and addressed. As already mentioned, these diffusion mechanisms are poorly covered in IS literature, but crucial for e.g. mobile data. A first attempt was made by Andersson and Boëthius (2003), with promising and industrially useful results.

Following the success of i-mode, too much focus has been placed on consumer applications. Attention needs to be paid to the *business segment*. As for the business segment it is not primarily office applications (although these are important) we have in mind. Instead it is the use of (mobile) ICT in order to improve processes and enable new ones. Here lies a huge market potential. The Mobitex case showed that such solutions were underutilized for a number of reasons. There are indications that this situation remains. If so, investigations into what barriers exist, and how to remove them, should be undertaken. It is important to conduct these studies at micro-level in cooperation with companies that could benefit from such development of business processes.

The processes of *technological and industrial convergence* call for further research in a number of dimensions. First, convergence will impact competition in the current sector. Opportunities for new services imply that current actors are diversifying into new industries and vice versa. Technological convergence will intensify competition where current and future services can be provided over previously protected infrastructures. For instance, IP telephony will strike at the heart of incumbent telecom businesses. CATV and more recently Digital TV add to such a trend. Both these areas need to be followed closely. In addition, technological and industrial convergence implies regulatory convergence. Therefore, further strain will be put on the present regulatory framework, which should be analyzed and understood. Important and current issues include the impact of IP telephony and Digital TV, which both lie at the heart of convergence, in particular since regulatory frameworks previously have been both separated and very differently designed.

The mechanisms of *technology competition* are other areas that need to be further researched. Recent examples important for the STIS are e.g. WLAN vs. 3G, Bluetooth versus e.g. IrDA and WLAN, WCDMA versus CDMA 2000, etc. What are the driving forces, and which factors determine which technology prevails? Central to understand is what issues should (and could) be monitored and influenced in early stages of technology competition.

There are also a number of empirical areas which we have not covered in detail, but nevertheless are of great importance for the development of the Swedish telecom innovation system. For instance, *sub-suppliers* are poorly covered in available literature; their size, growth, internationalization and importance for the Swedish economy are all but neglected in most studies, including this one.

During the late 1990s, the telecom industry (and IT industry in general) loudly complained about a lack of available competence and a slack in the educational system. When the market collapsed, major over-education was instead the reality. The *role of the educational system* as both knowledge creator and competence supplier is a further area to explore in more depth.

In addition, there are *standardization* issues in need of further research. This is a key area for the strength of an innovation system, particularly in ICT. Handling standardization is accordingly both a management and policy issue. Still, it is poorly covered in both management and policy literature, and in education. Today engineers are graduated without having knowledge about the strategic importance of standards. Another interesting standards-related question to explore further is why American firms made use of the open standards IP and Ethernet, to a larger extent than others. With the continuing convergence of telecommunications and computer communications, open standards will probably play an increasing role in the future. The border lines between computer communications and telecommunications will eventually be blurred, with a multipurpose communications industry emerging. Thus far, it seems that firms originating in the computer industry have been the most successful in making use of the convergence.

Another area only briefly discussed in this report is *the emerging actor system*. The increasing number of levels in the actor hierarchy, in combination with converging actor systems (value-chain), creates both complexity and uncertainty – regarding what roles to take (how to handle competition and collaborations, new and old players etc.), as well as how the structure will develop. This uncertainty also slows down development, thus calling for uncertainty reduction. There are numerous analyses of the mobile Internet value systems, most of which are delivered by consultancy firms, and not based on proper research (industrial organization theory etc.). Such research is therefore justified.

Still, the future of mobile Internet includes a number of key uncertainties. One commonly used method to deal with important uncertainties is *scenario analysis*. However, few of the scenarios that we identified in this study take the analysis further (a) by identifying implications for key actors, (b) by identifying "early warning signals" (i.e. indicators to monitor which scenarios are actually coming true), (c) by revising scenarios and, perhaps most importantly, involving decision-makers in the process of scenario-making. For VINNOVA, identifying bottleneck functions in different scenarios could be a fruitful approach.

There is also a need for comprehensive *policy and regulatory analysis* of telecom markets and IT uptake more generally. The development of any innovation system is often crucially influenced by laws and regulations, and this holds in particular for telecommunications markets, with their long-standing tradition of a process of liberalization and re-regulation. Since the 1970s, there has been an on-going evolution of the role of government (through legislation and regulation) and industry development, starting first with the dismantling of telecom monopolies, the emergence of competition and creating a fair playing field. Recently, the European Union and member states implemented a new telecom regulatory package, but technology and market developments will not rest. There are plenty of issues remaining, and new ones will emerge, especially since innovation and growth concerns will increase in importance. As a conclusion, it is safe to say that the field of *telecom policy* will not only remain an active and relevant field for future research, but will be increasingly so.

A number of weaknesses of IS approaches were identified in Chapter 2. These are partly addressed in the above suggestions. Generally, the processes of learning and diffusion need to be studied at micro-level, trying to link micro-level findings to the macro-level. The process of entrepreneurship needs to be integrated into innovation-systems literature. From a theoretical point of view, there is a need to link the different innovation-system concepts to each other. There is also a need to try to integrate the innovation-systems literature with growth theory. Finally, provided that a lack of early-stage financing is an accepted fact not only in mobile data and not only in Sweden, such a market failure needs further exploration.

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NMT 450 (6/92) no title available.

GSM

12/82 “annex 9 (no title)”

18/82 “Report of the Meeting on an Interim Public Land Mobile System in the 900 MHz band, Paris 27-28 October 1982.”

23/83 “Nordic Mobile Phone System expands into the 900 MHz band”

51/83 “An Interim Description of TACS”

24/84 “Report from GSM meeting no. 3”

28/84 “Report no. 2 to CCH regarding the progress of GSM”

76/84 “Franco-German cooperation in the field of mobile radio communications”

83/84 “First report on the comparison of different multiple access scenarios for a digital GSM system”

1/85 “Co-operation with EEC”

3/85 no title (from chairman on EEC involvement).

6/85 “Information about the Franco-German co-operation programme in the field of cellular mobile communication services”

64/85 “Information on the Franco-German cooperation programme in the field of cellular mobile communication services”

11/86 “Industrial property conditions to be included in contracts relating to experimental programmes”

73/86 “Swedish experimental programme in digital mobile communications”

31/87 “Report from GSM Meeting no. 12”

82/87 “Report from GSM meeting no. 13, Funchal, 1987.02.16-20.

101/87 “Advice to GSM concerning action to be taken relative to third party IPRs”

121/87 Memorandum of Understanding on the implementation of a pan-European cellular mobile telecommunications service by 1991”

149/87 “Patent panel advice to GSM”

168/87 “Intellectual property issues in GSM”

16/88 “Report from the GSM meeting no. 16 the Hague, 87.12.14-18”

SMG (ETSI)

234/93 “GSM in Future Competitive Environment”

480/97 “Proposal for concept groups for the definition of the UMTS Radio Access UTRA”

32/98 “Proposal for a Consensus Decision on UTRA”

471/98 “No title: Communication from Qualcomm to ETSI SMG Chairman on ETSI IPR Position and demands for Convergence of cdma2000 and UMTS”

482/98 “Comments on the Five Points”

ITU

ITU (1995) “Task Group 8/1: Liaison statement to working party 8B: Evolution/migration towards FPLMTS/IMT-2000, ITU Radio Communication Study Groups, Document 8D/85-E, 30 November 1995

APPENDIX A: SWEDISH FIRMS IN MOBILE COMMUNICATIONS (1997 & 1999)

Firm category	1997	1999	Main activity
Ericsson	Ericsson (LM Ericsson, Ericsson Radio, Mobile, Components, Microwave, Utveckling, Software, Infotech and Eritel)	Ericsson (LM Ericsson, Ericsson Radio, Mobile, Components, Microwave, Utveckling, Software, Infotech and EMDD)	Development, production, sales of telecommunications infrastructure, terminals, radio circuitry, microwave links, radio base stations, software, mobile data technology, consulting services, etc.)
Operators			
	Telia, Telia Mobile	Telia, Telia Mobile	Operator
	Comviq, Tele2 Mobil	Comviq, Tele2 Mobil	Operator
	Europolitan	Europolitan	Operator
Base station sub-systems and antennas			
	Allgon	Allgon	Antennas and base station sub-systems (also for mobile phones)
	Radio Design	New name	Base stations, antennas, and other equipment for 450 MHz
	LGP Telecom	LGP	Amplifier equipment
	Antel	Antech	Antennas for base stations
	Mafi	Mafi	Radio masts
	Wibe	Wibe	Radio masts
	Cue-Dee	Cue-Dee	Radio masts
Mobile phones			
		Spectronic	Mobile terminals for NMT
Mobile phone antennas			
	Allgon (se above)	Allgon (se above)	
	Carant	Carant	Car antennas
	Moteco	Moteco	
	Universalantenner		
	Intenna	Intenna	
Components			
	Nolato	Nolato	Plastic details for terminals
	Samhall	Samhall	Batteries
	Arkivator	Arkivator	Mechanical components for Ericsson
	Segerström & Svensson	Segerström & Svensson	Casings for switches and base stations
		Quartz Pro	Crystal oscillators for GSM networks
Development centers			
	Nokia	Nokia	Development center base stations
	Oracle	Oracle-Telia	Development
		IBM	Development center MI
		Intel Wireless Center	Competence center MI
Development tools			
	Telelogic	Telelogic	
Service development			
	Teligent	Teligent	Mobile fax and other services
Terminal OS			

Firm category	1997	1999	Main activity
		Symbian	Terminal OS
Accessories			
	Krusell	Krusell	accessories
	Elektromekan	Elektromekan	Re-chargers, cables and other accessories for Ericsson
	Alfta		Packaging for mobile phones and base stations
		Smartaq	Handsfree, telematics products
	Nefab	Nefab	Packaging for mobile products
Specialist consultants			
	AU System	AU System	Specializing in mobile Internet
		Kipling	
		Northstream	
		Razorfish	
		Nocom	
Other consultants			
	Netcom Consultants	Netcom Consultants	
	Enator	Tieto-Enator	
	Enea Data	Enea Data	
	Frontec	Frontec	
	High Q	High Q	
	Mandator	Mandator	
	Semcon	Semcon	
	Sigma	Sigma	
		Framfab	
		Icon	
		VM Data	
		Information Highway	
		Ångpanneföreningen	
Mobile Internet			
	Cectronic	Cectronic	Mobile Internet services
	SendIT	Microsoft Mobile Internet	Mobile Internet solutions
		Icomera	Fast access to Mobile Internet
		Red Message	Information services
		Oracle	
		Roam info	
		Netch	M-commerce
		Aspiro	
		Consafe Infotech	
		Kipling	
		Movearound.com	
		Celltribe	
		E hand	
		Infocast	
		Melody Interactive	
		Wireless Maingate	M2M services
		Room 33	Mobile portals
		Wireless solutions	
Specialized VC			
		Startup factory	
Other			
	Time space radio	Time space radio	Wireless broadband
	Saab Ericsson Space		Antennas and RF equipment for mobile satellite-based
	Lysacom		Microwave products
	Partnertech	Partnertech	Production of electronics
	Essex	Essex	Production of base station

Firm category	1997	1999	Main activity
			equipment
			Development center
	Possio Systems	Possio Systems	GSM FAx
		Mecel	Car-based mobile solutions
		Axis	Wireless home networks
		Teracom	Mobile broadband radio (development?)
		Sivers ima	Microwave components
		Sectra Wireless	
		Indevia	
		Flectronics	Production of mobile phones
		Across Wireless	Mobile systems
		Cellpoint systems	GSM positioning
		Micro systemation	Software-based modems
		Mobile Eyes	EPOC
		Pipe beach	Speech recognition
		Satsafe	Positioning
		Trio	Mobile PBX
		Unwire	Mobile Positioning
		Newline information	N/A
		Mobile mind	N/A
		Solectron	N/A

Source: Adapted from Ny Teknik (1998/21, 2000/8)

VINNOVAs publications

July 2004

See www.VINNOVA.se for more information

VINNOVA Analysis VA 2004:

1 The Swedish National Innovation System 1970-2003 - a quantitative international benchmarking analysis

2 Trämanufaktur - det systembrytande innovationssystemet

3 *Under production*

4 Telecom Dynamics - History and State of the Swedish Telecom Sectors and its Innovation System 1970-2003. Final Report. *Only available as PDF*

VINNOVA Analysis VA 2003:

1 Innovationssystemanalys inom flygindustri och luftfart. Förstudie

2 Swedish Biotecknology - scientific publications, patenting and industrial development

4 Svensk sjöfartsnärings innovationssystem - igår, idag och imorgon

VINNOVA Analysis VA 2002:

2 Det Svenska Nyföretagandet 1986-1997 förändringar i företagsstrukturer och sysselsättningseffekter.

VINNOVA Innovation in Focus VF 2002:

1 Effekter av VINNOVAs föregångares stöd till behovsmotiverad forskning – Fyra effektanalyster av insatser under perioden 1975 – 2000 *(for a short version in swedish & english, see VI 2002:7 & VI 2002:8). Only available as PDF*

2 Stimulating International Technological Collaboration in Small and Medium-Sized Enterprises. A Study of VINNOVA's SMINT Programme.

3 Regional ekonomisk tillväxt i Sverige 1986–2001. En studie av tillväxtens utveckling i Sveriges lokala arbetsmarknader.

VINNOVA Forum VFI 2003:

1 Commercialization of Academic Research Results *(Innovation policy in Focus)*

VINNOVA Forum VFI 2002:

1 Betydelsen av innovationssystem: utmaningar för samhället och för politiken *(Innovation policy in Focus)*

2 Innovationspolitik för Sverige: mål, skäl, problem och åtgärder *(Innovation policy in Focus)*

3 Teknikparkens roll i det svenska innovationssystemet - historien om kommersialisering av forskningsresultat *(Innovation policy in Focus)*

VINNOVA Information VI 2004

1 Årsredovisning 2003

2 *Under production*

3 VINNOVAs activities within Biotechnology. *Replaces VI 2003:3. Only available as PDF*

VINNOVA Information VI 2003:

1 Verksamhet inom Transporter

2 Årsredovisning 2002

3 *See VI 2004:3*

4 The Competence Centres Programme. Third International Evaluation. Group 1 (8 Centres)

5 The Concept of Innovation Journalism and a Programme for Developing it. *Only available as PDF*

6 EUREKA

VINNOVA Information VI 2002:

1 Research and innovation for sustainable growth. *Replaces VI 2001:2*

2 VINNOVAs verksamhet – pågående och planerade aktiviteter. Juli 2002. *Replaces VI 2001:10*

3 Tillväxt i regioner genom dynamiska innovationssystem

4 VINNOVAs årsredovisning 2001

5 IT i verkstadsindustrin. Program för mångvetenskaplig forskning i samverkan industri, högskola och institut

6 Regionala företagskonsortier 1994-2001

7 Effekter 1975–2000. Stöd till behovsmotiverad forskning. *Short version of VF 2002:1*

8 Impact of R&D during the period 1975-2000. The impact of VINNOVAs predecessors support for needs. *English version of VI 2002:7*

9 Verksamhet inom BioTeknik. Speciellt framtagen för BioTech Forum och Medicintekniska konferensen oktober 2002.

VINNOVA Policy VP 2004:

1 Nationell strategi för transportrelaterad FUD

VINNOVA Policy VP 2003:

1 VINNFORSK - VINNOVAs förslag till förbättrad kommersialisering och ökad avkastning i tillväxt på forskningsinvesteringar vid högskolor. HUVUDTEXT. *For appendixes see VP 2003:1.1*

1.1 VINNFORSK - VINNOVAs förslag till förbättrad kommersialisering och ökad avkastning i tillväxt på forskningsinvesteringar vid högskolor. BILAGOR. *For main text see VP 2003:1*

2 Behovsmotiverad forskning och effektiva innovationssystem för hållbar tillväxt. VINNOVAs verksamhetsplanering 2003-2007. *Replaces VP 2002:1. For English version see VP 2002:4, for full Swedish version see VP 2002:3*

3 VINNOVAs forskningsstrategi. Strategi för hållbar tillväxt

4 Nationell Innovations- och forskningsstrategi för området Miljödriven teknikutveckling. *Only available as PDF*

VINNOVA Policy VP 2002:

1 *See VP 2003:2*

2 Nationellt inkubatorprogram

3 Behovsmotiverad forskning och effektiva innovationssystem för hållbar tillväxt. En fördjupad version av VINNOVAs verksamhetsplanering 2003-2007. *For short Swedish version see VP 2002:1, for short English version see VP 2002:4*

4 Effective innovation systems and problem-oriented research for sustainable growth. VINNOVA's strategic plan 2003 - 2007. *For Swedish veersion see VP 2002:1 and 3*

5 Nationell strategi för FoU inom området tillämpning av informationsteknik.

VINNOVA Report VR 2004:

1 Nya material och produkter från

förnyelsebara råvaror. En framtidsbild och vägen dit. *Replaces VR 2002:16*

2 Nya material och produkter från förnyelsebara råvaror. *Short version of VR 2004:1. Replaces VR 2002:22*

3 Evaluation of the NUTEK-VINNOVA programme in Complex Technical Systems 1997-2001. Utvärdering av ett FoU-program i Komplexa Tekniska System 1997-2001

4 Förnuft och känsla - en narrativ studie om äldre kvinnors bilkörning. *Only available as PDF*

5 Equipment for Rational Securing of Cargo on Railway Wagons. Utrustning för rationell säkring av last på järnvägsvagnar (jvgRASLA). *Only available as PDF*

6 Innovationspolitik för ITS. En studie av aktörsnätverk kring Intelligenta TransportSystem. *Only available as PDF*

7 Svensk forskning - rik på upplevelser. *Only available as PDF*

8 *Under production*

VINNOVA Report VR 2003:

1 Fysisk planering i det digitala samhället. *Telematik 2004*

2 Kina störst på mobiltelefoni - konsekvenser för omvärlden. *Telematik 2006*

3 Framtidens fordon - mötet mellan två mobila världar. *Telematik 2006*

4 Efter 11 september 2001: - Kan storebror hejdas? *Telematik 2006*

6 Kunskapskultur och innovation. Innovationssystem kring energirelaterad vägtransportteknologi. Förstudie. *Only available as PDF*

7 Förändrad finansiering av tranportforskningen. *Only available as PDF*

8 Inledande laboratorieförsök - Projekt AIS 32. Delrapport 1. *Only available as PDF*

9 Inledande fältförsök - Projekt AIS 32. Delrapport 2. *Only available as PDF*

10 Hur går det till i verkligheten? Innovationsprocessen utifrån 18 fall

11 Returlogistik - Utveckling av logistiksystem för returgodsflöden. *Only available as PDF*

12 Genusperspektiv på innovationssystem - exemplet svensk musikindustri

VINNOVA Report VR 2002:

1 Explorative System-Integrated Technologies – EXSITE

2 Rationalitet och etik i samhällsekonomisk analys och Nollvision. Expertseminarium november 2001. *Only available as PDF*

3 Regionala innovationssystem. En fördjupad kunskapsöversikt. *Only available as PDF*

4 Funktionshindrades resmöjligheter. Sammanfattning av senaste årens forskning. *CD with all related reports*

5 Organisationsövergångar och unika kulturer. Förändringsdynamik och utvecklingsstöd via Växtkraft Mål 4. *For short version see VR 2002:21*

6 Metanoldrivna bilar i Trollhättan – Göteborg. Förstudie. *Only available as PDF*

7 Hållbart arbete i informationssamhället. Slutrapport från projektet "Callcenter i utveckling – långsiktigt hållbart arbete med kunder på distans"

8 Knowledge exchange, communication and context in electronic networks (KnowHow). *Only available as PDF*

9 Systemiskt lärande som ansats i logistikutvecklingen – en studie av internethandeln. *Only available as PDF*

10 Framväxten av en ny vetenskapsbaserad basteknologi (nanoteknik) och dess relevans för det transport-teknologiska området. Förstudie. *Only available as PDF*

11 Den nya ekonomin – ett internetperspektiv. *Telematik 2004. For short version see VR 2002:12*

12 Den nya ekonomin – ett internetperspektiv. *Telematik 2004. Short version of VR 2002:11*

13 Projekt Camelot. Rundabordssamtal och seminarier kring framtidens boende. *Telematik 2004. Only available as PDF*

14 Tyskland och användningen av Internet - en jämförelse med Sverige *Telematik 2004*

15 DIGITALA NYHETER. Nyhetsförmedling via Internet *Telematik 2004. Only available as PDF*

16 Nya material och produkter från förnyelsebara råvaror. En framtidsbild och vägen dit. *For short version see VR 2002:22*

17 Transportinformatik och personlig integritet. *Only available as PDF*

18 Utvecklade leverantör – kundrelationer: Supply Link Management. *Only available as PDF*

19 Trämekanisk framsyn. Ett projekt för utveckling av den trämekaniska industrin. Slutrapport. *Only available as PDF*

21 En sammanfattning av boken: Organisationsövergångar och unika kulturer. Förändringsdynamik och utvecklingsstöd via Växtkraft Mål 4. *Short version of VR 2002:5*

22 Nya material och produkter från förnyelsebara råvaror. *Short version of VR 2002:16*

23 Transporteffektivisering med integrerad informationsteknologi, TRANSMIT. *Only available as PDF*

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25 Face synthesis as a communication aid for hard-of-hearing people. Teleface l and ll. Final project report. *Only available as PDF*

26 Communication & Services in Open Networks. Kommunikation & Tjänster i Öppna Nätverk. 1999-2002. *Only available as PDF*

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30 Dialogprojektet - Framtida handel. Rapporter framtagna av Arbetsgruppen för samordning av dagligvarutransporter. *Only available as PDF*

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