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The Telephone and Society in the Past 100 Years

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INTRODUCTION

In the 100 years that the telephone has been with us, it has directly and profoundly affected man's daily life. It has also had a large impact on the arts and on the sciences. In rendering a new sort of service, it has given rise to a new sort of industry—a complex, high-technology system whose actual operation, in the sense of the origination and completion of calls, is carried out directly by the users.

In supplying telephone service, different nations have taken various paths with varied success and impact on their citizens; all telephone systems, however, interconnect. The new service and the complex system that the telephone's invention has brought into being are resources that can be and have been exploited in many ways unforeseen by its originators.

I propose to say something about all these aspects of the telephone and society: its novel nature, its exploitation, the influence of telephone systems, and the impact of telephony in our individual lives.

In 1876, when Bell invented the telephone, there was no need for it. Society did very well without it, just as it did without electric power or automobiles. Today the telephone has become more than a luxury or a convenience; it has become a basic part of man's world.

The telephone's power is not that of an idea, a creed or an ideology; it is the power of science and technology to enlarge man's life. This enlargement began 100 years ago through one man, Alexander Graham Bell. Like many Americans, Bell was

born in another country, Scotland. A scientist of speech, his interest in electricity was pragmatic. He tried to improve telegraphy and he invented telephony. James Clerk Maxwell's Rede lecture of 1878 put this very well:

Now, Prof. Graham Bell, the inventor of the telephone, is not an electrician who has found out how to make a tin plate speak, but a speaker who, to gain his private ends, has become an electrician. He is the son of a very remarkable man, Alexander Melville Bell, author of a book called *Visible Speech*. . . .

The inventor of the telephone was thus prepared, by early training in the practical analysis of the elements of speech, to associate whatever scientific knowledge he might afterwards acquire with those elementary sensations and actions, which each of us must learn from himself, because they lie too deep within us to be described to others. . . .

I shall, therefore, consider the telephone as a material symbol of the widely separated departments of human knowledge, the cultivation of which has led, by as many converging paths, to the invention of this instrument by Professor Graham Bell.

For whatever may be said about the importance of aiming at depth rather than width in our studies, and however strong the demand of the present age may be for specialists, there will always be work, not only for those who build up particular sciences and write monographs on them, but for those who open up such communications between the different groups of builders as will facilitate a healthy interaction between them.

Bell brought together different parts of knowledge and produced a workable telephone; once this was accomplished, he sought to exploit it. After he patented it, he showed it at the Philadelphia Centennial Exposition; a year later in association with others, he formed a telephone company.

From this man and these early acts has grown all that I write about.

STATISTICS AND THEIR INTERPRETATION

Happily, many statistics concerning the telephone and its usage are available for the entire history of telephony. In his chapter "The Telephone and the Uses of Time," Martin Mayer has made excellent use of statistical data to elucidate many details of telephone usage. The statistics I use are largely aggregated; they explain overall usage in times and at places where usage may vary widely among the population (many having no telephones). The message conveyed by the statistics may not be entirely clear,

but our considerations should begin with incontrovertible numerical data rather than preconceived ideas.

When was telephony introduced and how rapidly did it grow? Figure 1 shows telephones per 100,000 people as a function of time. We see that telephony grew rapidly from the year of its invention. This is characteristic of good, useful, inexpensive new products or services that work well from the start. The history of Xerography and hand calculators must be similar.

The rate of growth of telephony increased abruptly in the mid 1890s since Bell's original patent expired in 1893, and it was possible for anyone to make telephone equipment and sell service. Many competing companies were formed. Some served cities that already had Bell exchanges, but many provided service where none was available before. Partially, the expansion of telephony near the turn of the century must also have been associated with the new potential of commercial long-distance service (Table 1).

Telephony's spurt of growth in the 1890s is clearly associated with non-Bell capital and enterprise. Figure 2 shows the fraction

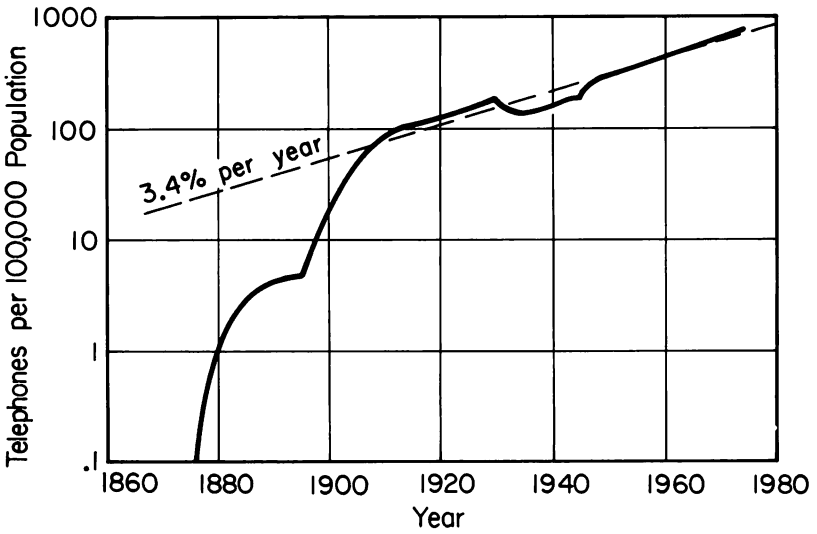

Figure 1
Telephones per 100,000 population. (Data from *Historical Statistics of the United States: Colonial Times to 1957*, U.S. Department of Commerce.)

Table 1
Initiation of Commercial Long-Distance Service

Date	Cities
1881	Boston–Salem
1884	New York–Boston
1892	New York–Chicago
1893	Boston–Chicago
1893	New York–Cincinnati
1895	Chicago–Nashville
1896	Kansas City–Omaha
1896	New York–St. Louis
1897	New York–Charleston
1897	New York–Minneapolis
1897	New York–Norfolk, Virginia
1898	New York–Kansas City

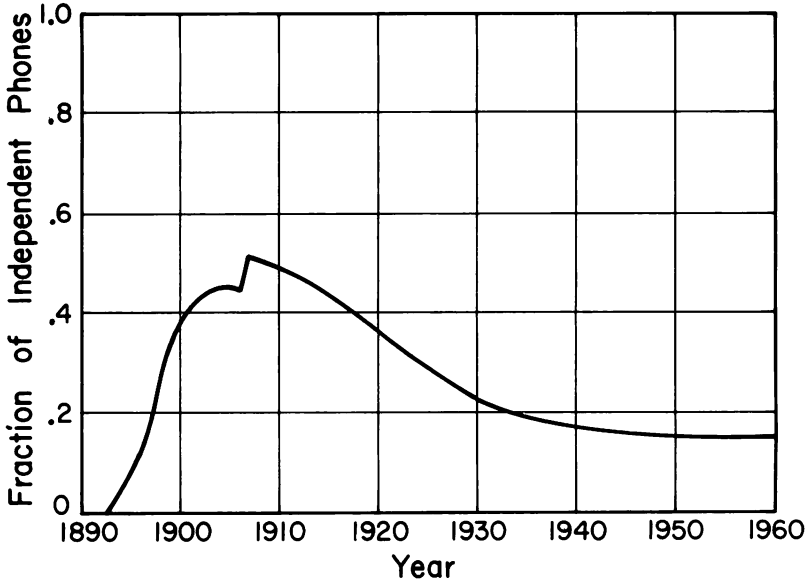

Figure 2
Fraction of independent phones. (Data from *Historical Statistics; Statistical Abstracts, 1974*, U.S. Department of Commerce.)

of independent (non-Bell) phones as a function of time. The initial growth of independents was rapid, peaked around 1910, slowly fell off, and rose again somewhat after 1960.

We have seen that long-distance service developed gradually after 1881. When the independents began operation in 1894, many phone systems were isolated. Independents (Figure 3) first interconnected with Bell System phones in 1898; this fraction increased gradually until 1907. Initially, Bell sometimes refused to interconnect and give competitive independents the advantage of serving Bell customers. In 1908, Theodore N. Vail, president of AT&T, announced a policy of eliminating dual service in one city by either buying the competing service or abandoning the field to it. A rapid rise in interconnection followed, and also in the fraction of independent phones between 1907 and 1908 (Figure 2).

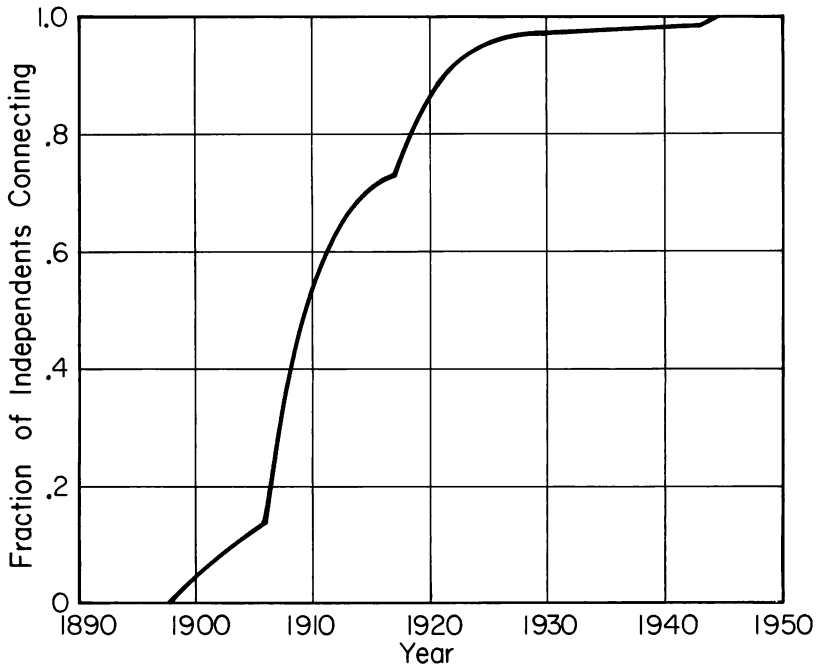

Figure 3
Fraction of independent phone companies that connect with Bell. (Data from *Historical Statistics; Statistical Abstracts.*)

In 1913, AT&T agreed to provide long-distance connection to any independent and not to purchase any more independents (except when approved by the Interstate Commerce Commission), but competition of independents not interconnected with Bell in the same service areas nevertheless persisted for some years. However, the next spurt of interconnections did not come until 1918, and it may have resulted more from World War I than from phone company policies. From July 14, 1918, to July 30, 1919, the country's telephone systems were operated under the Post Office Department by direction of President Wilson; after 1918, interconnection of independents rose smoothly.

The chief growth of independents preceded the interconnection agreement of 1913. It seems clear that the provision of telephone service did not prove to be a get-rich-quick business; rather, telephony became an increasingly challenging task that required much capital and technical know-how and was beset by many problems. Today, independents supply a minority of service at a price no less than Bell's, but the service is sometimes inferior. The fraction of growth in independent and Bell phones is now chiefly dictated by growth in the geographical areas served by each; while Bell serves most of the population, the independents control over half the geographical area of the country; this area's population is currently growing at a more rapid rate than that of the Bell area.

Let us return to Figure 1, which gives the number of phones as a function of time. As indicated by the dashed line, telephones per person have grown exponentially at a rate of about 3.4 percent a year since 1910. This growth was interrupted by the depression of 1929 and perturbed by World War II, but it has been remarkably steady. Most homes and all businesses now have telephones. Today the growth in number of telephones per person must be attributed to more phones per home and per employee.

We have seen that telephony has grown steadily since its inception. What has this done to other modes of communication?

Is telephony replacing travel? No. Very roughly, in recent years the number of telephone calls and the number of air miles flown have increased at about the same rate, and the number of car miles traveled about half as fast. Undoubtedly, a telephone

call sometimes substitutes for a trip, but more and faster communication tends to engender widespread associations and activities that result in trips.

What about books as a means of communication? Is the telephone somehow affecting publication? No. Figure 4 shows this clearly.

Has the telephone call displaced the letter? The number of telephone calls per person per year (Figure 5) is over three times as great as the number of first-class plus airmail letters per person per year, and the recent rate of growth of telephone calls is over twice as great as the rate of growth of letters. Letters per person still appear to be growing, but this may change slowly or abruptly; it seems plausible that telephony together with data transmission will eventually displace much mail.

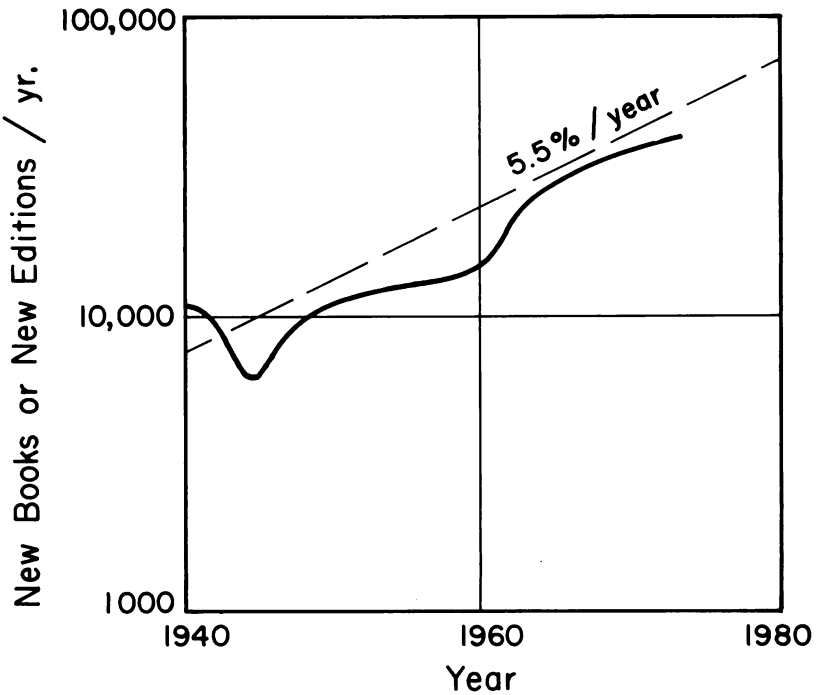

Figure 4
New books or new editions published in various years. (Data from *The World's Telephones*[AT&T]; *The American Almanac, 1972.*)

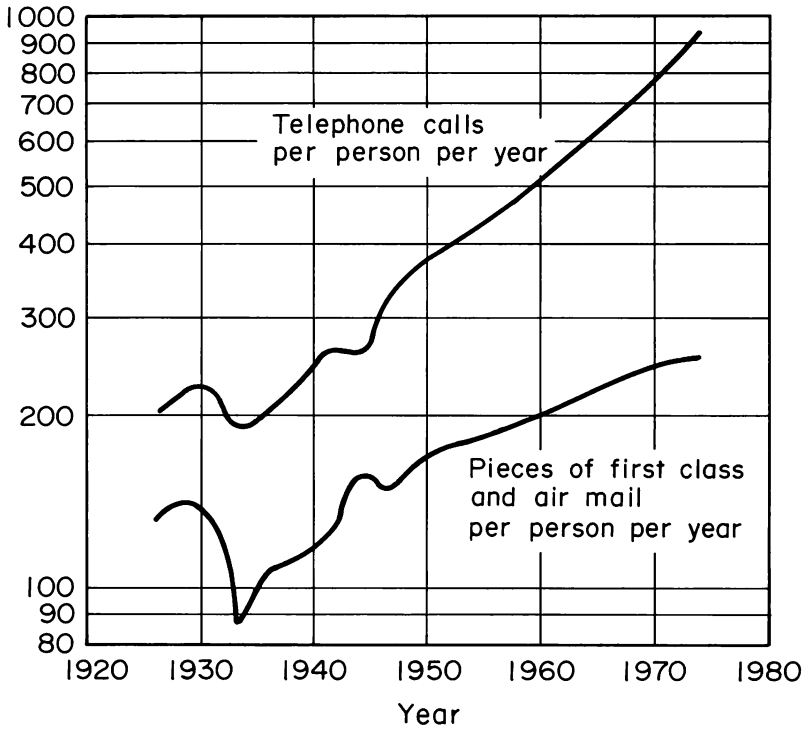

Figure 5
Domestic telegraph messages per year. (Data from *The American Almanac, 1972.*)

The telephone call has definitely displaced the telegram (Figure 6); and the yearly number of telegraph messages has declined steadily since 1945, while telephone calls have steadily increased.

Telephone calls are immediate and convenient, but text is advantageous for many purposes; indeed, data communication is growing. Telegraph service is falling in volume partly because it no longer delivers text (messages are telephoned) and partly because it is costly and increasingly inconvenient. I can remember when telegraph messengers did deliver text, and when office switches summoned telegraph messengers to pick up text to be telegraphed.

Telegraphy has failed primarily because it is labor-intensive in a world where the cost of labor rises continually; telephony is

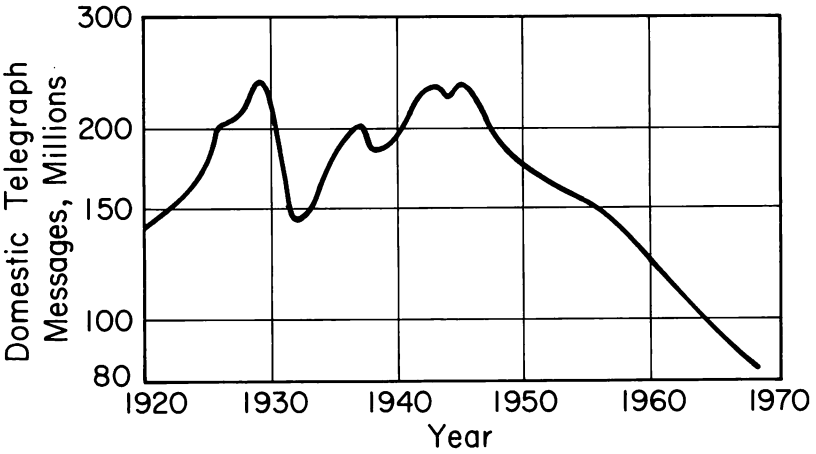

Figure 6
Domestic telegraph messages per year. (Data from *The American Almanac, 1972*.)

a combination of automation and do-it-yourself. The user dials, picks up the phone and replaces it. Except in credit-card and person-to-person calls, machinery does almost everything. Credit-card calls and person-to-person calls are necessarily expensive, and directory assistance is a great financial burden to telephone companies.

Unless our society changes fundamentally, labor-intensive services will decline in comparison with do-it-yourself and automated services. The burden of delivery continually increases postal cost; telegraphy has abandoned physical delivery, but an employee still has to transcribe the message for transmission and read the message to the recipient. Economic forces have worked to the disadvantage of mails and telegraphy, but data transmission (such as teletypewriter service) may increase when terminals become cheap enough. The traditional telegram is on the way out.

We have noted the importance of automation to the survival of telephony. In Figure 7 the number of telephone calls per Bell System employee per day is shown as a function of time. Up to about 1920 there is no consistent rise or fall; this is surprising. As the number of subscribers increases, it becomes more complex for one subscriber to reach another; thus, we might expect

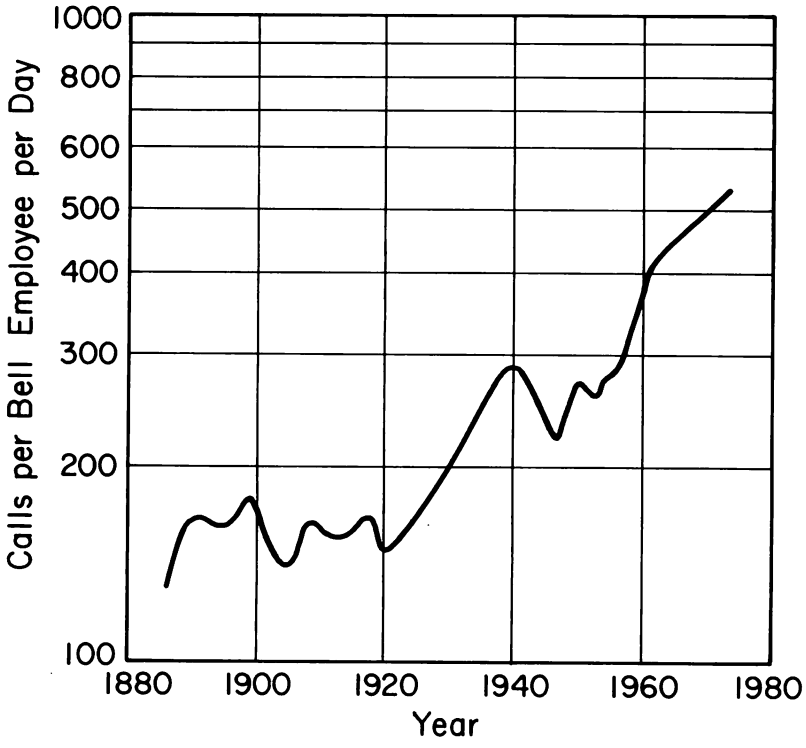

Figure 7
Calls per Bell employee per day. (Data from *Historical Statistics; Statistical Abstracts, 1974.*)

a decrease in calls per employee.

Automatic switching was invented in 1879 and tried in the Bell System in 1902, but the first large-scale switching system was not put into use in the Bell System until November of 1919. The introduction of automatic switching convincingly explains why the average rise in calls per employee has been about 2.5 percent per year and shows no sign of falling.

While rising manufacturing productivity is the source of America's affluence, steadily rising service productivity is atypical. A rise in productivity has been attained through an intense program of automation, not only of calling but of testing and maintenance as well.

While many telephone statistics are aggregated, separate fig-

ures are available on local, toll, and overseas calls. Calls per person per year in these categories are shown for recent years in Figure 8. Toll calls grow more rapidly than local calls, and overseas calls grow more rapidly than toll calls. This reflects a changing pattern of life and work. Families tend to disperse and children go to far universities, yet friends and relatives keep in touch by telephone. Commercial, scientific, and cultural relations are increasingly dispersed and increasingly international. Despite the intense nationalism characteristic of present governments, the scope of man's activities does not halt at national boundaries. This is reflected in the rapid rise of overseas calls, which in turn reflects improved technology.

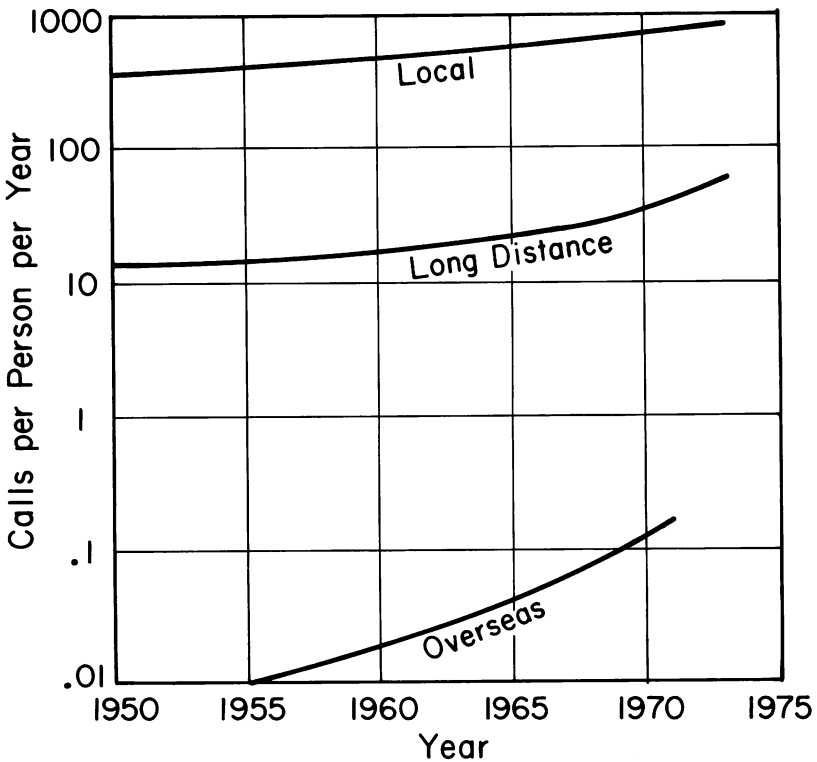

Figure 8
Overseas, long distance, and local calls per person per year. (Data from *The World's Telephones*.)

There was no commercial overseas telephony until radio service was established in 1926, and consistently high-quality service came only with the first trans-Atlantic cable in 1956; trans-Atlantic calls rose rapidly thereafter. Since the first commercial telephone service by communication satellite in 1965, the number of nations that can be reached by telephone has increased remarkably. The bulk of international telephone traffic, however, is still among the highly developed nations, and the part carried by satellite is dictated by government regulation rather than by cost or quality of service.

The discussion of international telephone traffic leads naturally to the matter of telephony in various countries. In Figure 9, the horizontal axis denotes gross national product in dollars per year per person and the vertical axis denotes telephone calls per person per year.

It is plausible that telephone usage in the United States, Canada, and Sweden should be similar, because these three countries have a high gross national product and very good telephone service. We also note that these countries have the only telephone systems that own manufacturing as well as research and operating facilities.

It is easy to see why telephone usage in France is low: service is abominable. It is difficult to get a telephone, hard to get dial tone, and hard to get the called party—even if one has a phone. Telephone service in Italy is poor, too, as it is in many other countries.

There must be other reasons, however, that calls per person are so low in such nations as Switzerland, West Germany, and the Netherlands. This may partly reflect a lack of aggressive promotion of service, but it also may be due to language problems. Teletypewriter service for businesses is much more common in continental Europe than it is in the United States; many people who have an adequate reading knowledge of another language cannot communicate satisfactorily in that language over the telephone. Perhaps the reliance on text in business carries over into private life, but this is mere speculation. Whatever the cause, telephony is not as prominent in the lives of many advanced nations as it is in our own.

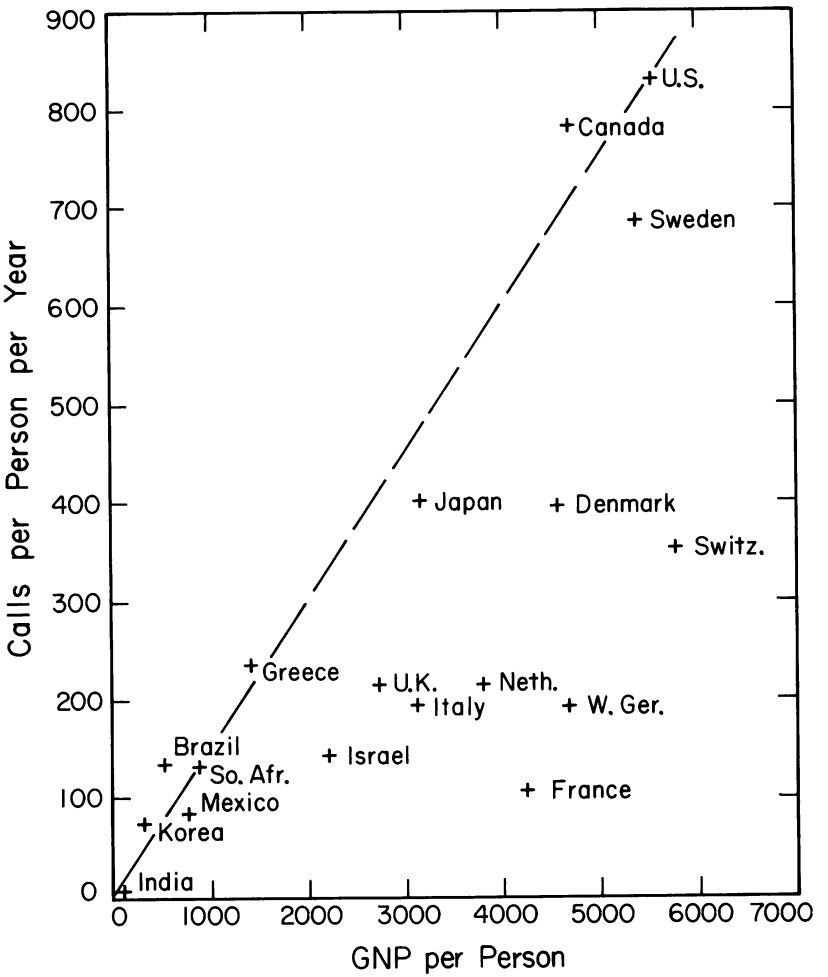

Figure 9
Comparison of per capita calls and GNP. (Data from *The World's Telephones*; *The World Almanac, 1975*.)

In terms of GNP (Figure 9), telephone usage is high in Korea, South Africa, Brazil, Mexico, and Greece. In Korea we may suspect American influence, but in all the countries cited, telephone usage is probably intense among a small segment of the population who consume most of the GNP. That is, average GNP and average telephone usage are both diluted by the same body of nonconsumers and nonusers. In the case of South Africa, the nonconsumers and nonusers are presumably black; in Greece, Brazil, Mexico, and Korea, they are presumably merely poor.

Here we conclude our examination of telephone statistics. What have we learned?

Telephony was attractive enough to find an immediate place in society (Figure 1); telephony expanded rapidly after the expiration of Bell's first patent and has had a remarkably steady growth since 1910. Independent companies played a great role (Figure 2) after 1895 and a lesser role in later years; the fraction of the market served by independents declined (Figures 2 and 3) as interconnection increased. A surge in interconnection followed (Figure 3), not Bell's 1913 agreement to interconnect with any independent, but rather America's entry into World War I when the government took over operation of telephones.

Telephony has grown with, rather than superseded, transportation. It has not cut into the publication of books (Figure 4), it is replacing first class and airmail only gradually (Figure 5), and has largely replaced the traditional telegram (Figure 6) although not the teletypewriter. The increase in calls per employee (Figure 7), attained through automation, has allowed telephony to flourish despite rising labor costs. Long-distance calls (Figure 8) are increasing more rapidly than local calls, and overseas calls more rapidly than either. Telephony does not play as large a part in the lives of peoples of some other nations (Figure 9), even technologically advanced nations, as it does in our lives.

We should keep these facts in mind as we consider various social aspects of telephony.

TELEPHONE USAGE

Our knowledge of telephony's role in our lives and work has largely been common and anecdotal. In their papers, Martin

Mayer, A. A. L. Reid, John Brooks, and Jean Gottmann have added considerably to our knowledge of telephone usage. It may be worthwhile, however, to note a few aspects of the telephone and of telephone usage that sometimes escape attention.

The telephone provides quick and private access to others at a time of one's choice. We may note that it seems quicker and easier to reach individuals in the Soviet Union by phone, from outside or inside the borders, than in any other way. The telephone is used widely among friends for gossiping, verbal amusement, or reassurance. The picture of the housewife, phone propped on shoulder, gossiping while she irons, is drawn from life, but many people gossip by telephone while they are not working.

Such gossiping might seem superficially akin to watching TV or listening to the radio since both are electrical communication and both provide amusement. In all of their uses, however, the telephone and mass communication are poles apart; mass communication distracts people from their neighbors and community and focuses attention on national soap operas or national or international affairs. The telephone draws neighbors and communities together (or splits them apart) by providing people with shared knowledge. And, unlike mass communications, telephone service might be described as *discretionary*. The telephone, unlike TV or radio, allows the user to choose whom or what service he shall call and when.

In a broader context, mass communication tells lots of people at one time what is happening, while the telephone enables them to choose their own time and associates to protest against it. Mass communication is from the few to the many; the telephone is always from person to person. Mass communication fits people to schedules; the telephone fits people. It is no wonder that politicians subsidize the delivery of periodicals, encourage television, and tax telephone calls.

The discretionary person-to-person characteristics of the telephone take many forms; they may be used for entertaining gossip or friendly greetings or for arranging dates or parties, often on the spur of the moment. This sort of social interaction is rare in France where the telephone does not really work.

One can place orders by phone (if one can get them delivered). A special cut of meat may be ordered and then picked

up. The Yellow Pages, which are very profitable, are both convenient and informative; they may be considered the successor to the Sears Roebuck catalog. Although they do not list the exact item or its price, they do give us a start; with the telephone, we can do the rest ourselves.

The telephone is useful in making reservations for dinner, a play, or concert, for air travel, for a hotel, motel, or rental car; many businesses have a toll-free number through which reservations can be made.

Do you want to know something about Social Security, municipal services, or how hard the local water is? The telephone will tell you. If misfortune strikes, you call the fire department, the police, or a doctor; in this last case, it is said that the telephone once responded, "Take two aspirins and go to bed. This is a recording."

While the role of the telephone in our personal lives is extremely broad and very difficult to particularize, its role in business is perhaps narrower and clearer. Compared with the mails or the teletypewriter, the telephone is faster and cheaper if we take the cost of typing into account. For many purposes telephony is better than text, but not for examining legal documents, including patent specifications. Legalese goes in one ear and out the other with no intervening understanding; detailed contracts and specifications must be read line by line at leisure. When text is necessary, it is often mailed separately, preceded by a phone call or not, and the text is discussed during a subsequent phone call.

Internally in business and among close associates, a phone call is a quick way to get information or to ask someone to do something. As Alex Reid notes in Chapter 18, such a business phone call is different from a face-to-face encounter because it needs no social element; one does not have to ask about health, family, or the weather. A phone call can thus be more economical than and preferable to a face-to-face meeting. It is significant that data cited by Reid show that 53 percent of business phone calls give or receive orders, instructions, or information; only 24 percent of face-to-face encounters do this.

The all-pervasive use of telephones in business involves priority and etiquette. In stores, the telephone takes precedence over the live customer; the presumption must be that a tele-

phone customer might get away, but one waiting is hooked.

Busy people who are harried by callers often have their secretaries answer the phone; they accept the call only if they are free and willing. Some have their secretaries make calls as well. Except in the case of person-to-person calls, or when one does not know the number, this can be slow and wasteful if one has direct dialing. Going through a PBX for outside calls means misery for someone. The insistent priority of the telephone call is reasonable when there is no way for the caller to leave a message. I do not see how telephony could function without it.

The telephone allows businessmen, scholars, and ordinary people to search out information and individuals. I once organized a meeting of economists to discuss our declining balance of trade (this was in 1970 when people were not interested). At the beginning of the day I knew one economist, but by the end of that day I knew a good many. The telephone, together with people who know, can be an information source of great convenience and power.

IMPACT ON OTHER FIELDS

In "The First and Only Century of Telephone Literature," John Brooks exhibits the telephone and its place in our lives as depicted in stories and plays. Here I address briefly another matter on which Brooks touches: how the very existence of telephony and the development of the technology associated with telephony have influenced the arts, inspired and made feasible new work in the sciences.

In his book *The Summing Up*, Somerset Maugham writes:

> The drama pictures the manners and customs of the day, and in its turn affects them, and as these change minor changes follow both in the trappings and in the themes. The invention of the telephone, for instance, has made many scenes redundant, has quickened the pace of plays and has made it possible to avoid certain improbabilities.

The messenger need no longer arrive coincidentally as in Greek tragedies; we are spared both this nonentity and his salary. But the exploitation of the telephone has gone further than one might guess from Maugham's words. A sung or spoken soliloquy is unnatural; a telephone conversation, even a long and varied one is not. And like face-to-face dialogue, such a conver-

sation differs profoundly from communication by text.

Some study of communication preceded the invention of the telephone, but the telephone's existence has inspired studies of vocal communication in absence of sight. Such studies have told us new things and confirmed old impressions.

Written communication differs profoundly from spontaneous spoken communication. Indeed, transcriptions of talks often surprise the speaker by seeming nearly meaningless; a text is written to stand on its own. Once a speaker senses understanding on the part of a listener or an audience, he can exploit this very freely. The recording of actual utterances has been essential in revealing the nature of spoken language.

The study of speech and hearing became "scientific" with Helmholtz's work, which largely preceded the invention of the telephone, but telephony inspired studies of speech and hearing and provided apparatus which made new approaches possible. Much of this new work was done by Fletcher and his colleagues at the Bell Laboratories. The work included a major survey of hearing acuity conducted at World's Fairs in San Francisco (1939) and New York (1939–1940), the devising of hearing aids, investigations of the masking of one tone or sound by another, investigations of articulation (intelligibility of speech as affected by bandwidth and noise), the measurement of limens or just noticeable differences in frequency and sound level, and a host of other studies of speech and hearing.

The orthophonic phonograph and early talking pictures came from work in the Bell System. Homer Dudley at Bell Laboratories invented the vocoder (which has given us much insight into the nature of speech), and R. K. Potter and his associates devised the speech spectrogram, a running short-term record of spectrum vs. time which has become variously known as the sonogram or voiceprint.

The development of automatic telephone switching led to developments of another sort. Regarded as a whole, the switched telephone network (which now includes electronic as well as electromechanical switching systems) is certainly the most complicated machine system in existence. It was certainly the first multiprocessor computer and the first large computer devised to do "nonnumerical" tasks. The first electromechanical computer for arithmetic calculations was the Complex Computer made at

Bell Laboratories by George Stibitz in 1940. Other areas of wide importance which came directly from Bell work include the transistor, with its many manifestations, and Shannon's information theory.

To close, as we began, with the influence of telephony on the arts, we can cite the use of computers in the study and production of musical sounds. This has spread from the work of Max Mathews at Bell Laboratories to Boulez's Institute for Research and Coordination of Acoustics/Music (I.R.C.A.M.), a center of art and culture in Paris, to the work of Chowning and his associates at Stanford, and to a host of other places.

TELEPHONY AS A HIGH-TECHNOLOGY SYSTEM

It is a commonplace notion that the goods of life are a product of science and technology. Many practical efforts have been made to exploit technology systematically for human use. Edison's laboratory was an early example. The laboratories and factories of General Electric and chemical and pharmaceutical concerns are other examples. In telephony we see a high-technology system that changes very rapidly through research and invention.

Superficially, telephony may seem to be a slowly changing service. Such innovations as new types of phones, automatic vs. manual switching, transoceanic service, direct distance dialing, wide area telephone service (WATS), and new forms of PBX service (including direct dialing) have been spaced years apart. The provision of TV network transmission and of data transmission goes almost unnoticed by the average user.

Internally, the telephone plant changes rapidly. The problem of providing an ever more extensive and complicated service in the face of increased costs of labor and material has led to a continual search for new materials, devices, techniques, and methods. New plastics have replaced the wood, metal, and hard rubber of older telephone sets. The expensive lead of cable sheathing has been replaced by plastic. The first submarine telephone cables looked much like telegraph cables; in newer cables the steel for strength is in the center, not on the outside. Materials have also come to include highly purified semiconductors for integrated circuits and light-emitting diodes, artificial

magnetic materials, artificial quartz for frequency-selective networks, and highly transparent glass fibres for optical communication.

Techniques have advanced from transmission on single wires with a ground return to transmission on pairs of overhead wires, to transmission on pairs of wires in a cable with "loading coils" to decrease loss, to amplification with vacuum tubes, to putting many conversations on one pair of wires by frequency-division multiplex (and later time-division multiplex in which voice signals are transmitted as coded pulse trains), to more conversations on coaxial cables, to microwave radio for countrywide telephony and TV, to communication satellites (the first demonstration of transoceanic telephone and TV via satellite was done and paid for by AT&T), to waveguides and optical fibres.

Amplification and control have progressed from vacuum tubes and relays to transistors and integrated circuits. Switching has progressed from "step-by-step" in which control is spread through the switching network, to "common control" systems such as crossbar which can handle more complicated types of calls, to electronically controlled switches, and to all-electronic switching. As a product or byproduct of this advance, the telephone network has provided facilities for the transmission of TV and data.

The technological challenges in providing universal telephone service have been unique in that they involved integration of all sorts of new technologies into a stable and reliable system.

Let us compare telephony with the mails, for instance. Pen, ink, and paper existed long before there was a unified postal system; so did modes of conveyance. The postal system brings together current technical facilities for the collection, transportation, and delivery of the mails.

In travel by road and by canal, the path of transportation (road or canal) is supplied by one source and the vehicle (car or barge) by another; fuel comes from still another source. Problems of compatibility are fairly simple. Compatibility of motor fuel and oil is perhaps the most complex and is worked out between oil companies and car manufacturers. Tire problems are handled in a similar manner, and complex interrelations govern safety of vehicles.

The distribution of electric power and the interconnection of power systems pose problems of considerable complexity, but less than those of telephone systems. Air travel (which came after telephony) is complex and high technology, but the number and variety of operations are small compared with telephony.

Railroads with their tracks, rolling stock, schedules, and service are perhaps closer in nature and complexity to telephony than any other service; still, they are simpler, and they have scarcely maintained a high technology.

Telephony is characterized by an unusual combination of aspects:

1. In providing telephone service to many people, there is an inherent diseconomy of scale. It is more complicated to have access to 100 million other people than to have access to one other person. Electric power and cable TV can be distributed by means of a tree-like network which changes only slowly with time, but in telephony an individual pair of wires goes to each subscriber, and the network is reconfigured from call to call. Only high technology combined with economies of scale in research, design, manufacture, and operation can keep the cost of telephony down as service expands.

2. In carrying out its functions, telephone equipment must be operated by users without formal training (in this it is similar to auto travel). The function of telephone employees is to plan, install, maintain, and bill the customers.

3. The customer's equipment (the telephone set) is an almost negligible fraction of the telephone plant; most of the cost and complexity lies in wires to the central offices, switching, and transmission between offices.

4. While the purpose of the telephone system is to serve individual users, maintenance costs for the complex telephone network and for the user's terminal fall on the telephone company. And, unlike the burned-out light bulb or smoking power tool, there can be no clear distinction in the user's mind between different modes of failure.

The telephone company must maintain reasonably stable but ever expanding and improving services while continually improving the economy and internal functioning of the system. This involves research, exploratory development, development,

manufacture, installation, and operation. It involves planning and systems engineering.

Because telephony makes use of rapidly changing technologies, planning must be very general. Interconnection of the nation's and then the world's telephones, conversion from manual to dial switches, direct distance dialing, a transition from vacuum tubes to solid-state devices, a general expansion of digital transmission as opposed to analog transmission, automation of testing functions, and automated (computer) aids to installation, maintenance, and operation are broad, sound goals; they constitute planning of the highest order. Such goals cannot be implemented from the top down, however. They must be reached from the bottom up by those who are aware of the goals and adept in science and technology.

Systems engineering is necessary in reaching the overall goals of a general plan. Systems engineers try to take three things into account: the current state of the technological art, the current nature and (unfilled) needs of the telephone system, and the economics of development, manufacture, and operation. On these bases, systems engineers propose new systems that may or may not be accepted for manufacture. During development, systems engineering considerations are invoked when (as always) changes must be made because of misjudgments about the state or cost of technology or the cost or value of various operating features.

Systems engineering is a very chancy business. It must go hand in hand with development, and when systems engineers become isolated from development they misjudge the actual state of technology and, hence, both cost and performance.

Through science, technology, planning, and systems engineering, new devices, techniques, and principles must be incorporated into a complex, reliable, maintainable, yet ever-changing operating system. This complex system must not "crash" (in the computer sense) through obscure and unforeseen internal interactions. It must be maintained and operated by available personnel. Next to the armed forces, the Bell System runs the largest teaching program in the country. But training is not the whole answer to people problems.

Whatever machine fallibility may be, human fallibility is more varied, unpredictable, and harder to control. Hence, there is a

tremendous incentive in telephony to automate all the operations (or parts of operations) that can be automated and to use human beings only for functions requiring human qualities. Human beings intervene in person-to-person, credit card, and coin calls, but they have been supplied with computerized aids. Human skill and labor are still required in maintenance, but automated testing is more dependable than scheduled testing by maintenance personnel.

Automation is also furthered by the sort of personnel available to telephone companies in this country today and especially in large cities. Telephone personnel do not stay on the job as long as they used to, and their level of education is generally lower. For better or worse, it seems unlikely that anyone will ever again begin a career digging holes for telephone poles and finally become Chairman of the Board of AT&T, as Frederick R. Kappel did.

At one time the ability to plan, engineer, and operate complex reliable systems was largely confined to telephone companies. The Nike antiaircraft missile systems were designed by Bell Laboratories and manufactured by Western Electric. Today there is widespread competence in complex, high-technology systems, but the telephone systems remain the largest and most complex systems in the world.

OPERATING TELEPHONE SYSTEMS

We have seen something of the history and nature of the telephone system, the broad impact of telephony on the arts and sciences, and the difficult technical problems of building, expanding, improving, and maintaining a telephone system.

Telephone systems express high technology and serve users. As entities in themselves, they are part of the social and economic structure of any country. Although the services telephone systems render are similar in different nations, their organization varies from country to country. We can recognize four general patterns for supplying telephone service:

1. National telephone systems have been operated by a private organization such as the International Telephone and Telegraph Company, either directly or under contract for the national government. During this period of growing nationalism and grow-

ing "governmentalism," such systems have been nationalized as a matter of public (or political) policy.

2. Some telephone systems, including that of France, are operated as departments of the government (as the U.S. Post Office used to be), revenues go into the treasury, and both expenses and capital needs are met (or not met) through legislative appropriations.

3. The telephone system may be operated as a public corporation (as in Japan, and more recently in England), with public financing as well as sale of bonds. Sometimes there is a separate organization which handles international traffic.

4. The telephone system may be operated by one or more private companies, as in the United States and Canada (domestic service only in Canada). Such companies are always regulated and of course pay taxes; in the United States, federal, state, and local taxes are a large item of expense, second only to labor. In 1974 the total taxes shown on Bell System books were nearly 30 percent of operating expenses; however, because of deferred taxes (accelerated depreciation) and investment tax credits, the taxes actually paid in that year were a little less than 20 percent of total operating expenses. This does not include local sales taxes and federal excise taxes levied on telephone users; these taxes, for which the telephone companies serve as collection agencies, totaled about $2 billion in 1974. All such taxes should be taken into account in comparing private and government operation.

Whatever the nature of any telephone system, it primarily supplies a technological service but faces financial problems in doing so. When a telephone system is operated by a government department or administration and revenues go directly into the treasury, money for operating expenses, expansion of plant, and research and development must all come through legislative appropriation. Commonly, money for telephony is practically last in legislative interest and enthusiasm. Communication is less pressing than defense, pensions, welfare, or medical service. Telephone service is starved for decades, until it is so bad it scarcely seems to merit support.

The public corporation is an attempt to solve this problem of support; the telephone company is allowed to retain its revenues and may borrow money. In principle, this is much better.

However, it is sometimes difficult to sell bonds. The Nippon Telephone Public Corporation ingeniously insists that a new subscriber buy enough bonds to cover the capital cost the company incurs in serving him. Some public corporations, like the U.S. Post Office, do poorly because they struggle with the consequences of many years of bad practices and policies during operation as a government department. Past mischief seems almost irreparable.

Private telephone companies retain earnings, sell bonds, and sell stock when they can. The total Bell System construction expense in 1975 was about $9.5 billion; some came from depreciation, some from tax deferrals (accelerated depreciation), some from investment tax credits, and some from retained earnings. About $2.9 billion had to be raised through debt or equity. This seems a small amount compared with a GNP of $1,400 billion or even the $36 billion of auto sales in 1973; however, $2.9 billion is a very large amount to raise in competition with government borrowing as well as borrowing by and investment in industry.

Whatever their nature, telephone companies or administrations have tough financial problems; adequate money is a necessary but not sufficient condition for success. The success or failure of a telephone company or administration lies in its ability to generate and apply rapidly changing technology in its constant struggle with increasing volume of service, increasing costs of materials and labor, and the provision of new communication services.

How do various telephone systems cope with technological change? This is easiest for small companies, whether they be independent companies in the U.S. or companies or administrations in small independent nations; small companies or administrations cannot afford extensive research and development. What they can do is buy good, modern equipment that has been developed for a larger market. A certain amount of engineering is necessary to fit the equipment to particular needs, but this is far simpler than creating new technology and embodying it in new systems. In essence, small telephone companies or administrations exploit the state of the international telephone art. Because they can do it very well, some small companies or administrations provide excellent and economical ser-

vice, but others spend too little on equipment and give poor service.

We might also note that small nations with good governments are more adept at managing telephone systems than large nations are or can be. In a country like Sweden, public policies can be established and adhered to in a way that is impossible in a large and unhomogeneous country like the United States. Moreover, the Swedish telephone administration is very aggressive in promoting both good service and good technology. It owns a research and development company (Ellemtel) jointly with L. M. Ericsson. It also owns a company that manufactures telephone equipment.

All national telephone companies or administrations have research and development laboratories of some sort, but all companies except the Bell System, Bell Canada, and the Swedish telephone administration must rely largely on outside suppliers. Thus, in general there is difficulty in relating the problems, ideas, and proposals of the telephone administrations to the actual production of telephone equipment. Further, the suppliers themselves have research laboratories, and there is a problem of access in the telephone administration's laboratories to the real state of the art as understood by the suppliers.

These problems are usually approached through what would be regarded in this country as a collusive collaboration between the telephone administration or public company and several chosen suppliers. The telephone laboratory itself either develops a prototype system or components for such a system; because the laboratory (except in Sweden) has no manufacturing facilities with which to interact, the system or components are not manufacturable. The telephone administration, company, or laboratory also supports the development of prototype systems by one or, preferably, more than one supplier. By keeping in close touch during such work, the telephone administration or company keeps reasonably informed concerning current technology and practical problems, and the suppliers are kept informed concerning the telephone system's problems and goals. This procedure somewhat resembles the prototype concept David Packard introduced into defense procurement; several contractors undertake to produce prototype planes designed to meet a need rather than rigid specifications.

The only alternative in the relations between a telephone administration or company and suppliers in the development of new systems (as opposed to the purchase of existing systems) would be the antiseptic procedure of bidding to rigid specifications and awarding the contract to the lowest qualified bidder. This cannot really succeed, because both technology and goals must be modified during the course of development to cope with costs and technological reality. Such antiseptic contracting results in cost overruns and technological monstrosities and may create such barriers between the procurer and supplier that neither understands what the other knows, needs, or can do. It is understandable that government administrations and government-owned companies have uniformly pursued a policy of collusive collaboration with suppliers in which each learns something of the work of the other.

In the United States, the creation and application of new technology in telephony is pursued quite differently. The American Telephone and Telegraph Company owns the telephone operating companies and the Western Electric Company, which manufactures much of the telephone equipment used by the Bell operating companies. Together, AT&T and Western Electric own the Bell Telephone laboratories.

The work of the majority of Bell Laboratories' employees is the development (right up to drawings for manufacture) of systems and devices to be manufactured by Western Electric; they also do the systems engineering necessary for such systems and device development. This work is done in Bell Laboratories rather than in Western Electric to give the users more influence on the features and performance of the systems they will use and to give a more stable support to exploratory development than that afforded by manufacture. The sales of Western Electric, like those of other manufacturing companies, change much more drastically through the economic cycle than do the revenues derived from telephone service. While Bell Laboratories derives support from Western Electric for specific development projects, it also receives support for longer-term exploratory and research work from the telephone operating companies through AT&T. Thus, support from operating revenues gives Bell Laboratories stability, and design for manufacture by Western Electric keeps Bell Laboratories in touch with reality.

Among the 16,000 Bell Laboratory employees, a little more than 1,000 are in a research division; research work is supported almost wholly by funds derived from the telephone operating companies. Research work is long-term exploration relevant to the problems of communication. It includes fundamental work in physics and chemistry. Four men have received the Nobel Prize while working for Bell Laboratories, and one ex-employee received that prize. Research also includes the fabrication of new devices and the construction and testing of novel transmission and switching systems; sometimes work continues for decades (as in the case of waveguides) before a practical application is found. The strength of research at Bell Laboratories derives from the long-term support from the relatively stable operating revenues, close association with development, manufacture, and operation, and from an overall Bell management that appreciates the benefits of science and technology.

We have seen that telephone companies or administrations and their operations differ greatly in different countries. What can we say of their effectiveness? Some small telephone systems, such as that of Sweden, are admirable. Among large telephone systems, it is universally accepted that the Bell System is best, both in standard of service and in innovation. Despite a heavy burden of taxation that government systems do not have, its rates are low.

Can or does the success of telephone systems change with time? A strong effort has been made to improve telephone service in the United Kingdom by transferring operation from a government department to a public corporation, but the outcome remains to be seen. Telephone systems embody large amounts of equipment built in the past that must be made to operate in the present. Large organizations are lethargic; it is hard to improve telephone service in a short time.

It would be far easier for telephone service to degenerate rapidly. We have seen an example of such degeneration of service in the American railroads. Through regulation or blindness, the railroads became tied to a technology rather than a service. Others exploited buses, trucks, and planes. Overregulation and bad management added to the catastrophe.

The Bell System has fought for the right to evolve and exploit new technologies of communication. So far it has failed to

maintain this freedom only in international satellite communication. By and large, the Bell System has been well managed, though there have been instances of bad management (as in New York) and the consequences have been disastrous and dramatic. So far, the Bell System has always recovered.

It is quite conceivable, however, that telephone and other communication services in this country could degenerate dramatically in a very few years to the level of many other countries. The likeliest causes would be drastic government actions aimed at bringing the Bell System in line with current ideology. Inability to raise sufficient funds for renewal and expansion or bad management are other possibilities.

In general, telephone systems are wonders of the world. It is remarkable that such complex systems can operate, grow, and change to provide new services. It is remarkable that any human organization can operate such systems, yet several forms of organization do operate telephone systems. The Bell System is the clearly acknowledged greatest wonder of telephony, and has grown into what it is over a century. Past wonders have not been eternal. Who knows what the future may hold?

INTERNATIONAL RELATIONS IN TELEPHONY

Is it not remarkable that the telephone systems of various nations interconnect, so that we can call from one nation to another? Yes and no. The problems of interconnection are twofold. One aspect of interconnection is financial and procedural. How do telephone companies of different nations agree to operate together? How do they arrange financial matters? Here the experience of postal service and telegraphy service provided precedents.

The other aspect of interconnection is technological. How is it technologically possible to interconnect telephone systems? Here the answer is very simple. Before World War II (and for some years thereafter), world telephony copied American standards almost slavishly. In recent years, conformity to international standards has become a two-way street. Common standards, however, are built on a firm foundation of past technological standards that were largely American or copies of American standards. Only in one other field—airplanes and their opera-

tion—has American leadership so dominated world practice. That domination came through technological leadership, not political intervention. Indeed, the first major political intervention into telephony (America's approach to international satellite communication) first introduced a nationalistic and competitive element into what had been an area of technological and operational cooperation.

Formally, international cooperation in telephony takes place through the International Telecommunications Union, which grew out of the International Telegraph Union created in 1865. It was an intergovernmental organization for countries to work out uniform agreements on rates, equipment, and operating techniques. Today's basic charge unit for telephone calls—three minutes—was laid down at an ITU Conference in Budapest in 1896.

The International Telecommunications Union now finds itself in a strange environment of rampant nationalism and rivalry, for it has become an agency of the United Nations. Nonetheless, it retains much of its character of international technological cooperation.

The ITU has a General Secretariat responsible for preparing ITU conferences and publishing ITU recommendations. The International Consultative Committee for Radio (CCIR) studies technical and operating matters concerning radio and makes recommendations. The International Consultative Committee for Telephone and Telegraph (CCITT) has similar responsibilities for telephony. The International Frequency Registration Board maintains a registration of all radio frequencies used for all purposes except military.

Through the CCITT, the ITU is at its best in providing a means for technical people from various countries to consult together and arrive at operating standards enabling communication systems in various nations to interconnect effectively. Recommendations are just recommendations, but they are usually followed in whole or in part.

The CCITT is weakest in trying to plan for the future in the absence of firm technological input. Much early futile planning concerning data communication was done when data networks were just emerging and no sound information concerning the practical advantages of various approaches was available. The

effectiveness of the ITU must be in promoting international exchange and cooperation; grandiose and detailed plans for the future are either futile or inhibit progress, whatever their source.

Many problems of international communication have traditionally been worked out directly between the telephone companies of different countries. The first telephone cable across the Atlantic was brought into being and owned jointly by the American Telephone and Telegraph Company and the British Post Office. Later cables have been owned and operated between AT&T, German, and French telephone administrations, and other groups. The greatest telephone traffic has been between particular nations or among particular groups of nations, and these nations have worked together in pairs or groups to provide for such traffic.

Satellite communication has been a revolutionary departure from this general pattern because of the approach adopted by the American government. The nature and history of this departure are complex. The final result has been Intelsat, an international organization serving over 100 countries, territories, and possessions. In principle, nothing can be done without the consent of all members. The leading and American member, Comsat (the Communications Satellite Corporation), acts as manager.

American policy has been not to launch regional satellites to link groups of nations outside of Intelsat, but it will launch national satellites such as Canada's domestic satellites.

Communication satellites have been a resounding technical success. They have also been a subject of much national rivalry and international and domestic confusion; an extended discussion would be difficult and probably unrewarding. Perhaps it is best to defer any further discussion of communication satellites until 2076.

EXPLOITING TELEPHONE SYSTEMS

Telephone companies and the widespread use of telephony have provided opportunities for various types of exploitation not initially contemplated. One of these forms of exploitation is wiretapping. People appear to trust that telephone conversations are private. Few phones are tapped, legally or illegally by gov-

ernments or illegally by others, but telephony has provided a new mode of surveillance, akin to skulking behind bushes or opening letters.

Tapping phone lines and listening to conversations is more difficult and time consuming than intercepting and reading letters. If we accept common report, telephony within and to the Soviet Union is relatively reliable and secure compared with the mails. Recent news reports in this country indicate a considerable government interception and reading of letters, but the public impact of talk about wiretapping has been greater.

Wiretapping strikes at the individual by exploiting the telephone system; other forms of exploitation strike at users by increasing the cost of service. Telephone companies cannot print money, and only government telephone companies can pass costs on to the general taxpayer. Added costs in telephony must be paid for by telephone users.

One of the best-known forms of exploitation is the "blue box." A subscriber is allowed to exercise control over the telephone network in dialing, but other forms of control are in theory reserved for the telephone company. In many cases, both sorts of control are accomplished by the transmission of audible tones. The blue box generates tones that control functions of the telephone network ordinarily controlled by the telephone company, so a successful blue box enables the user to make long-distance calls without being billed. The cost of these calls is spread over paying users. Newer telephone equipment makes use of common channel signaling, where control signals are not sent over the talking path, but over separate signaling channels. This speeds the setting up of connections and also renders the blue box ineffective.

Codes are an alternative to the blue box. In one code, the distant party (a husband on a trip, for instance) calls at a prearranged time, lets the phone ring a prearranged number of times, and hangs up. By counting the rings, the called party gets the message without picking up the phone. Again, the costs are spread over other users. In a more elaborate code, the caller puts in a person-to-person call to a given number. The person called is never there, for the name is fictitious, and the name itself conveys the message. This is a very powerful form of communication; just three initials can be used to specify

17,576 messages, and the number of names is of course far greater. The cost to the caller is zero and again the cost is spread over other users.

When the prices of various services are not closely related to the costs of the services (through regulation, "social policy" on the part of the telephone company, historical accident, or inadvertence), the difference can be exploited through a procedure called "cream skimming." As an example, the price of leased circuits is based on airline miles only, yet the costs of circuits is less over high-volume routes served by advanced equipment than it is over low-volume routes. In this country, a number of companies have engaged to provide data and voice service between large cities where the volume of traffic is high and the cost of transmission is low. They sell this service for less than the Bell System price. Where the cost of transmission is high (as in local connections), they rent circuits from the Bell System.

If prices were closely related to costs, cream skimming would be impossible. Through a long history of relating prices to average cost per mile rather than to cost for a particular route, cream skimming has become possible. The Bell System has proposed to go part way toward relating price to cost, but the Federal Communications Commission, which regulates common carriers, is reluctant. Of course, the costs of cream skimming are passed on to Bell System users.

Governments find taxes on businesses a convenient way of raising money for general use. As has been pointed out, a considerable part of the user's telephone bills goes to pay federal, state, and local taxes. In addition, the telephone companies serve as a collection agency for the $2 billion in sales taxes and federal excise taxes that telephone users pay each year. This exploitation of telephony as a way of getting money from users for general government purposes is not, of course, unique to telephony, but telephony is a very lucrative source.

Another form of exploitation may be either advantageous or disadvantageous to the user. Telephone companies provide circuits between remote points, and a variety of terminal devices can be connected to these circuits, whether they are dialed-up connections or private lines. Connectible terminals include second-hand telephones, aids for the deaf, dialing and answering devices, teletypewriters, various data terminals, computers, mo-

bile telephone systems, and private telephone services (PBX's—private branch exchanges serving various organizations).

Why shouldn't anyone connect any old thing to the telephone network? Careless interconnection *can* have several bothersome consequences. Accidental connection of electric power to telephone lines can certainly startle and might conceivably injure or kill telephone maintenance men and can wreak havoc with telephone equipment. Milder problems include electrically unbalancing telephone lines (causing cross-talk) and dialing wrong numbers or false numbers, which ties up telephone equipment.

For technical and economic reasons, a telephone company would like to avoid interconnection as much as possible. In general, telephone companies cordially interconnect only with other telephone companies, but in an era of mushrooming new uses (especially data), interconnection has advantages for the person who interconnects if not for other users.

Interconnection is a troubled field. Unbridled or poorly planned and controlled interconnection can harm communication networks, yet no interconnection is too little. However advantageous it is, interconnection essentially exploits an existing resource, the telephone network. This is not to say that it is an undesirable exploitation.

Another form of exploitation of telephone companies and their customers is the imposition of social goals that the company would not ordinarily work for and the customers would not willingly pay for.

Like electric, gas, and water distribution, telephone service is a "natural monopoly." Provision of service in a given area by two or more competing companies would be costly to the user, and it seems unlikely that in free competition more than one company would survive. In these circumstances a single company in a single area is tolerated by the government, provided that the government regulates rates and some aspects of the service supplied.

A common explanation of regulation has been that it substitutes for competition in assuring a low price and good service. The effect of regulation on price has been studied most carefully, not in a natural monopoly, such as telephony, but in a case where regulation limits competition. Recently, economists have compared prices in the unregulated intrastate segment of the

airline industry and in the interstate regulated segment. It seems clear that an unregulated airline forces the prices down.

An examination of regulation where there is no natural monopoly shows that regulators impose expensive practices and restraints on businesses, for which consumers would not pay if given a choice. Some economists have thus come to view regulation not as a means for reducing prices or providing the service for which a consumer is willing to pay, but rather as a means for attaining social goals desired by the regulator but not the consumer, at the consumer's expense.

This leads us to ask whether such exploitive regulatory practices are to be found in telephony. We find that in telephony regulation may be used to promote satellite communication (if that indeed needs promoting) by keeping transoceanic rates up and insisting that some quota of calls go by satellite. Regulation may be used to cause new entry into the common carrier field by promoting cream skimming; the regulators merely have to deny the existing carriers rates based on cost or deny any lowering of rates when advanced technology lowers costs.

Beyond regulation lie laws, new and old, including antitrust laws. Here there is no very serious pretense that the goal is benefit to the users of the telephone; the goal sought is abstract right or wrong, as deduced from history and enacted into law.

A final form of technological exploitation appears to benefit a great many people other than telephone users. Telephony draws from a large pool of evolving science and technology, and through Bell Laboratories it contributes to that pool. From some of the contributions, such as the transistor, huge and profitable industries have grown both here and abroad. In the consent decree of 1956, AT&T agreed to engage in no activities but common carrier communications and government projects. Thus, while technological fruits of Bell Laboratories' inventions have accrued to telephone users, the largest profits have gone to companies licensed under Bell patents.

An acute Soviet observer remarked: "In the United States, man is exploited by man. With us it is just the other way around." Exploitation is a universal feature of society, but universals have their particulars; the exploitation of telephone service and telephone companies is a little different from the exploitation of mineral resources, gullible investors, or slaves.

IN CONCLUSION

A story tells of the little old lady whose son asked her to fly across the country to visit him. "Me, get into one of those things?" she replied. "No, I'll sit by my fireside and watch TV, as the good Lord intended."

Although TV and telephones are acts of men, not acts of God, we tend to regard them as a part of nature. We encounter telephones so early in our lives that we seldom think of them, any more than we meditate on speech, hearing, vision, or the functioning of our internal organs—unless any of these give us trouble. Then we are annoyed.

If the reader who has followed me this far asks what this has all been about, my reply must be that it has been about a very uncommon commonplace of our lives. Like an iceberg, most of the telephone system is hidden from us, but all of it affects us directly. All of it is part of and affects our society.

Plenty of people look forward to glories 100 years hence, but I have rather looked backward over 100 years of progress. I have said something about the inventor of the telephone and something about the exploiters of the telephone. I have tried to give a picture of the history, nature, and impact of telephony through statistics, through usage, and through its impacts on art and science. I have pointed to telephony as a high-technology system and have depicted the differences among telephone systems in different countries, the problems they have in common, and international organization and relations in telephony.

What I have said is central but limited. The reader can find further information in the other papers prepared in connection with the centenary of the telephone and in earlier papers and books. In a number of articles and books he will encounter much ill-founded prophecy and polemics. On the whole, perhaps the wisest approach is to observe telephony, but with wonder rather than complacence.

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Editor's Comment

The chapters thus far have looked at the earliest days of the telephone. They have asked what early imprinting imposed itself on the system we know today, what presumptions the founders initially had, what choices the technology itself offered, and what decisions society eventually made.

The author of the next chapter has devoted his life to telephone research, most of it in Bell Labs. It scans the whole 100 years and gives an overview of the vast, complex system existing now. Pierce presents the basics of telephone growth and usage, the characteristics of the present system's functions, and the system's sensitivity to abuse. As he notes, the telephone system is the most complex machine yet created by man; it is remarkable how well it works. There are places in the world, experience reminds us, where it does not work well. The telephone can be degraded by a variety of misuses; Pierce presents his conclusions about the conditions of its successful or degraded operation.

APPENDIX

Kensington, March 25, 1878.

To the capitalists of the Electric Telephone Company:

Gentlemen—It has been suggested that at this, our first meeting, I should lay before you a few ideas, concerning the future of the electric telephone, together with any suggestions that occur to me in regard to the best mode of introducing the instrument to the public.

The telephone may be briefly described as an electrical contrivance for reproducing, in distant places, the tones and articulations of a speaker's voice, so that conversation can be carried on by word of mouth between persons in different rooms, in different streets, or in different towns.

The great advantage it possesses over every other form of electrical apparatus consists in the fact that it requires no skill to operate the instrument. All other telegraphic machines produce signals which require to be translated by experts, and such instruments are therefore extremely limited in their application, but the telephone actually speaks, and for this reason it can be utilized for nearly every purpose for which speech is employed.

At the present time we have a perfect network of gas pipes and water pipes throughout our large cities. We have main pipes laid under the streets communicating by side pipes with the various dwellings, enabling the members to draw their supplies of gas and water from a common source.

In a similar manner it is conceivable that cables of telephone wires could be laid under ground, or suspended overhead, communicating by branch wires with private dwellings, counting houses, shops, manufactories, etc., uniting them through the main cable with a central office where the wire could be connected as desired, establishing direct communication between any two places in the city. Such a plan as this, though impracticable at the present moment, will, I firmly believe, be the outcome of the introduction of the telephone to the public. Not only so, but I believe in the future wires will unite the head offices of telephone companies in different cities, and a man in one part of the country may communicate by word of mouth with another in a distant place.

In regard to other present uses for the telephone, the instrument can be supplied so cheaply as to compete on favorable terms with speaking tubes, bells and annunciators, as a means of communication between different parts of the house. This seems to be a very favorable application of the telephone, not only on account of the large number of telephones that would be wanted, but because it would lead eventually to the plan of intercommunication referred to above. I would therefore recommend that special arrangements be made for the introduction of the telephone into hotels and private buildings in place of the

speaking tubes and annunciators, at present employed. Telephones sold for this purpose could be stamped or numbered in such a way as to distinguish them from those employed for business purposes, and an agreement could be signed by the purchaser that the telephones should become forfeited to the company if used for other purposes than those specified in the agreement.

It is probable that such a use of the telephone would speedily become popular, and that as the public became accustomed to the telephone in their houses they would recognize the advantage of a system of intercommunication.

In conclusion, I would say that it seems to me that the telephone should immediately be brought prominently before the public, as a means of communication between bankers, merchants, manufacturers, wholesale and retail dealers, dock companies, water companies, police offices, fire stations, newspaper offices, hospitals and public buildings and for use in railway offices, in mines and other operations.

Although there is a great field for the telephone in the immediate present, I believe there is still greater in the future.

By bearing in mind the great object to be ultimately achieved, I believe that the telephone company cannot only secure for itself a business of the most remunerative kind, but also benefit the public in a way that has never been previously attempted.

I am, gentlemen, your obedient servant,

Alexander Graham Bell.