Chapter 3

New Technologies and Changing Interdependencies in the Communication Infrastructure

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Chapter 3

New Technologies and Changing Interdependencies in the Communication Infrastructure

INTRODUCTION

The communication infrastructure, which supports and negotiates the flow of communication within society, is a critical social structure. How it is constituted, and the rules that govern its use, will greatly affect the nature of all social interaction. The technical characteristics of the infrastructure, for example, limit the kinds of messages that can be exchanged, the ease and speed of exchange, and the fidelity of the messages. Similarly. the infrastructure's architecture-how facilities are arranged and distributed-will determine who will be able to communicate, under what conditions, and with what degree of effectiveness.

The form the communication infrastructure takes is determined by decisions made in the marketplace, as well as in the public, governmental arena. These decisions are greatly influenced by the economic relationships, or interdependencies, that exist among those involved in the formulation, exchange, and interpretation of information. And these interdependencies will depend, in turn, on the nature of the technological environment. Although at first glance the term "infrastructure" may suggest a permanent technological apparatus, the communication infrastructure, configured around economic interdependencies, is in fact very susceptible to technological change.

To establish optimal rules for governing the Nation's communication infrastructure in the future, Congress will need a more accurate picture of how technological advances are changing the communication infrastructure, its relationships, and its interdependencies. For, as Don R. Le Duc has pointed out in his analysis of broadcasting policies, all too often Federal communication policies have failed for lack of consideration of private market incentives and imperatives.[1] To assist in understanding these variables, this chapter will:

- define the communication infrastructure and describe how it develops and evolves in relationship to changing technology;
- identify and describe the major technological changes likely to impinge on the present infrastructure;
- provide a brief overview of the U.S. communication infrastructure, and identify and describe the major changes that are now taking place within it; and
- identify and describe the potential implications of these changes for communication policymakers.

THE COMMUNICATION INFRASTRUCTURE

To analyze how technological advances might affect communication, it is useful to view the communication infrastructure from a systems perspective.[2] Such a perspective is particularly useful for analyzing change because it focuses on the interdependence of social structures rather than on their more static, or constant, attributes.[3] For, as defined by social psychologists Daniel Katz and Robert L. Kahn:

> All social systems consist of the patterned activities of a number of individuals. Moreover, these patterned activities are complementary or interdependent with respect to some common output or outcome . . .4

[1] Don R. Le Duc, *Beyond Broadcasting Patter-m in Policy and Law (New York, NY:* Longman, 1987), P. 8.

[2] There is an enormous literature on the properties and behavior of social systems. See, for example, Daniel Katz and Robert L. Kahn, *The Social Psychology of Organizations (New* York, NY: John Wiley & Sons Inc., 2d cd., 1978); J.G. Miller, "Living Systems: Basic Concepts," *Behavioral Science, vol.* 10, 1965, pp. 193-237; and Talcott Parsons, *The Social System* (Glencoe, IL: Free Press, 195 1). In using a systems approach, it is important to avoid the problem of reification-that is, speaking of systems as if they possess a personality, Systems are not "real," but rather arc "interpreted" or "enacted" by their participants. See Eric Goffman, *Frame Analysis (New* York, NY: Harper and Row, 1974).

[3] Katz and Kahn, op. cit., footnote 2, p. 22.

[4] Ibid., p. 21. See also Karl E. Weich, *The Social Psychology of Organizing (New* York, NY Random How% 1979).

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Systems come into being as a result of, or in order to facilitate, exchange transactions.[5] Each transaction has a goal and some criteria for judging the success or failure of the interaction.[6] Over time, the relationships within social systems gain a degree of stability and consistency as certain kinds of behavior, attitudes, values, and criteria come to be associated with carrying out certain kinds of activities. Such expectations are generally socially reinforced and sanctioned.[7]

Although relatively stable, social systems are responsive to their environments and subject to change and dissolution. As Katz and Kahn point out:

> As human inventions, social systems are imperfect. They can come apart at the seams overnight, but they can also outlast by centuries the biological organisms that originally created them. The cement that holds them together is essentially psychological rather than biological. Social systems are anchored in the attitudes, perceptions, beliefs, motivations, habits, and expectations of human beings.[8]

A system's continuity will depend on the extent to which it produces outcomes that fulfill the expectations of its participants, and on whether it generates the necessary incentives to sustain a given social activity. Insofar as these relationships are contrived-that is, people invent them by reenacting complex patterns of behavior—psychological factors, such as attitudes and expectations, will be critical to their existence.

In accordance with this analytic frame of reference, the communication infrastructure can be characterized as a social system. Building on the definition of communication established in chapter 2, the infrastructure is comprised of interdependent relationships among individuals and groups who cooperate to provide the means and mechanisms for formulating, exchanging, and interpreting information, and for establishing the necessary relationships among these activities. Together, this entire network of apparatuses, knowledge resources, and institutional arrangements, which supports all forms of communication, constitutes the communication infrastructure.

in the U.S. communication infrastructure, where so many communication functions are carried out in the private sector, economic criteria and economic interdependencies provide the primary context in which relationships are determined.[9] And the marketplace provides the major institutional mechanism[10] by which the signals and incentives that induce individuals and groups to interact with one another are transmitted and exchanged.[11] For example, market prices reflect costs of production, and consumer behavior will reflect market demand. Economic situations are generally based on the principle of rationality-that is, the certainty of the relationship between means and ends. It is assumed that people know what they want and how to transact to attain it. In an economic transaction, then, the

[5] For a discussion Of exchange transactions, see L.B. Mohr, "The Concept of Organizational Goal," *The American Political Science Review*, vol. 67, *1973,* pp. *470481.*

[6] However, these interdependencies are not necessarily established around equal relationships; nor do the pales involved need to shine common goals. In order for these relationships to form, the people involved must believe that their ability to achieve their objectives will depend on what others do. For discussions, see Weich, op. cit., footnote 4, and J.D. Eveland, "Stakeholder Relationships *in* Communication Systems," OTA contractor report, October 1987.

[7] The expectations associated with the behavior of someone performing a particular task, or occupying a particular position, are called "roles." When individuals interact to accomplish a task, it can be said that they are in a reciprocal role relationship, and that their behaviors are governed by mutual role expectations. Because role relationships can be aggregated at any level. one can view society-or any subunit within it, such as the communication infrastructure-as a complex network of systematically interlinked units of reciprocal role behaviors.

[8] Katz and Kahn, op. cit., footnote 2, p. 37.

$'Exchange transactions and role behavior are not carried out in isolation, but within complicated sets of related goals, roles, rules, criteria, assumptions, and expectations about behavior and the outcomes sought, which are called "contexts." A context is embodied in language, descriptive vocabulary, and understanding of the implicit relationships between the parties involved in an interaction. It is the framework in which the construction and enactment of particular situations take place. Thus, for example, what distinguishes a family dispute from a manager-employee quarrel is less the absolute behavior, or even the words and body language, than the underlying assumptions about differences between family and organizational relations. People's assumptions about what outcomes they and others are seeking are central-in short, the criteria being used by oneself and others. For analytic discussions of the notion of context, see L. Smircich, "Implications for Management Theory," L. Putnam and M.E. Pacanowsky, *Communication and Organization: An Interpretive Approach* (Beverly Hills, CA: Sage Publication, 1983), and P. McHugh, *Defining the Situation* (Indianapolis, IN: Bobbs Merrill, 1968).

[10] There are, of course, a variety of other political and social institutions that carry out parallel functions in other areas. For a discussion, see "Markets, Bureaucracies, and Clans," *Administrative Science Quarter/y*, vol. 25, 1980, pp. 129-142.

[11] It should be noted that carrying out any role is heavily dependent on information. We need information, for example, to tell us what effect our behavior is having, what outcomes are being achieved, as well as what criteria are being satisfied,

emphasis is placed on the transaction rules of rationality, reciprocity, and competition.

By establishing the rules of behavior and the basic incentive structure in which economic players interact, national goals and public policies will also greatly affect the communication infrastructure. A discussion of communication policy and its impacts will be deferred, however, until the next chapter.

THE IMPACT OF TECHNOLOGY

As is the case in all social systems, the set of relationships that constitutes the communication infrastructure is subject to changes in its environment. One external factor likely to have a major impact is technological change. Technological advances will clearly affect such things as economies of scale, the availability of product substitutes, and the costs of production. As Porter has described:

> Technological change is one of the principal drivers of competition. It plays a major role in industry structural change, as well as in creating new industries. It is also a great equalizer, eroding the competitive advantage of even well-entrenched firms and propelling others to the forefront. Many of today's great firms grew out of technological changes that they were able to exploit. Of all the things that can change the rules of competition, technological change is among the most prominent.[12]

To a considerable degree, the impact of technological developments on the infrastructure will depend on the rate and speed of their diffusion. Although the diffusion of new technologies generally follows an S-shaped curve,[13] as depicted in figure 3-1, the rate at which a specific technology is adopted will depend on a number of factors, making it difficult to assess the long-range impact of technological change.

Because the infrastructure as a whole is comprised of hundreds of technologies coexisting, each at different points on their diffusion curves, how quickly communication innovations will be adopted will be highly dependent on factors such as interconnectivity and the interdependence of content and equipment.[14] Although these technologies often appear to be competing, in many cases the growth in one medium will actually support growth in others. For example, the popularity of music videos on cable television reinforces the sales of audio recordings rather than substitutes for them.[15]

But network interdependence may also retard innovation. For example, once users have invested in equipment conforming to a particular standard, they will be reluctant to purchase any equipment that is incompatible. Users will invest gradually as old equipment wears out or is written off.[16]

As Everett Rogers has pointed out, the growth of a new product, although slow at first, will quicken with the development of a critical mass of users. This pattern occurs because the value of any communication system increases for all with each additional adopter.[17] Diffusion will also increase because new communication media are used as tools whose applications will multiply as they are adapted to new and different tasks.[18]

The deployment rate of new communication technologies will depend not only on the role that users play, but also on how communication and information providers react to technological advances. To channel technological change in their favor, communication-related businesses might

[12] Michael Porter, *Competitive Advantage: Creating and Sustaining Superior Performance* (New York, NY: The Free Press, 1985), p. 164.

[13] Analysts have mapped the life cycles of technological innovations on "diffusion curves" that plot the number of users adopting the Product over time. For discussions, see J.C. Fisher and R.H. Pry, "A Simple Substitution Model of Technological Change," *Technological Forecasting and Social Change*, vol. 3, 1971, pp. 75-88; Ralph Lenz, *Rates of Adoption/Substitution in Technological Change* (Austin, TX: Technology Futures, Inc., 1985); and David Rink and John Swan, "Product Life Cycle Research: A Literature Review," *Journal of Business Research*, vol. 7, 1979, pp. 219-242.

[14] Everett M. Rogers, *Communication Technology: The New Media in Society* (New York, NY: The Free Press, 1986), pp. 116-149.

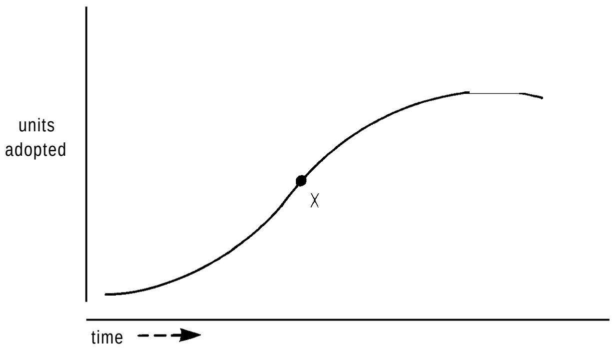
[15] When two or more means of communication seem t. fulfill the same function for potential users, they can both survive if each develops a particular niche in the marketplace. This is what happened, for example, with the introduction of television, which forced radio to become more of a local medium, financed through local advertising revenues. For a discussion of niche markets, see John Dimmick and Eric Rothenbuhler, "The Theory of the Niche: Quantifying Competition Among Media Industries," *Journal of Communication*, vol. 34, No. 1, Winter 1984, pp. 103-119.

[16] For example, growth in the sale of compact disc players is dependent on the availability of prerecorded compact discs. Thus, actions that affect the availability of discs will stifle growth in the sale of players as well. See John Quinn, "Help CDs Reach Their Market Potential," "Commentary," *Billboard*, Dec. 12, 1987, p. 9.

[17] See Rogers, op. Cit., footnote 14, p. 120. See also Lynne Markus, "Toward a 'Critical Mass' Theory of interactive Media," *Communication Research*, October 1987, pp. 491-511.

[18] Rogers, op. cit., footnote 14, p. 121"

Figure 3-1--Diffusion of Technological innovation



The classical diffusion curve is S-shaped, with the rate of change in the number of units adopted increasing until a "crltlcal mass' point (x), at which the rate of growth reaches zero, then becomes negative. Growth continues to slow until the market IS saturated Penetration stays at this ' 'plateau' unless new consumers enter the potential-adoptor pool (which causes new growth), or unless another Innovation replaces the product (which causes a gradual decline)

SOURCE: Office of Technology Assessment, **1990.**

seek, for example, to control patent developments, integrate markets, and/or employ the regulatory system to their advantage. Such strategies were adopted, for example, by Theodore Vail on behalf of AT&T in the years between 1879 and 1894.[19] According to Brian Winston, these defensive responses on the part of business give rise to what he has labeled "the law of the suppression of radical potential." This law, he says:

> . . . operates firstly to preserve essential formations such as business entities and other institutions and secondly to slow the rate of diffusion so that the social fabric can absorb the new machine.[20]

To understand how technological changes might impinge on the communication infrastructure, it is necessary to examine the changing technological/economic context in which communication decisions are being made, as well as the potential ways in which key communication industry players might respond to such changes.

THE TECHNOLOGICAL EVOLUTION OF THE COMMUNICATION INFRASTRUCTURE

The Technical Characteristics of the Communication Infrastructure

The technical characteristics of the communication infrastructure establish the range of communication opportunities available and how they are allocated throughout society. More specifically, the technical functionality of the infrastructure will determine the following aspects of a communication system or facility:

- capacity (speed and volume of data transmission);
- flexibility (how easily the system can be modified);
- versatility (the extent to which the system supports a wide range of applications or services);
- interoperability (the degree to which facilities can transfer information or share resources automatically);
- timeliness (overall speed of message exchange);
- fidelity (the extent to which the technical quality of a message is compromised by transmission or playback);
- security (the ability to protect messages);
- survivability (the degree of resistance to natural or manmade crises, as well as the extent and speed at which a system can be restored);
- reach (the extent of a system's or facility's service area);
- openness (the ease with which the system and the service components that comprise it can be accessed);
- penetration (the density of the facilities within a served area); and
- usage (the levels of usage by those within a service area).

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[19] For an account of these strategies, see Gerald Brock, The *Telecommunications Industry* The Dynamics *of Market structure* (Cambrid Harvard University Press, 1981).

[20] Brian Winston, *Misunderstanding Media* (Cambridge, MA: Harvard University Press, 1986), pp. 24-25. This law, argues Winston, "explains the delay of the introduction of television into the United States which lasted at least seven years, excluding the years of war. It explains the period, from around 1880 to the eve of the First War, during which the exercise and control of the telephone (in both the United States and the United Kingdom) was worked out while its penetration was much reduced. it accounts for the delays holding up the long playing record for a generation and the videocassette recorder for more than a decade. "

Technological Trends Affecting the Communication Infrastructure

The technical characteristics and capabilities of the communication infrastructure will be significantly affected in the future, given a number of recent technological advances and developments.[21] These developments can be summarized in terms of the following trends.

Greatly Improved Performance at Decreasing Costs

Performance has improved in all technical aspects of content production, encoding, transmission, decoding, and storage/retrieval. More than any other trend, this development will have an all-pervasive impact on the communication infrastructure. For many of these improvements result from advances in computer technology which, as can be seen in table 3-1, is ubiquitous throughout communication systems. The impact of these advances on the cost and performance of computer technologies can be seen in table 3-2.[22]

A critical factor in creating such performance/cost ratios has been the rapid advances in microelectronics resulting from the development of very large scale integration (VLSI) .23 VLSI allows the placement of over 106 logical operations on a single integrated circuit chip, and this number is doubling every 18 months. Given this level of integration, communication within computers can take place much more rapidly and efficiently; bits no longer have to travel between chips over shared buses when the source and destination both reside on the same chip. Over the past 20 years, chip densities have increased several orders of magnitude.[24]

Improvements in materials and in the use of gallium arsenide (GaAS) in the production of chips will also permit greater integration. All silicon-based materials have a 0.2 micrometer limit to line width and therefore a limit to possible circuit density per chip. Because gallium arsenide has a smaller limit, it permits more logical operations per chip; chips designed using this material therefore offer greater speed. In the more distant future, the speed and size limitations of electronic devices will be overcome by using optical computing elements .25 According to Ian M. Ross, President of AT&T Bell Laboratories, by the year 2000, it will be possible to place 1 billion components on a single silicon chip using these technologies.[26]

Advances in computer architectures and software have also helped to harness the processing power in communication applications.[27] In the Past, SwitCh ing mechanisms were used to replicate the manual operations entailed in placing a telephone call. The development of common channel signaling and intelligent databases now permits network switches to operate as computers, making real-time routing decisions based on the status of the network, call

21For additional discussion of advances see, for example, John S. Mayo, "Materials for Information and Communication," *Scientific American*, October 1986; Frank D. Reese, "Technology" Yesterday, Today and Tomorrow," *TE&M*, Jan. 15, 1988, p. 3: Bethesda Research Institute, "Study of Communications and Information Processing—Technologies, Structure, Trends, and Policy Considerations," OTA contractor report, 1986; U.S. Congress, Office of Technology Assessment, *Informing the Nation Federal Information Dissemination in an Electronic Age*, OTA-CIT-396 (Washington, DC: U.S. Government Printing Office, October 1988); Deborah Estrin, "Communication Systems for an Information Age: A Technical Perspective," OTA contractor report, December 1986; "Telecommunications: The World on the Line," *The Economist, Nov. 23, 1985;* "Hello Again: The Future of Telecommunications," *IEEE Spectrum* November 1985.

22Bartlett W. Mel et al., "Tablet: persona] Computer in the Year 2000,'" *Communications of the ACM*, June 1988, pp. 639-646; and G. Pascal Zachary, "Awaiting the Next Generation of Personal Computers," *The Washington Post,* July 11, 1988.

23Estrin, op. cit., footnote 21, pp. 12 I 3.

24Ibid.

25Ibid. One of the problems with such densely integrated chips is the complexity of design. For this reason, much effort has shifted to developing VLSI design technologies to allow exploitation of current and future densities. This is one example of a syndrome evident in many areas of information technology. The underlying hardware developments have outstripped our ability to exploit the complexities that they introduce. At the same time, these hardware capabilities may be the key to solving some of the problems of complexity by relieving some constraints and by supporting increasingly complex design, development, and management tools.

26Such advances can be made, according to Ross, by taking advantage of ultraviolet and electron beam and x-ray lithography, increasing the size Of chips, and moving to three-dimensional chip architectures. Ian M. Ross, Keynote Address for Publication in the Conference Proceedings of the 1988 Bicentennial Engineering Conference, Sydney, Australia, Feb. 23, 1988.

27VLSI is being used to support new computing architectures that provide for massive parallel processing (which allows computers to perform a number of operations simultaneously, rather than one by one). These architectures include dataflow, hypercube, and connection machine. VLSI also supports special-purpose architectures for specialized applications such as array processor image processing. These computing structures will eventually be found in the telecommunication system as switching components and as components of users' systems. Once again, the state of the art in operating systems and programming languages for these parallel architectures lags behind the system architecture itself, just as the system architecture lags behind the device technology.

Table 3-l—Types of Computers Used in Network Components

Network component	Types of computers used	Examples
Modem	Integrated circuits	Hayes Smartmodem, Xyplex Nonwire, CASE Communications Series 4000, IBM 5866, Telindus Hyacinth
Multiplexer	ICs, microprocessors	CCC ADCoMM 96/48, Aydin Monitor Systems T1 multiplexer
Matrix switch, PABX . .	Microcomputers, minicomputers	Bytex Autoswitch, M/A-Corn IDX750 Data PBX, T-Bar DSM Series 2001
PAD, network interface, protocol converter . .	ICs, microprocessors	ACC IF-370/DDN interface, BBN Communications C/10 PAD
Packet switch	Micro-minicomputers	BBN Communications C/300 PSN, M/A-Corn CP9000 Series II
Gateway	Micro-minicomputers, parallel processors	XMITxGATE 625, BBN Communications Multi-Corn X.25 Gateway
Network management & service systems . .	Micro-minicomputers, PCs, workstations	Northern Telecom DFMS, BBN Communications C/70 NOC, IDA-COM PT protocol tester

Key: ICs = Integrated circuits, LATA = local access and transport area, NOC = network operations center, PABX = private automatic branch exchange, PAD = packet assembler/disassembler, PBX = private branch exchange, PCs = personal computers, PSN . packet-switched network.

SOURCE: Reproduced by special permission of *Telecommunications* magazine.

Table 3-2-Computer Costs, Capabilities, and Speed Over Time

Decade	Computer costs, capabilities, and speed
1940	In 1945, it cost about $1,000 to do 1 million operations on a keyboard and took at least a month.
1950	In 1952, it cost about $300 to do 1 million operations and took 10 minutes.
1960	In 1960, it cost $75 to do 1 million operations and it took 1 second.
1970	Computers can do 1 million operations for less than 6 cents in about 1/2 a second.
1980	Computers can do 1 million operations for 1/10of a cent in 1/1O of a second. Cost per 100,000 calculations decreased to $0.0025 in 1980.
1990	Between 1983 and 1997, computer costs to decrease by a factor of 100 with a 20 to 30%. decrease in manufacturing costs.

SOURCE: Copyright 1989 by CMP Publications, inc., 600 Community Drive, Manhasset, NY 11030. Reprinted from *Communications-Week* with permission.

loads, and the characteristics of callers.[28] As depicted in box 3-A, using Signaling System 7—the international standard for common channel signaling—telephone company central offices can both exchange information on, as well as query databases about, the called or calling number.[29]

With new developments in switching technologies, these kinds of intelligent network operations can be executed with much greater flexibility and at increasing speeds .30 Fast packet-switching has been an important development in this regard.[31] This technology is similar to conventional (X.25) packet-switching in a number of ways. Like conventional packet-switching, fast packet-switching makes optimal use of a transmission channel. It breaks messages up into small bundles, or packets, each of which carries with it its own address; then interleaves them on a channel, taking advantage of the "silences" present in the information stream; and finally routes them throughout the network to their destinations where they are reassembled. Fast packet-switching offers the advantages of greater speed and flexibility. Whereas conventional packet-switching is suitable for data only, fast packet

[28] James E. Holcomb, "The Next-Generation Switch," *Bell Communications Research Exchange,* September/October 1987, pp. 23-27; and Hildergard Pusch, "Aspects of CCS7 Network Configurations," *Telecommunications,* October 1987, pp. 240-251.

[29] As discussed below, it is in fact this protocol that will provide the underpinnings of ISDN and the advanced intelligent network of the 1990s. See William Stallings, "Demystifying SS7 Architecture," *Telecommunications,* March 1989, pp. *41-44,46,48.* See *also* Paul Korzeniowski, "The Intelligent Transformation, " *CommunicationsWeek*, CLOSEUP, May 30, 1988..

[30] For a discussion, see Richard Vickers and Marek Wernik, "Evolution of Switch Architecture and Technology," *Telecommunications, May* 1988, pp. 55,58,60,62-64. As the authors note, this flexibility and speed is gained by separating the functions of call control from connection control, allowing for the establishing of virtual circuits, which provide logical rather than physical end-to-end connectivity. See also Denis Gilhooly, "Which Way for Broadband Switching?" *Telecommunications,* June 1987, pp. 36, 38-39,42, 45; and A.M. Rutkowski, "Emerging Network Switching Technology and Applications," *Telecommunications,* February 1987, pp. 40-41,44,46,48,50.

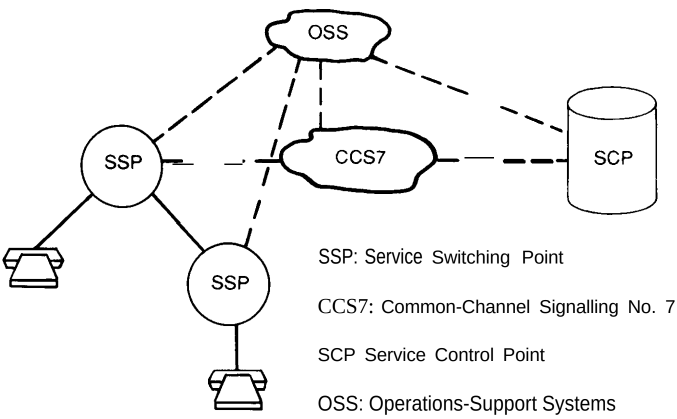
[31] Packet-switching was developed for data Communication between computers. Digital information is packaged into small pieces called packets, each containing information about the source and destination of the data and the relationship of that piece to the whole message. The packets are transmitted separately through the network, sometimes taking different paths depending on which ones are free at the moment. Packet-switching systems incorporate computers into the network in such a way as to make data transmission far more efficient. It is cheaper, faster, more accurate, and eliminates some incompatibilities.

Box 3-A—The Intelligent Network

The intelligent network is comprised of four basic elements. These include:

- A Service control Point (SCP), which consists of a centralized database that uses algorithms and customer instructions to route messages;
- A *Common Channel Signaling System (CCS7)* that provides out-of-band, packet-switched communications among network elements;
- A Service switching point (SSP) that consists of local and tandem-switching nodes designed to carry out low-level, high-volume functions such as dial tone, announcements, and routing. The SSP performs functions as directed by the SCP; and
- An *Operations Support System (OSS)* that provides for network planning, engineering, provisioning, monitoring, maintenance, and repair.

How these elements relate to one another to provide service can be seen in the figure below.



SOURCE: Art reproduced by special permission of *Telecommunications* magazine.

To envision how this network operates, consider what happens with an 800 call. When an 800 number call is generated, it is sent to the SSP, which identifies it as an 800 call. At this point the SSP sends the number, together with other information about the calling party, to the SCP via the CCS7 signaling network and asks for further instructions about how to treat this call. The SCP searches its database, translates the received 800 number into a standard telephone number, and returns this telephone number together with a routing instruction to the SSP, which then routes the call to its correct destination.

SOURCE: Paul Bloom and Patrick Miller, "Intelligent Network/2," *Telecommunications,* June 1987, p. 58.

technology can be used to switch voice, data, and video images in an integrated fashion (see table 3-3). Also, fast packet-switches can transmit hundreds of thousands or millions of packets per second, while conventional ones operate at a rate of only a few thousand packets per second.[32]

Even greater switching speeds can be anticipated in the late 1990s, when optical switching is expected to become a practical reality .33 Optical switches will operate at much greater speeds than electronic switches because beams of photons pass through each other without interfering, whereas electrons get in each other's way. Because high speeds permit massive parallelism and new kinds of architectures, photonic computers could have 1,000 times more power than today's electronic computers.[34]

Advancements in transmission technologies are keeping pace with, if not exceeding, those in switching. Developments in fiber optics, which provides an excellent medium for transmission, have been most significant. With minimal transmission loss, fiber allows many more signals to travel over

[32] David P. Helfrich, "Fast Packet Switching: An Overview," *Telecommunications,* November 1988, p. 68. See also James Brackett, "Fast Packet Switching: A Tutorial," *Telecommunications*, November 1988, pp. 65, 67-68, 70-72, and 76.

[33] Unlike optical transmission, optical switching is still a laboratory technology and is likely to be used only in specialized applications well th the end of the decade. Bell Laboratories in the United States and several commercial research laboratories in Japan currently lead the worl state-of-the-art fiberoptic research and development. See J. Lenart, S. Su, and L. Jou, "A Review on Classification of Optical Switching Systems," *Communications Magazine*, vol. *24, No. 5,* May 1986. See also Michael Warr, "There Are No FINAL Frontiers," *Telephony*, Dec. 14, 1987.

[34] Eric E. Sumner, "Telecommunications Technology in the 1990s," *Telecommunications*, January 1989, p. 38. See also Lee Greenfeld, "Optic Computing," *Computerworld*, June 26, 1986, pp. 83-89.

Table 3-3-Fast-Packet Technology Promises More Options and Greater Flexibility

Network technology	Current maximum speed	Planned maximum speed	Plans for standardized multivendor interoperability	Functions supported
ISDN	1.5 million bit/sec.	100 million bit/sec.	Yes	Voice, data, video, image
Traditional circuit-switched networks.	45 million bit/sec.	100 million bit/sec.	No	Voice, data, video, image
Packet-switched networks	64 thousand bit/sec.	1.5 million bit/sec.	No	Data
Fast-packet	1.5 million bit/sec.	100 million bit/sec.	Yes	Voice, data, video, image

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longer distances with smaller numbers of repeaters than does copper wire.[35] In addition, the capabilities of lightwave transmission are doubling every year, a trend that is likely to continue for another decade. Already, commercial systems have been developed that transmit 1.7 billion bits of information per second on a single pair of glass fibers, an amount equivalent to 24,000 simultaneous phone calls.[36] In the future, the use of laser systems and wavelength division multiplexing on a single fiber will push transmission capabilities into the range of 20 gigabits per second.[37] With wave division multiplexing, each fiber optic cable can accommodate multiple channels by assigning each data stream a different wave length or color.

Given these advances, it is clear that any constraints on the deployment of fiber technology will be economic, not technological. Although fiber is increasingly being used for interoffice trunk lines, and even in some local loop facilities for business users, it is not expected to be extended to the home (with the exception of new construction) for a number of years.[38] For most of the residential community, fiber loop systems are still not economically viable; splicing and cabling costs are still high, and high-speed multiplexing is not as yet cost effective. The demand for fiber in the local loop is still uncertain; most of the services in which residential users have shown an interest can be provided through the existing network, or, as in the case of video services, through alternative distribution channels such as cable TV and videocassette recorders.[39] Given its superior quality as a transmission medium, it is clear that fiber will eventually work its way into the home.[40] However, how and when this will happen will depend on a whole range of variables, a number of which are listed in box 3-B.

The major barrier to further improvements in the cost/performance ratios of information and communication technologies is in the area of software development. Software is pervasive throughout communication systems. and accounts for approximately one-half the cost of many systems. And programs are not only becoming larger in size; they are also much more complex. For example, a switching machine that in 1965 might have consisted of 100,000 lines of code would today require more than 2 million.[41] Thus, to fully exploit technological advances in other areas, software development will need to keep pace. Currently, however, software productivity is lagging behind hardware development.

[35] Commercially available fiber optic technology operates in the 500 million megabits-per-second range. However, fiber optics can carry data rates in the tens of billion gigabits-per-second range. Rates should increase in the future with the use of single mode fibers and coherent modulation/demodulation schemes, By 1990, two gigabit-per-second speeds should be commercially available. Estrin, op. cit., footnote 21, p. 17.

[36] Sumner, op. cit., footnote 34, p. 38.

[37] Estrin, op. cit., footnote 21, p. 16.

[38] For one discussion, see Robert M. Pepper, "Through the Looking Glass: Integrated Broadband Networks, Regulatory policies and Institutional Change," Working Paper No. 24, Federal Communications Commission, Office of Plans and Policy, 1988.

[39] For discussions, see Graham Finnie, "The Disciples of Fibre," *Telecommunications*, January 1989, p. 11; Les Hewitt and Mark Pitchford, "Making the Transition: Fiber Winds Its Way Home," *Telephony*, Feb. 15, 1988, pp. 35-39; Herb Brody, "The Rewiring of America," *High Technology Business*, February 1988, pp. 34-38; Bo Viklund, "Fiber Optics in the Local Loop," *Telecommunications*, May 1987, pp. 66, 68, 72; Graham Finnie, "Lighting Up the Local Loop," *Telecommunications*, January 1989, pp. 31-32, 37-38, 40; Lloyd F. Brisk, "Neighborhood Fiber: Putting a Laser in Everyone's POTS," *Telephony*, Feb. 20, 1989, pp. 27-28; and Tom Valovic, "The Rewiring of America: Scenarios for Local-Loop Distribution," *Telecommunications*, January 1988, pp. 30-31, 34, 36.

[40] Estimates are that within 2 to 4 years the cost of providing "plain old telephone w-vice" with fiber in the local loop will be less than the cost of providing POTS with copper wire. For a discussion, see Pepper, op. cit., footnote 38, p. 12.

[41] Sumner, op. cit., footnote 34, p. 38.

Box 3-B—Factors Affecting the Development of Residential Broadband Services

- the current level of penetration of analog coax-based CATV;
- PUC thinking as to the justification for BOC fiber-optic deployment;
- B-ISDN: technical advances in optical and fast-packet switching;
- demand for advanced information services in the residential setting;
- technical advances in video compression, HDTV, and other broadcast areas;
- convergence of the computer, publishing, and broadcast industries;
- ongoing deployment of fiber in the local loop by the BOCs;
- advances in LAN transmission over unshielded twisted-pair wire;
- investment incentives for BOC acceleration of CO switch upgrades;
- anticipated significant cost reductions in fiber-optic technology;
- the renewal of major cable franchises in the mid-1990 time frame,
- the threat of virtual remonopolization posed by a systems approach;
- the role of satellite transmission in television broadcasting; and
- current service demand levels as defined by POTS and entertainment video.

KEY: B-ISDN = broadband integrated services digital network, BOC = regional Bell operating company, CATV = community antenna television, CO= central office, HDTV = high definition television, LAN = local area network, POTS = plain old telephone service, PUC = public utility commission.

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The Convergence of Communication Functions, Communication Media, and Communication Products and Services

Technological advances over the last decade have also led to the convergence of communication functions and communication media. For example, data processing and telecommunication were once clearly distinct sets of operations. carried out by quite different economic actors. This is no longer the case.[42] Digital switching and data processing now serve as the centerpieces of modern communication networks, and the networking of computers into local area networks, metropolitan networks, and wide-area networks is fast becoming the norm.[43] With the deployment of fast packet-switching and the integration of further intelligence into the telecommunication network, it will become increasingly difficult to distinguish between the functions of switching and transmission.[44] To exploit the economic opportunities presented by this convergence, businesses that once were limited to providing telecommunication services are now joining forces with data-processing companies; and those that traditionally have focused on data processing are seeking to align themselves with those who have an expertise in transmission.[45]

One major technological advance contributing to this trend is digitalization-the process of transforming "analog" messages (a spoken word, a picture, a letter) into signals made up of discrete pulses that can be transmitted, processed, and stored electronically. When in a digital form, audio, video, and textual messages can be combined and recombined, allowing information to be integrated in a way

42See Stuart N, Brotman, "Integration in Key Communication Industries: Business and Policy Considerations," OTA contractor report, June 1988.

43See discussion below.

44Gihong Kim, "The Evolution of Transmission Systems for the Next 10 Years," *Telecommunications*, Aug. 10, 1987. Some examples noted by the author are statistical multiplexer, digital cross-connect systems, concentrators, and switches with built-in optical fiber interfaces such as DS3. See also A.M. Rutkowski, "Telecommunication Sandcastles: Boundaries That Have Outlived Their Usefulness," *Telecommunications,* June 1987, p. 8; and Richard Solomon, "Broadband ISDN: With Computers, the Sum Is Always Greater Than the Parts," *International Networks, vol. 5, No. 2,* Sept. 15, 1987.

45For examples, and a range of discussions, see John Foley, "Nynex Acquisition Strengthens Position as Systems Integrator," *CommunicationsWeek,* June 20, 1989, p. 8; Carol Wilson, "The 'New' IBM Beckons to Telcos to Become Technology Partners," *Telephony,* Mar. *21, 1988,* p. 8; "DEC Scores Partners," *CommunicationsWeek*, May 29, 1989, p. 1; Neil Watson, "HP Boosts T1 MUX. Packet Switch Offerings," *CommunicationsWeek,* Apr. 10, 1989; Christine Bonafield, "AT&T Targets SNA Customers," *CommunicationsWeek*, June 20, *1988,* p. 1; Timothy Haight, "IBM Buys Into Fiber Company," *CommunicationsWeek*, Jan. 16, 1989, p 20: and Peter Purton, "Olivetti Expands Into Telephones," *Telephony,* Mar. 6, 1989, p. 22.

that previously was impossible.[46] As Stewart Brand has described this phenomenon:

> With digitalization all of the media become translatable into each other---computer bits migrate merrily-and they escape from their traditional means of transmission. A movie, phone call, letter, or magazine article may be sent digitally via phone line, coaxial cable, fiberoptic cable, microwave, satellite, the broadcast *air,* or a physical storage medium such as tape or disk, if that's not revolution enough, with digitalization the content becomes totally plastic—any message, sound, or image may be edited from anything into anything else.[47]

Digitalization was first introduced into the short-haul exchange of the telephone network in the early 1960s, and into the long-haul sectors and local exchange markets in the 1970s. With the development of digital loop technologies providing digital connectivity to the customer, it became possible to offer digital data services.[48] The development of, and growing demand for, these kinds of services further encouraged digitalization.[49] Transmitting digital data is much more efficient than transmitting analog data; in digital systems, data do not have to be converted into tones simulating a voice signal. Improvements in the performance and reliability of digital technologies, together with a reduction in their size and cost, have also fostered this trend. Given these incentives to deploy digital technologies, it is likely that the interoffice telephone network will be almost totally digital by 1990, and that almost the entire local exchange will have acquired digital capability by the year 2000.[50]

The development of lightwave technology has also spurred the trend towards convergence. Given the generous bandwidths provided by fiber optics, telecommunication providers, for example, are no longer technically precluded from transmitting high-speed video images. According to one estimate, a broadband integrated services digital network (B-ISDN) could provide "four network-switchable channels with the capability of delivering current analog-type video services or future high-definition television on more than 100 megabits per channel."[51] Thus, with broadband networks, telephone companies will be candidates for providing video services at the leading edge."[52]

Epitomizing this trend toward convergence is the much touted B-ISDN.[53] Based on a common set of standards,[54] B-ISDN envisions a universal and ubiquitous system designed to provide efficient broadband interconnection for all possible communication services. Because it would not require separate systems for voice, data, and video, such a network would be truly integrated. To provide such

[46] The trend towards digitalization reflects the fact that digital technology is inherently more efficient than analog. In an analog network, data have to be converted into tones simulating a voice signal; in a digital system, the transmission of data does not require special processing. Digital technology has also been improved in terms of performance and reliability, while its cost and size have been significantly reduced. For a discussion, see Don R. Gibson and John M. Curry, "New Techniques for Digital Transmission," *Telecommunications,* January 1988, pp. 68-71.

[47] Stewart Brand, *The Media Lab: Inventing the Future at MIT* (New York, NY: Penguin Books, 1988), p. 19.

[48] Kim, op. cit., footnote 44.

[49] According to the Department of Commerce, data communication increased by almost 40 percent between 1970 and 1985. *See A Primer on Integrated Services Digital Network: Implications for Future Global Communications* (Washington, DC: NTIA, U.S. Department of Commerce, September 1983).

[50] Lawrence K. Vanston, Ralph C. Lenz, and Richard S. Wolff, "How Fast Is New Technology Coming?" *Telephony,* Sept. 18, 1989, pp. 47-52.

[51] M. Farooque Mesiya, "Implementation of a Broadband Integrated Service Hybrid Network, " *IEEE Communication Magazine,* vol 26, No. 1, January 1988.

[52] Whether or not they are free to do s. from a regulatory perspective is, of course, a different question. As Robert Pepper notes: "There are significant regulatory and legal obstacles to telephone companies expanding those fiber networks into broadband networks if, realistically, the only broadband service they see as worth offering in the foreseeable future is video programming. " Pepper, op. cit., footnote 38, p. 19.

[53] As defined by the Consultative Committee for International Telephone and Telegraph, Study Group XVIII, ISDN constitutes: "A network evolved from the telephone ISDN (Integrated Services Digital Network) that provides end-to-end connectivity support for a wide variety of services, to which users have access by a limited set of standards and multipurpose customer interfaces. " In practice, ISDN has come to mean different things to different people and in different contexts. For some general discussions, see Tom Valovic, "Fourteen Things You Should Know About ISDN," *Telecommunications,* December 1987, pp. 37-38,40, 42; Rolf Wigand, "Integrated Services Digital Networks: Concept, Policies, and Emerging Issues," *Journal of Communication,* vol. *38, No. 1,* Winter 1988, pp. 29-69; and Lou Feldner, "Some Unresolved Questions on ISDN in a Competitive Environment," Harry M. Trebing and Patrick C. Mann (eds.), *Alternatives to Traditional Regulation: Options for Reform,* Proceedings of the Institute of Public Utilities, 19th Annual Conference, 1987, Michigan State University Public Utility Papers, East Lansing, MI.

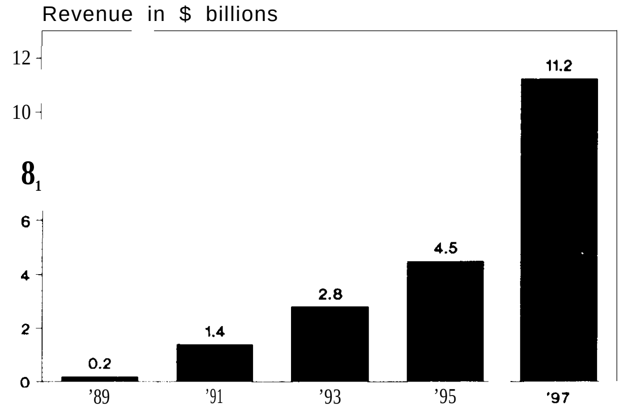
[54] Standards for ISDN are being established by the Consultative Committee for International Telephone and Telegraph (CCITT). All of the standard ISDN interfaces are based on a multiple of a digital voice-grade channel (64 kilobits per second). These include the Basic Rate Interface, or 2B+D format, which provides a total channel capacity of 144 kilobits per second, and the Primary Rate Interface, or 23B+D format, which provides the equivalent to a T1 channel, that is, a total capacity of 1.544 megabits per second, and broadband ISDN, which provides dynamically configurable charnels, or packets, at rates up to 150 megabits per second transmitted via an optical interface. Valovic, op. cit.. footnote 53, p. 37.

capability, this network will take full advantage of both digitalization and lightwave technology.

The development of B-ISDN is still essentially in the planning stage, although recent standards developments have been quite promising.[55] Most ISDN activity has been limited to trials of narrowband ISDN applications, and most of these have been relatively modest. There are, for example, only about 70 large customers who are either involved in ISDN trials, or who are using commercially released ISDN products.[56] However, the rate at which trials are being undertaken has been increasing, and the market for ISDN is predicted to grow significantly over the course of the next decade (see figures 3-2 and 3-3).

A number of factors have accounted for the slow diffusion of ISDN into the telecommunication infrastructure. The fact that there is a large embedded investment in the existing network is probably the most important one. Private users, in particular, have already expended significant amounts of time and money developing their own sophisticated data communication systems, most of which would be incompatible with ISDN technologies.[57] Also, the purported benefits of ISDN, while appealing in theory, have yet to be demonstrated in practice.[58] Given such uncertainty, it may be difficult to convince users to purchase ISDN-related products and services at prices sufficiently high to cover the cost of their development and implementation.[59] This problem of pricing is compounded by the fact that there is no real historical basis for pricing what,

Figure 3-2-Continued Deregulation and the Growth of Intelligent Carrier Networks Should Foster Rapid Growth in the ISDN Services Market Through the Next Decade



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in reality, is an experimental service.[60] The long and cumbersome process of achieving standardization will also delay the deployment of ISDN. Without finalized standards, vendors have been very reluctant to develop ISDN-compatible products.[61]

The major push for ISDN will come from the public telephone companies, Because it will allow them to offer the kind of sophisticated services that business users will need in the future, such as virtual networks and customer control, the telephone companies view the development of ISDN as the critical component of their strategies to compete with alternative service providers.[62] Telephone compa-

[55] One of the most important recent events has been the international agreement reached on a standard for the Synchronous Optical Network (SONET) interface. For discussions, see Rodney J. Boem, "SONET: The Next Phase," *Telecommunications*, June 1989, pp. 37-38, 40; Gilbert L. Pringle, "Sonet: Problem or Opportunity," Telephony, Aug. 14, 1989, pp. 61-63, 65; and Thomas C. Miller, "Sonet and BISDN: A Marriage of Technology, ''Telephony, May 15, 1989, pp. 32-35,38.

[56] Saroja Girshankari, "Gearing Up for ISDN's," *CommunicationsWeek*, CLOSEUP, Apr. 17,1989, p. 37.

[57] "Ultimately, the choice between a single public B-ISDN and separate, specialized, incompatible networks turns on the extent Of long-run economies of scale and scope in telecommunications, and on the cost of gateways to connect incompatible systems." William Lehr and Roger G. Nell, "ISDN and the Small User: Regulatory Policy Issues," Center for Telecommunications and Information Studies, Columbia University, 1989, pp. 11, 19.

[58] For discussions, see Edwin E. Mier, "ISDN: Another version of the Emperor's New *Clothes," Data Communications*, December 1986, pp. 45-60; Sarah Underwood, "ISDN on Trial," *Damnation,* Feb. 1, 1987, pp. 51-56; and Candee Wilde, "ISDN: Let the Buyer Believe," *CommunicationsWeek,* Feb. 27, 1989, p. 44.

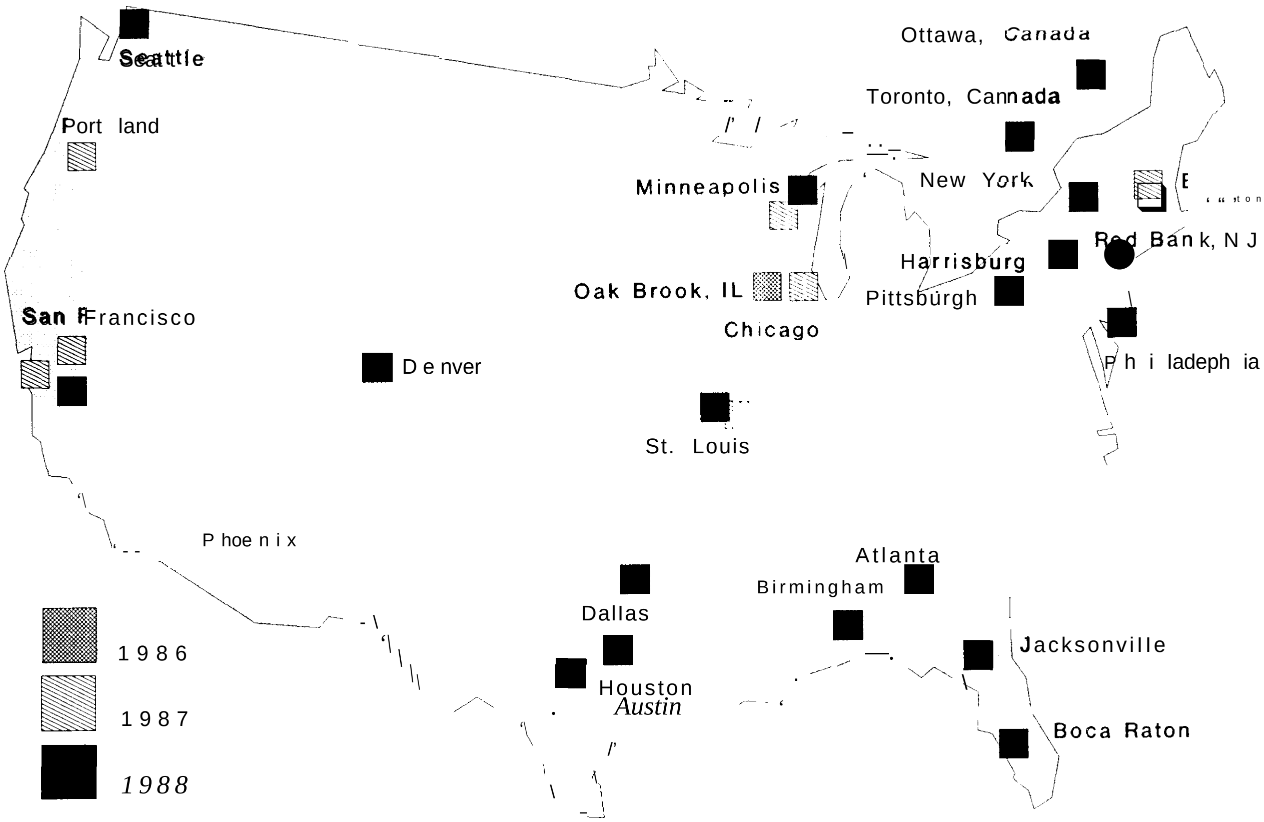
[59] See Kathleen Killette, "Controversial Costs," *CommunicationsWeek*, CLOSEUP, Sept. 18, 1988, p. C8; and Bruce Page, "Cost Is the Key," *Computerworld*, Dec. 12, 1988, p. 72.

[60] Ibid.

[61] Elizabeth Horwitt, "ISDN-Hungry Users Finding They're on a Restricted Diet," *Computerworld*, Feb. 27, 1989, p. 1.

[62] For one discussion, see Tom Valovic, "Will ISDN Replace Lam?" *Telecommunications*, September 1987, pp. 67-68,70.

Figure 3-3-The Number of Integrated Services Digital Network Trials Throughout the Country Doubled in Just a Year



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nies are already offering a number of Centrex services[63] that are designed to maintain, and even regain, their business customers and provide a transition to ISDN.[64] However, because the telephone companies have a large embedded investment in older equipment, they plan to move from narrowband ISDN to broadband ISDN in an evolutionary, rather than a revolutionary, fashion. One major dilemma they face is that, by the time telephone companies can provide broadband services, other ways of meeting the needs of large business users may already be firmly entrenched.

The effects of digitalization will be experienced far beyond telecommunication. By providing the capability to integrate and process voice, video, and text, digitalization will also give rise to a wide range of multimedia applications, some designed to run on desktop computers.[65] Although this multimedia industry is currently only in its infancy, it is expected to constitute a $7 billion market by 1994.[66]

One use of this technology will be to provide multimedia videotex, where the French have made a number of advances. This service is already

[63] Centrex services are the switched business telecommunication services that are provided from the telephone company's central office. rather than from equipment on the customer's premises. For discussions of the role of Centrex in the telephone company's competitive strategies, see John R. Abrahams, "Centrex Versus PBX: The Battle for Features and Functionality," *Telecommunications*, March 1989, pp. 27-28, 31-32; Carol Wilson, "Centrex II: The Telcos Revenge," *Telephony*, July 17, 1989, pp. 28-31; and James Quarforth, "Centrex to the Rescue," *Telephony*, July 17, 1989, pp. 22-23.

[64] See Martin Pyykkonen, "Centrex Now, ISDN Later," *Telecommunications*, February 1987, pp. 53-54, 84; and Martin H. Singer, "Hybrid Networks Move to Telecom's Center Stage," *Telephony*, Mar. 6, 1989, pp. 41-46,51.

[65] Michael Alexander, "Everyone's Talking Multimedia," *Computerworld*, September 1989.

[66] Ibid.

available on the French Minitel 10 system where it is used, for example, to provide foreign language instruction.[67] The French are also using multimedia technology to provide compact disc selection via ISDN,[68] and they are now in the process of developing interactive digital video for use in the near future.[69]

Characterizing the momentum driving the trend toward multimedia technology, Stewart Brand points out:

> Communication media are not just changing, they're changing into each other, and when they get together, they breed. Since the process self-accelerates and self-branches, there's no reason to expect a new stability any time soon.[70]

Decentralization of Intelligence Throughout Communication Systems With the Development of Software-Driven and Software-Defined Communication Facilities

The greatly improved performance of computer technologies and their convergence with communication technologies have facilitated the dispersal of intelligence and control throughout communication systems.[71] More and more, systems are becoming defined and driven by software.[72] This development will make future communication technologies and systems more flexible and more versatile.

As noted above, it was digital processing that initially brought intelligence to the telecommunication network. The first computer-controlled switching systems were deployed 20 years ago. In the 1970s, when advances in integrated-circuit technology permitted the creation of a solid-state exchange, telecommunication providers began to deploy all-digital switches.[73] Today, approximately 98 percent of all AT&T switches are digital.[74] With respect to the regional Bell operating companies (BOCs), Nynex is 38 percent digital, Bell Atlantic 34 percent, Ameritech 30 percent, US West 30 percent, Pacific Bell 28 percent, and Southwestern Bell 25 percent.[75] For the projected deployment, see table 3-4.

With the development of even more powerful microprocessors, faster computing speeds, and larger memories, it is possible to locate intelligence not just in the central office switch, but also at nodes throughout the network. Because these "intelligent" nodes can communicate in real time with one another, as well as with other networks, communication systems based on this kind of architecture offer greatly enhanced flexibility-they can respond quickly to network problems and to changes in user demand; optimize network capacity; and ensure greater system and service reliability.[76]

This dispersal of intelligence throughout communication systems is well illustrated in the intelligent network. Using intelligent switches and databases, together with common channel signaling, the intelligent network allows network control functions to be separated from network switching functions.[77] This capability permits the network to select the most appropriate services and optimal routes, and to introduce new value-added services via simplified and modularized software. Among the services that

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67 For a discussion, see Herve Layec and Pierre-Louis Mazoyer, "Implementing Multimedia Videotex," *Telecommunications,* May 1989, pp. 57-60.

68 Jean-Pierre Temime, "Videotex Enters Another Dimension," *Telephony,* Sept. 25, 1989, pp. 59, 62, and 64.

@Ibid., p. 60.

70 Brand, op. cit., footnote 47, p. 19.

71 For a powerful, and highly influential, discussion of this trend, see peter Huber, *The Geodesic Network: 1987 Report on Competition in the Telephone Industry* (Washington, DC: U.S. Government Printing Office, January 1987).

72 The distinction between hardware- and software-based technologies is somewhat artificial. Hardware technologies rely increasingly on software design tools, while software developments are shaped by hardware support and developments. Moreover, a function that today is implemented in hardware may tomorrow be implemented in software, and vice versa.

Software systems are built on top of hardware technologies. These technologies are highly application-dependent and therefore the technologies and techniques are very diverse; thus, they are difficult to categorize. Included are switching protocols, network configuration and management, distributed operating systems and databases, network services such as directories and security, and protocol conversion. For a discussion, see Estrin, op. cit., footnote 21, p. 11.

73 Allen Adams and John Wade, "Looking Ahead to the Next Generation," *Telephony,* May 23, 1988, *p. 57.*

74 Ross, op. cit., footnote 26, p. 12.

75 Paul Travis, "Which Way DO We Go?" *Telephony,* July 3, 1989, p. 36.

76 John O. Boese and Richard B. Robock, "Service Control point: The Brains Behind the Intelligent Network," *Bellcore Exchange,* November/December 1987, p. 13.

77 For discussions, see David G. Fisher and William Bauer, "Multiplexing With Intelligence," *Telecommunications,* February 1988, pp. 73-74, 79; see also Marcel E. Looson, "The State of the Intelligent Network Art," *Telecommunications,* February 1988, pp. 47,52, and 57.

Table 3-4--Switching Technologies: Percentage of Total Access Lines

Year	EM	Analog SPC	Digital SPC	Total SPC	Total
1980	58.88	41.09	0.03	41	100
1981	52.86	46.96	0.17	47	100
1862	48.27	51.39	0.35	52	100
1983	42.74	56.35	0.91	57	100
1964	36.20	58.47	3.34	62	100
1985	30.84	59.54	9.62	69	100
1986	23.36	59.98a	16.67	77	100
1987	16.76	58.12	25.11	63	100
1988	10.39	56.48	33.12	90	100
1989	6.55	53.73	39.73		100
1990	4.65	50.57	44.78	95	100
1991	2.10	44.35	53.55	98	100
1982	1.14	36.49	62.37	99	100
1993	0.61	27.57	71.82	99	100
1994		19.07	80.61	100	100
1995		12.19	87.77	100	100
1996		7.35	92.61	100	100
1997		4.26	95.70	100	100
1998		2.41	97.55	100	100
1999		1.35	98.61	100	100
2000		0.74	99.22	100	100

Key: EM = electromechanical, SPC= stored program control

● Peak percentage for analog SPC

SOURCE: Reprinted with permission from Telephony, July 3, 1989.

the intelligent network can provide are dynamic call routing, call forwarding, call queuing, credit card billing, reverse charging, control of calls based on data held in a central database, wide area Centrex, and virtual private networks.[78] A description of the basic components comprising the intelligent network, and a discussion of how they are joined together to provide intelligent services, was provided in box 3-A.

Because software databases and intelligent switches can be accessed and modified by customers as well as by telephone-service providers, the integration of intelligence into the network will allow users to exercise much greater control over the services they receive.[79] For example, employing software-based management technologies, similar to those used by public network operators, users can customize their own services to optimize their communication strategies, respond dynamically to emergencies, and optimize the use of the network's resources.[80] Eventually, residential users will be able to take advantage of these intelligent capabilities, using them, for example, to block 976 calls.[81]

The idea of developing an intelligent network is not new. It was first conceived by AT&T before divestiture as a means of providing nationwide 800 database services and private virtual networks.[82] Since divestiture, both AT&T[83] and Bell Communications Research (Bellcore), with the cooperation of other vendors, have been conducting research and development in this area. Equipment vendors are also engaged in developing products for these networks. As can be seen from figure 3-4, this activity is likely to increase in the future.

A number of factors should encourage this development. Most importantly, intelligent networks are likely to serve the needs and interests of both providers and users of communication services alike. With intelligent networks, for example, communication providers will be able to offer large business users the kinds of services and control to which they have become accustomed in their own private networks, thus helping the public switched network providers to regain, or at least maintain, a healthy portion of this lucrative business.[84] With continued advances in operating support systems (OSS), communication providers will also be able to exert greater control over the costs of the development and deployment of new services in the network. With sufficient revenues from business subscribers, providers will also find it easier to modernize the network while continuing to provide basic services that everyone can afford.[85]

Despite these incentives, the development of the intelligent network has been much slower than was originally anticipated. Initially, Bellcore planned to develop the intelligent network in stages—Intelligent Network/l (N/1), which was intended for completion in 1991, and Intelligent Network 2

[78] Denis Gilhooly, "Welcome t. a Future Where Less IS More," *CommunicationsWeek,* CLOSEUP, Sept. 4, 1989, p. C5.

[79] Bob Vinton, "Aptitude of the IN," *CommunicationsWeek,* CLOSEUP, May 22, 1989, p. 49.

[80] Ross, op. cit., footnote 26, p. 17.

[81] Vinton, op. cit., footnote 79.

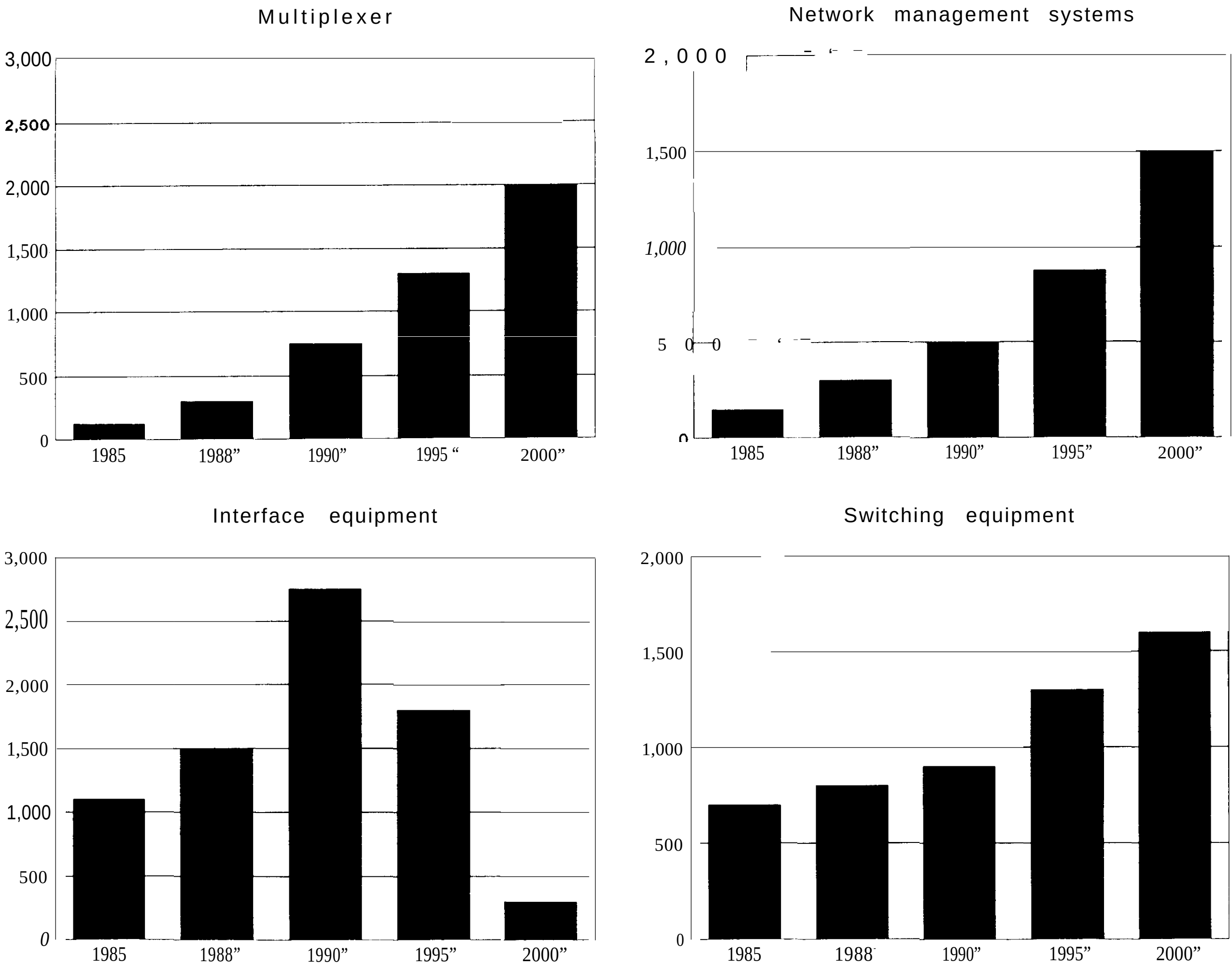
[82] Ibid.

[83] At divestiture, AT&T retained the Bell System resources that had been devoted to developing the intelligent network.

[84] For discussions, see Art Beaty, Jr., "The Evolution to Intelligent Networks,"' *Telecommunications,* February 1989, pp. 29-30,32,34, and 36; and Denis Gilhooly, "Towards the Intelligent Network," *Telecommunications*, December 1987, pp. 43-44,46,48,

[85] Ibid.

Figure 3-4-intelligent-Network Equipment Markets: Annual Revenue by Equipment Type ($millions)



“Projected
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(N/2), which was cast as the network of the 1990s. Designed to be even more flexible than N/l, N/2 would allow services to be provided in a variety of physical network configurations under the control of many different entities.[86] In January 1989, however, Bellcore adopted a revised, more staggered approach, and postponed the development of the Advanced Intelligent Network (equivalent to an enhanced version of N/l, often referred to as N/l+) until 1995, a delay of 4 years. As explained by Bellcore’s division manager for network services product management:

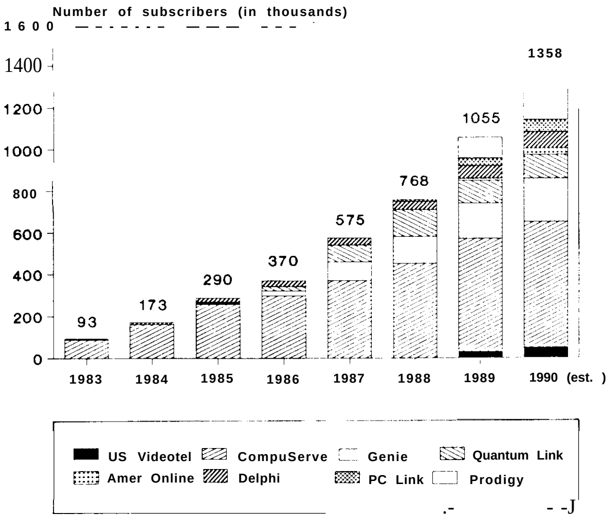
> I think the feeling was that we had better make sure that we understand what the performance implications of the architecture are well in advance of making a commitment to deploy .87

As part of this reassessment, Bellcore decided to coordinate its efforts more closely with telecommunication and data communication vendors. To this

[86] As described by Paul Bloom and Parnck Miller, the concept of N/2 was “based on the premise that each customer service can be assembled from essential service capabilities. What distinguishes one service from another are the specific elemental capabilities used and the order in which they are sequenced.” Paul Bloom and Patrick Miller, “Intelligent Network/2,” *Telecommunications,* February 1987, pp. 57-60,64-65.

[87] Robert Preston, “Bells’ Intelligent Network Could Be Delayed Until 1995,” *CommunicationsWeek*, Feb. 20, 1989.

Figure 3-5--Consumer Videotex Subscriber Growth Leading Services: 1983 to 1990



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end, it has set up the Multivendor Interactive Administrative Committee.[88]

The trend toward the dispersal of intelligence and control in communication systems is not limited to large telecommunication networks. Intelligence will also be provided to the user at office work stations or via computers, video terminals, or telephones in the home. For example, by 1993, according to one estimate, office work stations will be able to handle 32 million instructions per second; have 16 megabytes of random access memory, and cost approximately $350.[89] Given such performance/price improvements, market analysts expect that, by early 1990, the total number of computer workstations in Europe, Japan, and the United States will surpass 100 million.[90]

Just as users of the intelligent network will have greater control over the types of services they receive, so too will the users of intelligent customer-premises equipment. People can use interactive, intelligent terminals to do their own publishing, for example, by compiling, processing, and formatting information for themselves or others.[91] As Ithiel de Sola Pool described the situation:

> The technologies used for self-expression, human intercourse, and recording of knowledge are in unprecedented flux. A panoply of electronic devices puts at everyone's hand capacities far beyond anything that the printing press could offer. Machines that think, that bring great libraries into anybody's study, that allow discourse among persons a half-world apart, are expanders of human culture. They allow people to do anything that could be done with communication tools of the past, and many more things too.[92]

Although the distribution of intelligence in this fashion can greatly extend the ways in which end-users can employ communication technologies, it can also discourage the adoption and use of technology if it requires users to have greater knowledge and skills. Many have suggested, for example. that videotex would be more popular in the United States if users could access it, as in France, on "dumb" terminals.[93] They note that audiotex services, which can be easily accessed over the telephone, have been much more popular than videotex. Despite the industry's difficult early years, its prospects for the future appear brighter, as evidenced in figure 3-5. The factors likely to account for this change include:[94]

- the availability of better host/user software,
- the availability of improved gateway services,
- a greater number and variety of information services, and
- an increase in the use of (and therefore comfort in using) personal terminals.

[88] Michael Warr, "Bellcore Slows Program for Network Evolution," *Telephony*, May 15, 1989. p. 12. It should be noted that some regional Bell operating companies are aiming to deploy the intelligent network ahead of the Bellcore schedule.

[89] Gilhooly, op. cit., footnote 78, p. C4.

[90] Ibid.

[91] For a discussion of how new technologies allow individuals to more easily become creators and information providers in their own right, see "Impact of Technology on the Creative Environment," U.S. Congress, Office of Technology Assessment, *Intellectual Property Rights in an Age of Electronics and Information*, OTA-CIT-302 (Springfield, VA: National Technical Information Service, April 1986), ch. 5.

[92] Ithiel de Sola Pool, Technologies *of Freedom* (Cambridge, MA: The Belknap Press of Harvard University, 1986), P. 226.

[93] Sam Simon, President, Issue Dynamics, Inc., personal communication, September 1987.

[94] "Leading Videotex Services Top a Million: Revenues Follow 80/20 Rule," *Connect Times*, April/May 1989, p. 6.

Unbundling of Some Communication Services or Functions

Unbundling refers to the ability to separately purchase communication services or functions that were formerly available only as a single unit. Linked to the trends of convergence and decentralized intelligence, this phenomenon is becoming increasingly prevalent in all communication systems. While unbundling allows for greater access to, and control over, communication services, it can also create problems for the interoperability, security, and survivability of the communication infrastructure.

Unbundling first appeared in telecommunication with the Carterfone decision of 1968,[95] which allowed customers to add equipment to their telephones as long as they did not adversely affect the operation of the telephone system or its usefulness to others.[96] A clarification of this decision by the FCC in December 1988 extended its provisions to microwave systems and computers. The Carterfone decision ruptured the well-established arrangement whereby AT&T was assigned the responsibility of providing national end-to-end telephone service. Applied broadly, these decisions encouraged the entry of new entrepreneurs who wanted to plug into the network with new kinds of customer-premise equipment (CPE) or enhance the value of their private systems by interconnecting with the public network.[97] Thus, they cleared the way for the development of entirely new communication industries.

Many other factors and events also contributed to this development. As Stone has pointed out, given the numerous technological advances that had been made in communication and computers, together with the greatly increased post-war demand for service, it is likely that:

> . . . no one firm-not even one as large as AT&T—could possibly seize all of these opportunities as rapidly as they could be realized.[98]

The growing convergence of computer and communication technologies made it even more difficult to determine what "end-to-end" service should entail.[99] Capping off all of these developments was divestiture and the breakup of the Bell System.

Today, the unbundling of the communication infrastructure is clearly demonstrated by the emergence of a whole range of communication equipment providers. AT&T's share of this market has dropped precipitously; for example, with respect to equipment sold to telephone companies, its market share has fallen to between 40 and 60 percent.[100] As can be seen in table 3-5, CPE vendors constituted a $25.6 billion market in 1988. In recent years, however, profit margins have been eroding due to extremely competitive conditions and the failure of most vendors to offer overall system solutions.[101]

Unbundling is also apparent in the extent to which users now own their own dedicated units. As Peter Huber has pointed out:

> Twenty years ago CPE markets were comparatively tiny. Equipment that was located on customer premises-everything from handsets to mainframe computers-was provided only under lease, and then only grudgingly, with strict instructions that nothing was to be tampered with in any way. The real electronic brains stayed safely in the central-office, where the no-tampering policy could be enforced even more fully.[102]

Now major companies such as AT&T and IBM are in the business of selling equipment, not renting it.

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95 "AT&T—Foreign Attachments, Tariff Revisions, " 15 FCC 2d 605 (1968).

96 The Carterfone was a device that permitted callers to use the telephone network to communicate directly with others located at remote mobile radio terminals. It was not the first telephone attachment to be developed outside of the Bell System. As Alan Stone has pointed out, there have always been inventors developing attachments that could supplement or even substitute for Bell equipment. However, both AT&T and State regulatory authorities strongly opposed the use of such components, viewing them as inimical to the well-established requirement that AT&T provide end-to-end service. For a discussion, see Alan Stone, *Wrong Number The Breakup of AT&T (New* York, NY Basic Books, Inc., 1989), pp. 87-90.

97 Ibid., p. 95.

98 Ibid.

99 To sort out this issue, the FCC undertook a series of computer inquiries, (called Computer Inquiry 1, II, and III), none of which fully resolved this problem. For a discussion, see Anthony Rutkowski, testimony at hearings before the House Subcommittee on Telecommunications and Finance, July 30, 1987.

100 Roger Noll, "Telecommunications Regulation in the 1990s," Stanford University, Center for Economic Policy Research, Publication No. 140, August 1988, p. 19.

101 Susan Ubis and Czatdana Inan, "Feeding Frenzy Grips Competitive CPE Market," *Telephony*, Apr. 11, 1988, pp. 32-35.

102 Huber, op. cit., footnote 71, p. 1.11 .

Table 3-5-Domestic Shipments of Telecommunications Equipment by Major Product Categories, 1975-2000 (in current $million)

Year	Switching equipment	Transmission equipment	Customer premises equipment	Cable/wire and lightguide	Total
1987	4,075	6,525	11,240	2,230	24,070
1988	4,400	6,950	11,950	2,350	25,650
1989P	4,660	7,213	12,667	2,435	26,975
CGR 79-89	1.570	8.6%	5.40/0	–1 .20/0	4.4%
CGR 89-00	5.2%	5.5%	5.3%	3.00/0	***5.1%***

Key: CGR = average annual compound growth rate, p. projection.
SOURCE: U.S. International Trade Commission and Computer and Business Equipment Manufacturers' Association (CBEMA) Industry Marketing Statistics.

At the same time, many large users are growing accustomed to owning and operating their own communication networks. According to Huber, in 1987, private buyers accounted for 80 percent of the purchase of satellite transmission service, 40 percent of the telephone switching market, 20 percent of microwave transmission equipment, and 20 percent of fiber-optic cable and electronics.[103] In addition, sales of mainframes have greatly declined in favor of purchases of mini-and micro-computers.[104]

The development of open network architecture (ONA) will lead to the further unbundling of the telecommunication network. But, as previously noted, the ability to open the network will depend, in part, on both software development and the advance of the intelligent network.[105] If pursued far enough, open architecture would allow independent providers and other users to purchase the most elemental network functions. They could also create their own products, reconfiguring and customizing these functions to meet their own needs.[106]

However, technology will not be the only determinant of network architecture. Because open architecture will affect the security and interoperability of the infrastructure, as well as the efficiencies and costs of providing services, the issue of how open the communication infrastructure should be is a matter of considerable debate.[107] Also, not all users will want to buy unbundled services, As a number of business users are finding out, although unbundling can reduce prices and increase their purchasing choices, it also transfers to them the burden of network planning and management. Many businesses are finding it difficult to take on this new responsibility. For some, the only option is to pay a systems integrator to rebundle the products and services they need.[108]

Many of the advantages and disadvantages of unbundling telecommunication products and services, and hence the factors that are likely to drive this trend, can be seen by examining the private branch exchange (PBX). A private switching system located on a customer's premises, the PBX is, in effect, a small local telephone office. Because it competes directly with the providers of public switched services, the PBX provides an excellent paradigm for considering developments in this area. As Peter Huber explains:

> PBXs are complex and expensive, they require sophisticated forms of interconnection with the public network, and they compete directly with network-based services such as Centrex. PBX-based private networks are the main competitive threat to the local exchange monopoly.[109]

The fortunes of the PBX industry mirror those of many other manufacturers of customer premises equipment. The PBX was first developed and used within the Bell System and leased by telephone companies to business users. In the wake of divestiture, a number of companies, including AT&T and the BOCs, began to manufacture and distribute PBX

103 Ibid.

104 Ibid.

105 Ibid.

106 A.M. Rutkowski, "The Second National Open Network Architecture Forum," *Telecommunications,* May 1987, pp. 118-119, 123.

107 The policy issues entailed in this decision are discussed in chs. 10 and 11.

108 A discussion of the emergence of the systems integrator as a strategic player in the communication infrastructure appears later in this chapter.

109 Huber, op. cit., footnote 71, p. 16.1.

equipment for sale.[110] This market flourished in the aftermath of the Carterfone decision and divestiture.[111] New players abounded. Incorporating the latest digital computer technology into the PBX, the largest manufacturers such as Northern Telecom and Rolm were able to make considerable inroads into AT&T's share of the market.[112] With users eager to take advantage of the liberalized, post-divestiture environment, demand soared; between 1982 and 1985, total system shipments increased by about 20 percent.[113]

The tide turned, however, in 1986, when the demand for PBXs began to flatten out, a trend that is projected to continue in the near future.[114] Two factors have contributed to this reversal, both of which suggest that users are only now beginning to come to grips with some of the more problematic aspects of unbundling. The first of these is the reemergence and upgrading of Centrex services. Over the last several years, telephone company providers have sought to regain lost customers by aggressively marketing their Centrex offerings, providing services that compete directly with PBXs, such as central office local area networks (CO-LANs). And they have been quite successful. Many users, disillusioned by the hidden costs and problems entailed in running their own communication networks, are looking to public network providers to develop new kinds of solutions for them, such as hybrid and virtual private networks.[115] Thus we see that, while the PBX market has remained flat, Centrex has grown during the last 3 years at an annual rate of more than 20 percent.

The second factor contributing to the PBX industry's change in fate is the evolution of network technologies and the development of system standards such as integrated services digital network (ISDN) and open systems interconnection (OSI). While PBX manufacturers have tried to upgrade their systems technologically,[116] they have been slower at adapting their products to international standards. However, as more and more products and services are unbundled, it will become even more important to users that they be interoperable. And with recent progress towards developing international standards, many users are becoming less inclined to purchase PBXs without some assurance that they will be able to fit in.

Generalizing from the case of the PBX, we can see that there are more than just technical and regulatory constraints that limit the degree to which unbundling can effectively take place. If users are to take full advantage of unbundling, greater progress will need to be made in the areas of network management and standardization.

Increased Portability

Miniaturization and the ability to unbundle intelligent equipment from the communication infrastructure are also increasing the portability of communication products and services. With the development of cellular phones and paging systems, for example, users can now communicate from any location.

Advances in cellular technologies, in particular, have greatly enhanced the ability to develop and deploy portable communication systems. The development of cellular technology grew out of the use of radio communication technologies in World War 11. By the late 1940s and early 1950s, some radio common carriers and a few businesses, having been granted licenses and allocated radio frequency by the FCC, began to offer modest, local mobile communi-

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110 As Huber notes: "Vigorous competition in the PBX market developed between 1979 and 1982, during which period AT&T's share of the market dropped from almost 70 percent to under 30 percent." Huber, op. cit., footnote 71, p. 16.5. Although the BOCS are prohibited from manufacturing customer premises equipment, they are important distributors of PBXs and PBX-related equipment.

111 For a discussion, see Barry L. Marks, "The PBX Market: Past, Present, and Future." *Telecommunications*, January 1989, pp. 57-58.

112 Huber, op. cit., foomote 71, p. 16.5.

113 Marks, Op. cit., foomote 111, pp. 57-58.

114 See, for instance, James N. Budway, "PBXS From Riches to Rags," *Telecommunications,* November 1988, pp. 101-102.

115 For discussions, see Valovic, op. cit., foomote 62, pp. 67-70; and "Opportunities for CO Services," *Telephony's CO Services Special,* May 1989, pp. 1-28; Martin Pyykkonen, "Centrex Now, ISDN Later," *Telecommunications,* February 1987, pp. 53-84; and John R. Abrahams, "Centrex Versus PBX: The Battle for Features and Functionality," *Telecommunications,* March 1989, pp. 27-32.

116 For example, over 80 percent of new digital PBXs have data. switching capabilities. Moreover, these switches can perform extensive protocol conversion, and they support both synchronous and asynchronous transmission for electronic mail, file sharing, terminal-to-terminal, and terminal-to-host communication. For a discussion of the relationship between the PBX and ISDN, see Tibor G. Szekeres, "Will ISDN Make the PBX Obsolete?" *CommunicationsWeek,* Sept. 19, 1988, p. 16.

cation services. *17 Over the past 30 years, a number of different services have been developed, including radio paging; telephone-answering services; mobile telephones; private, two-way radio dispatch systems; citizen band two-way radio; public air-to-ground radio telephone service; and voice-mail services. [1]18

Although regulatory barriers retarded the development of cellular technology for a number of years, cellular mobile telephone service is currently available in most cities.[119] High-power satellites can track mobile units on Earth, making nationwide mobile telephony possible. Although mobile communication is now primarily focused on car telephones, efforts are being made to create portable equipment that would permit communication with anyone, anywhere, at any time. Motorola Inc. has already introduced a new cellular telephone that can fit easily into a pocket or purse. And pagers have been transformed from simply tone-only alerts to portable electronic mailboxes.[120] Many industry analysts predict that people will soon be able to carry an entire portable telecommunication center with them wherever they go.[121]

Advances in cellular technology are finding their rewards in the marketplace. In 1988, for example, the cellular telephone industry's customer base increased by 68 percent, a rate that is likely to continue, if not increase, over the next 5 years.[122] This demand will be fueled by a continued decline in prices. Reflecting these gains, the per capita value of the top 20 cellular licenses increased from $16.23 to $77.71 between 1985 and 1987, a figure that is expected to climb to $100 by the early 1990s.[123] Annual revenues for the entire U.S. cellular industry totaled $1.15 billion in 1988.[124]

How far cellular technology can evolve to meet the rising demand for portability will depend in part on how the public spectrum is allocated in the future. Although cellular technology was originally seen as a spectrum-saving technology, its deployment, like that of American highways, has typically generated more use than the capacity it created. Although the FCC recently agreed to grant the industry additional spectrum, most industry pundits fear these allocations will not suffice.

A second factor that could diminish the future prospects of cellular technology is standardization. Believing that standards may discourage technological innovation, the FCC has decided to back away from setting standards in this area. *25 However, without standards it will be difficult, if not impossible, to establish a nationwide cellular network. If each operator is free to divide up his or her 25 megahertz, and to decide which particular radio technique to use, there will be no way to assure that one operator's system would be compatible with another's.[126]

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117 Clifford A. Bean, "Trends in Mobile Communications," *Telecommunication,* January 1989, pp. 72-75. These services were generally limited to metropolitan areas. It should be noted that the development of cellular radio suffered from considerable regulatory delay. See George Calhoun, "The Next Generation of Cellular Radio," *Telecommunications,* June 1988, pp. 41-45.

1 I* Ibid.

119 The first commercial cellular mobile telephone service was deployed by Ameritech in 1983. For discussions about the diffusion of this technology, see'' Spreading Mobility," *Communications International,* August 1987, p. 8; "America Goes Mobile," *Communications international,* September 1987, p. 22; Rodney Gibson, Gerard MacNamee, and Sunil Vadgama, "Universal Mobile Telecommunication System—A Concept," *Telecommunications,* November 1987, p. 23; and Filip Linden, Jan Swerup, and Jan Uddenfeldt, "Digital Cellular Radio for the 1990s," *Telecommunications,* October 1987, pp. 254-265.

120 Margie Semilof, "The Upscaling of a Basic Carry out Item," *CommunicationsWeek,* CLOSEUP, Apr. 8, 1988, p. C4.

121 See, for instance, James L. Johnson, "The Times They Are A Changing," *CommunicationsWeek,* June 5, 1989, p. 12; see also Semilof, op. Cit., footnote 120, pp. C4-C5; and Frank Grimm, "Towards the Universal Mobile Telecommunication System," *Telecommunications,* November 1987, p. 9.

122 Johnson, op. cit., footnote 121, p. 12.

123 Maribeth Harper, "Will the RHCS Devour the Cellular Industry?" *Telephony,* July 11, 1988, P. 26.

124 Candee Wilde and Glenn Abel, "McCaw Bid Jolts Industry," *CommunicationsWeek,* June 12, 1989, p. 62.

125 The Europeans, in contrast, are taking a more deliberate approach to the pursuit of cellular standards. For a discussion, see Stephen Temple, "Pan-European Cellular Standards Lead the Way," *Telecommunications,* November 1987, pp. 28, 91. In the 1990s, Europe will comprise the single largest cellular radio market in the world. Most recently, Plessey has announced plans to begin constructing a wireless public switched telephone network for the entire United States, based on an enhanced version of the European Group Special Mobile digital cellular radio standard, which supports cheap, pocket-sized handsets. See Graham Finnie, "Plessey Unveils Wireless PSTN," *Telecommunications,* June 1989, pp. 29-30.

126 George Calhoun, "The Next Generation of Cellular Radio," *Telecommunications,* June 1988, pp. 41-45,

Improved Ease of Use

As technologies become more sophisticated and communication systems more complex, it will be important to develop system interfaces that make it easier for individuals to interact with technology in human terms. This means creating machines that can see, speak, hear, and reach conclusions much the same as people do.[127] Failure to develop user--friendly systems will increase the risk of error, which could have serious consequences in a society that is increasingly communication dependent. Fortunately, many new communication devices, ranging from video cameras to private data networks, are now being designed for operation by nontechnical users.

Until recently, computer technology was the exclusive province of a narrow technological elite. The use of computers required a special set of skills and knowledge possessed by highly trained computer scientists and a select group of self-educated computer hobbyists. Advances in hardware design and operation, as well as improvements in software design and applications, have now brought computer technology closer to the general public. Further progress is likely in the future with the development of natural language processors that will allow people to direct computers by conversing with them.

Searching online computerized databases was also done until recently by trained information specialists, such as librarians or technical specialists employed by large companies. Such searches not only required the use of highly specialized and arcane computer commands; users also needed a highly specialized knowledge of the databases themselves. More accessible software designed to reach online databases now makes it much easier to retrieve information using personal computers. Similarly, improvements in the design interface of online systems are making it easier to search and locate information.

Advances in speech processing and its integration into computer and communication systems will play a particularly important role in making these technologies more accessible. There are systems on the market now that can recognize isolated spoken words and phrases from a vocabulary of about 100 words. *28 And technologies are now being developed that can synthesize intelligible, reasonably normal speech from a written text. By the turn of the century-given the present rate of progress in the computerized analysis of natural languages, together with increased computing power—some experts think it will be possible to perform machine translation, and even re-create practical spoken conversation.[129]

Increased Networking Capability

Although seemingly paradoxical, the unbundling of the communication infrastructure, in conjunction with the distribution of intelligence throughout communication systems, has led to the simultaneous reintegration of communication systems through the process of computer networking. While the proliferation of communication networks makes the communication infrastructure more flexible and responsive to some users' particular needs, it could serve to limit communication access if it reduces overall system connectivity.

A computer network is a collection of computers that communicate with each other using common protocols. The computers may be microcomputers, commonly used in homes and businesses, or they may be larger minicomputers, mainframes, or supercomputers. Transmission can be provided using coaxial cable, optical fiber, satellite links, twisted pair, or telephone lines. Connections between hosts can be limited to a local area (local area networks, or LANs), or they may provide long-haul connectivity (wide area networks, or WANs). Employing such systems, data in the form of text, voice, and video can, in principle, be stored, modified, and exchanged by anyone. anywhere on the planet.[130]

Computer networks offer a number of benefits.[131] At a minimum, they can provide electronic mail and

127Ross, Op. cit., footnote 26, P. 27.

128For discussions, see Paul Wallich, "Putting Speech Recognizers to Work," *IEEE Spectrum*, April 1987, pp. 55-57; Torbjorn Svendsen, "Speech Recognition: An Overview," *Telecommunications,* December 1987, pp. 37-40, 65; Ben Hoh, "Beyond the Old Frontiers: Voice Processing Technology Enters the Third Generation," *Telephony,* Jan. 23, 1989, pp. 42-44; and Robert Rosenberg, "Speech Processing: Hearing Better, Talking More," Electronics, Apr. 21, 1986, pp. 26-30.

129Ross, Op. cit., footnote 26, p. 9.

130For a detailed description of computer networks, see Andrew S. Tannenbaum, *Computer Networks* (Englewood Cliffs, NJ: Prentice-Hall, 1981).

131See Peter Denning, "The Science of Computing: Computer Networks," *American Scientist,* vo1. 73, 1985, pp.127-129.

news services.[132] They can also provide remote processing, allowing any computer in the network to access computer programs stored on any other host. Network users can also gain remote access to supercomputers to do advanced graphics, chip design (and remote fabrication), and scientific or economic computer simulation, and can access remote databases. In addition, they can use the network to collaborate with others or to participate in computer conferences.[133] perhaps the most important attribute of networks is that they can sort out people with similar interests and bring them together. This capability will become increasingly important as the problems people face become more complex and the tasks they perform become more specialized.

Given this ability to link like-minded people remotely, it is not surprising that computer networks were initially developed to meet the needs of specific groups of users. For example, ARPANET, the first computer-based message system, was set up in 1968 in the Department of Defense by the Defense Advanced Research Project (DARPA) to provide communication between computer terminals and host computers. Building on the packet-switched network technology developed by DARPA, other agencies developed specialized networks for their research communities (ESNET, CSNET, and NSFNET). Meanwhile, other research-oriented networks, such as BITNET and Usenet, were developed in parallel by academic and industry users who, not being grantees or contractors of Federal agencies, were not served by the agency-sponsored networks.[134] Although telecommunication and electronic industries provided technology and capacity for these networks, they were not the innovators or promoters of these new systems.

Businesses also began to take advantage of computer networking to improve the productivity of their ever more powerful desktop microcomputers. Local area networks,[135] which allow users to rapidly transfer large files of information among personal computers, have been particularly popular in the business community, where they have proliferated without much thought to planning.[136] Describing the situation in the electric utility industry, which by all accounts is quite typical, Taylor Moore notes:

> . . . most utilities' computers and communications systems were designed only to perform specific functions, such as supervisory control and data acquisition in transmission or distribution operations or financial accounting in corporate systems. Most were put in place fairly piecemeal as needs arose or as new technology opened opportunities to automate . . . . Most systems were installed with no-or only limited-capability to communicate with other systems. And rarely have all the systems a utility uses come from the same vendor, with compatible interconnections or standard communication protocols.[137]

Reflecting this increasing demand for networking, the LAN industry has grown from about $2.6 billion in 1987 to approximately $4.2 billion in 1988. And predictions are that in 1992, 55 to 60 percent of new personal computers acquired by Fortune 1000 companies will be connected to LANs.[138]

Given the unruly way in which LANs have been deployed, businesses are now confronted with the task of managing them and trying to incorporate

132 The use of computers for electronic mail systems was originally constrained by the limited availability of computers. With the widespread deployment of personal computers, this is no longer the case. As Stephen A. Casswell points out, the cost of adding electronic mail for most personal computer users has dropped 200 percent in just 5 years. Stephen A. Casswell, *E-MAIL* (Boston, MA: Artech House and Gage Educational Publishing Co., 1988), p. 41,

133 Interest in videoconferencing has been increasing as more inexpensive and Sophisticated digital systems are being developed. The annual rate of growth in the United States has been between *25* and 30 percent. For discussions, see Mark Maltz, "A New Age of Videoconferencing," *Telephony,* June 26, 1989, pp. 30-34; and Scott Douglas, "Why Travel When You Can Call?" *Telephony,* Apr. 3, 1989, pp. 38-42.

134 John S. Quarterman, *The Matrix: Networks Around the World* (Burlington, MA: Digital Press, August 1989).

135 A LAN can be described as "a package of media that includes transmission devices, end-user interface units, gateways, servers, network management, hardware, software, and application software. Such networks typically provide communication between dissimilar nodes within a building, metropolitan, or campus environment." Martin Pyykkonen, "Local Area Network Industry Trends," *Telecommunications,* October 1988, p. 21. For a technical discussion, see also Ivan T. Frisch, "Local Area Networks Versus Private Branch Exchanges," *Telecommunications,* November 1988, pp. 23-26,

136 For discussions of the emergence of the LAN market, see Nina Burns, "Micro Melting Pot," *Computerworld, Nov.* 2, 1988, pp. 19-20; Jennifer Samuel, "Tapping In: Data Base LANs," *CommunicationsWeek,* CLOSEUP, Jan. 11, 1988, pp. 6,7, 10; Jennifer Samuel, "Departmental Nets," Nov. 21, 1988, pp. C12-C13; and Timothy Haight, "LANs Abound," *CommunicationsWeek,* Feb. 6, 1989, pp. 22,24.

137 Taylor Moore, "Building a Framework for Integrated Communications," *EPRI Journal,* July/August 1988, pp. 29-35.

138 Marc Cecere, "Backdoor LANs: How to Manage Unsanctioned Networks," *Computerworld,* Nov. 2, 1988, pp. 31-32.

them into larger and larger networks.[139] As Lee Sustar has described:

> Many companies are now reaching the conclusion that these strays must be gathered back into the mainstream of corporate computing, not only for the sake of accountability but also for improved efficiency for locally networked users, some of whom are beginning to suffer from the limitations inherent in their independent status.[140]

These management and coordination problems are compounded by the fact that standards for high capacity fiber optic LANs, referred to as the Fiber Distributed Data Interface (FDDI), are still being developed.[141] Failure to develop such standards may constrain networking in the future, since the further deployment of more powerful workstations will require higher performance systems.

This trend toward networking is also increasingly evident among individual computer users. A growing number of personal computer enthusiasts, for example, now keep in touch via computer bulletin boards. These networks consist of computerized storage space, offered by a computer owner, that is used to post messages. As detailed in chapter 8, people are now using these systems to find solutions to problems, seek support from others in similar situations, or overcome loneliness.

Although communication providers did not initiate this networking craze, they are working hard to capitalize on it. Some companies, for example, provide networking services to outside users for a profit. Included are service providers such as Telenet, Tymnet, the Source, and CompuServe. Others offer interLAN networking products and services such as bridges, routers, gateways, and brouters[142] (see box 3-C). To better position themselves to offer connectivity, a number of LAN providers are consolidating or forming alliances and partnerships (see table 9-3 in ch. 9). In addition, traditional telephone companies and other ISDN providers also offer solutions to the problems of wide area networking. As Tom Valovic points out:

> As the LAN market matures and ISDN inches closer toward the prospect of significant commercial deployment, the question of the relationship between these two technologies is beginning to be raised in the strategic and marketing arena. ISDN is a standard without a product. LAN, despite some preliminary efforts, is still a product without a standard.[143]

For a summary of the major trends occurring in the LAN industry, see box 3-D.

Increased Targeting Capability

Targeting specific messages to particular categories of people requires high capacity, easily accessible, online storage capability, together with high-speed reprocessing and editing capabilities. Taken together, many of the trends outlined above provide such capabilities, making it much easier to parse information, tailor messages, and address them to particular users and locations.

Using computers, for example, it is now relatively easy to compile and cross-reference mailing lists and telephone numbers so that direct mailers and telephone marketers can carefully target certain receivers. As described in figure 3-6, people often inadvertently register to be placed on such lists when purchasing an item or service.[144] Using technologies such as VCRs and pay-per-view to unbundle programming, users can also adapt mass media content to their own particular interests.[145] "People meters" and other improvements in audience measurement techniques allow media providers to better meet audience demand.

139 Robert Craven, "The Challenge of Enterprise-Wide Internetworking," *Telecommunications*, October 1988, pp. 31-37; see also Lee Sustar, "Pulling LANS Into the Act," *Computerworld*, May *23, 1988,* pp. S1-S4; Roy D. Gemberling, "ManagingLinked LANs," *Telecommunications,* September 1989, pp. 67-69; and Richard Patti, "LAN/WAN Integration," *Telecommunications,* September 1987, pp. 47-54.

140 Sustar, op. cit., footnote 139, p. 1.

141 The market for fiber optic LANs is expected t. triple by 1992. Its growth is tied to the development of a LAN standard. FDDI, which specifies the use of fiberoptic cable providing speeds of 100 megabits per second, is now being developed by the American National Standards Institute. Caryn Fox, "Fiber Lan Market to Triple By 1992," *CommunicationsWeek*, Mar. 20, 1989, p. 14. For another discussion of FDDI, see Michael V. Moore and Vickie A. Oliver, "FDDI: A Federal Government LAN Solution," *Telecommunications,* September 1989, pp. 35-40.

142 William Stallings, "Internetworking: A Guide for the Perplexed," *Telecommunications*, September 1989, pp. 25-30; Debbie Shimman, "Enter the Brouter: An Update on Linking LANs," *Telecommunications*, November 1988, pp. 38-41.

143 Tom Valovic, "Will ISDN Replace LANs?" *Telecommunications*, September 1987, pp. 67-60; see also Martin Sinnot, "ISDN Shows Promise as a LAN Booster," *Computerworld*, May 23, 1988, p. S7.

144 For a discussion, see Jeffrey Rothfeder, "Is Nothing Private?" *Business Week*, Sept. 4, 1989, pp. 74-82. See also Gary Slutsker, "Relationship Marketing," Forbes, Apr. 3, 1989, pp. 145-147.

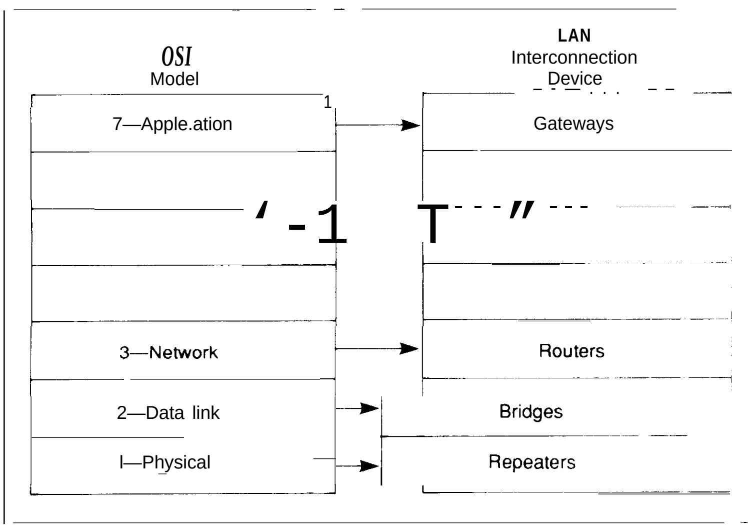
145 For one discussion, see peter Ainslie, "Confronting a Nation of Grazers," Channels, September 1988, p. 54.

Box 3-C—Repeaters, Bridges, Routers, and Gateways

Networks are designed in layers, starting at the bottom with hardware and moving upwards towards software applications. For example, networks built in conformance with the International Organization for Standards reference model, referred to as Open Systems Interconnection (OSI), consist of seven layers—the physical, data link, network, transport, session, presentation, and application. Where network equipment does not conform to this model, several devices can be used to achieve interoperability.

As can be seen in the figure below, there are four basic devices that can be used to interconnect networks into a larger network. These include repeaters, bridges, routers, and gateways.

Repeaters, Bridges, Routers and Gateways Mapped Into The OSI 7 Layer Model.



SOURCE: Reproduced by special permission of *Telecommunications* magazine.

Repeaters: Repeaters are the most basic of all the tools used for internetworking. Operating at the physical layer, they regenerate signals that are transmitted across the network. Repeaters can connect local area networks (LANs) that use the same or different media, but they cannot connect them if they use different protocols. Thus, while a repeater can connect an Ethernet LAN to another Ethernet LAN, it cannot connect an Ethernet LAN to a Token Ring LAN.

Bridges: To connect LANs that employ dissimilar protocols requires abridge. Bridges operate at Layer 2 of the OSI reference model, and thus they are protocol transparent. Bridges also offer some intelligence. They can filter messages to determine which ones should be forwarded to another segment of the network. Because their operations are more complex, bridges function more slowly than repeaters.

Routers: Routers are more intelligent than bridges. Whereas abridge can only determine whether or not to pass a message forward, a router will determine the optimal route that the message should take. This capability reduces not only the cost of transmission, but also network congestion. Routers operate at Layer 3 of the OSI model. They are protocol sensitive, and hence can only connect LANs based on the same upper-level protocols.

Brouters: Brouters combine some of the bridge's functions with those of the routers.

Gateways: Gateways operate at the applications, or top level of the *OSI* reference model. They link dissimilar networks by translating from one set of protocols to another, thereby overcoming differences in transmission speeds, signal levels, and data format.

SOURCE: Debbie Shimman, "Enter the Brouter—An Update on Linking LANs," ***Telecommunications***, November 1988, pp. 38-43. Also William **Stallings**, "Internetworking: A Guide for the Perplexed," *Telecommunications*, September 1989, pp. 25-30.

Box 3-D—Major Trends in the Local Area Network (LAN) Industry

Vendor consolidation: Mergers, acquisitions, and joint ventures among traditional LAN vendors are increasing as the industry matures and vendors consolidate. Driving factors include convergence in LAN applications and products and expanding geographic network scope towards WANs (i. LAN-to-LAN integration).

Public telephony network entrants: Local telephone companies will increasingly offer LAN and WAN on an intra-LATA basis as central-office switches are enhanced with data networking functionality. Telcos will either be a competitor to LAN vendors or possibly a partner in serving certain key strategic end-user accounts.

Software differentiation: LAN software is becoming the core differentiating technical factor. Vendor strategies are based on software platforms and protocols, and user product selections are based more on software performance than the underlying hardware.

Dual standardization-Ethernet and token ring: Recognizing that Ethernet and token ring have different applications suitability, users are increasingly standardizing on both and then allowing individual procurements to be made between them as applications dictate. Strong product support from multiple vendors in each case reinforces the dual standardization and places vendors of proprietary standards at more of a disadvantage than previously.

Network management: Before the industry's vendors have been able to adequately offer network management products for a single LAN, users are demanding more sophisticated products that can manage and integrate multiple LANs over a geographically dispersed scope. Network management limitations continue to be the single most frequent reason why users limit the size and scope of LAN implementations.

Network software performance and packaging: Multiple software protocols and interfaces will become more commonly included in a single server or gateway interface. As protocols are embedded in a common interface or protocol stack, overall network memory requirements will be reduced and users will have more capacity for applications-specific tasks.

FDDI emergence: Fiber-optic technology cost/performance is becoming feasible for LAN-to-LAN backbone integration *and* will be feasible for linking high-power workstations within 2 years. FDDI will become established as the primary fiber LAN standard. Major vendor support is now beginning, as seen by FDDI plans announced by DEC and IBM.

Pre-OSl acceptance of TCP/IP: TCP/IP is rapidly becoming established as a high-performance network protocol—recently in commercial applications segments as well as the federal government for which it was originally developed. User investments will not be discarded for at least several years until OSI protocols solidify--even then, specific integration plans will have to be available to address TCP/IP-to-OSI needs.

Workstation networks: More LANs will be based on nonhost access needs. As early mainframe and minicomputer processing power becomes available at the desktop, LANs will serve to distribute information and computing power in high-performance workstation groups.

LAN *security:* Beyond physical transport security (e.g., encrypt}(m), LAN managers are facing growing needs to establish information security-from unauthorized internal as welll as external access. As LANs proliferate so does general distribution of information, thereby compounding information security management in contrast to earlier centralized data processing environments.

Key: FDDI = fiber distributed data interface, LAN = Local area network, LATA -- local access and transport area, OSI = open systems interconnection, TCP/IP = transport control protocol/internet protocol, WAN = wide area network.

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Figure 3-6-How a Consumer's Credit File Can Travel

SOURCE: Reprinted from the Sept. 4, 1989 issue of *Business Week*, by special permission. Copyright 1989 by McGraw-Hill, Inc.

Targeting, however, is a two-way street. While individual users can employ targeting devices to customize the messages they receive, the transactional records they leave behind can be compiled and manipulated by others to target them for unsolicited information.

STRUCTURAL CHANGES IN THE COMMUNICATION INFRASTRUCTURE

For almost a century, technological developments in communication supported and sustained the U.S. communication regime, which was vertically structured around distinct media. Within each industry, control flowed generally from the top down, and relationships among the key players were extremely stable.

In telecommunication, for example, the business decisions facing a central office executive were quite straightforward because relationships among suppliers and customers were rather cozy.[146] And telecommunication users played almost no decisionmaking role at all. The situation was not much different with respect to the mass media. Although there was no monopoly, the large film studios and the three major television networks made the key decisions, establishing programming and determining the means of its distribution.

The patterns of these relationships have now been overturned, due in part to the technological trends identified above. Given the rate of technological change, it is difficult to predict what the future might hold. Nonetheless, four major structural changes in the communication infrastructure can be discerned:

1. the globalization of the communication infrastructure,
2. the heightened importance of the large user,
3. the need for system integration and the rise of the system integrator as a key player, and
4. the multiplication of communication networks.

Globalization of the Communication Infrastructure

With the liberalization of communication regimes worldwide, technological advances and economic developments will foster an increasingly global communication infrastructure. In the short period since the divestiture of AT&Tin 1984, communication vendors and users alike have taken a number of steps that will inexorably lead to such an outcome.

Historically, U.S. needs for communication-related products and services were met domestically. However, by rupturing old relationships and the established way of doing things, the process of divestiture opened up the U.S. market to foreign countries. Many foreign firms were quick to take advantage, and understandably so. At present, the United States represents approximately one-half of the world market for telecommunication equipment and services. And the Department of Commerce estimates that by 1992 the value of this market will be around $1 trillion.[147] Meanwhile, the world market is also sizable, estimated to be $140 billion by 1992[148] (see table 3-6).

Technological developments are also contributing to this trend. Although advances may lower the costs of products and services in the long run, in the short run such developments can greatly increase the cost of doing business. For example, it now costs approximately $2 billion over a 10-year period to develop a modern central office switch.[149] To spread these development costs, firms are expanding their markets beyond their national boundaries.

European firms have been particularly active in this regard. A good illustration is British Telecom, now the world's fourth largest telecommunication company.[150] In 1984, British Telecom did not boast an office outside of the United Kingdom; today, it has offices in 30 countries.[151] As part of its global strategy, British Telecom spent $1.37 billion to purchase a 22-percent interest in McCaw Cellular, the largest cellular carrier in the United States. To round out its efforts, it also bought the Tymnet

[146] See Robert J. Cymbala, "Strategies for Global Markets," *CommunicationsWeek*, Oct. 19, *1987*, p. 20.

[147] Jefferson Grigsby, "Global Report," *Financial World*, Apr. 18, 1989, p. 33.

[148] Fritz W. Ringling, "Going Global," *Telephony*, Aug. 28, 1989, p. 39.

[149] Grigsby, op. cit., footnote 147, p. 33.

[150] For a discussion, see Tom Valovic, '*BT Ventures Proliferate as International Markets Complicate," *Telecommunications*, September 1989, pp. 57-58.

[151] Grigsby, op. cit., footnote 147, p. 36.

Table 3-6-World Telecommunications Equipment Market (billions of dollars)

	1988 actual	1989 estimated	1992 projected
Customer premises equipment	40.0	44.0	59.0
Transmission	23.0	22.0	19.0
Cable and outside plant	11.5	11.0	9.0
Switching	40.0	43.0	53.0
Total	115.0	120.0	140.0

SOURCE: Reprinted with permission from *Telephony,* Aug. 28, 1989, p. 40

subsidiary of McDonnell Douglas Corp., thereby acquiring the second largest public data network in the United States. 152 Among British Telecom's other North American holdings are 51 percent of Mitel, the Canadian-based PBX manufacturer, and 80 percent of Metrocast, a national paging service.[153]

Ericsson, the third largest telecommunication company in Europe, has made equally impressive strides, now drawing 80 percent of its revenues from exports. Entering the mobile telephone business in the beginning of the 1980s, the Swedish company now accounts for 25 percent of the U.S. mobile telephone market and 40 percent of the world market.[154] While slow to enter the European telecommunication market, Ericsson has had considerable success selling in the Middle East, the Far East, and Latin America.

Given the success of Minitel in France, it is not surprising that the French have based their U.S. market debut on the future prospects of videotex and information services. *55 In May 1988, Minitel Services, a subsidiary of France Telecom's Intelmatique Division, was established through a joint venture between Minitel USA and Infonet. Thus, Americans with modems will now be able to access American, French, and Canadian information, entertainment, shopping, and other services.

Global acquisitions have not been limited to telecommunication. In the years since divestiture, foreign companies have spent more than $12 billion to buy book, magazine, movie, record, and printing companies that are based in the United States.[156] As one industry analyst notes with a touch of irony:

> Bruce Springsteen's anthems about life in America have made him a superstar, but when it comes to his record label, a Japanese company now calls the tune. [157]

In like fashion, the German media conglomerate, Bertelsmann AG, is today the owner of RCA Records and Doubleday Books, which publishes the prototypical American magazine classics, *Young Miss* and *Parents Magazine. '58*

It is only recently that U.S. communication businesses have begun to fully explore the possibility of developing their markets abroad. One reason for the delay is that, with deregulation proceeding in foreign countries more slowly than in the United States, U.S. firms have not been able to gain access to their markets. This situation should improve in the future, as all countries are now experiencing considerable pressure to liberalize their communication regimes.[159] A second reason why U.S. firms have been slow to develop global strategies is that the size of the U.S. market has been generally large enough to fulfill their revenue needs.[160] With a saturated domestic market and increased competition from foreign suppliers, such a parochial approach is becoming harder and harder to sustain.

in response to this changing environment, a number of U.S. companies are rapidly seeking foreign partnerships and alliances. Recently, for example, AT&T entered into a major agreement with Italtel to help it modernize the Italian telephone network and to jointly produce equipment for the European market.[161] And the BOCs, eager to extri-

152 John Williamson and Carl Wilson, "British Telecom Buys Tymnet; Expands U.S. Datacom Positron," *Telephony, Aug.* 7, 1989, p. 8.

153 Ibid.

154 Grigsby, op. cit., footnote 147, pp. 34-35.

155 Kathleen Killette, "French Minitel Services Coming to America," *CommunicationsWeek, Nov. 7, 1988,* p. 46.

156 See *Ben* H, Bagdikian, "The Lords of the Global Village," *The Nation,* June 12.1989 pp '?99-819.

157 Paul Farhi, "The Quiet Invasion of the Media Moguls: Global Firms' U.S. Acquisitions Raise Fears." *The Washington Post, Nov. 27, 1988,* p. HI.

158 Ibid.

159 Thus we see, for example, that the European Economic Commission is pushing legislation that would end state monopolies for certain telephone services. For a discussion, see M. Pyykkonen and S. Shekar, "The Impact of Europe 1992 on the Telecom Industry," *Telecommunications*, August 1989, pp. 59-60.

160 For a discussion, see Ringling, op. cit., footnote 148.

161 John Williamson, "AT&T, Italtel Finalize Stock Swap Agreement," *Telephony,* June 12, 1989, P. 8.

cate themselves from domestic regulatory restrictions, are now undertaking a number of international ventures. US West, for example, has joined a company from Hong Kong to bid for that country's first cable system. Pacific Telesis has joined Cable &Wireless to develop a $350 million undersea cable to Asia. And Bell South is involved in cable enterprises throughout the world.[162]

Characterizing the upheaval that is taking place in an increasingly global communication environment, telecommunication analyst Tom Valovic notes:

> It is increasingly an anything-goes scenario, with benefits accruing to users if, and only if, they can stop scratching their heads and start figuring out which companies they should start making alliances with. Take something as seemingly innocuous as cellular in the U.S. In Nynex's territory, there are no less than two other BOCs—Southwestern Bell and Bell South-looking for cellular business (besides, of course, Nynex). Extend that to the global market and the BOCs as a group have more irons in the fire than McDonald's has ISDN lines. Bell Atlantic, for example, is involved in upgrading Spain's public telephone network-no mean feat. But, as the British like to say, turn-about is fair play, so we should expect that the PTTs will increasingly be scouting for prospects in the BOCs backyards as well.[163]

The Growing Importance of the Large User in Defining the Communication Infrastructure

In the regulated environment before divestiture, communication users were extremely limited in the degree to which they could influence the communication infrastructure. The key decisionmakers were, first, the communication vendors, and second, public policy officials. As two industry analysts characterize the situation:

> Typically, the major vendor (or vendors) established industry standards regarding systems architecture, product features, and incorporation of new technology, technical protocols, performance standards and pricing. These parameters became the benchmarks against which other vendors designed and marketed their own products. And so in many respects, vendors paid more attention to one another than to the user. . . .
>
> Government policymakers determined market participants, specified which products and services the market participants could offer, and approved the rates that could be charged for these services.[164]

The role of the user began to change, however, in the face of technological advances.[165] As described above, the dispersal of intelligence throughout the network, together with the unbundling of communication products and services, gave users much greater control. It was, in fact, the new-found ability of users to design their own equipment or create their own networks that ultimately led to the breakup of the old communication regime.

Economic developments have also supported an enhanced role for the user, especially the large-business user. With the shift toward an information-based service economy, communication is becoming more of a strategic, competitive factor in business (see ch. 6). Hence, many companies are now spending unprecedented amounts on communication services. For a service business such as Citicorp, for example, telecommunication has become the third largest cost item.[166] Under such circumstances, large users are far more likely to both seek and bargain for the best set of arrangements to meet their own particular needs. With a much greater stake in communication and information services, they are also more likely to organize as a group to achieve their common ends. Business users also have much greater economic clout. Approximately 50 percent of all long-distance traffic is accounted for by 5 percent of domestic and long-distance users.[167]

Viewing communication as a competitive weapon, business users have been quick to adapt to their new role. As detailed in chapter 6, many have opted to bypass traditional providers, devising communication networks of their own. Others have joined forces to establish user groups to design and develop their own sets of standards. Users' efforts to

162 Grigsby, op. cit., footnote 147.

163 Valovic, op. cit., footnote 150, p. 57.

164 Sandra G. Tuck and Audley M. Webster, "Vendors and Users: They Need to Start Building Together," *CommunicationsWeek*, CLOSEUP, Feb. 29, 1989, p. 13.

165 For a history of the changing role of the large business user, see Dan Schiller, *Telematics and Government* (Norwood, NJ: Ablex Publishing, 1982).

166 Eli Noam, "The Public Telecommunications Network: A Concept in Transition," *Journal of Communication*, vol. 37, No. I, Winter 1987, pp. 30-48.

167 Peter Cowhey, "The Globalization of Telephone Pricing and Service," *Telecommunications*, January 1988, p. 39.

develop protocols for manufacturing and office automation are an example.[168]

Vertical Integration of Key Industry Players and the Rise of the System Integrator

As aptly portrayed in the nursery rhyme "Humpty Dumpty," trying to put things back together again often presents a great challenge. In the post-divestiture environment, the winners will be the vendors who do this best. As Peter Huber perceived with prescience in *The Geodesic Network,*[169] the demand for system solutions, one-stop shopping, and ease of management will eventually lead to the vertical reintegration of the communication industry. A number of signs already point in this direction.

One major indicator is the number of mergers and acquisitions occurring in the industry. Many businesses spawned by divestiture are now finding their situations more difficult. Not only is there more competition; users, having become more sophisticated consumers, are seeking more technically advanced and integrated solutions to their problems.[170] Notes Elizabeth Horwitt in this regard:

> They tell me that corporate network managers are crying for Mother-Ma Bell, that is. Well, why not? In the predivestiture days, companies ordered everything from AT&T and howled for AT&T whenever there was a problem. Those were the days. Now post-divestiture has complicated telecommunications departments' lives, with an ever-shifting array of tariff structures and diverse, rapidly evolving technology. Management is simultaneously demanding strategic, reliable communications and a firmer bottom line.[171]

To survive in this environment, businesses are finding it necessary to team up with one another. This kind of a response is particularly evident today in the market for LANs.[172] Throughout the industry, the number of players has been dwindling, with all of the major LAN companies—including Thernet, Novel, 3 Corn Corp., Excelan, Sytek, Inc., Netar Inc., Interlan, and Bridge Communications—involved in at least one acquisition.[173]

Many companies are also taking advantage of technology convergence to enhance their overall system capabilities. Digital Equipment, for example, recently announced four new alliances designed to bolster its strength in communication. It has signed agreements with DSC Communications Corp. to develop a service control point, with Cincinnati Bell Information Systems to design and market a new cellular billing management system, with Siemens Public Switching Systems to develop and market an information service gateway for the telephone market, and with DATAP Systems to help market its operations support system for telephone company network management.[174] In like fashion, AT&T has offered $250 million to purchase Paradyne Corp. in an effort to strengthen its position in the data communication marketplace.

To package their services to meet the needs of the business user, most vendors now see themselves in the role of "systems integrator." These vendors might include the classic systems integrator, such as Computer Sciences Corp. or Electronic Data Systems Corp., as well as major computer vendors, the BOCs, the big eight accounting firms, and independent companies such as Network Management Inc., that have merged to compete with the larger vendors.[175] According to one analyst: "They're all hungering for a pie that [is said] to be growing at 20 percent a year.''[176] As described by another:

> This whole thing of network management isn't about providing end users with what they want to see. The fight is about grabbing control of network management. He who manages the network controls the data processing center.[177]

168For discussions, see Stan Kolodziej, "No More Money to Burn: Industry Demands Solutions," *Computerworld*, Sept. 7, 1988, pp. 31-M; and Mitch Betts, "MAP/TOP User Patrons Plan Crusade Expansion," *Computerworld*, Feb. 20, 1989, p. 42.

l@ Huber, op. cit., footnote 71.

170For a discussion, see John Keller, "As the Big Get Bigger, the Small May Disappear," Business *Week*, Jan. 12,1987, p. 90.

171Elisabeth Horwitt, "When Others Tend Your Net," *Computerworld*, Mar. 6, 1989, p. 66.

IT&e Timothy Haight, "Merger Marks the Industry's Midlife," *CommunicationsWeek*, Apr. 3,1989, pp. 1, 46.

173Ibid.

174Carol Wilson, "Four New Alliances Target Telcos," *Telephony, May* 29,1989, pp.15-16.

175Kelly Jackson, "The Diversification of Systems Integration," *CommunicationsWeek*, Aug. 28, 1989, pp. 22, 23.

176Mark Breibart, "Systems Integration Surge," *Computerworld Focus on Integration*, Feb. 4, 1989, p. 12.

177As cited in Christine Bonafield, "AT&T Targets SNA Customers," *CommunicationsWeek*, June 20,1988, P. 1.

Multiplication of Communication Networks

In the past, one telecommunication network existed to provide universal service to all users. This arrangement was quite suitable, as users needs were very similar and the services that could be offered were relatively limited. Businesses used the telephone for voice communication in much the same way as households did.

Today, this is no longer the case. For many businesses, transmitting data now represents a more significant cost item than transmitting voice. Different kinds of businesses increasingly have different kinds of business needs. Thus, banks and other financial institutions have developed specialized communication services such as the Society for Worldwide Interband Financial Telecommunications (SWIFT'), while manufacturers have developed their own communication protocols, such as manufacturing automation protocol (MAP). Even system integrators are beginning to differentiate themselves by providing specialized networking services.[178]

Given this increased demand for specialized communication services, together with the technical ability to unbundle and reconfigure communication systems, the number of communication networks that comprise the communication infrastructure is likely to multiply in the future. As Eli Noam has pointed out:

> The emergence of technological and operational alternatives undercut the economies of scale and scope once offered by the centralized network. In the past, sharing a standardized solution was more acceptable to users because the consequential loss of choice was limited and outweighed by the benefits of the economies of scale gained. As the significance of telecommunications grew, however, the costs of nonoptimal standardized solutions began to outweigh the benefits of economies of scale, providing the incentive for nonpublic solutions. Furthermore, some users began to employ a differentiation of telecommunication services as a business strategy to provide an advantage in their customer's eye. Therefore they affirmatively sought a customized rather than a general communication solution.[179]

[178] Kelly Jackson, "The Diversification of Systems Integration," *CommunicationsWeek*, Aug. 28, 1989, pp. 22-24.

[179] Eli M. Noam, "The Future of the Public Network: From the Star to the Matrix," *Telecommunications*, March 1988, pp. 58-59,65,90.