Evolution of the Intelligent Telecommunications Network

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Anyone, at any time and virtually anywhere in the United States, can pick up a telephone and be connected almost instantly to any of about 175 million other telephones in this country and many more abroad. Placing a telephone call—something Americans do more than three-quarters of a billion times per day—is a simple task. But the nationwide telecommunications network that makes this possible is the largest and most complex mechanism on the earth, capable of interconnecting both people and machines and of carrying not only telephone calls but also a wide variety of other signals such as data communications, television, facsimile, and teletype. It is an "intelligent" network, and it is our society's key link to the information age.

Summary. A stream of new technologies has transformed the nationwide telecommunications network into the world's largest and most sophisticated information handling system. Computers and software have made the network "intelligent" and allow it to be programmed with great flexibility to bring a myriad of new services to homes and offices.

This article focuses on the evolution of the nationwide telecommunications network, whose facilities are owned by about 1500 independent telephone companies and other common carriers as well as the Bell System. This network has become the world's most sophisticated information-handling system by steadily incorporating state-of-the-art technology based on fundamental scientific advances. Increasingly, information in the network is handled by high-speed, digital transmission systems connected to electronic switching systems that are controlled by digital computers (*1*). The network is called intelligent because these computers perform extremely complex tasks and can be reprogrammed to perform new tasks and provide new services without rewiring or physical modification. Increasing intelligence is making the network more versatile and flexible, enabling it to provide a wide variety of information-age telecommunications services.

The facilities of the nationwide network include 22,000 switching centers and over 1 billion miles of transmission paths. Its trillions of interrelated parts, all designed to interact compatibly and reliably on user command, can promptly complete any of 6×10^{15} possible connections. Overall, the network represents a capital investment of about \$170 billion—about \$1000 worth of equipment behind every telephone.

The network's ability to adapt rapidly to changing conditions saves money by making the most efficient use of all the equipment in the network. It also permits quick and effective communication during disasters and emergencies. During the 1979 nuclear accident at Three Mile Island, for instance, emergency calls poured into and out of the accident area. To handle the surge and avoid blockages, calls were rerouted according to a coordinated, preplanned network management strategy that allowed 1,745,000 calls—almost double the normal traffic volume—to flow smoothly into and out of the area on a single day. In 1975, when a major fire destroyed a New York City telephone switching office, many callers in the New York area never realized that they were speaking to one another via connections set up through Los Angeles. And during the New York City blackout of 1965, the telephones continued to work.

Telecommunications is such an essential part of our nation's social and economic fabric that the network's computers must be even more reliable than the best general-purpose computers. The computer that controls an electronic switching system, for example, includes redundant hardware and self-diagnostic software designed to keep the system operating trouble-free for all but 2 hours of its 40-year lifetime. The network is never shut down for maintenance, checkups, repair, or improvements, so stringent reliability standards apply to other network elements as well. Continuous modification and improvement—from the installation of a 100,000-circuit switching system to the nationwide introduction of Touch-Tone signaling—are accomplished without any interruption in service.

Today's network is an accomplishment largely of the last few decades, but it was made possible by a stream of improvements over the past century. All have been driven by the nation's communications needs and made possible by intensive research and development in many areas of science and technology. In addition, all improvements have been based on planning for the network as a whole—a hallmark of telephony from its beginning. Advances in telecommunications technologies gave birth to the solid-state and data-processing industries. As a result, the United States not only has enjoyed the world's finest telecommunications service, but also is leading the world into an age in which most of the work force will create, process, or disseminate information.

From Telephony to Telecommunications

During three-quarters of a century, from Alexander Graham Bell's invention of the telephone in 1876 to the introduction of direct distance dialing in 1951, the goal of telephony was the achievement of "universal service"—providing telephone service to anyone who wanted it at reasonable cost. This goal, proclaimed by AT&T president Theodore Vail in 1907, was later codified by Congress in the Communications Act of 1934. But several difficult technical challenges had to be overcome before universal service could be achieved.

The first was the need to find efficient ways to interconnect telephones. Even before the turn of the century, the telephone instrument itself had become fairly rugged and reliable. As the number of telephones grew arithmetically, however, the number of potential connections among them grew geometrically, and

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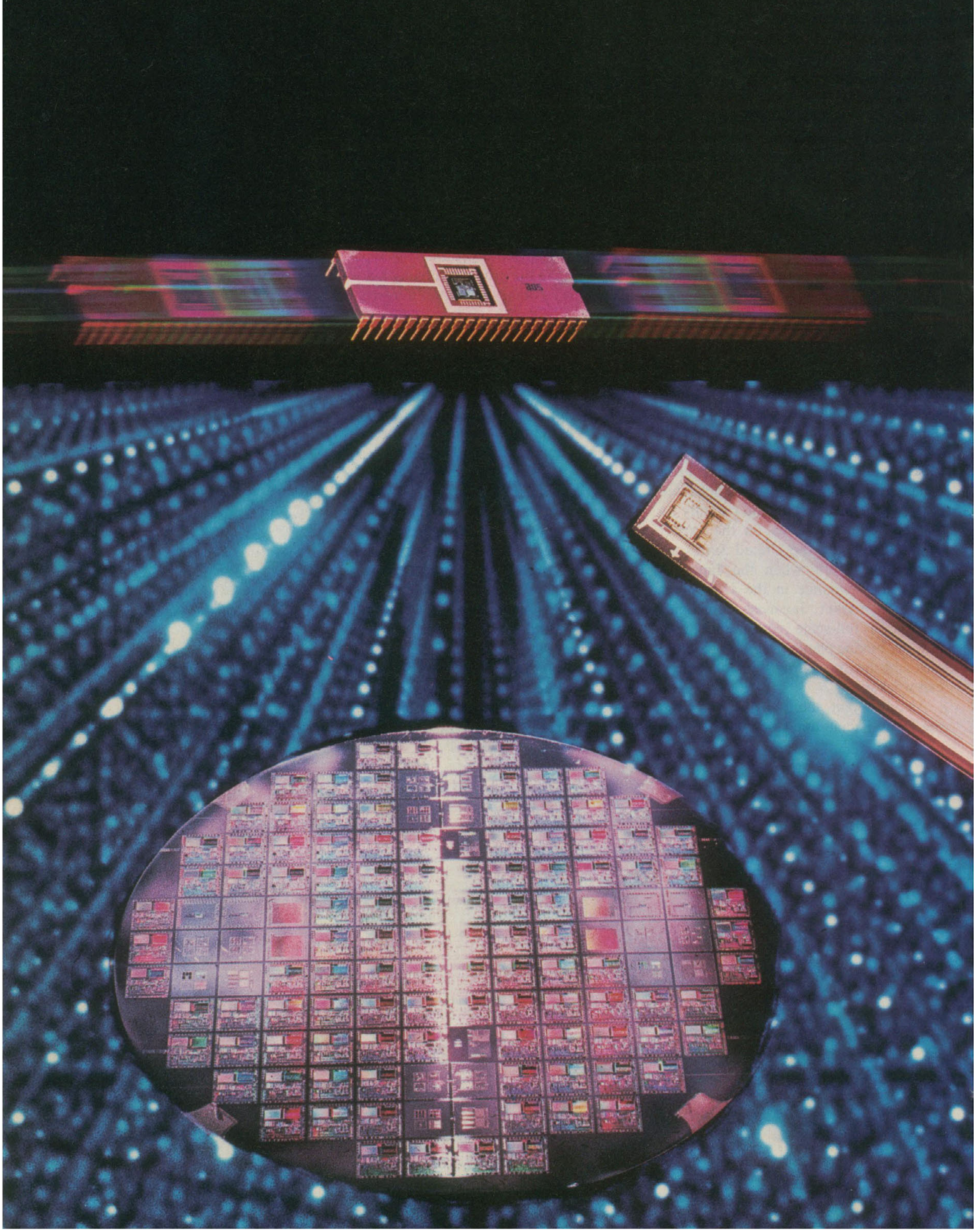
Communications and Personal Services



routing calls quickly became a problem. The concept of a central office—to which a large number of local telephones were commonly linked—enabled operators to route calls through plug-in switchboards. In 1889, A. B. Strowger invented a dial telephone system that paved the way for users themselves to place calls through the central switching office. Such advances spurred the rapid growth of local urban telephone networks.

The next challenge, interconnecting local networks into a national network, required systematic planning and establishment of network-wide standards for performance and design. It also required great improvements in the quality of voice transmission over long distances. Some of the best scientific and engineering minds of the day tackled this problem. M. I. Pupin's invention of the loading coil boosted signal strength sufficiently for calls to be made between cities, but it was Lee De Forest's 1906 invention of the Audion, made practical as a vacuum tube amplifier by H. D. Arnold, that allowed operators to set up the first long-distance calls from coast to coast in 1914.

The wave filter and H. Black's 1927 invention of the negative feedback amplifier further improved voice quality. In the 1930's and 1940's, development of carrier modulation techniques led to multichannel coaxial cable and microwave radio transmission systems that dramatically lowered the cost of long-distance calling.

Once local networks were interconnected in a reliable national network, the volume of telephone traffic increased so rapidly that switching equipment became strained, and more and more operators were needed to handle administrative functions. This posed a third challenge—the development of mechanized equipment. Rudimentary intelligence began to appear in automatic systems that recorded billing information in a form suitable for machine processing. In the 1930's, plans were made for a hierarchy of switching systems, which would be necessary to handle nationwide traffic automatically.

Development of the crossbar switching system, which used electromechanical relays to perform intelligently, greatly increased the network's capabilities. In earlier "step-by-step" switches, the equipment used to set up connections was also required to maintain them. But in crossbar switches, the equipment used to establish connections was then released to handle other calls. "Common" control equipment also could "remember" each called number, select a route through the switching system, and seek alternative routes if necessary.

The culmination of these advances was the introduction of direct distance dialing in 1951. Nationwide direct dialing was the result of a systems engineering effort that included establishment of a network hierarchy and routing plan, a standard nationwide numbering plan, and systems that could handle automatic billing and perform all the necessary control functions. With direct distance dialing, the telecommunications network could automatically interconnect tens of millions of users through thousands of switching centers across the country.

Science and technology were also transforming telephony into telecommunications as the network began to interconnect machines as well as people and to carry pictures and data as well as voice. As early as 1924, a method for transmitting pictures over telephone lines, developed by H. E. Ives, was used at the national political conventions. Telephoto was soon followed by work on television, and in 1927 the first long-distance transmission of television in the United States was achieved. Teletypewriter service was introduced in 1931 and was followed by improvements in systems and devices for transmitting digital data over telephone circuits. By the 1950's, this work resulted in dataphone service, which made it possible for users to transmit information from outlying points to a central computer installation and then to distribute the results. In addition, by the 1950's the telecommunications network was distributing nationwide radio and television programming (*2, 3*).

Over its first 75 years, the network had become a masterfully constructed machine capable of providing virtually everyone with low-cost, high-quality telephone service. It was on its way to becoming a versatile system capable of handling information in a variety of forms, and on the horizon lay several powerful technologies that clearly marked the course for the future.

Key Technologies

Prior to World War II, people of foresight had recognized the limitations of the vacuum tube. In 1939, M. J. Kelley of Bell Laboratories established a research program with the explicit goal of funding a smaller, more reliable amplifying device. The search paid off magnificently in 1947, when J. Bardeen, W. H. Brattain, and W. Shockley invented the transistor. The transistor made possible solid-state integrated circuits and modern telecommunications. With rapid dissemination of transistor technology through publications, symposia, and demonstrations, the transistor's invention put the United States far ahead in technology, created a solid-state electronics industry with over $10 billion in current sales, and revolutionized data processing and consumer electronics (*4*).

Even before the transistor was invented, A. H. Reeves, working with vacuum tubes, suggested in 1937 a feasible means of using on-off signals to transmit voice. The approach, called pulse code modulation, measures the amplitude of the speech wave form about 8000 times a second and converts each measurement into a binary number. The sequence of binary numbers is transmitted in the form of electrical pulses, and the speech wave form is reconstructed at the receiving end. There were early applications of pulse code modulation in military systems. But vacuum tubes were unreliable, power-hungry, and costly. The availability of the transistor made pulse code modulation practical for commercial applications.

The transistor also had a great impact on digital computers. In 1937, G. R. Stibitz at Bell Laboratories used relays and other telephone equipment to construct the first electrical digital computer. Soon afterward, he demonstrated that a remote terminal could be linked to a host computer via telephone lines (*5*). During World War II, the needs of the military—particularly for fast, accurate fire-control systems—hastened progress in the computer art. Harvard University's Mark I computer, the University of Pennsylvania's ENIAC, and J. von Neumann's conception of a stored-program, general-purpose computer demonstrated the potential of machine intelligence for a wide range of applications. Electrical computers soon left their mechanical predecessors far behind. In 1958, J. H. Felker and his associates at Bell Laboratories built the first fully transistorized digital computer. The transistor proved to be an ideal device for use in digital systems, and the digital computer revolution quickly followed.

At about the same time, transistor technology meshed neatly with rapidly evolving space technology, leading to the success of J. R. Pierce's proposal for communications satellites. After several experiments with passive reflecting satellites, the Telstar satellite—the first radio repeater to be placed in earth orbit—was launched in 1962. With Hughes Aircraft's development in 1963 of the Syncom synchronous satellite, which remained "fixed" over one point on the earth's surface, satellites opened the door to instant communications throughout the world. Although satellite technology has had a modest impact within the nationwide network, it is now being used extensively in point-to-point communications and distribution of many cable television channels, and is being developed to provide extensive digital communications capability.

Another breakthrough occurred in 1957, when C. H. Townes and A. Schawlow proposed the laser. This technology soon evolved into continuously operating gas lasers and tiny, reliable solid-state lasers. The extremely intense, highly directed beam of coherent light from solid-state lasers has enormous information-carrying capacity (*6*). But an efficient transmission medium for light had to be found. The ideal solution came with the emergence of transparent glass fibers which "conduct" photons even more efficiently than copper wires conduct electrons (*7, 8*). Both lasers and fiber lightguides are ideally suited to high-speed digital transmission. The laser is simply turned on and off by the digital pulse stream. Glass fibers are now becoming economically competitive with copper cable (*9*), and lightwave (or fiber optic) technology, already well established in the network, is expected to permeate all transmission elements.

Putting the Key Technologies Together

The potential impact of the transistor on the telephone network was recognized immediately, and Bell Laboratories began planning for the introduction of solid-state digital technology. Unlike analog technology, which represents information as continuously varying electrical currents, digital technology represents information by the presence or absence of electrical pulses. Although digital technology requires greater transmission bandwidths than analog, digital signals are more robust and digital techniques are extremely well suited to solid-state electronics and to computer-generated information.

Early solid-state circuits, though costly, were promptly used in two digital systems: the T-1 carrier system, which placed 24 voice channels on a single pair of wires in ordinary telephone cable, and the No. 1 electronic switching system (ESS) (*10*), which used the techniques of a digital computer to control the switching of telephone calls. Both applications of solid-state digital technology proved remarkably successful. The T-1 system went into service in 1962 (*11*), and the Bell System now has 130 million circuit-miles of digital transmission facilities—much more than exist in the rest of the world. The No. 1 ESS went into service in 1965, and today thousands of computer-controlled electronic switching systems offer a wide variety of advanced services to both residential and business users.

The potential of a largely digital telephone network also was quickly recognized. The T-1 digital carrier system interconnected local switches and coupled them with the large toll switches that handled long-distance calls. In the 1960's, the growth of T-1 systems, along with the rapidly declining cost of digital integrated circuits, suggested that rather than switching analog voice signals, large toll switches might switch the digital pulse streams carried by T-1. Digital switching could greatly simplify the transmission-to-switching interface. In addition, it would allow time-division switching, in which some switching paths are time-shared among many calls. In certain cases, this would offer cost and operational advantages over space-division switching, in which a path through the switch is dedicated to a single call for its duration.

Following a massive research and development program, which cost $400 million and took 2500 person-years of effort, the No. 4 ESS "superswitcher" began commercial service in 1976. This machine, which is capable of handling more than 1/2 million calls per hour, is based entirely on the technology of the information age. It is a solid-state, time-division switch for digital signals, controlled by an ultrareliable digital computer containing several million words of programmed instructions. In addition, the No. 4 ESS offers great flexibility through software changes in the network that controls it. It also provides a convenient digital access point in the heart of the network, facilitating attachment of equipment frames for new network services. And it marks a giant step toward a largely digital nationwide network (*12*).

Time-division digital switching in local central offices had been demonstrated in 1959 by project ESSEX at Bell Laboratories (*13*), but digital technology was too costly for use in local switching at

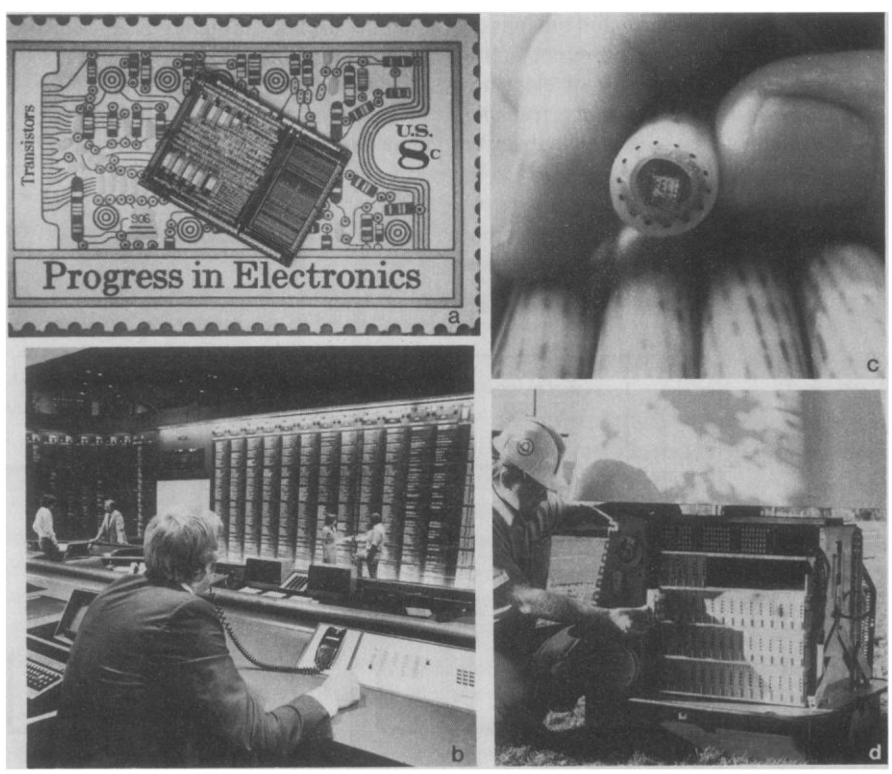


Fig. 1. Applications of key technologies. The transistor led to very large scale integrated circuits such as the BELLMAC-32 microcomputer (a), which has as much computing power as some minicomputers. The transistorized digital computer led to software-based operations systems such as the one (b) that displays nationwide call-handling information at the national Network Operations Center. Lightwave technology led to efficient transmission of light pulses. Lightwave cable (c), now being used in many large and small communications systems, contains 144 ultrapure glass fibers with tremendous information-carrying capacity. Solid-state technology and the pulse code modulation concept led to efficient digital transmission. The SLC-96 digital system (d), designed for suburban communities, handles a wide range of voice and data communications.

that time. As digital circuit costs fell over the next 20 years, digital switching became feasible in local offices as well as in large toll offices. Time-division digital switches are now being installed in local offices throughout the network (*14*). In addition, existing space-division electronic switching systems are being programmed to switch digital pulse streams as well as analog signals.

Similarly, advancing technology is extending digital transmission to extremely high rates and is making it economic on long as well as short routes. For example, many small, digital lightwave transmission systems are now in service, and some large systems are being planned and built. The Bell System is installing a high-capacity lightwave system over a 600-mile route connecting Boston with Washington, D.C. Another large lightwave system is being installed on the West Coast, and the first lightwave transoceanic submarine cable is being designed. In addition to lightwave systems, microwave radio and coaxial cable routes, along with satellites, are being used to transmit both digital and analog signals.

A largely digital network requires a means for delivering high-speed digital signals directly to homes and businesses. This is now becoming possible, mainly because of the falling cost of electronic circuits. For instance, a digital transmission system called SLC-96 (subscriber loop carrier 96) now employs ten pairs of copper wires to provide each of 96 users with 56,000 bits of information per second.

Two additional developments have helped bring the key technologies together into the systems and services of the intelligent network. One is the use of a dedicated data network to interconnect the computers that control call-handling functions. This interconnection, known as common channel interoffice signaling (CCIS), has added enormous flexibility to the network and has formed the world's largest packet-switched data system. The other development is the use of large databases in the network. These databases and CCIS, working together as the result of network-wide planning and systems engineering, have made possible new call-handling functions. For example, they allow a user to dial one telephone number, have the computer that controls the local switching machine query a remote database over CCIS, and have the call routed to another number stored in the database.

Thus an enormous amount of research and development translated the key technologies—solid-state devices, pulse code modulation, digital computers, satellites, lasers, and lightguides—into real communications systems (see Fig. 1). At the same time, a comprehensive systems engineering effort at Bell Laboratories enabled both the independent telephone companies and the Bell System to merge new technology smoothly with the old. As a result, the network evolved in a constructive, efficient manner. This deliberate yet rapid evolution has opened the door to a largely digital, multipurpose intelligent network and to the myriad new service capabilities of the information age (see Fig. 2).

Service Today and Tomorrow

The intelligent network supports a wide variety of new services today and offers enormous potential for tomorrow. For example, the ability to dial one telephone number and have the call automatically routed to another has numerous applications. Nationwide franchises could advertise a single number throughout the country. When that number is dialed, the call could be automatically routed to a preprogrammed destination—for example, to the nearest local franchise known to be open at that time of day. Also, a telephone number could be assigned to a person rather than to a telephone set. By dialing into the network database one's itinerary and the telephone numbers at which one can be reached, all calls could be automatically routed to an individual.

The intelligent network is now allowing more users to dial credit-card or bill-to-third-number calls without operator

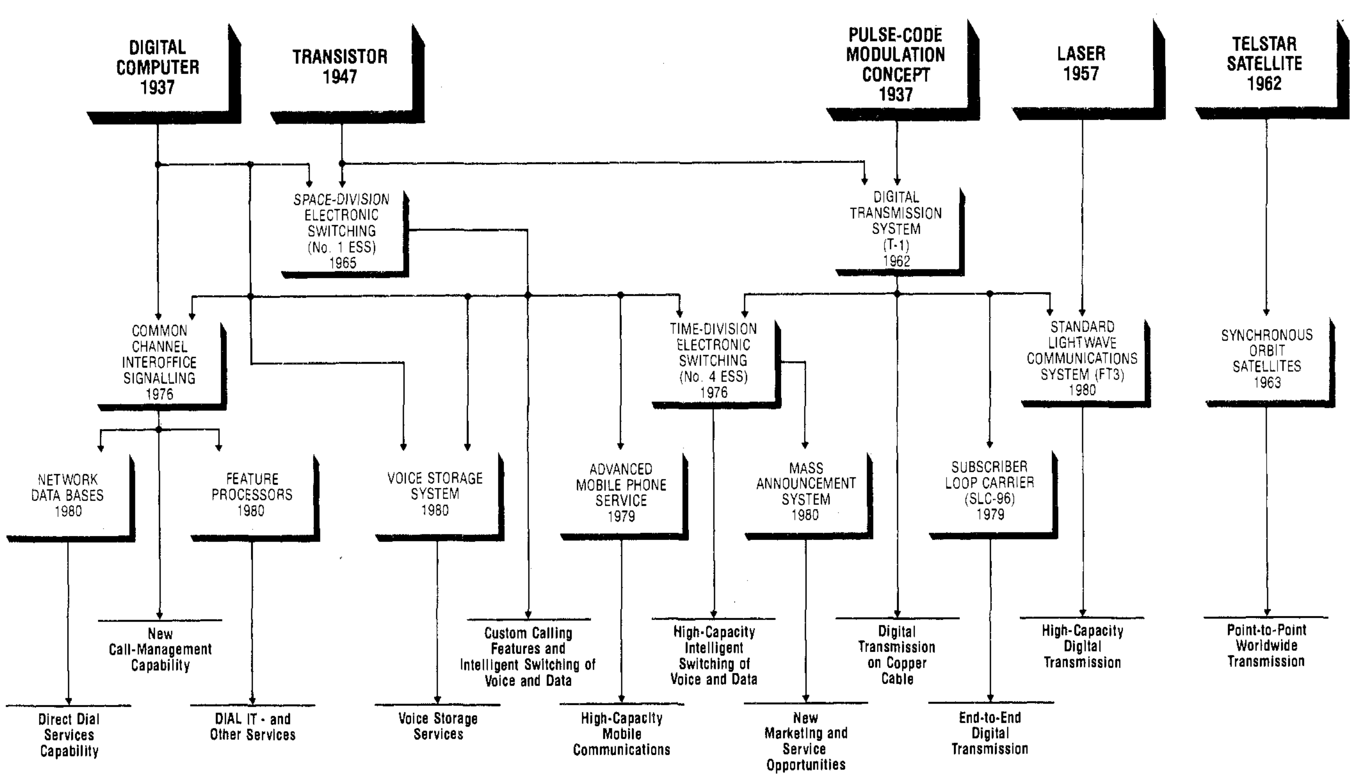


Fig. 2. Evolution of the intelligent telecommunications network. Five key breakthroughs were the transistor, digital computer, pulse code modulation concept, laser and lightguide, and communications satellite. These have led to sophisticated service-providing systems.

assistance. A range of call management services, including calling number display and special ringing for calls from selected phones, could give people more control over their communications services. For businesses, several new services based on a mass announcement system developed for No. 4 ESS will open up new marketing and service opportunities. DIAL-IT services let users dial a single nationwide number to receive recorded announcements and make possible instant national polls such as the one following the Carter-Reagan debate in 1980 (*15*).

While traditional telephone services help conquer distance, new services could also help conquer time. The computers within the network could interact with a digital system that stores voice messages. This would allow calls to be placed or received even at times when the caller or recipient is not at a telephone. For instance, users could record voice messages for delivery at specified times to specified telephone numbers. Or they could have their incoming calls automatically answered and recorded for later playback.

The intelligent network is also at the heart of the advanced mobile phone service. This mobile communications system, first demonstrated almost two decades ago, uses an intelligent switching system to "hand off" calls to another radio channel as a vehicle moves from one area to another. Thus scarce radio frequencies can be reused many times, and mobile service can be provided to hundreds of thousands of users in urban areas (see Fig. 3).

Other services now being planned and developed will take advantage of both the network's intelligence and its expanding digital capabilities. In the office of the future, for instance, new services will improve productivity. Flexible, software-based PBX's will make it easier for intelligent terminals to access host computers (*16*), and advanced digital PBX controllers will provide integrated electronic mail, automated filing and retrieval, text editing, and voice and data communications. Widespread use of teleconferencing, now available through Picturephone Meeting Service in a dozen cities, will eliminate needless travel and save time, money, and energy. And business systems, such as the DIMENSION PBX now used to control energy consumption in hotels and motels, will find even broader use for monitoring and controlling energy consumption.

Other intelligent communications capabilities will have dramatic effects on office routines. For example, private communications services now use the network's intelligence to provide advanced voice and data services to large organizations, allowing users to configure and control their own service features (see Fig. 4). The packet-switched Advanced Communications Service, along with such existing packet-switched networks as Telenet and TYMNET (*17*), will interconnect a wide variety of computer and display terminals. And an end-to-end digital communications capability will soon be added to the network. It will flexibly and economically support a variety of public needs, allowing people and machines to set up high-speed connections as easily as they now make telephone calls.

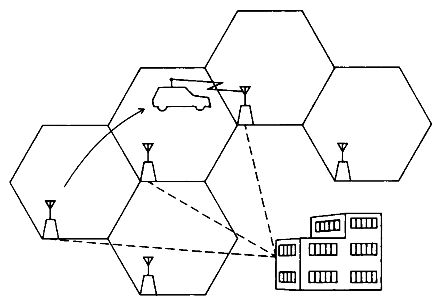


Fig. 3. Advanced mobile phone service. As vehicles travel from one cell to another, electronic switching equipment automatically hands off calls, without interruption, from one radio transmitter to another.

Ultimately, the expansion of digital technology and user demand for data-oriented services will lead to realization of the integrated services digital network (ISDN). This public, nationwide, end-to-end digital capability will let the user choose the type of terminal to be used, the rate at which information will be transmitted, and the size and density of messages—and will also allow simultaneous provision of a variety of voice and data services (*18*).

In the home, new communications services based on the capabilities of the intelligent network will make life richer and more secure. "Smart" telephones, such as the Touch-a-matic series, are already widely available. In the future, "teleterminals" combining features of both the computer terminal and the telephone will raise even more exciting possibilities, such as the electronic home information systems already under trial in the United States and abroad. In Florida, for instance, AT&T and Knight-Ridder are providing 160 families with news, information, and in-home shopping services through a modified television set with keyboard and controller. And in North Carolina, a system now being tried uses the network to link users' homes with energy utilities. The system lets consumers control their energy consumption, while the utilities can read meters remotely, detect tampering, and shut off service when users move. Farther in the future, local transmission systems will allow bursts of digital data to travel side by side with voice signals on ordinary home telephone lines, improving the economic potential of home information systems. Sensors linked to such transmission systems might let people control their energy usage and enjoy improved home security (see Fig. 5).

Dealing with Complexity

Today's network is so complex, and its parts so intimately interrelated, that efficient operations require the use of numerous computer-based support systems. The rapid growth of such systems has paralleled the growth of the net-

Fig. 4. Enhanced private switched communications service. With this service large business users can easily design and control their own private network services.

work's intelligence. Over 100 different types of systems, running on over 4000 minicomputers and 300 maxicomputers, are now accessible over more than 100,000 computer terminals. These systems are deployed in such locations as PhoneCenter stores, business offices, central switching offices, repair centers, and remote equipment installations, as well as factories and laboratories.

For example, one set of operations systems gathers information every 5 minutes from each switching system in the country. This information, collected at 27 regional centers, is sent to the national Network Operations Center in Bedminster, New Jersey, where it is displayed on a large wall map. Although the computer-based systems coordinate the multitude of automatic instructions necessary to monitor network operations on such a grand scale, control of the network ultimately depends on the skill and judgment of human managers.

Other operations systems, such as CAROT (centralized automatic reporting on trunks), continually measure the performance of over 5 million transmission circuits and compile and analyze the resulting data. TIRKS (trunks integrated records keeping system) keeps track of over 25 billion bits of information concerning interoffice trunk circuits, PICS (plug-in inventory control system) controls inventories of 80 million plug-in circuit boards worth over $7 billion, and LMOS (loop maintenance operations system) keeps records on 60 million lines. Still other systems replace paper records, monitor the status of equipment, generate reports, mechanize testing of facilities, keep track of equipment needs, and carry out a variety of other routine but necessary tasks. Without these operations support systems, it would be extremely difficult, if not impossible, to keep today's intelligent network operating.

The Challenges Ahead

For over a century, steady progress has been made in network capabilities. But in the past few decades, the pace of change has quickened. As information-age services proliferate, the development of software technology has become a major challenge. It is largely the software—the detailed programs of instructions that tell the hardware what to do—that makes the network intelligent. In fact, the network can be viewed as an enormous software package where system architecture and software, rather than hardware, form the enduring framework. The intelligent network, like all other computer-based systems, has an enormous appetite for software. Yet software development remains more of an art than a science. Currently the principal way to get more software is to use more programmers, so improvements in programming productivity are sorely needed (*19*).

Programming is being improved somewhat through development of better tools for programmers. For example, the UNIX family of computer operating systems, initiated by K. Thompson in 1969, includes a unified package of tools called Programmer's Workbench that helps Bell System programming teams create and modify large software systems. Ultimately, more dramatic increases in programming productivity might result from using more powerful hardware. The cost of digital integrated circuits has dropped by a factor of 1000 in the past 20 years, and hardware costs are expected to continue to fall at least until the end of this decade. Integrated circuits will soon contain 1 million components on a tiny silicon chip, which will cost about the same as present chips with fewer components. These highly complex chips should allow more modular and functional hardware to simplify and reduce the cost of software. Also, more powerful chips should make possible better and more economic computer aids to software design.

Another challenge is keeping telecommunications services simple to use. It is no accident that almost anyone, even a child, can use a telephone without special training. Human factors work has gone into every aspect of the telephone's operation, from the shape of the dialing pad to the nationwide numbering scheme. The same kind of "engineering for people" must be applied on an even wider scale to the design of increasingly complicated services and terminals.

For everyone to have access to the benefits of the information age, "friendly" interfaces with complex machines are needed. Present efforts to make machines friendlier include development of simplified computer operating systems and languages, and advances in display and sensing technologies. In addition, work on speech synthesis and voice recognition will permit people to communicate with machines in ordinary English.

Still another challenge is to make the

Fig. 5. Examples of increasingly intelligent terminals, made possible by the declining cost of digital electronics. (a) Users can automatically dial any of 12 prerecorded phone numbers by pushing one button on the microcomputer-based Touch-a-matic series telephone. (b) Residential energy management terminal, currently undergoing trial in North Carolina, lets users monitor and control home energy usage. (c) Experimental "teleterminal" with controls whose functions change as the display is changed. (d) Viewtron electronic home information system terminal, currently undergoing trial in Florida.

terminals and devices attached to the ends of the network as reliable and trouble-free as the network itself. For instance, fire and burglar alarm systems that send warning signals through the telecommunications network have great potential for improving home security. But fire and police departments cannot tolerate a large percentage of false alarms, so alarm systems must be intelligent enough to distinguish real emergencies from false ones. The same kind of careful systems engineering and the same approach to reliability that helped build the intelligent network must be applied to the intelligent terminals and sensors that interact with it.

The capabilities of the intelligent network have evolved in close synchronization with advances in science and technology. But in recent years the merging of telecommunications and computer technologies has raised difficult regulatory issues with potentially profound effects on the evolution of the network. There are many points of view on these issues. But on at least one point there seems to be consensus: that the benefits of rapid technological progress—new products and services—must continue to become promptly and widely available.

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Business Use of Satellite Communications

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The first commercial satellite communications system, INTELSAT, has been in operation since 1965. Growing at an annual rate of more than 20 percent, INTELSAT has progressed through five generations of satellites to provide global coverage devoted mostly to long-distance trunks for telephone circuits (*1*). The present system has 12 operational and standby satellites interconnecting 300 earth stations on six continents through a network of 800 links. The traffic load now exceeds 20,000 two-way telephone circuits, plus television and data. In addition to international communications, INTELSAT leases capacity to 20 countries for domestic communications.

INTELSAT has been a significant business success, over the years providing service of increasingly higher quality at lower cost. Its charge for a telephone circuit in 1981 ($4680 per channel) is one-sixth of its original charge. Moreover, INTELSAT is profitable for its members as well as its users—the communications carriers. From its revenues of $213 million last year, it will pay its members about a 14 percent return on their investments.

Several nations, including the United States, launched satellites to provide their own domestic communications services starting in the middle 1970's (*2*). Many of the same technologies that provide good communications links between countries across oceans have served as well to connect cities and towns, or even individual buildings, within a single nation. Special technology had to be developed for domestic systems to meet national and local requirements—for example, satellite antennas to provide high-power, limited-area coverage (Fig. 1) and small earth stations, which are particularly adaptable to user requirements in urban areas (Fig. 2).

Although it was thought that domestic systems would, like INTELSAT, be used mostly for telephone trunking, their major application has been for television program distribution to broadcasters and cable systems and, increasingly, for data transmission. In the United States, domestic satellite system traffic is projected to grow at the rate of 15 percent or more per year through the rest of this century (*3*) (Fig. 3).

Today, 22 separate satellite communications systems are operational worldwide, with a combined commercial revenue approaching $2 billion per year (*4*), and 30 additional systems are being built or planned. In this article we briefly review business communications development and then discuss business applications of satellite communications, systems technology, and prospects for future developments in digital transmission systems.

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Business Communications

Paralleling the expansion of satellite communications has been the information explosion in business operations and management, particularly in the United States. The number of white-collar workers is growing rapidly and their time is being devoted increasingly to the tasks of generating, storing, retrieving, manipulating, and transmitting information. The effectiveness of the white-collar work force now depends heavily on man-

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