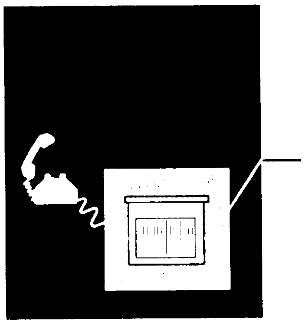
Technological Trends and Issues

CHAPTER 2



Technological trends will increase need for international standards, and will challenge the viability of traditional standards processes.

EMERGING TECHNOLOGIES AND INNOVATIVE, SOFTWARE-BASED SERVICES are undermining some U.S. telecommunications regulations and policies. Intelligent networks and information-based services will make it increasingly difficult to draw clear boundaries between public networks and private networks and between regulated ''basic' telecommunications services and ''enhanced' services. Such technological change may make the negotiating positions developed by the Office of the United States Trade Representative (USTR) irrelevant by the time they arc embodied in treaties, trapping the United States in agreements no longer in its best interests. These technological trends will both increase the need for international standards, and at the same time challenge the viability of traditional means of developing standards.

The broad technological trends that will shape the networks of tomorrow stem from three fundamental developments: 1) the progressive increase in processing power of microelectronnic circuitry, *2)* the continuing improvement in fiber optics, and 3) fiber optics: extraordinary reduction in cost. The first provides the necessary processing power for advanced switching systems and for compressing information signals into ever-smaller bandwidths. The second provides both vastly improved transmission quality and the necessary transmission capacity for bandwidth-intensive services that combine voice, data, and video signals.

Changing technology

Eight broad technological trends should be noted:

- conversion from analog to digital transmiss ion,
- common channel signaling,
- unbundling of stored-program control switching functions,
- advances in transmission systems,
- advances in digital multiplexing,
- advances in packet switching,
- mobile communications, and
- greater functionality in terminal equipment.

The most basic and important of these trends is the progressive conversion from analog to digital systems. The great advantages arc better performance, easier multiplexing,[2] easier encryption, easier signaling, better monitorability of performance, integration of switching and transmission,

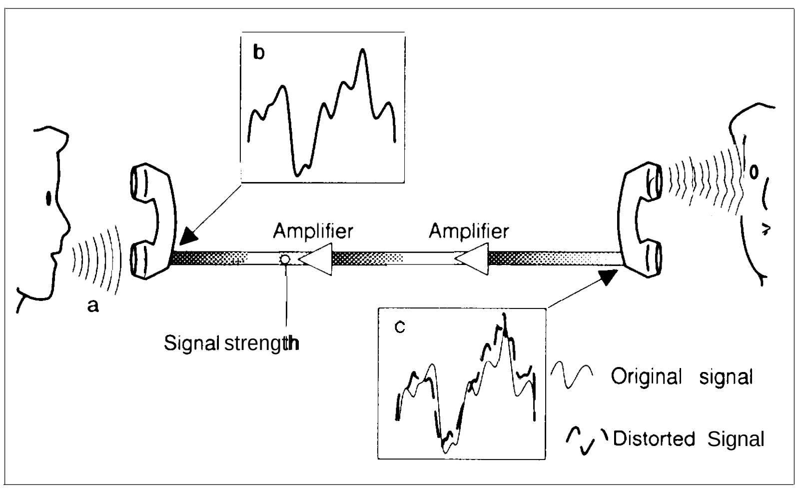
NOTE: Much of the material in this chapter is based on an Office of Technology Assessment contractor report: Hatfield Associates, Inc., *Advanced International Telecommunications Technologies and Services,* December 1992.

[1] In an analog system, the signal weakens and becomes corrupted by noise and distortion as it moves along a wire, unless it is regularly boosted by amplifiers. But amplifiers cannot distinguish signal from noise, and they boost both, while adding some additional noise and distortion. These distortions accumulate over a long transmission path until the desired signal may become almost unintelligible. In a digital system, regenerators are used along the path rat her than amplifiers. Regenerators merely detect whether a pulse is present and, if so, they generate and send on tot he next regenerator a new (noise-free) pulse. The same sequence of pulses presented at the beginning is delivered at the end without weakening and without the accumulation of noise and distortion.

[2] Multiplexing is the process of combining multiple signals into a single channel for transmission over a common facility, e.g., a lightwave or radio carrier, thus Increasing effective capacit y.

and accommodation of other services.[3] Compression techniques are steadily reducing the number of bits per second that must be transmitted to reproduce a given signal, and advanced modulation techniques allow higher bit-rates to be transmitted per unit of bandwidth. (See figure 2-1 and 2-2.)

A second important trend is common channel signaling, or separating voice traffic from signaling. Signaling is the information associated with setting up, maintaining, and taking down calls. Until recently, analog tones were used to convey signaling information, which was carried on the same channel as the voice conversation. With common channel signaling, all of the signaling associated with multiple conversations is handled on a common packet-switched subnetwork. Conversation channels are circuit-switched, while signaling information in the common channel is digitized and packet-switched. Common channel signaling is faster than traditional analog signaling, allowing calls to be set up faster. The signaling does not consume conversation capacity on the trunk. The network can ' 'look ahead" to see if lines or trunks are busy before setting up a call on the circuit-switched network, and then pick a route through the network that minimizes congestion. These improvements become even more powerful when enhanced computer processors and databases are added to common channel signaling to create ''intelligent networks.



SOURCE OFFICE OF TECHNOLOGY ASSESSMENT, 1993

Figure 2-1. Analog Transmission

NOTE In order to transmit a voice over the telephone network, the soundwaves (a) are converted to a corresponding electrical wave (b) when the waves contact the mouthpiece of the telephone handset. The signal weakens as it travels along the wires of the network, and therefore must be amplified at intervals The signal inevitably picks up noise and distortion, and this noise and distortion is included with the original sound when the signal is amplified (c)

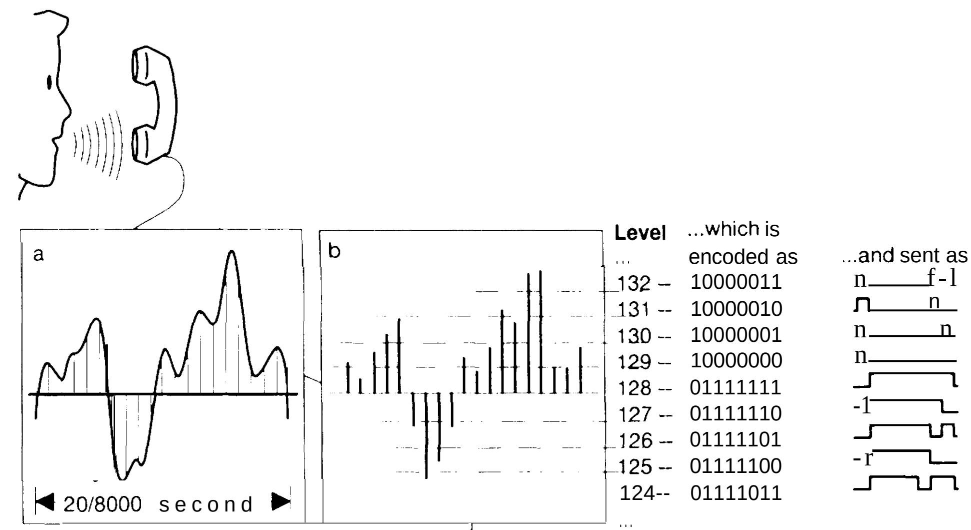
A third trend is toward unbundling of stored-program control switching. Modem computerized or stored-program circuit switches are composed of two basic parts— the matrix where physical connections arc made between circuits, and a processor that contains the logic that controls the switching. In early ''stored program control switches, the switch (matrix) and processor elements were integrated. (In computer terms, there was no separation between the "application program' and the "operating sys- tern, ' The customer could not modify the switch software to create new or changed services-the switch manufacturer had to do that, usually with a new switch.

Separating the switch control from the lower-level switching functions allows networks to be programmable by a carrier, an enhanced services provider, or the customer/ end-user. In the case of a public network, a local switch can suspend an incoming call, look up the called number in a database, and route the call to the intended recipient at another number and location (call forwarding). In a corporate network, a private branch exchange (PBX) can be linked to external computers; calls can be delivered to particular corporate agents along with different screens of information depending on the

[3] John Bellamy, *Digital* Telephony, 2nd Edition (New York, NY: John Wiley& Sons, Inc., 1991).

Figure 2-2. Digital Transmission

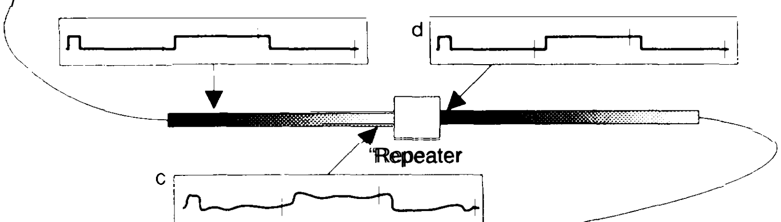
SOURCE OFFICE OF TECHNOLOGY ASSESSMENT, 1993.



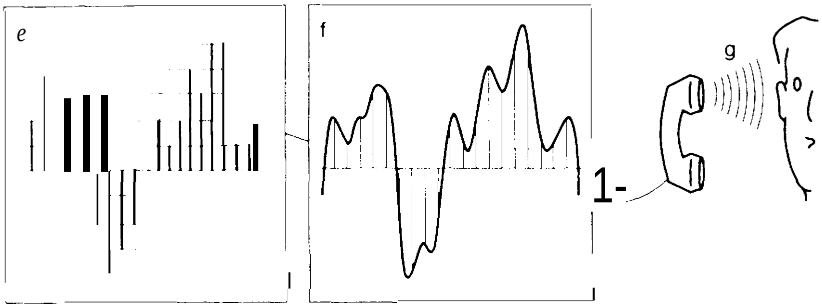
In a digital system, the soundwave is sampled (a) at sufficiently close intervals (1/8000 of a second) to very accurately reproduce the wave's shape. The amplitudes of the samples are then quantized (b) -- or given approximate values according to the range into which the amplitude falls. The new signal is encoded into an 8-character binary format (which permits 256 possible levels) for transmission through the network. In this example, the digitized signal would be:

10000000,01111111,10000000 ,.. (129, 128, 129...)

The digital signal is regenerated rather than amplified (as in analog) during transmission; the repeater reads the deteriorating signal (c) and generates a fresh sequence of 1s and 0s (d).



Finally, the signnal is converted back into an electrical impulse (e, f) and to soundwaves (g).



The "Intelligent Network' '-locating processors and databases throughout the network—permits a wide variety of specialized network services, including virtual private networks.

identity of the customer placing the call. This ccm~putcr/telephone integration is one of the most important trends changing telephony.

The "Intelligent Network" is a natural extension of these advances in switching and signaling. Computer processors and their associated databases arc placed in the network where they can be accessed from the signaling channel. The system uses the calling and called numbers plus other information to handle calls in special ways--e. g., to route calls to different locations depending on the time of day and/or the originating location. Public or private networks can be reconfigured to reflect changing traffic conditions or to respond to network failures. An intelligent network can also create software-defined virtual private networks.

One characteristic of intelligent network concepts is that the call-handling logic and databases can be stored at a handful of centralized locations, to be accessed by a large number of switches. This makes it easy to reprogram them, since the software and databases need be updated only at a limited number of locations. As a result of these developments, the logic and data associated with the handling of individual calls can be optimal] y distributed among customer premises equipment, the local or metropolitan or regional portion of the network, or the long-haul portion, and linked using advanced signaling systems.

Greatly improved transmission systems arc a fourth broad technological trend. Transmission systems for traditional services evolved from open wire line to twisted-pair copper cable, coaxial cable, line-of-sight microwave, satellite, and optical fiber cable. While technological advances have produced significant capacity increases in even the older technologies such as twisted-pair copper cables, the largest increases are associated with the deployment of optical fibers or lightwave systems; these systems operate routinely at speeds as high as 2.4 Gbps (billion bits per second) on a single fiber.

A family of transmission standards now being extensively implemented, called Synchronous Optical Network (SONET),[4] allows transmission rates in the range of 51 Mbps (million bits per second) to 2.4 Gbps. Because SONET uses synchronous transmission, individual channels can be efficiently added or dropped at intermediary nodes without the usc of back-to-back multiplexer. This allows the creation of ring architectures that can provide added reliabil - ity. (See figure 2-3.) Moreover, SONET includes special data channels that facilitate various network management functions such as surveillance and rerouting from a central location. By installing high-capacity facilities to the customer's premises and using the advanced network management features of these systems, additional or reconfigured channels can be provided to the customers quickly, and without an on-site visit by a technician. Through this 'preprovisioning, ' a customer can even get additional capacity by directly accessing the network management system—a form of ''bandwidth on demand.

Packet-switching is another powerful technological trend. The public switched telephone network with circuit-switching was optimized for voice communications. In the

[4] Generally known outside of North America as Synchronous Digital Hierarchy (SDH), the international standard.

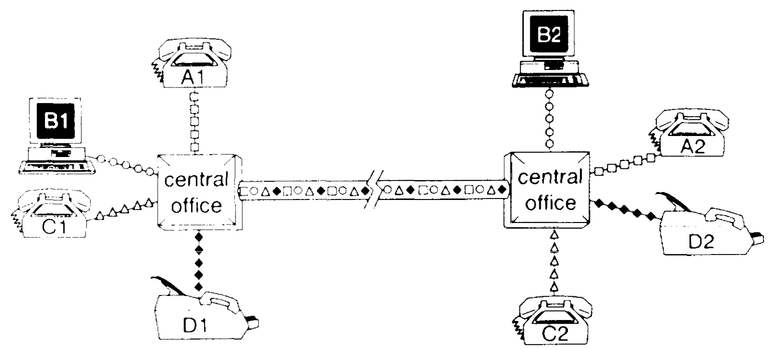
digital mode, it switches 56/64 kbps (thousand bits per second) circuits, corresponding to the uncompressed bandwidth requirements of ordinary voice communications. For data communications, there are two drawbacks to circuit-switching: the inefficiency of having dedicatcd connections when traffic is intermittent or "bursty,' and the constrained 56/64 kbps transmission speed. The lattcr can be partially overcome by modifying or redesigning switches to handle multiples of the *56/64* kbps rate. (This is currently being done to achieve speeds up to 1.5 Mbps.) A wideband, circuit-switched service of this type is appropriate for bulk file transfers, vidcoconfcrencing, and other applications with relatively constant bit-rates.

Traditional packet-switched networks arc effective for handling bursty data, but are currently 1 i m i ted to speeds of about 64 kbps. This is because the packet switch at each network nodc must read the address information, check the data contained in the packet for errors, correct the errors or request a retransmission, reassemble the packet, and forward it to another node. New technology, known generically as ''fast packet-switching, ' can reduce these delays.

Frame relay and cell relay are two forms of fast packet-switching. Both rely on the fact that modern digital transmission systems have very low error rates compared with analog systems, and the end user's terminal equipment now has the processing power to correct errors or ask for retransmission. Both frame relay and cell relay are attempt to improve a situ at ion in which the ability to transmit information at high speeds exceeds the ability of switches to route it. These technologies have given rise to the important developments of Asynchronous Transfer Mode (ATM) and Switchcd Multi-Megabit Data Service (SMDS), described below.

Frame relay utilizes the same type of variable length packets characteristic of traditional packet systems, but the individual packets--called frames-arc relayed through the switch in: nodes with no effort to recover from any errors detected. Much of the error detection and all error recovery is left to the terminal devices. Transmission rates in the 1 to 2 Mbps range arc possible.

Cell relay operates similarly, except that the packets-here called cells—have a short, fixed length, and because of this can be switched at extremely high speeds (in the range of hundreds of megabits per second). The expectation is that the high speeds and small delay will allow integrated combinations of' voice, data and video traffic to be handled through a common switch. With all the transmitted information divided into individually addressed cells, both variable bit-rate (i.e., data) and constant bit-rate (i.e., voice) traffic can be switched. While early applications of cell relay technology are for data communications, the goal is to extend



SOURCE OFFICE OF TECHNOLOGY ASSESSMENT, 1993

Figure 2-3. Multiplexing

NOTE Multiplexing is the process of combining multiple signals into a single channel for transmission over a common facility (e.g , lightwave or radio carrier). Multiplexing is used to Increase transmission efficiency by allowing mult @e circuits to be earned by the common facility

Engineering or economic forces are shifting telecommunications intelligence and functionality from the center to the edge of the networks.

the technique to voice and video. In addition, cell relay works in a synergistic way with SONET,

Frame relay is both a technology and a service. It is designed to carry data communications and interconnect local area networks (LANs), and it may be used to transport a variety of higher-level data communications protocols. Frame relay services are being introduced both in the United States and internationally, by U.S. carriers and value-added network providers. European public telephone operators (PTOs) are also planning to introduce public frame relay services.[5] However, there are still unanswered quest ions about performance characteristics and about support from carriers in several countries. A major unresolved issue for the United States is the nature of interconnections between major carriers such as AT&T and MCI. Some users say that national policy should insist on immediate action to ensure interoperability.

Switched Multi-Megabit Data Service is a broadband public data communications service based on the second form of fast packet switching-cell relay. SMDS was developed primarily for LAN-LAN interconnection (i.e., data communications). However, specifications for handling voice and video are being developed. The cell relay structure is compatible with a new protocol known as Asynchronous Transfer Mode intended for use in switching and transmitting voice, data, and video simultaneously.

ATM is the basis for Broadband Integrated Services Digital Network (ISDN), and SMDS could be an interim step pending the arrival of Broadband ISDN.[6] The standards for Broadband ISDN are not fully developed. One configuration would provide for a channel of approximately 150 Mbps to customer premises, with integrated switching and multiplexing.[7] This would allow transmission of high-quality, two-way video telephone and vidcoconferencing, and other multimedia services combining audio, video, graphics, text, and data. There is still much uncertainty about architecture and standards for this development.

Another marked trend is toward wireless or mobile communications, with the rapid growth of pm-table communications including cellular- mobile radio, specialized mobile radio, cordless telephones, and radio pagers, and in the future wireless forms of Personal Communications Services (PCS).[8] Some observers suggest that there may be a fundamental shift in the way people communicate, with access to telecommunications services through wireless technology becoming the rule rather than the exception. (See figure

[5] Robin Gareiss, "International Frame-Relay Services Expand," *Communications Week,* November 1992, p. 27; Peter Heywood and Elke Gronert, "Public Frame Relay Goes Global," *Data Communications*, March 1992, p. 77.

[6] "SMDS: The First Broadband Public Network Service," supplement, *Business* Communications Review, 1992, p. 6.

[7] Another possible configuration calls for four channels, butt his is considered unlikely to be deployed in t he foreseeable future.

[8] Donald C. Cox, "Wireless Network Access for Personal Communications," */EEE Communications*, December 1992, p. 96. Some studies suggest PCS could find 100 million customers ın the United States.

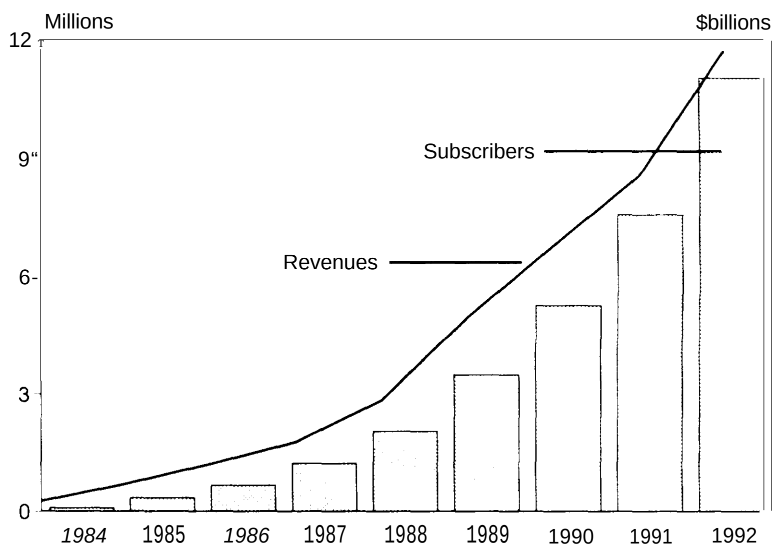
2-4.) Rapid growth[9] has been encouraged by government actions to reallocate spectrum for advanced mobile communications systems. by the continued increase in processing power (e.g., Digital Signal Processing chips, or DSP), by steady improvements in battery technology, and by increased use of computers within the supporting land-based infrastructure.

Still another trend shaping telecommunications networks is increased functionality in terminal equipment. The provision of terminal equipment has been deregulated in many countries and the markets arc intensely competitive. Intelligence and functionality in terminal equipment at the edge of the network can substitute for intelligence and functionality within the network. For example, frequently called telephone numbers can be stored either: on a ''smart card' that is plugged into a handset. in the terminal equipment itself. within a telecommunications network (e.g., in a PBX or CENTREX), or at some common location or database accessible to the customer from any network.

Hard engineering or economic reasons arc leading to locating intelligence and functionality at the edge of the network rather than internal to it. It may also be done to respond to customer preferences. Some customers want to develop proprietary solutions to their communications needs to gain some competitive advantage, and such customization may be difficult on a network designed to serve general requirements. Other customers may feel more secure if information critical to their competitiveness is embodied in software and hardware on their own premiscs. Thus advances in telecommunications services will occur not just within networks but at the edge as well. The time needed for such developments is often shorter than for developments in the internal network infrastructure.

The evolution of advanced services

The broad technological trends discussed above are the basis on which advanced services will evolve. Perhaps the most highly touted advanced telecommunications service is ISDN. The concept of ISDN originally developed as an outgrowth of standards development work in international bodies. It represented a combination of two of the technological trends identified above: the conversion from analog to digital networks, and the separation of the signaling channel



SOURCE CELLULAR TELEPHONE INDUSTRY ASSOCIATION, 1993.

Figure 2-4. Growth in U.S. Cellular Subscribership and Revenues, 1984-92

[9] In the United States, the number of f Irst-generation cordless telephones grew from 8 million in 1984 to 50 million in 1992, and the number of cellular subscribers has grown from 100,000 to 8 million. Irwin Dorros, "Diversity, Success, and Change," *Be//core Exchange,* November/December 1992, p. 4.

Figure 2-5.
A Network Topology

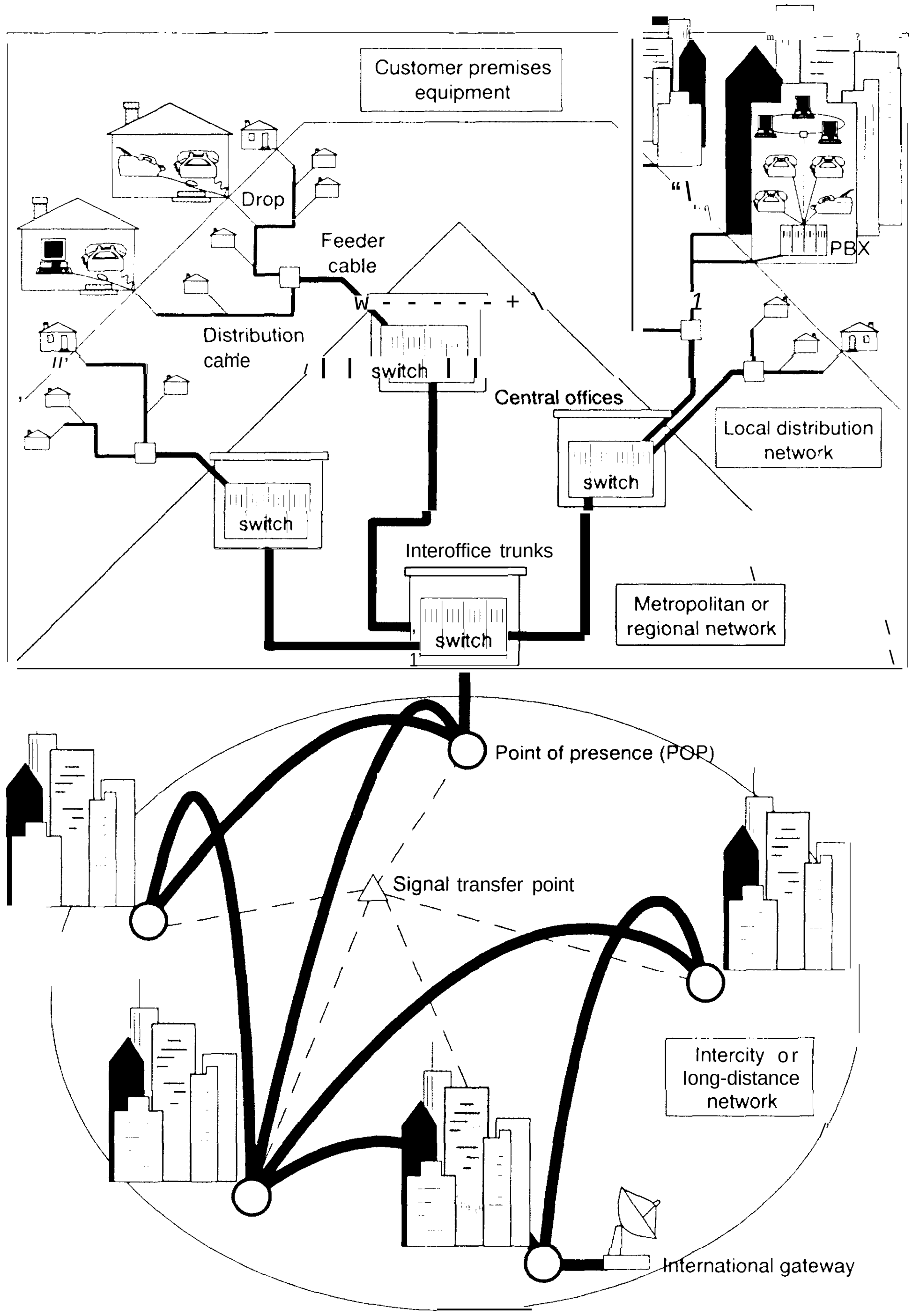
NOTE The public-switched telephone network consists of four major segments

Customer premises equipment (CPE) refers to the communications devices (including the inside wiring) in the user's home or office, such as telephones, facsimile machines, and computers and modems. The CPE of larger companies often includes private branch exchanges (PBXS) and local area (computer) networks (IANS).

Local distribution network refers to the portion of the network connecting homes and offices to the telephone company's central office.

The metropolitan or regional network consists of the central office switches and the interoffice trunk lines connecting those switches. Each central office switch corresponds roughly to a neighborhood so a city will be served by multiple central offices. Telephone traffic for points outside the metropolitan network is collected at and routed through a tandem switch.

The most obvious part of the **intercity or long-distance segment** is the web of high-capacity trunk lines (mainly fiber optic, but also microwave) that carry the telephone conversations or messages; the packet-switched data network (represented by the thin dashed line) is transparent to the user but is critical as it is the intelligence of the network—determining the best route for a call and allocating the circuits, handling billing, etc. The interexchange (or long-distance) carriers interconnect for **access** to the local network at the point of presence (POP).



SOURCE OFFICE OF TECHNOLOGY ASSESSMENT, 1993, from the channel carrying customer messages.

ISDN offers two primary transmission speed- 144 kbps (the Basic Rate Interface) and 1.544 Mbps (the Primary Rate Interface). The former is divided into two 64 kbps voice and data (bearer) channels plus a 16 kbps signaling channel. The Primary Rate Interface is divided into 23 voice and data 64 kbps data channels plus a 64 kbps signaling channel. These speeds are compatible with the bandwidth capabilities of twisted-pair copper cable. The bearer channels can be circuit-switched or packet-switched.

ISDN was designed to support many applications, including mutimedia communications (i.e., simultaneous voice and document transmission). The National ISDN Users Forum identified 16 important applications for ISDN: [10]

1. high-speed file exchange,
2. videoconferencing,
3. data conferencing,
4. multipoint screen sharing,
5. customer service call handling,
6. telephone/workstation integration,
7. image Communicant ions,
8. remote terminal access to LANs,
9. automatic number ID/calling linc ID,
10. at-home agents,
11. multidocument image storage and retrieval,
12. multiple ISDN phones on a single ISDN basic rate interface loop,
13. transparent feature operation between ISDN,
14. frame relay support,
15. centralized fax server with ISDN access, and
16. engineering workstation interface to ISDN.

In 1990 the Federal Communications" Commission (FCC) required Bell operating companies (BOCS) to include plans for ISDN in their open network architecture plans. [11] According to these plans, the seven BOCs expect to convert over 2,000 of their 9,000 switches by 1994, making over half of their regional access lines ISDN capable.

Some European countries arc much further along. (See table 2-1.) The ISDN

Table **2-1.** *National ISDN Status and Goals*

	Percent of networks converted	Target date	Percent of networks now ISDN capable (1 991)
Belgium	80%	1992	20%
Denmark	100	1992	0
France	100	1991	100
Germany	100	1993	60
Ireland	80	1993	0
Italy		"late 1990s"	0
Netherlands	100	1995	0
Portugal	100	1994	0
Spain		"late 1990s"	0
United Kingdom	100	1992	60

SOURCE THE YANKEE GROUP, AND COMMISSION OF THE EUROPEAN COMMUNITIES, 1992

[10] John D. Hunter and William W. Ellington, "ISDN: A Customer Perspective," *IEEE Communications Magazine*, August 1992, p. 21.

[11] The FCC's Computer III decision required that Bell Operating Companies provide their competitors Comparably Efficient Interconnect Ion (CEI) through an open network architecture acceptable to the FCC.

[12] Bellcore data reported in *ComputerWorld, Nov.* 9, 1992. There are large differences in the regional Bell operating companies' plans—from 21 percent of access lines for Southwestern Bell to 87 percent for Bell Atlantic, About 30,000 ISDN-equipped lines are now in use in the area served by Bell Atlantic. General Industry acceptance of a national ISDN-1 standard was shown with a multivendor 22-node ISDN network demonstrated in November 1992.

Programmable networks open the opportunity to customize them to meet customers' needs, either by carriers, third parties, or (corporate) customers themselves.

concept evolved largely outside the United States and was identified with European Postal, Telephone, and Telegraph (administration) (PTTs). It was adopted by the International Telecommunications Union's Consultative Committee for International Telephone and Telegraph (CCITT) in 1972, and was intended as the response of PTI's to the growing demand for data communications. It assumed a unitary ''solution' in a monopoly environment.

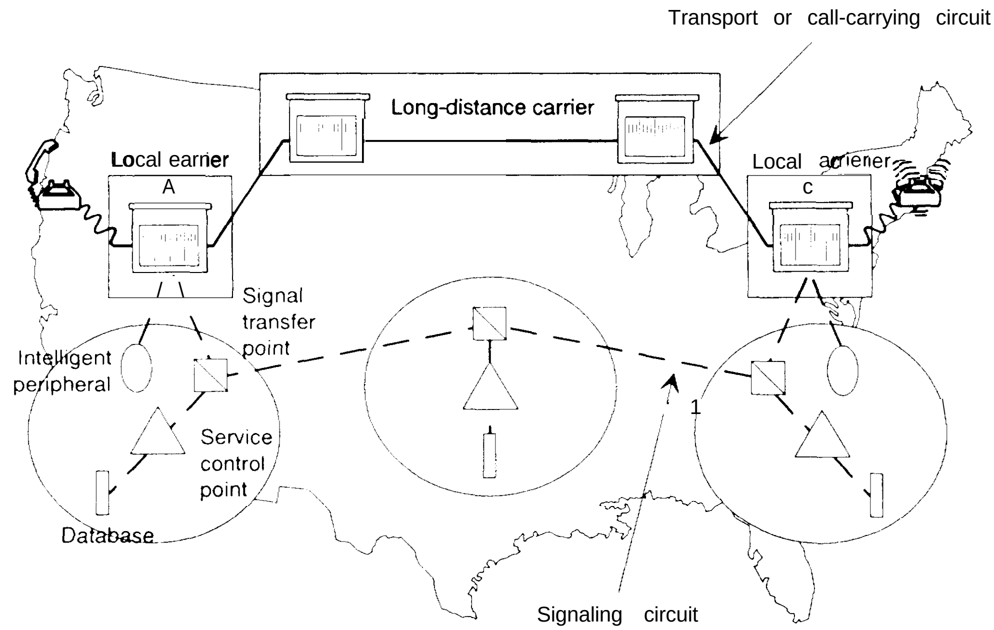
In the United States there may now be more critics than advocates of ISDN. ISDN has not lived up to early expectations. Its slow growth has been attributed to a number of factors, including lack of user input in its design, slow development of ISDN standards, the high cost of terminal equipment, and competition from newer technologies. Widespread acceptance of ISDN may have lagged so far that other advanced technologies based on fiber optics and fast packet-switching will further limit the appeal of ISDN. AT&T officials point out, however, that these alternative technologies will benefit only big corporations, and the lack of ISDN severely limits the services that can be offered for middle-sized and small businesses, as well as for residences.

On the positive side, France and Germany arc heavily committed to ISDN and the European community is pushing it as a means toward an integrated European network. There is now a greatly increased demand for data services, and according to the International Telecommunications Users Group (INTUG), which is not a strong advocate of ISDN, interconnection between most of the various European ISDN systems has now been substantial y achieved. [13] However, ISDN may not increase PTT revenues because it sometimes replaces higher revenue services.

The ISDN outcome could possibly affect the pattern of suppliers of equipment in international networks. ISDN is part of the European pattern of centralized network intelligence, whereas the U.S. trend is to diffuse intelligence (i.e., computer logic) throughout the network, making it effectively a web of computers. The former strategy will encourage European telecommunications companies to stick with their traditional equipment suppliers; the latter strategy could benefit U.S. firms such as IBM. On the other hand, long-lived ISDN centralized switching and processing installations would, in the long run, work against small new firms with rapidly changing technologies, many of which arc U.S. firms.

A second category of emerging services are those based on the ''intelligent network concept described above, The intelligent network allows network switching elements to interrogate remote processors and databases to determine how to route a call, Making the network programmable in this way opens up the opportunity to customize it to meet the needs of individual customers, whether this is done by the carrier, by a third part y on behalf of the customer or customers, or by a (corporate) customer alone. This was the basis for ' '800' service--when a customer dials an 800 number, the call is briefly suspended while a remote database is consulted via the signaling network. In the

[13] INTUG News (July 1992) reviews the status of European ISDN based on two reports: *ISDN: 7-he Illusory Ho/y Grail*, by The Yankee Group Europe (The Old Free School, George Street, Watford WD1 813X, United Kingdom), and *ISDN Communications in Western Europe 1992*, by CIT Research Ltd. (23 Dering Street, London WI R 9AA).



SOURCE OFFICE OF TECHNOLOGY ASSESSMENT, 1993

Figure 2-6.
Intelligent Network

NOTE The advanced intelligent network (AI N), elements of which are currently installed in today's public-switched telephone network, envisions greatly increased operating efficiency as well as a broad array of *sophisticated* network *services* by separating the call t ran sport (i e., t he voice circuit) function from the signaling and control function and employing the powerful software in the switches.

Imagine, for example, an instance where a caller places a call to a fam ily member who while on vacation has ind icated that calls from certain numbers are to be rerouted to the new location and given a unique nng to Indicate priority In this illustration, the vacationer would have preprogrammed the pnonty telephone numbers (other calls m ight be routed to an answering service or machine) and the new destination number by dialing into the Intelligent peripheral and inputting these data When the caller dials the number, the local switch queries the signal transfer point for billing and accounting information and ascertains from the service control point a clear path through the local network to the point of presence of the caller's long-distance earner of choice The signaling networks of the two local exchange companies and the long distance carrier interact to learn the status of the called party and thus how to set the call up, in this case, the call has been red irected to a telephone address in a new location so a third local company is Involved and once again the status of the called party is learned (for example, if the line were in use, the network would direct local carrier A to transmit a busy signal to the caller) and establishes a calling path Local carrier C is also Instructed to deliver the special nng

database, the 800 number is translated into a regular telephone number, which is sent back to the switch where the call was intercepted, and the call is then handled as a regular circuit-switched call. It can be routed differently depending on the place it originated, the time of day, or other variables. Intelligent networks can route calls automatically to a customer location nearest the caller (for example, from a chain of retail stores or pizza parlors) and could take into account the closing hours of the stores and the time at which the call is made.

Another usc of the intelligent network concept is the creation of Virtual Private Network (VPN) services. One of the advantages of a real private network is that corporate customers can employ their own numbering plans, using fewer digits than required by a public-switched network because the private network serves a limited number of locations and telephones. An inelligent public network can emulate that feature on VPNs, translating a 7-digit number dialed on a VPN into a normal 10-digit number, and muting it accordingly. Another feature of private networks is the ability to restrict calling from certain telephones to reduce toll calling abuse (e.g., to prevent employees from making unauthorized international calls). The same type of restriction can be imposed by an intelligcnt public network by examining the calling and called numbers. Other features possible on VPNs include, for example, alternative destination routing, account codes for cost allocation purposes, management reports, hot lincs, and call forwarding. VPN (and new tariffs for high volumc traffic) may already have swung the balance for large corporations away from developing private networks and back toward reliance on public networks.[14]

VPN services are not limited to voice communications; AT&T offers an international Software Defined Data Network in about 20 countries. Intelligent networks will be crucial to the development of Personal Communications Services or Personal Number Calling, which will require use of data concerning user identity, completion preferences among available alternative networks, user-selected features, and billing procedures. [15]

First-generation cordless telephones and cellular mobile radio systems are now widely available in most parts of the world. The United States has lagged behind Europe in development of cordless telephone standards. Here, the first-generation of analog cordless phones operated on a few channels, near 50 MHz in the radio spectrum. Some manufacturers have recently introduced digital cordless telephones that operate in a band in the 900 MHz region that is set aside for low power, unlicensed devices. U.S. cellular service providers are beginning to convert their first generation systems (operating in the 800 MHz region) from analog to digital transmission. The FCC is expected to reallocate a substantial block of spectrum near 2 GHz for PCS.

In Europe, two second-generation cordless telephone systems have already been developed, CT2 and DECT. CT2 is a low-powcr system in accord with a standard known as the Common Air Interface, that allows a single handset to be used in residential, business, and public (Telepoint) applications.

There is a pan-European standard for a digital cellular system operating in the 900 MHz band, the Global System for Mobiles (GSM),[16] The GSM network will support not only ordinary speech transmission but transmission of short data messages, videotex, teletex, and facsimile .17 The Digital Cellular System, DCS1800, is another standard for a Personal Communications Network that was derived from the GSM standard, but operates in a different region of the spectrum (1800 MHz) at lower powers with smaller cells. The Europeans are also working on a third-generation mobile system known as the Universal Mobile Telecommunications System.

Satellites have proven to be especially effective in delivering one-way video services and two-way data services utilizing Very Small Aperture Terminals (VSATs). VSATs arc extensively used in the United States, but development of VSAT services in Europe lagged because of regulatory restrictions. As discussed in chapter 5 (Users' Perspectives), they may become: increasingly important in the near future.

[14] For discussion of this trend, see U.S. Congress, Off Ice of Technology Assessment, *U.S. Banks and International Telecommunications*, OTA-BP-TCT-1 00 (Washington, DC: U.S. Government Printing Office, September 1992).

[15] Irwin Dorros, "Diversity, Success, and Change," *Be//core Exchange,* November/December 1992, p. 9.

[16] It is also known as Groupe Speciale Mobile. The GSM system was scheduled to begin commercial service in several countries in mid-1 991 but was delayed for various reasons, including problems with subscriber equipment-type approvals.

17 Raymond Boult, "EuropeAwards Herself t he GSM," *Network Management Europe,* May/June 1992, p. 28.

The implications of technological change

Telecommunications networks are becoming more software-intensive and the costs Of developing networks and services is increasingly in software rather than hardware. The way in which networks and services are competitively differentiated is in the software incorporated in them. Fortunately, this plays to the strength of U.S. firms.

Telecommunications networks are increasingly software--intensive and this plays to the strength of U.S. firms.

In early generations of switching equipment, hardware and software were tightly coupled and had to come from the same vendor. This is likcly to remain the case for simple switching software, but carriers, third - party services providers, and users all will in the future have increasing ability to ''program networks to meet specialized needs. Carriers can be increasingly responsive to customer needs, and decreasingly dependent on hardware manufacturers and vendors. Customization through software can help private network operators, such as financial services providers. develop and offer innovative services and maintain a competitive edgc.

The pressure will thus grow to unbundle applications software and make basic transmission a more commodity-like product. There is likely to be more commingling of carrier-provided and customer-provided logic and databases. Both may be necessary. for example, in call-routing that is sensitive to time of day or changing recipient locations.

Internationtal traffic has traditionally been carried over national carriers' ''half circuits"; that is, circuits were provided by contractual agreement between two national monopoly' operators. Now there is a shift toward "light carriers," providing international service by reselling. rerouting. and reprogramming capacity leased from the traditional (' 'heavy") carriers. This movement is driven by the ability to usc software to provide "least-cost global routing' through a wide choice of carriers (although in fact none of the light carriers can yet offer "globa" service).[18]

Carriers that have residual monopoly power over basic telecommunications services will have a continued means and incentive to leverage that power into the provision of enhanced services. For example, a carrier might providc customer access to its internal logic and databases more efficiently or effectively than it would provide access to external logic and databases belonging to a competitor. This means that regulatory issues such as open network architecture and open network provision will remain important topics in the future.

As private networks also become more complex, some corporations arc contracting with carriers, value-added network operators, and other outside firms to manage their existing networks ("outsourcing"). But carriers arc also seeking help in network management, administration, and maintenance. For example, Ericsson, the Swedish telecommunications company, and Hewlett-Packard, the U.S. computer manufacturcr. recently announced a joint venture to provide telecommunications operators with network management systems. This was described as being "aimed at winning business from the growing demand among telecommunications operators to place orders outside their own companies for systems that combine net-

[18] Gregory Staple, "Winning the Global Telecommunications Market," *Telegeography 1992* (London: International Institute of Communications, 1992).

Regulators and policymakers will find it increasingly difficult to separate regulated basic services from unregulated enhanced services.

work management with administrative and customer support systems. '[19]

Because of the creation of services within software rather than in hardware, regulators and policy makers will find it increasingly difficult to separate regulated telecommunications services from nonregulatcd enhanced information services, or to distinguish definitively between public and private networks. Similarly, agreements reached by trade negotiators that depend on distinctions between basic and enhanced services will be difficult to implement and enforce----a- will tend to stultify innovative developments.

As networks become more software-intensive and more complex, like ' 'giant distributed computer systems,"[20] they may also find that they are increasingly vulnerable to various kinds of systems failure resulting from software and hardware defects, human error, effects of natural disasters, and hostile and criminal intrusion. The core cause of failure may be simply the inability to comprehend and manage the proliferating relationships and dependencies within extremely complex systems. In international networks, coping with these vulnerabilities will require global cooperative actions.

Standards

Issues of standards development are increasingly important in the context of U.S. competitiveness in European markets. U.S. firms engaged in international commerce want a communications infrastructure that is seamless, reliable, cost-effective, and flexible. Above all, they want transoceanic and pan-European networks that, whether public, private, hybrid, or shared, are fully interconnected and interoperable. This implies the necessity of international standards.

A standard is an agreed upon technical specification or set of specifications used in producing goods or services. ' 'Product standards' define a particular item, system, function, or service. "Process standards' define features or functions that must be the same in all versions of a product or service in order to assure their safety, reliability, or interoperability with other products or services. The latter is of paramount importance for computers and telecommunications.

Many standards develop informally or *de facto;* that is, one kind of product or services captures the market, either by being first or by winning nearly universal approval.[21] Standards may also be formally set by agreement among producers; these are called voluntary standards. Finally, standards may be mandated by governments, usually for reasons of safety, health, or environmental protection. Standards traditionally were promulgated long after a technology was invented, but recently they are often ''anticipatory —that is, they may be agreed on at an early stage of a technology's development in order to guide its design and make it attractive to a larger **market** than it would otherwise find.

19 R. van de Krol, "Ericsson Joins Hewlitt in Network Systems Venture," *Financial Times,* Dec. 11, 1992.

20 Hatfield Associates, Inc., *Advanced International Telecommunications Technologies and Services*, OTA contractor report, December 1992.

21 David Hack, "Telecommunications and Information-Systems Standardization—Is America Ready?" Congressional Research Service, CRS 87-458 SPR, May 211987. Such informal standards can be taken as a sign, Hack says, t hat "past creativit y has provided societ y with a solution which if adopted broadly and consistently can move creative efforts to a new level."

Anticipatory standards create a target toward which technology development can be directed.

While simple product standards deal with the characteristics of stand-alone devices or components, such as the 12-button keypad of a modern telephone, integrated-systcm standards deal with the structure or architecture of complex technological systems or networks. Such standards assure that one part of a system will not disallow something that is important for another part of the system. For example, Open Systems Interconnect ion is an anticipatory integrated-systems standard that may allow multiple development efforts to be integrated into a cohesive structure.[23]

Networks and interoperability

Because of the imperative of interoperability, there is a strong incentive for developing international network standards that span many national markets.[24] Telecommunications network standards were originally developed for analog, hierarchical systems where the carrier was the dominant (or only) decisionmaker and the users had, or were treated as though they had, ' 'monolithic, invariant needs,"[25] In analog networks, the content of the message (e. g., whether it is voice or data) determines how it is to be treated or transmitted. Digital systems arc fundamentally different: ''a bit is a bit is a bit,' and what matters is what happens at the interface to the user's application. With programmable or intelligent networks, as described above, control of the network may be shared between carrier and user, and flexibility becomes essential. Carriers and providers of services have a disproportionate advantage here; standards, and user participation in standards-setting, are increasingly important to assure users of full and cost-effective interconnect ion.

In the 1980s, although computer costs were dropping rapidly, telecommunications network costs were soaring because of problems of incompatibility.[26] which had to be solved one at a time with converters, translators, and gateways, and other kinds of customized connectors. In traditional methods of standards development, the cost-effectiveness of manufacturing is balanced

22 Process standards to assure interoperabilit y, compatibilit y, or modularity are especially important wit h networks, whose value to users depends not only on the products' intrinsic qualities but on the number of others who have compatible products. The most familiar examples of this qualit y of beneficial externally y are telephone systems, whose value to each customer is assumed to Increase with the number of subscribers it connects. (Stanley Besen, "AM vs FM: the Battle of the Bands," *Industrial and Corporate Change, vol.* 1, No. 2, 1992,) Besen points out that the number of other users may directly effect performance, or may bring about Improvements in the supply or qualit y of com elementary goods and im prove t he quait y of after-sales service by enlarging the market.

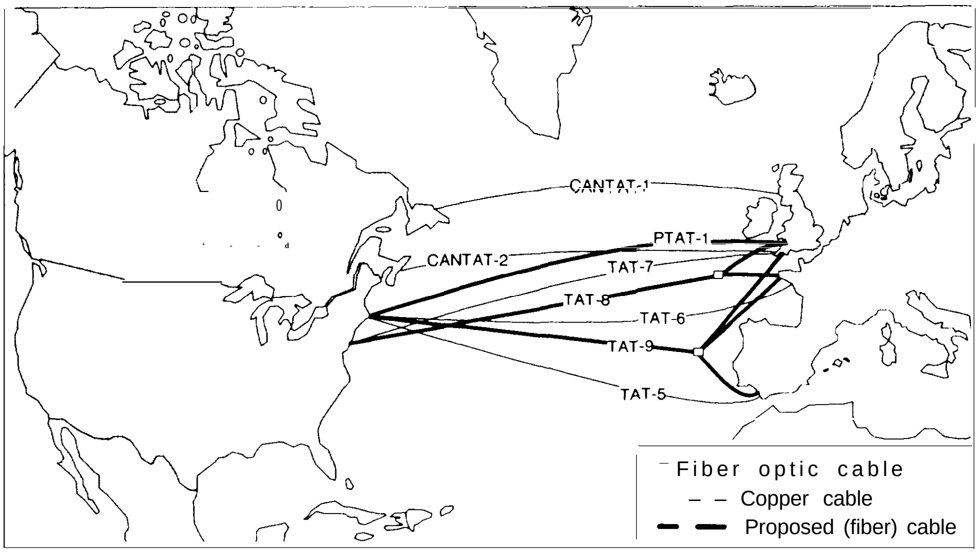
23 David Hack, op. cit., footnote 21.

24 As used here, "international" means standards that are globally accepted, rather than standards fort he International l inks between disparate national networks.

25 Richard Jay Solomon and Anthony M. Rutkowski, "Standards-Making for IT: Old vs. New Models," presented at the Conference on the Economic Dimension of Standards—Users and Governments in IT Standard ization," sponsored by Ministry of International Trade and Industry, Ministry of Posts and Telecommunications, and Organization for Economic Cooperation and Development, Tokyo, Nov. 18, 1992.

26 Stanley Besen, op. cit., footnote 22.

Figure 2-7. *Transatlantic Communications Cables*



SOURCE OFFICE OF TECHNOLOGY ASSESSMENT, 1993.

against protection for consumer safety and health. Standard-setting is slow and cumbersome, and largely dominated by technology producers, with very limited participation by users. This makes it difficult for standards to respond to customers' emerging needs. For rapidly advancing telecommunications technologies, standards should also have three characteristics, according to Richard Jay Solomon and Anthony M. Rutkowski:

- *ectensibility* --the ability to incorporate evolving technology without complete replacement of components;
- *scalability* --applicability to local, regional, national, and international networks; and
- *timeliness* --synchronization with evolution of technology and markets.[27]

The U.S. process for standards development is increasingly unsatisfactory to many critics, and perhaps to most participants.[28] It is plagued with dissension and rivalry; it is cumbersome and arcane; it is dominated by a few organizations with the considerable resources and dedicated expertise necessary for sustained participation. Intellectual property issues are unresolved. The dissemination of standards is often limited by copyrights and costs. Critics say that the process, developed for reaching consensus on relatively simple and slow-changing manufacturing technologies (e.g., the number of threads on a screw) is not appropriate for advanced electronic technologies and services to meet the highly varied and continu-

27 Solomon and Rutkowski, op. cit., footnote 25.

28 Fora full description and analysis of the process and the growing dissatisfaction witht, see U.S. Congress, Office of Technology Assessment, *Global Standards: Building Blocks for the future, OTA-TCT-512* (Washington, DC: U.S. Government Printing Office, March 1992).

ally changing needs and desires of large users.

New ways of achieving interoperability

This widespread dissatisfaction. and the implementation of packet networks in the early 1970s, resulted in an effort to find a new way of assuring interoperability, by defining a generic open systems interconnection model.[29] "Open means that any two systems conforming to a reference model and its associated standards can interconnect. One such model was developed for the Department of Defense's research computer network, ARPANet, and included a suite of protocols known as Transmission Control Protocol and the Internet Protocol (TCP/IP). Another, called the Open Systems Interconnection (OSI) model, was adopted by the International Standards Organization (IS0) and the International Telecommunication Union (ITU).[30] Both define the functions that the communicating computers (as well as some of the internal network components) must perform. Both define ''protocols, ' i.e., the precise stream of data bits that must traverse from one computer to another.

In each standard, the definitions of functionality and the protocols arc organized into layers. In the Department of Defense model, four layers are recognized; in the OSI model, there arc seven. Layers make it possible for different committees to work in parallel on the development of the standards. The reference model defines the layers. A layer bounds the responsibility of each committee. A well-conccivcd reference model can greatly speed up standards development.

Producers vs. users

When products conforming to different standards (including proprietary standards) must communicate with each other, devices known variously as protocol converters, translators, or gateways can sometimes be used. Such devices have limitations. Their development depends on deep understanding of both standards; they can only support features that arc implemented in both products, and they may become unworkable

2 Solomon and Rutkowski, op. cit., footnote 25.

30 The International Organization for Standardization is an Independent, specialized International agency whose members are 97 national standards-setting bodies. The I SO promulgates voluntary standards in all fields except electrical and electronic engineering, where standards are promulgated by the International Electrotechnical Commission (IEC), also an independent specialized agency. Standards for interconnecting national networks are established by the International Telecommunication Union (ITU), now a specialized agency of the United Nations. In its standards-setting activities the ITU works primarily through two committees, the Consultative Committee for International Telephone and Telegraphy (CCITT) and the Consultative Committee for International Radio (CCIR). The ITU recommendations do not carry the force of law, but they are often Implemented and enforced at the national level.

The ITU, as a United Nations agency, recognizes only governments. PTTs automatically have governmental status but not the United States' American National Standards Institute (ANSI) and the Exchange Carriers' T1 committee, which are private sector organizations. The U.S. Department of State therefore picks delegates to international standards meetings, but chooses largely representatives of the telecommunications industry and some large user corporations. Critics of the voluntary standards-setting process note that the head of the State Department's Bureau of Communications and Information Policy, which makes these appointments, is a political appointee, and complain that the delegations may be politically vetted. In the ISO, which unlike the ITU is not a treaty organization, ANSI is the U.S. member-representative.

when one or the other of the connected devices is upgraded. (See box 2-A.)

On the other hand, either the informal triumph of one standard, or the voluntary formal acceptance by the industry of one standard, can cause nonconforming network products to suddenly lose all value. The standard that prevails may not necessarily be the best, and always some users will be left with incompatible equipment or networks. The large installed bases necessary for global networks make it particularly costly for users later to shift to newer, more technologically advanced standards. But while standards may cut off innovation at one level by mandating one path of technological development, they make it possible to put one set of problems behind and move up another path. There is always tension between uniformity and optimality, between universality and innovation. Compromises are necessary, and this may set producers against users. The challenge is to find just the right time to freeze a standard.

*Users tend to urge ear/y adoption of standards, **while** equipment producers tend to resist early adoption.*

Users, whose chief concern is with interoperability of systems, are generally eager to see the adoption of international standards so long as these do not unduly hinder the continuing evolution of technology and services. In a survey and several case studies of large-scale U.S. users of international telecommunications conducted by the Office of Technology Assessment for this assessment the need for international standards was among the points most frequently made by users. (See chapter 5, Users' Perspectives.) Telecommunications providers and equipment producers tend to agree on the need for international standards but are much more immediately and urgently concerned with the specifics of those standards. Their individual market goals often drive them to resist agreement on standards longer than is in the interest of the industry as a whole. The standards-development organizations themselves have self-aggrandizing motivations and behaviors that often frustrate, rather than advance, the development of consent to voluntary standards.

Standards and the future

Competitiveness in foreign markets is increasingly tied to standards. The European Community is now giving strong attention to standards as a fundamental mechanism for pursuing the goal of a single market, and has particularly targeted telecommunications technologies as a high priority sector for European standards development. The EC has shown itself willing and able to develop new institutions and adopt new procedures for standards development. In 1988 it created a special standards organization, the European Telecommunications Standards Institute (ETSI), which is developing approximately 300 European standards. Most will be voluntary but some will be mandatory, and these are likely to include standards aimed at assuring interconnectivity.[31]

Europe is a large market that is potentially worth large investments by U.S. firms in meeting its standards. U.S. firms active in Europe therefore have a strong incentive to participate in ETSI standards-setting, but to

31 ETSI is now studying this question, according to information supplied by Anna Snow, Trade Division, Commission of the EC, Washington, DC. See also U.S. Department of Commerce, International Trade Association, "E.C. Telecommunications," release of Oct. 1, 1991. ETSI's technical comm ittees are staffed by technical experts rather than representatives of affected industries. To accelerate their promulgation, adoption of standards will be decided not by consensus development but through weighted voting.

BOX 2-A. INTERNET STANDARDS DEVELOPMENT

ARPANet, originally sponsored in 1969 by the National Aeronautics and Space Administration (NASA) and the Department of Defense to link scientists in certain research centers, has expanded to become Internet. Internet consists of many linked regional computer networks like SuraNet, PrepNet, etc., and as many as 10,000 small networks, with an estimated 20 million users worldwide. The actual connections are often modems connected to T1 leased lines, paid for by universities, research institutions, or corporations to Iink themselves to a local carrier that in turn connects them with T3 "backbones" between major locations. Several government agencies, especially the Department of Defense, NASA, and the National Science Foundation, continue to be heavily involved with funding and support of Internet for the use of universities, research organizations, and government, but a number of private sector companies provide access to it for corporations and individuals, at varying costs to users.

A new form of standards-setting appears to be evolving in connection with Internet. An Internet Society has been formed as a global coalition of carriers, information services vendors, and equipment manufacturers. It includes a group called the Internet Architecture Board (IAB), whose job is to develop the series of international standards through progressive electronic discussion and standard-drafting on the network, which is open to all users at very Iowcost. IAB has established a "cooperative relationship" with international bodies such as the ITU to encourage the use of Internet to enhance global telecommunications collaborate ion in standards setting.

It should be noted, however, that in part as a result of the informality and rapid, random growth celebrated by Internet enthusiasts, access to and use of Internet remain complicated and obscure to many potential users and there are few "road maps" to the system.

The growth of Internet has given rise to a great many policy issues related to its commercialization and the role of government in its future. Many proponents of Internet, especially its earliest users in universities and research centers, have resisted any hint of government regulation; hence many issues such as universal service, privacy and intellectual property rights are unresolved even as Internet approaches the status of a major public utility.

SOURCE OFFICE OF TECHNOLOGY ASSESSMENT, 1993.

do so they must have a European presence. This is a powerful incentive for them to develop joint ventures or other strong alliances with European firms, or find other means to establish European subsidiaries.

The U.S. process of standards development may require reform if it is to match the pace and increased effectiveness that is the aim of the EC current initiatives. This is unlikely to happen unless government policy provides leadership for, coordination of, and strong pressure on the contending factions within the private sector standards community. In international standards-setting arenas, the influence of European institutions will be increasingly strong and effective because of the support provided to, and the insistence on, communitywidc standards development by the EC Commission. This too implies closer cooperation by U.S. participants, and possibly a stronger leadership role for the Federal Government in pursuit of strong competitive policy goals.

National or regional standards can be used deliberately to create trade barriers and inhibit competition. Every nation wants its telecommunications companies to be major players in world markets. In order to provide a strong domestic base, many nations discriminate in favor of domestic firms through procurement or by adopting a national standard that is different from that used by foreign producers, thus effective y closing their market to foreigners by raising the costs of penetrating it.[32] Some U.S. critics fear that EC members may form a solid voting block in international standards negotiations to impede the introduction of superior networking technology because it is perceived as U.S. dominated.[33]

Thus standards inevitably become the subject of trade negotiations. In the 1979 GATT Agreement on Technical Barriers to Trade, signatories agreed to refrain from using national standards to frustrate trade in products. This agreement was embodied in the U.S. Trade Agreements Act of 1979. However, since the GATT Standards Code explicitly does not apply to services or to government purchasing, European PTTs are usually exempt.

Along with a strong movement toward international standards, there are parallel and complementary movements to achieve interconnectivity and interoperability by other means. The FCC's Computer III decision required that Bell operating companies provide their competitors with "Comparably Efficient Interconnection" (CEI) and an open network architecture (ONA) acceptable to the FCC.[34] ONA means that components of the telephone system must be made available to competing suppliers on an unbundled basis so that they can be combined with the services of these suppliers in any manner desired. If components can be obtained on a bundled basis only, the interface between them is inaccessible to the competing supplier. The effect is the same as if the interface were accessible but incompatible.[3s] The nature of the unbundling and identity of basic service elements are contentious issues because they affect the potential for competition. Services suppliers and telephone companies want different levels of aggregation.

The European Community has issued a directive entitled "Open Network Provision (ONP) Framework and Services."[36] It calls for open access to harmonized services across national borders. Whereas ONA is aimed at technical interfaces, ONP is aimed at institutional change, but the intent is the same: to foster the development of expanded markets with heightened competition, and allow translational companies to enjoy telecommunications and information services

32 Robert W. Crandall and Kenneth Flamm (eds.), "Overview," *Changing the Roles: Technological Change, International Competition, and Regulation in Communications* (Washington, DC: The Brookings Institution, 1989), pp. 1-10.

33 Sa'id Mosteshar, "Notes on Standard Setting: Bod ies in Telecommunicate ions," in a Report of t he Working Group on Telecommunications, information Technology, and Broadcasting, of the American Bar Association Special Task Force on EC 1992, June 29, 1990.

34 This was a condition for waiving an earlier FCC requirement that the Bell operating companies offer enhanced services only through subsidiaries.

35 Stanley M. Besen and Gart h Saloner, "The Econom ics of Telecommunication Standards," Crandall and Flamm, op. cit., footnote 32.

36 0. A/. P.: *The* Progress *Report-European Telecommunications 2,* Analysis Briefing Report Series (Cambridge, England: Analysis Publications, 1991).

without regard to national boundaries.[37] Implementation of the ONP Framework has so far been uneven.[38] Some EC membcr-states have not yet taken the first step of separating telecommunications operating functions from regulatory functions.

Expectations are, nevertheless, that in time the economies of scale made possible by ONA and ONP policies will begin to transform the market for telecommunications equipment into a commodity-type market in which goods compete more on price than on features. This in turn will make the telecommunications" services market highly competitive. However. given the global scale of the market and the importance placed by large companies on having efficient access to a broad menu of facilities and services, the likely outcome is not that many small companies will be offering highly individualized services but that small numbers of major players will provide international companies with services and Support.[39]

The U.S. opportunity to compete in Europe in developing and delivering enhanced communications and information services depends on both the increasing interoperability of U.S. and European networks, and the increased inter-operability of networks within Europe. The competitive advantage of U.S. firms in Europe however also depends on their differential ability to offer innovative, flexible, user-oriented services and technology. The challenge is to combine those imperatives.

37 Japan has a comparable initiative, called Open Network Development (ON D), aimed at limiting the dom inance of Nippon Telephone and Telegraph (NTT) by allowing access to its network to competitive operators and resellers.

38 "Update on ONP," *INTUG News* (International Telecommunications Users Group, London), January 1992, p. 12, and October 1992, p. 10.

39 Besen and Saloner, op. cit., footnote 35.