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A Primer on Integrated Services Digital Networks (ISDN): Implications for Future Global Communications

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U.S. DEPARTMENT OF COMMERCE
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PREFACE

This report describes the Integrated Services Digital Network (ISDN) concepts and issues in terms understandable to persons not working directly in this technical area.

It has been prepared by staff members from the Systems and Networks Division of the Institute for Telecommunication Sciences. These persons have been working directly in the field by conducting studies on ISDN and by contributing to organizations engaged in developing ISDN standards.

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LIST OF ACRONYMS

ACD	-	automatic call distribution
ANSI	-	American National Standards Institute
ASCII	-	American Standard Code for Information Interchange
AT&T	-	American Telephone and Telegraph
A/D	-	analog-to-digital
BIT	-	binary digit
BOC	-	Bell Operating Company
b/s	-	bits per second
CATV	-	cable television
CEPT	-	European Conference of Posts and Telecommunication Administrations
CCIS	-	common channel interoffice signaling
CCIR	-	International Radio Consultative Committee
CCITT	-	International Telegraph and Telephone Consultative Committee
CPE	-	customer premises equipment
CPU	-	central processing unit
CRT	-	cathode ray tube
CSDC	-	Circuit Switched Digital Capability
CSDN	-	circuit-switched data network
DCE	-	Data Circuit-Terminating Equipment
DTE	-	Data Terminal Equipment
D/A	-	digital-to-analog
EBCDIC	-	Extended Binary Coded Decimal Interchange Code
EFT	-	electronic funds transfer
EIA	-	Electronic Industries Association
ENIAC	-	Electronic Numerical Integrator and Calculator
ESS	-	electronic switching system
FAX	-	facsimile
FCC	-	Federal Communications Commission
FDM	-	frequency division multiplex
FTSC	-	Federal Telecommunications Standards Committee
HI-OVIS	-	high interactive-optical visual interactive system
IAN	-	Integrated Analog Network

LIST OF ACRONYMS (cont.)

IC	-	integrated circuit
IDN	-	Integrated Digital Network
IEEE	-	Institute of Electrical and Electronics Engineers
IFIP	-	International Federation for Information Processing
IFRB	-	International Frequency Registration Board
ISDN	-	Integrated Services Digital Network
ITS	-	Institute for Telecommunication Sciences
ITU	-	International Telecommunication Union
I/O	-	input/output
JWP	-	Joint Working Party
LADT	-	Local Area Data Transport
LAN	-	Local Area Network
LSI	-	large scale integration
MSI	-	medium scale integration
NTIA	-	National Telecommunications and Information Administration
PABX	-	private automatic branch exchange
PBX	-	private branch exchange
PC	-	personal computer
PCM	-	pulse code modulation
PSDN	-	packet switched data network
PSTN	-	public switched telephone network
PTT	-	Post, Telegraph, and Telephone organization
RAM	-	random access memory
RPOA	-	recognized private operating agency
R-O	-	read-only
SPC	-	stored-program control
SSI	-	small scale integration
STP	-	signal transfer point
TCM	-	time compression multiplex
TDM	-	time division multiplex
TWX	-	Teletypewriter Exchange Service

LIST OF ACRONYMS (cont.)

T1	- multiplex of 24 voice channels	North American Standards
T1C	- multiplex of 48 voice channels	North American Standards
T2	- multiplex of 96 voice channels	North American Standards
VAN	- value-added network	
VDT	- video display terminal	
VLSI	- very large scale integration	
VSF	- voice store-and-forward	
WATS	- wide area telephone service	

A PRIMER ON INTEGRATED SERVICES DIGITAL NETWORKS (ISDN): IMPLICATIONS FOR FUTURE GLOBAL COMMUNICATIONS

ITS Staff*

The report is a primer on Integrated Services Digital Networks (ISDN's). The ISDN concept is believed by many to be the communication means for the future information age. A number of national ISDN's interconnected together can provide a high-performance, multi-service, digital network for global communications.

This primer on ISDN is for persons unfamiliar with telecommunications but who wish to know about this important concept. The report explains the developments in telecommunications technology--from analog to digital--that make possible the efficiencies and economies of an ISDN or ISDN's. Also addressed are technical and policy considerations: Why is an ISDN needed? How is it expected to evolve? What problems will it cause? Who is working on them?

Key words: data communication; digital communication; integrated services digital network; ISDN; telecommunications

1. INTRODUCTION

A need to move information is growing worldwide. Increasingly, the information transfer must be rapid and inexpensive, between points near or far. In response, a global effort is underway to establish a digital network that will transport voice and non-voice information as needed. This network is called the Integrated Services Digital Network (ISDN). An ISDN, or a number of ISDN's, might evolve in each country from existing network(s). In the United States, several ISDN's could emerge from existing telecommunications systems. This report discusses why plans for an ISDN(s) are being formulated, what an ISDN is, and some issues that require resolution.

Digital technology makes the ISDN concept feasible. Telephone systems in the United States and abroad are using digital technology to improve and expand capabilities. Traditionally analog non-voice information, such as facsimile and television, is becoming more dependent on digital transmission. New services such as videotex and teletex already use digital transmission techniques.

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The marriage of digital technology and information transfer is important to multibillion dollar industries such as banking, product distribution, insurance, manufacturing, medicine, and travel reservations. Industries such as these have their own extensive private telecommunication networks. Office automation, dependent on digital systems, is integral to them.

A potential ISDN configuration may consist of the concept illustrated in Figure 1. The U.S. ISDN(s) may interconnect to non-U.S. ISDN's, International Record Carriers (IRC's), value-added networks (VAN's), and private networks, including local area networks (LAN's). Initially, the U.S. ISDN will use in-place equipment to handle digital bit-streams. As the network and services evolve, the ISDN will include communication equipment that permits integration of voice and non-voice services. Subscribers of each network, public or private, would be able to communicate with each other. Variable transmission rates dependent on a user's need will be available on demand. Although all ISDN services have not been defined, they are expected to include digitized voice, data transfer between computers, facsimile, graphics, video, and other services such as telemetry (energy management, security monitoring), videotex, electronic mail, and data base access for word processors -- in all, a broad scope of information services in an Information Society.

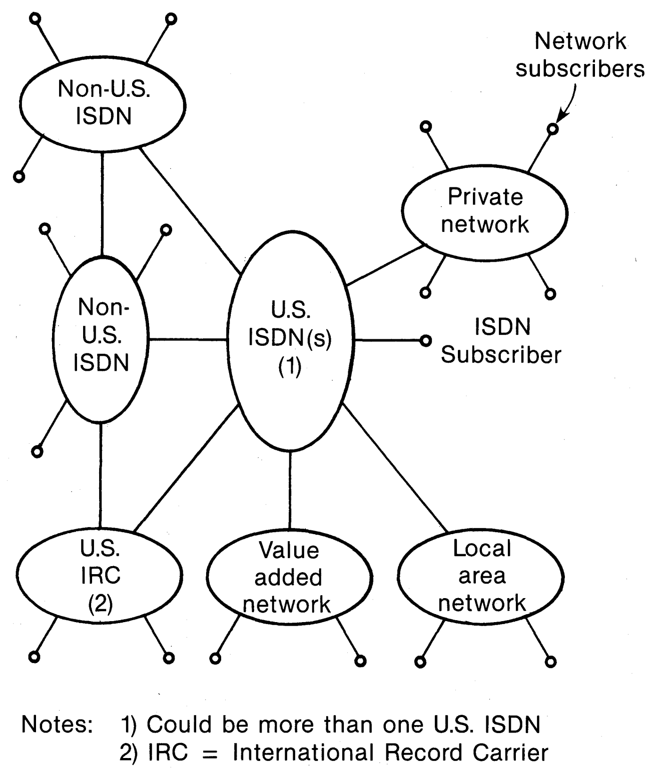


Figure 1. Potential ISDN configuration.

Standards for an ISDN are being developed by the International Telegraph and Telephone Consultative Committee (CCITT) of the International Telecommunication Union (ITU), an agency of the United Nations. The United States and other countries are working to define the ways that subscribers will have access to an ISDN or to ISDN's. Contributions to the CCITT are made through a coordinated effort by these countries. In this country, the U.S. CCITT Joint ISDN Working Party is the focal point for ISDN effort by government and industry.

Many issues need to be resolved before the ISDN becomes a reality. The U.S. communications environment is unique because of the many common carriers, public and private networks, and multitude of different services. To be answered are such questions as:

- What should be the geographical or network boundaries of the U.S. ISDN(s)?
- Where do the public and private, cable TV, and local networks fit within an ISDN?
- How will all these networks interconnect to the ISDN or to each other?
- How will the U.S. ISDN(s) interconnect with foreign ISDN's?
- Who, or what, will manage, set standards for, control, and operate an ISDN?

Section 2 provides an insight into the economic aspects leading to an ISDN(s). It includes an introduction to a basic element of digital technology, the computer-on-a-chip.

Section 3 is intended for readers who may not be familiar with communications terminology. Subsection 3.1 explains such terms as analog, digital, interfaces, protocols, and modems. Subsection 3.2 becomes more advanced by discussing circuit, message and packet switching. Descriptions of services offered by representative communications carriers are also given.

Section 4 provides a description of the ISDN and the evolution toward it in the United States and in some other countries.

Section 5 provides a list of some major ISDN issues and the actions that may be taken to resolve them.

Appendix A provides a description of the organization, structure, and processing of standards, known as Recommendations, within the CCITT.

Appendix B is a reprint of the text of Question 1 of CCITT Study Group XVIII, concerned with overall studies related to the general features of future ISDN's that can satisfy the requirements of many different services.

Appendix C is a description of the Open Systems Interconnection (OSI) reference models of the International Organization for Standardization (ISO) and the CCITT.

2. WHY AN ISDN?

Primary reasons for establishing ISDN's are economy and flexibility made possible by integrating emerging new services with existing services. It is more efficient to use and reuse existing networks than to build a separate network for each service. With digital technology, communication resource sharing among services has become feasible.

Three factors motivating an ISDN are 1) technological developments that make possible expanded capabilities, 2) the lower cost of offering new equipment and services (because of digital technology and digital network characteristics), and 3) the demand and subsequent availability of new or expanded services. Combining these three factors results in economic benefits through service integration.

This section explains, "WHY AN ISDN?" by expanding on the above factors. First, the merging of the computer and telecommunications technologies is illustrated to show how the distinction between the two has been blurred. Second, a brief history of semiconductor developments is outlined. This history depicts both the increased capability of microelectronic chips and their simultaneous decrease in cost. These advances in technology lead to new services at reduced cost. Finally, a discussion of industries requiring data communications services, illustrates how these industries (and others) have been forced to increase efficiency (using data communications) so that they can improve productivity to offset rising labor costs. The obvious conclusion of the discussions in this section is that, while technology advances have made an ISDN possible, demands for services and increased efficiency have made it mandatory.

2.1 Merging of Two Technologies

The groundwork for the ISDN may have begun four decades ago with the onset of convergence between two technologies. Starting with the 1940's, computers and communications technologies were two distinct areas of development. With time, these technologies have become dependent on each other.

During the past four decades, communication technology in such fields as microwave radio, cable, satellites, and telephone switching systems developed on a separate, but convergent course with computer technology. Electromechanical computers were in existence when the first electron-tube computer (the ENIAC) came into being. It was followed by solid-state computers that used transistors and integrated circuits (IC's). Eventually, switches controlling telephone lines required computers for control and to provide new customer services. Concurrently, computers accessed by telephone lines required higher data rates and digital networks. A data terminal that at one time was limited as a human interface to a computer, now contains communications and computing ability. The communications and computer industries converged and aided each other. Differences between data processing and communications have become less distinct: communications now use extensive computer control and computer services have communication embedded within them.

Figure 2 illustrates the overlapping of the communications, data communications, and data processing industries, by showing dollar totals (in billions) for each of the three industries for the years 1970, 1975, 1980, and 1985 (estimated).

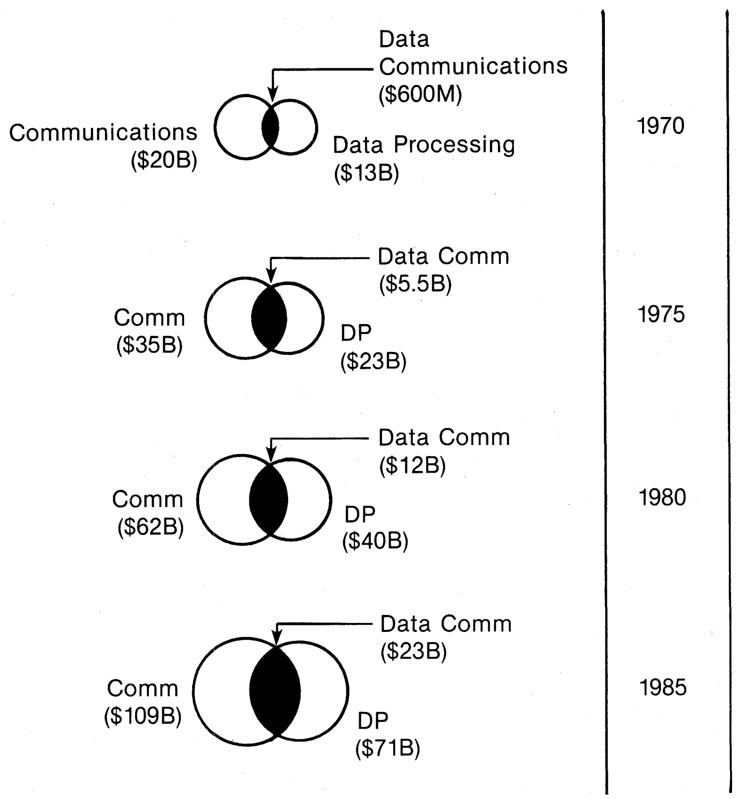


Figure 2. Growth of data communications industry.

Figure 3 shows the changing composition of the U.S. workforce, by percent from 1860 to 1980. Stage I was mainly an agricultural economy, stage II an industrial economy, and stage III is the information economy.

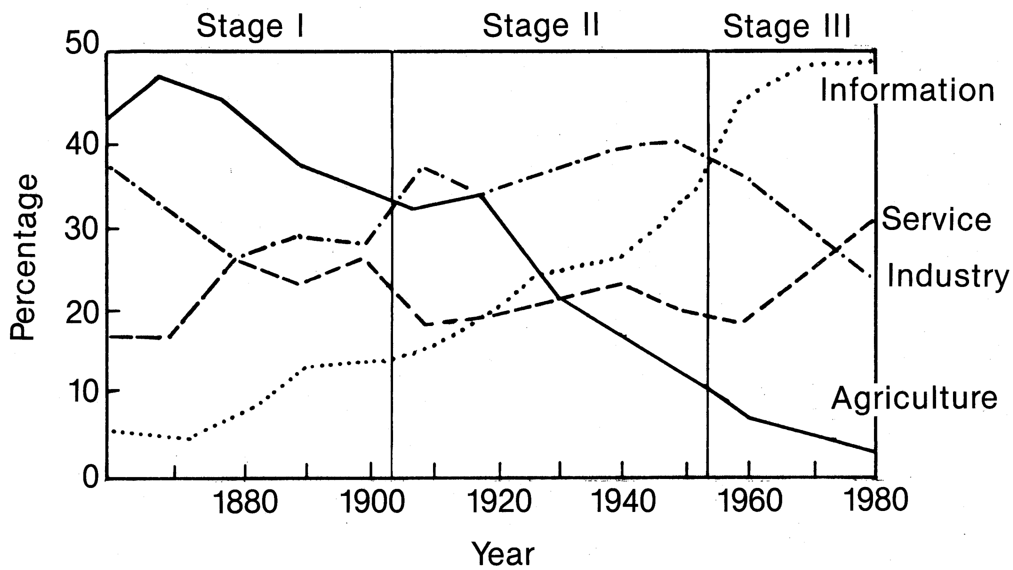


Figure 3. Changing composition of U.S. workforce.

As our society becomes increasingly involved in information services, the use of communications increases, and the efficiency of digital communications becomes more important to us. Improvements in communications technology become very significant as we try to improve our nation's productivity to compensate for rising labor costs.

2.2 Technology Advancements

One of the reasons for the merging of telecommunications and data processing is that individual electronics components have increased in capacity and speed, while simultaneously decreasing in cost. These simultaneous developments have made it easier to add a small, inexpensive chip to a terminal or a telephone to provide enhanced capabilities.

To understand the nature of these enhancements, it is necessary to understand the basic elements of a computer. Figure 4 illustrates the fundamental structure found in all computers, ranging from large super-computers to microcomputers.

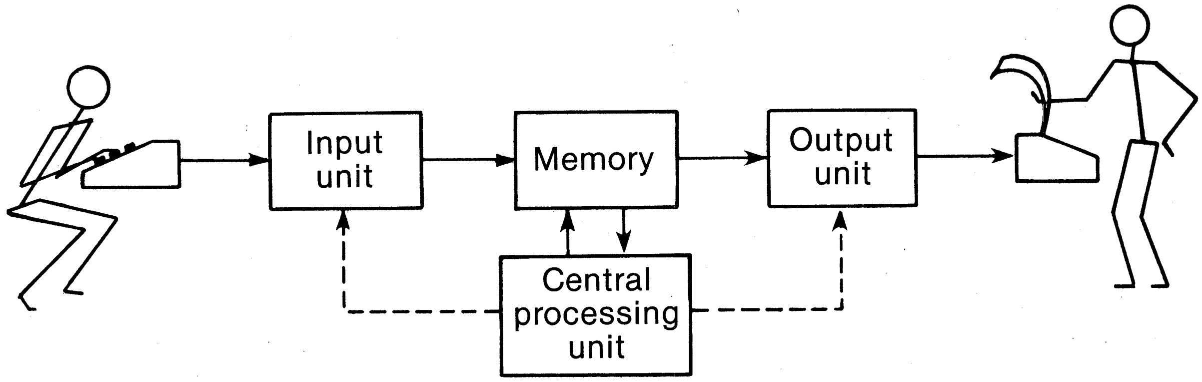


Figure 4. Basic structure for large computers and microcomputers.

Each computer consists of three basic units:

- the central processing unit (CPU),
- the internal memory, and
- the input/output (I/O) capability.

The CPU performs arithmetic, logic, and control functions, manipulating and directing traffic in a computer. The direct memory contains the programming instructions that are performed by the CPU. It also contains the data that are being operated on by the CPU. The I/O capability is the communications link between the internal computer functions and the outside world. The input unit is the interface through which humans can control the computer with keyboards and tape instructions. The output unit is the interface for recording results on external storage media such as paper, magnetic tape, discs, or solid-state devices.

Microcomputers use different chips to perform the CPU, memory, and I/O functions. It is the chip unit that underlies telecommunications technology and the ISDN. The term "microprocessor" has been used to mean the CPU.

Microcontrollers, such as those used in microwave ovens and other home appliances, contain the CPU, memory, and I/O functions on one chip. The limited instructions and memory requirements to control a microwave oven allow integration of the three functions.

The tremendous advances made in semiconductor technology since the development of the vacuum tube and transistor have completely revolutionized the computer industry. In 1946 the first computer, the Electronic Numerical Integrator and Calculator, called "ENIAC", had 18,000 vacuum tubes and weighed 30 tons.

Reliability was not its strong point. The microcomputer of today is a tiny, yet more powerful computer. It has the same three elements (CPU, memory, and input/output capability) that ENIAC had, but is composed of a complex of circuits on thin wafers of silicon approximately as small or smaller than the end of a finger. It is 20 times more powerful than ENIAC and extremely reliable. These microcomputer advances are the result of miniaturization and mass production.

With the introduction of the transistor in the 1950's, subsequent higher densities of transistors and complete circuits on a wafer chip, came lower per-unit costs of production and a flourishing digital technology. Chips have invaded almost every segment of society: the home, office, factory, hospitals, and entertainment centers. As the technology has advanced, so have its applications. Although computer companies use over 40% of all chips produced, semiconductors are also used in air conditioners, refrigerators, cameras, digital watches, typewriters, telephones, electronic toys, stereos, airplanes, autos, and machine tools.

One of the reasons that chips are used in so many devices today is that they are small with very large capacity. Figure 5 illustrates the increasing density of component circuitry on a chip and the decreasing cost per memory bit. The growth of electronics capabilities is characterized in one way by the number of components on a single chip. In 1960 one discrete device (transistor) was encapsulated in a package. Today, very large scale integrated (VLSI) circuits contain a total of a million transistors and related components on a chip within a package.

Figure 5 also shows the declining average price of memory devices that store bits of information. This has enhanced data communications and data processing services through digital technology at a lower cost. According to U.S. Department of Commerce data, the average price per memory bit dropped from two cents to less than one one-hundredth of one cent (1983 value) in a little over a decade.

Cost trends are further illustrated in the U.S. Industrial Outlook for 1983:

> the popular memory devices called "64k random access memories" or "64k RAMS,"--the most common element in many computers--were projected to have an average selling price of $50 by 1981. In fact, the 81-82 selling price was well below $10 per device. Predictions for 1983 are that the device will be selling in the $3-to-$4 price range with some quotes dropping below $3 per 64k RAM.

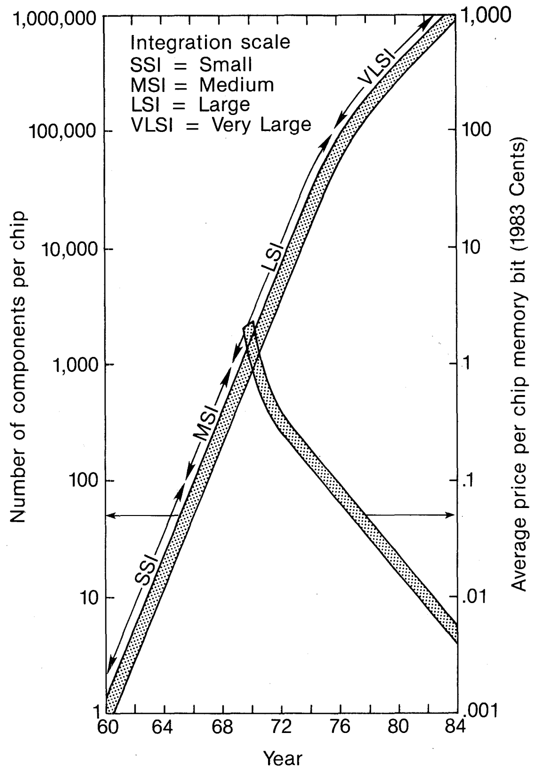


Figure 5. Trends for increasing density of components and decreasing cost of memory.

2.3 Market Size

According to the U.S. Department of Commerce, chip technology is now used in the production of more than $200 billion worth of goods and services in the United States alone. As more uses have been found for semiconductors, international demand for chips has skyrocketed. Production of semiconductors has doubled every year during the 1970's. Total world sales increased from $1 billion to $13 billion.

The value of U.S. production and consumption of all integrated circuits (the technical name for chips) per year is graphed in Figure 6. Projections call for a world market of over 100 million units of 64k RAM's in 1983--that's two-thirds larger than in 1982.

The use of semiconductors should increase even further in the 1980's and 1990's. The U.S. Department of Commerce expects that the world market for semiconductors will exceed $50 billion by 1988 and $200 billion by the end of the century.

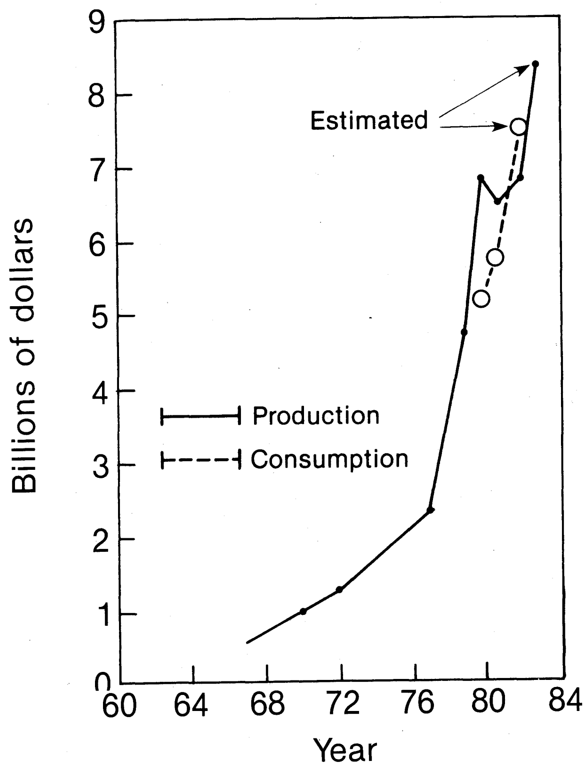


Figure 6. Value of U.S. production and consumption of all integrated circuits.

A learning process in utilization and economies of scale have assisted this trend in consumption.

The use of integrated circuits has also made possible the manufacture of many new products such as personal computers and pocket calculators. Shipments of electronic components, adjusted for price changes, are expected to reach $25.5 billion in 1933, up 12.4% from 1982. The innovative application of electronic components has to a degree offset the impact of the 1981-82 recession.

Computers are so heavily used today that their U.S. worldwide sales alone reached an estimated 2 million units in 1982, with a value exceeding $35 billion. For personal computers, the 1982 market was $4.5 billion, with an expected increase to $7 billion in 1983.

2.4 Users of Communications Services

There are several major industries that require voice and non-voice communication services on a large scale. A few of the obvious ones to mention are:

- banking
- insurance
- manufacturers
- distributors
- reservations services
- medical industry
- office automation industry.

These industries are sizable, and each has a significant impact on the U.S. economy. To illustrate size and to show the extent to which they are involved in data communications, two industries have been chosen for illustration. They are banking and office automation.

Banking. The size of the banking industry as a whole can be illustrated with Department of Commerce statistics: for 1982, commercial banks had assets of over $1,800 billion. Savings and loans institutions had an additional $708 billion in assets (U.S. Department of Commerce, 1983). In 1980, electronic data processing equipment in banks handled more than 250 billion data transactions over telecommunication lines. An American Bankers Association 1979 survey showed that as a rule, large banks with over $500 million in deposits had the most extensive telecommunications facilities: facsimile, Wide-Area-Telephone Service (in-WATS), electronic funds transfer, telecommunications for security and alarm systems, switched wideband or digital service, word processing equipment, computer terminal systems, telephone bill-paying service, etc.

The total annual domestic telecommunication expense for the commercial bank industry was over $866 million in 1979, compared to $788.4 million in 1978, and $626.6 million in 1977.

ComputerWorld and other journals have reported savings in time and money when banks have automated certain teller functions and used EFT (electronic funds transfer). Further costs can be saved for the banking industry by using an ISDN for its sizable data communications operations since there would be no need for banks to buy or build separate networks for each type of data transfer application: with an ISDN, voice and non-voice would be transmitted over the same network.

The Office Automation Industry. Office automation, which is part of all of these industries that rely heavily on data communications, is a big industry in itself. Fortune Magazine estimated that U.S. spending for advanced office gear will quadruple from 1981 to 1986, going from $3 billion in 1981 to an estimated $12 billion in 1986. U.S. shipments of gear that can be linked to form electronic offices, or automated offices, should grow 34% per year through 1986, they said. And office automation is still growing as our information society develops. [In 1980, 60% of $1.3 trillion paid out for wages, salaries, and benefits in the United States went to U.S. office workers.]

New Services. Accompanying the increase in capability of individual components has been an increase in applications of those components. Customized software (or "programs") has made possible a wide range of telecommunications products and services. These new service requirements have created an increased demand for an ISDN. A partial list of such new services would include:

- distributed processing
- electronic mail
- electronic funds transfer
- teleconferencing with data and facsimile
- mixed services (teletext and video) in one network.

As our information society grows, as technology develops, as component prices fall or stabilize, our use of communications goods and services will increase to maintain productivity levels and offset the rising cost of labor. Efficiencies of an ISDN can assist in this effort by making efficient use of transmission network(s) for a variety of telecommunications services rather than building a separate network for each type of service. While the emphasis within this section has been placed on data communication and processing, one should not dismiss the importance of voice communications. Voice is expected to maintain 80% to 90% of the communications traffic for many years.

3. TELECOMMUNICATIONS PRIMER

Defining any telecommunications network is a difficult task. This is particularly true today when networks are becoming more complex, are performing more functions, and providing additional services daily. The material in this section is intended for the reader who may not be completely familiar with some terminology, or aware of various facets of telecommunication network operation. While not intended to be exhaustive, the terms and concepts in this section will assist understanding the description of ISDN(s) in Section 4.

The aim of "communications" is to transfer information between two or more individuals or "things." Telecommunication means to transfer information at a distance. A telecommunication system like the telephone network provides economical information transfer to many separated users. This is because the telephone network uses "switches" so that many intermittent users can share the same resources or elements.

What are the resources? They include

- terminals like the telephone,
- switching nodes like the nearest telephone exchange, and
- transmission links or paths among terminals and nodes.

A simple telecommunications network is shown in Figure 7.

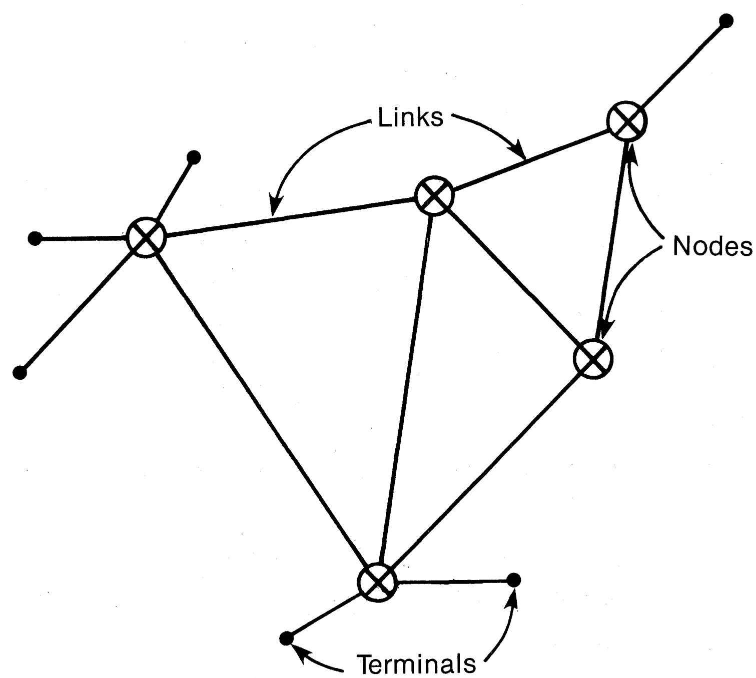


Figure 7. A telecommunications network.

Section 3.1 deals with the basic elements of communications. This includes a description of telephone system operation in placing a phone call, conversion of signals between analog and digital forms, and a way to reduce communication costs by reducing the number of phone lines, but not the required communication capacity.

Section 3.2 describes the elements of a telecommunication system such as terminals located at a user's premises, the means for transmission and control of messages; circuit, message, and packet switching, some network services that are provided, and local area networks (LAN's).

3.1 Basic Communication Concepts

The aim of a communication is to transfer information between two, or among a number, of points. The communication may be a conversation, either face-to-face, or a telecommunication over a telephone. It also could be the sending or receiving of a letter, watching television, reading a book, attending a lecture, or an art exhibit. There could be other examples, but each of these communications requires a minimum of three common elements. They are a source, that generates information and places it on a transmission medium, which relays the information to the receiver (Figure 8). The medium can be the air we breathe, communication lines of metallic wire, or the postal service that conveys letters and packages.

The information that is transferred over any medium can be called a message. In data communications it is also called data.

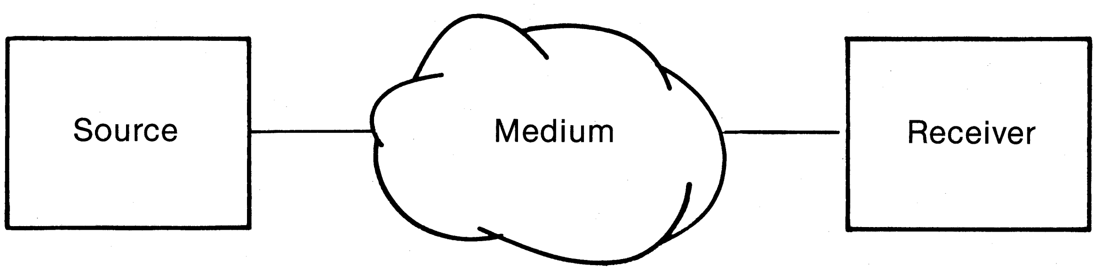


Figure 8. The three components needed for a communication.

Message communications involve a combination of message source, medium, and receiver that compose a communications network. In a communications network (also called a system) the emphasis may be on voice communications or on non-voice applications. In a voice communications network the source and receiver can be telephone instruments with communication lines in between. In a non-voice network the source and receiver can be a teleprinter, video display terminal (VDT), computer, or facsimile machine. Generically, these devices are called Data Terminal Equipment or DTE's. Again, the transmission media can be a communication line or a satellite in stationary orbit provided by a telephone company. In either example, the source and receiving units provide a user interface and media conversion device to the system for a human operator (Figure 9). Also, while the communication lines are usually telephone lines, they may also be wires or cables installed as private network media apart from the telephone company. An installation such as this might exist where a company decides to be responsible for its own communications lines.

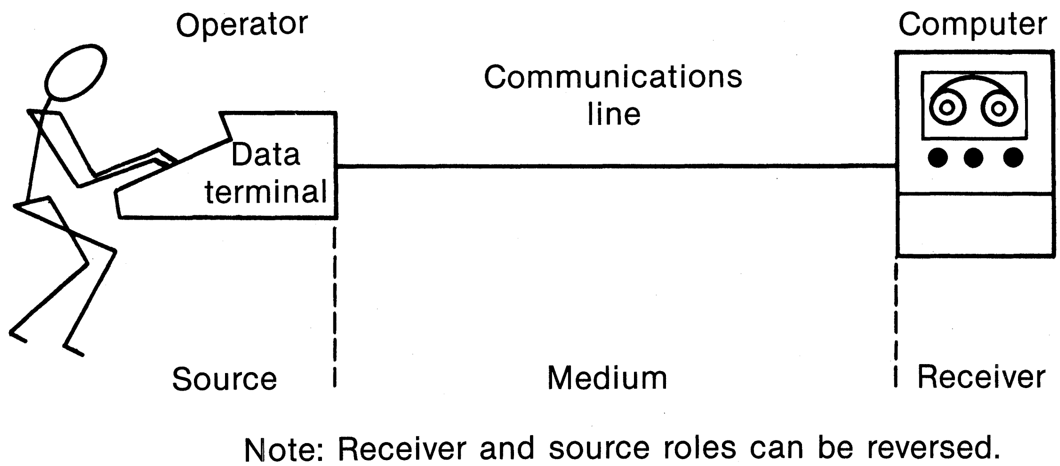


Figure 9. Operator interface with communications network.

Whether part of a telephone company installation or not, the installation of communication lines is expensive. The installation of a separate wire between each pair of users within a communications network, and especially through a telephone switching company with millions of customers, would be prohibitive. For example, in Figure 10 there are 21 wires interconnecting only seven users. Therefore switches are used to interconnect users to overcome logistical impossibilities and expense. They are part of the transmission network. Switches can be located at company locations or at telephone company central or trunk offices. At company locations the switches are called private branch exchanges (PBX's) or private automatic branch exchanges (PABX's). The telephone company has a structure of switches across the country to serve the user needs. Use of switches in this way enables sharing of transmission resources between many users and substantially reduces costs.

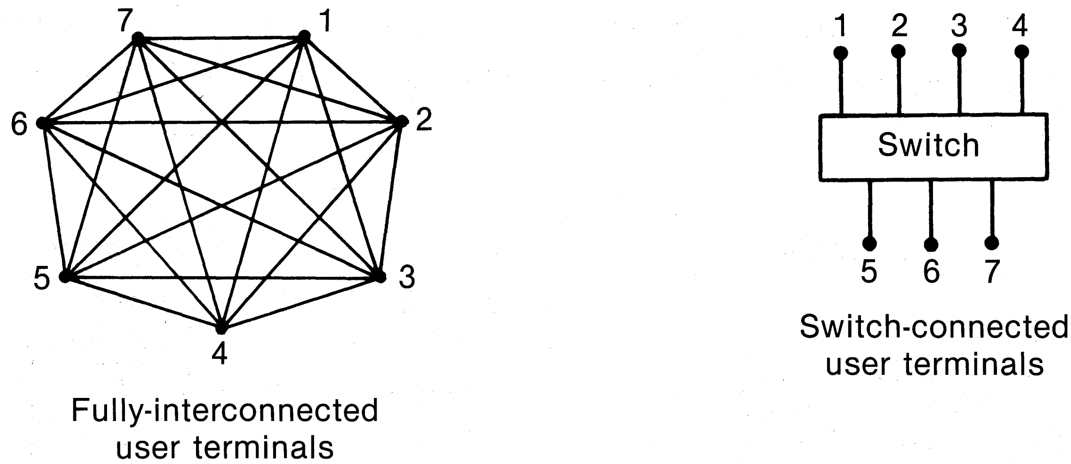


Figure 10. Fully-interconnected and switch-connected users.

A simple telephone call illustrates the source, medium (including switch), and receiver concepts just described. In this example, another idea is introduced. Something must tell the switch to behave in a certain way to make the connection between two specific users that are the source and the receiver. This instruction is called switch <u>control</u>, which takes place when a telephone is dialed, or push-buttons are depressed, and <u>signaling</u> is generated to control the switch remotely (Figure 11).

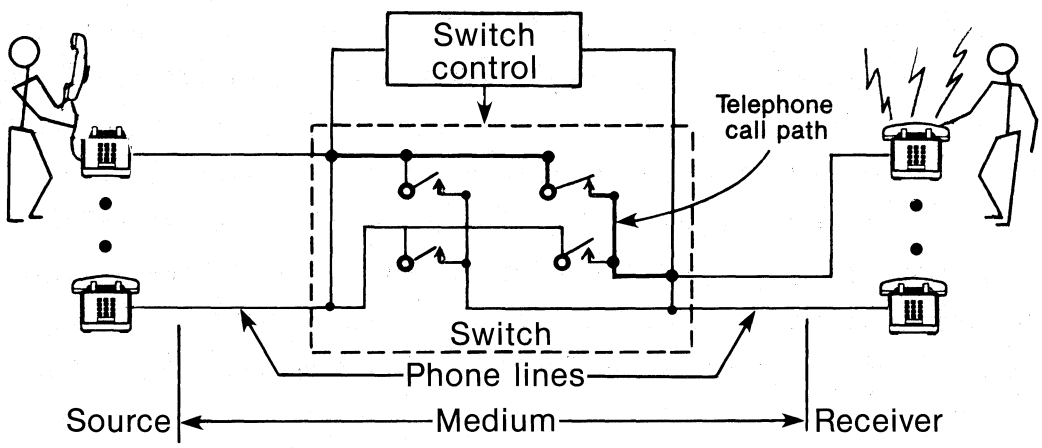


Figure 11. Placement of call by telephone switch control.

A telephone call is originated as follows:

1) An individual at the source lifts the handset off the cradle to start the call. This is called going "off-hook," and is detected at the local telephone office.

2) The local telephone office returns a dial tone signal heard by the caller on the source phone.

3) Rotary dialing or pushbutton depressing by the caller provides instructions to the switch control.

4) A connection is established through the switch to the receiver and ringing is initiated. A ring-back signal is heard at the source telephone.

5) The receiver handset is lifted off the cradle and conversation may commence.

There are many other elements that go into making a telephone call but the relative context of a source terminal (in this example, a telephone), transmission medium (telephone lines and switches), and receiver terminal (another telephone) applies to all communications networks.

The telephone conversation that takes place in this example also provides insight to data communications. Normally, the individuals at each end take turns speaking. This is called half-duplex transmission when the medium carries conversations in either direction, but on an alternating basis. Other examples of half-duplex operation are police radio calls and tennis volleys.

If the callers could understand each other while talking at the same time, without attempting to take turns speaking, this would be full-duplex operation. Most telephones can operate in this manner and the caller can be interrupted by the listener by speaking at the same time. Full-duplex operation is simultaneous transmission in both directions over the same medium. Other examples of full-duplex operation are two-way streets and man/computer communications.

A simplex communication takes place when the caller at the source does nothing but talk while the individual at the receiver does nothing but listen. Radio and television broadcasts and one-way streets are other examples of simplex operation.

In voice or non-voice communications the medium is called a channel that extends from the source to the receiver. Simplex and half-duplex channels require only two wires at the DTE, while four wires are usually needed for full-duplex operation. Under certain conditions, two wires can be used for full-duplex operation in data transmission.

It is now worth considering what is analog as used for voice communication, and what is digital as used for non-voice communication.

An analog signal can be represented as a continuous though changing waveform (Figure 12). In the case of the transmission of a human voice over the telephone system, the sound waves consisting of fluctuating air pressure are converted within the handset to electrical form. (Recall that the source generates information and places it on a transmission medium.) Media conversion takes place through this mechanism at the source and in its inverse form at the receiver so that the original voice is reconstituted. The waveform characteristics of the voice transmission are contained within certain frequency limits determined by the telephone company circuits. The limits are generally 300 to 3,400 cycles per second (3,400 Hertz). While adequate for analog voice communication they limit the data rate for non-voice communication.

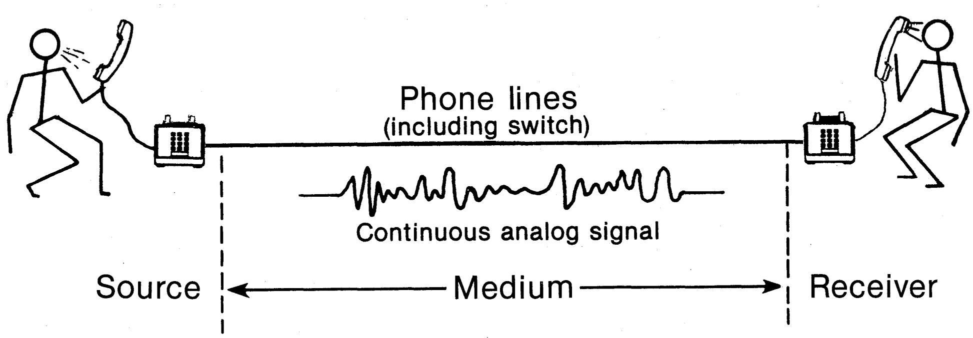
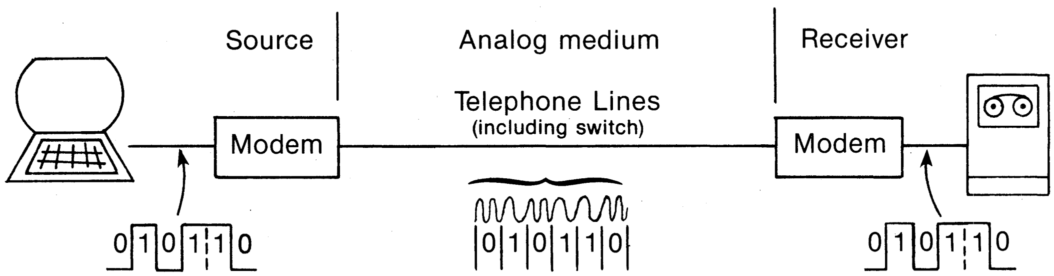


Figure 12. Analog signal on a phone line.

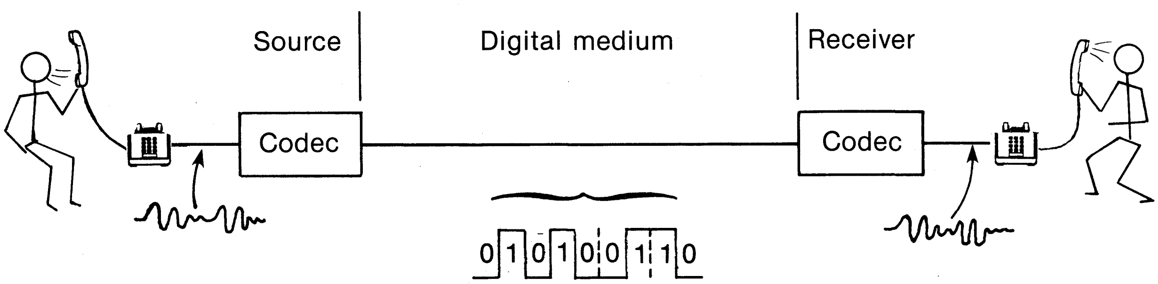
A digital signal is not continuous and can have only discrete values. The most common digital signal is a string of pulses having only two or "binary", values such as "on"/"off," "light"/"no light", and "0"/"1." Digital communication is the transmission of these binary digits, or bits, over transmission channels. This is the language of the data terminal and computer.

For a long time digital signal channels were not available from telephone companies (also called common carriers); analog channels were therefore used for digital data transmission. To send digital signals over analog channels, a device called a modem is needed. Modem stands for modulator-demodulator and is a device that converts digital signals to analog form at the source for transmission over analog channels and reverses the process at the receiver (Figure 13). The figure depicts the conversion of digital 0's and 1's to analog 0's and 1's between a terminal and a computer. The ability to convert between analog and digital signals is called encoding and the transmission speed is expressed in bits per second (b/s). The modem is called a data set in the Bell System.* Generically, modems are called Data Circuit-Terminating Equipment or DCE's.

It is also possible to convert analog voice to digital form using a coder and decoder or codec for transmission over digital lines (Figure 13). Use of this voice conversion process is important to the ISDN, since digital channels can now be used for both voice and non-voice transmission.



(a) Modem conversion of digital signals for transmission on analog channels.



(b) Codec conversion of analog signals for transmission on digital channels.

Figure 13. Conversion of signals for transmission.

*Certain commercial equipment, instruments, or materials are identified in this report to specify adequately the experimental procedures. In no case does such identification imply recommendation or endorsement by the National Telecommunications and Information Administration or does it imply that the material or equipment identified is necessarily the best for the purpose.

With encoding techniques it is possible to send data bits over analog voice communication channels at such common values as 300, 1200, 4800, or 9600 b/s. The ability to send data at a high data rate makes it possible to improve communication efficiency and reduce costs through a technique called multiplexing.

Assume that a company regional office in Denver has eight terminals that can send data information at 1200 b/s to a headquarters computer in Chicago (Figure 14a). On a per-terminal basis, 8 leased phone channels and 16 modems (one at each channel end) are needed to transfer data. Each telephone line transfers data at the rate of 1200 b/s through each modem. Acquiring two multiplexers and two modems that can transfer information at 9600 b/s over one 9600 b/s telephone line will result in significant monthly and annual operating cost savings (Figure 14b). Introduction of digital telephone lines in the concept shown in Figure 14 permits removal of the modems that are needed for compatibility with analog telephone lines.

Information that is transferred between source and receiver often is in the form of bits that convey digital information. They are sent in groups of five, six, seven, or eight bits that represent a character on a keyboard. (A character is a letter, figure, punctuation, or other sign contained in a message.) One of the most common character sets for keyboards is called the ASCII (American Standard Code for Information Interchange) code. The ASCII code is usually associated with asynchronous transmission where characters are sent one at a time at an intermittent rate dependent on the dexterity of the keyboard operator. Each set of character bits must be individually synchronized with the transmission rate of the system, for example at 300 b/s or 1200 b/s. However, asynchronous transmission is wasteful of transmission time because of its start-stop nature. Synchronous transmission has a constant time interval between characters or bits and is a more efficient means of transferring information at faster rates. ASCII characters can be sent synchronously as well as asynchronously, but another alphanumeric code is used with synchronous transmission. It is called EBCDIC (Extended Binary Coded Decimal Interchange Code).

Before data or character transmission can take place, certain physical connections must be made, as for example, between a modem and a telephone company line. Another very important connection is between the modem and data terminal. This is called an interface. Essentially, it is a boundary between two dissimilar devices. Definitions, in the form of standards, are made to state what the voltage, timing, and sequence of operation shall be across a boundary connector for data and control

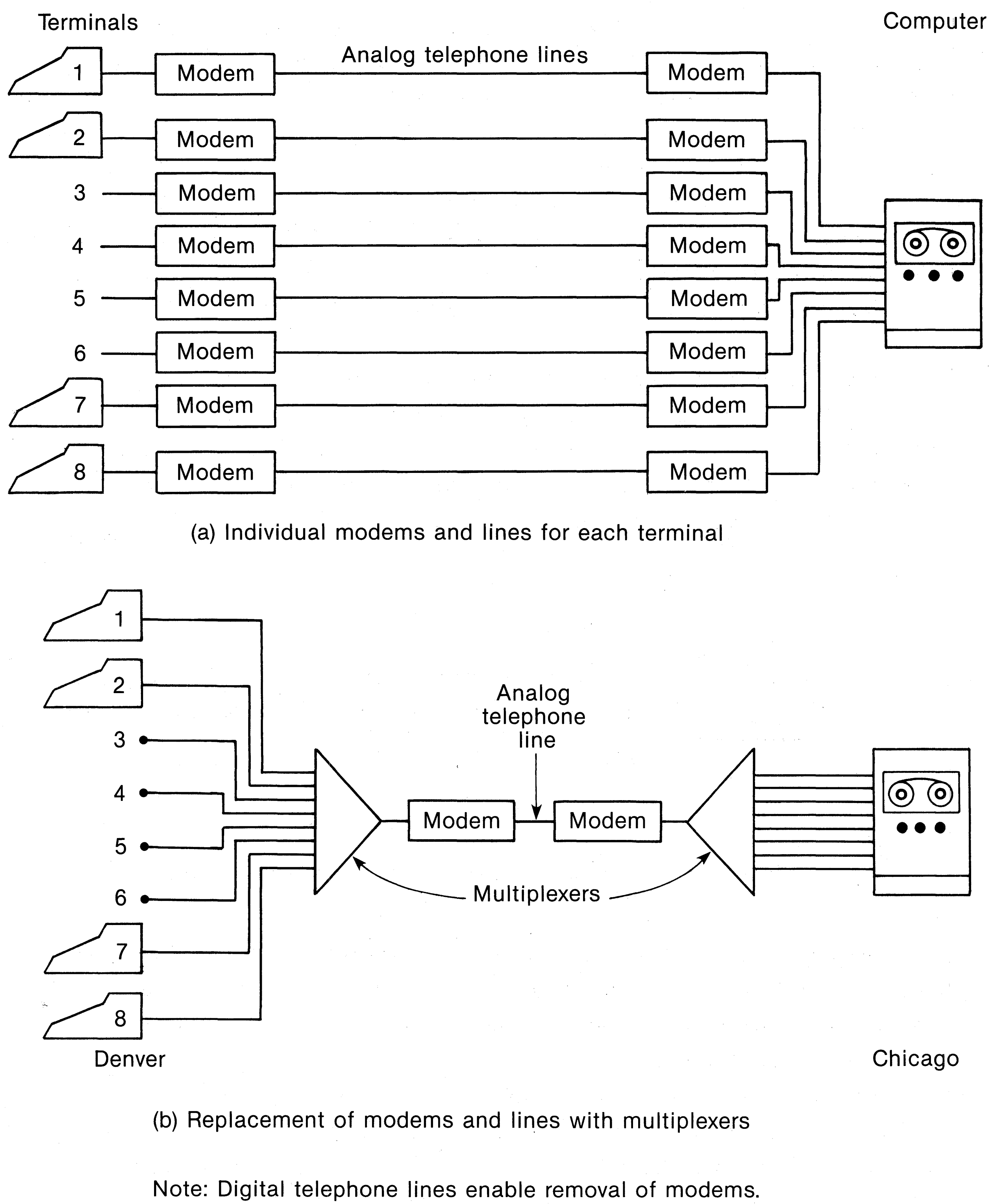


Figure 14. Eliminating modems and telephone lines through multiplexing.

signals. An example is RS-232-C. Physically, it is a standard for the small connector that exists on the back of a DTE which is connected through a small cable to another connector at the modem. The RS-232-C designation is one interface standard for data transmission from the Electronic Industries Association (EIA). Other interface standards have been defined by the EIA in the United States, and by international standards organizations. A major activity of standards organizations such as the EIA, American National Standards Institute (ANSI), the International Telegraph and Telephone Consultative Committee (CCITT), and International Organization for Standardization (ISO) is defining functions of interfaces.

A simple example that describes the basic characteristics of a terminal that is connected to a modem for data transmission can be listed as follows. The DTE has an ASCII character set, operates half-duplex, with an RS-232-C interface ("to the modem," which is implied); transmission is asynchronous at 300 b/s.

Figure 15 shows an example of a DTE-DCE interface.

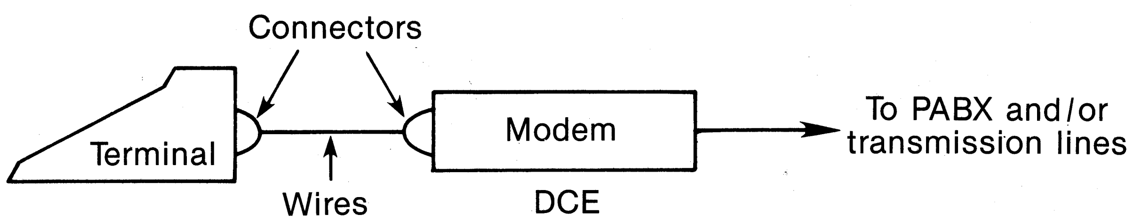


Figure 15. Interconnection between a terminal and modem through an interface.

Acoustic couplers are a special form of interface, but the maximum possible data rate that can be sent is lower, such as 300 b/s. Acoustic couplers allow the use of a telephone handset as a connection to telephone lines that are used as transmission channels.

One last concept to be introduced is the protocol. A protocol is a rule, or set of rules, that initiates and maintains communications in a network. There are rules to make a phone call, and there are rules for sending and receiving non-voice information such as data. To place a phone call it is necessary for the dial tone to be heard before dialing after going "off-hook." Similarly, with data transmission, certain steps such as acknowledgments between source and receiver are part of the protocol procedure. The RS-232-C interface defines not only a physical connector, but also a protocol encompassing certain procedural steps.

3.2 Communication System Elements

This section will look at elements that have been mentioned within the context of explaining basic communication concepts. These elements are the many different kinds of communication terminals that are available to the user, the transmission media and switching facilities that are in use by common carriers, and the use of so-called "dedicated" networks.

3.2.1 Terminals

So far there has been reference to types of user terminals: telephone, teleprinters, and VDT's which also have been called CRT's (cathode ray tubes). These are among the simplest available for information exchanges between locations, and can be categorized as voice, data, and graphics terminals.

Voice Terminals. Voice terminals can encompass telephones with multiple keys when many lines are connected to a telephone at a business location. The keys are used to select the lines for outgoing or incoming calls.

Associated peripheral equipment can include automatic call distribution (ACD), automatic dialer telephones, and telephone answering machines.

Automatic call distribution is used by the airline industry to respond to reservation requests. When all ticketing agents are busy, the caller is put on "Hold" and then is served by the first available agent. Other users of ACD are credit card companies (credit verification), and the banking and insurance companies.

Automatic dialing makes use of "intelligence" in the form of microchips built into a phone. Preprogrammed numbers can be dialed by pushing a single button.

More exotic voice terminals are available which change (digitize) the analog voice signal to digital form for storage on a memory device such as a disk that stores digital bits. Devices for voice store-and-forward (VSF), speech recognition, and voice response are on the market.

Voice store-and-forward is an electronic voice mail box. Improved communications are possible in a company where messages can be retained until the recipient can receive them. Time is saved through VSF in two ways. First, three out of four phone calls do not reach the intended party on the first try. Second, the VSF system can direct the voice messages to more than one recipient. The digitized voice bits on a memory storage disk can be sent, received, or redirected in voice form under computer control.

Speech recognition allows the recognition of specific spoken words of an individual. Recognition of certain words is applicable in air traffic control training, in security where voice prints are matched with a person's pronunciation of specific words, in battlefield control of weapons, and in sorting packages by routing that is under voice control.

Voice response is useful where an entry function is performed on a keyboard and a chosen set of words is orally required to prompt the user. Particular applications for voice response are in personal banking such as credit card verification, account status requests, and electronic funds transfer.

Data Terminals are frequently classified on the basis of characteristics and may be labeled as dumb, smart, and intelligent. Characteristics, and costs, frequently overlap. Common characteristics are that a video display and keyboard are provided for each terminal. After that, the extent of microprocessor computing and control power designed into a terminal determines operating features, flexibility in usage, and cost.

The major operating differences are that the dumb terminal is connected to a computer or retrieval service and acts as an electronic typewriter. A computer memory provides data for display to this person-machine interface. The smart terminal is able to operate, to a limited extent, by itself (stand-alone) without connection to a computer. The intelligent terminals have all the characteristics of smart terminals, but with additional features. Intelligent terminals have much more significant stand-alone ability because of extensive microcomputer power and memory storage.

Perhaps the best example of an intelligent terminal is the personal computer (PC), or microcomputer, with communications ability. Microcomputers and PC's are available that can communicate asynchronously, synchronously, and have extensive programming capability.

Point-of-sale (POS) terminals and automatic teller machines (ATM) provide a data transmission function. The POS records the sales transaction at a department store or supermarket while the ATM handles a financial transaction between a bank and a customer.

Teleprinters (Figure 9) are a kind of terminal device that is usually associated with sending telegrams. They have an alphanumeric keyboard for sending (usually asynchronously), a printer for receiving, and a communications interface.

Teleprinters, or teletypewriters, are being replaced by VDT's. Still, they retain a part of the marketplace because of cost effectiveness where a printed copy is required. A VDT with a printer is more expensive than a teleprinter by itself. A low data speed is dependent on maximum print speed that is determined by how characters are formed on a page, either mechanically or under electronic control.

Some models of teleprinters are popular for their portability. They are lightweight and carried as briefcases by traveling business people. An acoustical coupler is built in, and information can be transmitted by using the hotel-room telephone. Another category is the receive-only (R-O) printer. These printers do not have a keyboard, but share many characteristics of the teleprinters that do.

Graphics Terminals frequently means "facsimile," although charts and graphics information can be generated and displayed on video displays. Facsimile enables accurate transmission of photographs, weather maps, signatures, and written or printed matter. It can be used for electronic mail distribution. The original graphic material is scanned by reflected light, electronic beams, or lasers, converted to electronic signals, relayed over transmission lines to a remote location, and recreated. The facsimile signals that are sent over transmission lines can be analog or digital. In the past, analog facsimile transmission of an 8-1/2" x 10" document could be expected to take several minutes--for example, 3 or 6 minutes. This is no longer true. Some analog units can send a page of text in less than a minute. Most digital facsimile units can send a page in less than 90 seconds. The image reproduction quality, or resolution, is related to the transmission speed--the higher the resolution, the longer the transmission time. Extremely short transmission times along with high resolution are possible on digital machines when high-speed data transmission lines are available from a common carrier.

The problem of compatibility that has existed is being overcome. It was once impossible to send a message unless the same model facsimile machine from a particular manufacturer was used at both ends of the transmission. Compatibility between fax units of different manufacturers is possible and improving because of adherence to standards developed by international agreement.

3.2.2 Transmission, Transmission Control, and Connectivity

Currently, transmission signals on telephone lines can be analog or digital. A combination of both is likely when a circuit is completed across the country. Analog transmission links between telephone offices are the result of previous technology and capital investment. Digital transmission is an answer to more recent economic need: wire cable is expensive and below ground it is often difficult to find room for additional wire without tearing up streets. More efficient transmission over wire and other media was needed.

In 1962, AT&T introduced digital transmission to solve this problem. It is called pulse code modulation. Transistors made this technology possible due to low cost and low power dissipation compared to vacuum tubes. The initial cost of this technique was justified on the basis of performance improvement and savings in capital investment.

As the number of digital transmission lines increased, it became clear that additional cost savings would accrue if digital switches were to take the place of analog switches at telephone offices. The reason is that costly conversions are needed at the analog and digital interfaces of the switch. Consequently switches now being installed by the telephone company are digital.

Pulse code modulation (PCM) is a technique that enables voice that has been changed into an analog signal, to be changed to a digital signal. The analog signal is sampled at 8 kHz, encoded at 8 bits/sample and transmitted at 64,000 b/s (64 kb/s). After traveling through switches and transmission lines to the telephone office nearest the receiver, the encoded voice signal of 64 kb/s is decoded and smoothed by filtering to analog and returned to voice form (Figure 16).

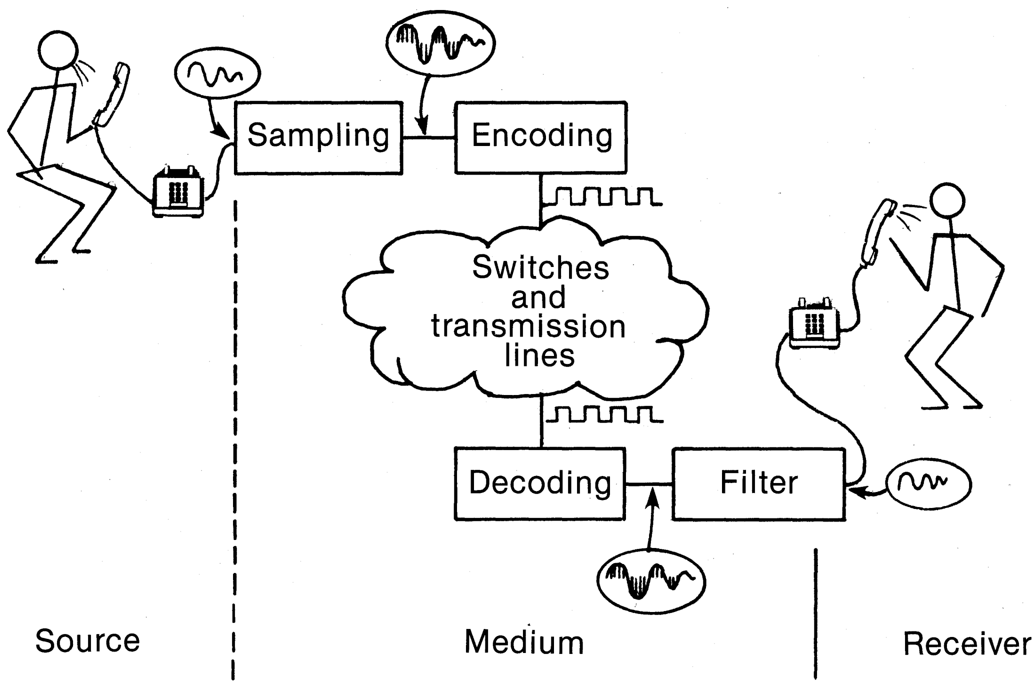


Figure 16. Digital transmission of voice for one channel.

There are other kinds of analog-to-digital (A/D) and digital-to-analog (D/A) conversion schemes, but PCM is the most common.

The one 64 kb/s digital signal just described is usually multiplexed with 23 other signals for sending through switches and transmission lines. The 24 digital voice signals are combined for efficient transmission over wire pairs in a cable or other media. Combining of the signals through time sharing is called time division multiplex (TDM). The 24 channels of 64 kb/s with added framing bits (to delineate a group of bits) are sent at a data rate of 1,544 kb/s or 1.544 million bits per second (Mb/s). This is a T1 carrier and is a standard in North America. Higher orders of TDM, such as 48 (T1C carrier) or 96 (T2 carrier) voice circuits are also sent over cable. The European standard combines 32 channels in a similar way resulting in an overall rate of 2.048 Mb/s.

Previously, the circuits that had been designed for analog voice transmission used a process called frequency division multiplex (FDM) to transmit multiple conversations over a single channel. Since its introduction, TDM has proven more efficient at shorter distances and is replacing FDM.

Switches were introduced earlier as part of the medium, and signaling was introduced as part of the control of the switches (Section 3.1). The evolution of switching is based on three eras of technology: manual, electromechanical, and electronic. All three types of switches have survived simultaneously, although each type has predominated during a given period. Until recently, the number of telephone lines controlled by electromechanical switches has predominated, but that is changing in favor of electronic switches. Electromechanical switches are of two types, the "step-by-step" and crossbar. Both of these types are automatically controlled for routine functions by wiring logic, or "hardwired." However, it is difficult or impossible to make wiring modifications for control of these switches. Beginning in 1965, electromechanical switches were replaced in public telephone networks by computer-controlled electronic switching systems (ESS). (Computer controlled PBX's were available in 1963.) Hardwired, also called hardware, control of switches has changed to programming instruction sets linked to computers. This software control of switches also aids in flexibility in offering services to the public and is called stored program control (SPC). For example, with SPC, 800 Service is now feasible and allows a customer to receive calls without charge to the calling party.

SPC is a set of instructions stored in computer memory to set up calls handled by the switches. Solid state technology, based on very large scale integrated

(VLSI) circuits for microprocessors, and smaller and cheaper memory, has permitted combining the telephone and computer.

Electronic switches based on SPC, can be analog or digital. These switches can be considered as having two parts: the SPC units that control the switches and the switches themselves. The control is always digital, its only operating mode. An electronic switch, however, can be designed for switching analog (a space-division switch) or digital signals (a time-division switch).

Space-division switches provide a physical path through metallic or solid state contacts for each signal through the switching system. The signal on the path can be analog or digital. Space-division mode operation was chosen to be compatible with the electromechanical telephone plant (installations) already in place to interface with existing customer equipment.

Time-division switches use high-speed solid-state circuits. Digital information being switched is separated and assigned to time slots. (Recall TDM.) Using memory, the signals in time slots are shifted and interchanged with other time slots as needed to switch the travel path of the information bits to a destination. Because of this mechanism, the time-division switch handles only digital signals and cannot handle an analog signal unless that signal has been previously converted. In practice, most modern switches are a combination of space and time-division design with signal conversion at the appropriate interface.

Signaling, fast enough to control these computerized switches efficiently, was needed to realize their potential. The Bell System responded with a system called Common Channel Interoffice Signaling (CCIS) to transfer control information between switches. Conventional analog signaling systems pass the control information, in the form of tones, within the same path that later carries the voice conversation (Figure 11). It is called in-band signaling. In contrast, the CCIS sends the information over its own data network for control of many voice and data circuits (Figure 17). This is called common-channel signaling. Essentially, a complete transparent subnetwork controls the switches by transferring control information between SPC processors at locations that are called Signal Transfer Points (STP's). With CCIS, phone calls and data message services are connected faster and more efficiently, thus saving time and operating expense. This also permits more service offerings to the customer.

Connectivity of voice and non-voice terminal equipment at user premises depends on various transmission facilities such as wire-pairs, coaxial cable, microwave radio, fiber optics, and geostationary satellites. Telephone offices are

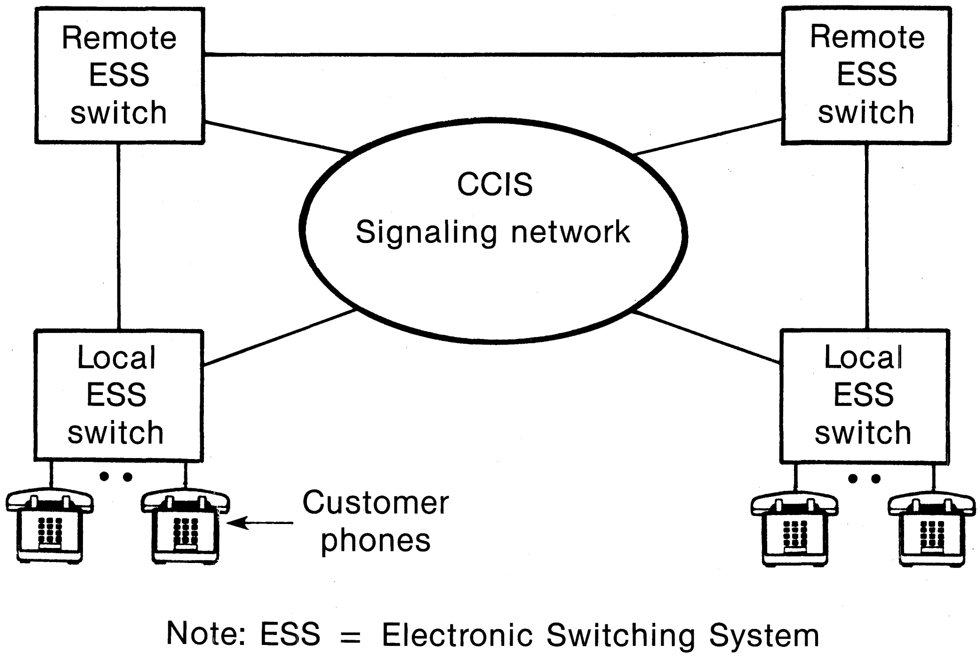


Figure 17. A separate network for control of the telephone system.

connected to these media to provide customer services. Cables consisting of hundreds of wires provide connections in a metropolitan area. Coaxial cables, radios, satellites, or combinations of both make the connections over long distances.

The block diagram of Figure 18 shows the basic elements of a telecommunication system that connects a source to the receiver through the various transmission media. At the users' premises, the equipment can consist of computers, terminals, modems, and PBX's. The modems and PBX's may be maintained by the user or telephone company at the customer's discretion. Typically, customer equipment is connected to the local telephone office switch via the local loop (also called subscriber loop) which usually consists of two wires. Other equipment can be digital multiplex equipment that can combine up to 96 voice channels for transmission to user locations. This digital connectivity uses the same voice digitization techniques (i.e., PCM) as the T-carrier system.

New digital technology permits half-duplex operation on wire pairs that looks like full-duplex to the user. High speed data bursts are sent in alternate directions between the user and local office in a "ping-pong" fashion. This is called time compression multiplex (TCM) and is being tested extensively and successfully. TCM is part of the technological evolution to ISDN.

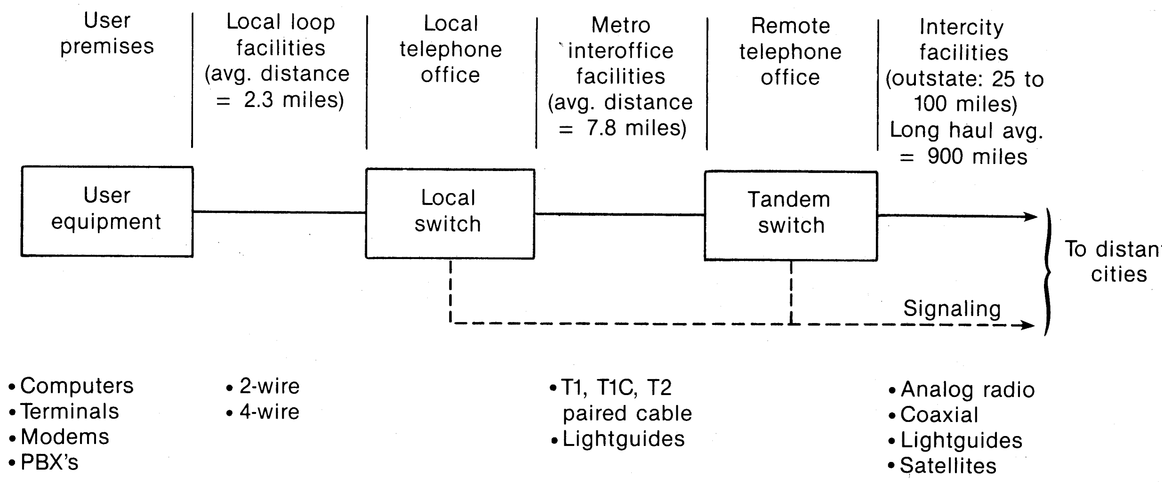


Figure 18. Telecommunication network elements and facilities (after Skrzypczak et al., 1981).

The metro/interoffice facilities between the local telephone office and another telephone office within a metropolitan area consists of many wire pairs in a cable used for transmission of the T1 carrier (24 voice channels), T1C carrier (48 voice channels), or T2 carrier (96 voice channels).

The intercity facilities for connectivity may consist of analog microwave radio, coaxial cable, lightguides (also referred to as fiber optic cable and optical waveguides) and satellites. All are capable of extremely high capacity message transmission.

The reason for using analog radio over long distance is that it is still more economically advantageous over 250 miles (400 kilometers) than some form of digital communication. In contrast, digital connectivity has been proven less expensive for local loops and metro/interoffice facilities.

Lightguides have been or are in the process of being installed in a number of locations, such as between Oakland, San Francisco, and Sacramento, California; in the West, and between Washington, DC; New York; and Boston in the East.

Satellites are another important facet of long-haul digital connectivity. A number of satellites such as the WESTAR and COMSTAR have been in geosynchronous orbit for years. They are capable of carrying thousands of voice circuits simultaneously. New satellites with greater capacity such as the TELSTAR 3 series are to replace COMSTAR, with launches scheduled for 1983, 1984, and 1985.

3.2.3 Networks

At times there is overlapping terminology in communications that may be confusing. "Network" is one of those words. One use of the word "network" actually involves the technologies that are used to set up circuit paths for communication networks; these are circuit, message, and packet switching. A second use relates to transmission services that are provided as public or private networks. A public network is "plain old telephone service" (POTS) available to the general public, while a private network may consist of leased lines for exclusive use of a large company. Elements of POTS have been shown in Figure 18. To provide services, public and private networks can use circuit, message, or packet switching (Figure 19), and can use switched and nonswitched (leased) lines.

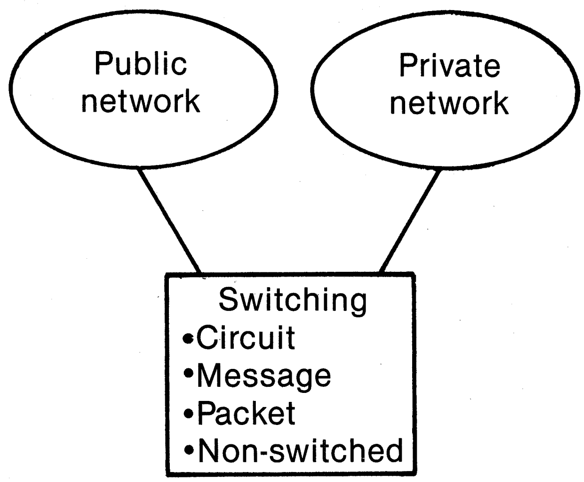
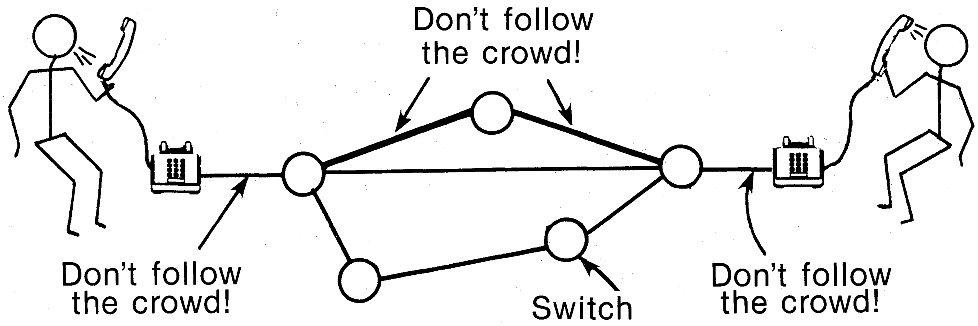


Figure 19. Public and private networks can use similar technology.

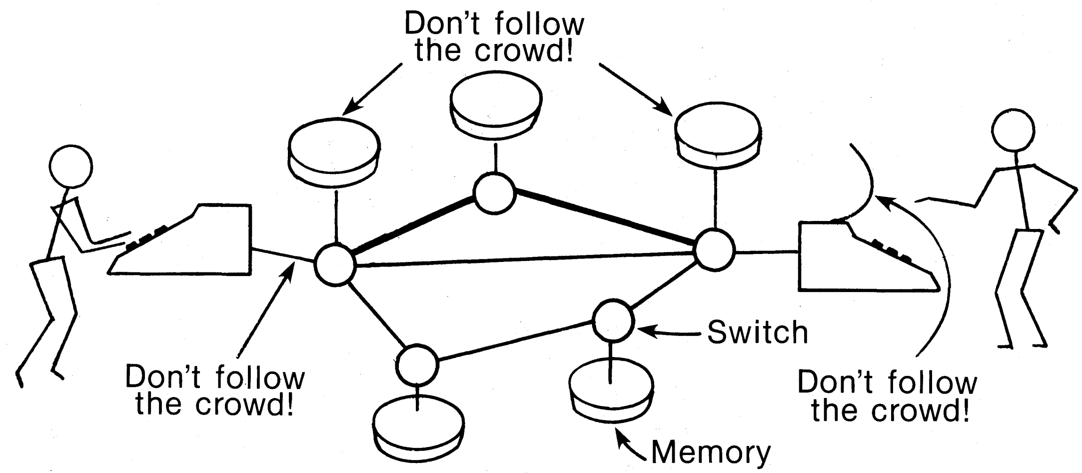
This section will first address the technology, and then, service aspects.

A circuit- (or line-) switched network provides service to subscribers by way of a dedicated path between two users. Telephone lines, switch connections, and other facilities are allocated on an exclusive basis for the duration of the call (Figure 20a). A telephone call is an example of circuit switching. The complete message (voice or non-voice) travels without apparent delay between the source and receiver.

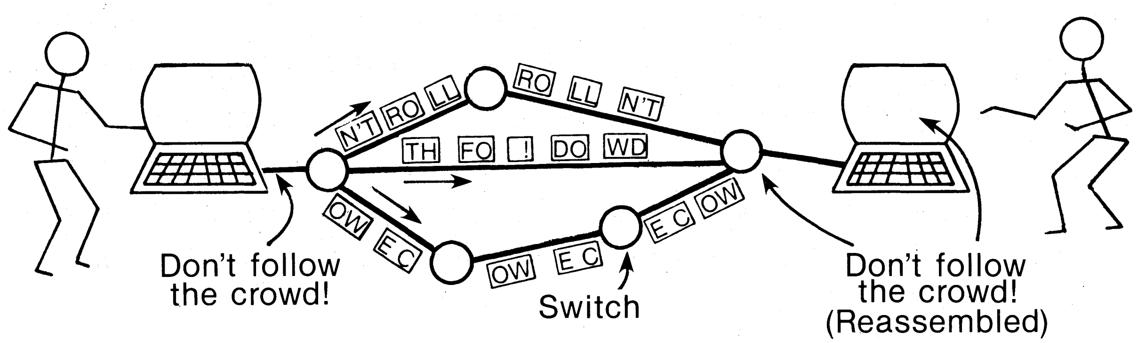
A message-switched network stores entire messages at switch locations for transmission on circuits when message channels and the called terminal become available. Each switch location has a memory disc for message storage and



(a) Circuit switching with dedicated physical path.



(b) Message switching with temporary memory storage for complete message relay.



(c) Packet switching with limited size message packets.

Figure 20. Circuit, message, and packet switching.

subsequent forwarding (store-and-forward) to the next nodes (Figure 20b). (In data transmission, a node is a location that interconnects data transmission lines.) Telegram service is an example of message switching. Delays between sending and receiving can accumulate as the complete message is stored at each successive node while awaiting transmission to the next node. Messages are not transmitted in "real time" as in circuit-switched transmission. Message switching is used where tradition or procedures require that a hard copy be provided for record purposes such as in military communications. Messages are usually sent and received on teleprinters at each user location.

A packet-switched network is a form of message switching. However, each message is divided into small units called packets (Figure 20c). After the message is broken up at the first node, each packet travels independently to the destination node where it is reassembled in proper order. Each packet has its own destination address. Packet-switching is a store-and-forward technique, except that the storing is of very short duration compared to message switching. An important point is that the packets shown in Figure 20c can be mixed with many other packets. This permits more effective use of resources (transmission media and other facilities) than with the other switching techniques. Packet-switching can be used for voice communications. Examples of packet-switched networks are Telenet and Tymnet.

CCITT Recommendation X.25 provides the functional guidelines for implementing packet-switching. There are many X.25 packet-switched networks in existence within the United States and abroad. Not all are compatible, as Recommendation X.25 is not yet complete in all details and networks deviate in some aspects.

Services are a set of functions provided over a network's facilities. In the ISDN concept, one network could provide many services.

Services may be switched or nonswitched (private or leased lines). Both service types are related to technical and pricing parameters provided by a carrier. Technical parameters to be selected by a customer willing to pay a fee for their use includes bandwidth (meaning capacity or range of transmission speeds, such as Hertz or bits per second and described as low-speed, voice-grade, or wideband). Quality of transmission is another parameter since some voice and nonvoice channels are better than others.

Facilities are the physical entities that have been previously described, including wire, cable, switches, and satellites.

A network can be a series of points connected by communication channels and can refer to the public switched telephone network (PSTN) or a private network dedicated to the use of one group of customers. Other network names are circuit switched data network (CSDN) and packet switched data network (PSDN).

Representative service offerings include those offered by AT&T Information Systems (formerly American Bell), American Satellite, GTE Telenet, Tymnet, and Western Union.

AT&T Information Systems/Net 1000 provides public switched and private line services over a nationwide packet-switched communications network. Services are for data transmission, data processing, programming, and network management. A uniqueness of this value-added network (VAN) is the feature that enables dissimilar computers and terminals to communicate with each other.

A VAN is a network formed by leasing lines from traditional common carriers to interconnect computer-controlled switches at different nodes. Added features are offered through this arrangement and packet switching is an integral part. GTE Telenet and Tymnet are examples of other carriers basing services on packet switching technology.

American Satellite, RCA Americom, Satellite Business Systems, and Western Union are examples of companies that offer private line services over satellite facilities. The main attraction of using satellite channels for long-haul is the lower cost compared to terrestrial circuits. The investment cost of a satellite system is the same whether the message travels 200 or 2000 land miles. This makes satellite usage economically attractive over longer distances for large volumes of traffic.

Western Union also offers a service that is similar to the public telephone system with an important difference. While the public telephone system is voice-oriented with telephone terminals, the Western Union service uses teleprinters in a similar way for text transmission. Teleprinters, which have been traditionally used, and display terminals communicate with each other on a message basis. This service is called Telex II since it incorporates the Teletypewriter Exchange Service (TWX) that was formerly owned by AT&T. On a technical basis, it is a message-switched, low speed (110 b/s), half-duplex service that uses ASCII code for the teleprinters and terminals.

Just as video game machines are dedicated computers given to a single function, Telex is a good example of a dedicated network where a system may be used for a single purpose. Cable TV (CATV) is also a dedicated network. A formerly dedicated network is the Facsimile Service from Graphnet, Incorporated. This is a value-added network using store-and-forward techniques to transmit digitized graphic images (facsimile) on the network. Graphnet has since added digital data communications services using its store-and-forward facilities base, so that it is no longer a one-purpose dedicated network.

Telemail, offered by GTE Telenet, uses packet-switching and can accept messages from many kinds of data terminals that would normally be incompatible. Incompatibility is overcome through speed and protocol conversion. GTE Telenet has announced intentions of providing interfaces for facsimile, voice store-and-forward (voice mailbox), and high-speed data transmission. Adding these services makes it a non-dedicated network that encompasses the ideas of the ISDN.

Local area networks (LAN) are another class of system. The LAN's are:

- high speed, private networks for voice and non-voice applications,
- limited in geographical size, usually within a building, or a number of buildings in a small area such as a business park or university campus,
- an interconnection of multiple devices such as computers, data terminals, teleprinters, word processors, energy monitors, alarm systems, security alarms, and video monitors,
- normally, but not necessarily, independent of common carrier telephone lines,
- unregulated by the Federal Communications Commission (FCC) if no phone lines or digital radio are used,
- based on media such as twisted wire pair, multiple wire cable, coaxial cable, fiber optic cable, or digital radio.

An LAN is usually designed and built with a certain physical pattern, known as topology, in mind. The topology has three basic forms, a star, ring, or a bus (Figure 21).

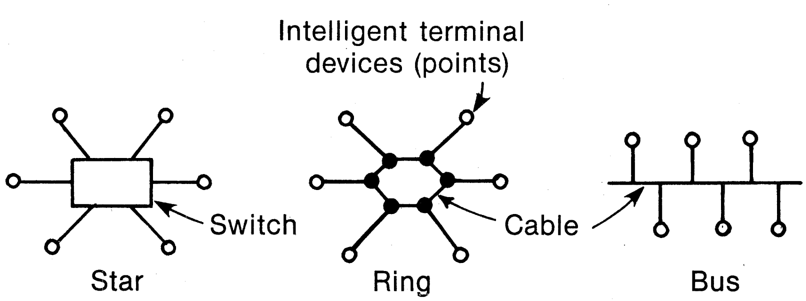


Figure 21. Basic LAN network physical patterns or topologies.

The characteristics of these topologies are as follows:

Star - a central switch makes terminal-to-terminal (point-to-point) connections for information transfer. The PABX is an example of a central switch.

Ring - information is transferred in one circular direction between points without a control switch.

Bus - one or more cables interconnect devices for information transfer, without a central switch, but under a distributed control mechanism.

Messages from different terminals travel over the same medium (resource sharing) when using a ring or bus topology. A contention exists to determine which message has precedence to be sent. Protocols based on standards resolve the contention. The use of microprocessors in LAN's permits progress to be made in the distribution of network control and interfacing. Local Area Network standards have been developed by the Institute of Electrical and Electronics Engineers Project 802 technical committee. More than 50 companies market LAN's in various topologies and with different degrees of user participation, hardware sales, and installation. Applications for LAN's are in office automation, business data processing, personal computing, real time voice, and video.

All of the elements discussed in this section have a bearing on the future ISDN(s). A familiarity with this section will aid in understanding Section 4.

4. THE ISDN

The ISDN is a concept that is nearing reality. It is planned to provide a broad range of user communication needs through a total digital communication system. Many components already are in place. The current digital telephony and digital data communication networks that are now in existence are intended as the basis for evolving to the ISDN.

Telephone networks have evolved through two distinct stages, and are now embarking on the third. The three network stages are called the Integrated Analog Network (IAN), the Integrated Digital Network (IDN), and the Integrated Services Digital Network (ISDN).

The IAN stage was dependent on switched networks providing voice or voice-simulated (e.g., modem conversion of data) services by managing costs through the application of analog transmission and analog switching technology.

The IDN stage is dependent on switched networks providing voice or voice-simulated services by minimizing costs through the application of digital transmission and digital switching technology.

The ISDN stage is to depend on switched networks providing user-to-user (end-to-end) digital transparency where voice and non-voice (e.g., data) services are provided over the same transmission and switching facilities.

4.1 CCITT View

The discussion in this section expresses essentially a CCITT view as portrayed in CCITT draft Recommendations and related documents. The United States is a participant and makes contributions to CCITT proceedings. But the CCITT ISDN approach reflects a strong influence of European administrations where the provision of communication services is a government monopoly. The U.S. view differs, for example, in the sense that there will be a number of service providers.

The original ISDN concept was based on the premise that a digital public telephone network would be transparent to the type of information being transmitted - whether speech, facsimile, or bulk data. It was assumed that the ISDN would be based on the public telephone network. This rationale implied that an ISDN network would be a digital successor to the public telephone network. In the United States, this led to the idea of "multiple ISDN's" with similar characteristics and interconnection of these networks. As CCITT studies have progressed, recognition has been made that this may be an over-simplified approach. In the real world it may be necessary to be aware of the types of information being transmitted. Now the concept has been introduced that a limited set of multipurpose user/network interfaces will be used to interconnect users with the ISDN. "An ISDN" would then be a conglomerate of mutually interconnected networks, not necessarily having the same characteristics, with subscriber access via standard ISDN interfaces.

The predominant characteristic in ISDN planning is that a broad range of voice and non-voice services will be supported. These services will be integrated through digital connectivity between users. Services such as telemetry, security monitoring, electronic mail, electronic funds transfer, voice, facsimile, graphics, videotex, bulk data transfer between computers, and nonbroadcast video are intended to be available through an ISDN. The ISDN services are expected to use public and leased data channels, network interconnection, and circuit and packet-switched facilities. Media will consist of wire pairs, coaxial cable, fiber cable, and satellite systems. Message-switching does not appear as part of the current planning.

A fundamental principle underlying ISDN service integration is that the interfaces between the user and the network will be defined and kept to a minimum (Figure 22). Currently, there are many interfaces for connecting between a customer terminal and a network. Many would be eliminated as the ISDN interfaces

Figure 22. A minimum number of user/network interfaces are planned for the ISDN.

become defined and implemented. An interface such as RS-232-C could operate in an ISDN environment but would need an adaptor. Such an interim solution will eventually be phased out. Another key principle is that bearer services (facilities such as circuit- or packet-switched channels provided by a carrier) be limited. The premise is that the communication carriers would provide the user with a minimum number of standard channel services over circuit- and packet-switched facilities. The basic user-network interface will have two 64-kb/s (B) channels for information transfer and a 16 kb/s channel for signaling and low-speed data. This is a 2B + D basic channel structure. Multiples and submultiples of these data rates are being determined by the CCITT. High-volume users will have available a 23B + D configuration at the user/network interface. This is a primary rate channel structure for PABX and LAN connection to the ISDN.

The ISDN is being designed in such a way that current service-dedicated networks may be integrated into "an ISDN" where appropriate and cost-effective. Dedicated facilities to be integrated are those of the telephone networks, circuit- and packet-switched data networks, and telex. Private line, PBX, and LAN networks are not expected to be integrated, although interconnected to the

ISDN (Figure 23). The evolution is expected to take one or two decades. This evolution will probably take place according to national or geographic boundaries based on national priorities or needs. Facilities that are already in place are to be part of this transition. The present digital networks are to be the basis for the integration of services based on economic considerations and technological evolution. Equipment is not being discarded except through obsolescence. The 64 kb/s PCM digital signal, the T-carriers, stored program control, and user-network signaling are to be an integral part of the ISDN.

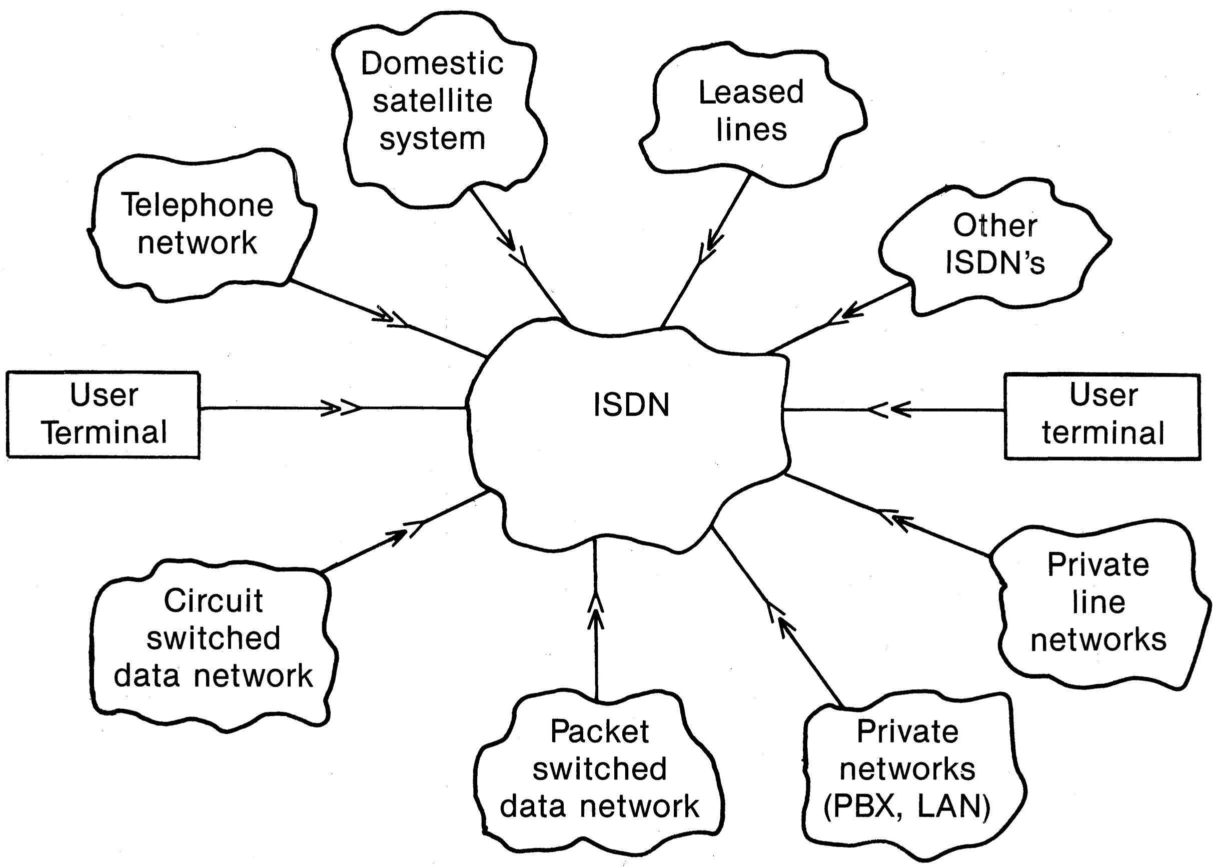


Figure 23. Interim interconnection of dedicated networks and ISDN(s) via interfaces.

Other factors influencing the integration and evolution to an ISDN are the competitive and regulatory atmosphere that exists in a country. The United States has many providers of communications facilities. Other countries have one--an organization of Post, Telegraph, and Telephone (PTT)--that acts as the sole common carrier. The multiplicity of carriers in the United States implies multiples or a conglomerate of ISDN's in the United States. For the last 15 years competition in telecommunications has been increasingly encouraged. Restructuring AT&T and its subsidiaries has an influence that remains to be determined. This also effects the evolution toward "an ISDN."

4.2 Capabilities

In the United States, AT&T and other carriers have recognized the need for flexibility in designing the ISDN. Flexibility is needed to provide the many services that have been defined and others that are still unforeseen. The following view of ISDN in the United States is based on papers from AT&T.

An example of the wide range of bit rate information requirements for various services is shown in Figure 24. The message characteristics for alarm services

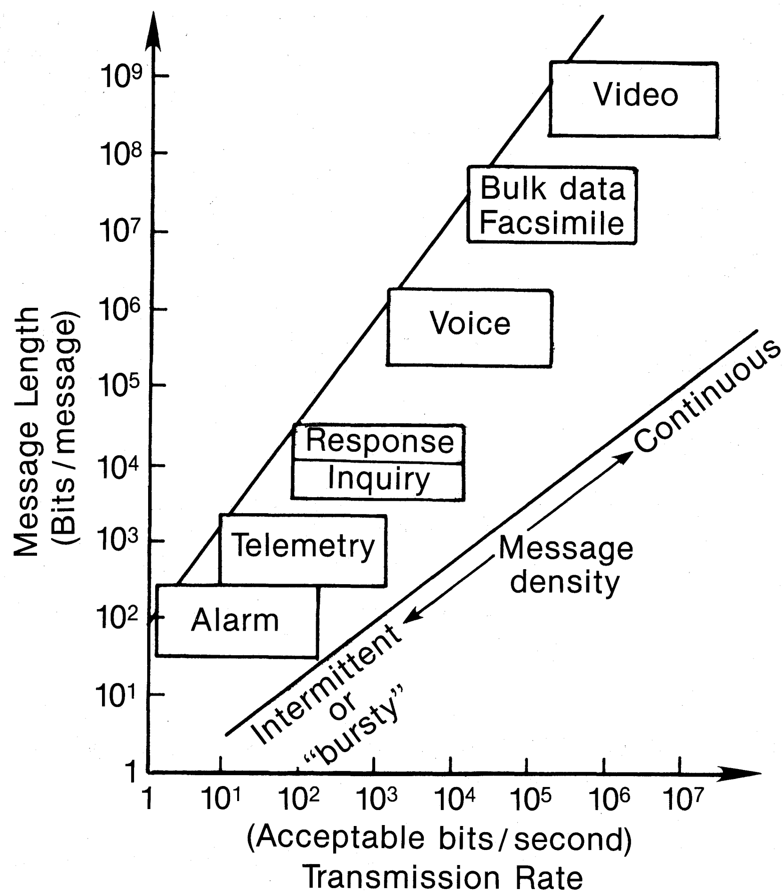


Figure 24. Range of message lengths, density, and transmission rates for ISDN planning (after Skrzypczak et al., 1981).

are very different from requirements of bulk data, facsimile, and video. The alarm services have very low average bit rates (10 b/s), and short message lengths. The full-scan video at the other end of the scale requires 1.5 to 6 Mb/s depending on available transmission techniques. The message density ranges from very intermittent or "bursty" to continuous. Message lengths vary from a hundred to billions of bits. Planning for this range of user needs is a formidable task.

A customer will have access to an ISDN through a standard interface of 64 kb/s channels (Figure 25). A 16 kb/s channel also is to be available to the customer for signaling and low speed data. The Customer Controller provides a standard interface protocol from the customer premises to the multibandwidth "digital pipe." The dynamically assigned bandwidth of the "pipe" is variable and will depend on the customer's needs for each transmission. The variable bandwidth concept is also used for circuit- and packet-switched transmission between the serving

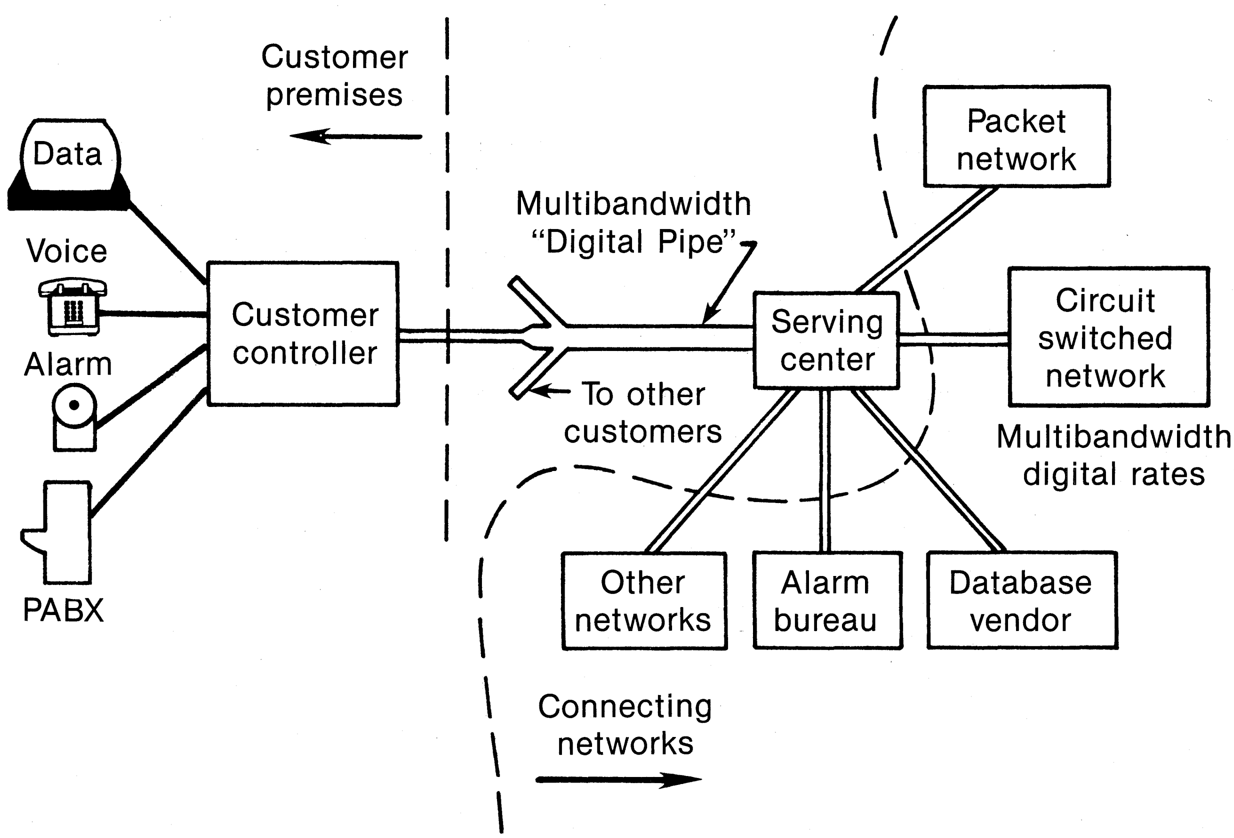


Figure 25. ISDN approach in the United States (after Dorros, 1983).

center, other networks, and other customers. Services that will be included are teleconferencing, video conferencing, facsimile, computer connections, and data base networks (Dorros, 1983).

In the transition toward the ISDN, AT&T has announced that end-to-end, digital connectivity will be introduced using major portions of its present network. This is possible because the system can be converted to handle digital signals. Capabilities will be installed for transmission of voice and non-voice services.

One is Circuit Switched Digital Capability (CSDC). The CSDC will allow users to send and receive analog voice and digital data alternately on the same customer connection, the local loop. A second capability is called Local Area Data Transport Service (LADTS) which is intended for two types of users: the occasional user who does not require voice communications while accessing a data base, and another user who requires voice communications while accessing a data base. A third capability, Data Bridging is intended to transmit digital data, such as graphics or teleconferencing, from one user location to another or to many (point-to-point and multipoint). Basic packet switched service, for private networks on shared switches is to be available soon. Enhanced services, (such as packet assembly, disassembly, and data storage) have been announced as AT&T Information Services/Net 1000.

As previously noted in Section 3.2.3, other U.S. carriers such as GTE Telenet and Tymnet are offering competitive packet-switched services.

The U.S. networks are examples of evolution toward integrated digital network facilities from the in-place quality telephone service. France, in contrast, has leapfrogged a generation of analog technology to go to advanced digital transmission and switching. In 1971, the telephone system in France was considered obsolete. Now it is considered by the French to be one of the most modern in the world as the result of establishing a national priority, coupled with massive investment and development plans. New equipment embodies the latest technology in the TELEMATIQUE program of the French PTT. Extensive installation of digital switches, transmission, and common channel signaling are basic elements in the modernization process. Only digital switches are expected to be installed in the future, with many time division switches already in place. Nearly 50 percent of the local network and 25 percent of the long-haul network is digital (Dorros, 1983). A satellite service, Telecom 1, will offer digital services to large business customers via earth stations near the customer's premises. The French packet network, Transpac, has been in operation since 1978 and has been interconnected to U.S. packet networks, Telenet and Tymnet, since 1979.

In Japan, progress toward the ISDN is also based on digital technology. Metallic wire is in place now, with lightguides and satellites expected to play major roles in the future. A videotex service such as CAPTAIN (character and pattern telephone access information network system) has been in service since 1979. A model network called HI-OVIS (high interactive optical visual interactive system) will offer services to 10,000 subscribers. Services to be offered on the model network include alarm services, telemetry, teletext, videotex, and facsimile. Facsimile is extremely important in Japan because written Japanese ideography (Kanji) is fairly easily sent on fax.

The United States, France, Japan, and other countries--including Canada, the United Kingdom, Italy, and West Germany--all are contributors to the evolution toward an ISDN. Evolution in each country is based on different geographical, political, economic and regulatory influences. Nonetheless, there is a commonality in the sense that the developing technology is exportable for international trade. Extensive penetration of the U.S. facsimile market has been made by digital machines made in Japan and sold under American and Japanese brand names. Digital switches made in France and the United States are being exported around the world. Computers, PBX's, video terminals, and other devices based on digital processors are part of this marketplace. Compatibility is a prerequisite for success, and standards are needed.

4.3 Standards

National and international standards organizations are involved in developing criteria for the ISDN. Among these are the American National Standards Institute (ANSI) and Electronic Industries Association (EIA) in the United States. The European Conference of Posts and Telecommunications Administrations (CEPT) is emphasizing ISDN studies and has placed emphasis on defining a common approach in Europe. At the international level, the International Telegraph and Telephone Consultative Committee (CCITT) and the International Organization for Standardization (ISO) are also involved. The ISDN is a focal point of particular attention by the CCITT during the 1981-1984 Study Period. Other organizations that are involved are the International Federation for Information Processing (IFIP), the Federal Telecommunications Standards Committee (FTSC), and the Institute of Electrical and Electronics Engineers (IEEE).

The CCITT Study Groups are addressing customer access, services, networks, signaling, and switching. Types of services include analog telephony, digital telephony, digital data, telex, telegraphy, telemetry, low-speed data, and broadband. All of these and other areas of interest are not fully defined, but are being developed, and appear as a basis for discussion and consideration.

Current (October 1983) considerations of the CCITT relative to the ISDN have resulted in 13 draft Recommendations. They are called I-series Recommendations and are listed in Table 1.

Table 1. CCITT I-Series Draft Recommendations for the ISDN

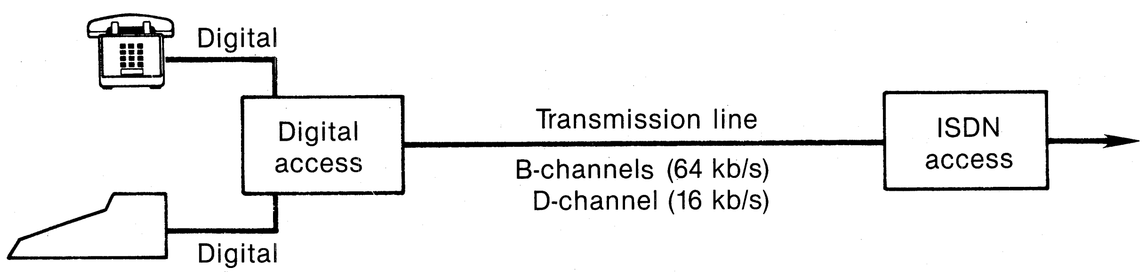
I.110	General Structure of I-Series Recommendations
I.111	Relationship with Other Recommendations Relevant to ISDN's
I.120	Integrated Services Digital Networks
I.200	Services Supported by an ISDN
I.310	ISDN Architecture Functional Model
I.311	ISDN Protocol Reference Model
I.320	Addressing and Numbering Principles in ISDN
I.3XX	Network Connection Types in an ISDN
I.411	ISDN User/Network Interfaces - Reference Configurations
I.412	ISDN User/Network Interface Structures and Access Capabilities
I.431	Basic User/Network Interface: Layer 1 Specification
I.432	Primary Rate User/Network Interface: Layer 1 Specification
I.www	Rate Adaptation and Multiplexing of 8, 16, and 32 kb/s Information Streams in a 64 kb/s B Channel

Three of the draft Recommendations are highlighted here to illustrate the scope of the work.

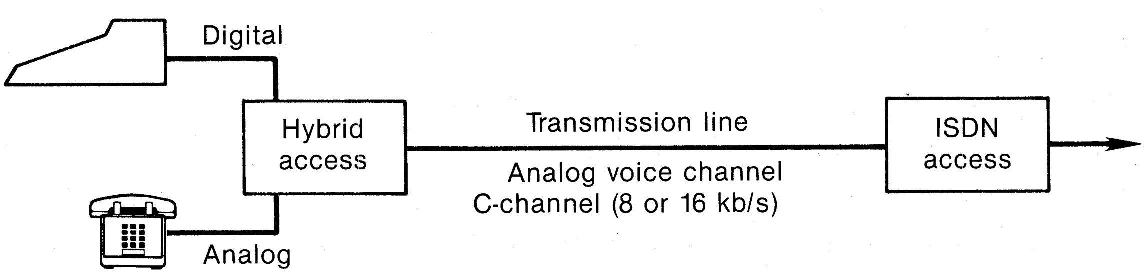
The principles of ISDN are given in I.120. Support is given for such principles as: 1) voice and non-voice services on the same network, 2) use of circuit-, packet-, and non-switched connections, 3) use of a layered protocol structure, and 4) the recognition that ISDN's may be implemented according to national requirements.

Draft Recommendation I.411 provides reference configurations and conceptual drawings for a user's physical access to a network in terms of reference points and functional groupings.

Draft Recommendation I.412 defines channel structures with respect to information and signaling transfer and access capabilities. Important principles in this Recommendation are that signaling information is carried on a D-channel (16 kb/s), separate from the main user information B-channel (64 kb/s) (Figure 26a). This, in principle, permits complete transparency and freedom of use of the B-channel to the user. The intent is to achieve lowest cost for the physical interface arrangements and to allow maximum standardization of terminal and other equipment with respect to the network interface. A C-channel is associated with an analog channel as a hybrid access arrangement that may be used in a transitional period when full digital access to ISDN is not yet universally available. The C-channel may carry telemetry, packet switched data, and signaling information on the same line with analog voice (Figure 26b).



(a) B-and D-channels for ISDN



(b) Analog and C-channels for ISDN (interim)

Figure 26. Comparison of user/network channel access arrangements for ISDN.

While the definition of the ISDN is continuing, other standards are being adopted by the CCITT that will be important to the ISDN. One of these is CCITT Recommendation X.25, which sets the criteria for interfacing subscriber data terminals to packet-switched data networks. It specifies the interface characteristics, access procedures, packet formats, packet lengths, and other parameters for operation between the user and network.

Another standard that serves as a guideline for developing the ISDN is the Open System Interconnection (OSI) reference model. There are two draft proposals in existence. The first was developed by the ISO for data networking, and the second is under development by the CCITT to encompass all networks. The CCITT draft of the ISO OSI reference model is currently known as CCITT Provisional Recommendation X.200, Reference Model of Open Systems Interconnection for CCITT Applications.

In the past, consideration was not given by vendors to protocols, standards, or network architectures for connection with a competitor's products. A manufacturer's own set of conventions for interconnecting their equipment was often developed to gain a competitive edge. However, the ISO recognized a need for an "open" system where the terminals and computers (end-systems) of one manufacturer could be interconnected to those of another. The reference models provide a framework of standard evaluation and development for interconnections and communications between end-systems. The models provide seven layers of functional groupings of protocols. The grouping of the seven layers permits changes in one layer without disturbing others. Protocol software development for one layer can proceed without disturbing the whole structure. (See Appendix B for details on Open System Interconnection.)

Standards studies have led to a general conclusion that the ISDN concept is a practical idea. The CCITT focus is on developing standard user/network interfaces on a functional basis. Defining these interfaces and interconnection standards between networks will have a number of beneficial effects. One is that manufacturers will have confidence in the long-term utility of their equipment. Another is that innovation will be promoted within the functional guideline of the standards. Nevertheless, before a user can connect to a network through a wall socket comparable to a universal telephone outlet, a number of issues remain. These are covered in Section 5.

5. ISSUES AND ACTIONS

In the previous sections we have attempted to explain why the ISDN concept is expected to evolve and what its implementation is likely to be. Assuming these projections are basically correct and ISDN does become a major telecommunications resource, then a number of questions arise. For example, how does ISDN impact the regulatory posture in the U.S.? How are competing networks integrated into the system? Is the network control centralized or distributed? Who will administer it? What is being done and by whom to resolve technical and policy issues?

In attempting to sort out ISDN issues and categorize them, it is first necessary to define the basic premises from which these issues evolve. This is particularly important for the United States, where the regulatory environment for telecommunications differs from most other countries. A historical perspective of this environment is therefore given in Section 5.1. Then in Section 5.2, we outline some major issues by separating them into two broad areas of concern, international and national. This is because international issues involve more than one country in the nature of network relationships and controls. Also, the communications environment in the United States is highly competitive in contrast to most other countries where the national telecommunication systems are owned and operated by a ministry or Department of Post, Telegraph, and Telephone (PTT). Additional classification levels for the issues are also used as shown in Figure 27. Technical issues involve such matters as numbering plans, interface specifications, and signaling techniques. Such technical issues are addressed by industry working through various standards organizations. Policy-oriented issues like tariffs, transborder information flow, and international trade are usually addressed by the various administrations and their regulatory bodies. In the United States this includes users and industry working in close cooperation with various Government agencies to establish public policy. Agencies include NTIA (which is the principal advisor to the President on telecommunications matters); the Congress (which prepares legislation affecting telecommunications); and the FCC (which was established by the Congress to oversee the industry). Also, the courts get involved when major FCC decisions are challenged and in antitrust suits. One recent antitrust suit resulted in a major restructuring of the industry as noted earlier.

Note that our separation into technology-oriented and policy-oriented issues is somewhat arbitrary because policy issues obviously affect technical aspects and vice versa.

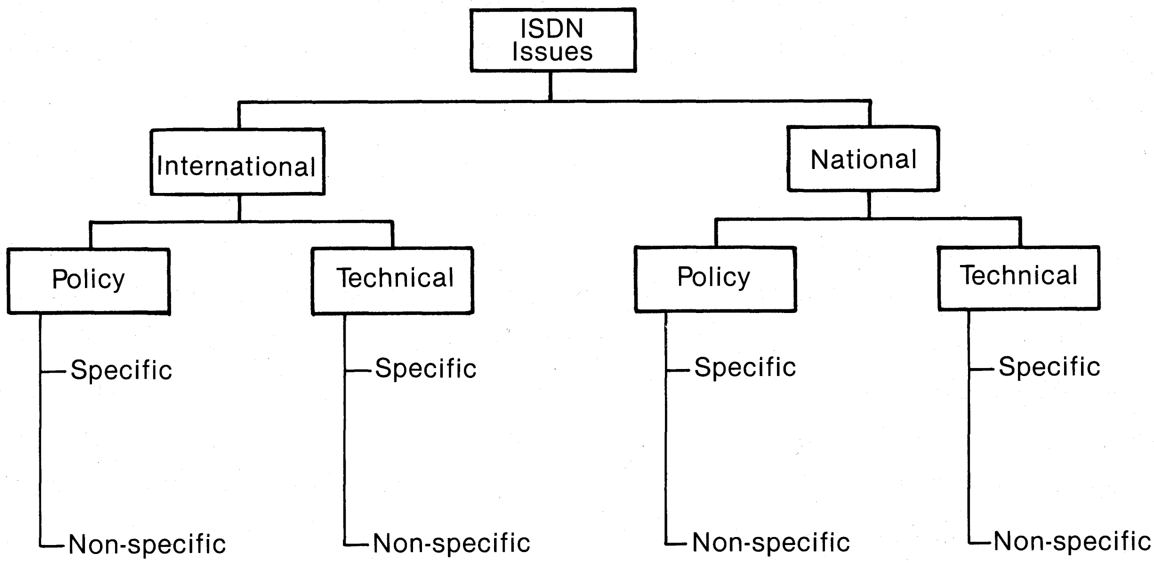


Figure 27. Classification of issues relating to ISDN.

Finally, it is useful to indicate to what extent a specific issue is related to ISDN. In many instances the issue could arise whether an ISDN evolves or not. Thus, the classifications ISDN-specific and ISDN-nonspecific is given.

In subsequent sections (i.e., 5.3, 5.4, 5.5, and 5.6), we expand on the four major issue categories and then in Section 5.7 describe the organizations that are addressing them.

5.1 Basic Premises

To define certain issues we must first ascertain objectives or goals that underlie all public policymaking in the United States. Perhaps the most fundamental principal is the First Amendment of the Constitution and its interpretations. For example, in 1969 the U.S. Supreme Court noted that "It is the purpose of the First Amendment to preserve an uninhibited marketplace of ideas in which truth will ultimately prevail."

This inherently implies public exposure to diverse sources of information using multiple forms of communication media, i.e., radio, TV, telephone, etc. This need for expanding and protecting the diversity of information flowing to the public was recognized by the Congress when it passed the Communications Act of 1934 enabling the Federal Communications Commission (FCC) to oversee its process. A primary objective of this Act was to provide "a rapid, efficient, nationwide and worldwide wire and radio communication service with adequate facilities" made available "to all of the people of the United States at reasonable charges."

There have been different views on how this so-called universal, affordable, service could be obtained. In 1934 a primary goal was to expand plain old telephone service (POTS) to more and more users. The provisions of communication service were regulated by the FCC on the assumption that telephone service would best serve the public as a monopoly. In this way, savings accrued from combining and controlling the large-scale facilities by a single entity. In addition to the advantage of these so-called "economies of scale," the concept of universal, affordable telephone service led to a principle of rate averaging. The more profitable high-traffic portions of the network would subsidize the low traffic portions and thereby make service available to almost everyone at a price all could afford. By the mid-1960's, POTS was generally available and new goals were established--namely to add new features and functions, thereby permitting an even greater diversity of message content, transmission services and terminals.

Beginning with the now famous Carterfone Decision in 1968 and culminating with an equipment registration program that allows consumers to connect their own equipment to the network, if that equipment conforms to certain technical standards, the FCC has consciously followed a policy of promoting competition in the terminal equipment market. The terminal equipment market's competitive potential is reflected today by the fact there are hundreds of manufacturers and suppliers of all kinds of devices to connect to the network.

The growth of the specialized common carrier industry began in 1963 when Microwave Communications Incorporated (MCI) first filed for permission to construct a long-distance microwave system from St. Louis to Chicago. Six years later, a landmark decision by the FCC permitted MCI to begin construction and this was followed a short time later by many other applicants.

At about this same time (mid-1960's), the computer industry was developing the technology that would permit computer time-sharing and remote access via telecommunications. This required more efficient communicating facilities and different terminal equipment. The FCC initiated what became known as the First Computer Inquiry to explore the issues and to assess the regulatory impact of interfacing computers with communications and of allowing common carriers to offer data processing services. It concluded that the transmission of data and the processing of data were separable and that data processing should not be regulated.

However, by the mid-1970's the distinction between processing and communications became blurred as these two information industries converged. Electronic digital switches with stored-program control became common and so did widely distributed computer networks. It was apparent that regulation based on a dichotomy between processing and communication was no longer feasible.

In the final decision following a Second Computer Inquiry in 1980 (FCC, 1980), the FCC adopted a regulatory distinction based on two types of service, basic and enhanced, rather than the type of technology involved. Basic services furnished by the dominant carrier, AT&T, were to be regulated, enhanced services would be unregulated. Basic services were defined by the Commission as follows:

> A basic transmission service is one that is limited to the common carrier offering of transmission capacity for the movement of information. In offering this capacity, a communications path is provided for the analog or digital transmission of voice, data, video, etc. information. Different types of basic services are offered by carriers depending on a) the bandwidth desired, b) the analog and/or digital capabilities of the transmission medium, c) the fidelity, distortion, or other conditioning parameters of the communications channel to achieve a specified transmission quality, and d) the amount of transmission delay acceptable to the user. Under these criteria a subscriber is afforded the transmission capacity to suit its particular communication needs.

The Commission defined an "enhanced service" as follows:

> The term "enhanced service" shall refer to services, offered over common carrier transmission facilities used in interstate communications, which employ computer processing applications that act on the format, content, code, protocol, or similar aspects of the subscriber's transmitted information; provide the subscriber additional, different or restructured information; or involve subscriber interaction with stored information.

The Commission permitted AT&T to offer enhanced services and customer premises equipment (CPE) on a nontariffed, competitive basis provided they did so through a fully separate subsidiary to insure that there is no cross-subsidy between the regulated and unregulated business. This separate subsidiary today is known as AT&T Information Systems.

Another conclusion of Computer II was that all customers' premises equipment should be detariffed and separated from a carrier's basic transmission service. The Commission arrived at this conclusion because they "repeatedly found that competition in the equipment market has stimulated innovation on affording the public a wider range of terminal choices at lower costs."

For two decades the concept of enhancing competition to provide marketplace regulation by reducing government involvement has been the philosophy of the FCC, the Congress, and the Justice Department. This was further demonstrated in 1982 by Congress introducing two bills (S898 and HR5158) to Rewrite the Communications Act of 1934 and by the Justice Department's settlement of an antitrust suit against AT&T. Although the Rewrite bills did not pass, they probably influenced the settlement of the antitrust suit, which resulted in a major restructuring of the industry under the terms of a modified final judgment by Judge Greene (1982). AT&T must divest itself from its 22 Bell Operating Companies (BOC's) by January 1984. The BOC's will provide local telephone exchange service but not long-distance service. They may market and sell terminal equipment but they cannot manufacture such equipment. They must provide "equal access" to all long-distance carriers. AT&T, in addition to providing long-distance service, can also enter the data processing field. This later service had been denied previously by a 1956 Consent Decree which prohibited AT&T from entering the unregulated telecommunications business. AT&T cannot, however, enter the electronic publishing business (e.g., information such as news, weather, or sports disseminated through some electronic means like videotex). This latter restriction will be reviewed in seven years to assess competitive status. Restructuring the dominant carrier in this way is intended to have major consequences on the industry by reducing many of the entry barriers to new competitors.

Based on this background some general principals underlying U.S. communications policy can now be given. The basic premise is that information, ideas, and their means of dissemination should be available to the American people from as many sources as possible. Emphasis is on promoting a competitive marketplace for greater diversity and economic efficiency. To enhance the freedom of choice the public policy should:

1. Use market forces wherever possible to displace regulatory control.
2. Ensure equal access protection to information service providers to afford reasonable opportunity for conflicting viewpoints to be heard.
3. Maintain separation between information providers and information carriers.
4. Promote effective competition by eliminating barriers to those seeking to enter the market.

The old objective of universal, affordable service is not replaced but new objectives are added namely: efficiency, innovation, and diversity, based on a competitive environment where customers' needs are expressed in the marketplace and where price is more directly related to cost.

With these objectives in mind, we are now in a position to categorize and explore issues that could arise from ISDN.

5.2 Issues Summary

Examples of international issues that apply to all countries and the United States include:

1. Policy issues resulting from the desire for national sovereignty,

   (a) National security and survivability issues such as network control and restoration priorities,

   (b) Issues involving the transborder flow of information including those which might affect personnal privacy, internal industry development and jobs,

   (c) International trade issues resulting from a foreign administration's desire to compete against other countries in the world markets, or to protect its internal market from foreign competition,

   (d) Issues involving standards developments, e.g., ensuring that International standards do not contravene national policies or regulations,

   (e) Issues raised by new technologies that may pose a threat to sovereignty and cultural identity,

   (f) Fair and equitable routing and tariff regulation issues.

2. Technical issues resulting from the need for universal, affordable services,

   (a) Interconnection issues arising due to different national networks requiring different interfaces or code and signal conversions,

   (b) Issues resulting from the need for a common addressing scheme,

   (c) Signaling and digitization issues affecting defense posture,

   (d) Technical issues involving the development of international standards for accessing, addressing, routing, interconnection, billing, etc.,

(e) Technical issues concerning quality of service as perceived by the users.

National issues follow that arise primarily from policies unique to the United States. Note that not all are necessarily ISDN-pecific. The list includes:

1. Policy-oriented pro-competitive issues resulting from desire to expand the "marketplace of ideas."

   a) Issues concerning ownership and control of certain telecommunication functions. For example, where is demarcation between transmission provider and customer premises equipment.

   b) Issues involving location of certain intelligence functions, in network or in terminal. This affects relative shares of the market accessible to common carriers on one hand and interconnect industry on the other.

   c) Issues concerning innovative services and functions and the introduction of new technologies. Who pays for impact?

   d) Interconnection issues that arise in the United States due to the multiple networks in an ISDN structure. Policy issues include service provider allocation principles and routing, priorities that affect billing and ultimately a carriers revenue.

   e) The distinctions defined by the Computer II inquiry raise several issues. The basic and enhanced dichotomy as well as the necessity for boundaries between network equipment and customer premises equipment may not always be compatible with an ISDN environment.

   f) The issue of where certain user features should reside--in the network or in the terminal. Complexity in the network favors the carrier industry whereas complexity in the terminals favors the terminal manufacturer in terms of market share.

2. Technical issues resulting from emphasis on increasing source diversity.

   a) Interconnection issues resulting from multiple ISDN's in the United States. These include questions involving equal access from other networks, addressing data or voice terminals and interfacing with non-ISDN carriers.

   b) Issues involving feature selection and carrier routing assignment, including questions on how to utilize specialized networks in a conglomerate ISDN to ensure equitable traffic distribution over participating networks.

c) Issues concerning the performance differences between voice and non-voice services e.g., error rate, delivery time, access time. Also includes questions on charging rate for various levels of performance quality. Some user performance requirements affect signal design more than network design.

d) Issues involving technology advances such as the impact on an interface when fiber optical facilities are introduced or when bit rates change from 64 kb/s to 32 kb/s.

e) In the United States, the telephone network provides access to nearly every business and home in the country. But these subscriber loops (primarily one twisted-wire pair) are designed for 4 kHz analog voice transmission, not high-speed data transmission. This raises technical issues concerning access to ISDN from many potential users. Can the existing facilities handle the standard rates? What alternatives are available? How much will it cost? Who pays for the change over? How long will it take?

In the section above, we summarized several ISDN issues in outline form. In the following four sections we expand on some of these issues and identify which are ISDN-specific and which are not. The four sections follow our major issue classifications of International Policy, International Technical, National Policy, and National Technical.

5.3 International Policy Issues

National defense is a major concern to any country, and the nation's telecommunications networks are crucial to that defense posture. The impact of ISDN on this posture depends on when and how it evolves. In the United States the interoperability between competing networks is an obvious requirement for survivability reasons, regardless of when and how ISDN develops.

The right to personal privacy in many countries may restrict the flow of information to other countries. Countries that provide this right are reluctant to transmit protected information to countries that do not. The unregulated flow of information across country boundaries can also affect the economic growth. For example, the use of foreign data processing capabilities could restrict the growth in that area internally. Although these issues arise with any network, the worldwide scope of ISDN focuses the problem and makes it seem more urgent.

Communications between countries must be a cooperative venture. However, at the same time many countries are actively competing in the worldwide telecommunications market. Today the United States has about 50% of the world telecommunications.

This market is relatively open compared to other countries that are typically much smaller and much less open to outside competition. Most of the world outside North America and Japan follow recommendations of the CCITT for telecommunications equipment manufacturing and procurement. The CCITT's recommendations for ISDN will undoubtly become the standard interface for user access throughout many countries, although each country may implement the network in any way it desires. International standards-making organizations such as the CCITT have usually recognized national needs and generally take into account the regulatory environment. This is done to allow each country to meet its administration's policies in its own way. The United States participates in these activities to ensure that industries' competitive interests are allowed.

In the United States the ISDN could consist of many networks (voice and data, circuit- and packet-switched, basic and enhanced) interconnected and accessed by users via standard ISDN interfaces. In other countries a single, unified network under control of a single administration may develop.

It is expected that the existence of worldwide ISDN interface standards will encourage more manufacturers to develop new terminals and enter the international market.

5.4 International Technical Issues

The ISDN concept was, in part, conceived to provide universal service in an efficient manner using available digital networks. The ISDN has been expected to evolve primarily from public telephone networks that come closest to providing universal connectivity. Although there are over half a billion telephones in the world, 90% are concentrated in 15% of the countries. Thus the global concept for ISDN remains a major issue.

In many countries the administrations control and operate the network (e.g., the PTT's in Europe) and they also control the charges. Thus the "universal and affordable" concept is approached based on total cost of facilities. Cross subsidies are imposed (and accepted) where necessary. In the United States the goal of universal, affordable service has not changed, but the means of achieving it has. Market forces are replacing regulatory controls. The United States policy reflects wide concensus that the marketplace appears to be the best means of allowing new technologies (e.g., digital networks) and services (e.g., those contained within ISDN) to develop.

Since the ISDN implementation may evolve in different ways from different base networks in each country, a number of issues arise. One is the problem of interconnections between the networks for interoperability. This includes not only a physical gateway, but possibly code, address, and signal conversions. A common numbering scheme is desirable for international access. This raises problems in some countries where switching facilities may be unable to handle the number of digits necessary. Also, in the United States it is desirable that the numbering scheme allow for carrier selections, whereas this is unnecessary in the PTT's.

Another issue concerns the dichotomy between voice and data services. At first, one might expect that digitized voice could be handled just as data is handled because both are similar streams of bits. But there are differences and these differences could affect the cost of providing these services. The efficiency of resource utilization is a major issue. For example, the statistics of voice and data traffic are very different. The dead times between speech sounds can be used to carry other traffic. With data there are no such dead times. Also, voice conversations, whether their transmission is analog or digital, must occur in real time or at least essentially real time. The use of satellites, and the corresponding delay of about 1/4 second associated with such circuits is disagreeable to many people and considered unacceptable by many for multihop circuits. Interactive data circuits require fast turnaround times whereas bulk data transfers can often be delayed by several minutes or sometimes hours without objection. Other quality of service measures may also differ such as access delay, error performance, blocking probability, etc. One of the questions this data-voice dichotomy raises is whether it is better to develop an integrated network with fully shared resources and possibly nonoptimum grade of service or whether it is better to separate resources and optimize each for a particular service. In either case an equitable rate structure is needed where multiple carriers are involved.

The routing and accounting for calls, especially incoming international calls, is another issue. The route selected could impact which carrier receives revenue. Although this is not necessarily caused by ISDN, its importance is increased as a result of the wide interest in ISDN. Both technical and policy issues are involved.

These are just a few examples that can, in part, be resolved by developing appropriate international standards. International standards for accessing ISDN, addressing, routing, interconnecting, and billing will ultimately be recommended by the CCITT, but will take time to be developed.

5.5 National Policy Issues

The ISDN concept raises a number of policy questions in the United States because of our commitment to a competitive environment. For example, one question is how can we ensure that the CCITT process accommodates the established pro-competitive policies of the United States? Competition provides the incentive to develop new, low-cost technologies, minimizes the costs of facilities and services, and provides a wider range of services at prices based on costs. For competition to develop, competing technologies must exist, be readily available to all, and be economical relative to existing service. The Government policy, both economic and legal, must allow entry to competitors by reducing barriers whenever possible.

One of the underlying conceptual principles of ISDN is that it will contain intelligence for the purpose of providing service features, maintenance, and network management functions. This may not be entirely feasible in the U.S. regulatory environment where basic information transport services are regulated and enhanced services (like videotex and electronic mail) or customers premises equipment (like telephones, modems, or PABX's) are not.

The transition toward ISDN in the U.S. competitive environment will likely involve several competing networks. This raises the question: are there technological, economic, or legal barriers that make multiple ISDN networks uneconomical or inefficient relative to a monolithic structure? The multiple carrier, procompetitive philosophy of the United States presents many questions concerning U.S. participation in an international ISDN.

Still another issue involves the regulation of these networks when necessary or their deregulation when feasible. The Communications Act of 1934 gives the FCC exclusive regulatory power over interstate common carrier communications services. Authority over intrastate services is reserved to the states. The line between state and Federal jurisdiction is not always clear because the same facilities may often by used for both types of service. The transition to an ISDN may be delayed in the United States unless these jurisdictional disputes are resolved. New firms may be reluctant to enter the integrated services market unless they know if, by whom, and how they will be regulated. For example, the FCC regulates some video aspects of cable, but not the common carrier services provided by the cable operator. Jurisdictional disputes raise several questions concerning availability of services and economic impacts which must be addressed.

5.6 National Technical Issues

As noted previously, ISDN implementation in the United States would probably consist of multiple networks provided by competing carriers. In addition to conventional wire pair, the access to an ISDN could take other forms, e.g., radio, coaxial cable, and fiber optics. The user in the United States could have a number of choices to select including, for example, the access path, the carrier, the routing and so forth. This selectability raises a number of technical questions concerning ISDN. How are the selections made? How are the networks interconnected? Who assigns routing? What are the cost accounting procedures? What is the impact on a numbering plan? Who administers the plan?

Two key issues affecting the ISDN's survivability and endurability during national emergencies are signaling and digitization. Signaling is important because it is the key to service integration, damage assessment, and restoral. Digitization is an issue because it is currently not cost effective in the U.S. to use digital transmission over long distances. The network must be all digital if restoral routing involving many tandem links is to become feasible.

Developing standards that will impact these issues include CCITT recommendations on signaling (e.g., Signaling System No. 7) and ISO standards in the Open Systems Interconnection (OSI) family. The technical communities developing these standards, CCITT and ISO, have traditionally been separated by their charters and authorities. Consequently, there is a dichotomy of standards, and often, a "gray area" of uncertainty at the intersection points. For example, in ISO standard 1745 (BISYNC), only the "logical connection" process is addressed; the establishment and subsequent disconnection of the physical circuit are simply referenced as "CCITT responsibilities." An ISDN implies one signaling system that does both.

Signaling is the key to integration in the ISDN because it controls the services provided by the same (shared) resources. As an example, services requiring packet switching and circuit switching will be provided by ISDN on a user selectable basis. The user's service selections, and the service features he or she desires, will be communicated to the network by the signaling system. The signaling systems currently used for circuit-switched voice and packet-switched data are substantially different because the systems are not integrated. That difference will largely disappear as ISDN becomes real.

Signaling is also a key to damage assessment and restoral in a damaged network. Restoral must be based on a knowledge of which switching centers and transmission links have survived after a disaster, and how these surviving elements can be reconstituted. Signaling provides a key linkage between the control points of the network, and could provide the means to collect such information.

The existing PSTN employs analog frequency modulation and multiplexing for its long-haul transmission facilities for economy reasons. Although extensive portions of the network operate in a digital mode (e.g., voice encoded PCM), these "islands" of digital operation are generally limited to densely populated areas. At present, high-capacity digital transmission is available for direct customer use primarily in large metropolitan areas. The digital portion of the network covers a relatively small part of the geographic area of the U.S. An all-digital network is essential if many links must be operated in tandem to connect user pairs--a very likely requirement in a severely damaged network.

The ISDN concept is to provide end-to-end digital channels to the user interface that are compatible with the PCM voice digitization rate of 64 kb/s and multiples or submultiples thereof. Unfortunately, this concept will not become a reality until digital long-haul transmission becomes cost-effective. At present, it is not. A "hybrid" service offering (analog and digital) is being planned by CCITT Study Group XVIII as an interim measure in recognition of this problem.

In the United States various loops, lines, and trunks currently constitute the transmission part of the telephone network. In addition to over 200,000,000 subscriber loops, the interswitch trunks provide huge country-wide connectivity. According to recent estimates (1981) there are nearly 7,000,000 trunks bundled into some 300,000 trunk groups. The channel mileage covered by this network must be in the hundreds of millions of miles. The local loops are predominately 2-wire voice frequency transmission, whereas the majority of the toll trunks are 4-wire using all sorts of carrier systems. As the length of a given line or trunk increases, different systems are used because they are more cost effective. On the long haul trunks in the United States, analog carriers still prevail because they still cost less than other facilities. In Europe, long-haul distances are much less (typically less than 200 miles) and the transition to digital facilities is progressing at a much faster rate.

Recently, the CCITT has developed a Recommendation for encoding voice for transmission over a 32 kb/s channel. This would present an obvious cost advantage over the 64 kb/s systems currently in use and extend the range over which digital

T-carrier type systems are cost effective, thereby increasing the rate at which the network is digitized.

5.7 Actions

We have raised a number of issues, some technically oriented and some policy oriented and noted that not all of these issues are specifically the result of ISDN implementation but could arise from almost any future global network architecture.

Although these issues are many and complex there is also considerable work already being done to resolve them by industry with government support in various standards organizations. In this section we will describe some of these organizations and the activities currently under way that relate to ISDN. In the limited space available we can only highlight some of these activities, recognizing that this is only a small part of the total effort.

From a regulatory and policy standpoint the U.S. position is implemented and promulgated by legislative actions of the Congress, Administrative actions of the President, actions of the Department of Justice, and decisions by the courts. Two supporting entities are the FCC, which has the regulatory authority over interstate common carriers, and the NTIA in the Department of Commerce, which advises the Adminstration on telecommunication matters.

The FCC has established an intra-agency task force on the ISDN made up primarily of persons previously involved in the Computer II Inquiry. The Commission recently issued a Notice of Inquiry (Docket 83-383, Adopted August 4, 1983) in the matter of ISDN. The purpose of this notice is to provide the FCC with background on ISDN developments to date, in related telecommunications policy, and to discuss various issues raised by the potential implementation of ISDN's.

The NTIA and its technical research arm, the Institute for Telecommunication Sciences (ITS) in Boulder, Colorado, has, in addition to its radio spectrum policy development and management functions, several other important missions including: 1) furthering the efficient development and use of telecommunications and information services; 2) promoting the development and international adoption of technical standards in the telecommunications and information industries; and 3) formulating and advocating regulatory, legislative, and institutional reforms to the FCC, Congress, and industry in order to promote competition and deregulation where feasible and to ensure the universal availability of basic telecommunication services.

It is with these goals in mind that NTIA participates in numerous standards activities on both a national and international basis.

The National Communication System (NCS) is the primary U.S. agency concerned with the management and coordination of telecommunication resources and services during national emergencies. The impact of ISDN on the U.S. communications posture is, of course, a major concern of the NCS. Efforts are under way to ensure that certain interface standards will allow the emergency managers community to meet specific needs in this area including survivability, restoration, and critical user priorities.

There are several national and international standards organizations involved in ISDN standards development activities either directly or indirectly as noted in Section 4.3. The primary focus on ISDN activities is in the CCITT. Several of the technical issues have already been addressed by the CCITT and its member nations. Appendix A describes the International CCITT and the U.S. CCITT organization, which makes contributions to it, and determines the U.S. position concerning various Recommendations. These Recommendations are the result of a continuing process that begins with a list of technical "Questions" prepared by the plenary assembly of the CCITT. The basic Question for ISDN that was entrusted to Study Group XVIII for the 1981-1984 study period is given in Appendix B. The list of Recommendations given in Section 4.3 was the result of that group's efforts to date concerning this Question. These Recommendations, along with any others completed, will be submitted to the 1984 plenary assembly of the CCITT for approval and subsequent publication.

In the United States, the National Committee of the CCITT is headed by a representative from the Department of State. The U.S. CCITT has been divided by subject matter into five groups as follows: A) regulatory matters (chaired by the FCC), B) telegraph operations, (chaired by MCI/Western Union International), C) telephone operations (chaired by AT&T), D) data transmission (chaired by NTIA), and E) the ISDN Joint Working Party (chaired by NTIA). The ISDN Joint Working Party is the means whereby U.S. industry and Government agencies can coordinate their inputs to the appropriate CCITT Study Group. An ISDN working group was recently formed to conduct technical studies in assigned areas in support of the ISDN Joint Working Party. This group consists of industry and Government members working together to resolve many conflicting viewpoints. Contributions from this group to the CCITT are submitted via the U.S. Department of State. The process is intended to establish a unified U.S. position at the international meetings.

The development of any Recommendation in the CCITT is a complex and continuing process which often takes many years to complete. The process is exemplified by Recommendation X.121, The International Numbering Plan for Public Data Networks. This Recommendation evolved from a Question first entrusted to Study Group VII in 1972. At that time the only numbering plans in existence were for telephone and telex networks, neither of which seemed to meet needs for interworking data networks on a worldwide basis. Study Group VII established a working party to concentrate on developing a workable plan. Canada subsequently submitted the first contribution during the 1972 to 1976 study period. This plan, to be administered by the CCITT, provided for a 14-digit address including a 3-digit country code, a 1-digit network code, and a 10-digit network terminal number. Canada's contribution served as the basis for subsequent plan development. The working party, consisting of 15 to 30 members from 10 or more countries, met once or twice each year to review and discuss contributions and to amend the original Recommendation. Recommendation X.121 was finally adopted by correspondence in 1978. This adoption and subsequent publication of X.121 between the normal meetings of the plenary assembly was the result of the urgency expressed by a number of countries. Since that time the working group has continued its efforts and is currently working on additional amendments to X.121 focusing on subaddressing including the allocation of address to terminals on the Public Switched Telephone Network.

The numbering plan developed for Public Data Networks is also of interest to the CCITT group responsible for an ISDN numbering plan. This group is currently engaged in developing criteria for the ISDN numbering plan.

The numbering plan for the ISDN can be established in one of four ways:

a) evolution from the Telephone Numbering Plan, Recommendation E.163

b) evolution from the Data Numbering Plan, Recommendation X.121

c) introduction of a new Numbering Plan,

d) integration of existing Numbering Plans.

The following factors are to be considered:

a) the ISDN will evolve from the digital telephone network (Recommendation I.120);

b) the number of ISDN customers initially will be small relative to the number of analog based (non-ISDN) customers;

c) interworking will be required to existing networks.

6. SUMMARY AND CONCLUSIONS

We have discussed why and how ISDN's are expected to evolve and what they may look like in the future. To describe ISDN we first had to develop some elementary concepts and define certain terms that are commonly used by the carrier and terminal manufacturer's industry. Then after describing the U.S. communications regulatory environment from a historical perspective, we presented some international and national issues raised by ISDN. Although there are a number of policy and technical issues, these are already being addressed by experts from industry and from certain government agencies working together in both national and international forums.

The ISDN concept promises a number of high-performance, multiservice digital networks with potential for global communications when interconnected. While ISDN does hold promise, it is still just a concept. Many serious questions remain. Will ISDN, as a distinct network actually be realized? How soon? Will it overlay existing networks or exist primarily as digital islands?

The impact of the modified final judgment by Greene (1982) and the subsequent divestiture of AT&T by January 1984 is yet to be felt. Already there is concern and indications that local telephone rates will increase and long distance rates will decrease. If the Congress passes legislation to limit these rates it would affect revenues available to the operating companies for network enhancement - and thus the evolutionary process toward ISDN.

In the U.S. the existing analog telephone plant is gradually being replaced with digital facilities. Although some of the key elements of ISDN (such as digital switching with stored program control and common channel interswitch signaling) are already in place for the long-haul network, several portions still use analog switches and in-band signaling.

Microwave facilities are still used for transmission over major portions of the long-haul network and these employ analog frequency modulation for voice and data. Although a wide variety of digital terminals is available for all kinds of uses, the basic telephone is still analog, accessing the network over analog loops. It is apparent that we face a transition period of one or two decades before an all digital network like ISDN can become a reality.

In the future we can expect to see many changes in the telecommunications industry. Technical advances will continue to occur, causing dramatic changes in network concepts including ISDN's. Users will always demand new services and the new concepts will, we hope, be available at acceptable prices.

It is difficult in a primer like this to cover all aspects of a complex undertaking like ISDN. We realize that there are many conflicting viewpoints between administrations and between the carriers, suppliers, and users. We have only introduced issues here and suggest that interested readers pursue the subject further. Some useful material for this purpose is listed below.

CCITT and the ISDN

The CCITT: Organization, U.S. Participation, and Studies Toward the ISDN, by D. M. Cerni, NTIA Report 82-101, (NTIS Access. No. PB 82-230871).

International Telecommunication Standards: Issues and Implications for the '80's, A Summary of a July 1982 Workshop, by D. M. Cerni and E. M. Gray, NTIA Special Publication 83-15, (NTIS Access. No. PB 83-242271).

Telephone Nets Go Digital, by I. Dorros, IEEE Spectrum, Vol. 20, No. 4, April 1983.

Basic Communications

Data Communications and Teleprocessing Systems, by T. Housley, Prentice-Hall, Inc., Englewood Cliffs, NJ 07632.

Communications and Switching

Digital Telephony, by J. Bellamy, John Wiley and Sons, NY.

OSI Reference Model

Coming of Age: A Long-Awaited Standard for Heterogeneous Nets, by H. C. Folts, Data Communications, Vol. 10, No. 1, January 1981.

7. REFERENCES

Dorros, I. (1983), Telephone nets go digital, IEEE Spectrum 20, No. 4, April.

FCC (1980), Final decision in the second computer inquiry, FCC 80-189, adopted April 7.

Folts, H. C. (1981), Coming of age: a long-awaited standard for heterogeneous nets, Data Communications 10, No. 1, Jan.

Greene (1982), Opinion entered in AT&T antitrust case, District Court, District of Columbia, Civil Action Nos. 74-1698, 82, 0192, and 82-025.

ISO (1982), Information processing systems - open systems interconnection - basic reference model, Draft International Standard (DIS) 7498.

Skrzypczak, C., J. Weber, and W. Falconer (1981), Bell system planning of ISDN (integrated services digital network), IEEE International Conference on Communications, Denver, Colorado, Vol. 1 of 4, pp. 19.6.1 to 19.6.6.

U.S. Department of Commerce (1983), 1983 U.S. industrial outlook, for 250 industries with projections for 1987. Available from Bureau of Industrial Economics, Washington, DC.

APPENDIX A: CCITT AND ISDN

A.1. Introduction

This appendix describes the organization and activities of the International Telegraph and Telephone Consultative Committee (CCITT) and the U.S. participation therein, particularly as they relate to the ISDN. It summarizes the functions, structure, and membership of the CCITT, a permanent organ of the International Telecommunication Union. It also describes the considerable involvement of the United States in the work of the CCITT and shows how U.S. contributions are channeled through the U.S. CCITT organization. The driving force behind this increased U.S. participation in international standards development is the changing international market for services and equipment. This is particularly true for ISDN. The U.S. telecommunications industry is showing great interest in the development of ISDN, and (through the U.S. CCITT organization) is making major contributions to the international standardization efforts. The method by which these contributions are made and the approval processes required are also presented.

For more detailed information the reader is referred to a report entitled "The CCITT: Organization, U.S. Participation, and Studies Toward the ISDN" by D. M. Cerni (NTIA Report 82-101) from which much of this summary was taken.

A.2. The ITU and the CCITT

The ITU is a specialized agency of the United Nations. As an international treaty organization it consists of some 157 member nations that signed the ITU convention. The ITU functions through seven organs: 1) the Plenipotentiary Conference, 2) the Administrative Council, 3) the Administrative Conferences, 4) the General Secretariat, 5) the International Frequency Registration Board (IFRB), 6) the International Radio Consultative Committee (CCIR), and 7) the International Telegraph and Telephone Consultative Committee (CCITT). See Figure A-1.

Since it is the CCITT that is in the process of developing Recommendations (or standards) for ISDN, that organization is described here.

The CCITT, conducting work through 15 technical Study Groups, other committees, and special autonomous groups, attempts to promote and ensure the operation of international telecommunication systems. This is done by issuing Recommendations (or standards) for end-to-end performance, interconnection, and maintenance of the world networks for telephone, telegraph, and data communication. Certain tariff and operating principles are also established by the CCITT.

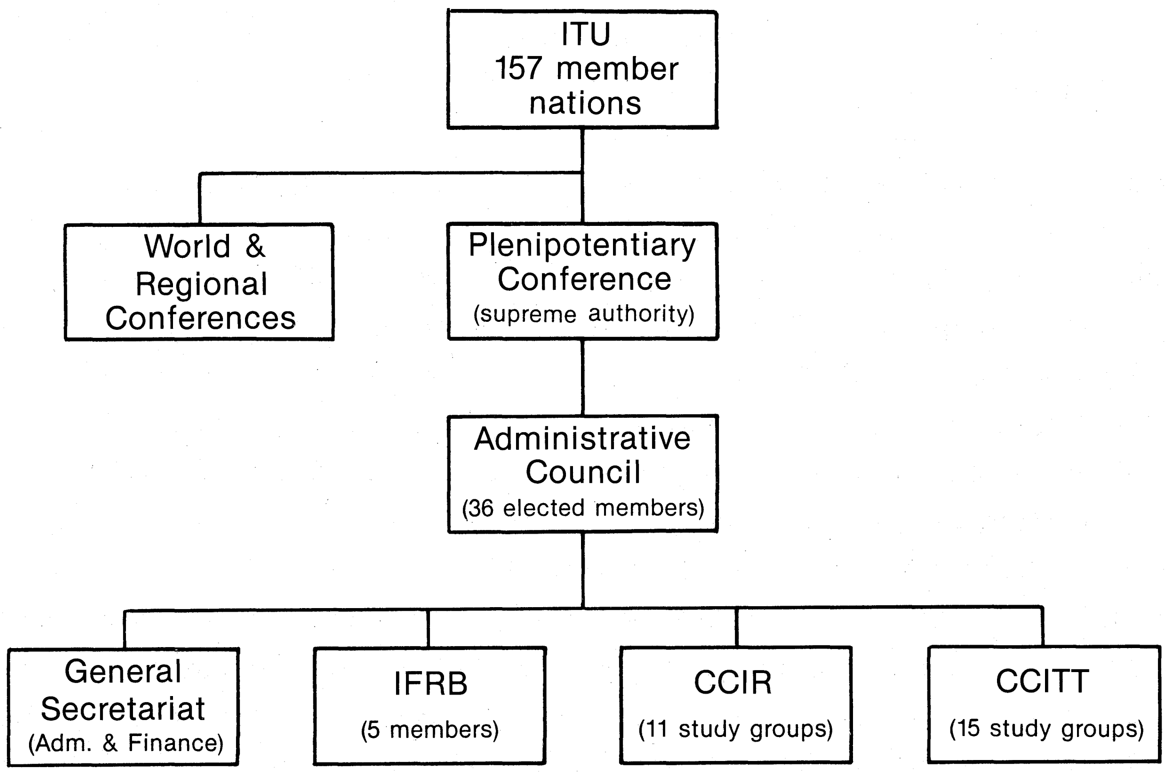


Figure A-1. The International Telecommunication Union.

Full membership in the CCITT is offered to the administrations of all members of the ITU and to any recognized private operating agency (RPOA) with a member's approval. An RPOA is a private or government-controlled corporation that provides telecommunication services (e.g., AT&T in the United States). They are nonvoting members of the CCITT that act as principal advisers to national administrations. Limited participation is extended to certain other international organizations (e.g., the International Standards Organization) and to scientific or industrial organizations.

Study groups provide the means for developing "Recommendations" that are issued as a basis for voluntary international standards. The 15 Study Groups for the 1981-1984 Study Period are listed in Table A-1. Study Group XVIII, entitled "Digital Networks" is primarily concerned with ISDN during the 1981 to 1984 study period. Other groups covering related fields such as Data Communication Networks, Telephone Switching and Signaling, and Telephone Transmission Performance are also involved in various aspects of ISDN.

Table A-1. The Titles Designated to the 15 Technical CCITT Study Groups for the 1981-1984 Study Period

Designated Group Number	Title
1. Study Group I	Definition and operational aspects of telegraph and telematic services (facsimile, teletex, videotex, etc.)
2. Study Group II	Telephone operation and quality of service
3. Study Group III	General tariff principles
4. Study Group IV	Transmission maintenance of international lines, circuits and chains of circuits; maintenance of automatic and semi-automatic networks
5. Study Group V	Protection against dangers and disturbances of electromagnetic origin
6. Study Group VI	Protection and specifications of cable sheaths and poles
7. Study Group VII	Data communication networks
8. Study Group VIII (and XIV)	Terminal equipment for telematic services (facsimile, teletex, videotex, etc.)
9. Study Group IX (and X)	Telegraph networks and terminal equipment
10. Study Group XI	Telephone switching and signaling
11. Study Group XII	Telephone transmission performance and local telephone networks
12. Study Group XV	Transmission systems
13. Study Group XVI	Telephone circuits
14. Study Group XVII	Data communication over the telephone network
15. Study Group XVIII	Digital networks

Recommendation development starts, in theory, with the Plenary Assembly which normally meets every 3 years. This body draws up a list of technical communication subjects, or "Questions" as they are called, the study of which would lead to improvements in international communications in many cases. Questions also result from the overflow of work done in the previous study period. Questions are entrusted to an appropriate study group in the interval before the next assembly, called a study period. Appendix B is a copy of the key Question concerning ISDN. Eighteen other questions relating to the ISDN have been entrusted to various CCITT study groups.

The work of the study groups is brought to a close when final reports are presented to the plenary assembly. These final reports contain the draft Recommendations and amendments developed by the group as well as general information about the work and the status of each question. The plenary assembly examines the study group reports, approves new or revised Recommendations, and selects and assigns questions for the next study period.

A.3. The U.S. CCITT

The U.S. participation in the work for the CCITT is channeled through the U.S. CCITT Organization. This organization, whose function is to do preparatory work for the international CCITT meetings, is advisory to and under the jurisdiction of the Department of State. Delegations to the international CCITT meetings are under the aegis of the Office of International Communications Policy, Bureau of Economic and Business Affairs in the State Department.

The U.S. CCITT organization is structured as shown in Figure A-2. The National Committee constitutes a steering body and has purview over the agenda and work of the four study groups and of the Joint Working Party (JWP) on the ISDN as indicated in Figure A-2. Each of the four study groups, A to D, covers the work of several relevant international CCITT study groups.

The JWP on the ISDN was established by the National Committee in May 1981. It contains members of all four study groups in recognition of the probable impact of the ISDN on existing telegraph, telephone, and data services. The JWP is concerned mainly with the contributions from the United States to Study Group XVIII pertaining to the ISDN. The groups' functions also include reviewing contributions of other countries to Study Group XVIII, approving U.S. positions with respect to these contributions, and maintaining liaison with the appropriate U.S. Study Groups studying such Recommendations.

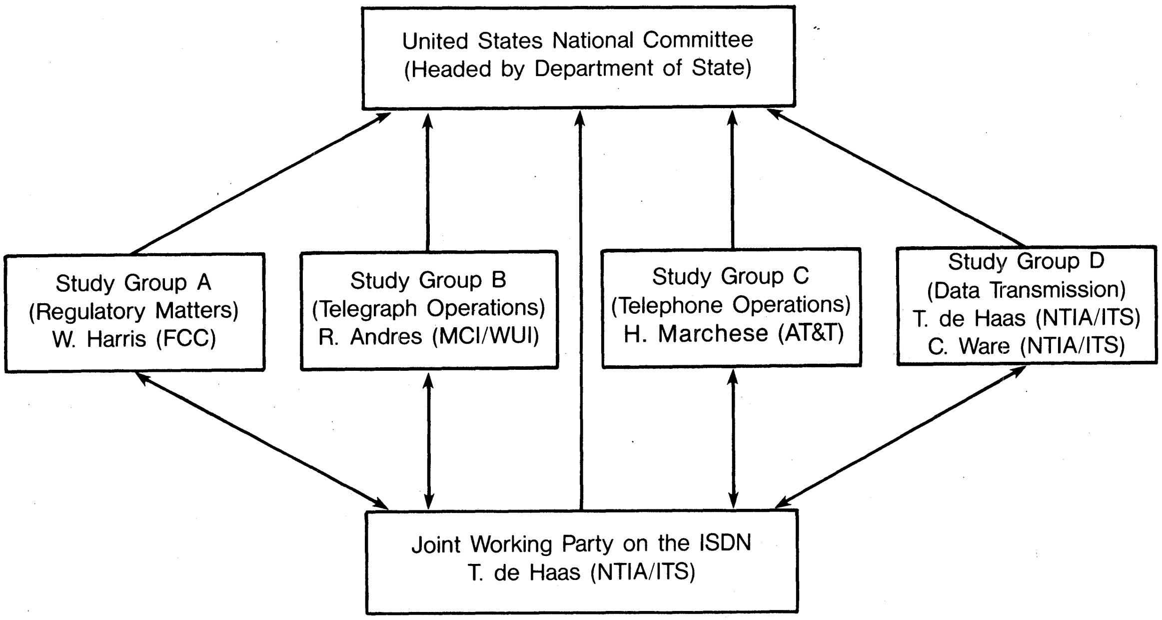


Figure A-2. The structure of the U.S. CCITT and chairmen for 1981-1984.

Each of the U.S. Study Groups meets at the discretion of its chairman and meetings are usually keyed to the agenda of international meetings. The dates of each meeting, and proposed agenda, are announced to the public both in the Federal Register and in a Department of State release at least 15 (working) days prior to the convening of a meeting. These meetings are open to the public.

The four main functions of the U.S. CCITT follow:

1) it offers to the U.S. telecommunication industry, in general, a forum for participation in the standards-making process;

2) it serves as an arena for discussion and debate in its study group activity, preparatory to the development of U.S. positions and contributions;

3) it provides, through this discussion and debate, guidance for delegates at the international meetings; and

4) it serves as a pool of informed and interested personnel from the private sector that can be drawn upon to staff the U.S. delegations to the international CCITT meetings; these delegates assist and advise the official U.S. representation or head of the delegation.

Membership in the U.S. CCITT covers a broad spectrum of U.S. industry, Government agencies, scientific organizations, user groups, and standards groups such as the

American National Standards Institute (ANSI) and the Electronic Industries Association (EIA). These members also participate in working groups to study assigned topics.

The contributions from the United States to the CCITT are not sent directly to Geneva from a member organization. Rather, the contribution is first passed through a formal chain of approval and coordination. The resultant approved contribution, depending on its content and source, may be either an "U.S." contribution or an "individual member" contribution. A U.S. contribution represents the position of the U.S. study group; an individual member contribution is usually more limited and keyed to the interest of one of the private organizations (presently 57) that are members of the CCITT. The vast majority of these individual contributions, past and present, have emanated from AT&T.

Figure A-3 illustrates the chain of approval for a U.S. contribution. The chain starts with a presentation of a draft contribution to the relevant study group by a U.S. CCITT member or an ad hoc committee appointed by the study group. The resultant discussion provides feedback to the contributor, and lends understanding and support to the position expressed by the formal contribution. Upon approval, the document is sent to Geneva via the Department of State.

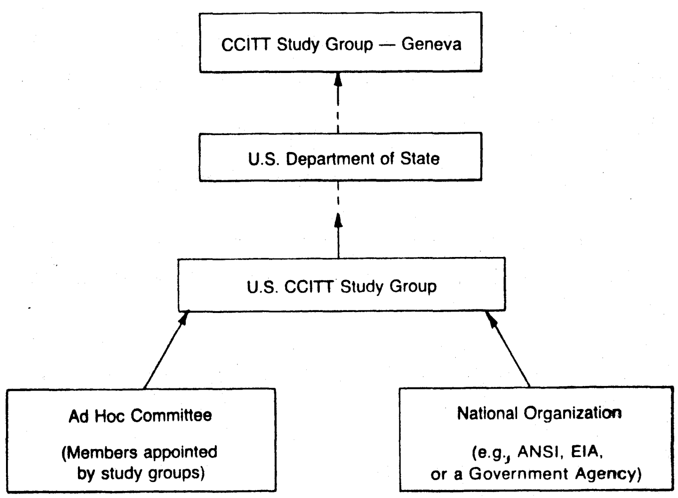


Figure A-3. Approval chain for "U.S." contributions to the CCITT.

Figure A-4 illustrates the chain of approval for an individual contribution. This figure shows that the CCITT member organizations, although always encouraged to present their contributions to the relevant U.S. CCITT study group for discussion and feedback, are not obliged to do so under constraints of time or other factors, but may work through the study group chairman, instead.

The purpose of this chain of approval, or system of coordination, is to avoid having highly controversial issues sent directly to Geneva from different quarters, which could lead to difficulties at the international CCITT meetings.

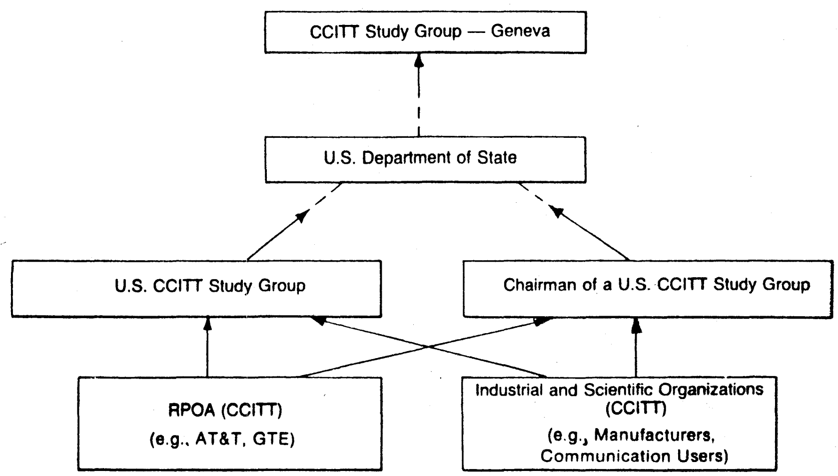


Figure A-4. Approval chain for "individual member" contributions to the CCITT.

Many countries, and particularly the European countries, have been exerting strong pressures on the CCITT to produce basic Recommendations for the ISDN during the 1981 to 1984 study period. Development of such Recommendations is presently moving ahead but results are still changing. To present a status report in this dynamic environment is very difficult, and impossible to summarize here. The CCITT documents themselves must be constantly reviewed to stay up to date. The Draft Recommendations under development by Study Group XVIII will be submitted for approval to the next Plenary Assembly in 1984.

A.4. References

Cerni, D. M. (1982), The CCITT: organization, U.S. participation, and studies toward the ISDN, NTIA Report 82-101.

APPENDIX B: QUESTION 1, STUDY GROUP XVIII, 1981-1984

Question 1/XVIII - General network aspects of an Integrated Services Digital Network (ISDN) (continuation of part of Question 1/XVIII, studied in 1977-1980)

This question is concerned with overall studies related to the general features of future Integrated Services Digital Networks capable of satisfying the requirements of many different services. Study Group XVIII will define the scope and framework of an ISDN and identify the services which may be incorporated in such networks. It will study the evolution of Integrated Digital Networks (IDN's) dedicated to specific services (e.g., telephony, data) towards an ISDN.

The objectives will be to define overall network and system principles which can form a basis for study and Recommendations by appropriate specialist CCITT Study Groups. The generic features appropriate and applicable to an ISDN will be identified together with optional service dependent features applicable to part of an ISDN.

The study of the following five related aspects will take into account the considerata arising from studies carried out during the 1977-1980 study period as recorded in Annex A to this Question. In addition, the multiple aspects of this work require coordination between the various Study groups involved (e.g., Study Groups III, VII, XI, XV, XVI, XVII and XVIII).

Some of these Questions have to be studied initially by Study Group XVIII, with high priority, to enable other Study Groups to initiate or continue their work and to draft Recommendations within the current CCITT study period. In other cases Study Group XVIII needs information from other Study Groups in order to make progress in its own network studies.

Recommendation No. G.705 provides information and future developments of the ISDN.

Studies of ISDN aspects were carried out under Questions 1/XVIII during the 1977-1980 study period and a partial reply to that Question is reproduced as Annex 1 to this new Question. Annex 2 records many points already identified and of relevance to the ongoing studies. Annexes 3 and 4 contain significant information which was not fully considered before the end of the study period. These Annexes are also of relevance to other new Questions of Study Group XVIII.

Note: The Chairmen and Vice-Chairmen of the Study Groups involved (Study Groups III, VII, XI, XV, XVI, XVII and XVIII) will jointly assess the progress made by the various Study Groups and initiate any steps necessary to expedite the work. This should take place at about the middle of the study period (e.g., beginning of 1982), with the Chairman of Study Group XVIII acting as convenor for this coordination.

Considering

a) that the requirements of data transmission services and several new non-voice services are being studied by CCITT.

Note: In several countries services dedicated digital networks are already in service or will be installed for non-voice services that may use part of the ISDN for access to this network.

b) many countries wish to adopt a common strategy for extending the use of Integrated Digital Networks (IDN) beyond the telephony application to form Integrated Services Digital Networks,

c) telephony service will constitute the major portion of the carried load on digital networks characterized by time division transmission and switching and common-channel signalling,

d) efficiency and economy of methods of access to the ISDN from customer terminals are significant factors in planning the local network,

e) CCITT Recommendations on digital switching and inter-exchange signalling, which take into account the future evolution of the IDN for telephony towards the ISDN, are already available in the Q series and may form the basis for future Recommendations on ISDN.

Point A. Service aspects

1. Which services should be taken into account in the establishment of network features of the ISDN?

2. What are the network features needed to support these services? Which network features should be regarded as general throughout the ISDN, and which should be classed as service dependent for particular service applications?

Note: Among other network features, attention should be paid to charging so that adequate information could be made avilable for charging purposes.

3. For which services, if any, should a change of service on an established connection be envisaged? What are the implications and requirements of such a feature?

4. What kinds of leased paths will be required in the ISDN when it is in widespread operation?

Note 1: Services should be identified which will supplant existing leased line services.

Note 2: Consideration should be given to the use of semi-permanent connections, closed user group and hot-line features, remote switching units etc.

Point B. Network aspects

1. What are the principles in terms of network structure and systems architecture which define the ISDN and which form the basis for study of specific aspects?

2. Should layered protocols and functional layers be adopted for ISDN to form the basis of CCITT Recommendations? If so, what are the characteristics of this layering, and in which way is the concept of functional layers used with respect to sub-systems, such as, e.g., the signalling channels?

3. What are the implications of ISDN on numbering plans and service indicators for telephony and other services?

4. What methods of voice band encoding other than standard PCM (see also Question 7/XVIII) and what forms of digital speech interpolation can be considered in relation to the evolution of the ISDN?

Point C. Customer access

What are the principles in terms of network structure and systems architecture which define customer access to ISDN and which should form the basis of studies of related transmission, switching, signalling and interface aspects?

Point D. Interworking

What are the principles which should form the basis for detailed study of the interfaces interconnections and interworking between ISDN and service dedicated networks?

The following specific points should be included in the studies:

i) At what point in the connection should special processing for interworking be accomplished (e.g., in the originating or terminating country)?
ii) What networks should be given preference to complete connections in a transit call situation?
iii) What special problems arise from the use of ISDN to provide interconnections of particular services (e.g., according to X.21, etc.) via different networks, and what restrictions or restraints should be placed on services or networks when interworking (e.g., to accommodate accounting, timing and signalling, features)?
iv) What methods should be recommended for accessing one network from another?
v) How should conversions be accomplished (e.g., data to data, voice to data)?
vi) What arrangements or procedures are needed to accommodate the accounting function for a connection involving mixed networks?
vii) What influence would different national applications of service integration have on the international network with regard to interworking?

viii) What special problems arise from the use of ISDN to interconnect networks carrying services to existing standard terminal interfaces?

ix) What are the possibilities of application of service bits allocated in primary PCM and higher order digital systems in national and international digital networks?

Point E. Guidelines to facilitate evolution towards ISDN

Which strategy should be followed in order to facilitate and speed up the establishment of a worldwide ISDN?

Note: It should be taken into consideration that, in the introductory period, it will be necessary to establish an all-digital network mainly for the needs of "business subscribers" who represent only a small percentage of the overall number of subscribers but who orginate a substantial portion of the traffic. It may be useful to create a digital "overlay network" in each country and to interconnect these national networks by digital links.

APPENDIX C: OPEN SYSTEMS INTERCONNECTION

The purpose of the Open Systems Interconnection Reference Model "is to provide a common basis for the coordination of standards development for the purpose of systems interconnection, while allowing existing standards to be placed into perspective within the overall Reference Model" (ISO, 1982)

Use of the model permits an orderly process for 1) analyzing existing standards and 2) determining areas that need new standards.

C.1. The Reference Model

The OSI Reference Model has a layered structure that permits the application of standards to interconnect dissimilar end-systems. This is done by making architectural layers modular in a way that permits software development according to functional definitions. The reference model has seven layers chosen so that 1) any layer would not be too complex and 2) the number of layers would not become a problem in itself. Figure C-1 shows the layers with a brief description of functions within each layer.

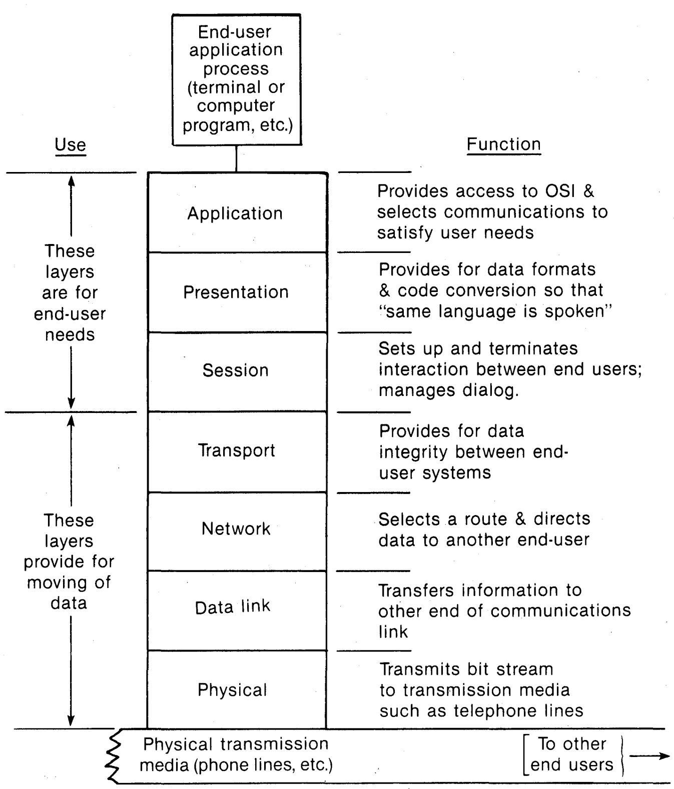


Figure C-1. Functional layering of the OSI reference model.

The functions that are listed are fulfilled by applicable standards. For example, RS-232-C would apply to the physical layer. Another standard is CCITT Recommendation X.25. It applies to the physical, data link, and network layers. The protocols associated with each standard reside in the terminals and nodes of a network.

Within the context of the reference model a number of terms should be noted. Interconnection standards encompass 1) "protocols," referring to a set of rules for communication between similar processes (or peer layers) such as actions between computers or terminals, and 2) "interfaces," or more appropriately, "interactions," referring to a set of rules for communication between dissimilar processes (or adjacent layers) such as between a person and a terminal, or a terminal and a network. The ultimate user of OSI is the "application process". It can vary from a simple keyboard program to a complex computer data base operation between end-users. The applications process serves user needs in Government and private industry. This includes Government information systems such as Social Security and Internal Revenue. Private industry includes electronic funds transfer (EFT) for banking and record keeping for insurance.

According to Folts (1981), the OSI reference model fits into the overall communications scheme as follows. The OSI users are application processes (AP's), "X" in end-system I and as "Y" in end-system II. Each is located within its own local system environment.

When an AP in one end-system wishes to communicate with an AP in a distant end-system, the interconnection is performed by the OSI Environment (OSIE). The local system manager (LSM) provides the control for invoking the OSIE functions to create the interconnection for the desired communications.

The AP's communicate through the application layer and the underlying layers along the path shown in Figure C-2. A peer protocol for each layer controls and coordinates the designated functions between communicating end systems. A message generated in one local system enters the OSIE through a window of the applications layer. After being processed by each of the seven layers, a formatted message traverses the transmission medium.

The interaction between the functional layers and the (LSM) is detailed in Figure C-3. The message (called a data unit) is appended with a control-header, containing information defined in a peer protocol, by each of the seven functional layers. The original message data unit, combined with the header of a specific layer, is viewed in the next layer as an integral data unit.

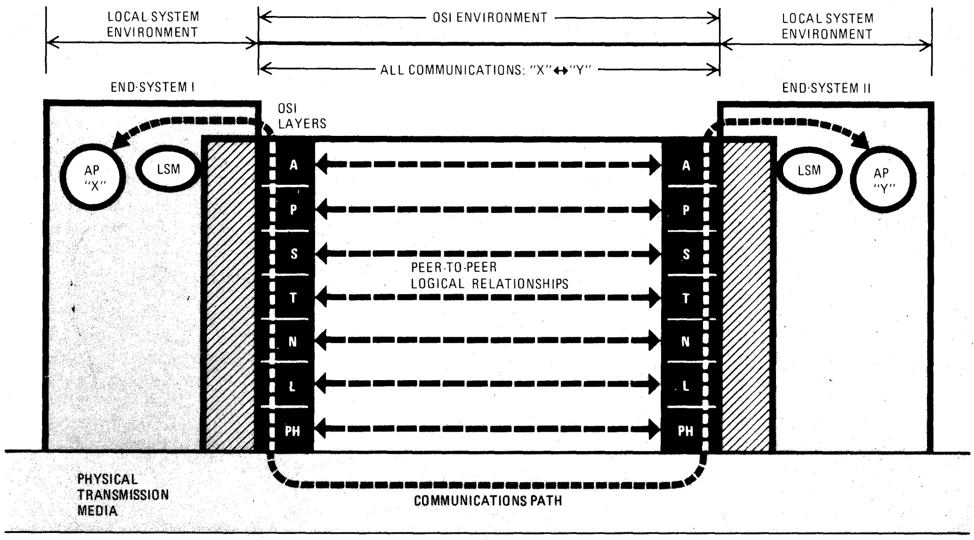


Figure C-2. Structured message flow (Folts, 1981).

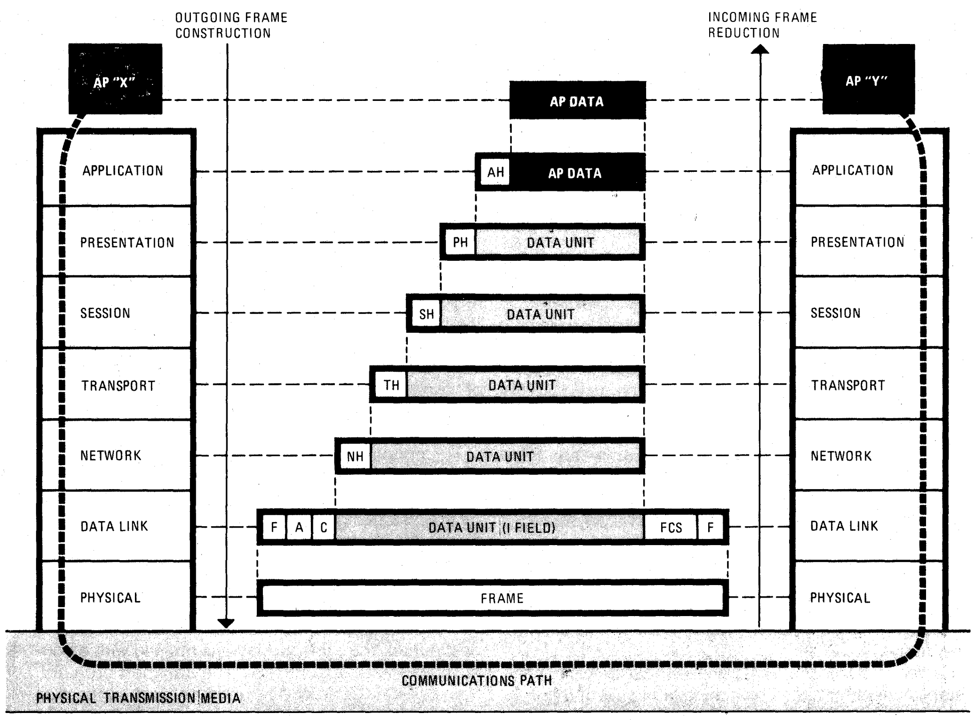


Figure C-3. Frame construction (Folts, 1981).

This is an example of basic OSI reference model communication. Ordinarily, there might be several intermediate nodes, with communication switches between end points. Various lower level layers may or may not be invoked as the data traverses the communications path at the intermediate node.

C.2. References

Folts, H. C. (1981), Coming of age: a long awaited standard for heterogeneous nets, Data Communications 10, No. 1, Jan.

ISO (1982), Information processing systems - open systems interconnection - basic reference model, Draft International Standard (DIS) 7498.

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The report is a primer on Integrated Services Digital Networks (ISDN's). The ISDN concept is believed by many to be the communication means for the future information age. A number of national ISDN's interconnected together can provide a high-performance, multiservice, digital network for global communications.

This primer on ISDN is for persons unfamiliar with telecommunications but who wish to know about this important concept. The report explains the developments in telecommunications technology--from analog to digital--that make possible the efficiencies and economies of an ISDN or ISDN's. Also addressed are technical and policy considerations: Why is an ISDN needed? How is it expected to evolve? What problems will it cause? Who is working on them?

16. Key Words *(Alphabetical order, separated by semicolons)*

data communication; digital communication; integrated services digital network; ISDN; telecommunications

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