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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 165

TRANSPORTATION TELECOMMUNICATIONS

TRANSPORTATION RESEARCH BOARD
National Research Council

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RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. OCTOBER 1990

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to the National Research Council is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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NCHRP SYNTHESIS 165

Project 20-5 FY 1987 (Topic 19-10)
ISSN 0547-5570
ISBN 0-309-04913-X
Library of Congress Catalog Card No. 90-71055

Price $10.00

Subject Area
Administration

Mode
Highway Transportation

NOTICE

The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical committee according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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The Transportation Research Board evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America

PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of interest to administrators, operating personnel, and others interested in the management and operation of telecommunication systems in transportation agencies. Information is provided on the fundamentals of telecommunications, types of systems available, current uses in state DOTs, and implementation procedures and alternatives.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

Most departments of transportation have telephone and radio systems in use for communications with their own personnel and with the public. This report of the Transportation Research Board describes those systems as well as other telecommunications options that are in use by transportation agencies or are available for their use.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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ACKNOWLEDGMENTS

This synthesis was completed by the Transportation Research Board under the supervision of Robert E. Skinner, Jr., Director for Special Projects. The Principal Investigator responsible for conduct of the synthesis was Herbert A. Pennock, Special Projects Engineer. This synthesis was edited by Judith Klein.

Special appreciation is expressed to Philip J. Tarnoff, President, Farradyne Systems, Inc., and Ted Pugh, Vice President, Farradyne Systems, Inc., who were responsible for the collection of the data and the preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Donald Drew, Director of Operations, D19, Texas State Department of Highways and Public Transportation; Robert Ellington, Highway Engineer, Federal Highway Administration; Michael L. Halladay, Highway Safety Specialist, Federal Highway Administration; Milton Harmelink, Director, Transportation Technology and Energy, Ontario Ministry of Transportation; Wesley Lum, Chief Systems Development, Division of Traffic Operations, California Department of Transportation; and Theodore Todorovich, Information Technology Center Manager, Washington State Department of Transportation.

Kenneth E. Cook, Transportation Economist, Transportation Research Board, assisted the NCHRP Project 20-5 Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

TRANSPORTATION TELECOMMUNICATIONS

SUMMARY

A wide variety of telecommunications options are now available to transportation agencies. Moreover, the industry is undergoing rapid change as a result of technological developments and industry restructuring. These changes have broadened the range of equipment and services available as well as implementation and operating choices.

Telecommunications is the transmission of information using an electromagnetic medium. In its simplest form it includes a transmitter, a transmission medium, and a receiver. However, in current usage, telecommunications includes personal computers, video conferencing, electronic mail, voice mail, and specialized data-retrieval services in addition to the traditional telephone and radio. Thus the transmitter can be the mouthpiece of a telephone, the output of a computer terminal, etc.; the medium that carries the information from the transmitter to the receiver can be copper wires, fiber optics, radio waves, etc.; and the receiver can be the earpiece of a telephone, the computer processor and display, etc.

The numerous alternatives for transmission systems include copper twisted-pair wires, coaxial cable, fiber optic cable, radio (low or high frequency or microwave), telecommunications service providers (local or long-distance telephone companies, cellular telephone), packet-switched data networks, satellite services, and leased facilities (telephone and cable television). These may be used for telephone systems, local area networks (LANs), wide area networks, videotext, or teletext.

Applications of telecommunications in transportation agencies include traffic surveillance and control, which involves control of field equipment such as closed-circuit television, traffic signals, changeable-message signs, and traffic detectors; office automation; computer-aided design and drafting (CADD); and motorist information systems. Telephone and radio communication with remote units and with the public has been used for many years, including microwave transmission for administration and operations. Newer technologies can be used for various transportation functions; for example, a leased T1 telephone channel can support as many as 416 traffic controllers at eight signals per line. Cable television systems have been used for traffic surveillance and control, but there may be difficulties with franchise agreements and transmission noise. The integrated services digital network is being tested in several locations, including communications between Arizona DOT headquarters and the motor vehicle building. Integrated services digital network-equipped terminals are being used for data entry for driver's license and vehicle registration information.

A voice processing (voice mail) system is being used in one city to distribute traffic congestion information; callers can get recorded information on specific geographic areas using a touch-tone telephone. The California Department of Transportation is implementing a teletext system in Los Angeles that will provide traffic information to motorists. The system will use data from the existing surveillance and control system as well as from the highway patrol and construction and maintenance schedules.

A survey of state and city transportation agencies showed that most used Centrex and private branch exchange telephone service and equipment. Only about 20 percent used voice mail. Many are using LANs for office automation, sharing of resources, data base management, CADD, terminal emulation, file transfers, communications,

and software sharing. All but a few agencies use radio for mobile communications, especially for highway maintenance. Microwave systems were used by 75 percent of the states and two cities. Cellular telephone was being used for a number of applications other than mobile communications, including control of portable signs, data transmission for dispatching, control of permanent variable-message signs, and administrative purposes. Value added networks are being used by some agencies, and most use some form of wide area telephone service.

As the traffic congestion increases on the nation's highway system and transportation agencies find themselves unable to construct new facilities, there will be an increase in the use of traffic surveillance and control systems. These systems will require an extensive communications network. Although transportation agencies are relatively progressive users of telecommunications systems, they will need to evaluate the impacts of the growth in area-wide communication to identify telecommunication facilities that are dedicated to transportation but may be installed for multiple purposes.

CHAPTER ONE

INTRODUCTION

REPORT OVERVIEW

The telecommunications industry supports a broad and rapidly developing technology, equivalent to the transportation industry in its size and scope. This industry is currently undergoing rapid change as a result of technological developments and industry restructuring caused by the AT&T divestiture of the local operating telephone companies. The telecommunications field is also experiencing explosive growth because of increases in data transmission caused in part by the proliferation of personal computers within the business community.

The telecommunications and transportation fields are tightly coupled. In some areas, such as video conferencing, facsimile, and electronic mail, telecommunications represents an alternative to the physical transportation of people and mail. Telecommunications services are also used to support many of the activities of both the public and private sectors of the transportation community. Public-sector applications include office communications (both voice and data), mobile radio and cellular telephone communications with field personnel, and communications with surveillance and control systems for both freeway and traffic signal applications. In addition, many special applications exist, such as automatic vehicle location (AVL) and automatic vehicle identification (AVI).

Technological and regulatory changes occurring in the telecommunications industry are making it increasingly difficult for managers to implement and operate effective systems. Until recently, these systems consisted of equipment installed by the local operating telephone company (telco). The telco would wire the building, install the necessary equipment, and provide continuing maintenance. As a result of regulatory changes, these turnkey services are no longer readily available.

Technological change has broadened the range of telecommunications equipment and services to include personal computers, video conferencing equipment, electronic mail, voice mail, and specialized data-retrieval services. Although it is not necessary to be an engineer to manage a telecommunications system, it is helpful to understand the basic operating principles of the system. Such an understanding will increase the manager's ability to deal with suppliers and technical staff members. Awareness of these principles will also be helpful in understanding the interaction between various elements of the system and recognizing when expert assistance may be required. This will reduce the possibility of purchasing equipment or services that are incompatible with other elements of an existing or proposed system.

A knowledge of the changing structure of the telecommunications industry is also important. The Bell System divestiture has had a significant impact on the telecommunications industry. The regulatory and institutional changes among major telecommunication and computer system corporations will have a lasting effect on the industry's structure and future applications of telecommunications in the transportation industry.

This synthesis is intended to familiarize members within the public sector of the transportation community with both the technological and institutional aspects of this rapidly developing technology. It will also provide a basic understanding of the procedures required for the analysis, design, implementation, operations, and maintenance of telecommunications systems.

Objective

The objective of this synthesis is to provide mid-level managers within the public sector with a broad understanding of the telecommunications field and its application to the transportation community. This synthesis spans the range of technical, management, and legal issues associated with its use. A secondary, but equally important, objective is to provide an understanding of the opportunities that exist within the telecommunications field to develop systems applications that enhance the effectiveness of public-sector administrative, engineering, and traffic control activities.

Scope

The synthesis addresses the role of telecommunications within the public sector of the transportation community. It covers the entire range of telecommunications facilities including telephone services, value added networks, satellite services, microwave systems, cellular radio services, cable television services, and dedicated agency-owned transmission facilities such as twisted-pair cable, coaxial cable, fiber optic cable, and radio.

The synthesis also covers a broad range of agency applications. It includes telecommunications usage in support of office automation, such as word processing, engineering functions, management information systems, computer-aided design and drafting (CADD) systems, and telephone systems. It also includes surveillance and control applications for traffic signal systems, freeway control systems, AVL, AVI, motorist information systems, and traffic management systems. Subsets of these systems such as traffic counting are also included.

The scope of this synthesis is restricted to overview discussions of telecommunications technology. Although the technical discussions included in the synthesis are adequate to provide an understanding of the relative capabilities of available technological alternatives, they do not provide the engineering details essential for preparation of detailed system designs. A Bibliography is provided that contains this information. A glossary of terms is provided in Appendix A.

THE CHANGING ROLE OF TELECOMMUNICATIONS IN TRANSPORTATION

Telecommunications technology has always had a significant impact on the transportation industry. This technology is used throughout the transportation industry to support normal business communications, to serve its unique requirements for communications with mobile units, and for surveillance and control applications. As new telecommunications services and equipment have become available, the transportation industry has moved to take greater advantage of their enhanced capabilities. Continuing change of this nature is anticipated for the future. It is also important to recognize that telecommunications offers the opportunity to enhance the efficiency of an existing transportation system, both through the introduction of new systems (such as motorist information systems) that require extensive telecommunications facilities and through the use of telecommunications services as an alternative to transportation.

Existing Applications

A review of the manner in which transportation agencies conduct their business reveals the degree to which telecommunications technology has become an essential element of their operations. Today it is commonplace for telephone and mobile radio communications to be used for communication with remote units in other agencies and with the public. It is also common for telecommunications to be used for the control of field equipment such as the closed-circuit television (CCTV), traffic signals, changeable-message signs, and traffic detectors used in surveillance and control systems. This technology is also being used for applications that did not exist 10 years ago, such as office automation, computer-aided design (CAD), and motorist information systems.

Reliance on this broad usage of telecommunications technology requires the development of staff expertise within agencies that have traditionally emphasized the civil engineering skills associated with the highway construction industry. For example, the telecommunications applications listed above make use of the entire spectrum of transmission media including twisted-pair, coaxial, and fiber optic cable; cellular telephone; radio; and satellite communications. All of these media are used (or are likely to be used) for both voice and data communications. Many of these media are used for transmission of video information. Staff members responsible for the design, procurement, operation, and maintenance of these systems must be thoroughly familiar with all aspects of telecommunications technology.

Changes in the Agency Workplace

Local Area Networks

The changing impact of telecommunications in the workplace is most dramatically demonstrated through the current use of office automation systems supported by local area networks (LANs) within the transportation community. A survey of telecommunications usage conducted in support of this synthesis revealed that state departments of transportation have installed LANs with a total of more than 2700 workstations. Because this is a relatively new technology, it is likely that the majority of these installations have occurred within the past five years. Only 2 of the 27 states responding to this survey indicated that they do not currently have a LAN.

The manner in which these LANs are being used is representative of the impact of telecommunications on the workplace. The respondents indicated that their systems are being used for:

- office automation—word processing, spreadsheets, electronic mail, etc.,
- resource sharing—common access to devices such as printers, disks, etc.,
- data base management—maintaining data bases of personnel, contracts, inventories of equipment, etc.,
- common access to computer-aided design systems,
- terminal emulation for access to mini- and mainframe computers,
- file transfers between workstations and mini- or mainframe computers,
- communications with remote workstations and computers, and
- automatic backup of agency files.

This list is likely to grow to include more extensive use of LANs for support of engineering functions, access to remote data bases, facsimile transfer, on-line storage and retrieval of scanned documents, preparation of presentation-quality graphics, electronic (desktop) publishing, and interfaces with surveillance and control systems.

The increased use of LANs will lead to further growth in the need for wide area telecommunications in order to permit increased exchanges of data between LANs and with remote workstations. For example, developments currently under way will permit field maintenance technicians to remotely access central data bases for maintenance and inventory information using a portable laptop personal computer (PC) carried in their maintenance vehicles.

Thus the PC and its supporting telecommunications system is rapidly becoming as essential as the telephone in the transportation agency workplace.

Cellular Telephone

Another relatively new technology being adopted for use by the transportation industry is the cellular telephone. Fourteen of the 27 respondents indicated that they are using cellular telephones for a variety of applications including:

- communications with hazardous-materials teams,
- control of remote equipment,
- communications with traffic signal repair crews,
- communications with motorist call boxes,
- transmission of dispatch data,
- control of portable changeable-message signs, and

- communications with management and other staff members.

It is anticipated that cellular telephone, like LAN technology, will see increased usage in the future.

THE PUBLIC WORKPLACE

One of the dominant themes that has evolved in recent years among many transportation visionaries is the substitution of telecommunications for travel. A number of authors have written about the potential for telecommuting (the substitution of computer and telecommunications technology for the journey to work) that could occur in the future. If the alternative is to work at home, a number of management concerns, such as the distractions of the home environment and the inability to interact with peers, may limit telecommuting. However, with the rapid growth of office automation and the evolution of the service industry as a dominant employer, many employees could benefit from the establishment of neighborhood or other local work centers in place of major business facilities typically located in areas with high concentrations of other businesses.

This change in travel patterns and work locations would only be practical if supported by a broad spectrum of telecommunications services such as video conferencing, computer conferencing, and facsimile systems. However, the rapid emergence of digital transmission on fiber optic media plus the impetus of competition in the long-haul trunk carrier system is steadily decreasing the costs for these types of services.

Although not specifically addressed by this synthesis, there is a definite relationship between the use of telecommunications services and the relative convenience and cost of both local and long-distance travel. At the present time, the displacement of travel by telecommunications is negligible but growing. Telecommunications is also being used by handicapped individuals, for whom travel is difficult or impossible.

A much more likely scenario is the impact of urban land use and of the rescheduling of work activities on travel patterns that will result from the use of telecommunications as a substitute for travel. Transportation departments with responsibility for traffic operations in congested areas should be aware of the growing use of telecommunications services as an alternative to travel. Use of telecommunications capabilities provides users with information mobility as an alternative to personal mobility. This may alter traditional travel patterns and provide planners with opportunities to modify highway construction programs.

CHANGES IN TRAFFIC SURVEILLANCE AND CONTROL SYSTEMS

One of the most visible uses of telecommunications by local transportation agencies is traffic surveillance and control applications. Although it is possible to lease telecommunications services for the support of these applications, the majority of agencies have elected to install their own systems in order to avoid the loss of technical and fiscal control often associated with the use of leased facilities. Communications facilities account for nearly 80 percent of the total system cost for the majority of traffic surveillance and control systems installed today.

The magnitude of these costs suggests that alternative forms of telecommunications should be explored during the system design. However, many agencies are reluctant to explore these alternatives in order to avoid the potential problems associated with the use of a technology that is new to the field of traffic control, even though it might be a mature telecommunications product. As a result, the majority of systems are installed using telephone-type communications technology that has been in use for the past 20 years.

In spite of this resistance to change, some progress is being made. Systems are being installed, on a limited basis, that use fiber optics and digital radio communications. Some suppliers are offering distribution systems in which communications requirements are minimized through the use of the processing capabilities of the remote field equipment. It is anticipated that the successful implementation of these systems will encourage further advances. However, this success requires the availability of knowledgeable personnel for their design, installation, and maintenance.

CHAPTER TWO

TELECOMMUNICATIONS FUNDAMENTALS

TELECOMMUNICATIONS SYSTEMS OVERVIEW

The definition of communications is usually expressed as the exchange of information between a sender and a receiver. Telecommunications is commonly defined as the transmission of information using an electromagnetic medium. The transmission might include data, pictures, spoken words, etc. Thus, telecommunications is a subset of the broader field of communications. This synthesis will use the term "telecommunications" when discussing transmission of information electromagnetically. All types of telecommunications are considered electromagnetic transmission, including transmission using metallic cable, fiber optics, and radio.

Basic Components of a Telecommunications System

In its simplest form, a telecommunications system includes a transmitter, transmission medium, and receiver. The transmitter is the point where information is generated and transformed into an electrical or optical signal compatible with the transmission medium. The transmitter can be the output of a computer terminal or the mouthpiece of a telephone. The medium is the material that carries the information from the transmitter to the receiver. The receiver is the device attached to the transmission medium for the purpose of translating the transmitted information into a recognizable form. The receiver of a telephone is the earpiece; the receiver of a computer terminal is the processor and operator display. In the telephone, the process of receiving and translating the information into a useful form is performed by a single device—the earpiece of the telephone (see Figure 1).

Other types of systems require two devices, one to receive the information and one to translate it into a format that permits subsequent processing. Computer terminals using interface equipment known as "modems" provide the translation function.

The utility of a communications system is significantly increased with the addition of a switching device that will permit a user to select the individual or equipment with which communications is desired (see Figure 2). The switch may be an identifiable item of equipment. Alternatively, the effects of switching can be approximated through a set of rules known as "protocols" that define the times a user can transmit information and information can be received. These techniques are often used for transmission of computer data.

Telephone Systems

The components of a typical telephone system include the:

- *Telephone Set* Also known as "station equipment," the telephone set is the traditional telephone equipment that is connected to a switch or directly to incoming telephone lines.
- *Switch Equipment* This is the distribution point for routing incoming, outgoing, and internal calls. The switch may be located on the customer's premises or at the telephone company's central office. Two categories of telephone equipment are available, key systems or private branch exchange (PBX) switches. Hybrid systems incorporating combinations of the two are also available. The differences between these two types of switches are described in Chapter 3.
- *Trunk Lines* The telephone equipment located at the customer's premises is connected to the local telephone operating company's (LOC) central office using telephone trunk lines. A trunk line is a transmission medium that may be capable of carrying several calls simultaneously. The number of trunks and

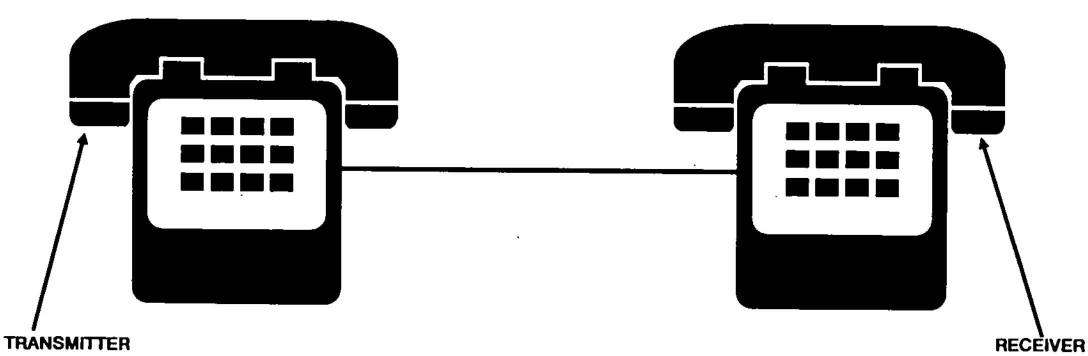

FIGURE 1 Telephone earpiece.

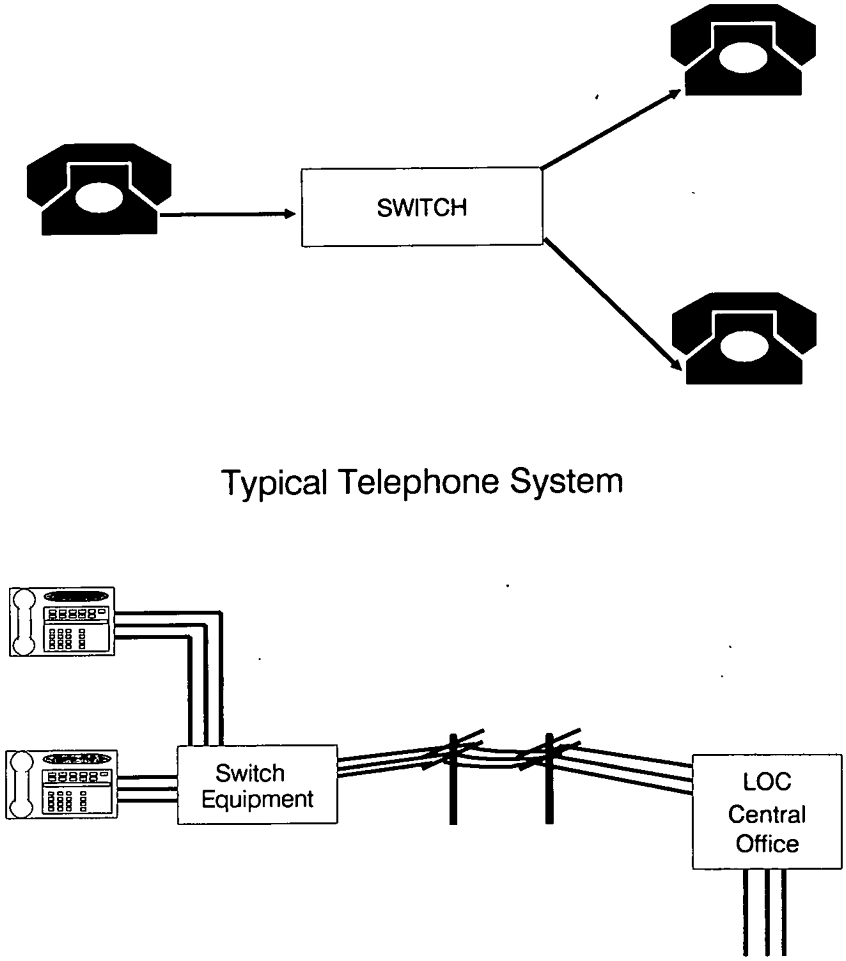

FIGURE 2 Switching device.

their capacity determines the total number of calls that can be made simultaneously between the premises and the outside world.

- *Central Office* The central office provides switching functions for a number of commercial and residential customers in a given local calling area. It also provides connection with trunks for calls outside this area. In some cases, central office switching services can be used to provide off-premises switching services for businesses. This service is known as Centrex.

A wide variety of telephone system components are also available to supplement the basic features of the telephone system. These components include equipment such as automatic call distributors (ACD), used for handling large numbers of incoming calls by several service operators. Automatic call distributor equipment might be used by mass-transit agencies for providing bus routes and schedule information to transit customers. A variety of voice messaging equipment is available for recording messages during periods of unattended operation. This equipment ranges from the basic telephone answering machine to sophisticated voice mail systems. Additional components include facsimile machines, attendant consoles, maintenance consoles, paging systems, and data terminal interfaces. The selection of this equipment is determined by agency needs and anticipated operational procedures.

In addition to these basic telephone system components, there are numerous other types of equipment used to support the routing and transmission of telephone system communications. Enhanced transmission quality is provided by devices such as amplifiers that increase the amplitude of the transmitted signal for long-distance communications. Various types of multiplexers are used to combine multiple communications paths into a single path such as a trunk. The selection of this equipment is a basic telephone system engineering function performed by the service provider. This engineering activity is an important aspect of the system design in that it can have a significant impact on the quality and cost of the telephone system service.

Many components of the telephone system are unique to the type of transmission medium being used. For example, if the medium is twisted-pair cable, loading coils may be used to alter the electrical properties of the transmission lines in order to minimize distortion at the destination. If the transmission medium is microwave, the telephone system will include microwave radio transmitters, antennas, and towers. These components are described later in this chapter.

Local Area Networks

By definition, a LAN is any telecommunications system that serves a limited geographic area. Typically, a LAN will serve a single building or campus. The term "network" is a reference to the fact that multiple users are interconnected.

Technically, because a building telephone system satisfies this definition, it can be considered a LAN. However, common usage generally applies this terminology to a system of digital computers. Telephone systems are not usually designated local area networks.

It is difficult to provide a general description of a LAN because they are installed in many different configurations and support the exchange of data between users in many ways. Although the simplest types of LANs are designed to permit exchange of information between computers or computer-like devices, such as word processors, more complex forms of LANs support transmission of video and audio information as well.

The components of a LAN (as distinguished from a telephone system) include the user's equipment (designated workstations in this synthesis), supporting processors, and peripheral equipment.

User workstations are the most visible component of the local area network. The workstations may be conventional PCs, intelligent workstations, and terminals. All of these devices perform the common functions of:

- displaying output to the user, usually using a device such as a cathode ray tube (CRT), although other types of outputs such as plasma and liquid crystal diode (LCD) displays are also used,
- receiving data from the user, usually entered from a keyboard, although a mouse, graphics tablet, or bar code reader may also be used,
- interfacing with the communications medium, a function that includes formatting and transmitting data at the appropriate times and rates, and
- processing the data, the degree of which, performed by the workstation, is a function of the LAN design, the capabilities of the workstation, and the type of software used.

Supporting processors, known as servers, are connected to the LAN to perform functions that cannot be provided by the individual workstations. These processors are typically used to execute large programs that exceed the workstation capacities, provide centralized data base storage and retrieval functions (file servers), interface with external communications facilities (communications servers), and interface with peripheral devices. The capacity of the supporting processors can vary from that of a PC to a large mainframe computer. The required capacity is a function of the design of the local area network, the number of users sharing the supporting processor, and the functions being performed.

A diverse set of peripheral devices are available for connection to the LAN. These devices include printers, plotters, telex and fax machines, modems, optical character readers, scanners, and even copiers. Local area networks capable of supporting video and voice transmission may also be connected with television equipment and telephone systems.

Larger LANs accommodating hundreds or thousands of users include the installation of a special processor known as the network control station. This processor continuously monitors LAN communications traffic to accumulate statistics on workstation usage, transmission quality, and network configuration. The network control station provides many of the monitoring functions performed by the switch and maintenance console of the telephone system.

The LAN, like the telephone system, may also include a number of components required to support the transmission of information. These devices include hubs, taps, and splitters, which are used to interconnect the LAN cables and to connect the LAN cables with computer systems and workstations. Amplifiers and other devices known as repeaters may also be required to regenerate the LAN signal for longer-distance transmission. The selection of this equipment is an engineering function that should be performed by the system provider. Figure 3 provides a diagram of a typical baseband LAN topology.

Wide Area Networks

Wide area data-communications networks are used throughout the transportation community for a variety of applications including communications between remote computers, access from remote data terminals, and control of field devices associated with surveillance and control applications. These networks include dedicated data transmission facilities, in which devices are permanently connected to each other, and switched facilities, in which devices access each other using a switching mechanism that performs functions similar to those of a telephone switch. Dedicated facilities are typically designed to meet the specific requirements of the system and to operate using the data formats, access rules, and addressing procedures defined by the system supplier. The alternatives for the design of dedicated networks are discussed in Chapters 4 and 5.

Wide area switched data communications are typically acquired as a telecommunications service such as Telenex. Unless these capabilities are provided as part of a telephone system, wide area switched communications systems are implemented using a technique known as packet switching. A packet is essentially an envelope that holds data until it is opened at its destination. A typical message consists of one or many packets. Multiple packet messages require sequential numbering so that the packets are assembled at their destination in the correct order. A typical packet is up to 2048 characters (bytes) in length and contains a packet header, the packet data, and a packet trailer. The header contains the information required for control of the packet, including its origin, destination, and pertinent control information. The node (packet switch) serving the transmitting station checks a mapping table to determine where to route the packet and adds the routing, control, and error checking information required to successfully transmit the packet through the network. The network transmits the packets from node to node to the desired destination.

The route followed by a given packet is determined based on network loading between the origin and the destination. As a result, there is no guarantee that successive packets that make up a single message will necessarily follow the same route or arrive in the order they were transmitted. The assembly of packets in the correct order is performed at the final node of the network.

The interface between the user's data equipment and the packet network is provided by either a computer front-end proc-

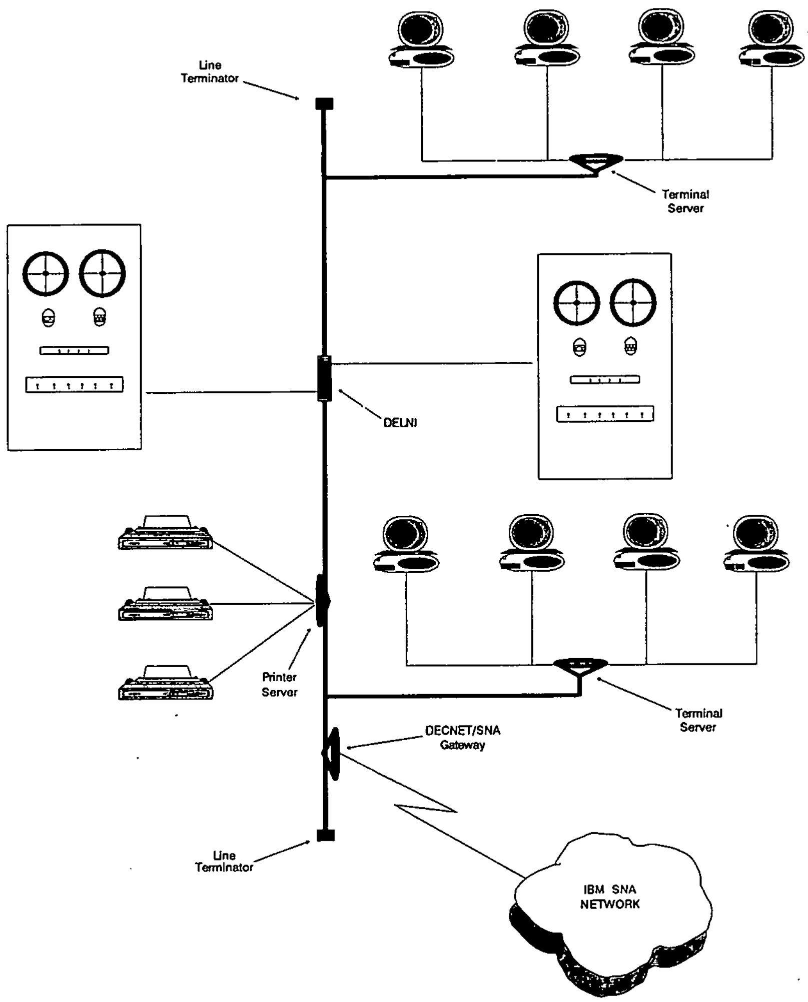

FIGURE 3 Representative local area network.

essor or a packet assembler/disassembler (PAD). This equipment organizes the transmitted data into packets, inserts the desired header information, and inserts the packets into the network. The PAD at the receiving end performs the reverse functions, so that the presence of the network and the packet switching process is essentially invisible to the terminal equipment.

Other digital telecommunications devices such as multiplexers and concentrators are installed in packet networks to make efficient use of the available transmission facilities. These devices perform the function of combining multiple sets of low-speed communications into a single high-speed data stream. A diagram of a typical large packet network is presented in Figure 4.

Transmission

A transmission medium is required to support the movement of intelligence from one location to another. Telecommunications transmission media were first required with the development of the telegraph and telephone systems. These early systems were exclusively supported by the use of wire as the transmission medium. It is interesting to note that telegraph transmission was a crude form of digital transmission in that it relied on the use of a binary (off/on) form of transmission, whereas telephone (speech) transmission was based on analog transmission.

Before discussing the characteristics of different communication media, it is important to understand the relevant electrical concepts underlying their performance and capabilities.

Analog Transmission

Analog transmission occurs when a continuous varying voltage level is transmitted in which some property of the voltage level, such as its magnitude or its rate of change, is analogous to the information being transmitted. The voltage level may be used to represent the human voice in telephone transmission in that the voltage is proportional (analogous) to the intensity of the sound waves.

Alternatively, analog transmission can occur as an alternating voltage. The magnitude of the amplitude of the alternating voltage can be made proportional to the value (volume level) of the information transmitted, such as the voice in telephone transmission. This is known as amplitude modulation and was also one

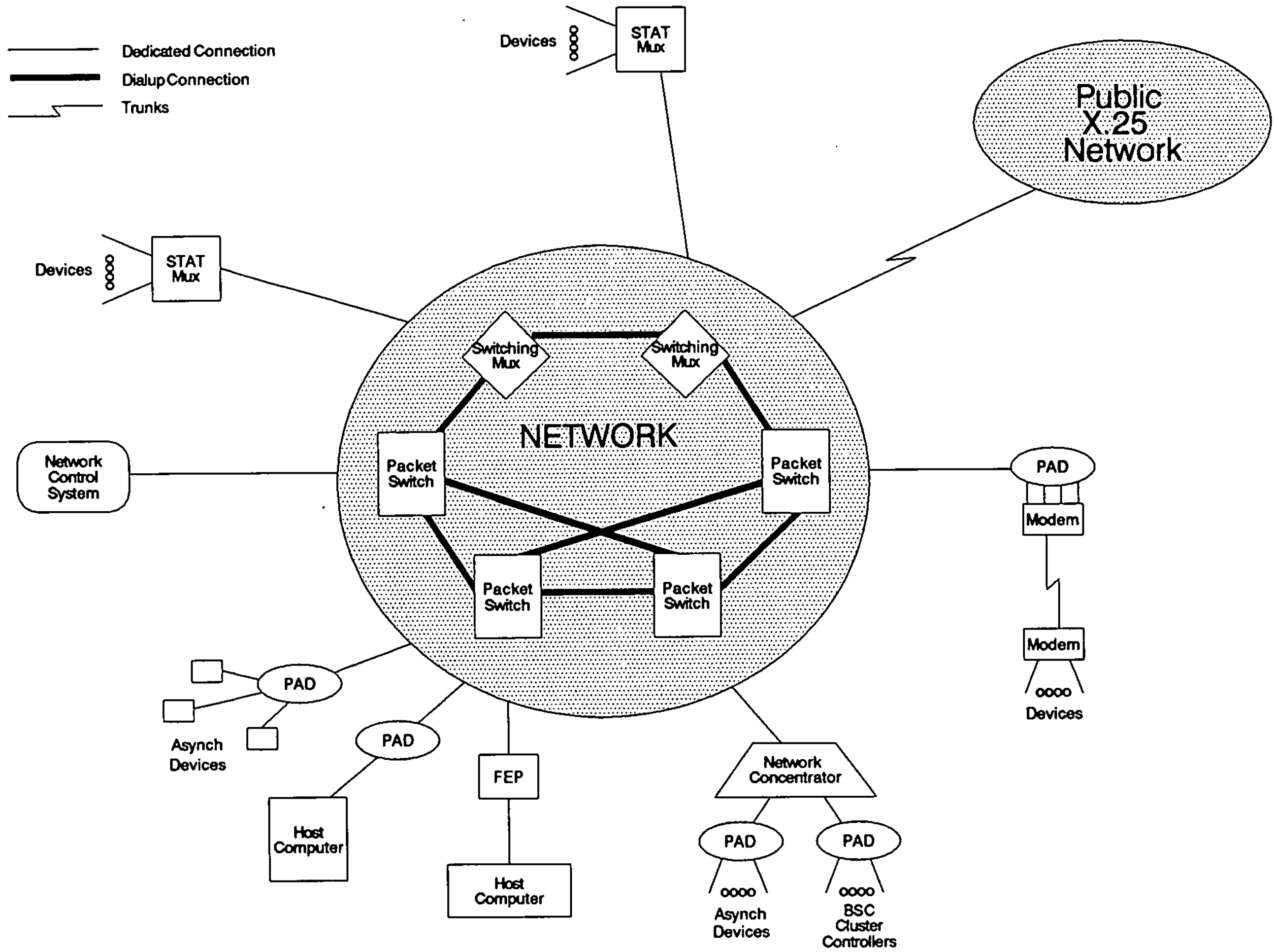

FIGURE 4 Overview of packet network switching.

of the first methods of transmitting voice signals by radio (see Figure 5).

The *rate* at which the voltage alternates is known as its frequency, which is measured in hertz (Hz). One hertz is equivalent to one complete sinusoidal cycle per second. Traffic control systems of the 1950s and 1960s used the transmitted frequency as the basis for communicating the desired signal cycle length to local controller equipment. The higher the frequency, the shorter the cycle length that was to be implemented.

Frequency modulation is usually used as an alternative to amplitude modulation. In this form of modulation (used in the FM radio), the frequency changes in proportion to the value of the information transmitted (see Figure 6). Frequency modulation is preferred over amplitude modulation because it is less sensitive to electromagnetic interference (noise).

A third form of modulation, known as phase modulation, is often used as an alternative to frequency modulation. Phase modulation transmits information by shifting the time at which the voltage peaks occur, such that the amount of shift is proportional to the information being transmitted. Phase modulation is often used for high-speed data transmission.

Digital Transmission

Digital transmission is a technique in which discrete values are applied to the transmission medium by the transmitting device. Usually only two levels are used, although some forms of digital transmission employ multiple levels. When two levels are used, one level is interpreted as a numerical zero or "off" state, and the other level is interpreted as a numerical one or an "on" state. These two values are transmitted sequentially by the transmitting device over the transmission medium to the receiving device, where they are processed in the manner defined by the application. In its original use for telegraphy, the interval between the "off" and "on" periods was interpreted as "dots" and "dashes" for the transmission of intelligence. Today these electrical impulses include:

- representation of a character (letter or number) to be displayed on the screen of a CRT,
- storage in a computer memory or on another storage device, such as a disk or tape,
- interpretation of a numerical value that is converted to a voltage connected to a telephone and heard by the user as spoken words, and
- conversion to a voltage level used to display a television picture.

The data rate (sometimes known as bit rate) defines the maximum speed at which digital data are transmitted. Each value of one or zero transmitted digitally is known as a "bit," and the

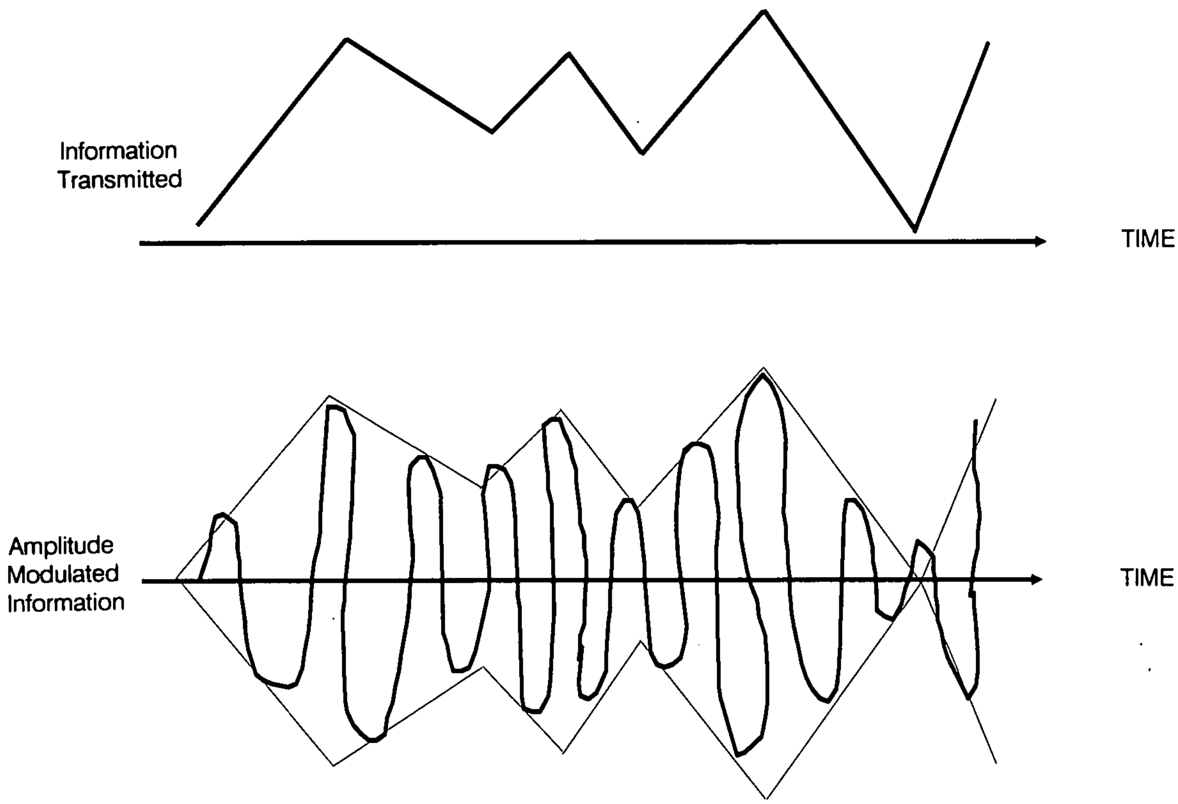

FIGURE 5 Amplitude modulation.

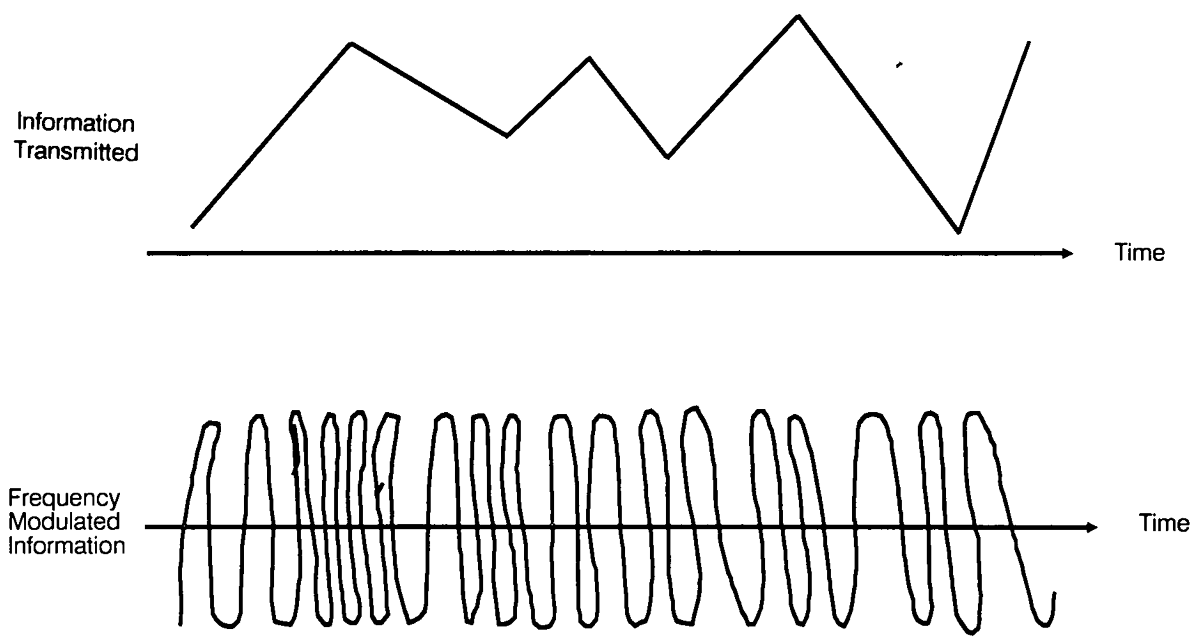

FIGURE 6 Frequency modulation.

data rate is expressed in bits per second (b/s). The maximum data rate that can be transmitted is a measure of the capacity of the digital telecommunications system (see Figure 7).

Bandwidth

One of the most important measures of a transmission system is its bandwidth—the range of frequencies that can reliably be transmitted. Reliable transmission of frequencies includes transmitting a given frequency without affecting either its amplitude or its phase with respect to other frequencies being transmitted. A change or shift in phase sequence is known as phase distortion. A good phase distortion characteristic is crucial to error-free transmission in digital systems.

Bandwidth is the basic measure of the capacity of the transmission system and is measured in hertz. Bandwidth is directly related to the amount of information that can be transmitted over a telecommunications facility and is controlled by the characteristics of the medium (wire or fiber optic cable) and the electronics equipment.

There is a relationship between the bandwidth of the communications facility and its maximum data rate. Because a digital pulse is a square wave form, it can be expressed as the sum of an infinite number of different frequencies. Thus, narrow bandwidths will tend to distort the pulse because they will produce undesirable changes in the amplitude and phase of the frequencies that are combined to produce its square wave form. For example, the intelligence in a signal with a transmission speed of 2000 b/s becomes unrecognizable when transmitted over a medium with a bandwidth of only 500 Hz. Special techniques must be employed for digital transmission at rates higher than twice the bandwidth of the system.

Simplex and Duplex Transmission

The terms simplex and duplex refer to the direction that information is transmitted on a telecommunications system. Simplex transmission uses a transmitter at one end of the transmission medium and a receiver at the other end. Commercial broadcast radio is an example of simplex communications. Duplex transmission occurs when information is transmitted simultaneously in both directions on the communications system. The telephone is an example of duplex transmission.

A modified version of duplex communication, known as "half-duplex," permits communication in both directions but not simultaneously. This form of communication is used instead of full duplex because it requires less transmission capacity. Transmission in a particular direction must cease before the medium is used for transmission in the opposite direction. However, a time delay is introduced between the two directions of flow to ensure that the transmission medium is ready to accept transmission in the other direction. This delay reduces the "effective" information capacity of the communications system. A mobile radio with a "push to talk" microphone is an example of half-duplex communications.

TRANSMISSION SYSTEM ALTERNATIVES

All telecommunications systems rely on some form of transmission medium to transport information from the transmitter to the receiver. The medium may be a physical device, such as metallic cable or glass (fiber optic) cable, or it might be electromagnetic radiation through free space associated with radio transmission. The characteristics of these various media are described in this section.

Copper Twisted-Pair

Twisted-pair cable, the most common form of cable used in a telephone system, consists of sets of two wires wrapped around each other. A single cable may include as many as 2600 twisted pairs of wires.

Twisted-pair cable provides an effective, low-cost form of transmission that is easy to splice and does not require special interface equipment. Note, however, that data cable splicing is not recommended.

The twisted-pair wire configuration is designed to minimize the effects of external interference, as well as interference between adjacent wire pairs in a cable (crosstalk). This is accomplished by the fact that the twisted conductors are physically

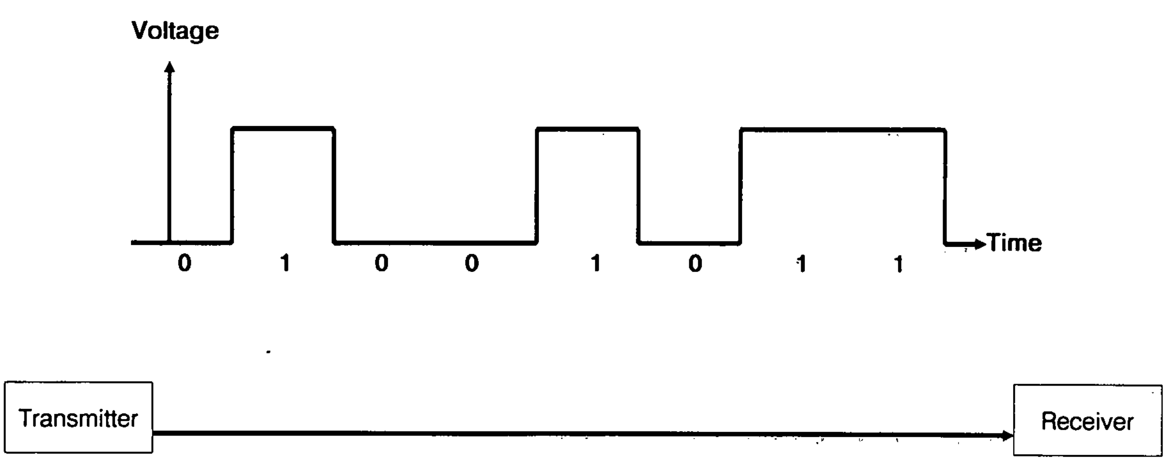

FIGURE 7 Digital data signal.

adjacent to each other, with the result that potential interference is produced (or received) in roughly equal but opposing magnitudes by both conductors of the wire pair.

The electrical characteristics of twisted-pair copper wire are very favorable to basic analog transmission; however, its tendency to attenuate high-frequency electrical signals limits its ability to transmit digital information at very high data rates. This bandwidth limitation has also prevented the use of twisted pair for transmission of live television images, although recent developments permit the transmission of slow-scan television. It should be noted, however, that prototype equipment is available for the transmission of full-motion television over twisted-pair copper wire.

Coaxial Cable

Because of its physical structure, coaxial cable (coax) is more immune to electromagnetic interference and has a much higher bandwidth than twisted-pair cable. Because of its high bandwidth, coaxial cable can be used for transmission of video signals (cable television using coaxial cable can transmit as many as 75 independent video signals) and for the transmission of digital data at very high rates.

Coaxial cable can be described in terms of a transmission line consisting of an unbalanced pair made up of an inner conductor surrounded by an outer conductor, which is held in a concentric configuration by a dielectric that separates the two conductors. The dielectric can be of many different types, such as solid polyethylene or polyvinyl chloride, foam, Spirafil, or an inert gas. When gas is used, the center conductor is kept in place by spacers or disks. The cable is essentially a set of two concentric circles that share the same axis, hence the name.

Coaxial cable, in all its forms, cannot be spliced together by the manual strip-and-twist method. Like twisted-pair wiring, it can be spliced using press-fit connectors that clamp over the end of the wires and are then screwed together. A number of alternative connector and splicing arrangements have been developed for inserting taps at midpoints in the cable and for terminating cable runs. However, the inherently heavier nature of the cable, and the importance of conductor alignment, make the coaxial cable much more difficult to splice.

Until recently, coaxial cable has served as the most popular broadband telecommunications medium. Telephone systems use coaxial cable as a transmission medium with the capability of transmitting from 120 to 10,800 voice channels. Community antenna television (CATV) systems use coaxial cables for transmission bandwidths in the order of 450 million hertz (MHz), which is adequate for transmission of 75 channels.

The technique of using a coaxial cable (or another broadband transmission facility such as fiber optic cable or microwave) for simultaneous transmission of multiple television channels is known as frequency division multiplexing. This technique assigns each channel a different center frequency with a 6 MHz frequency band around this center frequency. The television channels are simultaneously transmitted over the same communications medium within their own frequency bands.

Coaxial cables are widely used for computer systems and data-communication transmission applications. The bandwidth of this cable permits theoretical data transmission rates as high as 700 million bits per second (Mb/s). These rates are more favorable than typical twisted-pair rates that are limited to less than 24 Mb/s for short distances.

Fiber Optic Cable

Communications using light as a signal carrier and optical fibers as a transmission medium are termed optical fiber communications. In an optical fiber communication system, voice, video, or data are converted to a coded pulse stream of light using a suitable light source. This pulse stream is carried by optical fibers to a regenerating or receiving station. At the final receiving station the light pulses are converted to electric signals, decoded, and converted into the form of the original information. Optical fiber communications are currently used for telecommunications, data communications, military applications, industrial controls, and medical applications.

A lightwave communication system consists of a transmitter, a transmission medium, and a receiver. The transmitter converts the coded electronic signal (voice, video, or data) to the light signal, which is then carried by the transmission medium (an optical fiber cable) to either a repeater or the receiver. At the receiving end the signal is detected, converted to electrical pulses, and decoded to the proper output.

Since its inauguration, approximately 10 years ago, fiber optic technology has begun to support diverse user applications and realize substantial use in the telecommunications industry. Telecommunication common carriers currently are the dominant users of fiber optic technology through the development of fiber transmission services and installation of numerous fiber backbone circuits. However, communications equipment manufacturers are rapidly developing fiber products that serve a variety of applications. Users are becoming more aware of how fiber offers a solution to problems that were unsolvable or ineffective with other transmission methods. Some examples are:

- Fiber is used to support the physical isolation of printers and tape and disk drives from mainframes so as to place them where they are most effective without concern for possible electrical interference.
- Fiber is used to multiplex high-speed data on point-to-point or multi-point networks. Fiber modems and multiplexers can be used for creation of networks with large distances between field equipment.
- Fiber supports campus backbones to interconnect conventional LANs, as well as devices with high data transfer rates, such as host computers, CAD/computer-aided manufacturing equipment, and peripherals. The technology is also used for repeaters and cabling to extend nodal distances in LANs.

The concept of fiber optic communication is a simple one. Transmission is performed using a tubular glass fiber rather than a metallic conductor. The transmission of intelligent signals is performed by means of light impulses that are transmitted into a glass fiber structure ("waveguide" or "lightguide") that confines and guides a beam of light between points of origin and destination. Fiber optic transmission principles are complex, involving light wavelength, phasing, refraction, and reflection within the light distribution medium; light signal attenuation through the medium; and other critical factors. Designing a fiber optic network entails substantial engineering planning effort.

Nevertheless, the benefits make fiber optic transmission superior to metallic transmission. Some of the elements that differentiate fiber optic transmission from a metallic medium transmission are:

- a pair of light tubes can support many more circuits than a metallic path,
- immunity from electromagnetic interference (EMI) and radio-frequency interference (RFI),
- high integrity for data transmission,
- secure transmission,
- use of small cable diameters and low-weight cable, and
- safety in hazardous environments.

Classification of Optical Fibers and Attractive Features

Fibers used for optical communication are waveguides made of transparent dielectrics whose function is to guide light over long distances. An optical fiber consists of an inner cylinder of glass, called the "core," surrounded by a cylindrical shell of glass of lower refractive index, called the "cladding." Optical fibers may be classified in terms of the refractive index profile of the core and whether one mode (single-mode fiber) or many modes (multimode fiber) are propagating in the guide.

In general, when the transmission medium must have a very high bandwidth, a single-mode fiber is used. For intermediate system bandwidth requirements between 200 MHz/km and 2 billion Hz/km (GHz/km), such as found in intracity trunks between telephone central offices or in local area networks, either a single-mode or graded-index multimode fiber is the choice. For applications such as short data links, in which lower-bandwidth requirements are placed on the transmission medium, either a graded-index or a step-index multimode fiber may be used.

Because of their low loss and wide bandwidth capabilities, optical fibers have the potential for being used wherever twisted wire pairs or coaxial cables are used as the transmission medium in a communication system. The small size, small bending radius, and light weight of optical fiber cable are very important where space is at a premium, such as in crowded ducts under city streets. Because optical fibers are dielectric waveguides, they avoid many problems such as radiative interference, ground loops, and, when installed in a cable without metal, lightning-induced damage that exist in other transmission media.

Fiber optic transmission is immune to EMI and RFI because it is a dielectric and is not affected by electrical signals. A fiber cable can be installed in an environment that would cause interference to the transmission of electrical signals. Therefore, fiber can be used in electrically noisy environments. Data transmission error rates are extremely low when using fiber transmission. Bit error rates are typically on the order of one error in a billion bits ($1{:}10^{-9}$) of transmitted information. Fiber optic transmission emits no radiation. As a result, it is difficult to tap a fiber tube without detection of the resulting loss of signal. Therefore, it is a highly secure medium.

Using optical fibers offers a great deal of flexibility. An engineer can install an optical fiber cable and use it initially in a low-capacity (low-bit-rate) system. As the system's requirements expand, the engineer can take advantage of the broadband capabilities of optical fibers and convert to a high-capacity (high-bit-rate) system simply by changing the terminal electronics. Many manufacturers have developed fiber solutions for local area network technology. Several manufacturers offer products that permit LAN interconnections using a 100 Mb/s fiber backbone.

Fiber Transmission Characteristics

The proper design and operation of an optical communication system requires a knowledge of the transmission characteristics of the optical sources, fibers, and devices used to join lengths of fibers together (connectors, couplers, and splices, etc.). The transmission criteria that affect the choice of the fiber type used in a system are signal attenuation, information transmission capacity (bandwidth), source coupling, and interconnection efficiency. Interconnection efficiency is usually measured in terms of signal attenuation that is attributable to losses within the fiber plus the losses occurring in splices and connectors.

The information-carrying capacity, or bandwidth, of a fiber depends on dispersion of the transmitted light. This is the phenomenon that causes light that is originally concentrated into a short pulse to spread out into a broader pulse as it travels along an optical fiber. If the pulse is spread enough so that the last portions of one pulse arrive after the first portions of the following pulse, then intersymbol interference occurs and the individual pulses can no longer be distinguished from each other. Pulse dispersion occurs as a function of both pulse width (data rate) and distance. For this reason, the capacity of fiber optic systems is expressed in millions of bits per second per kilometer (Mb/s-km), the products of data rate and distance. Single-mode fiber offers significantly higher capacities than multimode fiber, and for this reason, the single-mode fiber tends to be used for long-distance communications. However, these capacities far exceed the requirements of most transportation agencies. Practical systems offer capacities of up to 20,000 Mb/s-km. This capacity is equivalent to a data transmission rate of 500 Mb/s at a distance of 40 km. Experimental efforts have achieved capacities of 500,000 Mb/s-km, rates that are equivalent to 4 gigabits [4 billion bits per second (4 Gb/s)] at distances of 117 km. So it is clear that even lower-performance multimode fiber optic systems can provide ample capacity for the vast majority of transportation agency requirements.

The transmitters used for fiber optic cable include injection laser diodes (ILDs) and light-emitting diodes (LEDs). The ILDs provide high power and high bandwidth but are expensive. Light-emitting diodes are used for transmission distances of less than 10 km and for data rates of 100 Mb/s or less. However, the state of the art is changing so rapidly that these capabilities are likely to improve substantially in the near future.

Receivers include photo diodes and photo transistors similar to the light meters in cameras. They are selected to match their characteristics to that of the medium and the transmitter.

The practical implementation of optical fiber communication systems requires the use of interconnection devices such as splices or connectors. The diameter of individual fibers is less than that of a human hair, yet splicing requires nearly perfect alignment of two fibers so that light can be transmitted between them with minimal attenuation. Automated equipment is becoming available to simplify this process. A connector, by definition, is a removable device used where it is necessary or convenient to easily disconnect and reconnect fibers. A splice, on the other hand, is employed to permanently join lengths of fiber together. The losses introduced by splices and connectors are an important factor in the design of a fiber optic system because they can be responsible for a significant percentage of the attenuation in a multi-kilometer communication link.

Applications of Optical Fiber Communications

The unique advantages of lightwave communications—the tremendous information-carrying capacity, the freedom from electromagnetic interference, the light weight of fibers, and the relative chemical and high-temperature stability of fibers—suggest that a communication revolution will occur in the near future. Already the telecommunications market for optical fibers has exploded in the United States and an unprecedented demand for fiber optic systems is being experienced. So far the field of fiber optics has been technology driven, but the future will be application driven. Lightwave application may be broadly classified into telecommunications applications, industrial applications, military applications, medical applications, and sensor applications.

However, enthusiasm for the use of these systems must be tempered by the fact that they require precise engineering, are often more difficult to install, and are always more expensive to acquire than metallic transmission media. This cost is, in part, caused by the relative immaturity of fiber optic technology and the physical requirements of the installation. Because of the high cost of fiber optic systems compared with copper transmission, they are typically used for trunking applications in which large amounts of information must be transmitted over long distances or for high-speed local area networks that are to be distributed over a campus area.

Typical transportation applications include freeway control systems, communications with remote groups of signals for traffic control systems, and limited use for video surveillance applications. Fiber optic cable is likely to have a reduced life-cycle cost when compared with copper transmission media. Therefore, the use of fiber optic technology to displace coaxial cable is becoming more common.

Radio

The cable transmission media described above differ from radio in that they provide a predictable transmission path with relatively controlled characteristics. Radio, on the other hand, requires a substantial investment in the calculation of the *probable* behavior of the path and selection of modulation and signal-processing techniques that will overcome defects of the medium. The characteristics of the path are significantly affected by the transmission frequencies of the system.

Low-Frequency Communication

Certain generalizations can be made regarding radio transmission behavior and application for various frequency ranges of the electromagnetic spectrum. The lowest frequencies, below 300 kilohertz (kHz) [very-low-frequency (VLF) and low-frequency (LF)], are useful for very-long-range communications but have very limited information bandwidths and require very high transmission power. Because propagation at these frequencies tends to follow the curvature of the earth, radio transmissions can be received worldwide, with the result that they can only be used a single time (i.e., they cannot be assigned again in another part of the world). The medium-frequency (MF) band, which includes the 300 to 3,000 kHz frequency range, is traditionally used for broadcast and marine applications. It also has limited information capacity and requires a high output power in the order of kilowatts. Its effective daytime range is in the hundreds of miles, with the frequencies also following the curvature of the earth.

High-Frequency Communication

The high-frequency (HF) band, which covers the 3 to 30 MHz frequency range, is the traditional long-haul, point-to-point communication band. Transportation applications in this portion of the frequency spectrum include the older public-safety and trucking company communications systems. Propagation at long distance is accomplished using one or more reflections from ionospheric layers, known as "skip." This can vary as the ionosphere varies with sunspot conditions and time of day. The ionosphere is multilayered and changes in an unpredictable manner. Because large areas of the ionosphere are involved in the propagation path, the received signal can be degraded by the reception of multiple reflections known as multipath interference. It is also subject to changes in received signal strength known as "fading." The ionosphere can also produce undesirable interference from remote locations such as that often received at night on commercial AM radio stations. This interference is known as "skip interference." Because of these problems, the HF band has been abandoned by most users except those requiring long-range communication.

Communication can be effective for a few hundred miles when using HF communication paths, and sometimes worldwide coverage can be obtained. Nearly 90 percent path reliability can be expected over the longer term for well-designed HF radio circuits. To accommodate the demand for HF frequencies, modulation bandwidths are limited by the Federal Communications Commission (FCC) to 12 kHz, the equivalent of four telephone channels.

Line-of-Sight Communications

Above 30 to 50 MHz, radio signals tend to pass through the ionosphere and are unreliable beyond the visible horizon. As a result, these higher frequencies are only useful for line-of-sight communication. These radio systems offer advantages and disadvantages for the design of communication transmission links. Radio links in the 150 MHz very-high-frequency (VHF) band and in the 450 MHz and 900 MHz ultra-high-frequency (UHF) spectrum bands provide multichannel transmission capability of 12 to 120 voice channels. Radio systems in these frequency spectrums support the majority of the mobile voice and data radio systems applications within the transportation industry, particularly those restricted to urban areas that can readily be covered by a multiple antenna system.

The transportation community uses these frequencies for both mobile and point-to-point applications. Mobile applications include public-safety, dispatching, and cellular telephone functions. Data transmission can also be reliably performed in these frequency ranges. Point-to-point applications include communications with motorist call boxes, control of variable-message signs, and traffic signal control.

Microwave Radio Systems

Microwave systems are essentially radio systems that operate at very high frequencies. As such, their characteristics are similar to those of the UHF radio spectrum. Above 2 GHz, microwave "line-of-sight" systems have a high communication channel capacity. Radio waves in line-of-sight systems travel in virtually a straight line. They are limited by the horizon (curvature of the earth) and geographic topology of the selected path. Microwave energy can be focused into a narrow, strongly directional beam, similar to a beam of light. Antenna towers must, therefore, be rigid enough to withstand high winds without excessive antenna deflection, which can result in increased path attenuation.

Most civil government and industrial microwave radio systems operate in the 6, 11, 18, and 23 GHz bands. The spacing between microwave repeater stations is determined by the geography of a given radio route, the technology used in the terminal equipment, and the transmitter power permitted by the FCC. Typical repeater spacings in the 6 GHz spectrum are 20 to 25 miles, and 1 to 3 miles in the 23 GHz spectrum. Much longer spacings are possible when the effects of fading are expected to be minimal.

Long microwave paths are particularly subject to fading. At microwave frequencies this can be caused by a variety of effects including atmospheric changes or ground and water reflections in the propagation path. When using frequencies above 10 GHz, rainfall attenuation must also be taken into account. For example, heavy ground fog or very cold air over warm terrain (such as thunderstorms) can cause enough atmospheric refraction to reduce the power of the signal below a usable level. This fading affects a wide band of frequencies and may last several hours. The remedy is to change antenna height or to position sites closer together.

A second type of fading, called "multipath fading," occurs at night and at dawn during the summer, when there is no wind to break up atmospheric layers. Normally, microwave energy radiated outside the line-of-sight path (called "off-axis energy") is bent by atmospheric refraction into the receiving antenna. This energy travels a longer path than the line-of-sight signal and, therefore, has a longer travel time. Depending on the amount of off-axis energy and its phase (the amount of delay relative to the primary signal), instantaneous reduction and even cancellation of the primary signal may occur. Multipath fading may recur frequently but lasts only a few seconds and is generally restricted to a limited frequency range. It can be minimized by using "frequency diversity." Because frequency diversity requires more use of the already limited radio-frequency spectrum, it is generally not applied to low-density routes. An alternative approach, "space diversity," is used in this case for paths that experience severe fading.

Because the microwave communications path can be controlled, the same frequencies can be reused at relatively small distances, with the result that the identification of available frequencies is simplified. The FCC allocates a portion of the radio-frequency bands of the electromagnetic spectrum available for government and public-service use. Consequently, many government transportation organizations own and operate microwave radio systems to support both administrative and operational communication requirements.

Telecommunications Services

Telecommunications services can be broadly defined as a public offering of telecommunications functions or facilities for a fee. Service offerings can be divided into two categories: (a) the payment of a fee for use of a telecommunications service such as long-distance calling on the public telephone network and (b) the leasing of transmission facilities such as leased telephone lines for a traffic control application. Many types of services are available in both categories. The following discussion of services has been divided into these two categories.

The decision to use a service as opposed to a dedicated, agency-owned, telecommunications system is usually made on an economic basis. Telecommunications services may be less expensive than dedicated facilities when a large coverage area is involved, or when the cost of installing dedicated facilities cannot be justified by the anticipated communications usage. Other reasons for the use of services as opposed to agency-owned facilities include:

- the absence of trained staff for the maintenance and operation of the facility,
- a short-term need for the telecommunications facility that does not justify the cost of installation, or
- unanticipated future functional or geographic expansion that might require future modifications to the facility.

When comparing the relative benefits of telecommunications services and agency-owned facilities, it is important to consider:

- the ability of the service provider to provide maintenance response times consistent with agency requirements,
- future escalations in the price of the service,
- the quality of the service being provided and the reputation of the provider, and
- the true life-cycle costs of the facility in comparison with the life-cycle costs of an agency-owned facility. Frequently, the cost comparison is limited to the initial capital costs of the two installations, a comparison that is both misleading and inaccurate.

A final factor to be considered when making such a comparison is the possible use of federal-aid funds to support the cost of the telecommunications facilities. Federal-aid funds are generally available to support the capital cost of a system implementation; they are not available to support its ongoing operations and maintenance. Because fees associated with the use of a telecommunications service are considered operations and maintenance, federal participation cannot be used. However, federal-aid funds can be applied to the capital cost of an agency-owned system.

For purposes of cost estimating when conducting a benefit evaluation, ongoing operations and maintenance costs should be computed on a basis that annual costs will equal approximately

10 percent to 15 percent of the original cost of a facility or system.

Telecommunications Service Offerings

Telecommunications services may be provided by a number of different organizations, including the local telephone companies, long-distance carriers, private cellular telephone companies, and suppliers of radio communications service. This broad and sometimes confusing mix of services is accompanied by a variety of rate structures that can only be compared if the purchaser has a thorough understanding of his/her organization's present and future communications requirements.

Telephone Services

Leased telephone services fall into three general categories: terminal equipment, switching equipment, and transmission facilities. These categories encompass such leased services as office communications service, analog and digital point-to-point services, foreign exchange service, wide area networking service, broadband video transmission service, switched digital data service, and channel bank termination service in central offices. An understanding of the opportunities for leasing telephone services requires an appreciation of the impacts of deregulation on the offerings of the local Bell operating companies (BOCs).

Impacts of Deregulation The change in the regulatory environment has radically altered the costs and service mix associated with leased telephone service. The two areas that have been most significantly affected are the switching and transmission services traditionally offered by the local telco and AT&T. Key terminology associated with the leasing of telephone service includes:

- Point of presence (POP)—This is the physical location where all services from an interexchange carrier (AT&T, MCI, etc.) enter and leave a geographic area known as a local access and transport area (LATA). Normally, there is only one POP per LATA, although densely populated areas may have more than one location.
- Minimum point of penetration (MPOP)—This is the point of demarcation or the interface point between the telephone company's outside plant cabling and the building cabling at any office building or residence. The term "minimum" normally implies a basement location in an office building. In today's telecommunications environment, building cabling is owned either by the building owner or the tenants of a building. In most, but not all, circumstances the telephone company has no service responsibility beyond the minimum point of entry of its cabling unless a subscriber contracts for additional support at an added cost.

In the area of switch systems, local BOCs no longer offer leased PBX services. Although Centrex services are offered as an alternative, they do not include any terminal equipment (telephone sets). Centrex service is equivalent to the provision of PBX functions for premises' switching functions from the central office. It has suffered a severe decline in popularity because of the economic advantages of PBX ownership. End users are free to lease either Centrex or PBX equipment from any vendor they may select and connect the equipment to the telephone network, as long as it meets prescribed FCC Part 68 requirements. Thus the telephone company's responsibilities end at the MPOP, with responsibility for intraorganization switching assumed by the building owner or its tenants.

Subtle changes have also occurred in the quality of service provided by the BOCs related to support for data-communications facilities. Before the AT&T breakup, telephone companies guaranteed 4800 b/s data transmission over standard voice-grade channels. Today, BOCs will not support data services unless the end user subscribes to "data conditioned" circuits—at extra cost. Consequently, the BOC will not correct data-communications problems identified by the customer even at speeds as low as 1200 b/s.

Tariff charges associated with broadband transmission services have also been affected by deregulation. Costs can vary as much as $200 per month per circuit, depending on whether a service is rated as an intrastate service versus interstate. This determination can be quite esoteric and is more a function of service use than a technical parameter. In the area of network design, both voice and data costs can be affected substantially by direct connectivity to a long-haul carrier's POP.

Impacts of Deregulation on Building Wiring One of the most recent and least-understood events that has occurred in the leased telecommunications services arena is the deregulation of building wiring. Cable deregulation has been in effect for two years and some of the local BOCs are still formulating inside wire policies.

Deregulated wiring has been subdivided into two categories: simple and complex. "Simple" is classified as one- and two-line residential or business wiring. "Complex" (or intrasystem cable) is the lateral or horizontal wiring that includes conduit and associated connector components connecting common equipment to key telephone stations and other terminal equipment, usually within the same building or between buildings on contiguous property.

Installation of new complex cable was deregulated in 1981. The installation and maintenance of simple wiring and the maintenance of complex wiring were deregulated in January 1987 (except in New York, where the date is 1990). The FCC has ordered the BOCs to fully amortize their embedded cable investments by 1994.

The deregulation of inside cable and wire was an outgrowth of the FCC's 1980 decision to deregulate customer premises equipment (CPE). Although no end user or industry sector supported this action, the FCC was convinced that deregulation of inside cable and wire would stimulate competitive business opportunities in the installation and maintenance of building cable and wire. This would lead to reduced cost for these services and also reduce local and long-distance costs because of the removal of cable costs from the BOCs' rate base. This expectation has not materialized. Inside cable and wiring services are more expensive and vendors are difficult to locate.

Although the FCC elected to deregulate horizontal distribution wiring, it stopped short of addressing building backbone (riser) cabling, so-called "black" cable. The ongoing regulated treatment of most riser cable continues to be the source of much confusion. To the end user or building owner, it is often the most useful or essential component of a building's telecommunications wiring system. The FCC ruled that under certain circumstances (usually limited to single-tenant-occupied buildings), the customer or building owner can request that the demarcation point (demarc) be relocated to the building cable entrance or some similarly convenient point, thereby freeing the riser or distribution cable to be used like deregulated complex cable. The customer or building owner must reimburse the BOC for the time and materials to relocate the physical demarc, but this cost is relatively insignificant compared with that of purchasing the riser cable.

The FCC permits the BOCs to transfer riser cable investments and amortize them in the same manner as complex cable. This can be done either systemwide or on a case-by-case basis. Consequently, the BOCs can freely relocate riser demarcations without concern for recovery of their initial cable investment.

Several points should be understood. First, "deregulation" is not necessarily synonymous with "detariffing." Most cable and wire services were performed by the BOCs on a regulated basis without being covered by any specific tariff provisions. Under deregulation the BOCs can still provide the same services, but they are required to account for their costs—and revenues—separately from their regulated operations. However, BOCs are not required to offer deregulated cable services through a separate subsidiary.

Second, the FCC defined the demarc or network interface in *functional* rather than hardware-specific terms. The demarc is the point where the BOC's regulated responsibility ends and nonregulated customer responsibility begins. Sometimes the demarcation point will be distinguished by a piece of physical hardware or network interface, but there are no standard industry designs or physical specifications for the network interface.

Thus, use of leased telecommunication services not only requires detailed initial planning but also should include an annual review of tariffed services, their use, and a consideration of cost-effective alternatives.

Long-Distance Service The second major category of telephone services is the long-distance market. Although this market continues to be dominated by AT&T, significant inroads have been made by competing services. A survey completed in 1988 indicated the following market share among the commercial competing long-distance services:

- AT&T has maintained its position as the largest provider of long-distance services, with 62 percent of the market.
- MCI is the second-largest provider, with 15 percent market share.
- U.S. Sprint tripled its market share of the previous year, to achieve a 9 percent total market share.
- The remaining services, including ITT's United States Transmission Systems, Allnet, and Western Union, shared the remaining 14 percent of the market.

All of these companies offer a broad array of long-distance services and rate structures that are beyond the scope of this synthesis. An economic comparison of services must be based on a knowledge of the agency's long-distance calling patterns that includes both the locations called and the times at which the calls are made.

Equally significant, however, particularly if these services are to be used for data transmission, is a comparison of the quality of these competing services. Organizations such as Datapro Research Corporation (see Bibliography) regularly perform surveys of user satisfaction in categories that include planning assistance, ease of installation, circuit quality, circuit reliability, problem diagnosis, and overall performance for all of the available services. The use of this information is recommended as a supplement for the selection of the most appropriate service.

Cellular Communications

To understand the difference between cellular service and the radiotelephone service that was its predecessor, imagine a large circle with a transmitter tower located at its center. The circle represents the service coverage area for a conventional mobile radio system operating in the VHF spectrum. The coverage area (radius of the circle) can be anywhere from 25 to 50 miles. This coverage would normally be adequate for communications within the boundaries of a large city and its surrounding suburbs. All radiotelephone communications would be transmitted through the antenna installed on this tower.

Only a dozen channels were typically available in most urban areas, with the result that a maximum of 12 people could use the system simultaneously. As a result, extremely long waiting times could occur before a free channel became available. In order to limit these waiting times, the telephone company would usually limit the total number of system subscribers to approximately 70 per channel. One additional problem associated with this service was the high transmitter power that was required to cover an entire urban area. This prevented reuse of the mobile telephone frequency in another city within 75 to 100 miles because of frequency interference problems.

System Operation Cellular telephone service was developed to overcome these problems. The system operates on the basis of small radio sectors, or "cells," that provide communications coverage in a series of small, slightly overlapping areas. Cellular service requires a bandwidth of 30 kHz per channel and has a total of 666 channels in the assigned frequency spectrum. This includes 42 common channels for call processing and signalling requirements. The assigned frequencies are in the UHF spectrum, between 825 and 845 MHz for mobiles and 870 and 890 MHz for base stations, with an additional 20 MHz in reserve. These frequencies are to be shared by two systems operated by separate companies in each of the 90 designated cities, with certain rural areas assigned thereafter.

A separate antenna is located at the center of each cell, which is designed for coverage of between 2 and 10 miles. The frequencies used in a given cell can be reused in other cells within the same system, providing the distance between cells using the same frequencies is adequate to avoid interference.

When moving across a city area while conducting a telephone call, a cellular radiotelephone transmits a signal that is received by the tower in the cell closest to it. The mobile unit is assigned a frequency by the current cell and remains in communication with the cell until its signal strength is diminished, at which time the mobile unit is automatically switched to another channel associated with the transmitter area of the next cell. The switching between cells and frequency assignment process is performed by a central computer, called a "mobile telephone switching office" (MTSO). The MTSO constantly monitors the signal strength at each of the cell sites nearest a user's vehicle. At the appropriate time, the computer "hands off" the call from one cell to another, a process that occurs within a few milliseconds and is indistinguishable to the user. Although the changes in signal strength and the loss in communications associated with the hand-off process are barely noticeable for voice communications, they seriously degrade data communications. This fact limits the possibility of using this form of communications with cellular service from a moving vehicle.

Business Issues Initially, cellular service was considered part of the Bell System's telephone system. However, with deregulation, the market was subdivided into "wireline" and "non-wireline" service for each urban area. "Wireline" service is offered only by a regional Bell operating company (RBOC). "Wireline" service connotes that the cell base stations are interconnected using conventional telephone cabling and also have access to the nationwide long-distance network. "Non-wireline" service is provided by a commercial enterprise in which the cell base stations are interconnected using microwave radio links or another privately owned transmission facility.

Cellular telephone service can be expensive, depending on usage. Currently, basic service usage charges vary from about $0.30/min to $0.50/min, with either a 1 min or 30 sec minimum call duration. These charges apply regardless of whether a cellular telephone user originates the call or merely receives an incoming call. With added feature capabilities, the service becomes even more expensive. However, as a business tool, it can significantly improve the efficiency of managers or technical personnel who spend a substantial period of time in a vehicle.

Many transportation agencies have considered the use of cellular telephone service as an alternative to the use of fixed point-to-point communications for traffic control purposes. Although cellular might offer an expedient approach for implementing a system quickly, its cost is significantly higher for permanent installation than for nearly any other type of system if frequent communications with the remote-control equipment is necessary.

Assume, for example, that communication with a changeable-message sign is required six times a day to change sign messages and to check sign operability. Also assuming that the minimum cellular cost is $0.50 per call, the cost of operating this system would be $3.00 per day ($1080 per year) to support the operation of a single sign. Although the cost of a leased line to provide the same capability is a function of the distance between the sign and the control center, it is likely to be on the order of $50 to $80 per month. Thus, unless the sign installation is temporary, leased telephone lines are likely to be cheaper. If several signs are to be controlled that can share a multi-drop line, the cost of leased lines will be even lower. Thus, the use of cellular as a point-to-point service is most useful for temporary applications requiring communications with a limited number of field devices.

Packet Switched Data Communications Systems

A number of commercial telecommunications services are available to provide packet switched data communications. These packet switched networks are known as value added networks (VANs).

In addition to providing switched data communications services, the VANs provide a number of "value added" features including electronic mail, local error protection, protocol conversion, and electronic data interchange (EDI) of commercial documents such as purchase orders, shipping notices, invoices, and other common business documents. Some networks such as CompuServe also provide access to data bases that contain general information such as airline schedules and stock quotations.

The dominant providers of VAN services include:

- AT&T's ACCUNET Packet Service (APS), which provides dial-in facilities at data rates between 300 and 2400 b/s. AT&T is restricted to offering basic services, and for this reason the APS does not include value added features.
- CompuServe is a VAN offering that provides remote access to approximately 300 locations in the United States and Canada. This service features access to general-information data bases for both home users and commercial enterprises.
- The IBM Information Network is a nationwide VAN that serves 276 U.S. cities and more than 50 foreign countries. The network includes both electronic mail and EDI services, as well as access to application-development tools and information data bases. The IBM network is anticipated to serve as the telecommunications medium for the American Association of Motor Vehicle Administrators (AAMVA), where it will be used for transmission of motor vehicle registration and driver licensing information among the state MVAs.
- Telenet was one of the early pioneers in the field of packet switched data services, and as a result, currently serves more than 50 percent of the market. It is one of the most pervasive of the available services in that it serves more than 1000 cities in the United States. Telenet also offers electronic mail services.
- TYMNET is second only to Telenet in terms of the number of cities served. It offers a similar range of services.

When evaluating these services, agencies should consider the value added services offered, customer satisfaction ratings (available from the Datapro Research Corporation), and the rate structure of the offering. Thus, the VAN offerings should be compared on a basis that is similar to the comparisons recommended for the long-distance services discussed above.

Satellite Services

Communications satellites are radio-relay stations in space. Communication satellites receive radio signals transmitted from the ground, amplify them, translate them in frequency, and retransmit them back to earth. Because satellites are at a high altitude, they can cover almost half of the earth. This provides their principal communications advantage, insensitivity to the relative locations of the transmitter and receiver. Because of their large coverage areas, they can also be used to provide point-to-multipoint services, such as those required for broadcast television.

All communications satellites operate in synchronous equatorial orbits. This provides a reception and transmission point with minimal tracking by earth stations. Satellites receive signals transmitted from earth (up-link) on frequencies in the 6 GHz or 12 GHz band and retransmit them back to earth (down-link) on frequencies in the 4 GHz or 11 GHz band.

An earth station transmits powerful radio signals to the satellite and receives the weak signals transmitted by the satellite. Earth stations connect the satellite network to the terrestrial communications network. Earth stations may interface with terrestrial public telephone systems or private business networks. An earth station reorganizes the incoming signals from terrestrial networks into groupings suitable for satellite transmission. Each group of signals is modulated for radio-frequency transmission, and amplified to power levels of between 1 watt and several kilowatts. The amplified signal is fed to a parabolic antenna ranging from 1.8 m to 30 m in diameter, depending on the application. The function of an antenna is to focus the radiated energy beam aimed at the satellite.

After traveling 22,300 miles through space, the signal is received at the satellite. The satellite amplifies this signal, translates it to the down-link frequency band, and beams it back to the ground. At the earth station, the antenna collects the energy and feeds it into a low-noise receiver. There it is amplified and transmitted over its terrestrial distribution network.

Satellites offer unique opportunities to develop communications networks that would be difficult to achieve with terrestrial transmission. Two types of networks are prevalent: preassigned access, and demand assigned multiple access. Preassigned access networks are established by assigning fixed subsets of telephone channels to various destinations. When such subsets are large, load variation between destinations is negligible, making preassigned network control efficient. A single transmitted carrier permits each station to reach all others within the view of the satellite's down-link. Each station can receive carriers transmitted by all others and select the desired channels. Today most telephone traffic carried on both international and domestic satellite systems uses this simple, preassigned network-control method.

Although preassigned operation is well suited to high-volume trunk telephone service, it is inefficient for medium and "thin-route" telephone service in which the average traffic is a small fraction of the traffic found on high-volume trunks. The need for thin-route telephone service was identified early in the evolution of satellite systems. The fractional channel requirements of the thin-route service can be efficiently accommodated by allowing an earth station to have access to a pool of channels. When a call is placed, the earth station makes use of an available channel from the pool, which it returns when the call is completed. This method is generally referred to as demand-assigned multiple access. It is a unique type of service used exclusively for satellite communications.

One relatively new application of satellite communications within the transportation industry is the mobile satellite communications services being offered to long-haul trucking companies. These services require the installation of relatively inexpensive equipment within the truck that includes a transmitter, receiver, and antenna. The service provides the ability for the trucking company dispatchers to transmit digital messages to the truck, where they are presented on an LCD display. Alternatively, messages can be originated at the truck for display to the dispatcher. These systems also provide the ability for tracking individual trucks. It should be emphasized that these services are most applicable for areas in which interference from buildings, trees, and power lines is minimal. For this reason, they are of limited use in urban areas.

With the exception of mobile satellite applications, transportation agencies are infrequent users of satellite services, because their communications requirements tend to be somewhat localized. However, as the cost of earth station equipment decreases, the use of satellite service for data transmission is becoming more economical. This form of communications should be considered for future use by the larger states.

Leased Facilities

Leased facilities differ from the communications services described above in that the lessor is paying for the use of a dedicated communications facility as opposed to paying for the delivery of information. This distinction is significant in that the leasing of a facility places the responsibility on the lessor to identify the services required and provide the interface equipment needed to ensure that the facility is being properly used. The responsibility of the lessee is restricted to providing a transmission facility that meets the requirements of a set of specifications. These specifications should define both the transmission quality of the facilities and the installation and maintenance responsibilities of the lessor.

Leased Telephone Cable

Leased twisted-pair telephone lines are frequently used for traffic surveillance and control system application. The most common type of leased telco channel in traffic control applications is the 3002 conditioned analog circuit conforming to the characteristics of the Bell Telephone System Interstate Tariff FCC Number 260. This channel is used for transmission of data over voice grade facilities. Typical data rates used with the 3002 facilities are 1200 b/s and 2400 b/s with acceptable error rates. These facilities can be used for both half-duplex and full-duplex operation.

Leased telephone cable facilities may be used to provide interconnection between a central computer and remote field equipment such as traffic signal controllers, variable-message signs, freeway ramp meters, traffic counting equipment, etc.

Characteristics The transmission characteristics and performance of the telco channels are equivalent to a twisted-pair cable network with only a few exceptions. For example, the distance of the transmission line is not a consideration when the channel is leased from the telephone company. All amplification is handled by the telephone company, and the owner is assured the channel will meet certain specifications and tolerances regardless of the distance. Another important difference is that, unlike the twisted-pair cable network, telco channels may not provide a continuous electrical path to the remote field locations. The channel may be multiplexed into larger groups of channels and then transmitted over fiber optics or microwave.

Costs The primary difference between jurisdiction-owned twisted-pair cable and leased telco channels is cost. On the positive side, leased telephone lines normally offer a very low initial installation cost compared with the jurisdiction-owned network, especially if an underground installation is required. However, the recurring cost (monthly lease) is substantially higher with leased lines than jurisdiction-owned facilities. Future increases in the cost of leased system are also unpredictable, and cannot be guaranteed by the telco.

Telco rates and charges are established by tariff and are subject to approval by state regulatory agencies. This produces significant variations in costs and prevents the presentation of generalized tariffs. The method by which these costs are calculated also varies from state to state. Some tariffs are based on the "drop-to-central office mileage," in which the distance from one drop (traffic signal controller, ramp meter, etc.) to the telco central office servicing that exchange is measured in distance increments (usually ¼ mile) and a fixed charge per increment is assessed. Other tariffs use "drop-to-central office fixed," in which a fixed charge per drop is assessed regardless of the distance. Additional charges are usually assessed when communications between central offices are required in the path from field to central equipment. These charges may be the most significant element of the total cost, with the result that it is frequently desirable to explore alternatives to leased lines for distant communications requiring multiple central offices.

Leased Telco Channels

Many different services and facilities can be leased from the local telephone company, ranging from unconditioned copper wire pairs to wide band telephone trunks. The physical media provided for these leased facilities may include twisted-pair cable, coaxial cable, fiber optics, or terrestrial microwave.

Because the telephone company's primary business is voice communications, most of its digital transmission facilities are based on the use of digitized voice channels. Therefore, in order to understand the leased telco services in terms of their digital transmission capacities, it is necessary to understand the process by which voice is converted to digital data, a process that is significantly different from that which is performed by a modem. At the lowest level, a single voice channel is converted from a continuously varying analog signal to a series of discrete samples—8000 samples per second. These samples are then quantized or assigned to one of 256 discrete voltage levels through a process known as pulse-code modulation (PCM). Each quantized sample is then digitally encoded into an 8-bit word. Through this process, each voice channel is converted to a 64 kilobit per second (kb/s) digital data stream.

These 64 kb/s channels are then combined (multiplexed) into larger groups of channels. Twenty-four 64 kb/s channels make up a T1 channel operating at a rate of 1.544 Mb/s. T1 channels are grouped into even higher data rate channels. This system, whose structure is shown in Table 1, is called a T-carrier system.

Obviously, many of these systems have capacities that far exceed the requirements of an agency for either voice or data transmission. However, the T1 and T2 channels may be applicable both for traffic control and other agency communications requirements in situations in which high point-to-point (trunking) capacities are needed. When considering the use of these trunk facilities for data transmission, it is important to recognize that multiplex equipment is available to subdivide the available channel capacity in combinations other than those shown in the last column of Table 1. For example, one common multiplexer combines 54 1200 b/s full-duplex data channels into a T1 channel output. The outputs of four of these multiplexers could be multiplexed onto a T2 channel with a capacity of 216 1200 b/s channels. In a traffic control system designed to accommodate eight signal controllers per line, a single T1 channel could support as many as 416 controllers.

The use of these systems is applicable to large urban areas where a high volume of voice or data communication is required between separate facilities. The cost and difficulty of obtaining or installing conduit over a long distance through a crowded urban underground might make direct physical connection infeasible, even for a single fiber optic or coaxial cable. In these cases, a single T1 or T2 channel leased from the telephone company could provide a cost-effective connection between these two areas. Leased facilities can also be attractive as an interim or temporary measure to provide communications to an area that may later be served by other facilities.

Community Antenna Television (CATV)

Because CATV (cable television networks) are usually implemented using coaxial cable, the characteristics of the CATV channels are very similar to those of dedicated coaxial cable systems. There are two major exceptions to this: One is that the available bandwidth on the CATV system, which is a function of the network loading (number of active channels), and the franchise agreement may be very limited. The other exception is that not all systems are designed for bidirectional capability communications, and some of those with bidirectional capability may not provide equal transmission quality in both directions. Thus, in many respects, the CATV system is unique because it is both a shared resource and a leased medium. These differences result in both advantages and disadvantages.

Community antenna television systems normally use a single cable with transmission bandwidths on the order of 450 MHz that have the capability to support up to 75 video channels. With proper maintenance, they have a low incidence of errors, support high data rates, and can easily be tapped into using devices such as splitters, couplers, and broadband modems.

Community antenna television systems, with appropriate modification, lend themselves to two-way interactive communications. A number of experimental interactive systems have been developed. Examples include Warner Cable's QUBE system, which uses polling, and Cox Cable's INDAX system, which uses a contention type of technology. Community antenna television systems generally provide areas of metropolitan coverage of 10 to 100 miles. When adapted for two-way communications, they may be candidates for use in metropolitan area communications.

TABLE 1
T-CARRIER SYSTEM

System	Bit Rate	Voice Channels
DS0	64 kb/s	1
DS1	1.544 Mb/s	24
DS2	6.312 Mb/s	96
DS3	44.736 Mb/s	672
DS4	274.176 Mb/s	4,032
Optical Fiber	up to 54 Gb/s	up to 800,000

Community antenna television systems are commonly designed using a tree-type topology (see Figure 8 for a simple system). It consists of a main trunk cable feeding out from a head end. Trunk amplifiers installed along the trunk maintain the signal level and compensate for cable transmission characteristics. Multiple branches are connected to the trunk through bridger amplifiers. Subscriber branches and subbranches are connected to the system through the use of passive taps.

Cable systems provide bandwidths of between 300 and 450 MHz, with some versions going as high as 600 MHz. These are split into 6 MHz channels that carry the television signals. In the case of two-way data transmission applications, the frequency range is divided and used to carry signals upstream (to the head end) and to downstream data traffic. Each 6 MHz channel can in turn handle multiple data channels, depending on the bit rate and modulation technique used.

Most CATV networks are designed and installed with emphasis on the downstream transmission of video signals from a central location to the cable subscribers. These video channels are likely to use most of the available bandwidth. Thus the band-

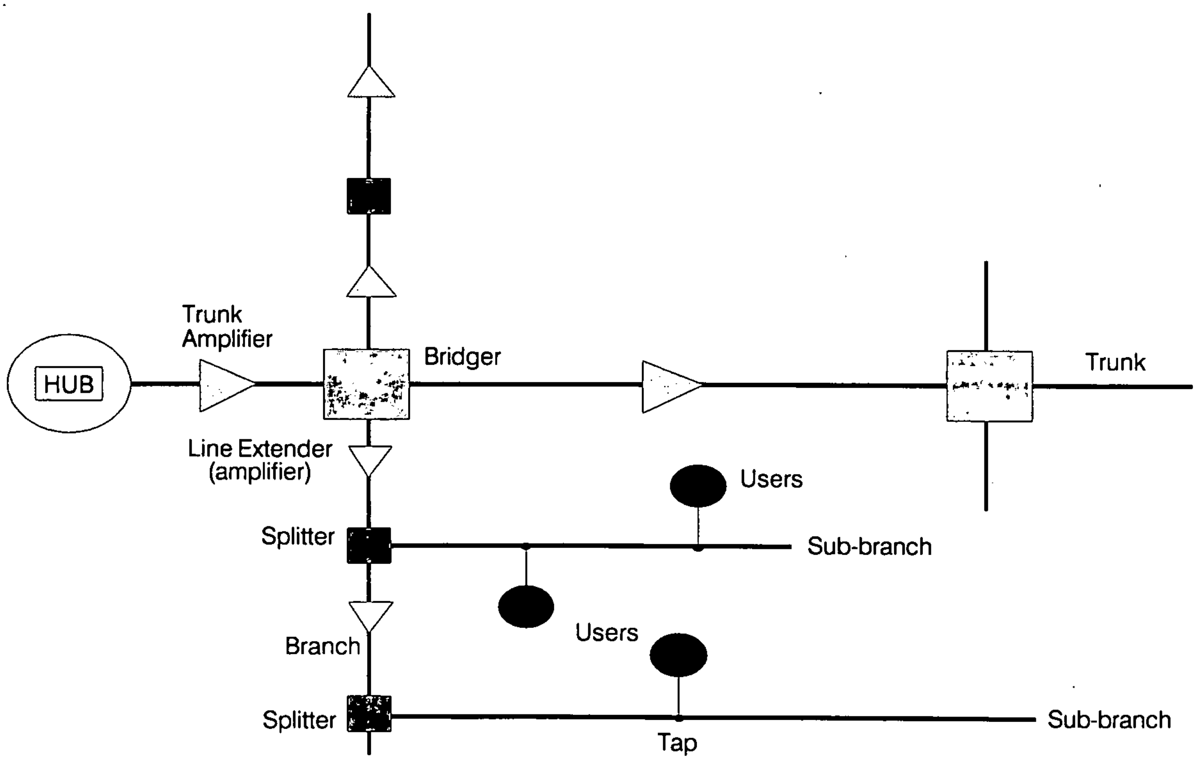

FIGURE 8 Single-trunk CATV layout.

width available for traffic surveillance and control applications may be very narrow, ranging from a single 6 MHz channel up to four or five channels. The available channel capacity can have a significant impact on CATV utilization. For example, although a single 6 MHz channel would be quite adequate for data transmission, it would not support both video and data transmission. An associated problem is that the available channels typically operate at the least desirable frequencies, in terms of their susceptibility to external noise and interference.

It should also be noted that types of noise that do not adversely affect video transmission (which might appear as lines or snow on a video monitor) may wreak havoc on data transmission. For this reason, the transmission techniques used for twisted-pair cable cannot blindly be applied to CATV systems. It is usually necessary to use sophisticated error detection and correction procedures to overcome data errors associated with the system noise. Commercial equipment is available to provide both the electrical interface with the cable and the required error processing. The use of equipment with these capabilities is important if satisfactory operation is to be provided.

Although there are operational systems using CATV facilities, a number of surveillance and control system installations have encountered difficulties with the use of CATV. In order to avoid these problems, the following steps are recommended:

- Review franchise agreements to ensure that upstream and downstream channels are available for such use and that the allocated frequencies are adequate. The evaluation of frequencies should be performed through actual noise measurement and bit error rate (BER) testing.
- Assure the cooperation of the CATV company, through the franchise agreement and supplementary agreements, if necessary. This cooperation is required for interconnection of the CATV system with the local field equipment, and at the central facility.
- Prepare acceptance test criteria for the CATV network on the basis of the contractual agreements. This provides for assurances of transmission quality before investment in other aspects of the field installation.
- Receive firm commitments from the franchise for ongoing support and maintenance.

STANDARDS

Communications standards define the processes, formats, and electrical and physical requirements for the interface of switching systems, computers, terminals, and networks. This section provides an overview of the dominant standards and the most influential standards organizations.

The Need for Standards

The basic premise supporting the creation of communications industry standards is to provide safe and effective interfaces between diverse communications and computing devices. In the absence of such standards, users would not be able to create, expand, or interconnect their systems and networks. Until recently, standards were established within a single manufacturer's product line. One such standard is IBM's systems network architecture (SNA). In the absence of industry-wide standards, telecommunications and computer systems users were restricted to the use of equipment supplied by a single vendor. Although the single-vendor approach may still be desirable under certain circumstances, few vendors manufacture the full range of equipment required for modern telecommunications networks. In addition, most users are unwilling to rely on a single vendor because the multi-vendor environment frequently offers price and performance advantages. Perhaps most important from the perspective of a public agency is the fact that competitive procurement procedures preclude the selection of equipment from a single vendor without extensive supporting justification.

Because of their significance both to the operation and future expansion of telecommunications systems, it is essential that organizations responsible for the implementation of these systems take existing standards into account throughout their development cycle. This is particularly true of systems incorporating data transmission, because the standards for this form of communication tend to be the most complex. In addition, the transportation community should place increased emphasis on the use of existing telecommunications standards for the design of surveillance and control systems in order to make use of available telecommunications hardware and software without requiring expensive specialized development for single applications.

A Standards Model

In order to provide complete compatibility between the transmitting and receiving devices, it is necessary to define all aspects of the data transmission and reception process. An extensive list of items must be developed to provide the required compatibility. For this reason, the International Standards Organization (ISO) has developed a telecommunications system model that is to be followed as the basis for describing standards, known as the open systems interconnection (OSI) reference model. The organization name and reference model name are sometimes combined to form the designation ISO-OSI model.

The OSI model is made up of seven layers as shown in Figure 9. Each layer of the transmitting device must be compatible with its counterpart in the receiving device. The relationship is equivalent to the relationship between two large organizations, where the director at the top of one organization communicates with the director of a second organization down through its chain of command to the bottom level of the second organization and up to the director of the second organization. Each level in the chain of command of each organization has a specific responsibility and must understand the actions of its counterparts in the other organization. The actual physical communication travels down through the transmitting organization and up through the receiving organization. This process is also shown in Figure 9, using solid lines to indicate the direction of information flow and dashed lines to indicate compatibility between levels.

The functions of each layer in the OSI reference model are as follows:

- Layer 1—The Physical layer is the only hardware definition in the OSI model and defines the electrical and mechanical characteristics of the equipment interface with the network's

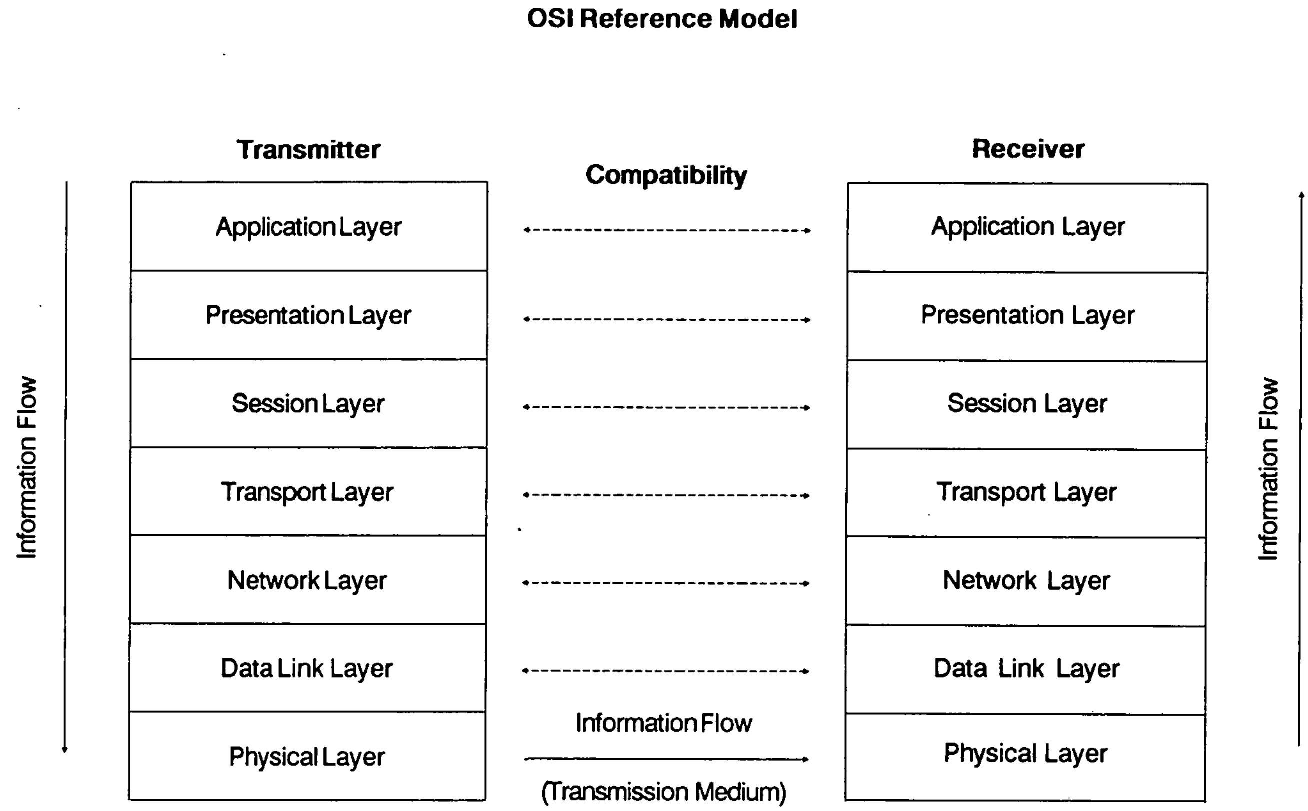

FIGURE 9 Open systems interconnection reference model and information flow.

transmission medium in terms of voltage levels, connector types, pin assignments, and modulation frequencies.

- Layer 2—The Data Link layer defines the specific formats to be used for transmitting data from their origin to their destination. Where multiple devices can communicate with each other, this layer defines the manner in which a transmitting device identifies the receiving device for which the data are intended, the amount of information to be sent with each transmission, and the manner in which the beginning and ending of messages are identified. These techniques are known as protocols.
- Layer 3—The Network layer is required for a network in order to define the routing of a message through intervening communications points. Because many local area networks do not provide alternative routing, layer 3 is frequently not required for LANs.
- Layer 4—the Transport layer defines the manner in which errors are detected and acknowledgments of data reception treated. For example, parity is checked at this level, and if an error is detected, a retransmission is requested from the transmitting device before data are passed to a higher level.
- Layer 5—The Session layer is the level where virtual connections are made between the sending and receiving devices. This layer identifies the beginning and ending of transmissions between these two devices.
- Layer 6—The Presentation layer is the interface between the communications system and the processing software. This layer reformats all received data in a manner that permits them to be "understood" by the applications software. All addresses and parity information are removed and data stored in locations that permit subsequent processing.
- Layer 7—The Application layer is user-defined software prepared to perform a specific processing function. It might be an accounting, word processing, or engineering analysis program. It could also be the traffic control software installed in a central computer. This layer is rarely specified as part of a communications system design.

An understanding of the OSI model provides the basis for understanding and specifying compatible devices that must work together in a common system. Many existing standards are being reformatted for compatibility with this model and most new standards are being developed in terms of its layers.

None of the existing telecommunications standards define all seven layers of the OSI model. The layers defined are those that are appropriate to the system being developed.

Fiber Distributed Data Interface (FDDI) Standard

In October 1982 the American National Standards Institute (ANSI) Committee X3T9.5 was established to develop a high-speed data networking standard. It comprises various industry representatives, many of whom are members of the Computer and Business Equipment Manufacturers Association (CBEMA). The standard to be developed by the X3T9.5 committee is known as the fiber distributed data interface (FDDI). The standard specifies a packet-switched LAN-to-LAN backbone that transports data at high throughput rates over a variety of multimodal optical fibers. It allows development of metropolitan area-sized networks accommodating 100 Mb/s data rates across the backbone. The FDDI standard is for a token ring network with dual counterrotating fiber rings that will stretch over tens of kilometers. It will become a reality in the future when the final layer of the ANSI standard is approved.

Fiber distributed data interface evolved from the need for high-speed interconnections among mainframes, minicomputers, and associated peripherals. The general charter of the ANSI X3T9 parent committee is the development of standards for computer inputs and outputs. There currently are 68 members in the X3T9.5 committee representing key U.S. manufacturers, such as IBM, AT&T, and AMP Inc., among others.

For the most part, the FDDI standard will address the bottom two layers of the OSI model. To fully understand the FDDI standard, one must be familiar with the OSI model and its application to the LAN environment. The FDDI standard will include specifications for the higher layers of ISO protocols whenever possible. The optical-based FDDI LAN is designed to provide the same type of serial interconnection provided by current LANs while maintaining the high bandwidth, noise immunity, and security offered by fiber. Although optical fibers will support much higher transmission rates, FDDI is focused on the 100 Mb/s rate to provide relatively inexpensive connections. At the present time, practical FDDI configurations can support a sustained transfer rate of approximately 80 Mb/s.

Fiber distributed data interface is a token-passing twin-ring network that accommodates synchronous and asynchronous data transmission, as well as isochronous channels for real-time digitized voice and compressed video. The FDDI ring is designed for an overall bit error rate of less than 10^{-9}. The fiber network will support distances between stations of up to 2 km (6500 ft) and can support a total cable distance of 100 km (60 miles) around the ring with 500 attachments (1000 physical connections and a total fiber path of 200 km).

Multimode fiber tubes with a 62.5 μm core size will be the fibers used in most FDDI systems, although other fiber types are permitted if their performance is within limits of the standard.

Basic FDDI transmission is based on a duplex transmission design. The standard specifies an attenuation factor of 2.5 dB/km at a 1300 nanometer (nm) light source wavelength, with a maximum link attenuation of 11 dB through fiber and connections, and a minimum bandwidth of 500 Mhz/km. The 1300 nm technology allows the use of less expensive LEDs as signal drivers.

The FDDI standard directly addresses the need for reliability. This need arises from the fact that a backbone system transports a large number of user sessions and its loss would be serious. Fiber distributed data interface incorporates three reliability-enhancing methods:

- First, a failed or unpowered station is bypassed by an automatic optical bypass switch;
- Second, wiring concentrators are used in a star wiring configuration to facilitate fault isolation and correction; and
- Third, two rings are used to interconnect stations so that failure of a repeater or cable link results in the automatic reconfiguration of the network.

The token-passing protocol used in FDDI is based on the IEEE 802.5 standard for a 4 Mb/s twisted-pair ring.

Fiber distributed data interface employs a ring topology based on the characteristics of optical communication. Bus and passive star topologies require the optical transmission to be detected at several sources simultaneously. Although practical fiber optic taps are becoming available, the attenuation is still such that the number of nodes in this type topology is relatively limited. Fiber optic transmission is best handled with a point-to-point configuration, and FDDI includes this aspect in its definition. Two types of topologies are possible with point-to-point links: the active star and the ring. The active star topology is a problem because a single point of failure incapacitates the entire network. A similar problem exists with a single ring. Consequently, the FDDI specification calls for a dual-ring configuration.

Synchronous Optical NETwork (SONET)

Concurrent with the development of an FDDI standard, telecommunication common carriers have been developing their own high-bandwidth fiber interface standard. Bell Communications Research's (Bellcore's) Exchange Carriers Standards Association developed a standardized optical interface called Synchronous Optical NETwork (SONET), which is a 2.46 Gb/s transport supported by the North American telephone industry.

Synchronous Optical NETwork is built on a standard base rate called OC1 (Optical Carrier 1), which represents a transmission rate of 51.84 Mb/s over optical facilities. The electrical equivalent of OC1 is STS-1 (Synchronous Transmission System 1). There are no electrical transmission standards above STS-1. However, rates below the STS-1 standard such as DS1 transmission facilities can be aggregated to create an OC1 or higher-rate transmission facility.

The SONET hierarchy in high-speed optical transmission builds in multiples of OC1, up to and including OC48, with an equivalent bandwidth of 2.48832 Gb/s over an optical carrier. The extraordinarily large bandwidth and simple multiplexing method of SONET are outstanding benefits that allow a multitude of possible opportunities for applications supported by public and private networks.

SONET Transmission

Transmission equipment refers to all the equipment required to carry a physical layer signal over a transmission medium and provides such functions as scrambling, error monitoring, and protection switching. All broadband transmission streams are SONET signals operating at the STS-3 rate.

The major benefit of the universal adoption of SONET synchronization is that multiplexed T3 signals can be transferred among carrier facilities regardless of the use of different vendors' equipment by the carriers. Equipment costs are lower because of the elimination of an intermediate multiplexer, and signals from a SONET-compatible transmission system can be transmitted to a customer site using customer-provided equipment or a carrier-provided cross-connect system.

Although the need for interconnecting private FDDI networks with common-carrier SONET-based networks is undoubtedly several years away, the issue has been raised at a recent technical-requirements forum. Solution of the problem of how to interface the two standards has received different approaches. One method suggests transporting FDDI packets transparently through the physical layer of SONET. This method would dedicate a SONET subchannel to two 100 Mb/s unidirectional channels to accommodate two FDDI rings. The limitation imposed by this bridging technique would be significant token latency when bridging FDDI rings separated by long distances. Intelligent gateways have been suggested as another approach to the problem, but there are obstacles involved with mapping between the two networks.

Telephony Standards

Before deregulation of the telephone industry, the vast majority of U.S. telephony standards were developed by AT&T. However, as a result of both deregulation and the increasing importance of standardization with foreign equipment and networks, these standards are being developed in the United States and abroad by both national and international standards organizations.

One of the most significant standards to emerge in recent years is the integrated services digital network (ISDN) standard. Its development is based on the fact that the telephone industry is currently in transition from analog to digital technology. This transition includes customer equipment (because many customers are attempting to use the telephone system for the transmission of digital information), the transmission medium, and the switching equipment.

The origins of ISDN began almost 25 years ago, when the concept of a universal network for voice, data, text, and video transmission was proposed as a result of the increasing use of PCM for digital transmission. The ISDN concept was formally defined and named in 1972 when a working group of the International Telegraph and Telephone Consultative Committee (CCITT) agreed that "an integrated services digital network. . .might be the ideal worldwide communications network of the future." Since that initial agreement, the CCITT has released a continuing series of standards from 1980 through the present time.

To a subscriber, the ISDN standard appears as a digital access line between the telco central office and the subscriber premises. This access line provides two types of digital channels: (a) a 64 kb/s "bearer" or B channel and (b) a 16 kb/s signaling or D channel. The former carries the usual voice and data information, whereas the latter is used for messages associated with call control. A small user such as a homeowner would subscribe to the basic rate interface, providing two B channels and a D channel—written as "2B+D." The larger user would employ a primary rate interface consisting of 23 64 kb/s, B channels and a 64 kb/s, D channel—written as "23B+D." The channel configuration of the 2B+D channel is designed for compatibility with the existing service between small subscribers and the central office (designated the local loop), whereas the 23B+D interface is designed for compatibility with the existing T1 telephone trunk.

Integrated services digital network is currently undergoing trials at eight locations throughout the United States. One trial is being conducted by Mountain Bell at the Arizona Department of Transportation. The test involves the use of a Northern Telecom switch located at Mountain Bell's central office, with 200 lines of the basic 2B+D access. It will provide voice and data over a single twisted-pair wire, as well as remote packet data access into the network. Approximately 50 DOT users are participating in the experiment at two Phoenix sites—the DOT headquarters building and the motor-vehicle building situated 1½ blocks away. Employees will be using special ISDN-equipped terminals for data entry of driver's license, vehicle registration, and other information. The motivation for the experiment is the possibility of replacing the coaxial cable currently in use with conventional twisted-pair telephone wiring.

Although ISDN appears to be a potentially promising technology that is gradually being adopted, it is not being uniformly accepted throughout the industry. Telecommunications managers are debating its usefulness, and many suspect that it will increase rather than decrease total system costs. The telephone industry has been promoting the use of telephone transmission equipment and switching equipment as a substitute for dedicated data-communication networks (with only limited success), and many feel that this is another attempt to integrate voice and data systems.

Agencies with possible applications for data and voice transmission over a wide area should explore the status of ISDN with their local telco to determine if it is available or feasible for their application.

Data-Communications Standards

Data-communications standards are essential to the evolutionary development of the data-communications industry. Organizations implementing either local area or wide area data-communications networks (including traffic surveillance and control systems) must be thoroughly familiar with these standards to ensure that compatible equipment is being acquired.

Modern data-communications standards are organized to conform with the OSI model described above. Most communications standards are concerned with layers one through three of this model, although a limited number of standards also define the higher levels. Thus the following discussion of data-communications standards is presented in terms of the bottom three layers of this model.

Layer One—Physical Standards

Physical standards, defining the electrical interface between devices, are the most stable and best-defined layers of the OSI model. The best known of these standards is the RS-232-C interface, which is used for most personal computers and many other peripheral and communications devices. This standard defines the connector type, voltage levels, and functions of every pin on the RS-232-C connector. For example, RS-232-C Pin 4 always transmits a Request-to-Send signal to the receiving device. The demand for additional functions requires more pins on a connector.

The popularity of the RS-232-C standard is a result of its early use by the data-processing industry. This standard, which was initially defined by the data-processing industry in the 1960s, has become the lowest common denominator for interconnection of computer equipment. However, it is important to recognize that it has two serious shortcomings:

- The definition of functions in terms of connector pins limits the number of functions that can be performed at the interface without adding pins (and thus changing the connector). Newer layer one standards define functions in terms of transmitted characters rather than pins.
- The RS-232-C standard defines an unbalanced interface, which means that it uses one wire for signaling and one wire for the return path (signal ground). The ground is common for all signals on the connector, which precludes the use of a separate twisted pair for each function. Thus the advantages of twisted-pair described earlier in this synthesis are lost.

Alternative standards such as the RS-449 and RS-422 standards provide for a balanced interface, which permits higher data rates (100 kb/s over distances of 4000 ft) than the RS-232-C standard, which is limited to data rates of 20 kb/s at distances of up to 50 ft. The improved characteristics of these standards result from the use of the balanced interface.

Layer Two—Data Link Standards

The data link layer provides protocols that ensure agreement between the sender and receiver on synchronization, error detection and recovery, and system initialization. This layer is defined by the product architectures of the major computer manufacturers. It is also defined by the standards organizations concerned with local area networks and wide area networks.

The most commonly used standards for local area networks are the IEEE 802 series of standards, which include:

- The 802.2 standards for logical link control. This standard defines the protocols associated with one or more logical connections to a single medium. It specifies the access methods to be used by each workstation connected to the medium.
- The 802.3 standard for the Ethernet type LAN, which operates using a protocol known as carrier sense multiple access/collision detection (CSMA/CD) techniques. The 802.3 standard defines the manner in which each station can access the medium at any time, providing no other station is using it.
- The 802.4 standard for the token bus type LAN, in which each station coordinates its use of a shared medium by assigning the right to access the medium using a digital code known as a token. The station possessing the token has momentary control over the medium. The token is passed from station to station on the medium in order to provide the desired shared access.
- The 802.5 standard for the token ring type LAN, in which a token-passing scheme similar to that of the 802.4 standard is used, except that the communications medium is configured as a ring rather than a bus.

Layer Three—Network Standards

The network layer establishes a path through a network and defines the procedures by which connections between systems are established, maintained, and terminated. This layer emphasizes the flow of information through a wide area network, because it deals with problems such as routing (the determination of the most efficient paths through a network) and flow control (dealing with network congestion).

The best-known network standard is the CCITT X.25 standard. Network standards also exist that define the interfaces between independent networks. Typical "gateway" standards are the CCITT X.75 and Department of Defense Internet protocol (IP).

The X.25 and X.75 standards are two elements of an extensive series of standards promulgated by the CCITT to define the operation of packet switched networks. Other standards such as X.3, which defines procedures for packet assembly and disassembly, X.21, which derives the interface between synchronous terminals and networks, and X.28, which defines the interface between asynchronous terminals and networks, also exist for other layers of the OSI model.

The X.25 standard actually contains standards for layers 1 through 3 of the OSI model. However, because its definition of standards from layers 1 and 2 is by reference to other standards, it is sometimes considered a layer 3 standard. The X.25 standard provides a set of procedures for communications between the data terminal and the communications equipment operating in a packet environment. The data-communications equipment is the node that serves as the entry to the packet network system. The data terminal equipment can be a computer, a front-end processor, or an intelligent terminal. The standard defines the packet format and control procedures for the exchange of packets between these two devices.

Standards Organizations

Standards are normally created by industry and government committee organizations. These committee organizations are formed specifically to examine and evaluate recommendations from private and public bodies, such as AT&T, IBM, or European and Asian postal telephone and telegraph organizations. The committees select the best of each of the recommendations for creation of a standard. A committee is customarily an authorized body within a larger organization, such as a technical society, government agency, or an international consortium.

It is interesting to note that standardization in the United States has lagged behind that of the rest of the world. In most countries in which industry is more closely regulated by the government, standard communications protocols have been employed for years. Standards adopted by U.S. industries are frequently incompatible with their foreign counterparts. Some headway is being made in the establishment of international standards with the gradual U.S. acceptance and use of European networking and data interchange standards.

Organizations define standards in one of two ways: (a) when a technology advances in a predictable way or (b) when technology problems can be considered in advance of the practical introduction of the technology. Formal standards bodies normally establish rules governing the way in which a technology will ideally be made available. Most of the standards organizations consist of specialists whose expertise is at least equal to that of vendors in the field (some members actually represent vendors).

The formal standards-making processes operate similarly regardless of the standards organization involved. Industry groups, regulatory agencies, and formal standards groups monitor emerging technologies. When it is clear that commercial exploitation of a technology is imminent, one or more of these organizations will establish a committee or study group to review the technology and develop one or more standards to support it. Makeup of a study group varies with the membership of the organization, but most individuals who serve in a study group are experts in a particular communications field.

Generally, the study group/committee holds hearings or meetings to discuss the technology, its objectives, and the makeup of the standards that might regulate it. In theory, during this phase, the study group is receptive to input from many sources; however, in practice, it is normally influenced by key members who have the time and experience to expend on the study efforts. In many cases, these key people are employees of a vendor or communications common carrier whose full-time job is responsibility for precisely this task. The committee may solicit public input, but most often it expects interested users or suppliers to contact it with comments or suggestions. Those who do so, and who seem to offer reasonable levels of qualification, might be invited to participate in later stages of the drafting or review of the standard.

Drafting a standard is a long and often argumentative process. The discussion period is intended to produce a consensus that can be informally summarized and serve as the basis for a document. In many cases, the committee defines only vague concepts and requirements, and a working group within the study group/committee drafts a proposal for discussion. Depending on the unanimity of the working group and of the overall committee, a proposal can take months or even years to complete. When completed, the draft is circulated to the organization at large and to interested parties who have qualified themselves during the process. When the draft has been reviewed and revised according to the requirements of the organization, the working committee submits it for a formal vote of the membership at large. If the members approve the draft, it becomes a standard.

Some of the major domestic and international standards organizations and a brief profile are listed in Appendix B.

TELEPHONE INDUSTRY FOLLOWING DIVESTITURE

The divestiture of AT&T has had a significant impact on the telecommunications industry. For this reason, the following section is provided to permit evaluation of its impact on the acquisition and operation of telecommunications facilities by local transportation agencies.

Reorganization of AT&T

The U.S. Justice Department antitrust suit attempted to enhance competition for terminal equipment and long-distance service by separating the 22 BOCs from the more competitive segments of AT&T's business. Its primary intent was to encourage telecommunications pricing based entirely on the cost of services.

The divested AT&T is approximately one-fifth its original size. Under the terms of the divestiture agreement, AT&T was required to offer network services and CPE through separate subsidiaries. However, the FCC subsequently removed this restriction and, as a result, in mid-1986 AT&T consolidated its long-distance, network operations, and equipment units. Other corporate groups in the reorganized AT&T are AT&T Network Systems, AT&T Technology Systems, and AT&T Bell Laboratories. AT&T is now free to enter nearly any competitive market it chooses. Under the consent decree, however, the company was prohibited from being involved in the information services and electronic publishing industries until August 1989.

The 22 BOCs that existed before divestiture are now grouped into seven regional Bell holding companies (RBHCs). (These entities are identical to the previously mentioned RBOCs.) The RBHCs are disassociated from AT&T and are free to conduct business with any equipment and facilities vendor they choose, either AT&T or any of its competitors. The RBHCs can sell but not manufacture CPE. They have retained their yellow page service, along with their local exchange and exchange access service. Recently, the RBHCs have begun to diversify into many new areas including real estate service, computer retail operations, software development, and LAN design and installation. It is in these unregulated markets that the RBHCs anticipate significant growth opportunities.

The local operating companies that form the RBHCs serve market areas called local access and transport areas (LATAs). A LATA is defined as a geographic area within which a local exchange company (including all BOCs) have the monopoly franchise to provide service. Every area served by a BOC within a state must be included in a LATA. A LATA is further defined as that area that encompasses one or more continuous local exchange areas serving common social and economic purposes, even if these LATAs overrun municipal or other local government boundaries. However, LATAs are not allowed to cross state boundaries or include two standard metropolitan statistical areas unless approved by the federal court. The RBHCs may not do business or carry traffic beyond their LATAs except into an independent local operating company territory or where corridor exceptions occur. (A corridor may be allowed to avoid excessive network rearrangement costs by the RBHCs.)

Equal Access

As part of the modified divestiture agreement, all BOCs with the technical capability (i.e., with electronic switching systems) serving a market with at least 10,000 access lines must offer equal access to all long-distance common carriers. A recent assessment by the Justice Department determined that equal access is now available on the majority of telephone lines served by the BOCs. Because of the costs and technical requirements involved in converting to equal access, total market conversion may not be completed until the 1990s.

It is the responsibility of customers to select and make the arrangements for a primary carrier. If this is not done, the local telephone company will assign the customer to a primary carrier. Carrier assignment is made randomly, but the total magnitude of assignments made to individual carriers is based on the percentage of market share of each primary carrier.

Customer access charges for connection to the long-distance networks have been implemented by the FCC and are payable to the local telephone company. Monthly access charges vary by type of service, but they normally range from $3 to $6 per line.

State Regulation

The issue of FCC preemption of state regulation has been one of the most controversial issues affecting telecommunications regulation in the United States. It became the focus of industry attention in May 1986 in *Louisiana Public Service Commission v. FCC* when the Supreme Court ruled that the Communications Act of 1934 bars the FCC from preempting state regulation of the depreciation of dual jurisdictional property for intrastate rate-making purposes. Although the Supreme Court in its decision did not reject the FCC's preemption authority, it did rule that the commission does not have the right to preempt state regulation merely because it conflicts with federal telecommunications policy. Preemptive action should be taken in cases in which the interstate and intrastate components of telecommunications facilities or services cannot be separated. This Supreme Court ruling, industry analysts agree, has significantly weakened the preemptive powers of the FCC and has subsequently led to a more cautious approach by the commission on this issue.

For example, recently the FCC took limited preemptive action against the Wisconsin Public Service Commission in response to a request by a fiber optic network operator, Norlight, to be exempted from state rate and entry regulations. Similarly, petitions by US Sprint and MCI regarding interexchange regulations of the Connecticut Department of Public Utility Control resulted in no preemptive action by the FCC to prevent the practices opposed by the interexchange carriers (IXCs). This caution, which is likely to characterize the FCC's approach to future preemptive issues, may also affect the speed and manner in which new services and additional competition are introduced into the U.S. telecommunications market.

In addition, future court challenges to earlier FCC preemption orders may alter the competitive environment already established. Shared tenant services and the provision of private-line voice and data services by cable companies are examples of areas that may be affected.

In issuing its first full preemptive order since the Louisiana decision, the FCC has already encountered significant opposition. The order, effective January 1987, detariffed telephone company installation and maintenance charges for all inside wiring and removed the telephone company's obligations to offer inside wiring services. More confident of their rights, Virginia and California have joined with the National Association of Regulatory Commissioners in requesting that the FCC reconsider its decision. If unsuccessful, the state authorities have indicated that they would probably challenge the preemptive order in court. Similarly, the Maryland Public Service Commission, citing the Supreme Court decision, is challenging the FCC's authority to detariff the billing and collection services of local exchange carriers (LECs). The FCC had determined in a previous ruling that these billing and collection services were not communications services, and the LECs would therefore be free to charge whatever price they desired. The Maryland Public Service Commission is petitioning the FCC to relinquish to the states the authority to determine how much telephone companies may charge IXCs for disconnecting local service and for nonpayment of IXC long-distance bills.

Other Regulatory Issues

Another area of regulatory controversy involves the waivers of consent decree restrictions. Restrictions barring AT&T and the RBHCs from offering information and electronic publishing services also prohibit the RBHCs from manufacturing CPE and offering long-distance services. If an RBHC wishes to offer any type of service other than local exchange or exchange access, it must be granted a waiver of the decree by Judge Greene, based on recommendations by the Justice Department. American Telephone & Telegraph recently made a proposal to the federal court that the FCC take over the Justice Department's advisory role in reviewing requests for waivers. This proposal is being opposed by the FCC, which questions its own authority in antitrust issues and its resources to handle this responsibility. State regulatory authorities are also opposing the proposal for fear that states' rights would be adversely affected by the increase in FCC influence. At the heart of this controversy is the concern that the FCC is moving too quickly to implement a national, unregulated, and competitive telecommunications environment without establishing effective safeguards to protect user groups and prevent future market domination by AT&T and the RBHCs in specific market areas.

CHAPTER THREE

TYPES OF TELECOMMUNICATIONS SYSTEMS

TELEPHONE SYSTEMS

The telephone system is the most pervasive form of telecommunications in use today. Although almost everyone is familiar with its use, few are familiar with the details of its operation and available features. As a result, many organizations have failed to install telephone systems that effectively satisfy their business requirements.

System Function and Equipment

The components of a typical business office telephone system are shown in Figure 10. These include:

- The telephone set, which is also known as the station equipment. It is the device from which calls are initiated and received by the user.
- The switching equipment. This is the main distribution point for routing incoming, outgoing, and internal calls.
- The support of office automation and data-communication applications.
- The trunk lines used to connect the telephone switching equipment with the telco's central office. The central office switch interconnects with other users in the local calling area or with long-distance trunks for calls outside the local telephone system.

During the past decade, state-of-the-art switching and station equipment has been introduced with greatly expanded capabilities. In addition, equipment is being offered with the capability of providing significant improvements in the quality and quantity of information that can be transmitted over trunks and lines.

However, in spite of these improvements, the overall structure and components of the telephone system remain unchanged.

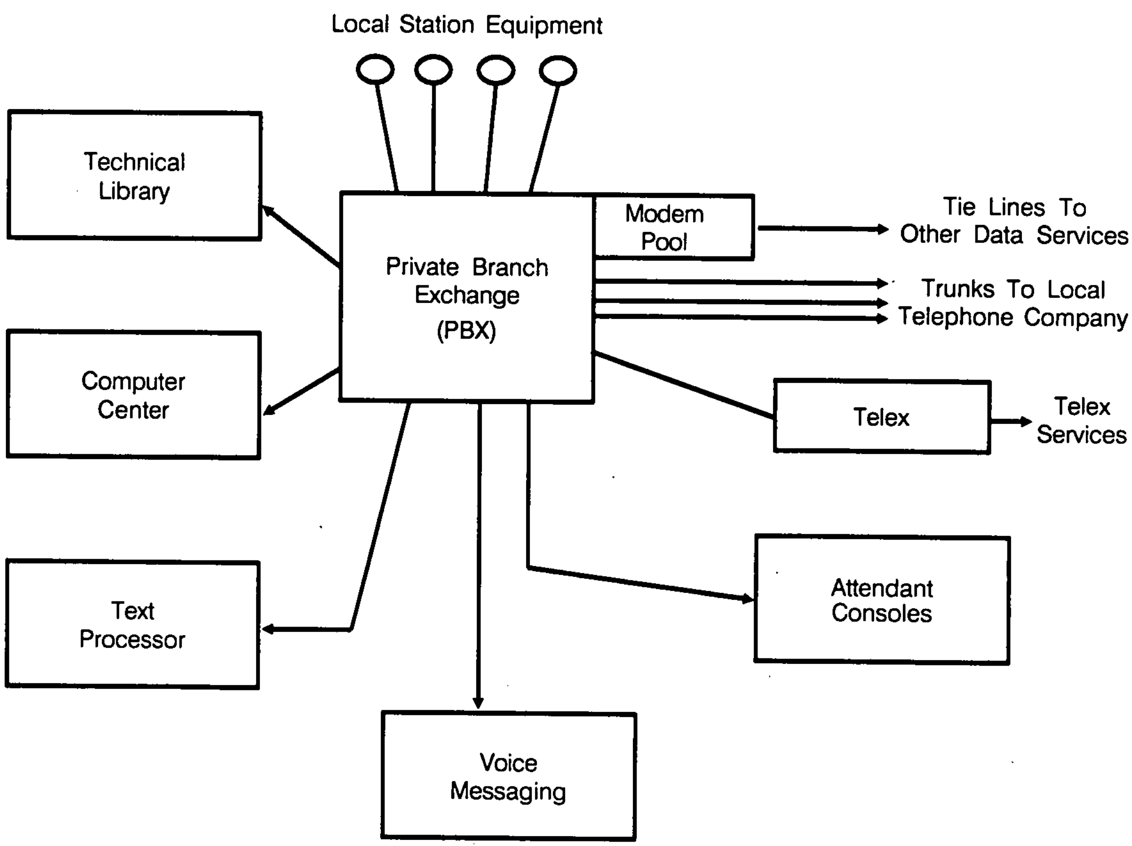

FIGURE 10 Business communications system.

Key Systems

The term "key telephone" originated more than 60 years ago during the development of the first commercial business systems. The term is a carry-over from the early days of telephony when the mechanical arrangements called "keys" were used to close a circuit in a manner that is similar to that of the old telegraph key. Each of the buttons on a key telephone set is designed to close electrical contacts for connection with a discrete line.

Key telephone design has its roots in electro-mechanical technology. The fundamental design characteristic of a key telephone system is the one-to-one correlation between a telephone central office line and a key button. Access to these lines is provided by multiple appearances of the same line on several telephones. As the need for access to many lines develops, additional "keys" or buttons must be provided on the telephone set. The older electromechanical key telephone sets, such as the AT&T 1A2 and Comkey systems, and their associated cabling can become extremely large as these systems increase in size.

Modern electronic key telephone systems using microprocessor technology offer a broad range of user features and reduced station wiring requirements through the use of integrated circuit technology. However, the one-to-one relationship between incoming lines, and their appearance on the station equipment in the form of keys, remains a basic characteristic of these systems.

It is essential to recognize the presence of this common set of characteristics among key systems, because their basic design limits the size and design configurations possible with these systems.

PBX Systems

Six basic components make up a PBX system:

- Common Control
- Switching Matrix
- Network Interface (trunks)
- Terminal Interface (station lines)
- Terminals (telephone stations, etc.)
- Transmission Media

Line and trunk circuits are used to connect or terminate telephone central office trunks and telephone stations. These are the transmission media used to communicate with user telephones or the public switched network. The PBX switch system's matrix and common control provide the basis for system operation.

The basic structure of the PBX switch has evolved from the manual switchboards of the past. The operations that switchboard attendants once performed manually, making connections by inserting and removing cords to a jack panel, are now performed by electronic circuitry. The development in recent years of stored program control systems has been nothing more than the application of computer technology to the functions formerly performed by an attendant.

Common Control

System control is essential to the operation of a PBX. The processor performs the functions contained in the program instructions. This includes monitoring all extensions, trunks, and special service circuits such as tie lines and the processing instructions dialed into the system by users (dialed number, feature codes, etc.). In addition, the processors in the majority of modern systems perform maintenance routines and indicate the existence of any problems as they occur.

The system control memory contains a large data base that includes definitions of the line functions and call-handling procedures. This information enables the system to assign unique sets of features to station users and define the manner in which calls should be processed. The ability to access a programmable data base that defines the system configuration and operation is the key to the capabilities of the modern PBX systems. An example is automatic route selection, sometimes called least-cost routing. This feature is used to determine the long-distance services to be used for completing outgoing calls based on the user making the call. An important advantage in processor-controlled switching systems is the ability to install new features and upgrades by making data base and program changes without disturbing the system's operation.

Virtually all small and medium-size PBX systems operate using commercial A/C power. Consequently, should there be an interruption to this service, the PBX system will fail. Most manufacturers offer service alternative arrangements at extra cost that will sustain a minimum level of service as a form of emergency operation. As an alternative to this arrangement, an uninterruptible power supply may be installed at additional cost.

When commercial electrical power is restored, the backup program for a system, usually a magnetic tape or disk, is used to reload the system control program into the system's random access memory. A variety of memory configurations and combinations of types of memory storage devices have been introduced in recent systems. The need for flexibility and reliability continues to motivate system designers to develop improvements in stored program technology.

Switching Matrix

The switching matrix is used to provide a communications path between pairs of lines connected with the PBX. In modern systems, the matrix design uses a time-division multiplexing (TDM) methodology in which periodic samples are taken from the analog voice signal, converted to a digital value, presented to the TDM system, and transferred into a series of time segments called "time slots." Different time slots are assigned to each line. In some systems, the analog-to-digital conversion is performed by the station equipment rather than the switch.

The signal samples, each in their respective time slots, are transmitted on a physical transmission path called a bus through the system. Switching is accomplished within the common control computer by assigning the signal samples to the appropriate time slots. At the receiving end, the samples of binary digital information are converted back to analog voice.

The analog voice signal is represented digitally using PCM. With PCM, the analog signal is sampled at a uniform rate (typically 8000 samples per second), and the sampled signal is translated into a digital code (usually 8 bits), the value of which represents the amplitude of the signal. In order to preserve the audio quality of the transmitted signal, the translation between analog amplitude and digital code is performed as a nonlinear process. As a result of these values for sampling and digital representation, PCM transmission typically requires a data rate of 64 kb/s for high-quality transmission of voice signals. However, extensive research is being conducted that offers the capability for transmission and switching of voice signals without reducing audio quality. Experimental systems are in operation that claim to provide equivalent quality at data rates as low as 19.2 kb/s.

It is important to note that the sound quality of digital transmission versus analog transmission is rarely evident to a user on a standard voice call. The benefits of digital transmission include: (a) the ability to perform signal quality error checking and correction; (b) the ability to support voice and data communications over the same transmission facilities; and (c) the ability to transmit larger quantities of information by using digital wideband transmission facilities. Perhaps most important, the digital representation of voice communications is the basis for the modern PBX operation.

Trunk Interface

Private branch exchanges interface with the public switched telephone network and other switches by means of trunks. Trunks can be configured for various traffic arrangements, such as incoming, outgoing, combination (transmission in two directions), direct inward dialing (DID, which provides service directly to station users without going through the system's attendant), and tie trunks (connecting two or more PBX systems directly).

The trunk interface circuitry within a PBX is the physical point of contact with the transmission facilities that connect the system to other systems and the public switched network. Most PBXs provide four-wire matrix technology (a dedicated path for both sending and receiving) to support trunk transmission requirements.

Wideband Transmission

Perhaps the key advantage of PCM is its compatibility with T-carrier transmission systems. This has led to the popularity of PCM for digital telecommunication networks. The potential benefits of PCM can be better realized through digital networking. A T-carrier facility (24 voice-grade channels per circuit) can interface directly with many PBX systems. Consequently, high-capacity connections can be made to telephone central offices or several digital PBXs can be interconnected from end-user digital terminal to end-user digital terminal through a T-carrier transmission link. This can result in savings by reducing trunk facility requirements between switch systems with high traffic volume or a community of interest.

It must be emphasized that use of T-carrier connections in a telecommunications network design can carry an inherent risk. Should there be a failure of a T-carrier transmission connection, 24 channels (trunks) will be out of service. This can be devastating from a business operations viewpoint. Therefore, T-carrier network designs should always have a contingency plan that supports a fallback position for service.

The potential for high-speed data transmission using T-carrier facilities (requiring no digital-to-analog or analog-to-digital conversion) is a major factor in the transition to all-digital telecommunications facilities in which digital transmission facilities are connected to digital switches with end-user terminal equipment that provides all digital signals.

Station Equipment

The standard interface between a user and the system is the telephone set or "voice terminal." The primary terminal is usually designated the attendant console. In most systems the console includes limited system control capabilities as well as features equivalent to those of a standard telephone set.

Modern PBX systems are being provided with new electronic telephone sets with the capability of supporting enhanced features in place of the traditional single-line set and key telephone unit. These sets offer simplified selection of features through the use of dedicated buttons, a capability that has increased the acceptance of this equipment. Electronic sets have significant advantages, including ease of feature access, provision of multiline capability, user-controlled programming of stored telephone numbers, direct interface with data terminal equipment, and reduced cabling requirements.

Integrated Voice and Data

Private branch exchanges are becoming more and more sophisticated and voice-data integration concepts are in the forefront of PBX system architecture and capabilities. The key factor is the compatibility of the terminal device with the switch. Nonvoice terminals that can interface with modern PBXs include CRTs, PCs, printers, facsimile, and freeze-frame video systems. Most systems today can support a wide variety of low- to high-speed data terminals, and support for higher-speed devices, such as full-motion video systems, is under development. Several PBX systems also provide vendor unique protocol support.

Automatic Call Distributors

More and more public organizations are discovering the benefits of ACD systems. These systems provide increased productivity, cost reduction, and good relations with the target population. Call distribution systems can have a major impact on how the public may view an organization and the success of its mission.

The basic functions of a call distribution system include:

- automatically answering incoming calls as they arrive in the system,
- placing calls in a holding queue until the next agent is available,
- switching and/or distributing calls to a group of agents in such a way as to maintain a relatively even level of activity among agents, and
- providing timely management information about the status of the system.

Automatic call distribution systems typically have four basic components:

- Incoming lines, which can be regular long-distance lines, 800 service lines, PBX lines, or facilities from a special common carrier.
- Agent positions.
- Supervisory position.
- The ACD itself, which:
  accepts the calls,
  routes them based on the system design, and
  provides detailed management information about system performance.

Each ACD system can be configured for a prescribed method of call handling based on the unique needs of each organization. Automatic call distributors can be either free-standing systems or an integral component in a PBX system. Each of these systems has a number of unique features, in addition to the features found on most PBX systems.

The most familiar use of call distribution systems is in the airlines industry. When a reservations call is made, one of two things will happen; either the caller will be connected with a reservations agent or the caller will receive a recorded message indicating that all agents are busy and asking the caller to remain on the line. Individuals placed on hold will ultimately be connected with the next available agent. This is typical of ACD operation.

Voice Processing

Better and faster call completion offers increased productivity and efficiency to business telecommunication users. A common annoyance in modern business is "telephone tag." This is defined as calling someone who is unavailable, leaving a message to have the called party call back, only to be out of the office when the call is returned. Studies conducted in office environments without voice messaging products show that more than 50 percent of all calls fail to reach the intended party on the first attempt.

Until about eight years ago, there were limited solutions for handling incoming messages. A telephone answering machine, one popular solution, was generally found to work better for residential users than in the office environment. More widely used methods included an answering service or message bureau, specialized telephone system features, and the use of receptionists to answer incoming calls. However, there was significant inefficiency as well as uncertainty as to whether messages got through to desired parties on a timely basis. Although the new PBX equipment offers many features intended to minimize this problem, none of these capabilities offer a complete solution to the problem.

Voice processing (VP) systems, also known as "voice mail" or "voice messaging" systems, handle calls that do not reach the intended called party. These specialized computer-based systems record and transmit voice messages. They are either integrated with a PBX or added as a peripheral system. The caller sends a voice message to the system, where it is digitized and stored on a magnetic disk subsystem. Some of these systems also offer a broadcast capability that permits a user to dictate a message and instruct the system to route the message to one or more other "voice mailboxes" or deliver the message outside the system.

Existing VP capabilities include messaging services targeted toward any size business user and networking, which allows the cost-effective bulk transfer of messages over long-distance facilities during off-peak hours. Voice mail networking allows all users on a system to receive or leave a message on the network by dialing a local telephone number. In this type of configuration, a user with a national organization could leave a message for someone in New York, Washington, and Sacramento by making a single local call.

A basic VP system has several distinct components. Because it is a computer-based system, the primary component is the system's central processor. Specialized software controls the system's operation. Devices that convert analog voice signals to digital form and back are key elements, because the information is stored and manipulated as digital data. High-speed magnetic disks with storage capacities ranging in the hundreds of megabytes hold all voice messages. The input/output units for the system are usually two-way tie lines that connect to an associated telephone system.

Voice processing technology generally requires dialpad (touch-tone) input for operation, although some systems have optional tone converters available to permit rotary dial input. Otherwise a system will default to an attended position. A number of specific codes must be entered to properly use the system's features, and most manufacturers provide detailed instructions and dial overlays that explain the various codes.

One of the most important developments in VP technology is the ability to integrate voice messaging systems into a PBX or Centrex. When VP subscribers want to access their mailboxes, they call an access number. Because VP systems integrated into a PBX can usually accept information from the host regarding the nature of a call in progress (e.g., that the call is being forwarded from a particular extension or that it is an outside call from a DID line), the caller forwarded into the VP system does not have to redial the extension number of the called party; the connection to the voice messaging system is automatic. An additional benefit of integration is the ability of the VP system to send message-waiting commands to the PBX, which then signals the user that there is a message in his or her mailbox. This indication can be a broken dial tone, a message-waiting lamp on the user's phone, or a callback from the VP system.

One of the most important aspects of some VP configurations is remote access. Users can get into the system from outside the associated telephone system. However, it requires a special number dedicated exclusively to the VP equipment. Some PBXs have a direct inward service access feature. This capability supports entry into the PBX for access to system features and works well with a VP system. The caller sends a voice message to the system, where it is digitized and stored on a magnetic disk subsystem.

Some VP systems offer a broadcast capability that permits a user to dictate a message and instruct the system to route the message to one or more other "voice mailboxes" or to deliver the message outside the system.

A creative transportation application of VP systems is being considered by one major city for distribution of traffic congestion information. Major urban areas are divided into a number of regions or corridors. Some traffic system designs define metropolitan regions by using a rectangular grid forming sets of quadrants, whereas others define a region in terms of a transportation corridor. When using a VP system for a traffic information application, each quadrant or corridor can be allocated an individual voice mailbox in which messages are stored. The message for a particular quadrant/corridor describes the traffic conditions within its boundaries. Incoming callers requesting traffic conditions for a specific geographical area are provided the mailbox code by a voice response unit (automated attendant) and the caller inputs the code (touch-tone access number) to access the recorded information. Traffic conditions are readily modified by an operator who periodically records a new set of conditions.

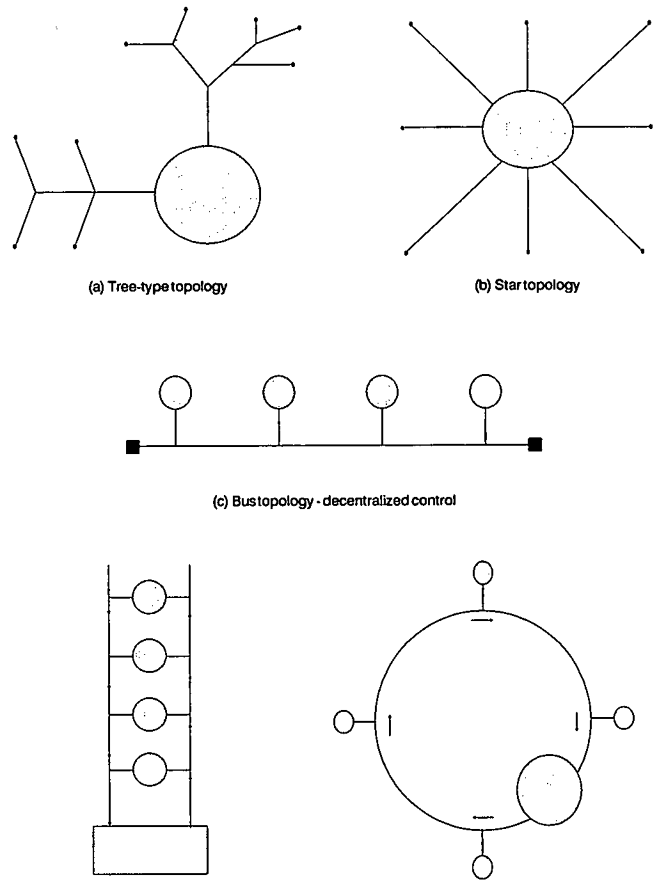
(a) Tree-type topology
(b) Star topology
(c) Bus topology - decentralized control
(d) Bus topology - centralized control
(e) Ring topology - centralized control

FIGURE 11 Popular LAN topologies.

LOCAL AREA NETWORKS

A LAN is defined as any data-communications network designed to serve a limited geographic area. Typically, a LAN will serve a single building or campus. The term "network" is a reference to the fact that multiple users are interconnected. This definition excludes telecommunications such as the public telephone network or a CATV network. Local area networks are used to interconnect digital computers, printers, word processors, and other equipment to simplify the transmission of text and graphics information among workers in a business or educational environment.

Examples of applications in which a LAN may be used include:

- The need for a number of PCs to access a common data base (computer storage of information) too large to be stored and maintained on multiple PCs.
- A central data base that must be updated by multiple users.
- The need for special-purpose devices that are too expensive to be purchased for each PC.
- The need for frequent exchange of information among computer users, such as a group of individuals working on a large project.
- The need to access a number of different computers.
- A desire to minimize the delay of information flow or reduce the amount of paper in an office.

There are many reasons for installing computer networks in medium or large offices. However, the justification for such an implementation should be examined carefully to avoid the acquisition of a system when it is not needed or cost-effective.

In the past decade, LANs have grown increasingly popular. Local area networks provide a way for microcomputers to communicate with one another and with other intelligent devices without relying on expensive mainframe computer systems. Local area networks were initially used for small office equipment and then for PCs. These decentralized interconnections among inexpensive, shared systems are now being extended to such diversified applications as factory automation, CAD, and online traffic control systems.

Network Topologies

There are three standard configurations for LAN topologies (its physical shape): (a) the star, (b) the bus, and (c) the ring configurations (see Figure 11). Each topology offers unique advantages and disadvantages that should be considered when designing a LAN.

Star Topology

The star topology system is most familiar to users of large mainframe or minicomputers. This configuration also applies to PBX systems, in which all telephones are connected to a central switch. Star configurations are also used with video display terminals and PC terminals in which all the outlying stations are physically connected to the communication ports of a central computer (PC, minicomputer, or mainframe) that is configured to operate as a multi-user system.

Communications protocols used with a multi-user system operating in a star topology are generally controlled by the central processor. All data transfers with the user workstations are initiated by the central processor using a polling technique. A variety of mainframe, mini, and PC software is available for the support of multi-user systems. The UNIX and OS/2 operating systems are the most popular systems for the support of this configuration.

The primary advantage of the star configuration is that it permits the purchase of lower-cost user workstations, because many of these configurations rely on the central computer to provide processing for the user. However, its primary disadvantage is the fact that all stations on the network will be disabled in the event of a central computer failure. A second disadvantage of the star configuration is that system expansion can be costly, because the central computer must be replaced when its capacity has been exceeded. It must be recognized, however, that the reliability of the PBX is equally critical to telephone facilities. Because the typical PBX provides redundant components and a power backup system, failure rates of one per five years are achievable in a typical PBX design. As a result, the use of a central PBX in a star configuration does not represent a significant single point of failure.

Bus Topology

The bus topology is the most popular LAN configuration in use today. This is the topology on which both the Ethernet and the token bus protocols are based. The bus configuration consists of a single transmission medium (usually coaxial cable, although both fiber optic and twisted-pair cable are becoming quite popular) that serves as the communications path for all data traveling between pairs of devices connected to the medium.

The Ethernet protocol is a contention protocol in which all workstations compete for access to the bus. A workstation with data to transmit samples the bus to determine whether another device is already transmitting data (carrier sense). If no data are being transmitted, the workstation initiates its transmission (multiple access). Following the initiation of transmission, the workstation continues to monitor the bus to determine whether another station has also initiated transmission (collision detection). If a collision has occurred, both workstations cease their transmission and "back off" for a randomly determined time interval. At the end of this backoff period, they again initiate transmission. Because of its operating procedures, this protocol is designated carrier sense multiple access with collision detection (CSMA/CD). It is a reliable form of contention communications that has been in use for many years. However, loading problems will become evident to users when the total bus loading exceeds 20 percent of the available communications capacity.

The bus length of CSMA/CD systems is typically limited to approximately 1000 ft. Typical contention systems provide data rates of 10 Mb/s on coaxial buses, although systems are commercially available with data rates as high as 50 Mb/s.

Token bus systems, like token ring systems, provide shared access to the bus. In this case, each workstation sequentially receives a digital code known as a token, which provides it with access to the network. When the workstation has completed its transmission, it passes the token to the next workstation on the system. Token systems operate at data rates that are similar to those of contention systems, except that loading problems do not occur until network loading exceeds 50 percent of the available communications capacity. However, these systems are more expensive to implement and require special equipment or procedures to avoid the problems associated with a workstation failure, which would prevent the operation of the token-passing scheme.

The primary advantage of the bus topology over that of the star configuration is that network growth can be readily accommodated through the connection of additional user workstations and specialized processors to the communications bus. Because most bus systems are designed for independent operation of individual workstations, each processor must provide the capacity required to execute the user's applications software. As a result, user workstations are generally more expensive for bus topology than for the star configurations.

Ring Topology

The ring configuration offers similar advantages and disadvantages to those of the bus topology. This topology is limited exclusively to the token-passing technique. Its primary advantage over the token bus is the fact that tokens can be passed in either direction around the ring. The IBM LAN is based on the use of the token ring protocol.

Although the ring topology is specified by IEEE Standard 802.4 and the token bus topology is specified by IEEE Standard 802.5, both specifications define the token-passing process. Arbitration by token is deterministic because each node in turn will eventually receive the token and ensure that the communication of each member of the nodes will be sent. As long as the number of nodes does not become excessive, the typical $1/_{30,000}$ sec delay time per node has little effect on system capacities.

Dual ring configurations may be implemented to eliminate the possibility of a failed device inhibiting the token-passing process. In this configuration, tokens are passed in opposite directions around each of the rings.

Baseband, Broadband, and Telephony LANs

All LANs belong to one of three basic categories: baseband, broadband, or telephony. Baseband and broadband LANs can operate using any of the network topologies described in the previous section. In addition, both forms of LAN implementation can operate using either the contention or token ring protocols. Telephony-based LANs are constrained to a star configuration, except that a PBX rather than a central processor controls the operation of the LAN configuration.

Baseband LANs

A baseband system uses a single carrier line with a specified base voltage and then reverses the voltage to represent an "on" bit for each specified period of time. This network signaling resembles the bit flow that occurs along a fixed direct connection between a PC and its printer or other device. Many baseband networks use variations on this idea.

As shown in Figure 12 information transmitted using a baseband LAN differs from that which is transmitted using a modem in that the information is unmodulated. Instead, an interface device known as a data service unit (DSU) is used to translate the information from a unipolar transmission, in which two different voltage levels are used to represent ones and zeros, into a bipolar transmission, in which negative and positive voltage transitions of equal value are used to represent the binary information. Baseband LANs differ from broadband LANs in that only one transmitter can make use of the LAN medium at a time.

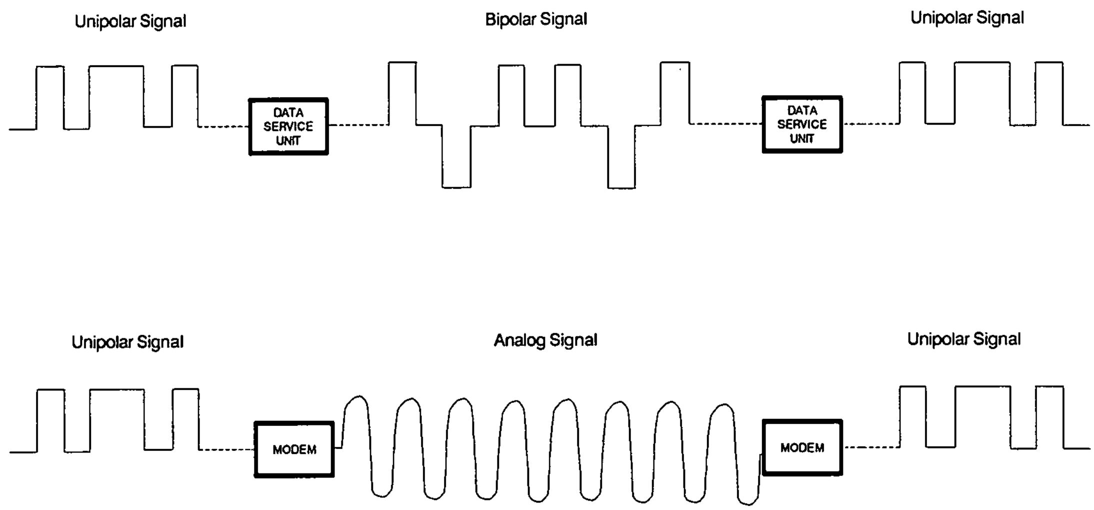

FIGURE 12 Baseband LAN signal versus modem signal.

Broadband LANs

In contrast to baseband, a broadband line simultaneously transmits information from multiple sources. The total cable bandwidth is divided into channels that can provide simultaneous transmission of different information on each of the independent channels. Thus the broadband LAN can be used for simultaneous television transmission, point-to-point data transmission, or LAN applications. The LAN operates as if it were a bundle of individual cables with the functions of each cable provided by a single channel.

The design of a broadband LAN design is usually identical to that of a CATV system. The total cable bandwidth that is divided into channels can provide simultaneous transmission of any mix of data, video (television), and voice communications using different channels. The broadband LAN designer allocates channels to different functions as if they were independent cables with the functions of each cable provided by a single channel (for example, stations transmit at approximately 50 MHz and receive at about 219 MHz). Each channel of a broadband LAN operates as a simplex communication path either between the transmitting device and the head end of the broadband LAN or between the head end and a receiving device.

Every broadband system requires a head end to act as a signal processor to receive an inbound channel and convert it to an outbound channel. These inbound/outbound relationships are fixed—a head end does not operate as a switch that will connect inbound and outbound channels at the direction of the transmitting equipment.

The head end can also serve as the interface between the broadband LAN and a satellite ground station to receive broadcast or closed-circuit data. It can also be connected with other CATV systems to receive transmissions from these systems.

Whereas digital devices can use transceivers or DSUs (combined transmitter and receiver) to tap directly in to a baseband system, broadband systems require a more costly modem on each network interface unit to make the transition from raw bits to the radio spectrum frequencies.

Telephony LANs

The PBX system also offers the ability to interconnect digital devices in a local area. This approach, which is consistent with the telephone system design, is significantly different from the baseband and broadband approaches in that individual physical and electrical connections are made between the circuits of the transmitting and receiving devices. This connection is known as "circuit switching." There is a dedicated wire pair for each data terminal device. The baseband and broadband LANs are configured so that all devices are permanently connected to a single cable. Connection between two specific devices is established through timing and addressing procedures that permit each device to know when to transmit or receive the data currently on the cable. This is known as "virtual switching."

Most state-of-the-art PBX systems can transmit and switch asynchronous data communications at speeds up to 19.2 kb/s and synchronous up to 56 kb/s over a standard, nonloaded, two-wire loop for distances up to 4000 ft with a bit error rate of 10^{-6} or better. There are also central office-based switch systems that can provide integrated voice and data capabilities for distances up to 2.5 miles from the central office.

It is worth noting that voice and data services can also be provided through remote peripheral modules that can be located up to 75 miles away from a PBX or central office switch system. This arrangement requires special transmission connections but is very cost-effective in office automation applications using centralized processing systems with station densities of 100 lines or more.

A major difference between the telephone-based system and that of a LAN is that most switch systems present what is essentially a "hollow pipe" for transporting data-communications signals. The system does not change, alter, or otherwise tamper with characters or bits when passing data-communications signals. Inherent in this, however, is the fact that neither does the system offer any form of protocol conversion. However, this capability can be provided through the use of an external device known as a protocol converter.

Normally, a data terminal is interfaced to a switch system through an add-on data module that allows for the direct connection of synchronous data or asynchronous data terminals. It can be an integral component of a telephone or configured as a stand-alone unit. In addition to the module, a user must also install special data interface cards in the PBX switch system.

With a 24-channel digital trunk interface (DTI), PBX systems can transmit voice and data in digital format directly to a compatible central office telephone switch or to another PBX system via cable, fiber optics, microwave, satellite, or leased facilities. The DTI emulates a channel bank on the carrier side of a connection and an analog trunk on the PBX side. Each DTI channel can transmit asynchronous data up to 19.2 kb/s and synchronous data to 56 kb/s.

When a terminal user places or receives a data call through a PBX to the public switched network and communication must be within the voice band of 300 Hz to 4 kHz, a modem pool may be used to provide access for data terminals served by the PBX. (A modem pool is a group of modems installed at the switch that are accessed by dialing a unique number from the station. Once a connection is made from the station to the modem, an outside number is dialed to connect the modem to the receiving terminal.) When switched networks become fully digital, modem pools will not be necessary. Until then, modems, which change digital information to analog signals, must be used whenever the public network is accessed. Incoming calls from the switched network are also accepted and routed to modem pools for conversion of the incoming analog signals to the digital form necessary for transmission through the PBX to the receiving data terminal equipment.

Typical LAN Applications

Local area networks can be categorized as special-purpose and general-purpose. Special-purpose LANs may also be proprietary, with the result that they lock the owner into a single vendor's hardware or software. These types of LANs are typically found in applications in which multiple terminals are connected with a traffic control computer. General-purpose LANs, although often developed to serve a limited function, can support a variety of vendors' devices and application software.

Because of the flexible manner in which they provide communications between a wide variety of data terminal equipment, LANs have been used for a variety of commercial, governmental, and educational applications. Several of the more common business applications are described here to demonstrate the manner in which alternative configurations can be implemented.

One of the most common LAN applications is the implementation of a general-purpose office-automation system. Such a system might begin as a small Ethernet LAN with secretarial workstations interconnected to provide resource sharing, such as access to a single high-speed printer too expensive to be installed at each secretary's desk (see Figure 13). Shortly thereafter, an executive might acquire a microcomputer to be used as an executive workstation. The executive workstation is then attached to the network so its user can edit and work on material being typed by secretaries. Other executives might acquire workstations, and soon the need for a mass storage device to serve as a central repository for documents, accounting information, and so forth is identified. The system is then expanded in the manner indicated in Figure 13. In the meantime, other segments of the organization might also be developing LANs. After a period of time, a need to interconnect these LANs is identified. The needs for interconnection might include:

- transmission of electronic mail from a headquarters location to branch offices,
- the need to acquire engineering or inventory data from the district offices, or
- the desire to access a "host" computer center to use its processing power or data-retrieval capability.

Frequently, at this point a broadband LAN is installed (see Figure 13).

A number of other services could also be connected to the LANs at any of these stages, including:

- Electronic Mail—A service in which memoranda and other messages are stored at a central file in reserved file space mailboxes for each of the users on the system. Users can query their mailboxes to retrieve an electronic copy of correspondence that can be printed at individual terminals.
- Shared Resources—A number of computer peripherals too expensive to be installed at every workstation. Several of these have already been mentioned, but others might include color printers, digitizers, and plotters used for CAD.
- Modem Pooling—Efficient Access to Outside Communications Transmission Services—Telenet and TYMNET are long-distance data-transmission facilities that are cost-effective, reliable forms of communications. A LAN offers an efficient means for providing a group of users with access to these facilities without requiring individual connection of each terminal. Other outside services that can be accessed through a LAN include some of the larger specialized data bases and services available in fields such as the legal profession, medical profession, etc.
- Office Automation—Office automation is a concept rather than a discipline or technical system. It is the merging and application of both telecommunications and computer systems. Essentially it is the practice of taking mundane manual office functions and improving white-collar employee productivity. An example is the replacement of the adding machine and bookkeeping ledger with computerized spreadsheets and data base entry programs. Better still, however, it is the capability to make these computerized resources and the derived information generally available to everyone in a discrete work group.

In addition to these general examples, numerous specific examples exist within the transportation field. Typical LAN applications include:

- Local area network technology has been incorporated into many of the new surveillance and control systems implemented for both freeway and signal control applications. These systems

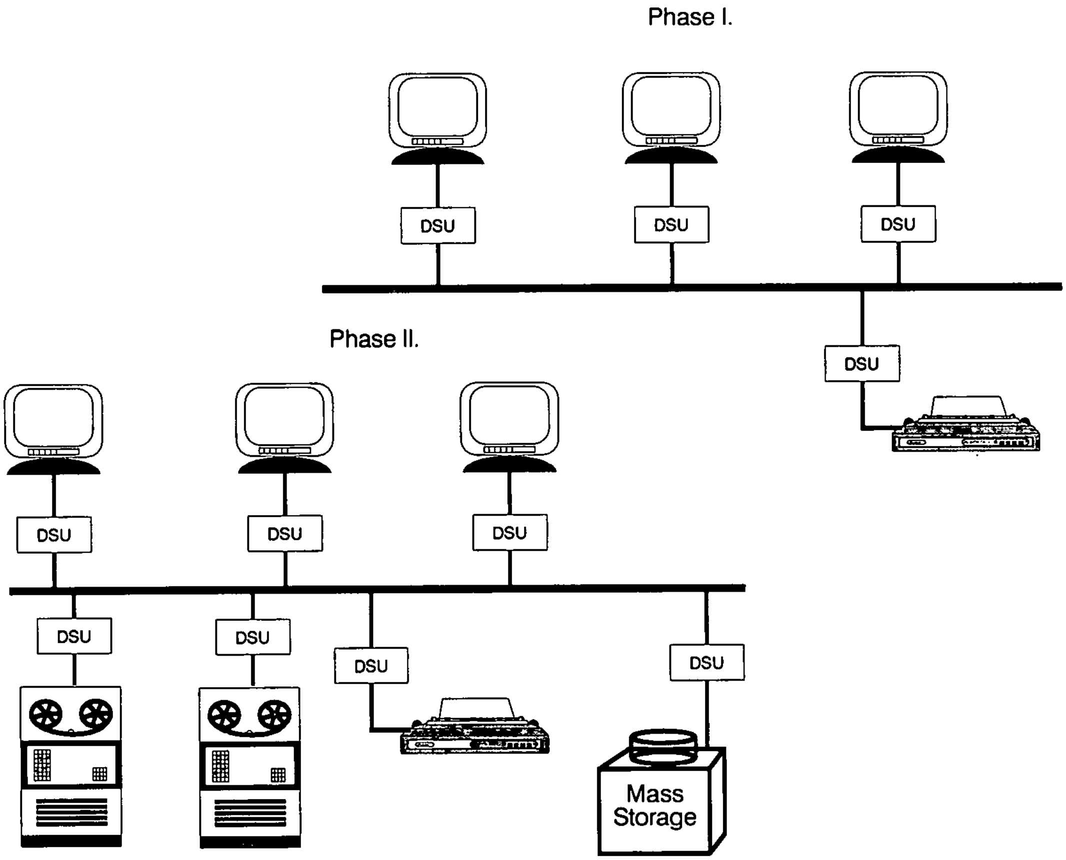

FIGURE 13 Small LAN with migration to large.

typically consist of a minicomputer to which multiple workstations are connected. The workstations are used to access the system data base, provide maintenance staff with the ability to monitor system operability, and provide numerous points for operational control of the system. New systems are under development that eliminate the need for a minicomputer and rely on PCs to provide data base management and communications control of the system.

- Local area network configurations are being developed for numerous dispatching applications. These configurations, which are used by public-safety agencies, transit companies, and maintenance organizations, provide dispatch personnel with PC workstations that display vehicle locations, mapping information, and summaries of the status of calls and mobile units.
- Local area network configurations are being installed at motor vehicle agencies and other transportation organizations incorporating multiple positions requiring simultaneous access to computer data bases.
- Computer-aided design and drafting systems are typically designed for LAN implementation in order to provide engineering and drafting personnel with access to system data bases and software and to permit common usage of expensive peripherals such as flat-bed plotters.
- Numerous specialized management information systems are in use by the transportation community for applications such as pavement management, transportation planning, sign inventories, personnel records, and maintenance records. These systems are rapidly increasing as the industry becomes more familiar with their potential.

All of these general and specialized systems are motivated by the common benefits of the LAN, which permits multiple access to data bases and resources, as well as communication between users.

Planning for a LAN

When planning for a LAN system, the first consideration should be selection of the type of system or topology that is most appropriate for the application requirements. Quite often LANs are selected based more on vendor recommendations than on technical or application requirements.

For simple system requirements, such as few PCs and a file server, an Ethernet type of system may be quite appropriate. However, for large numbers of PCs with large data-transfer volumes, a token ring system may be likely to be the best selection. Therefore, a rule of thumb is to consider the use of a baseband LAN for small office systems requirements and a token ring for large or host computer (mini/mainframe)-oriented systems.

Connections between LAN nodes can be established over twisted-pair cable, thin coaxial cable, standard coaxial cable, or optical fiber. Each of these alternatives has increasing capacities.

Devices called "bridges" are used when connecting similar LANs; other devices known as "gateways" connect dissimilar LANs to one another, LANs to mainframes, and LANs to the outside world in general.

Selection and implementation of a LAN involve consideration of capacity levels, potential for external interference, the distance covered, and future expansion requirements. A detailed engineering analysis can be worthwhile, because of the significant difference in the costs of alternative LAN media. Typical trade-offs include the use of twisted-pair as an alternative to coaxial or fiber optic cable and optical LED instead of ILD. Obviously, coaxial or fiber optic cable should be used in harsh environments, especially in environments with severe electromagnetic interference or lightning ground strike problems.

It is also important to consider the network's ability to diagnose and predict its own failure. Simple layouts and well-established procedures should facilitate quick repair.

The network should anticipate expansion. If possible, both internal building and external highway construction designs should incorporate routing ducts and conduit adequate for a minimum of 100 percent future growth. In addition, access rooms should be provided to ease the job of adding and maintaining a LAN.

Twisted-pair (telephone) cable is smaller and cheaper than coax. But coax has either wire mesh or external metal wrapping as a shield against radio frequency interference. Shielded twisted-pair cable resists external interference but doesn't prevent the elements of the two pairs from interfering electromagnetically with each other. Twisted-pair cable is physically flexible. It can fit in small crevices and make sharp turns. Coax cable diameters start at ¼ in., and a coax cable requires 2 or more in. of radius to make a turn.

Coax cable can, however, carry far higher frequencies than twisted-pair cable, and thus it (or fiber optic cable) is preferred for broadband applications. Coax cable can carry much larger data rates further than twisted-pair cable, typically 10 megabits for 1500 ft versus 300 ft.

Baseband systems are significantly less costly than broadband systems, partly because they do not require RF modems. Broadband, however, can carry multiple channels and is much better suited to transmitting video signals.

Fiber Optic Use

Computer networks are the current revolution in the data-processing world. One of the more important considerations today in local communications is connectivity.

In the fast-moving telecommunications industry, the user is faced with multiple decisions that affect local networking system architecture, software protocols, topology, bridges and gateways, OSI compatibility, Ethernet versus token ring, and the like. Designers tend to use the twisted-pair wiring that has been installed for the telephone system. In IBM or Wang systems, the decision is slightly more complex—coaxial cable or twisted pairs. However, the days of an easy decision with respect to media selection are gone. The trend toward distributed processing and local networking has placed a new focus on cable.

The use of fiber optic cable for LANs is rapidly increasing. Its popularity is caused by its small cable diameter, protection against electromagnetic or radio interference, low attenuation, and large bandwidth. In addition, it readily complies with fire code regulations. Because of these advantages, fiber optic cable can be installed in crowded ducts where new twisted-pair or coaxial cables cannot be pulled. Because of its light weight, it is easy for craftsmen to handle (an optical fiber cable is about one-tenth the weight of a comparable coaxial cable).

Hybrid systems incorporating fiber transmission are frequently used by multiplexing a number of low-speed terminals onto the fiber cable, which then serves as a trunk to connect these terminals with a central computer. This approach is particularly applicable to high-rise buildings in which a fiber trunk is installed in the riser conduits for communications between a computer center and the equipment installed on individual floors of the building. The data transmission speed possible with the fiber optic cable minimizes the distance constraints that exist with typical twisted-pair or coaxial cables.

Another consideration that may lead to the selection of fiber cabling is the high data rates required for graphics file transfers that are becoming popular with desktop publishing and graphics workstations. Because the emerging standard for the fiber distributed data interface will support 100 Mb/s, fiber optics are well suited to these types of applications.

The one area in which FDDI is not well suited is broadband LANs carrying full analog video (6 MHz). A broadband LAN can easily carry multiple channels of video as well as data. Digitizing a 6 MHz TV channel results in a 45 Mb/s to 90 Mb/s data rate (45 Mb/s is a slightly compressed version), which can easily swamp an FDDI backbone.

WIDE AREA DATA NETWORKS

Wide area network data networks operate in a similar fashion to their local area counterparts. Wide area data networks have been implemented using the entire range of media typically associated with local area networks, including twisted-pair, coaxial, and fiber optic cable. In some applications, wide area networks are also being implemented using radio communication.

In general, the same principles apply to both LANs and wide area networks. However, the following potential problems and design differences must be recognized:

- Because these networks are installed over large geographic areas and may be involved with the control of systems that affect the public's safety, increased emphasis must be placed on transmission reliability, maintainability, and network monitoring.
- Many of the protocols applicable to LANs must be modified, if they are to be used for wide area networks. Specifically, the CSMA/CD protocol will not work effectively with collision-detection features. It is necessary to use specialized contention protocols capable of operating with long cable lengths.
- The increased cable lengths will generally reduce the practical data rates that can be transmitted.
- The extent of wide area networks results in a higher probability of external noise interference. Additional shielding and grounding (or alternatively the use of an alternative medium) should be considered to overcome these problems.
- The grounding procedures employed with local area networks are not applicable to wide area networks. Although conventional practice dictates that a local area network should be

grounded at a single point, wide area networks should be grounded at frequent intervals to prevent interference.

In spite of these differences, the same general principles discussed in this section apply to the implementation of wide area networks. The design of these networks should also emphasize adherence to existing standards and commercially available equipment in order to avoid the pitfalls associated with specialized designs.

VIDEOTEXT SYSTEMS

Videotext is interactive and permits a user to access a computer from home or work and retrieve information for display on a specially equipped TV set or display terminal. Teletext is one-way and permits a user to select frames of information as they are being continuously recycled by the originator of the signal. A videotext system can be divided into three major segments: the service provider, the communication network, and the user.

More than three dozen videotext experiments have been carried out in the United States. One of the largest and most complete was conducted in Florida in 1983. Viewtron operated in the Miami area until 1986, when it was closed for financial reasons.

The most successful videotext services operating in the United States have been text-only services. The largest is CompuServe, which has more than 270,000 subscribers and supports a full range of applications including news, weather, and sports information; shopping; messaging; financial services; travel information; and educational exercises. Two other popular services are Dow Jones News/Retrieval and The Source.

The federal government has provided very little direct financial support and encouragement for the development of a videotext industry. Because of the large capital outlay required and the synergism that results, companies have found it advisable to form partnerships. Three of the larger partnerships are Trintex (IBM, Sears), COVIDEA (AT&T, Chemical Bank, Bank of America), and CNRPartners (CITICORP, NYNEX Corporation, RCA).

Service Provider

The service provider operates the computer system and either maintains the information base and services that are accessed by the users or supports a gateway to other computer systems where the information and services reside. A service provider may be a cable television operator, public data network, or a company (such as a newspaper) that is already in the business of providing information. Although there are certain regulatory restraints, telephone companies are interested in videotext because it offers an opportunity to increase revenue from higher levels of telephone traffic and the sale of electronic yellow pages.

Public data networks provide long-distance communications and regard videotext as a way to expand network usage and open new markets. Publishers, especially newspapers, have been actively involved with videotext since its inception and view it as a means to combat encroachment by media competitors such as broadcasters.

Videotext services are generally provided using a computer system that prepares TV broadcast-type frames (static screens of information) that are stored in a data base for subsequent retrieval in response to requests from subscribers.

User services vary widely among systems and include activities such as electronic messaging, distributed processing, opinion polling, interest matching, telemetering, and bill paying.

Communication Network

The backbone of a videotext system is its communication network, which is used to provide the interface between the subscribers and the various information sources. The communications system may also consist of gateways, which provide the interface between two videotext systems and enable a user of one system to communicate with a second system.

Videotext systems can provide access to information services through the public switched telephone network, value added data networks, or CATV systems. Videotext networks using the telephone network may involve either or both circuit-switching and packet-switching services.

The primary advantage of using the telephone network is that it is ubiquitous and relatively inexpensive. The disadvantage is that videotext ties up the telephone line, particularly because of the low-speed transmission capabilities of the system. In addition, because of the low-speed transmission, a frame containing a lot of graphic content can require an annoying amount of time to be displayed.

Packet switching found on value added networks is ideal for videotext applications because it is very cost-effective for transmitting short messages over long distances and because most packet networks can interface with equipment from different manufacturers. However, the use of videotext services is limited to existing subscribers to value added network services.

Cable TV has two advantages over the public switched network. They are its much wider bandwidth and the limited degree of regulation experienced by the cable industry. A major disadvantage is that only about 3 percent of the systems in the United States can support the two-way flow of information needed to sustain a videotext service.

User Components

In order to view a frame, a decoder is necessary to receive and translate the videotext signal, an access device is needed to select the particular frame desired, and a terminal is needed to present the frame. These items may be combined in a single piece of equipment or operate as three separate but interconnected components.

Videotext decoders can be designed to operate with a display device such as a television set, with a data-processing terminal, or with a microcomputer. Decoders for television sets and data-processing terminals are classified as either "set-tops" or "built-ins." Set-top units are generally cheaper and permit a user to easily upgrade a display unit by connecting the decoder to the antenna jacks. Built-in units provide a better picture because they are connected to the RGB (red, green, blue) color guns rather than to the antenna jacks. A microcomputer can function as a decoder by the insertion of an interface card in one of its expansion slots or by use of a software program that converts the microcomputer into a decoder.

The subscriber interacts with the decoder using either hand-held keypads, alphanumeric keyboards, or touch-sensitive screens.

Information Base

Information in a videotext system is stored, modified, and retrieved in a physical unit called a frame. Frames are often linked together in such a way that it is possible to pass from frame to frame as each is displayed. The information contained in the frame may be presented graphically. It may have variable-size lettering and specially created characters, including full-color displays.

An organization preparing and offering information for presentation through a videotext medium is known as an information provider (IP). Any person or organization can be an IP, but in general, the primary IPs in today's market include publishers, advertisers, and government agencies. Publishers are currently the principal source of information for videotext services.

Advertisers provide information that is directed solely at marketing a product, but they may also be sponsors. An analogy is the sponsorship by advertisers of television shows that are underwritten by paid commercials. In some videotext systems a frame or set of frames is sponsored in much the same way.

Government units and public agencies constitute a major source of information. In Europe and Canada there is a considerable body of information sponsored by these two groups. Government-sponsored information is typically focused on telling the constituency about how to contact certain officials and about the different types of services available. Public agencies have dealt with issues such as consumer rights, health care, and charitable contributions.

The videotext applications currently offered can be divided into eight general user classes:

- Information Retrieval
- Commercial Transactions
- Electronic Banking
- Electronic Shopping
- Electronic Messaging
- Educational Services and Personal Transactions
- Computations and Gaming
- Teleservices

Information retrieval—or electronic publishing, as it is sometimes called—is the most popular application. It takes the form of news, weather, airline schedules, and financial data such as stock prices.

There are also a number of commercial applications, including electronic banking and shopping. Electronic banking allows a user to check statement balances, review recent checks that have cleared, transfer funds between accounts, perform personal budgeting, and pay bills. Electronic shopping encompasses the retrieval of information and the payment for goods and services.

TELETEXT

Teletext is a broadcasting system that displays frames of information selected by the user. It does not provide the equivalent of videotext's ability for the user to interact with the system for applications such as electronic banking. The frames are combined into a block called a "magazine." The size of the magazine and the form of transmission determine the duration of a cycle before a frame is repeated, and thus determine the average access time to a desired frame.

System Components

The major components of a teletext system are the service provider's equipment, the information base, the transmission network, and the equipment that receives the teletext signal.

The computer at the service provider's site can be a micro- or minicomputer. This is attached to one or more display terminals, a printer, and special terminals for creating and storing frames. A teletext system operates in the following way: Frames are created and stored in a temporary memory called the editing store. When they are to be included in the broadcast cycle, they are transferred to the main working store. From the working store the frames are continuously cycled through the encoder, where the information is converted into a serial teletext format and broadcast.

The first frame displayed when the teletext option is selected is the main index of the magazine chosen. The items in the index have identification numbers that are entered by the user with a keypad or keyboard to "grab" that frame as it cycles past. Popular frames are often repeated at several locations in the magazine to reduce frame access time. If there is a companion two-way service, it may be accessed for more information about a subject first viewed on the teletext service.

There are a variety of methods available for transmitting teletext service information. These are:

- Vertical Blanking Interval (VBI)
  - Over the Air
  - Cable
- Full-Channel TV
  - Over the Air
  - Cable
- Subsidiary Communications Authorization
  - Subscription Television
  - Multipoint Distribution Services
- Direct Broadcast Satellite

The VBI method is the most popular. The VBI is a portion of the television signal that contains information for the correct operation of the set, such as equalizing and synchronization pulses. It is sometimes visible as a black line when the television picture "rolls." Only half of the VBI is needed for synchronization and control, leaving the balance for teletext. Full-channel teletext can carry more than 100 times the amount of information as the VBI, but it requires that an entire channel be dedicated to teletext. For example, a 100-frame magazine transmitted on

Screen 103

LONG BEACH FREEWAY

City:	Longbeach
County:	Los Angeles
Area:	San Bernardino Frwy. to Santa Ana Frwy.
Incident:	Accident
Location:	Pomona Frwy. Interchange
Direction:	Southbound
Time of Incident:	3:46 P.M.
Lanes Affected:	All Southbound Lanes
Re-open:	6:00 P.M.
Description:	Accident involving Gasoline Tanker Truck. All southbound lanes closed. All southbound traffic forced to exit at San Bernardino Frwy. Backup exceeds 9 miles. Motorists should seek alternate routes.

FIGURE 14 Sample traffic data screen.

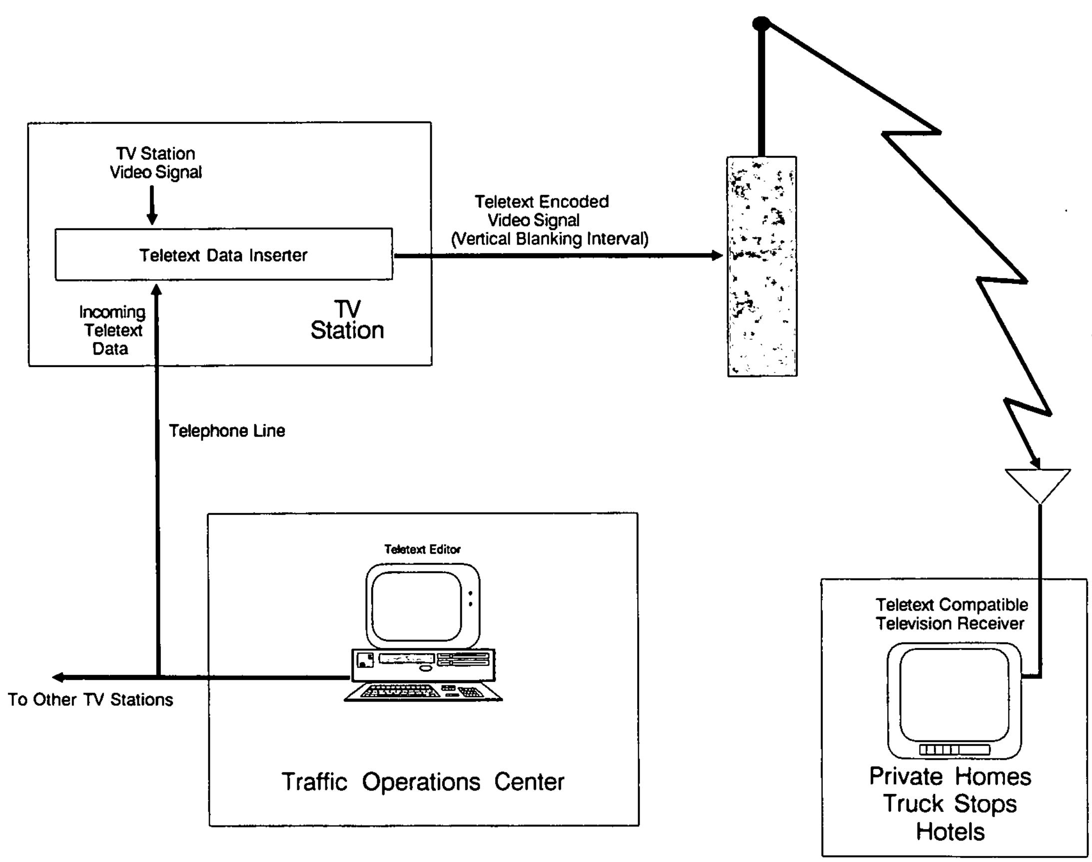

FIGURE 15 Teletext system components.

four scan lines of the VBI has an average access time of 6.92 sec. A magazine with 200 frames takes approximately twice as long. Changing the bandwidth of the transmission will directly affect the access time. The 100-frame magazine using an entire TV channel rather than just a few scan lines will reduce the access time for a specific frame to less than a second. Although this is not practical for commercial television transmission, it is quite feasible for CATV or satellite broadcasts.

Teletext receivers are generally standard television sets with the added capability of extracting and displaying data contained in the VBI of the video signal.

There are many less commonly used ways to transmit a teletext signal. The subsidiary communications authorization transmits teletext on an unused portion of the same signal that an FM radio station broadcasts its music. Subscription TV is the broadcast of a television signal over the air to subscribers with specially designed addressable decoders. The addressability feature permits the broadcaster to control and charge for special services such as teletext. Multipoint distribution services (MDS) can support VBI and full-channel teletext transmissions over the air by using microwave radio. An MDS requires that subscribers have an antenna and a special decoder. Direct broadcast satellite transmission involves the transmission of television and enhanced services from a new form of high-power satellite to small and relatively inexpensive antennas. The antennas are approximately 1 m in diameter and can easily be mounted.

Applications

Teletext is suited for information retrieval and education-based applications. Information of general interest with a short life is most appropriate because the broadcaster has to limit the size of the magazine to keep the access time low. Information should appeal to the widest audience possible. Because the magazine can be read in just a few minutes, it must be modified continuously. In some public services, editors make changes and add frames on a real-time basis as frames cycle past. Most services offer news headlines, weather, financial information, television and radio listings, and sports. In a few instances, educational material and simple games such as puzzles and quizzes may be broadcast.

The California Department of Transportation (Caltrans) is implementing a system that will provide traffic information regarding the downtown area of Los Angeles to motorists. The information used as input to the teletext system will be obtained from existing surveillance and control systems, the California Highway Patrol, and construction and maintenance schedules.

An example of an information frame that is being considered for this system is shown in Figure 14.

Teletext information will be broadcast by commercial and cable television stations in the Los Angeles area. Information will be inserted into the broadcast signal using a teletext inserter. The inserter will inject traffic data information into the VBI of the video signal. A diagram of the planned transmission arrangement is presented in Figure 15.

CHAPTER FOUR

CURRENT TRANSPORTATION AGENCY PRACTICES

TELECOMMUNICATIONS SURVEY

A survey of existing communications systems and practices was conducted to support the development of this synthesis. The objective of the survey was to identify the use of telecommunications systems within the transportation industry, both in terms of the technology being used and the applications for which it is required. The survey questionnaire, which was sent to both state and city transportation agencies, solicited information related to both voice and data systems used for administrative as well as technical applications. More than 50 responses were received from approximately 40 different jurisdictions.

As expected, the survey revealed that public transportation agencies are heavy users of telecommunications services. However, the survey also revealed the presence of many sophisticated applications throughout the United States, from which it has been concluded that the transportation industry is progressively applying the results of new telecommunications technology as it becomes available.

This section provides a summary of the survey results and includes a discussion of some of the newer systems being installed for transportation applications.

Telephone Systems

As might be expected, all public agencies currently have telephone service to support their business operations. The mix of equipment and services used by the respondents is typical of organizations that have been in existence for long periods of time. Many organizations continue to rely on the older key systems and Centrex services and have not taken advantage of the newer telephone system technology.

The following results were obtained from the 42 separate agencies responding to the questionnaire:

- Fifteen of the agencies (36 percent of the total) indicated that they currently provided telephone service using key systems. Two state highway departments operate large systems in excess of 800 lines.
- Twenty-eight agencies (67 percent of the total) indicated that they rely on Centrex service. Some of the services are used exclusively for district offices, whereas others use as many as 16,000 lines statewide. Eight other systems with more than 1000 lines were identified.
- Twenty-six agencies (62 percent of the total) indicated that they operate PBX equipment. It is interesting to note that nearly 50 percent of the agencies with PBX equipment also make use of Centrex service at different locations.
- The questionnaire results indicated that only 10 percent of the agencies used message centers and 21 percent used voice mail systems. Because four of the respondents indicated that they use both message centers and voice mail, it was concluded that 71 percent of the agencies had not implemented any form of automated answering capability.

On the basis of these results, it was not possible to identify any trend or underlying practices that characterize the telephone use of state and city transportation agencies. As indicated earlier, these results were characteristic of established governmental agencies that are constrained by the budget process and administrative requirements from taking advantage of recent technological capabilities. Considering the need for interaction between transportation agencies and the public, however, the absence of voice mail or message centers was surprising. The use of this technology should seriously be considered in view of the service orientation of this industry.

It should also be noted that many agencies operate a wide variety of equipment supplied by numerous vendors. Many of the respondents indicated that they owned as many as four different brands of key and PBX equipment. In some cases, this equipment was used in some locations and Centrex service was used in other locations. Past experience has shown that the administrative burden and economics of operating these types of systems are excessive. In addition, employee inefficiencies result in agencies in which personnel are transferred from one location to another. In many cases, a careful economic analysis can be used to financially justify the installation of a modern configuration provided by a single vendor.

Local Area Networks

The questionnaire results indicate that transportation agencies have moved rapidly to take advantage of LANs. Twenty-three out of 25 responses received indicated the installation of LANs ranging in size from 5 to 485 workstations. The majority of respondents indicated that their network sizes were fewer than 100 workstations, a fact that leads to the conclusion that these workstations are currently installed on a relatively limited basis.

Transportation agencies are using LANs for a wide variety of applications, including office automation, sharing of resources, data base management, CADD, terminal emulation, file transfers, various communications applications, and software sharing.

It is anticipated that the number of applications will increase as these networks become more pervasive because the vast majority of LANs appeared to be limited to office automation applications. For example, CADD applications are currently used by only three of the agencies. This was a surprising result, in view of the number of engineering functions performed by the majority of transportation agencies. However, the variety of applications tends to increase as the number of LAN users increases within an organization.

OTHER AGENCY TELECOMMUNICATIONS SYSTEMS

Information was solicited on the questionnaire to identify the types of communications applications currently being used by the transportation community. This category of questions attempted to identify the use of mobile radio, microwave, cellular telephone, value added (data) networks, WATS lines, satellite communications, cable television, and other forms of specialized telecommunications services. The responses demonstrated the extensive use of these various services, including:

- Only 4 of the 47 individuals responding to this question indicated that they did not use some form of mobile communications. However, because several respondents indicated that the question was not applicable, it was concluded that mobile communications were likely to be performed by another agency within their level of government. As might be expected, the majority of responses indicated that mobile radio was used for dispatching purposes. Other applications included the use of radio for telemetry, control, and monitoring field equipment. Some agencies specifically identified the use of mobile radio for highway maintenance purposes; others indicated a joint use for maintenance and law enforcement. Many agencies have moved to the newer trunked radio systems.
- Microwave systems are also used extensively by transportation agencies, including 75 percent of the states responding and two of the cities. In many cases, microwave is used as an adjunct to the radio communications system, although there were a wide variety of other uses, including telephone trunking, data transmission, communications with motorist call boxes, communications with field equipment for traffic surveillance and control, and closed-circuit television. Several respondents indicated that the microwave systems are shared by other state agencies.
- Nearly 25 percent of the respondents indicated that cellular telephone was used by their agency. Surprisingly, these systems were used for a number of applications in addition to mobile communications, including control of portable signs, data transmission for dispatching, control of stationary (not portable) variable-message signs, and administrative purposes.
- Value added network use is also surprisingly high among the transportation agencies. Although its use is limited exclusively to states (not surprising, because cities do not require the coverage offered by these networks), more than 30 percent of the states indicated that they use these services. The popularity of VAN services further supports the importance of data transmission within the transportation community.
- With the exception of 10 respondents, all agencies indicated that they used some form of wide area telephone service. Although the questionnaire identified this service in terms of the AT&T WATS offering, many agencies modified their response to indicate that other services (such as Allnet) were used. Other states indicated that the equivalent of wide area service was provided by dedicated statewide telephone systems.
- Several states indicated that they were users of CATV services, either as viewers or producers of programming. Cable television was used to monitor weather reports, to view commission meetings, and to provide information regarding road closings. It should be noted that plans are under way for the future use of CATV for more extensive reporting of traffic conditions. In addition, many organizations use their own closed-circuit television facilities to monitor traffic conditions. Although this technology is primarily used for freeway surveillance applications, it is also in limited use for monitoring traffic flow on city streets.

TELECOMMUNICATIONS USAGE FOR TRAFFIC CONTROL APPLICATIONS

Because of the significance of the role of telecommunications for both freeway surveillance and control and traffic signal control applications, a special questionnaire category was prepared soliciting usage information in this area. Nineteen responses were received in this category, all of which indicated some form of telecommunications use for these applications.

The respondents indicated that the types of telecommunications systems used for traffic control included twisted-pair cable, coaxial cable, fiber optic cable, and radio installations. Thus the entire range of communications technology (with the possible exception of satellite and microwave, which are more appropriate for long-distance communication) is in use by the transportation community.

The types of information transmitted using these systems include traffic signal control commands, detector data, sign control, ramp metering control, closed-circuit television, teletext graphics and text data, and highway advisory radio. These systems are also used for traffic counting, weather information, voice communications, receipt of lift bridge information, and lane control.

The responses indicated that:

- A high percentage of lease lines are currently in use for traffic control purposes. Sixteen of the 19 respondents indicated that twisted-pair telephone lines were leased for this purpose.
- In spite of the fact that a high percentage of leased lines are in use, not a single system is operating using CATV facilities. It cannot be concluded from this response, however, that CATV is not in use, only that none of the respondents are using it.
- The majority of systems that use coaxial cable include the use of closed-circuit television. It is likely that coax was selected in these cases to support the transmission requirements of the CCTV.
- Four agencies (more than 20 percent of the responses) are using radio for traffic control applications. This was a surprising result in view of the fact that radio has only recently emerged as a data transmission alternative to cable installations.

In general, this section of the questionnaire confirmed the fact that surveillance and control applications are an important element of the telecommunications services and systems acquired by the transportation community.

ADMINISTRATIVE PROCEDURES

The administrative procedures solicited by the questionnaire attempted to identify the types of organizations involved with the design of the various types of telecommunications systems: staff members, vendors, or consultants. This response was solicited for the range of systems for which other information was requested.

The results of this section of the questionnaire are presented in Figure 16. Because most of the agencies indicated that they use multiple sources for the design of their systems, the percentage of organizations involved in the various types of system design exceeds 100 for all categories.

As might be expected in large engineering-oriented organizations, agency personnel perform the majority of design work for most categories of telecommunications systems. The lowest level of staff participation in any category occurred in the design of fiber optic and CCTV telecommunications systems. It is likely that this response was caused by inexperience with the concepts of broadband system design. However, as broadband systems become more popular (through the implementation of various types of LANs), it is possible that the level of in-house expertise will increase.

The high level of vendor participation in these designs is somewhat surprising. The telephone system designs are dominated by vendor activities, a fact that is likely to be the result of a historical reliance on AT&T and the local operating companies. Reliance on vendor support for the design of radio systems is also likely to be the result of the dominance of Motorola in the mobile radio systems market. The use of vendors for design assistance, however, is not restricted to these markets. High levels of participation were indicated for all categories of telecommunications, even though a dominant vendor is not present in some of these categories.

The results of the survey indicated that, with the exception of microwave and CCTV, consultants made the fewest contributions to telecommunications system designs. Although this is understandable in categories such as telephone and radio systems, it is difficult to explain for the fiber optic and traffic control systems designs, particularly in view of the fact that neither of these markets is dominated by a single vendor, and at least in the case of traffic control systems design, procurement policies and federal-aid procedures require the use of the competitive bid process for acquisition of these systems.

It is recommended that in the future, transportation agencies reduce their heavy reliance on equipment vendors for the design of telecommunications systems. One of the dominant themes of this synthesis is that there are numerous alternative systems available to solve a given problem. As the telecommunications market grows, it is unlikely that companies such as AT&T and Motorola will be able to continue their market dominance. In order to ensure the acquisition of systems that satisfy their requirements in a cost-effective manner, agencies should either enhance the levels of in-house expertise or increase the use of technical specialists to support their design activities.

CASE STUDIES

This section presents two case studies of the use of new telecommunications technology. These case studies are not intended

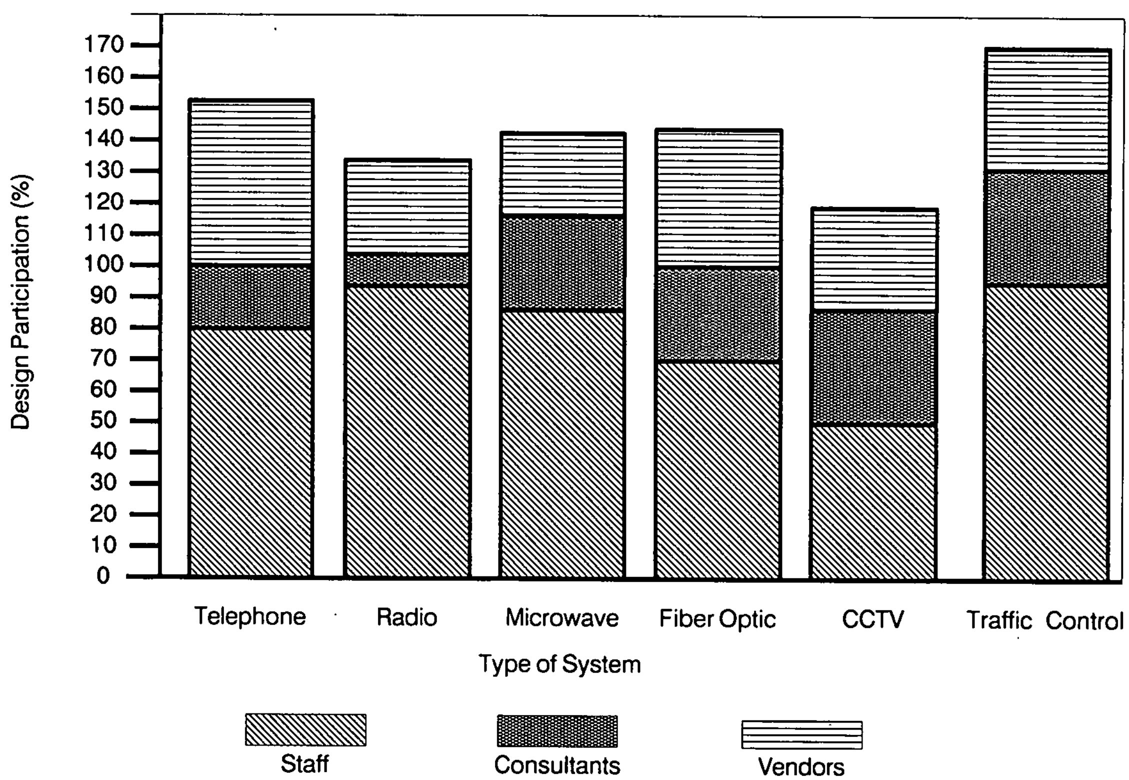

FIGURE 16 Administrative procedures.

to be representative of current agency practice, but rather they are provided as an indication of the potential benefits associated with the explorations of new technology. The first case study describes a radio system implemented for a freeway surveillance and control system in Albuquerque, New Mexico. The second case study discusses the area of motorist information systems, including their relationship to the fields of AVI, AVL, and corridor control.

Radio System Application

The system described in this section forms part of the research into alternative traffic control techniques performed by Farradyne Systems, Inc., under the sponsorship of the Federal Highway Administration (FHWA). The project involves the design, construction, implementation, and evaluation of an autonomous variable speed limit system for use on freeways using radio technology as the principal transmission medium. The prototype installation is in Albuquerque, New Mexico.

The objectives of the system were:

- To display a reasonable speed limit to the motorists on the freeway for the current traffic and environmental conditions. This speed limit should reflect the traffic speed.
- To display a speed limit that minimizes accident risk under both normal and adverse environmental conditions.
- To inform the driver, when appropriate, of adverse conditions.
- To perform in a credible manner.

The display of a variable speed limit is intended to reduce speed variance on the controlled freeway section. The type of variable-message signs selected was from technologies most commonly used in the traffic control field.

The variable speed limit system was designed to operate in either an isolated mode, in which each sign station acts separately, or in a linked mode, in which data from other sites can be used to give advance warning of downstream environmental data. This capability allowed the variable speed limit system to be installed in an isolated mode at rural interchanges while operating in a linked mode at closely spaced urban intersections. These operational modes necessitate a distributed architecture, with the majority of the processing performed by the field equipment.

The roadside station measures the traffic speed, light level, precipitation, and fog. This telemetry information is transported by radio to a computer system with software containing an algorithm that controls sign displays. The traffic and environmental data are inputs to an algorithm controlling the sign within the limits of a series of parameters that can be set by the system user.

To achieve the distributed system, the design of the roadside equipment used an IBM 7552. This is a rack-mounted computer processor equivalent to an IBM PS/2 Model 50. It is an industrial-grade system housed to operate in a field environment. See Figure 17 for a system diagram.

Communication between the stations is performed by a microcomputer acting as a central switch for message transfers. This central processor records the system status from all stations and monitors traffic data. The central processor can be accessed via a modem to obtain system status information at remote locations. Although the system is designed to function unattended, if required, an operator using a laptop computer can override all sign displays from a central location or from individual sign locations.

The communications system permits low-cost operations along the side of a freeway. Most of the existing U.S. freeways do not currently have installed communications cable, and for those that have installed these facilities, the existing cables do not have spare capacity. Installation of copper cable, even in soft ground, is expensive. In a distributed system such as this, packet radio is a more cost-effective communications option. Figure 18 illustrates the cost difference between installing cable and a radio system. As the distances increase between communication nodes, so do the commensurate savings. Based on this cost trade-off, a decision was made to use packet radio equipment for control of the remote stations.

The variable speed limit system radios support a 20-byte packet transmitted at 4800 b/s. The radio transmitter output is 2 watts and has been tested to provide an acceptable BER over a distance of 12 miles. The radio system incorporates a cyclic redundancy check and positive acknowledgments. It operates in a CSMA/CD manner similar to the IEEE 802.3 format of a LAN. When a radio supporting a sign station wants to transmit, it checks to determine if another station is using the frequency. If not, it sends the packet of data. If another user is detected, the radio backs off for a random time and tries again. A frequency of 151.1 MHz was made available by the New Mexico State Highway and Transportation Department. Thus, the radio system installed in Albuquerque operates in the same manner as an Ethernet LAN, although transmission occurs at a lower data rate than that which is found in the Ethernet system.

The radio system has been operating reliably for a period of six months. Its cost of approximately $5000 per station compares favorably with the estimated cost of a cable installation, and its successful operation demonstrates the feasibility of using this technology for other freeway surveillance and control applications.

However, there were several important lessons learned during the course of this installation that are applicable to other installations, including:

- The selection and mounting of antennas is critical to successful system operation. With the low power levels used, directional antennas can provide a significant improvement in system performance.
- The radio equipment used has extensive error checking and automatic retransmission in the event that erroneous data are received. These capabilities have resulted in the operation of an extremely reliable system, in spite of the potential for noise interference typical of radio systems.
- Calculation of system capacities is an important element of the data radio system design. The single most important consideration in the calculation of capacity is the characteristics of the radio in terms of the overhead associated with initiating a transmission and receiving an acknowledgment. The delays

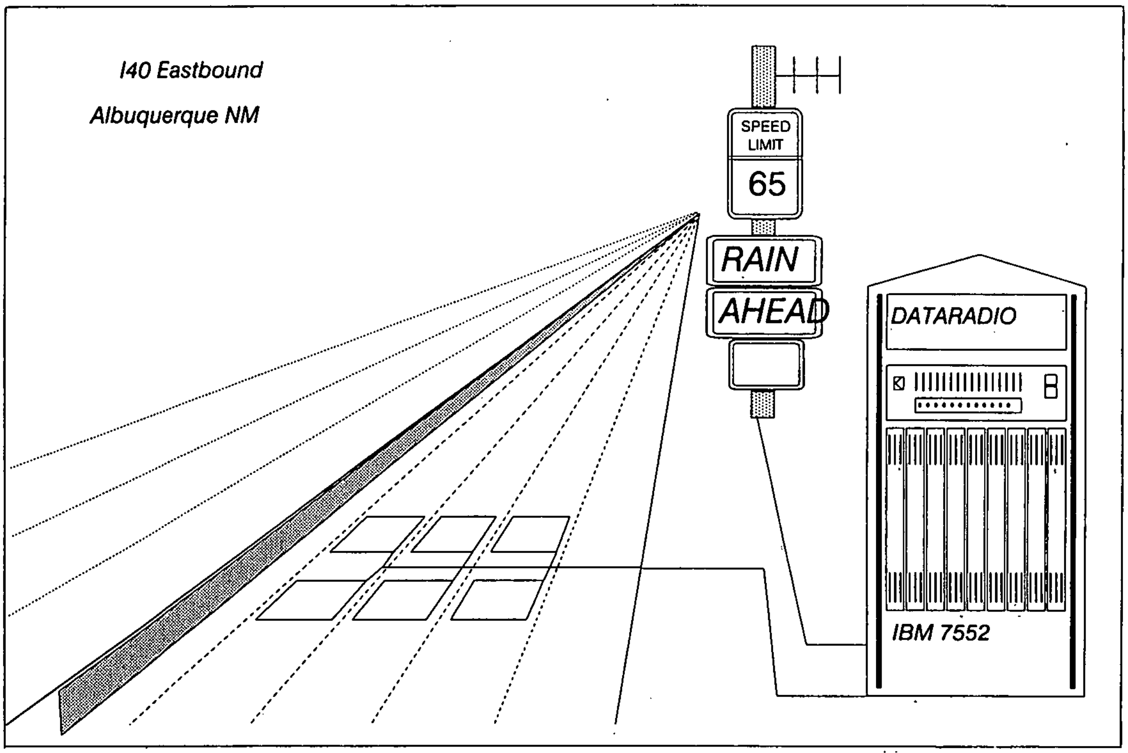

FIGURE 17 Variable-speed diagram.

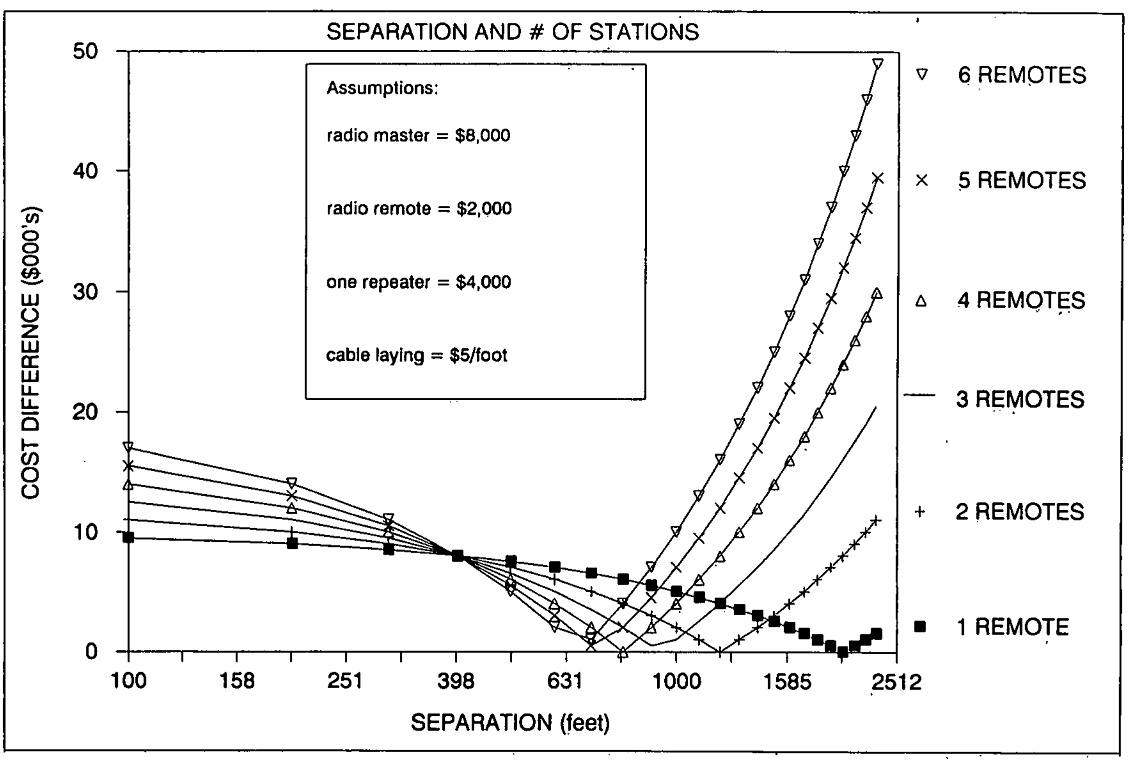

FIGURE 18 Cable versus radio costs.

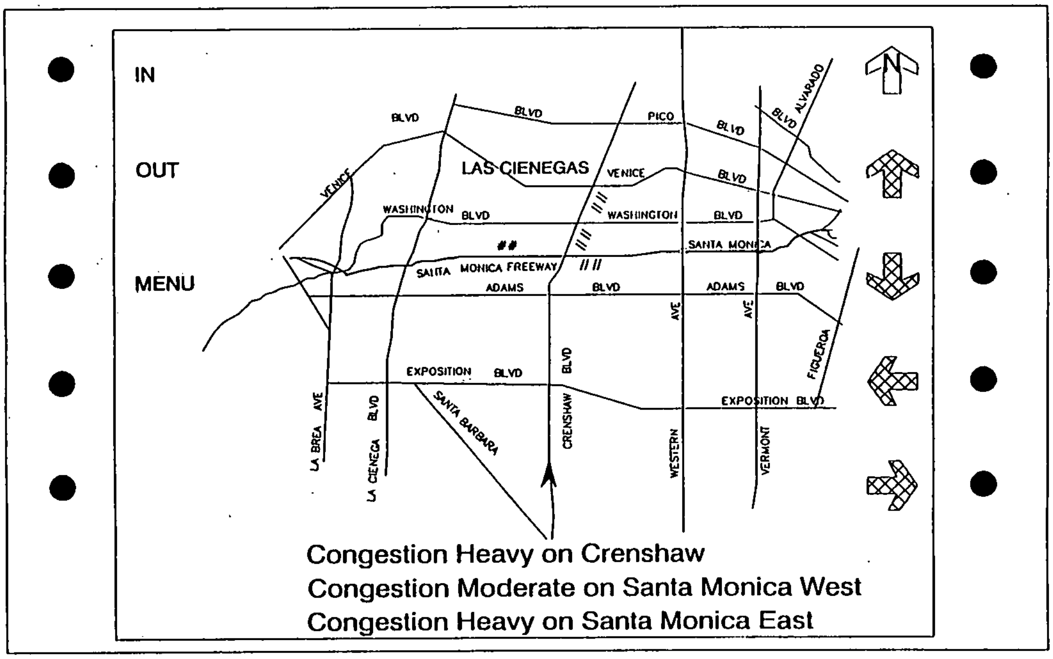

FIGURE 19 Pathfinder display.

associated with this process far exceed the time required for data transmission.

Motorist Information Systems

A relatively new technology known as advanced driver information systems is actively being developed in the United States, Europe, and Japan. This technology is likely to have a significant impact on the use of telecommunications in urban areas. Advanced driver information systems present motorists with area-wide traffic information at a level of detail required for an informed selection of routes to avoid congestion and reduce travel times, providing significant benefits because of the diversion of traffic from congested roadways. The technology embodies elements of AVI and AVL, because this information is essential to the derivation of traffic flow conditions throughout an urban area.

Motorist information systems can provide area-wide traffic information to vehicle operators using a variety of techniques including audio messages, CRT map displays, or CRT text displays. The information being presented is typically limited to the presentation of traffic conditions for the motorist's direction of travel. This information can be used for pre-trip planning and the selection of alternative routes. It conveys a more global and accurate view of congestion than can be provided by conventional techniques such as variable-message signs or traffic reports.

The vehicle receives its information from a central computer that broadcasts traffic status to all equipped vehicles for a large segment of a metropolitan area. Computers installed in the vehicle process the traffic status data so that information presented is restricted to that which is pertinent to the motorist's direction of travel.

Each vehicle continuously transmits its position and speed to the central computer, which uses these data to calculate traffic speeds in the instrumented area. Thus, each vehicle provides surveillance of traffic conditions for the area in which it is operating. When an adequate number of vehicles are equipped, the driver information system will be self-supporting, because the equipped vehicles will provide continuous monitoring of traffic conditions throughout the entire urban area without requiring supplemental information from transportation and public-service agencies.

The display of a prototype driver information system, designated the Pathfinder system, being installed along a 12-mile section of the Santa Monica Freeway in Los Angeles, California, is shown in Figure 19. This system is being implemented by Farradyne Systems under the sponsorship of FHWA, Caltrans, and General Motors. Its purposes are to demonstrate the feasibility of such systems and to evaluate their benefits to the motorist. The system uses off-the-shelf components installed in 25 vehicles to provide motorists with both visual (CRT) and audio information. Supplementary traffic flow information is being provided by existing traffic control systems installed in the Los Angeles area.

Limited-communications facilities are being installed that are inadequate for expansion to accommodate a commercial version of this system. These facilities make use of UHF mobile radio to broadcast traffic information to the vehicles and to receive information from each individual vehicle regarding its position, speed, and heading. The technique used for this communication is known as the slotted ALOHA technique, after an experimental system developed in Hawaii. Each vehicle is assigned a specific time slot within which to broadcast its data. The time slot is calculated from the end of the area-wide broadcast of traffic information from the central computer. This approach was selected in order to eliminate the capacity constraints associated with the CSMA/CD contention system used in the Albuquerque project described above. However, even the use of this efficient approach constrains the total system size to approximately 200 vehicles, a size that is inadequate for commercial implementation in most areas.

As a result, it is likely that future motorist information systems that communicate with a large numbers of vehicles will have to rely on the use of telecommunications systems with significantly higher capacities. One approach, currently used in Europe, is the use of low transponders (mileposts) located throughout the system. Each milepost communicates with the vehicles using either low-power radio or infrared communications. The mileposts are then connected to the central computer using either wireline, microwave, or CATV as the communications medium. Obviously, the installation of a system of this nature requires the implementation of area-wide telecommunications systems. However, the potential benefits from the motorist's perspective are obvious. Other techniques being considered include satellite and a modified version of cellular telephone communications.

The possible requirements for area-wide telecommunications capabilities suggest that transportation agencies should be planning for the future. These area-wide systems could be shared systems that are used for freeway surveillance and control, traffic signal control, and other agency communications. With the increasing capabilities of broadband communications media, it no longer makes sense to install multiple independent systems to support various transportation applications. Integrated communications systems could support transit agencies (another potential user of AVL and AVI techniques), surveillance and control applications, toll collection, CCTV, and the many other disbursed telecommunications requirements of local transportation agencies.

CHAPTER FIVE

FUTURE TRENDS

ASSESSMENT

Assessing the future of telecommunications use within the transportation field is a difficult task because it requires the development of accurate forecasts of two major industries: transportation and telecommunications. However, the following two general predictions can be made:

- The transportation industry will continue to be plagued with problems of increasing traffic congestion on the nation's highway system. In the absence of adequate construction funds and space in which to build new facilities, transportation agencies will increasingly rely on the use of various types of surveillance and control as well as driver information systems. These systems require extensive communications networks for their operation.
- The telecommunications industry will continue its rapid growth, in small part because of the desirability of using telecommunications as an alternative to transportation. (The industry has already made a small inroad in this regard through the popularity of facsimile transmission as an alternative to local delivery services.) The industry's primary areas of growth will be: (a) increased use of digital transmission for all purposes, including voice and video, (b) significant growth in the capacity of existing communications media, and (c) major increases in the use of radio-based systems for a wide variety of applications.

These forecasts are compatible with each other in that the transportation industry's use of telecommunications products and services is likely to increase dramatically, whereas the telecommunications industry is expected to introduce the products and services required to support this growth.

This section provides additional information relating to specific areas within the telecommunications industry that are expected to experience the greatest changes and make the most significant impacts on the transportation industry.

INTEGRATED SERVICES DIGITAL NETWORK

The serious application of ISDN by the telephone industry is still in the future. Many potential users are questioning its value, and many feel that it is likely to increase the overall cost of telephone service. However, there are eight experimental systems installed in the United States, and many more overseas. In addition, telephone equipment manufacturers, electronic-chip manufacturers, research laboratories, and standards organizations continue their active development of this technology. For this reason, it is anticipated that ISDN will become a major element of the nation's telecommunications systems within the next 10 to 20 years, and possibly sooner in selected urban areas.

Developments that occurred in 1988 to support this forecast include the Japanese demonstration of the first broadband ISDN network for transmitting information through fiber optic cable. The system transmits up to 150 Mb/s, the equivalent of 2000 voice circuits, and more than three orders of magnitude above the 144 kb/s standard for narrowband ISDN.

Other ISDN developments include the development of an optical fiber subscriber loop by Fujitsu with the capability of transmitting up to 1.8 Gb/s, enough for 12 separate 150 Mb/s channels. In addition, the asynchronous transfer mode of ISDN has been defined to include increased flexibility for other forms of information. Voice, video, and data traffic is divided into fixed-length packets, with the number of packets depending on the bandwidth required. A self-routing architecture has been defined that allows the ISDN hardware to select optimum transfer routes freely and automatically.

Although it is clear that these capabilities far exceed the anticipated telecommunications requirements of the transportation industry, they offer the future potential for implementation of integrated urban area telecommunications systems to support the full range of transportation applications. The ability to simultaneously transmit multiple forms of information over a fiber optic cable permits the use of this cable for CCTV as well as the numerous other forms of communications required by the industry.

RADIO USE

Radio systems are rapidly developing in a manner that permits their use for applications that were unanticipated 10 years ago. One of the most significant developments is an administrative development in which the FCC recently relaxed the rules governing unlicensed low-power radio transmitters, a development that has led to the announcement of several wireless LANs. As a result, it is anticipated that the cost of cabling for small LAN configurations will be eliminated, placing this technology within the reach of any organization using PCs. This is particularly significant for the district offices and individual departments of transportation organizations.

Other radio developments include the migration of cellular telephone technology toward digital communications. The use of this technology benefits the manufacturers because it permits improved transmission quality, the use of signal processing and compression to permit more than one call to be carried on each channel within a cell, and the use of encryption to enhance cellular telephone privacy. From the user's perspective, this capability increases the efficiency with which digital data can be transmitted over cellular telephone. This development will benefit agencies using cellular telephone for applications such as the control of portable variable-message signs.

STANDARDS

On the basis of developments that occurred during 1988, it is clear that standards will continue to play an important role in both digital and voice telecommunications technology. Although developments such as ISDN and radio systems continue to attract the attention of the public, slow, steady progress continues to be made in the less appealing area of standards.

The OSI protocols are rapidly appearing in new-product offerings. Although extensive installation of OSI-based networks is not anticipated for another two years, their development will be encouraged by the fact that the federal government has mandated that all new network purchases should be OSI compatible by 1990. Transportation agencies should be aware of this fact, in order to ensure compatibility with the product offerings of the 1990s. Even the Soviets have made a decision to use OSI protocols as the basis for the development of their communications networks.

Equally significant is the fact that major initiatives have occurred leading to the development of telecommunications standards at the upper levels of the OSI model. As indicated earlier in this synthesis, existing standards are predominantly used to define the lower three layers, although some standards define layers four and five. Protocols such as the X.400 electronic-mail standard will continue to be developed for layers 6 and 7 of the model. The electronic data interchange (EDI) standard used for interchange of commercial documents such as invoices, bills of lading, shipping documents, and inventory documents also defines processing at these layers. Recently, a decision was made by the Defense Logistics Agency to adopt the use of these EDI standards for the Department of Defense acquisition and transportation process. It would be advisable for the transportation industry to familiarize itself with these standards to ensure compatibility with the information-processing systems of the vendors with which it conducts business.

Local area network products will increase their adherence to emerging standards at all levels. Although IBM has resisted the use of international standards in the past, preferring the use of its SNA, it recently announced the implementation of software products that use the third, fourth, and fifth layers of the OSI model. Other manufacturers have also committed themselves to the use of these standards. For example, Digital Equipment Corporation and Hewlett-Packard will both release products compatible with the X.400 Electronic Mail standard.

Although the transportation industry has ignored most of these standards activities in the past, it would be advisable for the industry to pay greater attention to them in the future. As previously noted, the industry interacts with numerous commercial organizations and trucking companies that make use of the EDI standard. In addition, the industry will continue to purchase computer equipment and networks with the intent of providing interoperability between this equipment and these networks for many years in the future. The utility and life of this equipment will be significantly enhanced if it is compatible with emerging standards.

Traffic control systems, which in the past have been considered closed systems that need not be concerned with national or international standards, will also be affected by these developments. The majority of these systems will be implemented using commercial communications and computer equipment that will adhere to the emerging standards. In order to avoid costly reprogramming and specialized designs that have plagued the industry in the past, the use of standardized approaches must be encouraged. At least one traffic signal manufacturer is currently developing a new data-communications protocol that adheres to the OSI standards.

OTHER TECHNOLOGICAL DEVELOPMENTS

Although the preparation of a technology forecast for the telecommunications industry is clearly beyond the scope of this synthesis, it is obvious that significant advances will continue throughout this industry. A sample of these advances include:

- The continued development of fiber optics technology to provide increased bandwidth, more flexible interfaces, and lower-cost installations. This equipment is receiving increased acceptance for use in traffic control systems, local area networks, and CATV systems.
- The availability of inexpensive IBM PC-compatible processors capable of withstanding the environmental conditions of field installations. It is anticipated that these processors will eventually replace the special-purpose control equipment, such as the type 170 controllers, used in the field for traffic applications. This development may eventually include replacement of the traffic signal controller with an IBM-compatible unit.
- The greater use of radio equipment in the data-communications market. Data-communications services such as Motorola's Data Radio Network are being offered to provide data services equivalent to the voice services offered by cellular telephone. Trunked radio systems, low-power radio systems, and other innovative applications of the technology are likely to appear.
- The continued and expanded use of conventional telephone technology as a data-communications medium. This growth will be encouraged by the fact that telephone cabling and switching services are pervasive. The use of this technology will be encouraged by ongoing developments such as: (a) the decreasing cost and increasing performance of available modems, (b) the recent introduction of practical LAN products capable of operation on conventional twisted-pair telephone wiring, (c) continuous increases in the integrated voice/data capabilities of commercial PBX switches, and (d) the introduction of ISDN, with its associated broadband switched communications services.

CHAPTER SIX

IMPLEMENTATION PROCEDURES AND ALTERNATIVES

This chapter highlights the issues associated with the implementation of a telecommunications system. It focuses on the importance of system planning, and describes the pitfalls that are likely to be encountered with the use of various types of telecommunications system technology.

OFFICE SYSTEMS

Planning Process

The planning process includes analysis of user requirements, including equipment trade-offs, traffic engineering, cost analysis, evaluation of the benefits of system features, estimate of installation costs, and estimate of recurring costs (operations and maintenance). In many cases, the approach required for this process is a function of the major categories of facilities and characteristics defined above.

The planning process should be conducted both for new installations and replacement systems. In either case, it should be conducted with an open mind.

Planning is a three-step process that includes:

- Evaluation of telecommunications requirements including data, voice, and/or video.
- Development of alternative solutions to these needs. Alternatives developed should include technical, management, and financial. When existing facilities are involved, the "do nothing" alternative should be used as the baseline alternative.
- Comparison of alternatives on an economic and technical basis. The comparison should consider the compatibility of each alternative with the capabilities and interests of the organization that will assume responsibility for its implementation.

Requirements Analysis

The telecommunications requirements of a given facility are embodied in the people and organizations that use the facility. The procedure used for determining these requirements will be a function of its requirements.

User Requirements

Five sources of information should be used to determine user requirements:

- Telephone and data-communications users or potential users.
- Managers of user groups.
- Console attendants, network administrators, maintenance technicians, and other personnel who operate and maintain the system.
- Data-processing center personnel.
- Telephone usage records.

These information sources will provide a useful combination of operational information and specific data that can be combined to develop an effective telecommunications system design.

User Surveys

Interviews should be conducted with users in every department, or other logical grouping. At least 5 percent of the users—but no fewer than two people—in each major work group should be interviewed. The supervisor and at least one secretary should be interviewed.

Managers

A sample survey should be conducted at senior and middle management levels. Interviews should focus on operational issues dealing with information flow and responsibilities within the organization. They should also consider vertical and horizontal information flow between the managers and other organizational groups. Interviews with managers should be guided by the use of a questionnaire and conducted by knowledgeable interviewers who can explain technical terminology and communication applications issues not common to laymen.

The manager should be encouraged to review the inadequacies of the existing telecommunications system with the interviewer and to speculate about communication capabilities that would improve the current business operation. The requirements interview might be the first contact a manager has had with the telecommunications planning process. For this reason, it is important for the interviewer to relate well to people and to understand thoroughly the purpose of the interview and the options available with modern telecommunications systems.

Telephone Attendants

For the telephone system design phase, detailed operating data should be collected that describe the work load of the telephone attendants. The objective of this survey is to contact the group of individuals most knowledgeable about the current system and solicit their recommendations for modifications of or improvements to its operation. Data collected should pertain to the attendant's responsibilities, number of attendants on each shift, and length of shifts.

Telephone System Records

Records available from the telephone company and suppliers often furnish the most detailed description of the existing system equipment and usage. The following information should be obtained:

- Magnitude of incoming and outgoing local central office trunks.
- WATS trunk groups.
- Tie-line trunk groups.
- Station equipment and PBX equipment supplied by telephone equipment vendors.

Trunk usage statistics should be obtained in the form of call counts for the last trunk busy or all trunks busy. These data should be acquired for all trunk groups as well as attendant access trunks (dial 0), local access (dial 9), and interval access. These statistics would be used to evaluate the adequacy of the individual communications facilities. (These statistics cannot be obtained for Centrex-type service because there are no trunks associated with Centrex.)

The telephone bills of the organization being studied should be analyzed. They provide a reliable indication of the local service costs, monthly usage, and costs of long-distance service. These records are especially important if new long-distance services are being considered or the benefits of least-cost routing are being analyzed.

Alternative Configurations

Following the collection of data, alternative telecommunication system configurations should be developed. If the analysis is being conducted for an existing facility, the "do nothing" alternative should be considered to evaluate the impacts of continued operation of the systems currently in use.

The alternatives being considered should be defined in terms of:

- PBX Systems Alternatives—centralized switch, distributed switch, combined data and voice transmission, and Centrex using a separate LAN transmission system.
- Feature Alternatives—including switch features, data transmission features, and ancillary systems, such as video conferencing.
- Management Alternatives—including assignment of responsibilities for system operation and maintenance.
- Financial/Business Alternatives—primarily the decision to lease rather than purchase the equipment. Other business alternatives to be considered, however, include the manner in which the system will be procured, the manner in which it will be operated, and how it will be maintained.

System Alternatives

Telephone system alternatives should include the degree of centralization incorporated in a PBX system configuration and the additional possibility of using off-premises switching furnished by the local telephone company (Centrex).

Centralization is related to the number and location of PBX systems. A highly centralized system is one in which a single PBX serves the entire facility or organization. A distributed system is one in which more than one PBX serves a facility or the organization. Distributed systems usually include the installation of tie trunks between PBXs for interswitch communications. Tie trunks are installed when a high level of traffic exists between facility locations, or features such as least-cost routing or a message center are provided from a single facility.

A number of data-communications system alternatives are available. The range of alternatives considered will be dependent on the scope of the project. For example, if the existing telephone system is to be retained, and it does not include integrated voice/data capabilities, the PBX system alternative will not be feasible. Four alternatives that might be considered include:

- Transmission of all data through the PBX.
- Supplemental building wiring for point-to-point data communication.
- Baseband LAN.
- Broadband LAN.

The PBX provides switched data transmission within a facility or campus at rates up to 64 kb/s. Data transmissions outside the facility using the telephone system would be accomplished by using a modem pool located at the station equipment or provided through a modem pool located at the switch.

Use of the PBX for data transmission offers a relatively low-cost alternative for this capability, providing it is used to serve infrequent, short-term data transmission requirements. However, use of the PBX requires the installation of additional circuit cards in the switch and additional station equipment features. It is also important to note that a PBX system has limited capabilities to accommodate high usage data terminal equipment or printer requirements and therefore may be more expensive or cumbersome than a LAN.

Local area network alternatives have been described previously. Although a broadband LAN offers greater capacity and flexibility and is the only alternative that will permit the transmission of both video and data, it is significantly more expensive to implement. As a result, these two alternatives must be subjected to a detailed cost analysis based on the requirements identified during the earlier steps of this process.

Supplemental building wiring is an option that should be considered as a supplement to any of the other options discussed in this section. A typical twisted-pair supplemental configuration permits installation of additional telephone equipment at a given location as well as the straightforward point-to-point interconnection of any two devices in the facility.

Feature Alternatives

There are numerous features to be considered during the design of a telecommunications system. During the planning phase, only those features that have a significant impact on improved business operation or costs should be considered. Features included in this category are:

- Telephone-related features, such as the message center, least-cost routing of long-distance calls, and voice mail.
- Data transmission features, such as subscribing to a value added carrier or providing electronic mail services.
- Ancillary services, including video conferencing, telex, or facsimile services.

Management Alternatives

The primary management alternative to be considered is assignment of responsibility for system operation and maintenance. Here again, available alternatives vary depending on the type of facility that is the basis of the telecommunications design plan.

Before discussing alternatives, it is prudent to identify the activities associated with the management process:

- System Manager—Responsible for all activities associated with the telephone and data-communication systems. If these are to be two separate systems, two different managers may be assigned this responsibility.
- System Administrator—This position is unique to the LAN installation. The system administrator is responsible for configuration management, installation of new software, assigning of passwords, interfacing new peripherals, and general network troubleshooting. This is a full-time position for LANs of more than 50 workstations.
- Telephone System Attendants—These individuals (including a supervisor) may also operate the telex and facsimile machines.
- Data Base Management—All telephone number changes, feature changes, and updates to the telephone directory are included in this function.
- Moves and Changes—Both telecommunications and building maintenance personnel may be involved in modifications to the system.
- System Maintenance—Response to malfunctions of station equipment, wiring, and central equipment. This may be contracted out.

These various telecommunications system operation functions may be performed by a large group of individuals or assigned to a single individual who purchases these operational and management services on a contract basis. The annual cost of services is typically between 10 and 15 percent of the system purchase price. The manner in which these services are provided varies.

Capital Costs

Telephone System Costs

Capital costs of a PBX system acquisition normally include one-time costs such as engineering, equipment, installation, system testing, training, and document costs. If a phased system installation is anticipated, these costs may be incurred over an extended time period.

When estimating capital costs, initial emphasis should be placed on the cost of equipment acquisition and installation; engineering, testing, training, and documentation costs are calculated as a percentage of these costs.

LAN Costs

Installation of a LAN, which operates as a parallel facility to the PBX-based system, must be explicitly considered in the cost estimate. Equipment required by a LAN includes personal computers, computer interface equipment, and appropriate cable. If a broadband LAN is being installed, the cost of head end equipment should also be estimated.

Miscellaneous Equipment

It is possible that a number of equipment options will influence the cost of the system. Video conferencing, voice mail, ACD, paging system, message center, gateways to data services, and accounting systems are options that must be included in the estimate. Other costs that must be considered are installation of uninterruptible power supplies and trunks for connection with the local telephone company. The ratio of trunks to internal lines is between 5 and 20 percent, depending on the calling habits of the organizations occupying the facility.

Recurring Costs

The ongoing costs of system operations and maintenance include the personnel, services, supplies, and equipment required to sustain the telecommunications system operation. Additional categories of recurring costs are taxes, cost of capital, and depreciation associated with the system.

The annual maintenance costs of electronic equipment should be estimated at 12 percent of the system hardware cost. When making this estimate, however, it is important to recognize that many of the capital costs outlined above include installation documentation, testing, and training, as well as cost of the basic equipment.

Operations and Maintenance Responsibilities

One model of the industry identifies functions or services that a communications manager must either provide through in-house staff or obtain through outside contracts. These include:

- The local telco, which may be one of the RBOCs.
- Long-distance services, which are provided by many long-distance carriers, including AT&T and MCI.
- Planning and design services, which are normally provided by in-house organizations or various consulting and engineering organizations.
- Manufacturer-produced telephone equipment (which includes switching equipment, cabling, connectors, and other devices).

- System installation, which is performed by the manufacturer or an organization that specializes in systems implementation and maintenance.
- Maintenance services, which are performed by the manufacturer, the staff, or organizations that specialize in system maintenance.
- System operations, which may be performed in-house or provided by organizations offering the operations and maintenance personnel required for continuing system support.

The list of providers of these functions, services, and equipment is constantly growing. Some firms specialize in the provision of a single item and others provide multiple items. It is the administrator's responsibility to identify a source for each of these functions in the changing organizational climate of the telecommunications industry.

The effort to administer communications systems and control costs often can be a substantial management challenge. In today's complex communications environment, the availability of accurate and timely information is essential to the management and evaluation of organizational requirements and communication costs.

How readily information is available to answer simple questions is a critical element in good operations and maintenance management. These questions include:

- How many telephone sets and/or computer workstation types are installed?
- What was the incidence of repair of electronic equipment last month?
- How are multiple locations networked together?
- How are the costs on the installed equipment base controlled?
- How many technicians are needed to implement service and equipment changes?

These are questions asked of most communication managers during the course of a typical week. The activity that takes place to answer these questions depends on how a communications manager maintains records. If the records are kept in a paper-based system, it may take an enormous amount of time and effort to compile the information into a meaningful report. If the records are electronically stored, the time required to locate the data may be decreased, but creating a report may be just as difficult unless all data base information is integrated and has been updated with service order and repair activity.

A necessary tool in helping a communications manager meet the challenge is a totally integrated communications-management system. The system should match the capability of the communications system. Some applications may require more information than others. Basics include:

- Trouble Reporting
- Service/Work Order Processing
- Directory Service
- Call Accounting
- Equipment Inventory
- Transmission System Records

Data Base Integration

The key word here is "integration." This means that all appropriate data base modules are updated by a single input. Integration to some users means simply that the management functions reside on the same processor. This type of "integration" is nothing more than electronic paper, in that each data base must be individually updated. Obviously this latter type of integration is unacceptable because of the likelihood that the various system data bases will be out of synchronization in a short period of time.

Integrating management information functions should be considered essential when managing multiple locations. All functions working together will provide a communication manager with the tools needed to manage a technical staff and control overall communications costs. A communications-management system should provide flexibility within the inputs. Fields should be capable of being sized and renamed so as to be changed to meet specific requirements. This flexibility is also a factor to be considered when looking for future functionality and growth.

Reports

In order to address management needs for information and to evaluate corporate communications costs properly, the management system should generate reports in usable formats and in a timely manner. For example:

- For all inventoried equipment, equipment inventory reports should produce departmental summaries, organizational summaries, equipment-type summaries, feature summaries, etc.
- Service order activity reports will help to manage technician time and also to identify areas or departments that have a high level of move, add, and change activity.
- Repair activity reports, like service order reports, will help the communications manager allocate technical resources and identify problem areas.
- Cable record reports will help to locate cable fault problems quickly and to identify locations that should be supplemented to accommodate future growth.

The flexibility to design reports that meet changing management requirements is vital to maintaining the viability of any telemanagement system.

Implementation

The most costly and difficult part of implementing any telemanagement system is the creation of the data base itself. Depending on an organization's present methods of telemanagement, data base development will range from a 100 percent manual task to a combination of manual and automated techniques. Obviously, automated data, if accurate, are preferable for accomplishing this task.

The use of automated data to load the telemanagement system can also have a large cost associated with it, depending on the number of conversion programs that must be created and who does the programming work. The benefit to this method, however, can be a more accurate and timely implementation of the telemanagement system. If the only method available is manual data base creation, time to completion is the most critical factor. By shortening data base build time, the accuracy of the end product will be greatly improved.

Support

As with any systems that are implemented, ongoing support is a key issue and concern with a telemanagement system. Because telemanagement requirements are evolving, the issue of support must not be overlooked. The use of the system to support day-to-day operation will identify new areas of use and also areas where improvement or change is required. If a system cannot be expanded or modified to add or improve functionality, then its long-term value as an effective management tool is greatly diminished.

Implementing an integrated, flexible, and cost-effective telemanagement system offers an opportunity to take control of the communication provisioning process as well as to control communication costs. A telemanagement system is the single most important tool required to manage a complex communication system in the current regulatory and technical environment.

Traffic engineers may wish to consider the use of a similar capability to provide operational support and management control of traffic control systems.

TRAFFIC CONTROL SYSTEMS

The planning, design, implementation, operations, and maintenance of new traffic surveillance and control systems follow the same steps as those performed for office systems. The process includes:

- A requirements analysis, sometimes known as a feasibility study, analyzes the facility's traffic requirements to determine the types of control required.
- An engineering design produces the detailed plans and specifications needed for the system procurement.
- A system is procured (usually on a low-bid basis) and a turnkey installation is performed by the installation contractor.
- System operation and maintenance are performed by city or state personnel, contractors, or a mixture of these resources.

Although this approach is similar to those of the office system, there is one significant difference: The telecommunications system is being installed to support the functions of the traffic control system, rather than as a stand-alone independently functioning system. Thus, the telecommunications system requirements are driven by the data communications requirements of the traffic control system, rather than those of an end user.

Traditional Telecommunications Design Methodology

Typically, the telecommunications system design for a traffic control system is performed following the definition and specification of the overall system architecture. For example, if traffic signal control is required, the system architecture may include a central minicomputer that communicates with the individual traffic signal controllers at a once-per-second rate. Alternatively, the traffic control system might be configured as a closed-loop system that communicates with local area masters using dial-up telephone service. The local area masters would then communicate with the individual traffic signal controllers at the once-per-second rate.

Once the system architecture is defined, the system designer then performs an economic trade-off analysis of the communications alternatives. In most cases, this analysis is restricted to a comparison of the installation of city- or state-owned twisted-pair cable versus the use of leased facilities. However, this trade-off should be expanded to include the use of CATV, coaxial cable, fiber optic cable, or radio as an alternative to the more traditional use of telephone-type cable. Perhaps most significant, the designer should recognize the fact that hybrid systems are possible that incorporate multiple forms of communications media, based on the locations of the field installations with which communication is required.

An Alternative Telecommunications System Design Methodology

The specification of a system architecture based solely on a designer's knowledge of available product lines may artificially constrain communications system alternatives. At best, it will arbitrarily constrain the array of alternatives available to only those that can be supported by the preselected product lines. For example, the specification of a centralized system automatically leads to the requirement of an adequate number of low-speed communications channels to accommodate approximately eight traffic signal controllers per channel.

However, numerous alternative architectures exist within the traffic control community that offer the opportunity for economical telecommunications system installation. For example, distributed systems are available that can accommodate as many as 32 signal controllers on a low-speed communications channel. Other alternatives include the use of local area masters with either dedicated communications (possibly using radio) or dial-up service. Many of these alternative architectures are capable of providing the same levels of functional performance as the centralized architectures.

Thus, if the traffic control system is to be acquired using the conventional low-bid process, it is recommended that a specification be prepared that defines the functions to be performed rather than the architecture (centralized, closed loop, or distributed). It should be the system suppliers' responsibility to evaluate the available communications options in order to select the one that is best suited to their system. The low-bid process will then automatically select the most economical system design.

It should be noted that the use of a functional specification does not preclude the definition of constraints on the communications alternatives being considered. If CATV is not practical for institutional reasons, or if radio is not desired because it exceeds the capabilities of the maintenance staff, these restrictions should be defined in the specification.

Although the examples presented above describe alternative traffic signal system architectures, the same is true of freeway surveillance and control systems. Because these systems may cover a larger geographic area than the signal systems, their telecommunications costs can be significantly higher. In addition, many of today's freeway surveillance and control systems have been implemented using very inefficient designs from a telecommunications perspective.

These designs require telecommunications polling rates as high as 60 times per second in order to perform detector processing at a central computer. This design effectively shifts the processing load from the local field equipment to the central processor, at the expense of significantly increased communications loading (by a factor of 60 for the polling rates indicated). Agencies are reluctant to depart from these designs to avoid development of new central system software. However, this saving in software-development costs is more than offset by the additional communications cost borne by the agency. Thus, here again, it would be beneficial to permit system suppliers to bid efficient architectures that optimize the use of telecommunications facilities.

Although this process represents a departure from the manner in which many agencies currently prepare their system specifications, it is worthy of serious consideration in that it is likely to lead to significantly reduced system costs. Because the telecommunications system is usually the most costly component of a traffic control system, providing suppliers with the ability to optimize the design of this element of the system will lead to lower surveillance and control system bids.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

This synthesis has attempted to describe the telecommunications industry and its available products and systems in terms of the requirements of the transportation industry. It has summarized the characteristics of the many types of telecommunications systems currently in use by the transportation industry, and compared alternative forms of system implementation and usage. It should be clear to the reader that these two large industries are closely related, both as users of each other's services and because telecommunications technology represents a potential alternative to transportation services.

The data collected during the preparation of this synthesis indicate that state and local transportation agencies are relatively progressive users of telecommunications systems. Most existing forms of telecommunications are currently in use by these agencies, and many innovative applications have been identified.

However, a number of deficiencies have also been identified that exist throughout the industry. These deficiencies include:

- Heavy reliance on dominant equipment vendors, which has resulted in inefficient or costly systems.
- Inadequate knowledge of existing and emerging standards in order to ensure the compatibility of systems with future industry developments.
- Limited consideration of available alternatives before system design decisions are made.
- Shortcomings in monitoring telecommunications cost that have led to continued use of inefficient systems.

Although these deficiencies are certainly not true of all agencies, the evidence provided by the questionnaires and the experience of the project team supports these conclusions. It is recommended that agencies experiencing these problems take the steps necessary to design and implement more effective systems.

The synthesis also indicates that with the exception of the traditional telephone systems, the transportation industry is likely to experience significant growth in nearly all areas of telecommunications usage. This growth will be the result of increases in local area network installations and increased application of surveillance and control technology. Growth is also likely to be the result of new forms of motorist information and navigation systems anticipated for the future.

It is recommended that the impacts of this growth on areawide communications be evaluated to identify possible requirements for telecommunications facilities dedicated to transportation applications but installed for multiple purposes. It is also recommended that consideration be given to the installation of facilities that are shared by city and state agencies, when common geographic coverage is warranted.

If followed, these recommendations should provide for the continued application of telecommunications technology to the needs of the transportation industry.

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APPENDIX A

GLOSSARY

A

ABM Asynchronous balanced mode of high-level data link control.

A and B Signaling Procedure used in most T1 transmission facilities currently operated by telephone companies where one bit, robbed from each of the 24 subchannels in every sixth frame, is used to carry dial and control information; a type of in-band signaling used in T1 transmission.

Abbreviated Dialing A feature of some telephone switches that permits users to establish calls by entering fewer digits than would otherwise be required. Also called speed dialing. Speed dialing directories are predefined, though usually changeable by the user.

ABSBH See Average Busy Season Busy Hour Load.

Access Delay A performance measure of polling systems. It is measured from the time a data packet arrives at one of the stations sharing the common channel to the time the packet begins transmission.

Access Line That portion of a leased telephone line connecting the user permanently with the central office or wire center.

Access Time Elapsed time between when a frame is called and the instant it begins to appear on the screen.

Accunet Data-oriented digital services from AT&T, including Accunet T1.5, terrestrial wideband at 1.544 Mb/s (formerly called T1); Accunet Reserved T1.5, satellite-based channels at 1.544 Mb/s primarily for video teleconferencing applications; Accunet Packet Services, packet-switching services; and Accunet Dataphone Digital Service (DDS), private-line digital circuits at 2.4, 4.8, 9.6, and 56 kb/s.

ACF Advanced Communications Function. International Business Machines communications software products that add to other systems software the functions of systems network architecture (SNA) network operation, control, and management. With IBM's Network Control Program (NCP), the software load for front-end and remote communications processors (370X/3725) generated in the host and downloaded. Performs critical control functions for IBM SNA networks.

ACH See Attempts per Circuit per Hour.

ACK Abbreviation for acknowledgment. Control code or designation for a positive acknowledgment sent from a receiver to the transmitter to indicate that a transmission has been received correctly.

Acoustic Coupler A device allowing a telephone handset to be used for access to the switched telephone network for data transmission. Digital signals are modulated as sound waves; data rates are typically limited to about 300 b/s, some up to 1.2 kb/s.

A/D Analog-to-digital conversion.

Adaptive Differential Pulse-Code Modulation (ADPCM) Encoding technique, standardized by the International Telegraph and Telephone Consultative Committee, allowing an analog voice conversation to be carried within a 32 kb/s digital channel where 3 or 4 bits are used to describe each sample that represents the difference between two adjacent samples. Sampling is done 8000 times a second.

Adaptive Equalization A process in a receiver in which received symbols are used to continuously update the settings of a filter used for equalization.

ADCCP Advanced data-communication control procedure. American version of high-level data link control.

Address (a) A sequence of bits, a character, or a group of characters identifying a network station, user, or application. Used mainly for routing purposes. (b) In telephony, the number entered by the caller that identifies the party called. Normally a 7- or 10-digit sequence of numbers that identify the telephone or other customer-premises equipment to which a call is directed. The quantity of digits in the address is usually a function of whether the destination is inside or outside the numbering plan area from which the call originated. (c) Digital information (a combination of bits) that identifies a location in a storage device or equipment unit.

Addressing Specifying to the network the destination of a call.

Address Signal A signal used to convey call destination information such as telephone station number, central office code, and area code. Some forms of address signals are called pulses, for example, dial pulses, multifrequency pulses.

Adjacent Describes devices or programs connected directly by a data link in a network.

ADP Automatic data processing.

ADPCM See Adaptive Differential Pulse-code Modulation.

AIOD See Automatic Identified Outward Dialing.

AK Acknowledgment transport protocol data unit, OSI transport layer.

Alerting Generating an audio (or visual) signal to indicate that a call is being made.

Alerting Signal A signal sent to a customer, a private branch exchange, or a switching system to indicate an incoming call. A common form is the signal that rings a bell or causes an electronic tone in the station set being called.

Aliasing Distortion The error in reconstructing a sampled analog signal when the signal is sampled at a rate that is less than twice the signal bandwidth. Also called foldover distortion.

Alphageometric Creation of graphic displays from primitive geometric shapes in the form of points, lines, arcs, triangles, rectangles, and polygons.

Alphamosaic Creation of graphic displays by filling in points on the screen to form mosaic images.

Alternate Routing (a) A means of selectively distributing traffic over a number of routes that ultimately lead to the same destination. (b) A feature of network switches, especially private branch exchanges, in which a call is completed over other circuit routes when first-choice routes are unavailable, not in service, or occupied.

ALU Arithmetic logic unit. That part of a computer that performs arithmetic and logic operations, and other related operations.

AM See Amplitude Modulation.

AMA See Automatic Message Accounting.

Amplifier Any electronic component that boosts the strength or amplitude of a transmitted signal. An amplifier is equivalent functionally to a repeater in digital transmissions.

Amplitude Dispersion See Dispersion.

Amplitude/Frequency Distortion Distortion in a communications system in which the relative magnitudes of different steady-state frequency components of a signal are nonuniform in gain or attenuation during amplification or transmission over a channel. Also called Attenuation Distortion.

Amplitude Modulation (AM) A transmission method in which variations in voltage or current waveform of a carrier signal determine encoded information. The amplitude of a carrier signal is modified in accordance with the information input signal voltage level. One of several ways to modify a signal to make it "carry" information.

Amplitude-Shift Keying (ASK) A form of digital modulation in which discrete amplitudes of the carrier are used to represent a digital signal.

Analog A transmission employing variable and continuous waveforms to represent information values. Compare with digital, in which interpretation by the receiver is an estimated approximation (quantization) of the encoded value.

Analog Channel A transmission path that accepts a band of frequencies and is compatible with the transmission of analog signals.

Analog Loopback (a) A technique for testing transmission equipment and devices that isolates faults to the analog signal receiving or transmitting circuitry. (b) A received signal, echoed back by a device such as a modem, that is then compared with the original signal. See also Loopback.

Analog Signal A signal, such as voice or music, that varies in a continuous manner. An analog signal may be contrasted with a digital signal, which represents only discrete states.

ANI See Automatic Number Identification.

Anomalous Propagation A propagation condition that results from abnormal changes with altitude in the atmospheric index of refraction.

ANSI American National Standards Institute.

Answerback The response of a terminal or other communications device to remotely transmitted control signals, typically part of "handshaking" between devices.

Answer Delay The time from the beginning of ringing until the called station or an operator answers.

Application Layer The uppermost layer in the seven-layer hierarchy. It is the layer that ensures that two application processes, cooperating to carry out the desired information processing across a network, understand one another.

Area Code See Numbering Plan Area.

ARM Asynchronous response mode of high-level data link control.

ARPA Advanced Research Projects Agency, which operates within the U.S. Department of Defense.

ARPAnet A computer network developed by the Advanced Research Projects Agency of the U.S. Department of Defense.

ARQ Automatic request for repetition.

ARS See Automatic Route Selection.

ASCII American Standard Code for Information Interchange. The standard (and predominant) 7-bit or 8-bit, with parity, character code used for data communications and data processing.

ASK See Amplitude-Shift Keying.

ASR See Automatic Send/Receive.

Asynchronous A transmission not related to a specific frequency or to the timing of the transmission facility. A start/stop type of transmission.

Asynchronous Transmission A transmission mode in which each character, or byte, is individually synchronized by use of start and stop elements from which a receiver derives the necessary timing for sampling bits. The time intervals between transmitted characters may be of unequal length.

ATB All trunks busy.

Attempt A call initiation or bid for service in which at least one digit is received by the originating switching system. For some purposes, an attempt is said to occur as soon as an originating station goes off-hook and causes some response in the originating switching system.

Attempts per Circuit per Hour (ACH) A running count of the number of trunk requests (new calls). Used in network management as an indicator of calling pressure. See Connections per Circuit per Hour.

Attenuation Reduction or decrease in signal amplitude or signal strength during transmission from one point to another. Usually expressed or measured in decibels (dB). The opposite of gain.

Auto Answer Unattended operation for incoming dial-up calls. A terminal, modem, computer, or similar device responds to an incoming call on a dial-up telephone line and establishes a data connection with a remote device without operator intervention.

Autodial Automatic dialing. The ability of a terminal, modem, computer, or similar device to place a call over the switched telephone network and establish a connection without operator intervention. Also known as autocall.

Automatic Identified Outward Dialing (AIOD) An arrangement provided with Centrex service whereby stations associated with the service can be identified automatically when originating toll calls or for other purposes.

Automatic Intercept A centrally located set of equipment that is a part of a stored program control system used to inform the calling customer (by means of a recorded or electronically assembled announcement) why connection to the called number cannot be completed.

Automatic Message Accounting (AMA) The automatic collection, recording, and processing of information relating to calls for billing purposes.

Automatic Number Identification (ANI) The automatic identification of a calling station by a switching system, usually associated with automatic message accounting.

Automatic Route Selection (ARS) The capability of a telephone switch to automatically determine an optimal route when establishing a circuit. See also Least-Cost Routing.

Automatic Send/Receive (ASR) A type of operation, typically of a teleprinter terminal.

Availability The probability or fraction of time that a system is not in a state of failure.

Average Busy Season Busy Hour (ABSBH) Load The expected offered load for which a trunk group is engineered. Estimated by averaging the measured loads for a given peak hour of the day (Busy Hour) during each weekday of the peak season (Busy Season). Normally, measurements of the traffic load on 20 weekdays are averaged.

B

BAC Balanced asynchronous class of high-level data link control.

Backbone Network A transmission facility or arrangement of such facilities designed to interconnect lower-speed distribution channels or clusters of dispersed users or devices.

Balanced-to-Ground In a two-wire circuit, where the impedance-to-ground on one wire equals the impedance-to-ground on the other wire.

Balun Balanced/unbalanced. In a cabling system, refers to an impedance-matching device used to connect balanced twisted-pair cabling with unbalanced coaxial cable.

BANCS See Bell Administrative Network Communications System.

Bandlimited Applied to a signal or a channel that is limited in frequency content.

Bandpass Filter A circuit designed to allow only frequencies within a specific range to pass. The cutoff frequencies must be finite and nonzero. The band of frequencies between the cutoff frequencies is called the passband.

Bandwidth The range of frequencies that can be transmitted by a communications channel, a transmission facility, or a transmission medium, expressed in hertz (Hz).

Bandwidth-Distance Product The product of bandwidth and distance (usually in MHz/km), which specifies a limit on an optical fiber's bandwidth and repeater spacing.

Baseband Channel A channel that carries a signal faithfully without requiring modulation, in contrast to a passband channel.

Baseband Signal (a) The original form of a signal, unchanged by modulation. (b) The band of frequencies occupied by a signal below the point that the signal is modulated as an analog carrier frequency. In modulation, the frequency band occupied by the aggregate of the transmitted signals when first used to modulate the carrier.

Batch Programming (a) A type of data processing operation and data-communications transmission in which related transactions are grouped together and transmitted for processing, usually by the same computer and under the same application. (b) Usually regarded as non-real-time data traffic, consisting of large files. (c) Type of data traffic in which network response time is not critical.

Baud (a) The unit of symbol rate in modulation. Corresponds to a rate of one symbol or unit interval per second. (b) A measurement of the signaling speed of a data transmission device, equivalent to the maximum number of signaling elements or symbols per second that are generated. However, it may be different from bit per second (b/s) rate, especially at high speeds, because several bits may be encoded per symbol or baud, with advanced encoding techniques, such as phase-shift keying.

Baudot Code An aging data transmission code using 8 bits for character representation, usually with one start and one or two stop bits added.

BCC See Blocked Calls Cleared.

BCD See Binary-Coded Decimal and Blocked Calls Delayed.

Beam Splitter A device for dividing an optical beam into two or more separate beams, often a partially reflecting mirror.

Bell Administrative Network Communications System (BANCS) A computer system consisting of modules that form a message-switching network for business communications. Bell Administrative Network Communications System handles computer-to-computer, interactive terminal-to-computer, and store-and-forward output distribution traffic.

Bellcore Bell Communications Research. An organization established under the AT&T divestiture for the purposes of establishing telephone network standards and interfaces.

BER See bit error rate.

BERT Bit error rate test or tester.

Bifurcated Routing Multiple-path or channel routing. Also see Diversity Routing.

Bind Triangle Sequence of messages transmitted in systems network architecture when setting up a session.

Binary Backoff Procedure A procedure used to adjust the retransmission time in the carrier-sense multiple access with collision detection random access technique. It doubles the retransmission interval each time a collision is detected.

Binary-Coded Decimal Aging numeric-based character code set in which numbers 0 through 9 have a unique 4-bit binary representation.

Bipolar (a) A pseudoternary signal, conveying binary digits, in which successive "marks" are of alternate polarity (positive and negative), but equal in amplitude, and in which "spaces" are of zero amplitude. Also called alternate mark inversion (AMI). (b) The predominant signaling method used for digital transmission services, such as dataphone digital service and T1, in which the signal carrying the binary value successively alternates between positive and negative polarities. Values of 0 and 1 are represented by the signal amplitude at either polarity, whereas no-value "spaces" are at 0 amplitude. Also known as polar transmission. (c) A type of integrated circuit using both positively and negatively charged current, characterized by high operational speed and cost.

Bipolar N-Zero Substitution (BNZS) A form of bipolar transmission in which all strings of "N" zeros are replaced with a special "N" bit sequence containing bipolar violations.

Bipolar Violation A mark that has the same polarity as the previous mark in the transmission of bipolar signals.

BISP See Business Information Systems Programs.

Bisync Binary synchronous communications (BSC). Character-oriented data-communications protocol oriented toward half-duplex link operation.

Bit A binary digit, the representation of a signal, wave, or state as either a binary 0 or a 1.

Bit Count Integrity Preservation of the precise number of bits (or characters or frames) that are originated in a message or unit of time.

Bit Duration Equivalent to the time it takes one encoded bit to pass a point on the transmission medium. In serial communications, a relative unit of time measurement used for comparison of delay times (e.g., propagation delay, access latency) when the data rate of a transmission channel can vary.

Bit Error An error in which the value of an encoded bit is changed in transmission and interpreted incorrectly by the receiver.

Bit Error Rate (BER) The percentage or ratio of the number of bits incorrectly received to the total number of bits transmitted. Usually expressed as a number less than 1 referenced to a power of 10 (e.g., 10^{-6}).

Bit Interleaving A method of time-division multiplexing in which each channel is assigned a time slot corresponding to a single bit.

Bit Oriented A communications protocol or transmission procedure in which control information is encoded in fields of one or more bits.

Bit Rate The speed at which digital signals are transmitted, usually expressed in bits per second (b/s or bps).

Bits per Second (b/s or bps) The basic unit of measure for serial data transmission capacity: (a) kb/s or kilobits per second for thousands of bits per second, (b) Mb/s or megabits per second for millions of bits per second, (c) Gb/s or gigabits per second for billions of bits per second, (d) Tb/s or terabits per second for trillions of bits per second.

Bit Stuffing A technique in high-level data link control or synchronous data link control to eliminate the possibility that data might have the same sequence as a flag sequence by inserting a 0 at the transmitter any time five 1s appear. Also see Pulse Stuffing.

BIU Basic information unit in systems network architecture.

Blocked Calls Cleared (BCC) Designation for a queuing system in which demands (calls) that find no idle servers leave the system immediately. Commonly used to model systems for which waiting positions are not provided, such as trunk groups.

Blocked Calls Delayed (BCD) Designation for a queuing system in which demands (calls) that find no idle servers wait until an idle server becomes available (i.e., they never give up). Commonly used to model systems for which customers are not overly impatient, such as digit receivers.

Blocking The inability of the calling party to be connected to the called party because either (a) all suitable trunk paths are busy or (b) a path between a given inlet and any suitable free outlet of the switching network of a switching system is unavailable.

Blocking Probability The probability that customers are turned away in a queue or other service system.

BLU Basic link unit in systems network architecture.

BNZS See Bipolar N-Zero Substitution.

Bridged Tap A cable pair connected in parallel with a customer loop. The connection (tap) may occur at the central office or at some point along a cable route.

BOC Bell operating company, one of 22 local telephone companies spun off from AT&T as a result of divestiture.

Bridging Connection A parallel connection that draws some of the signal energy from a circuit, often with imperceptible effect on the circuit's normal operation.

Bridge Tap An undetermined length of wire attached between the normal endpoints of a circuit that introduces unwanted impedance imbalances for data transmission.

Broadband Channel A transmission channel with a bandwidth wider than that required for transmitting voice signals [e.g., 48 kilohertz (kHz), 240 kHz].

BSBH See Busy Season Busy Hour.

BTU Basic transmission unit in systems network architecture.

Buffered Timing A form of timing used with independent clocks in which buffers compensate for small disturbances in clock rates between equipments.

Buffering Temporarily storing data in a register or in random access memory that allows transmission devices to accommodate differences in data rates, perform error checking, and retransmit data received in error.

Buffer Storage Electronic circuitry in which data are kept during buffering.

Bulk Encryption The process whereby two or more channels of a telecommunications system are encrypted by a single piece of crypto-equipment.
Bunched Frame Structure A time-division multiplexing frame structure in which the frame alignment signal occupies contiguous bit positions. Also called burst frame structure.
Burst Frame Structure See Bunched Frame Structure.
Bus (a) A transmission path or channel with one or more conductors where all attached devices receive all transmissions at the same time. (b) A local-network topology, such as used in Ethernet and the token bus, where all network nodes "listen" to all transmissions.
Business Information Systems Programs (BISP) One of many computer-based systems for performing voluminous business and administrative operations associated with the provision of telephone service by a local operating company.
Busy Hour The hour(s) of the day during which traffic normally peaks. Hours during which there are peaks for abnormal reasons (holidays, special events) are not considered. Traffic systems are typically sized for busy hour demand levels.
Busy Season A period during the year when busy hours are at their highest.
Busy Season Busy Hour (BSBH) The hour of the business day that, on the average, is the busiest hour during the busy season.
Busy Tone An audible signal indicating that a call cannot be completed because the called line is busy. The tone is applied 60 times per minute.
Byte Generally an 8-bit quantity of information used mainly in referring to parallel data transfer, semiconductor capacity, and data storage. Usually referred to in data communications as an octet or character.
Byte Multiplexer Channel mainframe input/output channel that allows for the interleaving or multiplexing of data in bytes.

C

Cable Entrance Facility (CEF) The entrance area in a telephone equipment building for all types of outside plant cables carrying subscriber lines and interoffice transmission facilities. The typical cable entrance facility is a vault-like, below-grade area, 15 ft high and 12 ft wide, that runs the length of the building directly under the main distributing frame(s).
CAC See Circuit Administration Center.
CAD Computer-aided design.
CAI Computer-aided instruction.
Call Congestion The ratio of calls lost because of a lack of system resources to the total number of calls over a long interval of time.
Call Detail Recording (CDR) A feature of private branch exchanges in which each telephone call is logged. This record is processed on an adjunct processor to provide call cost information (usually time and charges) and is used for cost allocation charging by department. Also called station message detail recording.
Call Set-Up Time The time needed to set up an end-to-end dedicated path in circuit-switching systems.
CAMA See Centralized Automatic Message Accounting.
Capacity Expansion A network planning activity that determines types, sizes, locations, and timing of switching system and transmission facility installations.
CAROT See Centralized Automatic Reporting on Trunks.
Carriage Return Teletypewriter or teletype code for the start of new line of a message.
Carrier A continuous frequency suitable for modulation by an information-bearing second signal that is delivered over a communication transmission medium.
Carried Load The average number of busy servers in a traffic system. In blocked-calls-delayed systems, carried load equals offered load because all calls are served eventually. In blocked-calls-cleared systems, carried load is less than offered load because some calls are denied service.
Carrier-Derived Channel One of a number of channels provided by a carrier system.
Carrier Frequency A sinusoidal waveform with constant amplitude that undergoes modulation by an information signal to shift the information signal frequencies to a higher-frequency band.
Carrier Frequency Shift The change in frequencies between transmitting and receiving terminals in a nonsynchronized carrier system.
Carrier-Sense Multiple Access with Collision Detection (CSMA/CD) A leading local-network multiaccess control technique in which all devices attached to a local network listen for transmissions in progress before attempting to transmit. If two or more begin transmitting simultaneously, the transmitting stations will detect a collision and abort the transmission, with each deferring for a variable period before attempting to transmit again.
Carrier Signal A signal suitable for modulation by an information signal. It may be a carrier frequency or it may be a stream of constant amplitude pulses, as in pulse-code modulation.
Carrier System A transmission system in which one or more channels of information is processed and converted to a form suitable for the transmission medium used by the system. Common types of carrier systems are frequency division, in which each information channel occupies an assigned portion of the frequency spectrum, and time division, in which each information channel uses the transmission medium for periodic, assigned time intervals.
CATLAS See Centralized Automatic Trouble Locating and Analysis System.
CATV (a) Community antenna television or cable television. Data communications based on radio frequency transmission, generally using 75-ohm coaxial cable as the transmission medium. (b) Communications via coaxial cable where multiple frequency-divided channels allow mixed transmission to be carried simultaneously. (c) Broadband.
CBEMA Computer Business Equipment Manufacturers Association.
C Band That portion of the electromagnetic spectrum used heavily for satellite and microwave transmission at frequencies of approximately 4 to 6 GHz.
CBX See Computerized Branch Exchange.
CC Connection confirm transport protocol data unit, open systems interconnection transport layer.
CCH See Connections per Circuit per Hour.
CCIS See Common-Channel Interoffice Signaling.
CCITT International Telegraph and Telephone Consultative Committee.
CCS See Common-Channel Signaling. See also Hundred Call Seconds.
CCSA See Common-Control Switching Arrangement.
CDO See Community Dial Office.
CDR See Call Detail Recording.
CDT Abbreviation for "Credit Allocation." This is used for flow control in the open systems interconnection transport layer.
CEF See Cable Entrance Facility.
Cell A geographic area served by a single transmitter in a cellular radio network.
Cellular Radio Technology employing low-power radio transmission as an alternative to local loops for accessing a switched telephone network. Users may be stationary or mobile, in which case they are passed under control of a central site from one cell's transmitter to an adjoining one with minimal switchover delay.
Central Office Usually used to refer to a local switching system that connects lines to lines and lines to trunks. It may be more generally applied to any network switching system. The term is sometimes used loosely to refer to a telephone company building in which a switching system is located and to include other equipment (such as transmission system terminals) that may be located in such a building.
Central Office Code A three-digit identification under which up to 10,000 station numbers are subgrouped. Exchange area boundaries are associated with the central office code, which accordingly has billing significance. Several central office codes may be served by

a central office.

Central Office Equipment Engineering System (COEES) A time-sharing operations system that assists in the planning and engineering of local switching equipment.

Centralized Automatic Message Accounting (CAMA) A process using centrally located equipment (including a switchboard or a traffic service position), associated with a tandem or toll switching office, for automatically recording billing data for customer-dialed extra-charge calls originating from several local central offices. A tape record is processed at an electronic data processing center. See Tandem Switching System.

Centralized Automatic Reporting on Trunks (CAROT) An operations system that automatically schedules tests of trunks, performs the tests, and analyzes and records the results. Centralized automatic reporting on trunks also performs tests of trunks on demand to verify trouble and repair conditions.

Centralized Automatic Trouble Locating and Analysis System (CATLAS) An operations system designed as a maintenance aid for stored-program control systems. When trouble is detected and diagnosed, CATLAS automates trouble-location procedures that identify faulty circuit packs. See also Total Network Data Systems.

Centralized System for Analysis and Reporting (CSAR) An operations system that measures the accuracy, timeliness, and completeness of the total network data system data flow and the consistency of its record bases.

Centrex A widespread telephone company switching service for customers with many stations that permits station-to-station dialing, one listed directory number for the customer, direct inward dialing to a particular station, and station identification of outgoing calls. The switching functions use telephone company central office switching equipment exclusively, to which each customer telephone set at the customer's premises is connected via individual, dedicated, extension access lines.

Cesium Clock An atomic clock using the cesium element to produce a stable, accurate timing source.

Channel A single transmission path provided from a transmission medium between two points either by physical separation (e.g., multipair cable) or by electrical separation (e.g., frequency or time-division multiplexing). May refer to a one-way path or, when paths in the two directions of transmission are always associated, to a two-way path. It is usually the smallest subdivision of a transmission system by means of which a single type of communications service (that is, a voice, teletypewriter, or data channel) is provided.

Channel Bank Terminal equipment used to combine (multiplex) channels on a frequency-division or time-division basis. Voice channels are combined into 12- or 24-channel groups.

Channel Service Unit (CSU) A component of customer premises equipment used to terminate a digital circuit, such as DDS or T1, at the customer site. The channel service unit performs certain line-conditioning functions, ensures network compliance per Federal Communications Committee rules, and responds to loopback commands from the central office. It also ensures proper ones density in transmitted bit stream and performs bipolar violation correction.

Channel Vocoder A vocoder in which the vocal tract filter is estimated by samples taken in contiguous frequency bands within the speech signal.

Character Code One of several standard methods of binary representations for the alphabet, numerals, and common symbols, such as ASCII, EBCDIC, etc.

Character Interleaving A method of time-division multiplexing in which each channel is assigned a time slot corresponding to a single character. Also called word interleaving.

Character Oriented A communications protocol or transmission procedure that carries control information encoded in fields of one or more bytes.

Checksum The sum of a group of data items associated with the group for checking purposes.

CICS See Customer Information Control System.

Circuit The electrical path between two endpoints over which one-way or two-way communications may be provided. Frequently used interchangeably with channel to designate a communications path between two or more points. Other meanings include: (a) A configuration of interconnected network equipment that provides a transmission capability and (b) a closed path through which current can flow.

Circuit Administration Center (CAC) An operations center that administers the trunk network. The functions of the CAC include: (a) Determining demand and busy-season trunk requirements and issuing message trunk orders to provide the required trunks, (b) developing forecasts of trunk requirements for the network for one to five years, and (c) network routing.

Circuit Design The local operating company process that specifies the types of network equipment required to be interconnected to satisfy a functional capability.

Circuit Order The document used to transmit engineering design of a trunk or special-services circuit for the public switched telephone network to the department that implements the design.

Circuit Order Control (COC) A component system of the Trunks Integrated Records Keeping System (TIRKS) that controls telephone company message trunk, special-services, and carrier system orders. Reports produced by COC provide management with the current status of circuit orders. Circuit order control provides data to other TIRKS component systems to update the assignment status of equipment, facilities, and circuits as orders are processed.

Circuit Provision Center (CPC) An operations center that assigns equipment and facilities and prepares and distributes work documents for message trunk circuits, designed special-services circuits, and carrier systems. It also generates and maintains circuit records and inventory and assignment records for all interoffice facilities and equipment.

Circuit Provisioning The local operating company process that responds to needs for trunks and special-services circuits. It includes circuit design, assignment of specific components, and generation of work documents for the required installation work.

Circuit Record The local operating company document that records the specific configuration of equipment assigned to a circuit.

Circuit Routing A network planning activity that determines the most efficient configuration of transmission facilities to provide the required circuits.

Circuit Switched Digital Capability (CSDC) A network capability that provides a high-speed, digital path over portions of the public switched telephone network. Circuit switched data capability provides services such as audio, graphics, teleconferencing, and bulk-data transport.

Circuit Switching A technology that establishes and maintains a dedicated path between two or more users on demand so the users have exclusive use of the circuit until the connection is released.

Class of Service (COS) Designation for one of several variable system or network connection services available to a telecommunications user. It usually distinguishes the service or features offered or denied, such as encryption, transmission priority, or bandwidth. The user's class of service is normally established upon initial acquisition of a circuit.

Class X Office Designation of a telephone company switching facility in the toll telephone hierarchy. Class 5 is an End Office, Class 4 is a Toll Center, Class 3 is a Primary Center, Class 2 is a Sectional Center, and Class 1 is a Regional Center.

Clear Channel Characteristic of a transmission path in which the full bandwidth is available to the user.

CLEI See Common-Language Equipment Identification Code.

Clipping In speech interpolation, the loss of speech segments because of overload or delay in speech detection.

CLLI See Common-Language Location Identification Code.

Clock An oscillator-generated signal that provides a timing reference for a transmission link used to control the timing of functions, such as sampling interval, signaling rate, and duration of signal elements.

An "enclosed" digital network usually has only one "master" clock.

Closed-User Group A subgroup of users assigned to a network facility that restricts communications from any member of that subgroup to other members of the subgroup only. Data terminal equipment, however, may belong to more than one closed-user group.

Cluster Controller A device that handles remote communications processing for multiple terminals or workstations.

Coaxial Cable A popular transmission medium composed of a metallic, tubular communications cable consisting of an inner conductor that is centered within and surrounded by an outer concentric conductor. The inner and outer conductors are separated and stabilized through the use of insulating disks spaced about 1 in. apart. The outer conductor forms a cylinder around the disks and is encased in either a wire-mesh or extruded-metal sheathing.

COC See Circuit Order Control.

Coded Mark Inversion A two-level code in which binary 0 is coded so that both amplitude levels are attained within the bit duration, each for half the interval. Binary 1 is coded by either of the amplitude levels for the full bit duration in such a way that the levels alternate with each occurrence of a 1.

Codirectional Timing A form of timing for synchronous transmission in which timing is provided along with data by the data terminal equipment.

COESS See Central Office Equipment Engineering System.

Coherent Detection Detection using a reference signal that is synchronized in frequency and phase to the transmitted signal. Also called synchronous detection.

Common Application Service Elements Part of the protocol in the application layer that is common to all processes and interfaces with the presentation layer.

Common Carrier A supplier in an industry that undertakes to "carry" goods, services, or people from one point to another for the public in general or for specified classes of the public. In telecommunications, such carriage relates to the provision of transmission capabilities over the telecommunications network. A common carrier that offers communications services to the public is subject to regulation by federal and state regulatory commissions.

Common-Channel Interoffice Signaling (CCIS) A signaling system, developed for use between switching systems with stored-program control, in which all of the signaling information for one or more groups of trunks is transmitted over a dedicated high-speed data link, rather than on a per-trunk basis. Common-channel interoffice signaling can reduce call setup time and save money compared with individual trunk signaling.

Common-Channel Signaling (CCS) Out-of-band signaling for circuit switched networks. Control messages are carried over separate signaling channels.

Common Control An automatic arrangement in which items of control equipment in a switching system are shared; they are associated with a given call only during the periods required to accomplish the control functions. All Bell System crossbar and electronic switching systems have common control.

Common-Control Switching Arrangement (CCSA) An arrangement in which switching for a private network is provided by one or more common-control switching systems. The switching systems may be shared by several private networks and may also be shared with the public switched telephone network. This service provides uniform dialing to customers who use a network of dedicated transmission facilities between geographically dispersed locations.

Common-Language Equipment Identification (CLEI) Code An alphanumeric code that identifies network equipment by family, subfamily, and type.

Common-Language Location Identification (CLLI) Code A 10-character designation that identifies any physical location within the public switched network.

Common System A system that provides common power, interconnection, or environmental support for network elements associated with transmission and switching (e.g., power systems, distributing frames, and equipment building systems).

Common Update/Equipment (CU/EQ) A master record base that stores the traffic measurement requests generated by local operating company personnel.

Common Update/Trunking (CU/TK) A record base system that contains trunking network information and other information required by trunk servicing and trunk forecasting systems.

Community Dial Office (CDO) A small, electromechanical or electronic switching system that serves a separate exchange area and, ordinarily, has no operating or maintenance force located in its own building; operation is handled and maintenance is directed from a remote location.

Companding The process of compressing a signal at the transmitter and expanding it at the receiver to allow signals with a large dynamic range to be sent through a device with a more limited range.

Compandor An abbreviation of compressor-expandor, a device used to compress the range of talker volumes at the input to a carrier system (in particular, to increase low-level talker volumes) and to expand the received volumes at the output of the carrier system (to provide the complementary function and to make the transmission system transparent). This technique improves the signal-to-noise ratio (s/n) for low-level talkers and provides a substantially reduced received noise level during the so-called quiet intervals.

Computer Subsystem (CSS) The computer system used by a switching control center (SCC) or by several SCCs. It interfaces with the electronic central office switching systems supported by SCCs.

Computer System for Mainframe Operations (COSMOS) A wire center administration system operating in real time for subscriber services. The objective of COSMOS is to minimize congestion and long crossconnects on main distributing frames while maintaining load balance across the switching equipment in the wire center.

Computerized Branch Exchange Terminology developed by selected vendors to differentiate their systems from competing private branch exchange products. See also Private Branch Exchange.

Concentrated Range Extension with Gain (CREG) A design method that enables the increased use of finer-gauge cables in the loop plant through the use of switched range extension shared by many customers.

Concentration (a) A switching network (or portion of one) that has more inputs than outputs. (b) The process, in a traffic network, of combining calls on many lines or trunks to convey them more efficiently to other transmission or switching equipment. (c) The process of locating as much equipment as possible at a given place to achieve economies in such things as building costs, power arrangements, and maintenance.

Conditioned Diphase A two-level code in which diphase is applied to a conditioned nonreturn-to-zero (NRZ) signal.

Conditioned NRZ A two-level nonreturn-to-zero code in which the presence or absence of a level change is used to signal a binary number.

Conditioning Special treatment of voiceband data circuits provided by telephone companies. As provided by AT&T, for example, C-type conditioning controls phase and amplitude distortion, whereas D-type conditioning limits noise and harmonic distortion.

Connection (a) Generally, in terms of a telephone connection, a two-way voiceband circuit completed between two points by means of one or more switching systems. It contains two loops and may contain one or more trunks. (b) A point where a junction of two or more conductors is made.

Connection Request Transport protocol data unit, open systems interconnection transport layer.

Connectionless Data Service Service at a given layer of the open systems interconnection reference model in which there is no connection setup phase. Class of service, systems network architecture.

Connections per Circuit per Hour (CCH) A running count of the number of trunk connections between switching systems. Used in network management as an indicator of switching congestion. See also Attempts Per Circuit Per Hour.

Contention Multiple users competing for the right to use a transmission channel, whether a private branch exchange circuit, a computer port, or a time slot, within a multiplexed digital facility.

Continuously Variable Slope Delta Modulation (CVSD) A type of delta modulation in which the size of the steps of the approximated signal is progressively increased or decreased to make the approximated signal closely match the input analog wave. It is a speech-encoding and digitizing technique that uses a one-bit sample to encode the differences between two successive signal levels. Sampling is usually done at 32,000 times a second, though some implementations employ lower sampling rates. This modulation technique is popular for voice-encryption applications.

Contradirectional Timing A form of timing for synchronous transmission in which timing of the data terminal equipment is slaved to timing from the data circuit terminating equipment.

Control Characters (a) Any extra transmitted characters used to control or facilitate data transmission between data terminal equipment, including those associated with addressing, polling, message delimiting and blocking, framing, synchronization, and error checking. (b) Characters transmitted over a circuit that are not message or user data but, when encountered, cause certain control functions to be performed.

Control Program for Microcomputers (CP/M) A single-user operating system for 8-bit microprocessor-based computers.

Conversational Time-dependent data transmissions in which an operator, upon initiating a transmission, waits for a response from a destination before continuing. Also interactive.

Coordinate Network A switching network connecting stages of coordinate switches.

Coordinate Switch A switch with contacts or electronic cross-points arranged in a matrix, or gridlike, structure. The crosspoints are usually fine-motion electromechanical elements or electronic switching elements.

Core The central region of an optical waveguide through which light is transmitted; typically 8 to 12 μm in diameter for single-mode fiber, and from 50 to 200 μm for multimode fiber.

Correlative Coding See Partial Response.

COS See Class of Service.

COSMOS See Computer System for Mainframe Operations.

Country Code The one-, two-, or three-digit number that, in the world numbering plan, identifies each country or integrated numbering plan in the world. The initial digit is always the world zone number. Any subsequent digits in the code further define the designated geographic area (normally identifying a specific country). On an international call, the country code is dialed before the national number.

CPE See Customer Premises Equipment.

CP/M See Control Program for Microcomputers.

CPS See Circuit Provision Center.

CPU Central processing unit.

CR See Connection Request. See also Carriage Return.

Craft Force Local operating company personnel with specialized technical training who install and maintain equipment.

CRC See Cyclic Redundancy Check.

CREG See Concentrated Range Extension with Gain.

Crossbar Switch A form of electromechanical switch that uses moving electronic relays to connect vertical and horizontal leads. A crossbar switch is a relay mechanism consisting of 10 horizontal paths and 10 or 20 vertical paths. Any horizontal path can be connected to any vertical path by means of magnets. A two-stage operation is used to close any crosspoint. First, a selecting magnet shifts all selecting fingers in a horizontal row, then a holding magnet shifts a vertical actuating card to close the selected contacts.

Crosstalk Unwanted transference of electrical energy from one transmission medium to an adjacent medium; generally, in telephony, in the voice-grade frequency range and typical of unshielded twisted-pair wires. It is the phenomenon in which a signal transmitted on one circuit or channel of a communications system creates an undesired electromagnetic effect in an adjacent circuit or channel. Telephone crosstalk may be intelligible or unintelligible to the parties engaged in conversation.

CRT Cathode-ray tube.

Cryptographic Equipment A scrambling device based on digital logic used to encrypt communications.

CSAR See Centralized System for Analysis and Reporting.

CSDC See Circuit Switched Digital Capability.

CSMA/CD See Carrier Sense Multiple Access with Collision Detection.

CSS See Computer Subsystem.

CSU See Channel Service Unit.

CU/EQ See Common Update/Equipment.

Customer Information Control System (CICS) A program product and mainframe operating environment designed to enable transactions entered at remote terminals to be processed concurrently by user-written applications programs. Includes facilities for building and maintaining data bases.

Customer-Line Signaling The interaction between the customer and the switching system that serves the customer.

Customer Premises Equipment (CPE) In telephony, equipment that interfaces to the telephone network and physically resides at the user's location, including most of the gear referred to as network channel terminating equipment. See also Equipment.

CU/TK See Common Update/Trunking.

Cutover A brief interval in an overall conversion period when operation actually changes from an existing to a new system or system configuration. In some cases, the change occurs almost instantaneously and may be called a flash cut.

CVSD See Continuously Variable Slope Delta Modulation.

Cyclic Redundancy Check (a) A characteristic link-level feature of bit-oriented data-communications protocols in which data integrity of a received frame or packet is checked, using a polynomial algorithm based on the content of the frame, and then matched with the result performed by the sender and included in a 16-bit field appended to the frame. (b) A basic error-checking mechanism for link-level data transmissions.

D

DACS See Digital Access and Cross-Connect System.

Data Above Voice A hybrid transmission scheme that places a data signal above the voice spectrum in a cable or radio system. Also called data over voice.

Data Circuit A network equipment configuration that provides a capability for data services.

Data Circuit-Terminating Equipment (DCE) The interfacing equipment sometimes required to couple the data terminal equipment (DTE) into a transmission circuit or channel and from a transmission circuit or channel into the DTE. In a communications link, it is equipment that is either part of the network, an access point to the network, a network node, or equipment at which a network circuit terminates. In the case of an RS-232-C connection, the modem is usually regarded as DCE, whereas the user device is data terminal equipment (DTE). In a CCITT X.25 connection, the network access and packet-switching node is viewed as the DCE.

Data Link Any serial data-communications transmission path between two adjacent nodes or devices without any intermediate switching nodes.

Data Link Layer The network processing entity that establishes, maintains, and releases data link connections between adjacent elements in a network. It ensures correct transmission of information between adjacent nodes in the network.

Datagram Service Service at the network layer in which successive packets may be routed independently from end to end. There is no call setup phase. Datagrams may arrive out of order.

Dataphone A service and trademark of AT&T. Generally refers to transmission of data over the phone network or to data transmission equipment furnished by the telephone company.

Dataphone Digital Service (DDS) A synchronous digital service offered intra-LATA (local access and transport area) by

AT&T Communications, with data rates typically at 2.4, 4.8, 9.6, and 56 kb/s. Calls may be placed over the public switched telephone network in the normal manner or automatically, and after a connection is established, data terminals are connected at both ends for exchange of data. The term may also be applied to private-line service as well.

Data in Voice A hybrid transmission scheme that places a data signal in the middle of the voice spectrum in a cable or radio system.

Data Over Voice See Data Above Voice.

Data PBX A switch that allows a user on an attached circuit to select from among other circuits, usually one at a time and on a contention basis, for the purpose of establishing a through connection. Only digital transmission is supported.

Data Service Unit (DSU) A component of customer premises equipment used to interface to a digital circuit such as dataphone digital service and T1. Usually combined with a channel service unit and performs conversion of customer's data stream to bipolar format for transmission.

Data Set Equipment that converts signals (usually digital signals) from data processors or other terminal equipment into signals suitable for transmission over telephone lines and controls the connection. Data sets can be transmitters, receivers, or both. That portion of a data set that converts terminal signals for transmission (modulator) and received line signals for delivery to the terminal (demodulator) is called a "modem" (a contraction of modulator/demodulator). The terms data set and modem are often used interchangeably.

Data Terminal A device that is used with a computer system for data input and output. If it is situated at a location remote from the computer system, it requires data transmission. Examples of data terminals include cathode-ray tubes, teletypewriters, and magnetic tape readers. The term also applies to devices for terminal-to-terminal communications.

Data Terminal Equipment (DTE) Equipment consisting of digital instruments that convert the user information into data signals for transmission or reconvert the received data signals into user information.

Data Transfer Rate The average number of bits, characters, or blocks per unit of time transferred from a data source to a data sink.

Data Under Voice (DUV) A hybrid transmission scheme that places a data signal under the voice spectrum in a cable or radio system. Most commonly it is an arrangement for transmitting 1.544 megabits per second (Mb/s) pulse streams in the bandwidth available underneath the portion of the baseband used for voice channels on existing microwave systems.

dB See Decibel.

dBm Power level in decibels referenced to 1 milliwatt. Relative strength of a signal calculated in decibels when the signal is compared in a ratio to a value of 1 milliwatt. Used mainly in telephony to refer to relative strength of a signal (e.g., at 0 dBm, a signal delivers 1 milliwatt to a line load, whereas at -30 dBm a signal delivers 0.001 milliwatt to a load).

dBm0 Power level in dBm referred to or measured at a point of zero relative level.

DBMS Data base management system.

dBrnC0 C-message weighted noise power in decibels referenced to 1 picowatt (-90 dBm) and measured at a zero transmission level point.

DC (a) Direct current. (b) Disconnect confirm transport protocol data unit, open systems interconnection transport layer.

DCE See Data Circuit-Terminating Equipment.

DCT See Digital Carrier Trunk.

DDD See Direct Distance Dialing.

DDP Distributed data processing.

DDS See Dataphone Digital Service and Digital Data System.

Deadlock A situation in which traffic ceases to flow and throughput drops to zero.

Decibel (dB) A logarithmic measure of the ratio between two powers named for Alexander Graham Bell. (a) A unit of measurement used to express the ratio of two values, usually the power of electrical or electromagnetic signals. Equal to 10 times the logarithm derived from a ratio of the two power levels expressed in watts. (b) The relative gain or loss of a signal when the measured signal value is compared with a ratio to another value.

$dB = 10 \log 10\ p$

Decision Feedback Equalizer An equalizer that uses a feedback loop operating on the detector outputs to cancel intersymbol interference caused by previous symbols.

Dedicated Circuit A circuit designated for exclusive use by two users.

Delay Distortion The distortion of a waveform made up of two or more different frequencies that is caused by the difference in arrival time of each frequency at the output of a transmission system.

Delay Time The sum of waiting time and service time in a queue.

Delta Modulation A form of differential pulse-code modulation in which the magnitude of the difference between the predicted value and the actual value is encoded by one bit only. That is, where only the sign of that difference is detected and transmitted.

Demarcation Point (Demarc) In the interconnection environment, the physical and electrical boundary between equipment or facilities provided by another common carrier and Bell System facilities.

Demodulation The process of restoring a signal to its original form at the receiving end of a transmission system.

Dial The part of a telephone station set that generates a coded signal to control the central office switching equipment in accordance with the digits dialed. It may be either a rotary or push-button device. (See Station Equipment.) The term is sometimes used as an adjective, as in dial administration, the process of short-term rearranging and performance monitoring in a central office switching system.

DIAL-IT Network Communications Service Any of several services in which customers dial advertised telephone numbers to reach an announcement. Examples of DIAL-IT services are Public Announcement Service (Sports-Phone, Dial-a-Joke, etc.) and Media Stimulated Calling (telephone voting, telethons, and media promotions).

Dial Tone An audible tone sent from an automatic switching system to a customer to indicate that the equipment is ready to receive dial signals.

Dial Tone Delay A measure of time required to provide dial tone to customers. This measures one aspect of the performance of a switching system.

DID See Direct Inward Dialing.

Differential Manchester Encoding A modified version of Manchester encoding. In this scheme the phase of successive binary intervals is switched.

Differential Phase-Shift Keying (DPSK) A modulation technique for transmitting digital information in which each symbol causes phase changes of the carrier signal with respect to its previous phase angle. At the receiving end, phase changes are detected by comparing the phase of each signal element with the phase of the preceding signal element.

Differential Pulse-Code Modulation (DPCM) A process in which a signal is sampled and the difference between the actual value of each sample and its predicted value derived from previous samples is quantized and converted by encoding to a digital signal.

Digital Access and Cross-Connect System (DACS) Central office switching equipment that permits a T1 carrier facility or any of the subchannels nominally at 64 kb/s to be switched or cross-connected to another T1 carrier. Though originally designed to allow access to individual T1 channels for diagnostics, the equipment is expected to support switched digital services at up to T1 rates.

Digital Carrier Trunk (DCT) An internal interface that combines certain T-carrier transmission functions and electronic switching system control functions.

Digital Channel A transmission channel that carries signals in digital form.

Digital Channel Bank Pulse-code modulation multiplexer equipment used in the North American digital hierarchy.

Digital Data System (DDS) A nationwide, private-line, synchronous data-communications network formed by interconnecting digital transmission facilities and providing special maintenance and testing capabilities. Customer channels operate at 2.4, 4.8, 9.6, or 56 kilobits per second (kb/s or kbps).

Digital Signal A signal that has a limited number of discrete states before transmission. A digital signal may be contrasted with an analog signal, which varies in a continuous manner and may be said to have an infinite number of states.

Digital Signal (DS) Level One of several transmission rates in the time-division multiplex hierarchy. For example, the DS1 level is 1.544 megabits per second (Mb/s).

Digital Speech Interpolation (DSI) A form of digital multiplexing for voice that uses speech interpolation.

Digital System Cross-Connect An internal interface that acts as a central point for cross-connecting, rearranging, patching, and testing digital equipment and facilities.

Digital Termination Systems A form of local loop or local distribution in which digital radio is used to connect users to a long-haul communication network.

Digital Transmission A mode of transmission in which all information is transmitted in digital form, that is, as a serial stream of pulses. Any analog signal, such as voice, can be converted into a digital signal.

Digroup A digitally multiplexed group of 24 channels. Digroup usually refers to the T1 carrier line signal of 1.544 megabits per second (Mb/s); however, the term is also used to refer to the digital channel bank that provides the 24-channel multiplexing function.

Diphase A two-level code generated by the modulo 2 addition of a nonreturn-to-zero signal with its associated clock signal.

Direct Distance Dialing (DDD) The automatic establishment of toll calls in response to signals from the dialing device of the originating customer. It also refers to conventional long-distance switched telephone calls placed over the public network. See Message Telephone Service.

Direct Inward Dialing (DID) A feature that permits incoming calls to stations served by a private branch exchange or by a Centrex to be dialed directly; the call need not go through an attendant.

Direct Services Dialing Capability (DSDC) A set of service independent network capabilities that will allow the creation of specific services to meet specific customer needs. The capabilities are provided by a set of primitives in a switching system that can be summoned into use with any service. Examples of primitives are: route the call, make a billing record, play an announcement.

Direct Trunk A trunk between two Class 5 offices (End Offices) in the public switched telephone network hierarchy.

Dispersion The spreading, separation, or scattering of a waveform during transmission. Also called amplitude dispersion.

Distortion The corruption of a signal. Any departure from a specified input/output relationship over a range of frequencies, amplitudes, or phase shifts during a time interval. Quantitatively, the difference between values of two measured parameters of a signal, or between the transmitted and received characteristics of the same signal. The measured variation, for example, of frequency (frequency response), time (delay distortion), or harmonics.

Distribution In a switching network, the capability of connecting an input to any one of several outputs. In a traffic network, separating calls on incoming trunk groups at a tandem toll office and recombining them on other outgoing trunk groups.

Distributing Frame A manually operated hardware system used to interconnect network elements (outside plant cables, switching and transmission equipment, etc.) to provide telecommunications services.

Distributed Frame Structure A time-division multiplexing frame structure in which the frame alignment signal occupies noncontiguous bit positions.

Diversity Routing The provision of two separate physical media paths for routing telecommunication services from a facility location. It is a form of redundancy provided for service protection.

Doppler A shift in the observed frequency of a signal caused by variation in the path length between the source and the point of observation.

Double-Sideband Amplitude Modulation (DSBAM) Amplitude modulation in which the modulated wave is accompanied by both of the sidebands resulting from modulation; the upper sideband corresponds to the sum of the carrier and modulation frequencies, whereas the lower sideband corresponds to the difference between the carrier and modulation frequencies.

DPCM See Differential Pulse-Code Modulation.

DPSK See Differential Phase-Shift Keying.

DR Disconnect request transport protocol data unit, open systems interconnection transport layer.

Drift An undesirable progressive change in frequency with time. Also called frequency drift or wander.

DSDC See Direct Services Dialing Capability.

DSI See Digital Speech Interpolation.

DSU See Data Service Unit.

DSBAM See Double-Sideband Amplitude Modulation.

DT Data transport protocol data unit, open systems interconnection transport layer.

DTE See Data Terminal Equipment.

DTMF See Dual-Tone Multifrequency.

Dual-Tone Multifrequency (DTMF) (a) A means of signaling that uses a simultaneous combination of one of a lower group of frequencies and one of a higher group of frequencies to represent each digit or character. (b) A process in telephony whereby the push-button pad on a station set causes a signal where each depressed key generates two audio output tones, the combination of which is unique for each of the 12 keys.

Ducting The propagation of radio waves within an atmospheric layer whose refractivity gradients are such that radio waves are guided or focused within the duct.

Duobinary A three-level coding scheme that uses controlled amounts of intersymbol interference to achieve transmission at the Nyquist rate.

Duplex A type of transmission that affords simultaneous operation in both directions.

DUV See Data Under Voice.

E

EADAS See Engineering and Administrative Data Acquisition System.

EADAS/NM See Engineering and Administrative Data Acquisition System/ Network Management.

ECCS See Economic CCS.

Echo An energy wave that has been reflected or otherwise returned with sufficient magnitude and delay to be perceived in some manner as a wave distinct from that directly transmitted. Echoes are frequently measured in decibels (dBs) relative to the directly transmitted wave.

Echo Canceler A device that detects transmitted speech signals, generates a signal that is a replica of the echo, and subtracts this signal from the actual echo, thereby canceling the echo.

Echo Suppressor A device that detects speech signals transmitted in either direction on a four-wire circuit and introduces loss in the opposite direction of speech transmission to suppress echoes.

ECMA European Computer Manufacturers Association.

Economic CCS (ECCS) The load that should be carried on the last trunk of a high-usage group to minimize the total cost of routing the offered traffic, assuming that overflow from the high-usage route is offered to an alternate route engineered to meet an objective blocking probability. See also Carried Load.

Economic Evaluation An analysis of the economic impact on a company's overall financial position of designing, producing, or implementing a product or service.

Effective Earth Radius The radius of a hypothetical earth for which the distance to the radio horizon, assuming rectilinear propagation, is the same as that for the actual earth with an assumed uniform vertical gradient of refractive index.

800 Service See Wide Area Telecommunications Services.

Elastic Buffer A storage device using digital logic designed to accept data timed by one clock and deliver it timed by another clock.

Electromechanical Switching System An automatic switching system in which the control functions are performed principally by devices, such as relays and servos, that are electrically operated and have mechanical motion.

Electronic Switching System (a) A class of modern switching systems in which the control functions are performed principally by electronic devices. (b) A family of AT&T-manufactured, stored-program-control, central office switches; most notable are Nos. 1, 1A, 4, and 5 switches.

Electronic Tandem Switching (ETS) A private network service that provides customers with a uniform numbering plan and numerous call-routing features. The electronic tandem switching functions are furnished by the switching equipment that provides private branch exchange or Centrex service.

Electronic Translator The equipment in No. 4A and No. 5A crossbar systems that functions primarily to translate address codes, by means of electronic circuitry and stored-program control, into information required by the system to select an available route toward the central office of the called customer. See also Crossbar Switch.

E&M Lead Signaling A specific form of interface between a switching system and a trunk in which the signaling information is transferred across the interface via two-state voltage conditions on two leads, each with a ground return, separate from the leads used for message information. The message and signaling information are combined (and separated) by a signaling system appropriate for application to the transmission facility. The term E&M lead signaling is used also in some special-services applications.

Emulation The imitation of all or part of one device, terminal, or computer by another so the imitating device accepts the same data, performs the same functions, and appears to other network devices as the imitated device.

Encoder A device that generates a code, frequently one consisting of binary numbers, to represent individual characters or signal samples.

Encoding/Decoding The process of reforming information into a format suitable for transmission and then reconverting it after transmission. For pulse-code modulated voice transmission, the generation of digital signals to represent quantized samples and the subsequent reverse process.

End of Address (EOA) Header code.

End of Block (EOB) A control character or code that marks the end of a block of data.

End Office A local telephone switching office in which loops are terminated for purposes of interconnection to each other and to trunks. End offices are designated Class 5 offices.

End Office Toll Trunk A high-usage trunk from an end office that carries toll traffic only. It may be either a direct trunk to another end office or a trunk to a toll center in another toll center area (that is, not the toll center on which the end office homes).

End of Message (EOM) For single-message transmission, this is equivalent to EOT.

End of Transmission (EOT) A control code in character-oriented protocols or a bit field set to "1" in bit-oriented protocols that tells the receiver that all user data have been sent.

Engineered Capacity The highest load level for a trunk group or a switching system at which service objectives are met.

Engineering and Administrative Data Acquisition System (EADAS) An operations system in which traffic data are measured at switching systems by electronic devices, transmitted to a centrally located minicomputer, and recorded on magnetic tape in a format that is suitable for computer processing and analysis.

Engineering and Administrative Data Acquisition System/Network Management (EADAS/NM) An operations system that monitors switching systems and trunk groups that have been designated by network managers. Engineering and Administrative Data Acquisition System/Network Management reports existing or anticipated congestion on a display board at operating company network management centers.

Engineering Period A particular time period during which service is measured and compared with the objective grade of service. Sufficient equipment must therefore be provided (engineered) to meet service objectives during this period.

Enhanced Private Switched Communication Service (EPSCS) A private network service that, like the common-control switching arrangement, provides a uniform dialing plan for customers with geographically dispersed locations. Enhanced private switched communication service offers four-wire transmission (to improve transmission quality) within the private network and a customer network control center, which can be used by the customer to control some network operations and to obtain private network usage and status information.

Envelope Delay Distortion In a given passband of a device or a transmission facility, the maximum difference of the group delay time between any two specified frequencies. Also called group delay distortion.

Envelope Detection A form of demodulation in which detection is based on the presence or absence of the signal envelope.

EOA See End of Address.

EOB See End of Block.

EOM See End of Message.

EOT See End of Transmission.

EPLANS Computer Program Service Software systems used by local operating company engineering and related personnel to support their planning, record keeping, implementation, scheduling, ordering, network performance evaluation, network characterization, and other similar activities. The programs are Western Electric products and are offered as time-share or batch-run computer services by Western Electric or, in some cases, are run in telephone company data centers.

EPROM Erasable programmable read-only memory.

EPSCS See Enhanced Private Switched Communication Service.

Equalization (a) In the telephone network, the spacing and operation of amplifiers so that the gain provided by the amplifier, per transmission frequency, coincides with the signal loss at the same frequency. (b) In communications, the process of reducing frequency distortion or phase distortion, or both, of a circuit by the introduction of a combination of adjustable coils, capacitors, and resistors to compensate for the differences in attenuation, time delay, or both, at the various frequencies in the transmission band.

Equipment A term broadly applied to hardware components that includes customer premises equipment and switching and transmission (and other) components located in telephone company buildings.

Equipment and Facility Recovery The reduction of capital investment for additional equipment accomplished by providing accurate records of what capital equipment is already available to meet a current need.

Equipment-to-Equipment Interface Any interface between equipment units on a user premises that is not considered a network interface.

Erasable Storage A storage device whose contents can be modified (e.g., random access memory or RAM).

Erlang Standard unit of measurement of telecommunications traffic capacity and usage demand. Named for A.K. Erlang, the founder of the traffic theory. It is a dimensionless unit of traffic intensity widely used in circuit switching systems to express the average number of calls under way or the average number of devices in use. It is the product of call arrival rate and call holding (service) time. One erlang corresponds to the continuous occupancy of one traffic path for 1 hr [36 hundred call seconds (CCS)]. Traffic in erlangs is the sum of the holding times of paths divided by the period of measurement. The term erlang can be used to express the capacity of a system (e.g., a trunk group of 30 trunks, which, in a theoretical peak sense, might carry 30 erlangs of traffic but would actually have a typical capacity of perhaps 25 erlangs averaged over an hour).

Erlang B One of the basic traffic models and related formulas used in the Bell System. The assumptions are Poisson input, negative exponential holding times, and blocked calls cleared. Used for trunk engineering. Also called Erlang's Loss Formula.
Erlang-B Distribution Erlang distribution of the first kind, or Erlang Loss Formula.
Erlang C One of the basic traffic models and related formulas used in the Bell System. The assumptions are Poisson input, negative exponential holding times, and blocked calls delayed. Used for common-control engineering. Also called Erlang's Delay Formula.
ERN Explicit route number in systems network architecture.
Error Burst (a) A sequence of transmitted signals containing one or more errors, but regarded as a unit in error in accordance with a predefined measure. (b) A loss of synchronization between sending and receiving stations caused by enough consecutive transmitted bits being in error. It necessitates resynchronization.
Error-Free Blocks A measure of error performance based on the percentage or probability of data blocks that are error free.
Error-Free Seconds A measure of error performance based on the percentage or probability of seconds that are error free.
Error-Second A measurement of system performance for digital transmission facilities. An error-second is a 1-sec interval during which one or more bit errors occur.
Essentially Nonblocking Switches Those switches whose probability of blocking in the switching matrix is much less than the probability of blocking in a connecting link.
ETS See Electronic Tandem Switching.
Exchange Area Traditionally, an area within which there is a single uniform set of charges for telephone service. An exchange area may be served by a number of central offices. A call between any two points within an exchange area is a local call.
Expanded 800 Service An improvement over the basic 800 service that uses direct services dialing capability to provide customers with more options in defining service areas and determining the treatment a call receives.
Expansion The term applied to a switching network (or portion of one) that has more outputs than inputs.
Explicit Route The end-to-end physical path in systems network architecture into which the virtual route is mapped.
Exponential Delta Modulator A type of delta modulator that uses a resistive/capacitive circuit for an integrator that provides an exponential response to a constant input.
Extended Framing Format A framing format for 1.5 Mb/s digital channel banks introduced by AT&T with the D5 channel bank.
External Reference Synchronization A form of network synchronization in which a timing or frequency reference is obtained from a source external to the communication network.
Eye Pattern An oscilloscope display of a digital signal used to examine performance.

F

Facilities Assignment and Control System (FACS) An on-line data processing system that maintains inventories and provides assignment of outside plant and central office facilities.
Facilities Network The aggregate of transmission systems, switching systems, and station equipment; it supports a large number of traffic networks.
Facility Any one of the elements of physical telephone plant that are needed to provide service. Thus, switching systems, cables, and microwave radio transmission systems are examples of facilities. Facility is sometimes used in a more restricted sense to mean transmission facility.
Facility and Equipment Planning System (FEPS) A component system of the Trunks Integrated Records Keeping System (TIRKS) that supports the current planning process. Facility and Equipment Planning System helps planners use information in the TIRKS data bases along with forecasts of future growth to allocate existing inventories efficiently, to determine future equipment and facility requirements, and to update planning designs.
FACS See Facilities Assignment and Control System.
Facsimile (Fax) The communications process in which graphics or text documents are scanned, transmitted via a phone line, and reconstructed by a receiver. Facsimile device operation follows one of the International Telegraph and Telephone Consultative Committee standards for information representation and transmission (Group 1 analog, with page transmission in 4 or 6 min; Group 2, with page transmission in 2 or 3 min; and Group 3 digital, with page transmission in less than 1 min.).
Fade Margin The amount by which a received signal level may be reduced without causing the system (or channel) output to fall below a specified threshold.
Fading The variation, with time, of the intensity or relative phase, or both, of any frequency component of a received signal because of changes in the characteristics of the propagation path with time.
Failure The termination of the ability of an item to perform a required function.
Failure Rate The average rate at which failures can be expected to occur throughout the useful life of an item.
Far-End Crosstalk (FEXT) Crosstalk that is propagated in a disturbed channel in the same direction as the propagation of a signal in the disturbing channel. The receiving terminals of the disturbed channel and the energized terminals of the disturbing channel are usually remote from each other.
Fax See Facsimile.
FCC See Federal Communications Commission.
FCFS A service discipline of queueing systems, based on the first-come-first-served rule [First In First Out (FIFO)].
FDM See Frequency-Division Multiplexing.
FDX See Full Duplex.
Federal Communications Commission (FCC) A board of commissioners, appointed by the President of the United States under the Communications Act of 1934, having the power to regulate interstate and foreign communications originating in the United States by wire and radio.
FED-STD-1002 Time and frequency reference information in telecommunications systems.
FED-STD-1003 Synchronous bit-oriented, data link control procedures.
FED-STD-1005 Coding and modulation requirements for nondiversity 2.4 kb/s modems.
FED-STD-1006 Coding and modulation requirements for 4.8 kb/s modems.
FED-STD-1007 Coding and modulation requirements for duplex 9.6 kb/s modems.
FED-STD-1008 Coding and modulation requirements for duplex 600 bit/s and 1.2 kb/s modems.
Feeder Route A network of loop cable extending from a wire center into a segment of the area served by the wire center.
FEP See Front-End Processor.
FEPS See Facility and Equipment Planning System.
FEXT See Far-End Crosstalk.
Fiber Loss Attenuation of the light signal in optical fiber transmission.
Fiber Optics Transmission technology in which modulated lightwave signals, generated by a laser or light-emitting diode, are propagated along a glass or plastic waveguide and then demodulated back into electrical signals by a light-sensitive receiver.
Field Representative A member of the Bell Laboratories Quality Assurance Center responsible for monitoring the operation of Bell System telecommunications equipment in the field and participating in field evaluations and reliability studies.
File Server In local networks, a station dedicated to providing file and mass data-storage services to the other stations on the local network.
Filler Signal Unit Signal unit of common channel signaling used to transmit acknowledgment (ACK) and negative acknowledgment (NAK) information when messages are not available.
Filter Electronic circuitry that removes energy in unwanted

frequencies, such as noise, from a transmission channel. May be analog or digital in operation.

Final Group A trunk group that acts as a final (last-chance) route for traffic. Traffic can overflow to a final group from high-usage groups that are busy. Calls blocked on a final group are not offered to another route.

Final Trunk A trunk in a final group.

FIPS Federal Information Processing Standard.

Flat Fading Fading in which all frequency components of the received radio signal vary in the same propagation simultaneously.

Flat Rate A rate-setting principle for local service in which customers in a specific group or area are all charged the same rate for local calling regardless of the number of local calls they make or the length of the calls.

Flow Control Both congestion control and the control, by a receiver, to prevent overflow of its buffer.

FM See Frequency Modulation.

FNPA See Foreign Numbering Plan Area.

Focused Overload Abnormal calling from many points to one point; for example, after a disaster or when a radio or television station encourages mass calling.

Foldover Distortion See Aliasing Distortion.

Forecasting A network planning activity that provides estimates of future demands for existing and new services.

Foreign Exchange (FX) Service A special telephone company line arrangement that provides a circuit between a customer's main station or private branch exchange where calls can be placed into the switched telephone network from a central office other than the one that normally serves the exchange area in which the customer is located.

Foreign Numbering Plan Area (FNPA) Any numbering plan area (NPA) outside the boundaries of the home NPA.

Formant Vocoder A vocoder in which the vocal tract filter is estimated by the frequencies and amplitude of the spectral peaks, or formants.

Forwarding Data Base Routing table containing the least-cost outgoing link for each destination in digital network architecture.

Fractional Frequency Difference The algebraic difference between two normalized frequencies. Also called relative frequency difference or normalized frequency difference.

Frame (a) A segment of an analog signal or digital signal that has a repetitive characteristic in that corresponding elements of successive frames represent the same things. Examples are a television frame, which represents a complete scan of a picture, or a telemetry frame, which represents values of a number of parameters in a specific order. (b) In a time-division multiplex system, a set of consecutive digit time slots in which the position of each slot can be identified by reference to a frame alignment signal. The frame is repeated at the sampling rate, and each channel occupies the same sequence position in successive frames. The frame alignment signal does not necessarily occur, in whole or in part, in each frame. (c) A unit of data of the data link layer. (d) A physical unit of information equivalent to what would be seen on a display screen. (e) An assembly of telephone cable distribution equipment for terminating twisted-pair copper wire.

Frame Acquisition Mode A mode of operation in time-division multiplexing frame synchronization in which the frame alignment signal is detected. Also called frame search mode.

Frame Acquisition Time The time that elapses between a valid frame alignment signal being available at the receiver terminal equipment and frame alignment being established. Also called frame alignment recovery time.

Frame Alignment The state in which the frame of the receiving equipment is correctly phased with respect to that of the received signal.

Framing A control procedure used with multiplexed digital channels such as T1 carriers in which bits are inserted so the receiver can identify the time slots allocated to each subchannel. Framing bits may also carry alarm signals indicating specific alarm conditions.

Framing Bit A non-information-carrying bit introduced into a bit stream to facilitate the separation of characters at the receiving end of a transmission.

Frame Maintenance Mode A mode of operation in time-division multiplexing frame synchronization in which the frame alignment signal, after detection, is continuously monitored to ensure that frame alignment is maintained.

Frame Reacquisition Time The time that elapses between a loss of frame synchronization and the recovery of the frame alignment signal.

Frame Search Mode See Frame Acquisition Mode.

Free-Space Loss The signal attenuation that would result if all obstructing, scattering, or reflecting influences were sufficiently removed that they had no effect on propagation.

Freeze Frame (a) A type of digital television transmission in which screen images are replenished or painted every few seconds at the receiver set. Images are sent in real time, but there is no motion. (b) In video teleconferencing applications, allows a smaller-bandwidth transmission facility to be used than with full-motion.

Frequency The number of repetitions (cycles) or events per unit of time of a complete waveform. When the unit of time is 1 sec, the measurement unit is usually expressed in Hertz (Hz).

Frequency Accuracy The degree of conformity to a specified value of a frequency.

Frequency Band Portion of the electromagnetic spectrum within a specified upper- and lower-frequency limit.

Frequency Content The band of frequencies or specific frequency components contained in a signal. For example, the frequency content of a voiceband signal includes components between 200 and 3500 hertz (Hz).

Frequency Deviation In frequency modulation, the peak difference between the instantaneous frequency of the modulated wave and the carrier frequency.

Frequency Diversity A method of radio transmission used to minimize the effects of fading wherein the same information signal is transmitted and received simultaneously on two or more independent carrier frequencies.

Frequency-Division Multiplexing (FDM) A method of providing a number of simultaneous channels over a common transmission path by using a different frequency band for the transmission of each channel.

Frequency Drift See Drift.

Frequency Modulation (FM) One way to modify a signal to make it "carry" information. The frequency of a carrier signal is modified in accordance with the amplitude of the information signal.

Frequency Response The variation in relative strength (measured in decibels) between frequencies in a given frequency band, usually of the voice-frequency range of an analog telephone line.

Frequency-Selective Fading Fading in which not all frequency components of the received radio signal vary simultaneously.

Frequency-Shift Keying (FSK) A modulation technique for transmitting digital information having two, or possibly more, discrete states. Each of the discrete states is represented by an associated frequency. The most common form is binary FSK, which uses two frequencies to represent the two states. For example, where two different tones represent either the "0" or the "1" state of binary information.

Fresnel Zones In line-of-sight microwave radio, a cigar-shaped energy wave shell of circular cross section surrounding the direct path of the signal between a transmitter and a receiver. For the first Fresnel zone, the distance from the transmitter to any point on this shell and on to the receiver is one-half wavelength longer than the direct path, for the second Fresnel zone, two half-wavelengths, etc.

Front-End Processor (FEP) A dedicated computer linked to one or more host computers or multi-user minicomputers that performs data-communications functions and serves to off-load the attached computers of network processing.

FSK See Frequency-Shift Keying.

Full Duplex The two-way simultaneous operation of a voice or data-communications link between devices in which either user transmits at will at the same time.

Full-Motion Video Television transmission in which images are sent and displayed in real time and motion is continuous. Compare with Freeze Frame.

Fully Connected Network A network topology in which each node is directly connected by branches to all other nodes.

Fundamental Planning A network planning activity that develops long-range plans for changes and growth in network structure.

G

G See Giga.

Gain An increase in signal power during transmission from one point to another, usually expressed in decibels. Gain is measured in decibels for the ratio of an output signal level to an input signal level. It is the opposite of loss or attenuation. Also called amplification.

Gain Hits Cause of errors with phone-line data transmission, usually in which the signal surges more than 3 dB and lasts for more than 4 millisec. Bell standard calls for eight or fewer gain hits in a 15-min period.

Gateway Hardware and software that form the interface between two systems. Most important, it provides the necessary protocol translation between disparate networks. It is a conceptual or logical network station that serves to interconnect two otherwise incompatible networks, network nodes, subnetworks, or devices. It performs a protocol-conversion operation across a wide spectrum of communications functions or layers.

Gaussian Noise Undesirable background electrical noise and random electrical energy that is introduced into a transmission channel from the environment; generally of low amplitude but may still occasionally interfere with a carrier signal.

General Trade A Bell System term for manufacturers and suppliers of telecommunications equipment other than Western Electric.

Generic Program A set of instructions for an electronic switching system that is the same for all offices using that type of system. Detailed differences for each individual office are listed in a separate parameter table.

Giga (G) Prefix meaning one billion.

GOS See Grade of Service.

Graceful Close Method used to terminate a connection at the transport layer with no loss of data.

Graded-Index Fiber An optical fiber that has a refractive index that gets progressively higher toward the center, causing light rays continually to be refocused inward.

Grade of Service (GOS) (a) An estimate of customer satisfaction with a particular aspect of service (such as noise or echo). It combines the distribution of subjective opinions of a representative group of people with the distribution of performance for the particular aspect being graded. For example, with a specified distribution of noise, 95 percent of the people may judge the noise performance to be good or better; the noise grade of service is then said to be 95 percent good or better. (b) In traffic networks, the proportion of calls that receive no service (blocking) or poor service (long delay).

Ground An electrical connection or common conductor that, at some point, connects to the earth.

Group In frequency-division multiplexing, a number of voice channels (generally 12) occupying a 48 kHz frequency band.

Group Delay Distortion See Envelope Delay Distortion.

H

Half-Duplex A type of two-way communication transmission that affords communication in either direction but only in one direction at a time.

Harmonic Distortion Communications interference resulting from generated harmonic signals and measured in decibels, compared with the power of the input signal at the base frequency.

HDBN See High-Density Bipolar N.

HDLC See High-Level Data Link Control.

Head End A passive component in a broadband transmission network that translates one range of frequencies to a different frequency band and allows devices on a single cable network to send and receive without the signals interfering with each other on a single cable. Used extensively in cable TV networks.

Header Control information and codes that are appended to the front of a block of user data for control, synchronization, routing, and sequencing of a transmitted data frame or packet.

Hertz (Hz) (a) Measurement that distinguishes electromagnetic waveform energy. (b) Number of cycles or complete waves that pass a reference point per second. (c) Measurement of frequency, in which 1 hertz equals one cycle per second.

Hierarchical Routing Multiple-level routing. Used both in packet switching and circuit switching.

High-Density Bipolar N (HDBN) A form of bipolar transmission that limits the number of consecutive zeros to "N" by replacing the (N + 1)th zero with a bipolar violation.

High-Information Delta Modulation A form of delta modulation in which the step size is doubled for consecutively identical bits at the coder output and halved for consecutively opposite bits at the coder output.

High-Level Data Link Control (HDLC) (a) International Telegraph and Telephone Consultative Committee-specified, bit-oriented, data link control protocol and the foundation on which most other bit-oriented protocols are based. (b) Any related control of data links by specified series of bits rather than by control characters.

High Pass Filter A specific frequency level above which an analog filter will allow all frequencies to be passed.

High-Usage (HU) Group A trunk group between two switching systems that is designed for high average occupancy. To provide an overall acceptable probability of blocking, calls blocked on a high-usage group are offered to other routes.

High-Usage (HU) Trunk A trunk in a high-usage group.

HNPA See Home Numbering Plan Area.

Home Numbering Plan Area (HNPA) The numbering plan area within which the calling line appears at a local (Class 5) switching office (End Office).

Hub Polling A polling technique in which permission to transmit is passed sequentially from one designated user to another.

Human Factors A scientific discipline that takes human behavioral characteristics and physical capabilities into account when designing products to be used or tasks to be performed.

Hundred Call Seconds (CCS) In telephony, a unit of traffic measurement. A circuit connection, or port where usage of 36 CCS (3600 sec), or 1 erlang, indicates it is in use all the time. Typical usage for most voice communications circuits ranges from about 3 to 10 CCS per user station, whereas data circuits generally involve longer holding times, ranging from 12 to 20 CCS per station. Also used to compare relative nonblocking throughput capacity of a switch, PBX, or network.

Hundred Call Seconds (CCS) per Hour A transmission traffic measurement used to express the average number of calls in progress or the average number of devices in use. Numerically, it is 36 times the traffic expressed in erlangs.

Hybrid (a) A combination of two or more technologies. (b) In telephony, an induction coil and related circuitry at a central office that interfaces a two-wire local loop to a four-wire circuit, allowing for physical separation of the transmit and receive signals. The hybrid network is designed so that when the loop ports are properly terminated, the signal input to any particular port splits equally between the two adjacent ports with essentially no signal coupled to the opposite port.

Hybrid Transmission A type of transmission that carries frequency-division multiplexing voice and digital data on the same medium, such as cable or radio.

Hz See Hertz.

I

IEEE Institute of Electrical and Electronics Engineers.
IFRPS See Intercity Facility Relief Planning System.
ILS See Input-Buffer Limiting Scheme.
Impedance The effect on a transmitted signal of resistance, inductance, and capacitance.
Impulse Hits Cause of errors in phone-line data transmission. Voltage surges lasting from 1/3 to 4 milliseconds that usually come to within 6 dB of the normal signal level. Bell System circuit design for a standard voice channel allows no more than 15 pulse hits per 15-min. period. Also called "spikes."
Impulse Noise Short-duration, high-amplitude bursts, or spikes, of noise energy much greater than the normal peaks of message circuit noise on a transmission channel.
IMS/VS See Information Management System/Virtual Storage.
Inband Tone Signaling Signaling and control messages that use the same channel path as message information and in which the signaling frequencies are in the same band used for the message.
Incarnation Number A unique name or number sent within a data unit to avoid duplicate data unit accept.
Independent Clock Synchronization A form of network synchronization based on the use of clocks that are independently timed but constrained within specified limits of accuracy.
Independent Telephone Company A telephone company, not affiliated with the Bell System, that has its own "independent" territory. In 1987, there were more than 1450 independent telephone companies in the United States.
Individual Circuit Analysis (ICAN) Program Part of the Total Network Data System that detects electromechanical switching system equipment faults by identifying abnormal load patterns on individual circuits within a circuit group. These faults, for example, include defective circuits that prevent customer calls from being completed. Individual Circuit Analysis produces reports used by the network administration center.
Information Management System/Virtual Storage Oriented toward batch processing and telecommunications-based transaction processing.
Information Provider The entity that prepares information for presentation on a videotext or teletext system.
Input-Buffer Limiting Scheme (ILS) A flow control scheme that blocks overload locally generated arrivals by limiting their number at a buffer.
In-Service Testing A form of testing in which operational traffic is not interrupted.
Instantaneous Companding A form of companding used in delta modulation in which changes in step size are made at a rate equal to the sampling rate.
Integrated Digital Network A network in which connections established by digital switching are used for the transmission of digital signals.
Integrated Services Digital Network (ISDN) An integrated digital network in which an all-digital switched network handles a multiplicity of services with standard interfaces for user access. The same digital switches and digital paths are used to establish connection for different services--for example, telephony, data, and video services.
Integrated Voice/Data Terminal (IVDT) One of a relatively new family of devices that features a terminal keyboard/display and voice telephone instrument. Many contain varying degrees of local processing power, ranging from full personal computer capacity to directory storage for automatic telephone dialing. These terminals may be designed to work with a specific customer premises private branch exchange (PBX) or be PBX independent.
INTELSAT See International Telecommunications Satellite Consortium.
Intercept Calls Calls directed by a customer to an improper telephone number that are redirected to an operator or a recording. The caller is told why the call could not be completed and, if possible, given the correct number.
Intercity Facility Relief Planning System (IFRPS) An operations system that aids in facility planning for a toll network. Its function is similar to the metropolitan area transmission facility analysis program.
Intercom Calling Intralocation calling; calls between stations on the same customer premises.
Interconnection The direct electrical connection, acoustical coupling, or inductive coupling of user-premises terminal equipment (including terminal equipment that is a part of a separate communications system) to the telephone network. It also includes the direct electrical connection of other common carrier facilities to the telephone network.
Interexchange Carrier (IXC) Since divestiture, any carrier registered with the Federal Communications Commission authorized to carry customer transmissions between local access and transport areas interstate or, if approved by a state public utility commission, intrastate. Includes carriers such as AT&T Communications, Satellite Business Systems, Telenet, MCI, Sprint, and others.
Interface (a) A common boundary between two systems or pieces of equipment where they are joined. (b) A physical point of demarcation between two devices where the electrical signals, connectors, timing, and handshaking are defined. (c) The procedure, codes, and protocols that enable two entities to interact for the meaningful exchange of information.
Interface Specification A technical requirement that must be met at an interface.
Intermodal Dispersion See Multimode Dispersion.
International Telecommunications Satellite Consortium (INTELSAT) An international organization established in 1964 to govern a global commercial communications satellite system to provide communications between many countries. Membership is in excess of 80 countries. The Communications Satellite Corporation (COMSAT) acts as manager for INTELSAT and also represents the United States.
Interoffice Call A call between two switching systems.
Interoffice Facilities Network Part of the nationwide facilities network, consisting of interoffice transmission facilities, tandem switching systems, and local switching systems. See also Local Facilities Network.
Interoffice Trunk Signaling The exchange of call-handling information between switching offices within the network.
Intertoll Trunk A trunk between two toll offices.
Intersymbol Interference Extraneous energy from the signal in one or more signaling intervals that tends to interfere with the reception of the signal in another signaling interval.
Intramodal Dispersion See Material Dispersion.
Intraoffice Call A call involving only one switching system.
I/O Input/output.
IP Internetwork Protocol in the International Organization for Standardization activities, as well as Internet Protocol in Advanced Research Projects Agency protocol activities.
ISDN See Integrated Services Digital Network.
ISO International Organization for Standardization.
ITU International Telecommunications Union.
IVDT See Integrated Voice/Data Terminal.
IXC See Interexchange Carrier.

J

Jamming The intentional interference of open-air radio frequency transmission to prevent communications between a transmitter and a receiver.
JCL Job control language.
JES See Job Entry Subsystem.
Jitter The slight movement of a transmission signal in time or phase that causes short-term variations of the significant instants of a digital signal from their ideal positions in time. Jitter introduces errors and loss of synchronization for high-speed synchronous communications.
Job A large file or a set of data, including programs, files, and instructions, transmitted to a computer that collectively constitutes a

unit of work to be done.

Job Entry Subsystem (JES) Control protocol and procedure for directing host processing of a task in a host environment.

Jumbo Group In frequency-division multiplexing, a number of voice channels (generally 3600) composed of six mastergroups.

Jumper A patch cable or wire used to establish a circuit for testing or diagnostics.

Jumpers Temporary wires used on a distributing frame to cross-connect the termination points of cables from particular equipment and facilities to provide service to a customer.

Justification See Pulse Stuffing.

K

k See Kilo.

K An expression for 1024, or 2^{10}, standard quantity measurement for disk and diskette storage and semiconductor circuit capacity; e.g., a Kbyte of memory equals 1.024 bytes (or 8-bit characters) of computer memory (slightly more than a thousand).

k Factor The ratio of effective to true earth radius.

Ka Band A portion of the electromagnetic spectrum; frequencies approximately in the 12 to 30 GHz range.

(kb/s) See Kilobits per Second.

kbit/s See Kilobits per Second.

Key Telephone Set (KTS) A telephone set with buttons, or keys, located on or near the telephone, used as part of a key telephone system.

Key Telephone System (KTS) An arrangement of key telephone sets and associated circuitry, located on a customer's premises, that provides combinations of certain voice communications arrangements such as call pickup, call hold, call line status lamp signals, and interconnection among on-premises stations without the need for connection through the central office or private branch exchange. Generally with line capacities ranging from 2 to 24 trunk lines and from 4 to 40 extensions.

Kilo (k) Notation for one thousand (e.g., kilobit/s).

Kilobits per Second (kbit/s, kb/s) A standard measure of data rate and transmission capacity.

KTS See Key Telephone Set and Key Telephone System.

L

LAC See Loop Assignment Center.

LAMA See Local Automatic Message Accounting.

LAN See Local Area Network.

Large-Scale Integrated (LSI) Circuit An integrated circuit containing 100 gates or more on a single chip, resulting in an increase in the scope of the function performed by a single device.

LATA See Local Access and Transport Area.

L Band A portion of the electromagnetic spectrum commonly used in satellite and microwave applications with frequencies approximately in the 1 GHz region.

LBS See Load Balance System.

LCR See Least-Cost Routing.

LDM Limited-distance modem.

Leased Line A dedicated circuit that permanently connects two or more user locations, generally voice-grade in capacity and range of frequencies supported. Usually analog, though sometimes refers to digital data system subrate digital channels (2.4 to 9.6 kb/s). Used for voice (2000 Series leased line) or data (3002-type). A leased line may be point-to-point or multipoint and may be enhanced with line conditioning. Also called private line.

Least-Cost Routing (LCR) A routing algorithm used by private branch exchange systems to select the most cost-effective routing of a call based on the available facilities.

LEC See Local Exchange Carrier.

LED See Light-Emitting Diode.

License Contract The legal agreement that governed the relationship between AT&T and a Bell local operating company. Each license contract described the reciprocal services, licenses, and privileges that existed between the parties. All license contracts terminated with divestiture of the Bell operating companies.

Light-Emitting Diode (LED) A device that accepts electrical signals and converts the energy to a light signal. With lasers, the main light sources for optical-fiber transmission, used mainly with multimode fiber.

Lightwave (a) Refers to electromagnetic wavelengths in the region of visible light. Wavelengths are approximately 850 to 1500 nanometers. (b) Refers to the technology of fiber optic transmission.

Line (a) From a switching viewpoint, the transmission loop, station equipment, and central office-associated equipment assigned to a customer. (b) From a transmission viewpoint, the transmission path between a customer's station equipment and a switching system. In this sense, it is also called a loop. (c) In carrier systems, the portion of a transmission system between two terminal locations. The line includes the transmission media and associated line repeaters. (d) The side of a piece of central office equipment that connects to or toward the outside plant; the other side of the equipment is called the "drop" side. (e) A family of equipment or apparatus designed to provide a variety of styles, a range of sizes, or a choice of service features (e.g., a "product line").

Linear Distortion Distortion resulting from a channel having a linear filter characteristic different from an ideal linear lowpass or bandpass filter; in particular, amplitude versus frequency characteristics that are not flat over the passband, and phase versus frequency characteristics that are not linear over the passband. See also Bandpass Filter.

Linear Predictive Coding A voice coder based on prediction of speech samples from a linear weighted sum of previously measured samples.

Line Build-Out (LBO) Network Amplifiers (repeaters) in a cable transmission system may be designed to compensate for distortion over a specific length of cable. When the length of cable between amplifiers is less than that for which the amplifier is designed, one or more line build-out networks is used to bring the distortion to approximately the design level.

Line Hit An incident of electrical interference causing unwanted signals to be introduced onto a transmission circuit.

Line Fill The ratio of assigned circuits to total capacity in a facility or equipment unit.

Line of Sight (LOS) (a) A characteristic of ultra high frequency and super high frequency radio propagation in the atmosphere whereby the radio waves assume optical characteristics; a transmission path between a transmitter and a receiver must be clear and unobstructed (microwave, infrared, and open-air laser-type transmission). (b) A clear, open-air, direct transmission path free of obstructions, such as buildings, that may be impeded by adverse weather or environmental conditions.

Link A transmission facility in the telecommunications network.

Link Turnaround The inherent delay in a communications link between the time one block of data has been sent and received and the next block can be transmitted. In RS-232-C connections, the delay after request-to-send has been signaled and a clear-to-send indication is received.

Link Layer The logical entity in the open systems interconnection (OSI) model concerned with transmission of data between adjacent network nodes; the second layer processing in the OSI model, between the physical and network layers.

Load Balance System (LBS) A central office reporting system and part of the total network data system. Load balance system helps assure network administrators that traffic loads in switching systems are uniformly distributed. For example, reports generated by LBS are used to determine the "lightly loaded" line groups to which new subscriber lines can be assigned.

Load Balancing Procedures mainly used for equalizing the traffic load on customer-termination groups in switching networks.

Loading (a) Adding inductance to a transmission line to minimize amplitude distortion, generally with loading coils. (b) Adding a software program to a computer.

Loading Coil An induction device employed in telephone company local loops (usually those exceeding 18,000 ft in length) that compensates for the wire capacitance and serves to boost voice-grade frequencies. Often are removed for toll transmission circuits.

Loading Factor In a quantizer, the ratio of peak to rms (root mean square) amplitude for the input signal.

Load Lost In a traffic system, the portion of offered load that is not served because all servers are busy and all waiting positions (if any are provided) are occupied.

LOC Local operating telephone company.

Local Access and Transport Area (LATA) One of the 161 local telephone serving areas in the United States. Generally encompassing the largest standard statistical metropolitan areas, the subdivisions were established as a result of the Bell divestiture that now distinguishes local from long-distance service. Circuits with both end-points within the LATA are usually the sole responsibility of the local telephone company, whereas circuits that cross outside the LATA are passed on to an interexchange carrier.

Local Area Network (LAN) A network covering a small, normally geographically contiguous, area using principally cable transmission to connect multiple services and users.

Local Automatic Message Accounting (LAMA) A process using equipment located in a local office for automatically recording billing data for message rate service calls (bulk billing) and for customer-dialed station-to-station toll calls. The tape record is sent to and processed at an electronic data processing center.

Local Exchange Carrier (LEC) The local telephone company.

Local Facilities Network Part of the nationwide facilities network, consisting of local switching systems located at wire centers and the loop transmission facilities through which customers are connected to local switching systems. Local switching systems are considered the conceptual boundary between the local facilities network and the interoffice facilities network and, in this sense, belong to both networks. See also Interoffice Facilities Network.

Local Loop (a) A single connection from a local central office to the end telephone terminal or private branch exchange. (b) The signal path between a terminal and switch.

Local Switching System A switching system that performs End Office (Class 5) functions. Local switching systems connect customer lines directly to other customer lines, or customer lines to trunks.

Logical Channel Number Virtual circuit identified at the packet level of X.25.

Logical Link A virtual circuit concept of digital network architecture, existing at the end communications and session control layer above.

Logical Unit (LU) Access port for users in systems network architecture.

Long-Haul Trunk A final trunk or high-usage trunk that interconnects two regions in the public switched telephone network hierarchy.

Long-Route Design A codification of design practices used to plan customer loops that exceed the resistance design limit of the serving central office.

Loop A channel between a customer's terminal and a central office. A loop may also be called a line.

Loop Assignment Center (LAC) An operations center that assigns customer loop facilities, telephone numbers, central office line equipment, and miscellaneous central office equipment.

Loopback A diagnostic procedure used for transmission devices. A test message is sent to a device being tested, which is then sent back to the originator and compared with the original transmission. Loopback testing may be within a locally attached device or conducted remotely over a communications circuit.

Looping Problem encountered in distributed datagram routing in which packets return to a previously visited node.

Loop-Reverse Battery A method of signaling over interoffice trunks in which dc changes, including directional changes associated with battery reversal, are used for supervision. This technique provides two-way signaling on two-wire trunks. A trunk, however, can be seized at only one end (i.e., it cannot be seized at the office at which battery is applied). Also called Reverse Battery Signaling.

Loop Signaling A method of signaling over dc circuit paths that uses the metallic loop formed by the line or trunk conductors and terminating circuits.

LOS See Line of Sight.

Loss In the Bell System, insertion loss, a quantity that represents a specific relationship between the input and output of a network (e.g., a customer connection or a circuit). The basic insertion loss calculation determines the difference in decibels (dBs) between power applied to a load directly and power applied to a load through a network.

Loss Objective An objective for the amount of loss that can be tolerated in network components and still maintain a satisfactory grade of service.

Loudness Loss A measure used to express the loss of communications paths in a manner that reflects loudness perception. For partial and overall telephone circuits, loudness loss is the ratio of suitably weighted output signal levels to input signal levels. (The signals may be electric or acoustic.)

Low-Pass Filter A filter having a single transmission band extending from zero to some finite cutoff frequency.

LSI Large-scale integration, as in LSI circuit.

LTB Least trunk busy.

LU See Logical Unit.

M

m See Milli.

M See Mega.

MAC See Media Access Control.

Magnetic Ink Character Recognition (MICR) A process of character recognition in which printed characters containing particles of magnetic material are read by a scanner and converted into a computer-readable digital format.

Magnetic Medium Any data-storage medium and related technology, including disks, diskettes, and tapes, in which different patterns of magnetization are used to represent bit values.

Magnetic Stripe A strip of magnetic material similar to a piece of magnetic tape affixed to a credit card, ID badge, or other portable item on which data are recorded and from which data can be read.

Main Private branch exchange (PBX) or Centrex switch into which other PBXs, remote concentration, or switching modules are homed. A PBX or Centrex is connected directly to an electronic tandem switch. Also called a power source.

Main Distributing Frame (a) In telephony, where telephone subscriber lines are terminated. (b) In conjunction with a private branch exchange, where central office telephone lines are connected to on-premises extensions. (c) Where subscriber lines terminate in a telephone central office.

Main Network Address The logical unit (LU) network address used for SSCP-to-LU sessions and for certain LU-to-LU sessions.

Main Station A telephone that is connected directly to a central office by either an individual or shared line. Main stations include the principal telephone of each party on a party line. They do not include telephones that are manually or automatically connected to a central office through a private branch exchange or extension telephones (i.e., telephones that have been added to an individual or shared line to extend telephone service to other parts of the subscriber's home or business premises).

Maintenance Services Network services performed between a host system services control point and remote physical units that test links and collect and record error information. Related facilities include configuration, management, and session services.

Management Services Network services performed between a host system services control point and remote physical units that include the request and retrieval of network statistics.

Manchester Encoding A digital encoding technique in which each bit period is divided into two complementary halves. In this encoding scheme, half of the bit interval is transmitted with a positive signal and the other half is transmitted with a negative signal. A negative-to-positive (voltage) transition in the middle of the bit period designates a binary "1," whereas a positive-to-negative designates a "0."

Marker (Crossbar) The heart of common-control crossbar central office equipment. Markers perform the following functions in a No. 5 Crossbar switching system: (a) Determine terminal locations of calling lines, incoming trunks bidding for service, called lines, and outgoing trunks in the equipment. (b) Determine the proper route for the call, establish the connection within the office, and pass routing information to the senders. (c) Determine the calling line class of service and provide charge classification. (d) Recognize line busy, trouble, intercept, and vacant-line conditions. (e) Call in a trouble recorder when necessary. See also Crossbar Switch.

Market The set of actual or potential buyers of a product or service.

Marketing Those activities that influence the flow of goods and services from producers to consumers.

Marketing Mix The set of variables that can be adjusted to attract markets to a product or service. These include variables associated with the product itself and those related to price, product distribution, and promotion of the product.

Market Segmentation The division of a market into submarkets differing in such characteristics as customer needs and buying behavior.

Master Control Center (MCC) A frame of equipment in an electronic switching system office with lamps that show the current state of the office equipment and with keys for operating controls.

Mastergroup In frequency-division multiplexing, a number of voice channels (generally 300 or 600) consisting of 5 or 10 supergroups.

Master-Slave Synchronization A form of network synchronization in which a master clock is distributed and used to control other clocks, equipment, or nodes.

Material Dispersion In an optical fiber, the dispersion caused by the variation in propagation velocity with the wavelength of light. See also Intramodal Dispersion.

MATFAP See Metropolitan Area Transmission Facility Analysis Program.

Mbyte See Megabyte.

MCC See Master Control Center.

Mean Time Between Failure (MTBF) For a specific interval, the ratio of total operating time to the number of failures in the same interval.

Mean Time Between Outages (MTBO) For a specific interval, the ratio of total operating time to the number of outages in the same interval.

Mean Time to Repair (MTTR) The total corrective maintenance time divided by the total number of corrective maintenance actions during a given period of time.

Mean Time to Service Restoral (MTSR) The mean time to restore service following system failures that result in a service outage. The time to restore includes all time from the occurrence of the failure until the restoral of service.

Measurement Plan A compilation of service and performance measurements for operational units (e.g., operations centers).

Media Access Control (MAC) (a) Media-specific access control protocol within the IEEE 802 specifications currently includes variations for the token ring, token bus, and carrier sense multiple access with collision detection. (b) The lower sublayer of the Institute of Electrical and Electronics Engineers' link layer that complements the logical link control.

Medium A substance or material such as optical fiber, coaxial cable, copper wire, dielectric slab, water, air, or free space regarded as suitable for the propagation of signals from one point to another; usually in support of modulated radio, light, or acoustic waves.

Mega (M) Designation for one million (e.g., Mbit/s, Mb/s).

Megabyte (Mbyte) 1,048,576 bytes, equal to 1,024 Kbytes; basic unit of measurement of mass storage. Also used in describing data transfer rates as a function of time (e.g., Mbyte/s).

Message (a) In telephone communications, a successful call attempt that is answered by the called party and followed by some minimum period of connection. (b) In data communications, a set of information, typically digital and in a specific code such as the American Standard Code for Information Interexchange (ASCII), to be carried from a source to a destination. A header, with address and other information regarding handling, may be considered part of or separate from the message.

Message Circuit Noise The short-term average noise level as measured with a 3A noise-measuring set or its equivalent. This set includes frequency weighting and time constants to make the set most sensitive to noise that will impair transmission quality in telephone circuits used for speech.

Message Rate Service Telephone service for which a charge is made in accordance with a measured amount of usage, referred to as message units.

Message Signal Unit Signal unit of common channel signaling that carries a message corresponding to the information part or packet of the high-level data link control (HDLC) frame plus a message transfer part corresponding to the HDLC frame header.

Message Telephone Service (MTS) Non-private-line intrastate and interstate long-distance telephone service.

Message Trunk A trunk carrying message telecommunications service traffic on the public switched telephone network.

Message Unit That portion of data within a message that is passed on to and processed by a particular network layer (e.g., path information unit or PIU, request/response unit, or RU).

Metropolitan Area Transmission Facility Analysis Program (MATFAP) A program that aids in facility planning for metropolitan networks. Using various measures, MATFAP analyzes the alternatives available for future transmission facilities and equipment and identifies what transmission plant is needed at various locations and when it will be needed. The Metropolitan Area Transmission Facility Analysis Program also determines the economic consequences of selecting particular facilities and/or equipment and of selecting particular routes and provides the least-cost assignment of circuits to each facility as a guide to the circuit-provisioning process.

MICR See Magnetic Ink Character Recognition.

Microbending Minute curvatures in an optical fiber caused by external forces. Because the principle of total internal reflection is not fully satisfied at such bends, additional loss in the fiber is introduced.

Microcode Programmed instructions that are unalterable; usually synonymous with firmware and programmable read-only memory.

Microprocessor The control and processing portion of a microcomputer built with large-scale integrated circuitry capable of receiving and executing coded instructions. Microprocessors can handle both arithmetic and logic functions under control of a program stored in a memory chip.

Microsecond One-millionth of a second.

Microwave A portion of the electromagnetic spectrum above approximately 890 megahertz; high-frequency transmission signals and equipment that employ microwave frequencies, including line-of-sight open-air microwave transmission and satellite communications.

Midpoint equalization A combination of postequalization and preequalization used at intermediate points in a circuit.

Milli (m) Designation for one-thousandth.

Million Instructions per Second (MIPS) A general comparison gauge of a computer's raw processing power.

Millisecond One-thousandth of a second.

Minimum-Cost Routing A circuit-routing scheme that determines a path through the network for each point-to-point demand for each year, so that, when point-to-point demands are provided on these paths and the resulting capacity expansion problem is solved, the total cost of transmission facilities is minimized.

Minimum-Shift Keying (MSK) A form of digital modulation that uses offset quadrature phase-shift keying with sinusoidal pulse shaping. Also, a special case of frequency-shift keying in which continuous phase is maintained at symbol transitions using a minimum difference in signaling frequencies.

MIPS See Million Instructions per Second.
Mobile Telephone Service One of a class of services that uses radio channels to provide telephone service to customers on the move. Mobile telephone services include land mobile telephone service, BELLBOY personal signaling set paging service, air/ground service, marine radiotelephone services, and high-speed train telephone services.
Modem A contraction of "modulator/demodulator." An acronym for equipment unit that performs both of these functions. The device converts digital data signals to analog signals for transmission over the voice telephone network. The term may be used when the modulator and the demodulator are associated in the same signal--conversion equipment. See also Data Set.
Modified Duobinary A form of duobinary coding whose spectral shape has no dc component.
Modular Engineering The expression of equipment quantities (typically, trunk groups) as an integer multiple of some basic unit, the unit depending on physical constraints. Reflects the reality that certain equipment items can only be added in multiples, rather than one item at a time.
Modulation The process by which the amplitude, frequency, or phase of a carrier signal is varied in accordance with one of the characteristics of an information signal.
Modulation Index In frequency-shift keying, the ratio of the frequency deviation of the modulated signal to the bandwidth of the modulating signal.
Modulator A device that performs modulation.
MSK See Minimum-Shift Keying.
MTBF See Mean Time Between Failure.
MTBO See Mean Time Between Outages.
MTP Message transfer part of common channel signaling.
MTS See Message Telephone Service.
MTSR See Mean Time to Service Restoral.
MTTR See Mean Time to Repair.
Muldem A contraction of the words multiplexer and demultiplexer signifying an equipment unit that performs both of these functions.
Multidrop A communications arrangement in which multiple devices share a common transmission channel, though only one may transmit at a time. See also Multipoint Line.
Multiframe A set of consecutive frames in which the position of each frame can be identified by reference to a multiframe alignment signal.
Multifrequency (MF) Signaling An inband, interoffice, address signaling method in which 10 decimal digits and five auxiliary signals are each represented by selecting two frequencies out of the following group: 700, 900, 1100, 1300, 1500, and 1700 hertz (Hz).
Multimode Dispersion In an optical fiber, the dispersion resulting from the different arrival times of optical rays that follow different paths. Also called intermodal dispersion.
Multimode Fiber A fiber that supports propagation of more than one mode (optical ray) at a given wavelength.
Multipath Fading Fading that results when radio signals reach the receiving antenna by two or more paths.
Multiple Virtual Storage (MVS) A common host operating environment. Also called OS/VS2, Release 2.
Multiplex(ing) The equipment or process for combining a number of individual channels into a common frequency band or into a common bit stream for transmission. The converse equipment or process for separating into individual channels is called demultiplex(ing).
Multipoint Line A single communications channel to which more than one station or logical unit is attached, though only one may transmit at a time. Such arrangements usually require a polling mechanism (under the control of a master station) to ensure that only one device transmits data at a time. Also called multidrop line.
Multitasking Generically refers to concurrent execution of two or more tasks by a computer. May also be the concurrent execution of a single reenterable program that is used by many tasks.
Mutual Synchronization A network synchronizing arrangement in which each clock in the network exerts a degree of control on all others.
Mux Multiplexer.
MVS See Multiple Virtual Storage.

N

N See Radio Refractivity.
NAC See Network Administration Center.
NAK See Negative Acknowledgment.
Nanosecond One-billionth of a second.
Narrowband Channel A sub-voice-grade transmission channel characterized by a bandwidth narrower than that required for transmitting voice signals. It is commonly used to support data speeds of from 100 to 200 b/s.
Narrowband Coder A voice coder with a transmission rate that can be accommodated by 3 kHz telephone channels using modems.
Narrowband Frequency-Shift Keying A form of frequency-shift keying in which the modulation index is much less than 1.
National Cable Television Association (NCTA) A leading trade organization representing United States cable television carriers.
National Institute of Standards and Technology/National Computer Systems Laboratory (NIST/NCSL) The National Institute of Standards and Technology directorate, based in Gaithersburg, Md., concerned with developing computer and data-communications federal information processing standards used in (non-Department of Defense) government procurements.
Nationwide Rate Averaging A rate-setting method that has been used to establish rates for interstate telephone service. Like services and like calling distances carry the same charges even though the costs of interstate service to the common carrier may differ for routes in low-density, high-cost areas.
NAU See Network Addressable Unit.
NCC See Network Control Center.
NCP See Network Control Point.
NCTA See National Cable Television Association.
NCTE See Network Channel-Terminating Equipment.
NDCC See Network Data Collection Center.
Near-End Crosstalk (NEXT) Crosstalk that is propagated in a disturbed channel in the direction opposite to the direction of propagation of the circuit in the disturbing channel. The receiving terminals of the disturbed channel and the energized terminals of the disturbing channel are usually near each other.
Near Instantaneous Companding (NIC) The fast, essentially real-time process of quantizing an analog signal into digital symbols.
NEBS See New Equipment-Building System Standards.
Negative Acknowledgment (NAK) In synchronous protocols, a supervisory control-code message sent by the receiver to indicate that the previous data block was received in error and the receiver is again ready to accept a transmission.
Negative Exponential Distribution A probability distribution function used in many queuing models to describe the distribution of the length of completed telephone calls.
Negative Pulse Stuffing In time-division multiplexing, the controlled detection of bits from channel inputs so that the rates of the individual channel inputs correspond to a rate determined by the multiplex equipment. The deleted information is transmitted via a separate overhead channel.
Network (a) The facilities network is the aggregate of transmission systems, switching systems, and station equipment. It supports a large number of traffic networks. (b) A traffic network is an arrangement of channels, such as loops and trunks, associated switching arrangements, and station equipment, designed to handle a specific body of traffic. A traffic network is a subset of the facilities network. (c) An organization of stations capable of intercommunication but not necessarily on the same channel. (d) An electrical/electronic circuit, usually packaged as a single piece of apparatus or on a printed circuit pack. Examples are a transformer network and an equalization network. (e) The switching stages and associated interconnections of

a switching system are collectively called the switching network.

Network Addressable Unit (NAU) Systems network architecture (SNA) term for logical unit, physical unit, and system services control point. Each unit in SNA has a unique address.

Network Administration Center (NAC) An operations center with administrative responsibility for local and tandem switching systems. The functions performed by an NAC include data administration, daily surveillance of service and load in the switching network, equipment utilization, machine and trunk group performance analysis and monitoring, and participation in job contact committees associated with equipment additions, replacements, and rearrangements.

Network Channel-Terminating Equipment (NCTE) Equipment located on user premises that is necessary for terminating a telephone circuit or facility at the customer premises. Because of deregulation of a number of network services, current tariffs allow much of this equipment to be customer provided; therefore, this equipment may or may not be considered a part of the telephone network facility.

Network Control Center (NCC) Any centralized network diagnostic and management station or site; used primarily when referring to facilities in packet-switching networks.

Network Control Point (NCP) A node in the stored-program control network that connects to a signal transfer point in the common-channel interoffice signaling (CCIS) network. The NCPs-associated data base contains customer-service data accessed by signals routed over the CCIS network and used to support extended network services.

Network Data Collection Center (NDCC) An operations center that administers network data collection. Primarily, the NDCC supervises the operation and maintenance of the Engineering and Administrative Data Acquisition System (EADAS), 1A EADAS central control units, data links, and data-collection apparatus.

Network Interface (NI) In the interconnection environment, the physical and electrical boundary between two separately owned telecommunications capabilities. It also serves as the boundary for administrative and maintenance activities.

Network Layer The layer that manages routing and flow control of packets. Refers to the open systems interconnection reference model.

Network Management Center (NMC) An operations center responsible for surveillance and control of traffic flow in a specific geographic area. Control is an ongoing activity in response to overloads, especially from peak day calling, mass calling, network system failure, or network rearrangements. The NMC also plans strategies for potential overload situations.

Network Operations Center (NOC) The operations center, located in Bedminster, N.J., that oversees and coordinates management of the North American message network. It monitors the status of the intertoll network among the regions and coordinates the use of interregional switching system and trunking network capacity that is temporarily spare. The NOC also directs the network management of international traffic flows for the United States and monitors the status of toll facilities and the effect of any problems on the interregional intertoll network. In case of problems in the toll facility network, the NOC sets restoration priorities and coordinates restoration activities.

Network Operations Center System (NOCS) The primary support system for the network operations center located in Bedminster, N.J. Network Operations Center System provides near real-time surveillance of major switching systems and their associated trunking at a nationwide level.

Network Planning A multifaceted discipline that encompasses the functions involved in planning the evolution and implementation of the nationwide network, designing and engineering the configuration of the network, and managing the total network investments.

Network Service Center (NSC) An operations center responsible for ensuring the overall quality of network service, keeping management informed about levels and trends in the quality of service provided by the network, and stimulating improvement activities when instances of substandard service are identified.

New Equipment-Building System Standards (NEBS) A set of integrated specifications for both telecommunications equipment and equipment buildings.

NEXT See Near-End Crosstalk.

NEXT Coupling Loss For near-end crosstalk, the ratio of power in the disturbing circuit to the induced power in the disturbed circuit.

NI See Network Interface.

NIC See Near Instantaneous Companding.

NIST/NCSL See National Institute of Standards and Technology/National Computer Systems Laboratory.

NMC See Network Management Center.

NOC See Network Operations Center.

NOCS See Network Operations Center System.

Node (a) A point at which one or more functional units interconnect transmission lines. (b) A physical device that allows for the transmission of data within a network. (c) An endpoint of a link or a junction common to two or more links in a network (IBM systems network architecture). Includes host processors, communications controllers, cluster controllers, and terminals.

Node Type Classification of a network device based on the protocols it supports and the network addressable units it can contain. Types 1 and 2 nodes are peripheral nodes; Types 4 and 5 are subarea nodes.

Noise Any extraneous and unwanted signal disturbances in a communications link (e.g., electromagnetic interference). Usually, random variations in signal voltage or current or interfering signals.

Noise Suppressor Filtering or digital signal-processing circuitry in a receiver or transmitter that automatically eliminates or reduces noise.

Nonblocking A switch where a through traffic path always exists for each attached station. Generically, a switch or switching environment designed never to experience a busy condition because of call volume.

Nonreturn to Zero (NRZ) A binary encoding and transmission scheme in which ones and zeros are represented by opposite and alternating high and low voltages when there is no return to a reference (zero) voltage between encoded bits.

Nonreturn to Zero Inverted (NRZI) A binary encoding scheme that inverts the signal on a one and leaves the signal unchanged for a zero. A change in the voltage state signals a one bit, and the absence of a change denotes a zero bit value.

Nonvolatile Storage Any storage medium or circuitry the contents of which are not lost when power is turned off.

North American Basic Teletext Specification Interim standard for teletext transmission.

North American Presentation Level Protocol Syntax Standard that specifies the coding scheme for videotext and teletext services.

Not Ready to Receive (RNR) A special control frame used in high-level data link control.

NRZ See Nonreturn to Zero.

NRZI See Nonreturn to Zero Inverted.

NSC See Network Service Center.

Numbering Plan Area (NPA) The familiar area code, defining a geographic division with which telephone directory numbers are subgrouped. In North America, a three-digit N0/1X code is assigned to denote each NPA, where:

N = any digit 2 through 9
0/1 is 0 or 1
X = any digit 0 through 9

Nyquist Rate As described by Nyquist, the sampling rate (equal to twice the signal bandwidth) that permits the samples of a signal to completely determine the signal waveform.

Nyquist Theorem The theory states that two samples per cycle are sufficient to characterize a band-limited analog signal. In other words, the sampling rate must be twice the highest frequency component of the signal (e.g., sampling at 8 kHz for a 4 kHz analog signal).

O

OCC See Other Common Carrier.
Occupancy The fraction of time that a circuit or an equipment unit is in use, expressed as a decimal. Numerically, it is the Erlangs carried per circuit. Occupancy typically includes both message time and call-setup time.
OCR See Optical Character Recognition.
Offered Load The demand placed on a traffic system, defined by the product of two parameters: (a) The average rate at which customers place demands on the system, and (b) the average length of time they require service.
Off-Hook Station switchhook contacts closed, resulting in line current, or whatever supervision condition is indicative of the in-use or request-for-service state.
Offset Quadrature Phase-Shift Keying (OQPSK) A form of quadrature phase-shift keying in which the in-phase and quadrature bit streams are offset in time by one bit period.
OFNPS See Outstate Facility Network Planning System.
One-Way Trunk A trunk that can be seized for use by the switching equipment at one end only. Once a trunk is seized, two-way transmission may occur.
On-Hook Station switchhook contacts open, or whatever supervision condition is indicative of the equipment-idle state.
ONI See Operator Number Identification.
On-Line A condition in which a user, terminal, or other device is actively connected with the facilities of a communications network or computer. On-line pertains to the operation of a functional unit that is under the continual control of a computer.
Open Air Transmission A transmission type or associated equipment that uses no physical communications medium other than air. Includes most radio frequency communications techniques. Microwave, shortwave, FM radio, and infrared are said to be open-air transmission.
Open Systems Interconnection (OSI) The OSI reference model is a logical structure for network operations standardized within the International Organization for Standardization. It is a seven-layer network architecture being used for the definition of network protocol standards to enable any OSI-compliant computer or device to communicate with any other OSI-compliant computer or device for a meaningful exchange of information.
Operating Company A regulated telephone company whose primary business is providing telephone service to customers.
Operating Environment A combination of host software that includes operating system, telecommunications access method, data base software, and user application. Some common operating environments include multiple virtual storage/customer information control system (MVS/CICS) and MVS/TSO.
Operations Center A group of people, reporting to a common manager, who perform a set of closely related functions for a specific geographic area, group of customers, or service.
Operations Planning An ongoing activity to ensure that changes in the roles and responsibilities of people are linked to changes in the telephone business and that operations-related functions are assigned to people and operations systems in ways that realize potentials for greater efficiency and better customer service.
Operations Process The sequence of interactions between operations systems and operations centers that are required to perform a particular operation, such as adding a trunk to the network or maintaining a switching system.
Operating System (OS) The software of a computer that controls the execution of programs. Handles the functions of input/output control, resource scheduling, and data management (e.g., CP/M, MS-DOS, VS/370).
Operations System A computer-based system that local operating telephone company employees use to support operations activities. An operations system does not directly provide telecommunications service to customers, but supports operating company personnel in the performance of their duties, such as testing trunks or maintaining switching systems.
Operations Systems Network The collection of operations systems, communications terminals at operations centers, and the switched and direct communications links interconnecting them and connecting them to a variety of telecommunications systems (e.g., an electronic switching system).
Operator Code A code of the form 1XX, 11XX, or 11XXX that allows outward toll operators to reach inward, directory assistance, or other operators in distant cities.
Operator Number Identification (ONI) Operator identification of a calling station, usually for billing purposes, when automatic identification from a local office is not available.
Operator Services A variety of services normally performed by operators. These include completing or helping customers to complete toll calls and assistance calls; preparing billing inputs on those calls; providing directory assistance; intercepting and helping customers with calls to changed or nonworking numbers; providing special services, such as person-to-person, coin, calling card, collect, mobile, video teleconferencing service, and audio conference calls; and giving on-the-job consultation to business customers.
Optical Character Recognition (OCR) The process of reading graphics characters by light-sensitive devices that convert them into machine-readable digital codes. A popular method of inputting text or graphics data into a computer, storage device, or transmission device.
Optical Fiber A long, thin cylindrical glass fiber having a central core of one transparent material of high refractive index surrounded with a cladding of another transparent material of lower refractive index that provides a one-way path for light signals. The cladding that surrounds the core serves to reflect the light signal back into the core. The fiber is used to transmit laser or light-emitting diode-generated light signals. It is used in lightguide cable.
OQPSK See Offset Quadrature Phase-Shift Keying.
OS See Operating System.
Oscillator An electronic device used to produce repeating signals of a given amplitude or frequency.
OSI See Open Systems Interconnection.
Other Common Carrier (OCC) A telecommunications common carrier authorized by the Federal Communications Commission (FCC) to provide a variety of services. The FCC refers to these carriers as domestic satellite carriers, miscellaneous common carriers, and specialized common carriers.
Outage A condition wherein a user is deprived of service because of failure in the communication system.
Outgoing Access The ability of a user in one network to communicate with a user in another network.
Out-of-Service Testing A form of testing in which operational traffic is interrupted and replaced by a test pattern.
Outpulsing Sending address or other signaling information over a line or trunk.
Outside Plant The part of the telephone system that is located physically outside of telephone company buildings. Outside plant includes cables, supporting structures, and certain equipment items; it does not include microwave towers, antennas, and cable system repeaters.
Outstate Facility Network Planning System (OFNPS) An interactive computer system that aids in facility planning for rural networks. It is similar in function to the Metropolitan Area Transmission Facility Analysis Program.
Overflow A count of all calls that are offered to a trunk group but are not carried (see also Peg Count); usually measured for one hour.
Overhead All information that is in addition to user-transmitted data, such as control, routing, and error-checking characters. Overhead includes information that carries network status or operational instructions, network routing information, and transmissions of user-data messages received in error.
Overload (a) In transmission, a load greater than that which a device is designed to handle. May cause overheating of power

handling components and distortion in signal circuits. (b) In telecommunications traffic, an increase in offered load beyond the capacity for which network components (e.g., trunks and switching systems) are engineered. (c) In speech modulation, the error introduced in quantization when the input signal amplitude exceeds the allowed amplitude range of the quantizer. See also Clipping.

P

Pacing Control Systems network architecture term for flow control.

Packet A group of bits that is switched as an integral unit. Typically, a packet contains data, destination and origination information, and control information, arranged in a particular format.

Packet Assembler/Disassembler (PAD) Network interface device that allows multiple asynchronous and/or synchronous terminals or host computer ports to interface to a packet-switching network. It is a protocol conversion device that allows user terminals not equipped for packet switching to communicate over an X.25-based channel. It may allow connected user stations to open and close sessions with a remote host and to set specific transmission parameters. Packet assembler/disassembler operation and functions are fully delineated in International Telegraph and Telephone Consultative Committee recommendations.

Packet Radio A digital radio designed to handle multiple users who share a common high-speed channel and transmit data in bursts (packets).

Packets Small blocks of data into which messages are broken, for transmission across a network. The sequence of data with associated control elements that is switched and transmitted as a whole. Refers mainly to the field structure and format defined within the International Telegraph and Telephone Consultative Committee X.25 recommendation. Multiple packets may be required to carry one complete document or a lengthy block of information.

Packet Switching A technology that transmits packets from source to destination.

Packet-Switching Network A network that is designed to transport and switch data in packet form.

PAD See Packet Assembler/Disassembler.

Page Logical unit of information in a videotext system consisting of one or more frames.

Pair Gain A system that uses digital or analog carrier techniques to serve many customers over a few pairs between the telephone company central office and a remote electronic terminal.

PAM See Pulse-Amplitude Modulation.

Parity Bit An additional noninformation bit appended to a group of bits, typically to a 7 or 8-bit byte, which indicates whether the number of ones in the group of bits is an odd or even number. Parity bit is a basic and elementary mechanism for error checking.

Parity Check Process of error checking using the parity bit. Varied methods include longitudinal parity check and transverse parity check.

Partial Response A multilevel coding scheme that uses prescribed amounts of intersymbol interference to increase the transmission rate in a given bandwidth.

Path Control International Business Machines systems network architecture's network layer. A network processing layer that handles primarily the routing of data units as they travel through the network. The path control layer also manages shared-link resources.

Path Profile A graphic representation of a propagation path showing the surface features of the earth, such as trees, buildings, and other features that may cause obstruction or reflection, in the vertical plane containing the path.

PBX See Private Branch Exchange.

PC Pacing count in systems network architecture.

PCM See Pulse-Code Modulation.

PDU See Protocol Data Unit.

Peakedness A telecommunications traffic term signifying the ratio of the variance of the load to the mean of the load. For random traffic (Poisson arrivals, negative exponential holding times), the peakedness of the load is 1.0 (i.e., the variance equals the mean). For traffic overflowing a high-usage group, peakedness exceeds 1, reflecting the fact that overflow occurs in "bursts" or peaks.

Peak Load A higher-than-average quantity of traffic; usually expressed for a 1-hr period and as any of several functions of the observing interval, such as peak hour during a day, average of daily peak hours over a 20-day interval, maximum of average hourly traffic over a 20-day interval. Significantly higher peak loads occur infrequently as the result of catastrophes and on Mother's Day and Christmas Day.

Peg Count A count of all calls offered to a trunk group, usually measured for 1 hr. As applied to units of switching systems with common control, peg count, or carried peg count, means the number of calls actually handled.

Performance Measurement A measurement intended to reflect whether an operational unit (e.g., an operations center) is meeting objectives or whether network service characteristics and performance parameters are at levels required to meet service objectives.

Performance Objective A statement of the operational objective to be met by a component of the network or the network as a whole. For example, the message circuit noise objective for customer loops is stated in terms of an upper limit of 20 decibels above reference noise, "C" message weighted (dBrnC).

Permuter Table Routing table in TYMNET's packet network service.

Per-Trunk Signaling A method of signaling in which the signals pertaining to a particular call are transmitted over the same trunk that carries the call. Interoffice signaling other than common-channel interoffice signaling falls into this category.

Phase Delay In the transfer of a single-frequency wave from one point to another in a system, the time delay of the part of the wave that identifies its phase.

Phase-Shift Keying (PSK) A form of digital modulation in which discrete phases of the carrier are used to represent a digital signal.

Physical Layer The lowest layer in communication architectures providing a direct connection between neighboring nodes in a network. This layer is responsible for bit integrity.

Physical Unit (PU) Manages the communication resources at a given node in systems network architecture.

PICS/DCPR See Plug-in Inventory Control System/Detailed Continuing Property Records.

Picturephone Meeting Service An AT&T service, supported by high-speed switched digital service, that allows people in two distant, specially equipped rooms to hold a fully interactive audio and video conference.

Piezoelectric Effect An effect in certain materials such as quartz in which electrical energy causes vibration and, conversely, mechanical vibration induces electrical energy.

PIU Path information unit in systems network architecture.

Plant All of the facilities (such as land, buildings, machinery, apparatus, instruments, and fixtures) needed to provide telecommunications services. See also Outside Plant.

Plesiochronous The relationship between two signals such that their corresponding significant instants (transitions) occur at nominally the same rate, any variation in rate being constrained within a specified limit.

Plug-in Inventory Control System/Detailed Continuing Property Records (PICS/DCPR) An operations system that inventories plug-in units of equipment in telephone company central offices. The DCPR portion serves as an investment data base that supports a telephone company's accounting records for all types of central office equipment.

Plug-in Unit A prewired modular assembly inserted into a telecommunications switch system.

Point to Point (a) A circuit that connects two points directly where there are generally no intermediate processing nodes or computers, although there could be switching facilities. (b) A type of connection, such as a phone-line circuit, that links two, and only two, logical entities.

Poisson Process Named after Siméon D. Poisson, a 19th-century French mathematician, the Poisson process is: (a) One of the most common arrival processes in queueing theory. It has the memoryless property of successive arrivals. (b) In traffic theory, a distribution or a process resulting in a distribution of events such that the intervals between adjacent events are independent, random variables that are members of identical exponential distributions. (c) A method of approximating, under certain conditions, the arrival of telephone calls to be routed over a trunk group.

Positive-Zero-Negative Pulse Stuffing A combination of positive and negative pulse stuffing in which the two stuffing states are indicated by uniquely coded signals and the state of no stuffing is indicated by a third signal.

Postequalization Equalization of a circuit performed at the receiver.

POTS Plain Old Telephone Service.

Power Fading Fading caused by anomalous propagation conditions and characterized as slowly varying in time and causing long outages.

Preequalization Equalization of a circuit performed at the transmitter using a form of predistortion.

Preferential Assignment A method of attaining more short jumpers on a distributing frame through the selection of circuit assignments.

Primary Station (a) A network node that controls the flow of information on a link. (b) The station that, for some period, has control of information flow on a communications link (in this case, primary status is temporary).

Primitives Abstract representations of interactions across the service access points, indicating information is passed between the service user and service provider. There are four types of primitives in the open systems interconnection reference model: request, indication, response, and confirm.

Prioritization The process of assigning different values to network users. A user with a higher priority value will be offered access or service before a user with a lower priority value. This is increasingly available as an added option with network operation.

Private Branch Exchange (PBX) A telephone switch located on a customer's premises that is either manual or automatic and usually serving an organization such as a business or a government agency. It is connected via output trunks to the public network. Telephones served by the PBX are called stations. Calls from one station to another or to an external network such as the public switched telephone network may be handled manually or automatically, depending on the type of PBX. Most modern PBXs offer numerous enhanced features, such as direct inward dialing, least-cost routing of long-distance calls, and call-detail recording. Tie trunks are commonly used between PBX systems of a single customer to form a private network. Private branch exchanges vary in size from 50 lines up to 10,000 lines. Also called PABX (private automatic branch exchange) and CBX (computerized branch exchange).

Private Line A dedicated leased circuit used for an exclusive service application; a nonswitched circuit.

Private-Line Service A service in which the customer leases a circuit, not interconnected with the public switched telephone network, for the customer's exclusive use. The private line may be used for transmission of voice, teletypewriter, data, television, etc.

Private Network A network established and operated by a public organization or corporation that is intended for exclusive use by users within that organization or corporation. A private network is normally composed of point-to-point circuits and, sometimes, switching arrangements. These networks may be either local or nationwide in scope. An example of a private network is the federal government's FTS 2000 switched network, which supports both voice and data services.

Product Life Cycle The length of time from introduction of a product or service into the market until the product or service becomes obsolete and is replaced by a newer product. It typically has four stages: introduction, growth, maturity, and decline.

Progressively Controlled Network A switching network in which calls are set up by making a series of connections, stage by stage, based on the digits dialed.

Protector Devices Fuse-like devices mounted on distributing frames to guard telecommunications equipment against spurious voltages and currents that might result from lightning strikes or power-line crosses in the outside plant.

Protocol (a) Generically, a software application of any activity or systematic sequence of operations that produces a specified result. Typically it is a computer function that consists of or involves procedure code, data storage, and an interface for communicating with other processes. (b) A strict procedure for the initiation and the maintenance of data communications. (c) Agreement between two peer entities on the means of communication.

Protocol Data Unit (PDU) The unit of data in the open systems interconnection reference model containing both protocol-control information and user data from the layer above.

Pseudoerror Detector A bit error rate (BER) estimation technique that uses modified decision regions in a separate decision circuit to degrade the receiver margin intentionally and reduce the time required to estimate the BER.

Pseudorandom Sequence A sequence of numbers or bits that exhibits properties of a random signal. Although it seems to lack a definite pattern, there is a sequence that repeats after a long time interval.

PSK See Phase-Shift Keying.

PSTN See Public Switched Telephone Network.

PU See Physical Unit.

Public Communications Services Services provided through telephones installed at locations where a public need exists, such as airports, bus and train stations, hotel lobbies, large business offices, public streets, and highways.

Public Switched Telephone Network (PSTN) The portion of the total network that supports public switched telephone network services. It provides the capability for interconnecting virtually any home or office in the United States with any other. Public is the key word; any equipment indeterminately shared by more than one customer is part of the PSTN. May also be called the public switched network, public telephone network, or the direct distance dialing (DDD) network.

Public Switched Telephone Network Services Services provided by the public switched telephone network, including message telecommunications service (MTS), wide area telecommunications services (WATS), and Dataphone Digital Service (DDS), among others.

Public Utilities Commission (PUC) Agency charged with regulating communications services as well as other public-utility services, usually within a state.

PUC See Public Utilities Commission.

Pulse-Amplitude Modulation (PAM) A modulation technique in which the amplitude of each pulse is related to the amplitude of an analog signal. Used, for example, in time-division multiplex arrangements in which successive pulses represent samples from the individual voiceband channels; also used in time-division switching systems of small and moderate size.

Pulse-Code Modulation (PCM) A digital transmission technique that involves sampling of an analog information signal at regular time intervals and coding the measured amplitude value into a series of binary values that are transmitted by modulation of a pulsed, or intermittent, carrier. The analog signal, such as voice, is periodically sampled and the magnitude of each sample is converted to a digital format. Ordinarily the conversion of an analog signal is presented in terms of binary-coded pulses using 8-bit code words and a sampling rate of 8 kHz.

Pulse Rate The number of pulses transmitted per unit of time. May also be called the baud rate. When the pulses or symbols have only two possible values (binary), the pulse rate is also the bit rate.

Pulse Stuffing A process of changing the rate of a digital signal in a controlled manner so that it can accord with a rate different from its own inherent rate, usually without loss of information. Also called justification. Also see Bit Stuffing.

Pulse Stuffing Jitter Jitter caused by the removal of stuffed bits at the demultiplexer and the inability of a clock recovery circuit to eliminate completely the resulting gaps in the information signal.

Pure ALOHA A random-access technique developed by the University of Hawaii in the early 1970s. In this scheme a user wishing to transmit does so at will. Collisions are resolved by retransmitting after a random period of time.

Push Mechanism in transmission control protocol for ensuring immediate transmission of data.

Q

QAM See Quadrature Amplitude Modulation.

QPR See Quadrature Partial Response.

QPSK See Quadrature Phase-Shift Keying.

Quadrature Amplitude Modulation (QAM) Independent amplitude modulation of two orthogonal channels using the same carrier frequency.

Quadrature Partial Response (QPR) The use of partial response filtering on the two orthogonal channels of a quadrature amplitude modulation (QAM) system to increase the bandwidth efficiency of QAM.

Quadrature Phase-Shift Keying (QPSK) A form of phase-shift keying in which four discrete phases, separated by 90°, are used to represent two information bits per signaling interval.

Quality Assurance Continuous independent verification of satisfactory performance of products and services from the user's viewpoint.

Quality Assurance System In the Bell System, a series of audits and continuous monitoring to determine the effect of quality controls used by the designers and producers of a product or service.

Quality Control A set of procedures used by designers and producers of products and services to provide sufficient control of machinery, personnel, and material necessary to meet acceptable quality criteria in an economic manner.

Quantization A process in which the continuous range of values of a signal is divided into nonoverlapping but not necessarily equal subranges to each of which a discrete value of the output is uniquely assigned. Whenever the signal value falls within a given subrange, the output has the corresponding discrete value.

Quantization Noise An undesirable random signal caused by the error of approximation in a quantizing process.

Quantizing Distortion The distortion resulting from the process of quantizing.

Quartz Clock A clock made of quartz crystal.

Queuing (a) In telephony, a feature that allows inbound or outbound calls to be "held" or delayed at a switch while waiting for a trunk or line to become available. (b) Sequencing of batch data sessions.

R

Radio Refractivity (N) One million times the amount by which the refractive index of the atmosphere exceeds unity.

Raised-Cosine Filter A filter with a specific characteristic that produces no intersymbol interference at the sample times of adjacent signaling intervals.

RAO See Revenue Accounting Office.

Raster A scanning pattern used in generating, recording, or reproducing television, facsimile, or graphics images on a screen. Also called raster scanning.

Rate Center A defined geographic point used by telephone companies in determining distance measurements for inter-LATA (local access and transport area) mileage rates.

RBOC Regional Bell Operating Company.

Read-Only Memory (ROM) A data-storage device, the contents of which cannot be altered, except under certain circumstances; storage in which writing over is prevented.

Ready to Receive (RR) A special control frame used in high-level data link control.

Real-Time (a) A transmission or data processing operating mode in which data are entered in an interactive session. (b) Pertaining to an application where response to input is fast enough to affect subsequent input, such as a process-control system or a computer-aided design system. (c) Processing in which the results are used to influence a process while it is occurring.

Receive Only (RO) The operation of a device, usually a page printer, that can receive transmissions but cannot transmit.

Receiver A device that converts electrical or optical signals used for transmission back to information signals.

Redundancy (a) In data transmission, that portion of the gross information content of a message that can be eliminated without loss of essential information. (b) In computers and telephone switch systems, the duplication of essential components such as the processor, active memory, power supply, etc. to ensure the reliable operation of the system.

Reference Noise The level of circuit noise that will produce a measured reading equal to that produced by 1 picowatt (-90 dBm) of electric power at 1000 Hz.

Refresh Rate With conventional computer displays, the rate per unit of time that the displayed image on a video tube is renewed in order to appear stable; typically 60 times per second (60 Hz) in the United States.

Regeneration The process of receiving a digital signal and reconstructing it in a form in which the amplitudes, waveforms, and timing of the signal elements are constrained within specified limits.

Regional Center A Class 1 office in the hierarchy of toll switching offices; the highest-level toll office.

Register A part of an automatic switching system that receives and stores signals from a calling device or other source for interpretation and action, some of which is carried out by the register itself.

REJ See Reject.

Reject A special control frame used in high-level data link control.

Relative (Frequency) Drift The frequency drift divided by the nominal frequency value. Also called normalized frequency drift.

Relative Transmission Level The ratio, in decibels, of the test-tone signal power at one point in a transmission circuit to some other circuit point chosen as a reference.

Reliability The probability that an item will perform its intended function for a specified interval under stated conditions.

Remote Concentrator A remote extension of a local telephone switch often used to concentrate or multiplex remote users via one transmission facility to the local switch to which directed.

Remote Memory Administration System (RMAS) An operations system that changes translations in switching systems.

Reorder Tone A tone applied 120 times per minute that indicates that all switching paths are busy, all toll trunks are busy, there are equipment blockages, an unassigned code has been dialed, or there is incomplete registration of digits at a tandem or toll office; it also can mean that a called channel is busy or can indicate a fast busy tone.

Repeater Equipment, essentially including one or several amplifiers and/or regenerators and associated devices, inserted at a point in a transmission. The medium may operate in one or both directions of transmission.

Repertory Dialer A piece of station equipment that permits a user to dial telephone numbers automatically from a preprogrammed directory.

Reproducibility The degree to which independent devices of the same design can be adjusted to produce the same frequency, or the degree to which a device will produce the same frequency from one occasion to another.

Request to Send (RTS) Part of modem handshaking.

Reserve Capacity The amount of additional capacity (beyond that needed to meet service objectives) that should be provided in a long-term forecast to minimize the cost of underestimating the demand. Reducing reserve capacity in the long-term forecast generates short-term costs (for example, servicing during busy seasons). The "optional" reserve capacity balances the long-term capital cost against the short-term servicing cost.

Resistance Design A design method for customer loops in which an attempt is made to employ cable having the highest gauge (smallest wire) that will ensure a loop resistance less than the signaling limit of the telephone company central office serving the loop.

Response Unit (RU) Basic unit of data in systems network architecture. Also called request unit.

Return to Zero (RZ) A two-level code in which each level is held for a fraction (usually half) of the signaling interval and then returned to a reference level for the remainder of the signaling interval.

Revenue Accounting Office (RAO) A telephone company center using large, mainframe computers for billing and other data processing. Functions performed include receipt and processing of automatic message accounting data, preparation of the customer's bill, directory preparation, marketing support, internal reports, and payroll and inventory management.

RH Request or response header (Systems Network Architecture term).

Ringing The process of alerting the called party by the application of an intermittent 20 hertz (Hz) signal to the appropriate line; this produces a ringing sound at the called telephone set. When the ringing signal is applied to the called line, an intermittent signal called an audible ring is sent to the calling telephone to indicate that ringing is taking place.

Ring Latency The time required to repeat the frame at a station on a token ring type of local area network.

Ring Network A local area network topology in which each node is connected to two adjacent nodes.

RMAS See Remote Memory Administration System.

RNR See Not Ready to Receive.

RO See Receive Only.

Roll-Call Polling A technique in which every station is interrogated sequentially by a central system.

Routing The process of selecting the correct circuit path for a message or telephone call.

Routing Data Base Distance table in digital network architecture.

RR See Ready to Receive.

RTS See Request to Send.

RU See Response Unit.

Rubidium Clock An atomic clock using the element rubidium to produce a stable, accurate timing source.

RZ See Return to Zero.

S

Satellite Communication The use of geostationary orbiting satellites to relay transmissions from one sending earth station to another, perhaps multiple other, earth stations.

Scan Line One of the horizontal lines that makes up a TV picture. The National Television System Committee standard for TV broadcasting in the United States has 525 lines.

Scan Time The time between two successive polls to a station.

SCC See Switching Control Center.

SCCP Signaling connection part of common channel signaling.

SCCS See Switching Control Center System.

Scintillation In radio propagation, a random fluctuation of the received field about its mean value; the deviations usually are relatively small.

SDLC See Synchronous Data Link Control.

Sectional Center A Class 2 office in the hierarchy of toll switching offices. See Toll Office.

Secure Voice Telephone communications that are protected by an encryption system against compromise.

Seize, Seizure An action of a switching system in selecting an outgoing trunk or other component for a particular call.

Separation A rate-setting requirement that specifies that the costs of providing long-distance telephone service be appropriately distributed between interstate services, which are under the jurisdiction of the Federal Communications Commission, and intrastate services, which are under the jurisdiction of the state public-utilities commissions.

Service Code A code, typically of the form N11 (N = any digit 2 through 9), that defines a connection for a service (e.g., 411 for directory assistance; 911 for emergency assistance).

Service Evaluation The process of determining what customers and the Bell System expect of a service, setting appropriate objectives based on the expectations, and assessing compliance with objectives.

Service Measurement A measurement reflecting aspects of operations perceivable by the customer.

Service Objective A statement of the quality of service that is to be provided to the customer; for example, no more than 1.5 percent of customer calls should encounter a delay of more than 3 sec for dial tone during the average busy hour. See also Grade of Service.

Service Order An order prepared in the marketing department of a local operating company, at the request of a customer, to establish a service, to change an existing service, or to terminate a service. The resultant document contains all the information required to meet the customer's needs.

Service Representative An individual in the business office of a local operating company who typically deals with customers.

Serving Area Interface A rearrangeable cross-connect point between feeder and distribution cables in the loop plant.

Session (a) A connection between two stations that allows them to communicate. (b) The period that a user engages in a dialogue with an interactive computer. (c) Connection between end users in systems network architecture. The logical connection between two network addressable units.

Session Layer The layer in the open systems interconnection reference model that manages and controls the dialogue between the users of the service.

Settability The degree to which frequency can be adjusted to correspond with a reference frequency.

Settlement An accounting procedure based on the total investment in telephone equipment; the total investment of a company determines the base for the allowed earnings (called the rate base). Settlements define how revenue from a single call is distributed among different companies, both Bell and independent, involved in that connection.

SHF See Super High Frequency.

Shortest Path A least-cost path between a given source-destination pair.

Sidetone The portion of the signal from a telephone transmitter that appears at the receiver of that telephone. Some sidetone appears to be desirable to assure the customer that the telephone is working and to help the talker adjust the level of speech.

Signal An electrical, optical, or other representation of information for: (a) messages (e.g., voice, data, television), (b) network control (e.g., call routing, network management), and (c) internal operation of network elements (e.g., timing and control of switching systems).

Signaling The transmission of address, supervision, or other switching information between stations and switching systems and between switching systems, including any information required for billing.

Signal Constellation The signal magnitudes and phases of a digital modulation scheme when displayed by a phasor diagram.

Signal-to-Distortion Ratio The ratio of the amplitude of the desired signal to the amplitude of the distortion.

Signal-to-Noise Ratio The ratio of the average signal power at any point in a transmission path to the average noise power at that same point, often expressed in decibels (dBs).

Signal Transfer Point (STP) A switching node in the common-channel interoffice signaling network. Signal transfer points operate under stored-program control to connect signaling links to network switching systems and other STPs. They may also connect directly to network control points.

Simplex One-way transmission with no capability for changing direction.

Simplex Transmission Permitting the transmission of signals in either direction but not simultaneously.

Single-Frequency (SF) Signaling A method of conveying dial-pulse and supervision signals from one end of a trunk or line to the other, using the presence or absence of a single specified frequency. A 2600 hertz (Hz) tone is commonly used.

Single Mode An optical waveguide designed with a core radius so close to a specific wavelength of light that only one mode, and, perhaps, only a single phase, can be propagated. Essentially, an optical fiber that allows the transmission of only one light beam, or data-carrying lightwave channel, and is optimized for a particular lightwave frequency. See also Multimode Fiber.

Single-Mode Fiber Optical fiber.

Single-Sideband Amplitude Modulation (SSBAM) Amplitude modulation in which only one of the sidebands resulting from modulation is selected for transmission by a bandpass filter. A precise and stable carrier frequency is inserted at the receiving terminal for demodulation.

Slip The irretrievable loss or gain of a set of consecutive bits without loss of alignment. Also called timing slip.

Slope Overload Distortion In quantization, the distortion that results when the slope of the input signal exceeds the slope of the quantizer.

Slotted ALOHA A random-access technique extending pure ALOHA to the case in which messages may only be transmitted in slotted intervals of time.

Small Office Network Data System (SONDS) An operations system that collects traffic data from small step-by-step offices, processes the data, and provides reports to network administrators.

SNA See Systems Network Architecture.

SONDS See Small Office Network Data System.

Space Diversity A method of radio transmission employed to minimize the effects of fading by the simultaneous use of two or more antennas spaced apart.

Space Division Switching In telephony, a switching technology in which a separate physical path through the switch is maintained for each call.

Span A collection of span lines between two offices. The term is also used to refer to the collection of all span lines in a particular cable, all span lines on a particular route, or all span lines between two offices.

Span Line A repeatered T1 line section between two telephone company central offices (not necessarily contiguous offices). A T1 carrier system is made up of a tandem combination of span lines, plus a digital channel bank at each terminal.

SPC See Stored-Program Control.

SPCS See Stored-Program Control System/Central Office Equipment Reports.

Speakerphone An audio terminal, consisting of transmitter and loudspeaker units, used with a telephone set for teleconferencing.

Special Services Services requiring special treatment with respect to transmission, signaling, switching, billing, or customer use. Examples are private branch exchange (PBX) service; wide area telecommunications service (WATS); foreign exchange (FX) service; and private-line services such as circuits for voice, data, teletypewriter, and television.

Special-Services Circuit A transmission path used to provide special services to a specific customer.

Speech Interpolation A voice multiplexing scheme in which the gaps and pauses occurring in one voice channel are filled with speech bursts from other voice channels to reduce the bandwidth or transmission rate.

Spot Beam In satellite communications, a narrow and focused downlink transmission. This application is typical of newer satellite designs [such as very small aperture terminals (VSATs)] that allow the satellite to use different frequencies or reuse the same frequencies in other downlink beams. It covers a much smaller geographic area or "footprint" than older satellite downlink transmissions and enhances communications security integrity of the downlink by limiting undesired interdiction.

SSBAM See Single-Sideband Amplitude Modulation.

SSCP See System Services Control Point.

Stability The rate at which a device changes from its nominal frequency over a selected period of time.

Standard Refraction The refraction resulting from a gradient of radio refractivity equal to -40 N/km. Also corresponds to atmospheric refraction with $k = 4/3$.

StarLAN An AT&T local area network design and specification that complies with the IEEE 802.3 standard. It is characterized by a 1 Mb/s baseband data transmission over unshielded, two-pair twisted-pair wiring.

Station Equipment Equipment that allows a customer to access the network and the available services. The most common station equipment is the ordinary single-line telephone set.

Station Number The final four digits of a standard 7- or 10- digit address that define a connection to a specific customer's line within a telephone company central office. See also Central Office Code.

Statistical Multiplexing A form of concentration in data multiplexing in which time slots are allocated to whichever terminals are active at any one time.

Status Signal Unit Signal unit of common channel signaling used to initiate transmission on a link or to recover from loss of transmission.

Step-by-Step (SXS) System An automatic switching system using step-by-step switches. In most such systems, a call is extended progressively, step-by-step, to the desired terminal under direct control of pulses from a customer's dial or from a sender.

Step-Index Fiber An optical fiber that has an abrupt change in refractive index at the boundary of the core and cladding.

Stored-Program Control (SPC) A form of computerized switching system control in which system operations are controlled by a stored program executed by one or more processors. Operation of the system can be altered significantly by changing programs.

Stored-Program Control System/Central Office Equipment Reports (SPCS/COER) A series of time-shared programs that analyzes traffic data for electronic switching system offices and produces reports.

STP See Signal Transfer Point.

Subrefraction Refraction for which the refractivity gradient is greater than that for standard refraction. Also corresponds to atmospheric refraction with $k < 1$.

Suffix Any signal dialed after the address. Used by operators, for example, to indicate the end of dialing.

Supergroup In frequency-division multiplexing, a number of voice channels (generally 60) occupying a 240 kHz bandwidth and composed of five groups.

Super High Frequency (SHF) A portion of the electromagnetic spectrum in the microwave region with frequencies ranging from about 2 to 20 GHz.

Supermastergroup In frequency-division multiplexing, a number of voice channels (generally 900) occupying a 3872 kHz bandwidth and composed of three 300-channel mastergroups.

Super-refraction Refraction for which the refractivity gradient is less than that for standard refraction. Also corresponds to atmospheric refraction with $2 < k <$ infinity.

Supervision The constant monitoring and controlling of the status of a call.

Switched Circuit A circuit that may be temporarily established at the request of one or more of the connected stations.

Switching (a) The process of connecting appropriate lines and trunks to form a desired communication path between two station sets. Included are all kinds of related functions, such as sending and receiving signals, monitoring the status of circuits, translating addresses to routing instructions, alternate routing, testing circuits for busy condition, and detecting and recording troubles. (b) A field of work, such as system development, planning, or engineering, involving the application of switching technology in telecommunications networks. (c) In a more restricted sense, the technology associated with any circuit that operates discretely, particularly logic and memory.

Switching Control Center (SCC) An operations center responsible for the centralized installation and maintenance of a group of switching systems in a geographic area.

Switching Control Center System (SCCS) The computer subsystem (CSS) and the equipment units that duplicate the master control center capability of an electronic switching system. The SCCS provides for the administration, control, and maintenance of electronic switching systems from central locations.

Switching Network Switching stages and their interconnections within a switching system.

Switching System An electromechanical or electronic system for connecting lines to lines, lines to trunks, or trunks to trunks. The term includes private branch exchange switching systems and centrally located network switching systems. See also Switching.

Syllabic Companding A form of companding in which the step sizes are controlled by the syllabic rate of human speech.

Synchronous Data Link Control (SDLC) Data link control in IBM's systems network architecture.

Synchronous Detection See Coherent Detection.

Synchronous Signals Signals with corresponding significant instants having a desired constant phase relationship with each other.

Synchronous Transmission A transmission process such that between any two significant instants in the overall bit stream, there is always an integral number of unit intervals.

System (a) Those networks that connect users directly to system resources. See also Network. (b) A logical collection of computers, peripherals, software, service routines, accounting and control procedures, terminals, and end users. (c) A collection of man, machines, and methods organized to accomplish a set of specific functions. (d) An assembly of components united by some form of regulated interaction to form an organized whole.

Systematic Drift Frequency drift in an oscillator resulting from slowly changing physical characteristics and causing frequency changes that over a long period of time tend to be in one direction.

System Code A three-digit code, usually of the form 1XX but including 0XX (X is any digit 0 through 9) assignments, available only to operators or to switching equipment for use as part of a special or modified address to influence route selection. These codes are reserved for system-wide use; that is, they are the same across all numbering plan areas.

System Gain The difference, in decibels, between the transmitter output power and the minimum receiver signal level required to meet a given performance objective.

System Rise Time In an optical fiber system, the time for the system response to a step function to rise from 10 percent to 90 percent of maximum amplitude.

System Services Control Point (SSCP) The point in systems network architecture that manages all resources within an SNA domain. It provides a host-based network entity that manages the network configuration, coordinates network operator and problem-determination requests, maintains network address and mapping tables, and provides directory support and session services.

Systems Network Architecture (SNA) In IBM networks, the layered logical structure, formats, protocols, and procedures that govern information transmission.

T

T1 A digital carrier facility used to transmit a DS-1 formatted digital signal at 1.544 M/s with 24 voice channels at 64 kb/s each. See also Accunet.

T1C A digital carrier facility used to transmit a DS-1C formatted digital signal at 3.152 Mb/s.

T2 A digital carrier facility used to transmit a DS-2 formatted digital carrier signal at 6.312 Mb/s.

Table-Driven Process (a) A logical computer process, widespread in the operation of communications devices and networks, in which a user-entered variable is matched against an array of predefined values. (b) A frequently used logical process in network routing, access security, and modem operation.

Talker Echo An echo of a talker's voice that is returned to the talker. When there is delay between the original signal and the echo, the effect is disturbing, unless the echo is attenuated to a tolerable level.

Tandem Data Circuit A data channel passing through more than two data circuit-terminating equipment devices in series.

Tandem Office (a) A major phone company switching center for the switched telephone network that serves to interconnect central offices when direct interoffice trunks are not available. (b) A high-level switching center in the local exchange or serving area. (c) The interconnection of local central offices by a tandem exchange or switch as a central office interconnects individual subscriber lines.

Tandem Switch An intermediate switch connecting two other switching exchanges.

Tandem Switching System A broad functional category representing systems that connect trunks to trunks. Tandem switching divides into two applications: (a) Those offices that connect trunks within a metropolitan area are referred to as local tandem offices. (b) Those offices that connect trunks in the toll network portion ("Class 1" to "Class 4") of the public switched telephone network are called toll offices.

Tandem Trunk A trunk that connects wire centers through a local tandem office.

Tariff (a) The formal process in which services and rates are established by and for communications common carriers. Tariffs are submitted by carriers for government regulatory approval, reviewed, amended, and then approved. (b) The published rates, regulations, and descriptions governing the provision of communications service. The published rate for a specific communications service, equipment, or facility constitutes a contract between the user and the communications supplier or carrier.

TASI See Time Assignment Speech Interpolation.

T-Carrier A time-division multiplexed phone company-supplied digital transmission facility, usually operating at an aggregate data rate of 1.544 Mb/s and above.

T-Carrier Administration System (TCAS) An operations system responsible for T-carrier alarms.

TCAS See T-Carrier Administration System.

TCP See Transmission Control Protocol.

TDAS See Traffic Data Administration System.

TDM See Time-Division Multiplexing.

TDMA See Time-Division Multiple Access.

Teleconferencing Voice telephone service between a group of people and one or more other groups or individuals.

Telco A generic abbreviation for telephone company or telephone central office.

Telemetry The method or equipment used to transmit status information such as that represented by the operation of keys or by lamp displays to a remote location.

Telnet Terminal-remote host protocol developed for ARPAnet.

Teletext Broadcasting system that displays selected frames of information as they are being continuously recycled by the originator of the signal.

Terminal Equipment In the interconnection environment, any separately housed equipment unit or a group of equipment units located on user premises on the user side of a network interface.

Terminated Line A telephone circuit with a resistance at the far end equal to the characteristic impedance of the line, so no reflections or standing waves are present when a signal is entered at the near end.

Termination (a) The points on a switching network to which a trunk or a line may be attached. (b) An item that is connected to the terminals of a circuit or piece of equipment. (c) An impedance connected to the end of a circuit being tested.

Termination Layout Mask A plan that reserves space on a distributing frame for different termination categories of equipment and facilities. Thus, as the office grows, there will be room on the frame for the orderly addition of new terminations.

Test Center A facility for detecting and diagnosing faults and problems with communications lines and the equipment attached to them. If centralized, a network manager or technician can gain access to almost any circuit in a network for the purpose of running diagnostic testing. Also called network control center.

Text (a) Transmitted characters forming the part of a message that carries information to be conveyed. In some protocols, text is the character sequence between start-of-text (STX) and end-of-text (ETX) control characters. (b) Information for human, as opposed to computer, comprehension that is intended for presentation in a two-dimensional form.

TFS See Trunk Forecasting System.

Throughput (a) The total useful information processed or communicated during a specified time period. (b) A measure of the effective rate of transmission of data by a communications system.

TGC Transmission group control in systems network architecture.

TH Transmission header. Systems network architecture term.

TIE See Time Interval Error.

Tie Cable Cable that interlinks distributing frames.

Tie Trunk A special-services circuit connecting two private branch exchanges or equivalent switching systems.

Time Accuracy The degree to which a clock agrees to a specified standard time.

Time Assignment Speech Interpolation (TASI) In telephony, a form of speech multiplexing generally used with analog voice transmission to develop a line-efficiency technique in which telecommunications channels are activated or deactivated by the presence or absence of sound. An input ratio of five channels to three channels is generally achievable.

Time Base Error See Time Interval Error.

Time Congestion The fraction of time that resources (outgoing trunks) are busy.

Time-Division Multiple Access (TDMA) A satellite transmission technique in which several earth stations have use of total available transponder power and bandwidth, with each station in sequence transmitting in short bursts.

Time-Division Multiplexing (TDM) An access method that allocates each user a prescribed portion (slot) of a time period, thereby creating a form of multiplexing in which two or more channels may be interleaved in time for transmission over a common medium. It is used as a method for serving a number of simultaneous channels by assigning the transmission path sequentially to the various channels, each assignment being for a discrete time interval.

Time Interval Error (TIE) The error in time that accumulates when a frequency source is used as a clock.

Time-Multiplexed Switch An element of a time-division switching network that effectively operates as a very high-speed space division switch whose input-to-output paths can be changed in every time slot.

Timeout Expiration of a predefined time period, at which time some specified action occurs. Timeouts are employed to avoid unnecessary delays and improve traffic flow (e.g., to specify maximum response times to polling and addressing before a procedure is automatically restarted).

Time Sharing The use of a facility or piece of equipment for more than one purpose or function or for repetition of the same function within the same overall time period. This is accomplished by interspersing or interleaving the required actions in time.

Time Slot Interchange (TSI) An element of time-division switching that separates and switches signals from multiple calls that are presented in a time-division multiplexed format. Information is transferred from one time slot at the input to another slot at the output.]

Time to Loss of Frame Alignment After proper frame alignment, the time to loss of frame synchronization, often specified as a function of bit error rate.

Timing Slip See Slip.

Tip and Ring Conductors The two conductors associated with a two-wire cable pair. The terms tip and ring derive their names from the physical characteristics of an operator's cord switchboard plug in which these two conductors terminated in the days of manual switchboards. Use of the names tip and ring has extended throughout the plant. The cord switchboard plug also had a sleeve, and the name is occasionally used for a third conductor associated with tip and ring.

TIRKS See Trunks Integrated Records Keeping System.

TLP See Transmission Level Point.

TNDS See Total Network Data System.

TNOP See Total Network Operations Plan.

Toll A term describing service that is a part of public telephone service but under a tariff separate from the exchange area tariff. Also used to describe components of the facilities network that are used principally for toll service.

Toll Center A Class 4 office in the hierarchy of toll switching offices; the lowest level toll office.

Toll Center Code A three-digit code of the form 0XX (X = any digit 0 through 9) that identifies a specific toll center and is available only for local operating company use.

Toll Charge A charge for telephone service for calls outside the designated local exchange area. Toll service calls are billed individually.

Toll Connecting Trunk A trunk between an end office and a toll office.

Toll Office Those offices that connect trunks in the toll network portion (Class 1 to Class 4) of the public switched telephone network. See also Tandem Switching System.

Total Network Data System (TNDS) A coordinated family of operations systems. Total network data system consists of both manual procedures and computer systems that provide local operating company managers with comprehensive, timely, and accurate network information. It supports operations centers responsible for administration of the trunking network, network data collection, daily surveillance of the load on the switching network, and design of local and telephone company central office switching equipment to meet future service demands.

Total Network Operations Plan (TNOP) A Bell System operations plan that describes the operations processes, operations centers, and operations systems to be used in administering and provisioning the telecommunications network in the Bell operating companies.

TP Transport Protocol, open systems interconnection reference model.

TPDU Transport Protocol Data Unit.

Traffic The flow of information or messages through the network. This information flow may be generated by telephone conversations or may be the result of providing data, audio, and video services.

Traffic Data Administration System (TDAS) Part of the total network data system (TNDS) that formats and temporarily stores traffic data for other TNDSs.

Traffic Engineering A network planning activity that determines the number and type of channels or communication paths required between switching points and the call-handling capacity of the switching points.

Traffic Network An arrangement of channels (such as loops and trunks, associated switching arrangements, and station equipment) designed to handle a specific body of traffic. Traffic networks are provided by the facilities network.

Traffic Service Position (TSP) A cordless console that is associated with either a crossbar tandem office or a traffic service position system, equipped so that operators can provide assistance, if needed, on station-to-station calls, special toll calls, public telephone calls, and all local and toll assistance traffic. The operators provide assistance in completing these calls and ensure that correct data are recorded in the centralized automatic message accounting equipment or in the traffic service position system equipment. They also supervise coin deposits for calls originating at public telephones. The position is arranged for automatic display of both the calling and called numbers, as well as certain other information.

Traffic Service Position System (TSPS) A type of traffic service system, with stored-program control, that provides for the processing and recording of special toll calls, public telephone toll calls, and other types of calls requiring operator assistance. It includes traffic service positions arranged in groups called operator office groups, in which operators are automatically connected in on calls to perform the functions necessary to process and record the calls correctly.

Traffic Theory A branch of applied probability theory that produces models used to determine the capacity requirements to meet service objectives of systems with nondeterministic demands.

Transcoder A device that performs direct digital-to-digital conversion between two different voice-encoding schemes without returning the signals to analog form.

Transition Probabilities Probabilities of moving from one state to another.

Transitional Coding A coding scheme used to convert asynchronous data to synchronous transmission by transmitting the data values and data transition times.

Translation The operation of converting information from one form to another. In switching systems, the process of interpreting all or part of a destination code to determine the routing of a call.

Transmission (a) A field of work, such as equipment development, system design, planning, or engineering, in which electrical communication technology is used to create systems to carry information over a distance. (b) The process of sending information from one point to another. (c) Used with a modifier to describe the quality of a telephone connection: good, fair, or poor transmission. (d) The transfer characteristic of a channel or network in general or, more specifically, to the amplitude transfer characteristic. One may hear the phrase "transmission as a function of frequency."

Transmission Control Protocol (TCP) An ARPAnet-developed transport layer protocol.

Transmission Facility An element of physical telephone plant that performs the function of transmission (e.g., a multipair cable, a coaxial cable system, or a microwave radio system).

Transmission Level Point (TLP) A specification, in decibels, of the relative level at a particular point in a transmission system as referred to a zero transmission level point (0 TLP). The TLP value does not specify the absolute power that will exist at that point.

Transmission Objective Electrical performance characteristics for communication circuits, systems, and equipment based on both economic and technical considerations of telephone facilities and on reasonable estimates of the performance desired. Characteristics for which objectives are stated include loss, noise, echo, crosstalk, frequency shift, attenuation distortion, envelope delay distortion, etc.

Transmitter A device that converts information signals to electrical or optical signals for transmission purposes.

Transmultiplexer Equipment that transforms frequency-division multiplexed signals (such as group or supergroup) into corresponding time-division multiplexed signals that have the same structure as those derived from pulse-code modulation multiplex equipment. The equipment also carries out the inverse function.

Transponder In satellite communications, the circuitry that receives an uplink signal, translates it to a usually higher frequency, amplifies it, and then retransmits it as the downlink signal.

Transport Layer The layer that provides the appropriate service to the session layer. The layer that shields the session layer from the vagaries of underlying network mechanisms.

Transversal Filter An equalizer that uses a tapped delay line with weighting coefficients at each tap to eliminate intersymbol interference.

Tree A network topology characterized by the existence of only one route between any two network nodes. A network that resembles a branching tree, such as most cable TV distribution networks.

Trouble Ticket A form containing either symptoms or detailed information about malfunctioning equipment. It is given to a craftsperson whose job it is to locate and repair the equipment.

Trunk A communication channel between two switching systems. The term switching system includes telephone company central office types, toll switching systems, private branch exchanges, key telephone systems, manual and automatic switchboards, concentrators, etc.

Trunk Circuit A circuit, part of a switching system, associated with the connection of a trunk to the switching system. It serves to convert between the signal formats used internally in the switching system and those used in the transmission circuit, and it performs logic and sometimes memory functions associated with supervision.

Trunk Forecasting System (TFS) Part of the total network data system that forecasts message trunk requirements for five years in the future.

Trunk Group Multiple trunk circuits between two switching centers that can be used interchangeably between switching systems or accessed by dialing a single trunk number and using the same multiplexing equipment at both ends.

Trunk Servicing System (TSS) Part of the total network data system that processes traffic data from the traffic data administration system, computes offered load, and calculates trunk requirements. It is used by trunk administrators to maintain the message trunk network.

Trunks Integrated Records Keeping System (TIRKS) An operations system for maintaining the inventory and assignment of the facilities and equipment used to establish trunks of all kinds.

TSAP Transport service access point in the open systems interconnection transport protocol layer.

TSDU Transport service data unit in the open systems interconnection transport protocol layer.

TSI See Time Slot Interchange.

TSO Time sharing option.

TSO Command Language The set of commands, subcommands, and operands recognized under the time sharing option.

TSO/VTAM Time Sharing Option for the Virtual Telecommunications Access Method.

TSP See Traffic Service Position.

T-Span A telephone circuit or cable through which a T-carrier runs.

TSPS See Traffic Service Position System.

TSS See Trunk Servicing System.

T-Tap (a) A passive line interface used for extracting data from a circuit. (b) A device for extracting optical signals from a fiber cable or electrical signals from a coaxial cable.

Twisted-Pair Cable A communication cable consisting of two insulated conductors twisted together.

Two-Way Trunk A trunk that can be seized for use by the switching equipment located at either end of the trunk termination.

U

UHF See Ultra High Frequency.

ULP See Upper Layer Protocol.

Ultra High Frequency (UHF) A portion of the electromagnetic spectrum ranging from approximately 300 MHz to approximately 3 GHz. The frequency band includes television channels 14 through 83 and cellular radio frequencies.

Unavailability The probability or fraction of time that a system is in a state of failure.

Unigauge Design A design method for customer loops that provides for the exclusive use of 26-gauge cable on all loops within 30 kft of the telephone company central office. Requires range extension equipment developed specifically for the unigauge system.

Unipolar A two-level code using a single polarity for one level and zero voltage for the other level.

Universal Telephone Service The goal of establishing affordable and available nationwide telephone service.

Up Link The earth transmission station and the carrier signal used to transmit information to a geosynchronous satellite.

Upper Layer Protocol (ULP) Layer above transmission control protocol.

Usage-Sensitive Rate A rate-setting principle that relates directly to customer use of equipment and service. Those who use less, pay less.

V

Value-of-Service Pricing A rate-setting principle that relates directly to the customer density in a local calling area, the frequency of use, and importance of service to the customer.

VAN Value-added network.

Vertical Blanking Interval Twenty-one scan lines in a TV signal not seen by the viewer, some of which may be used to carry a teletext signal. The vertical blanking interval is seen as a black bar when the picture rolls.

Very High Frequency (VHF) That portion of the electromagnetic spectrum with frequencies between 30 and 300 MHz. The operating band for television channels 2 to 13 and commercial FM radio.

VF See Voice Frequency.

Videotext Easy-to-use interactive electronic service that provides information.

VHF See Very High Frequency.

Video Teleconferencing The real-time, two-way transmission of digitized video images between two or more locations. A wideband transmission facility is required, for which satellite communications have become a popular choice. Transmitted images may be freeze-frame (where a television screen is repainted every few seconds) or full motion. Bandwidth requirements for two-way videoconferencing range from 56 kbit/s (freeze-frame) to T1 rates (1.544 Mb/s).

Videotext An interactive data communications application designed to allow unsophisticated users to converse with a remote data base, enter data for transactions, and retrieve textual and graphics information for display on subscriber television sets or low-cost terminals.

Virtual Circuit In packet switching, a transmission path over network facilities that gives the appearance to the user of an actual end-to-end circuit. In contrast to a physical circuit, a dynamically variable network connection in which sequential user data packets may be routed differently during the course of a "virtual connection" and enable transmission facilities to be shared by many virtual circuits simultaneously. Packets are constrained to arrive at the destination in sequence.

Virtual Route Virtual circuit in IBM's systems network architecture.

Virtual Route Pacing Control Systems Network Architecture congestion control at the path control level.

Vocoder A type of voice coder that is based on a model of the human speech mechanism, in which the source of sound is separated from the vocal tract. A speech analyzer determines the source of sound and vocal tract characteristic and formats this information into a bandwidth that is much smaller than the speech signal itself. A speech synthesizer converts the formatted information back into artificial speech sounds.

Voiceband Channel A transmission channel with a nominal 4 kilohertz (kHz) bandwidth suitable for voice transmission.

Voice Frequency (VF) (a) An analog signal within the range of transmitted speech, typically from 300 to 3400 Hz. (b) Any transmission supported by a standard analog telecommunications circuit.

Voice-Frequency Facility An analog facility that provides one voiceband channel and carries the information in the voice-frequency band.

Volatile Memory A computer memory in which stored information is lost if the power supply for the memory fails or is turned off.

VRPRS Virtual route pacing response in systems network architecture.

W

Waiting Time Jitter In a pulse-stuffing multiplexer, the jitter occurring because of the delay between the time a stuff is needed and the prescribed times that stuffs are allowed.

Walk Time The time required to transfer permission to poll from one station to another.

Wander See Drift.

WARS See Wide Area Telecommunications Services.

Waveguide Specially constructed metallic pipe for containing, directing, and focusing microwave electromagnetic radiation for transmission. It is used as the transmission medium between a microwave radio's transmitter and receiver and the antenna system.

White Noise Noise whose frequency spectrum is continuous and uniform over a wide frequency range.

Wide Area Telecommunications Services (WATS) A service that permits customers to make or receive long-distance calls and to have them billed on a bulk basis rather than individually. Wide Area Telecommunications Services is provided within selected service areas, or bands, by means of special private-access lines, which are connected to the public switched telephone network through WATS-equipped central offices. A single access line permits inward or outward service but not both.

Wideband Generally, a communications channel offering a transmission bandwidth greater than a voice-grade channel. Data transmission speeds on wideband facilities are typically in excess of 9.6 kb/s and often at rates such as 56 kbit/s and 1.544 Mb/s.

Wideband Coder A voice coder with a transmission rate that exceeds the rate that can be accommodated by 3 kHz telephone channels using modems.

Wideband Frequency-Shift Keying A form of frequency-shift keying in which the modulation index is much greater than 1.

Window Control A credit or token scheme in which a limited number of messages or calls only is allowed into the system.

Wire Center The location of one or more local switching systems; a point at which customer loops converge. May be loosely used to mean the telephone company central office building at that location.

Wire Center Area The area surrounding a wire center containing all customers, other than those with foreign exchange service, whose loops are connected to the telephone company central office at that wire center.

Wire Pair Cable Cables composed of twisted pairs of wires rather than coaxial tubes, fibers, etc.

Word Interleaving See Character Interleaving.

Work Package Material sent to local operating company field forces that describes work to be performed.

Workstation Input/output equipment at which an operator works. A user can send to or receive data from a computer for the purpose of performing a job.

World Numbering Plan See Country Code.

World Zone Number A one-digit number that, in the world numbering plan, identifies a geographic zone. The world zone number is the initial number in a country code.

X

X.3 Packet assembly/disassembly facility in a public data network.

X.25 The International Telegraph and Telephone Consultative Committee three-layered interface architecture for packet switching connecting data-terminal equipment to data circuit-terminating equipment.

Z

Zero Code Suppression In pulse-code modulation transmission, The insertion of a "one" bit to prevent the transmission of eight or more consecutive "zero" bits. It is used to maintain clock recovery performance when using bipolar coding. Used primarily with digital T1 and related telephone company facilities that require a minimum "ones density" to keep the individual subchannels of a multiplexed, high-speed facility active. Several different schemes are currently employed to accomplish this while proposals for a standard are being evaluated by the International Telegraph and Telephone Consultative Committee.

Zero-Forcing Equalizer An equalizer in which the weighting coefficients of a transversal filter are selected to force the equalizer output to zero at sampling instants on either side of the desired signal.

Zero Transmission Level Point (0 TLP) In telephony, a reference point for measuring the signal power gain and losses of a telecommunications circuit at which a 0 dBm signal level is applied. Usually, though not always, referenced to the output signal level at the transmitting switch in a telephone circuit; the signal level reference unit dBm0.

APPENDIX B

STANDARDS ORGANIZATIONS

American National Standards Institute (ANSI)
1430 Broadway
New York, N.Y. 10018

American National Standards Institute is the principal coordinator of standards-making bodies in the United States. Originally formed in 1918, it is a nonprofit, nongovernmental organization. It is the United States' representative to the International Organization for Standardization (ISO). American National Standards Institute standards result either from the work of its 300 standards committees or from associated groups, such as the Electronic Industries Association.

Electronic Industries Association (EIA)
2001 I Street, N.W.
Washington, D.C. 20006

The EIA is a trade organization representing a large number of U.S. electronics manufacturers. It was founded in 1924 as the Radio Manufacturers Association. Through the efforts of more than 4000 government and industry representatives on more than 200 technical committees, the EIA Engineering Department has produced more than 400 standards and publications. The EIA's work is hardware oriented, whereas the ANSI committee's work is more procedure oriented.

European Computer Manufacturers Association (ECMA)
114 rue de Rhone CH-1204
Geneva, Switzerland

European Computer Manufacturers Association, formed in 1961, develops data-processing standards. It is not a trade organization. European Computer Manufacturers Association technical committees develop standards and work in close cooperation with the International Telegraph and Telephone Consultative Committee study groups and International Organization for Standardization subcommittees.

Federal Information Processing Standards (FIPS)
U.S. Department of Commerce National Technical Information Service 5285 Port Royal Road Springfield, Va. 22161

Federal Information Processing Standards is the identifier applied to standards developed under the federal government's computer standardization program. The FIPS program is the result of Public Law 89-306, which calls for the Secretary of Commerce to make recommendations to the President concerning uniform data-processing standards. The National Institute of Standards and Techology (NIST) drafts FIPS specifications. The NIST works closely with the Federal Telecommunications Standards Committee to develop FIPS data-communications standards.

Federal Telecommunications Standards Committee (FTSC)
General Service Administration Specification Distribution Branch Building 197--Washington Navy Yard
Washington, D.C. 20407

The FTSC is a federal government interagency advisory body established in 1973. Its objectives are to achieve interoperability among functionally similar telecommunications networks, to work with the National Institute of Standards and Technology to establish data-communications interface standards, and to ensure the federal government's participation in programs for national and international standardization. The FTSC avoids developing its own standards unless a clear need exists. Three areas in which the FTSC has been active, however, are the development of standards for modems (compatible with International Telegraph and Telephone Consultative Committee recommendations), defining system performance evaluation procedures, and developing standards for implementing the Data Encryption Standard (DES) algorithm.

Institute of Electrical and Electronics Engineers (IEEE)
IEEE Computer Society
Suite 608
111 19th Street, N.W.
Washington, D.C. 20036

The IEEE is a U.S.-based organization established in 1884. It actively establishes standards for the data-communications industry. Its best-known current effort is Project 802, which is attempting to define local area network (LAN) standards. Project 802 was begun in early 1980 and has received an unusually high degree of support, with more than 125 companies and universities actively involved. The Institute of Electrical and Electronics Engineers 802 recommendations consist of a set of standards that deal with the International Organization for Standardization's reference model for open systems interconnection. The IEEE 802 committee's charter is to seek a LAN model and to recommend interface and protocol specifications for logical link control, access methods, encoding techniques, and physical media.

International Organization for Standardization (ISO)
Central Secretariat
1 rue de Varembe
CH-211 Geneva, Switzerland

The ISO is a nontreaty organization founded in 1947 and currently comprises 90 member nations. Each nation assigns its principal standardization body to the ISO. Amercian National Standards Institute is the United States' member body to the ISO. Nations may be active contributors (participating members) or observers of the standardization process (correspondent members). Each of the participating members manages one or more technical committees or subcommittees.

International Telegraph and Telephone Consultative Committee (CCITT)
General Secretariat
International Telecommunications Union
Place de Nations
1211 Geneva 20
Switzerland

The Union Telegraphique was established in 1865 when nations realized the need for standards to create international telecommunications services. A treaty between participating nations formed the original organization, which was renamed the International Telecommunications Union (ITU) in 1947. More than 160 countries belong to the ITU. Either of two groups within the ITU handles standards recommendations: the International Radio Consultative Committee (CCIR) or the International Telegraph and Telephone Consultative Committee (CCITT). Although they are not intended to be mandatory, CCITT recommendations have the effect of law in many European countries.

THE TRANSPORTATION RESEARCH BOARD is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. It evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 270 committees, task forces, and panels composed of more than 3,300 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, the Association of American Railroads, the National Highway Traffic Safety Administration, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Frank Press is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Robert M. White is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Samuel O. Thier is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Frank Press and Dr. Robert M. White are chairman and vice chairman, respectively, of the National Research Council.

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