CHAPTER 16

16. DATA COMMUNICATIONS AND COMPUTER NETWORKS

With the miniaturization of hardware components and the drastic reduction in their cost, computer hardware has evolved from an item of major economic concern with first generation digital computers to one of minor concern in todays computing systems. The impact of this recession was a move from mainframes and minicomputers to small personal computers. The simultaneous advancements in data communications facilities have increased the usability of remote computing systems and have led to their consideration as alternatives to centralized data processing. With earlier computer systems, all components of the computer system were typically located in one or two rooms. Today computer systems are literally reaching out to us. Instead of taking processing jobs to the computer room, we are now bringing the computer systems to where the action is.

The marriage of computers with data communications is one of the most exciting developments in data processing today. The goal of this chapter is to introduce the various aspects of data communications technology and to discuss how this technology is combined with computer technology to form computer networks. Following are some of the important concepts which you will learn form this chapter:

1. Basic elements of a communication system.
2. The techniques, channels and devices used to transmit data between distant locations.
3. The various types of computer networks.
4. Communication protocols which are rules and procedures for establishing and controlling the transmission of data from one computer to another.
5. Characteristics and advantages of distributed data processing.

BASIC ELEMENTS OF A COMMUNICATION SYSTEM

Communications is the process of transferring messages from one point to another. As shown in Figure 16.1, the three basic elements of any communications process are :

1. A *sender* (source) which creates the message to be transmitted.

2. A *medium* which carries the message.

3. A *receiver* (sink) which receives the message.

For example, when you speak to your friend on the telephone, you are the sender. The telephone line through which your voice is transmitted is the medium and your friend is the receiver. This is a simple example of voice communication. The same concept holds good for data communications also. Data communications is the function of transporting data from one point to another. In this case, the sender and the receiver are normally machines, in particular, computer devices (computers, terminals, peripheral devices like line printers,

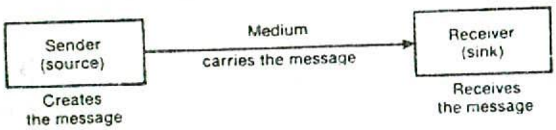


Figure 16.1. Basic elements of a communication system.

teletypes, disks, etc.) and the transmission medium may be telephone lines, microwave links, satellite links, etc. However, the messages that are transmitted are data, not voice conversations. Thus, the electronic systems that transfer data from one point to another are called *data communications systems*. Unlike computers that process and rearrange data, data communications systems transmit data from one point to another without any change.

DATA TRANSMISSION MODES

There are three ways, or modes, for transmitting data from one point to another. As shown in Figure 16.2, these are simplex, half-duplex, and full-duplex.

SIMPLEX

If transmission is simplex, communication can take place in only one direction. Devices connected to such a circuit is either a send-only or a receive-only device. For example, a data collection terminal on a factory floor (send only) or a line printer (receive only). At first thought that might appear adequate for many types of applications in which

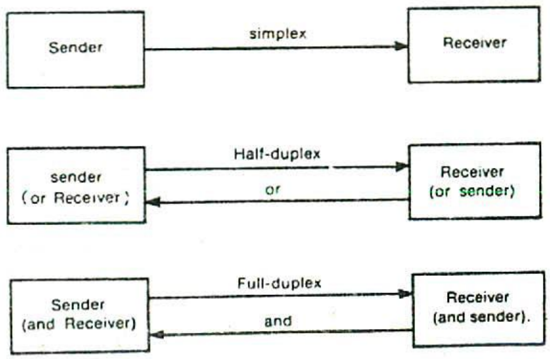


Figure 16.2. Modes of transmission.

flow of information is unidirectional. However, in almost all data processing applications, communication in both directions is required. Even for a "one-way" flow of information from a terminal to a computer, the system will be designed to allow the computer to signal the terminal that data has been received. Without this capability, the remote user might enter data and never know that it was not received by the computer (due to some problem somewhere). Hence, simplex circuits are seldom used because a return path is generally needed to send acknowledgement, control, or error signals.

HALF-DUPLEX

A half-duplex system can transmit data in both directions, but only in one direction at a time. Thus, a half-duplex line can alternately send and receive data. It requires two wires. This is the most common type of transmission for voice communications because only one person is supposed to speak at a time. It is also used to connect a terminal with a computer. The terminal might transmit data and then the computer responds with an acknowledgement.

FULL-DUPLEX

In a half-duplex system, the line must be "turned-around" each time the direction is reversed. This involves a special switching circuit and requires a small amount of time (approximately 150 milliseconds). With high speed capabilities of the computer, this turn-around time is unacceptable in many instances. Also, some applications require simultaneous transmission in both directions. In such cases, a full-duplex system is used that allows information to flow simultaneously in both directions on the transmission path. Use of a full-duplex line improves efficiency as the line turn-around time required in a half-duplex arrangement is eliminated. It requires four wires.

DATA TRANSMISSION SPEED

A term used to describe the data-handling capacity of a communications system is bandwidth. *Bandwidth* is the range of frequencies that is available for the transmission of data. A narrow range of frequencies in a communications system is analogous to a narrow road. The flow of information in such a system - its data transfer rate - is limited, just as is the flow of traffic in the narrow road. Wider bandwidths permit more rapid information flow. Thus, the wider the bandwidth of a communications system, the more data it can transmit in a given period of time.

When dealing with computer input/output devices we think in terms of characters per second. However, in case of data transmission, we talk in terms of bits per second. Recall that the ASCII code uses 7 data bits per character plus a parity bit. For data communication, additional bits are added to control the process. Although the number of bits depends upon the communications system used, commonly encountered systems use a total of either 10 or 11 bits per character. Hence a terminal having a speed of 30 characters per second would probably be used with a communications system which transmits at the rate of 300 bits per second.

The communication data transfer rate is measured in a unit called *baud.* In general usage, baud is identical to bits per second. For instance, a rate of 300 baud is 300 bits per second. Therefore, the 30 characters per second terminal would be said to operate at 300 baud. However, technically baud refers to the number of signal (state) changes per second. Thus, using more sophisticated coding techniques, 1 baud can represent 2 or even 3 bits per second. But, with most communications systems, 1 baud represents only one signal change per second and thus is equivalent to 1 bit per second.

Depending on their transmission speeds, communication channels (paths) are grouped into three basic categories - narrowband, voiceband, and broadband.

NARROWBAND

Narrowband or subvoice grade channels range in speed from 45 to 300 baud. They are used for handling low data volumes and are adequate for low-speed devices. They are used mainly for telegraph lines and low speed terminals.

VOICEBAND

Voiceband channels handle moderate data volumes and can transmit data at speeds upto 9600 baud. They are so called because their major application is for ordinary telephone voice communication. They are also used for data transmission from card reader to CPU or from CPU to line printer. Moreover, most remote terminals are connected to computers through voiceband channels.

BROADBAND

Broadband or wideband channels are used when large volumes of data is to be transmitted at high speed. These systems provide data transmission rates of 1 million baud or more. A company might use a broadband facility for high speed computer to computer communication or for simultaneous transmission of data to several different devices.

As might be expected, the cost of the service increases with speed. Hence a thorough analysis of the business needs and associated costs is necessary in making a proper choice.

TRANSMISSION MEDIA

The sender-medium-receiver concept has actually been with us for a very long time. For example, shouting to another person does in fact involve voice transmission over a distance via the medium air which carries the sound wave. Needless to say, the use of telephone lines as a transmission medium considerably enhances the possible distance. Like telephone lines, there are several types of physical channels (communication media) through which data can be transmitted from one point to another. Some of the most common data transmission medium are briefly described here.

WIRE PAIRS

Wire pairs are commonly used in local telephone communication and short distance (upto about 1 km) digital data transmission. They are usually made of copper and a pair of wires are twisted together (Figure 16.3) to reduce interference by adjacent wires.

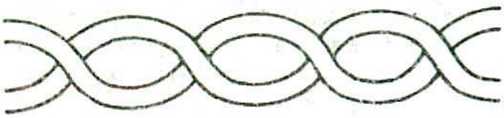


Figure 16.3. A wire pair.

Wire pairs are normally used to connect terminals to the main computer if they are placed at a short distance from the main computer. Data transmission speed of upto 9600 bits per second (or 9600 baud) can be achieved if the distance is not more than 100 meters. H/ vever, for longer distance, local telephone lines are used. In this case, typical speed of digital signal transmission is 1200 bits per second.

Wire pairs are an inexpensive medium of data transmission. They are easy to install and use. However, their use is limited because they easily pick up noise signals which results in high error rates when the line length extends beyond 100 meters.

COAXIAL CABLE

Coaxial cables are groups of specially wrapped and insulated wire lines that are able to transmit data at high rates. As shown in Figure 16.4, they consist of a central copper wire surrounded by a PVC insulation over which a sleeve of copper mesh is placed. The metal sleeve is again sheilded by an outer shield of thick PVC material. The signal is transmitted by the inner copper wire and is electrically shielded by the outer metal sleeve.

Coaxial cables offer much higher bandwidths and are capable of transmitting digital signals at very high rates of 10 mega bits per second. They are extensively used in long distance telephone lines and as cables for closed circuit TV. They are also used by telephone companies to transmit data. In many cases, coaxial cables are packaged into a very large cable that can handle over 15,000 telephone calls simultaneously. Furthermore, coaxial cables have much higher noise immunity and can offer cleaner and crisper data transmission without distortion or loss of signal.

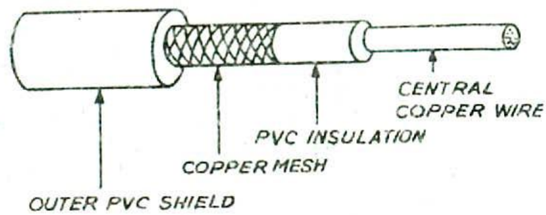


Figure 16.4. A coaxial cable.

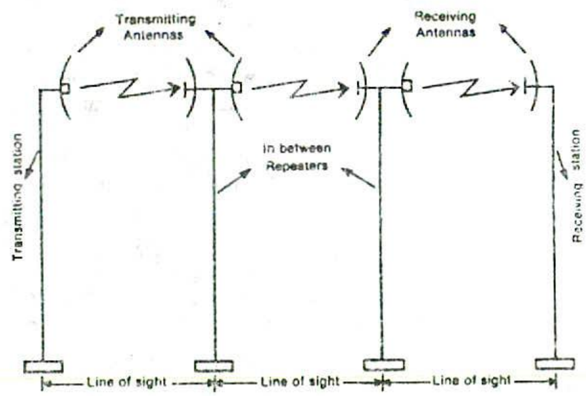


Figure 16.5. Illustrating microwave communication from one point to another.

MICROWAVE SYSTEM

Another popular transmission media is microwave. This is a popular way of transmitting data since it does not incur the expense of laying cables. Microwave systems use very high frequency radio signals to transmit data through space. However, at microwave frequencies the electromagnetic waves cannot bend or pass obstacles like hill. Hence it is necessary that microwave transmission is in a line-of-sight. In other words, the transmitter and receiver of a microwave system, which are mounted on very high towers, should be in a line-of-sight. This may not be possible for very long distance transmission. Moreover, the signals become weaker after travelling a certain distance and require power amplification.

In order to overcome the problem of line-of-sight and power amplification of weak signals, microwave systems use repeaters at intervals of about 25 to 30 kms inbetween the transmitting and receiving stations (see Figure 16.5). The first repeater is placed in line-of-sight of the transmitting station and the last repeater is placed in line-of-sight of the receiving station. Two consecutive repeaters are also placed in line-of-sight of each other. The data signals are received, amplified, and retransmitted by each of these stations.

Microwave systems permit data transmission rates of about 16 Giga (1 Giga = 10^9) bits per second. Furthermore it can carry literally thousands of voice channels at the same time. The link can support 250,000 voice channels. However, the capital investment needed to install microwave links is very high and hence they are mostly used to link big metropolitan cities with heavy telephone traffic between them.

COMMUNICATIONS SATELLITE

The main problem with microwave communication is that the curvature of the earth, mountains, and other structures often block the line-of-sight. Due to this reason, several repeater stations are normally required for long distance transmission which increases the cost of data transmission between two points. This problem is overcome by using satellites which are relatively newer and more promising data transmission media.

A communication satellite is basically a microwave relay station placed in outer space. These satellites are launched either by rockets or by space shuttles and are precisely positioned 36000 kms above the equator with an orbit speed that exactly matches the earth's rotation speed. Since a satellite is positioned in a geosynchronous orbit, it is stationary relative to earth and always stays over the same point on the ground. This allows a ground station to aim its antenna at a fixed point in the sky. Dozens of satellites are now in orbit to handle international and domestic data, voice, and video communications needs. The Indian satellite, INSAT-1B, is positioned in such a way that it is accessible from any place in India.

As shown in Figure 16.6, in satellite communication, microwave signal at 6 GHz (read as gigahertz = 10^9 Hz) is transmitted from a transmitter on earth to the satellite positioned in space. By the time this signal reaches the satellite it becomes weak due to 36000 kms travel. The satellite amplifies the weak signal and transmits it back to the earth at a frequency of 4 GHz. This signal is received at a receiving station on the earth. It may be noted that the retransmission frequency is different from the transmission frequency in order to avoid the interference of the powerful retransmission signal with the weak incoming signal.

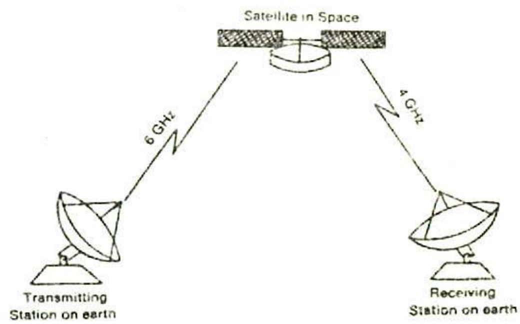


Figure 16.6. Illustrating satellite communication from one point to another.

The main advantage of satellite communication is that it is a single microwave relay station visible from any point of a very-very large area. For example, satellites used for national transmission are visible from any part of the country. Thus transmission and reception can be between any two randomly chosen places in that area. Moreover, transmission and reception costs are independent of the distance between two points. In addition to this, a transmitting station can receive back its own transmission and check whether the satellite has transmitted the information correctly. If an error is detected, the data would be retransmitted. However, a major drawback of satellite communications has been the high cost of placing the satellite into its orbit. Moreover, a signal sent to a satellite is broadcast to all receivers within the satellite's range. Hence necessary security measures are to be taken to prevent unauthorised tampering of information.

OPTICAL FIBERS

A potential cost-effective earth alternative to satellite communications for the future will be the use of optical fibers. The Bell System of U.S.A. has tested small half-inch-diameter cables that could transmit as many as 50,000 voice messages simultaneously by means of advanced optical techniques based upon laser technology.

In fiber optics, semiconductor lasers transmit information in the form of light along hair-thin glass (optical) fibers at 186,000 miles per second (the speed of light), with no significant loss of intensity over very long distances. As shown in Figure 16.7, the system basically consists of fiber optic cables that are made of tiny threads of glass or plastic. Towards its source side is a converter that converts electrical signals into light waves. These light waves are transmitted over the fiber. Another converter placed near the sink converts the light waves back to electrical signals by photoelectric diodes. These electrical signals are amplified and sent to the receiver.

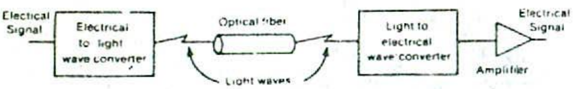


Figure 16.7. Illustrating transmission through optical fiber.

Some of the interesting features of optical fibers are :

(i) They provide high quality (low error rate) transmission of signals at very high speeds. Digital transmission speeds of 1 giga bits per second have been used with error less than 1 in 10^9 bits. Some transmissions that take about an hour over copper wires can actually be sent through optical fibers in under one second.

(ii) A normal fiber in a glass fiber cable is about the size of a human hair. In some large cities, there simply is no room for additional bulky copper wires. The conduits used to house the copper wires are typically of a fixed size, and replacing existing conduits for more copper wires would be too expensive. In this case, the use of smaller fiber optical data communications systems is very effective.

(iii) Optional fibers may be used to communicate either analog or digital signals. In analog transmission, the light intensity is varied continuously whereas in digital transmission the light source is turned on or off.

(iv) Fiber optic transmission are not affected by electromagnetic interference. Hence noise and distortion are also reduced with fiber optics.

(v) Optical fibers are most commonly used for point-to-point one way communications link because it is extremely difficult and expensive to tap a fiber optic cable at various points. This feature also provides security against unauthorised tampering of information.

While experts agree that the fiber optic transmission will be widely used in the future, there are still some technical difficulties to overcome. For instance, optical fibers do not currently allow complete switching or routing of light signals. As a result, at switching points, optical signals must be converted into electrical signals for routing and then back into light for further optical transmission. Despite such glitches, however, fiber-optic transmission systems are already on the market, and their popularity is growing rapidly.

DIGITAL AND ANALOG TRANSMISSION

Data is propagated from one point to another by means of electrical signals which may be in digital or analog form. As shown in Figure 16.8(a), in an analog signal the transmitted power varies over a continuous range, for example sound, light and radio waves. The amplitude (v) of analog signals is measured in volts and its frequency (f) in hertz (Hz). The higher is the frequency of the signal, the more number of times it crosses the time axis. However, a digital signal is a sequence of voltage pulses represented in binary form (see Figure 16.8(b)).

Computer generated data is digital whereas the telephone lines used for data communication in computer networks are usually meant for carrying analog signals. When digital data are to be sent over an analog facility, the digital signals must be converted to analog form. The technique by which a digital signal is converted to its analog form is known as *modulation*. The reverse process, that is the conversion of analog signal to its digital form, at a destination device, is called *demodulation*.

Modulation is most often used for superimposing digital data on analog waves. There are three forms of modulation which are discussed below.

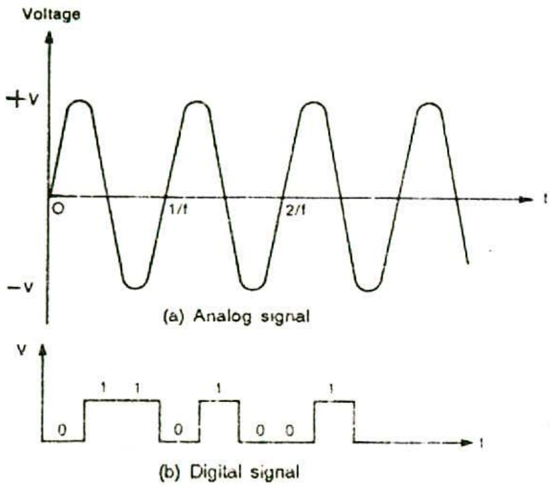


Figure 16.8. Analog and digital signals.

AMPLITUDE MODULATION (AM)

Two binary values (0 and 1) of digital data are represented by two different amplitudes of the carrier signal keeping the frequency and phase constant. On voice grade lines, it is used upto 1200 bits per second. However, amplitude modulated signals are sensitive to impulse noises that arise due to electrical sparks near the transmission line.

FREQUENCY MODULATION (FM)

Two binary values of digital data are represented by two different frequencies while the amplitude and phase are kept constant. Frequency modulation of digital signal is also known as *frequency shift keying* (FSK). It is less susceptible to error than amplitude modulation. Moreover, frequency modulation devices are easier to design because discrimination between two frequencies is simpler than detecting phase changes. Thus for medium speed communications (1200 to 2400 bits per second) the FSK scheme is preferred.

PHASE MODULATION (PM)

Two binary values of digital data are represented by the shift in phase of the carrier signal. That is, a sine wave with phase = 0^0 represents a digital 1 and a sine wave with phase = 180^0 represents a digital 0. This technique is more noise resistant and efficient than both amplitude modulation and frequency modulation. For higher speed transmission of 9600 bits per second, phase modulation is more reliable and is preferred to other methods.

The process of modulation and demodulation, that is, the conversion of digital data to analog form and vice-versa, is carried out by a special device called a *modem* (*mo*dulator/*dem*odulator). Hence, when an analog facility is used for data communication between two digital devices (say a terminal and a computer), two modems are required, one near each digital device. As shown in Figure 16.9, the digital signal generated at the terminal is converted to analog form by the modulator of the modem placed near it. The analog signal is transmitted through the telephone line which is converted to digital form by the demodulator of the modem placed near the computer. This digital data is processed by the computer. The processed digital information is modulated to analog form and returned via the telephone line to the terminal where the analog signals are demodulated to digital form for display on the terminal.

There are two main reasons for using modems. They allow higher speeds of transmission on a given analog line, and they reduce the effects of noise and distortion. Modems can do a lot more than simply transport data across telephone lines. A good modem can also perform tests and checks on how it is operating. Some modems are able to vary their transmission rate, commonly measured in baud. While the typical baud rate is 300, some modems can transmit at 1200 baud or even 9600 baud. Some of the more expensive modems actually contain microprocessors that allow them to operate and function under a large number of different circumstances. These modems are called *smart modems*.

A large number of portable terminals are now being used by salespersons, managers, engineers, and others to communicate with distant CPU's. A special type of modem called an *acoustic coupler* is used in these situations to provide the necessary interface. The acoustic coupler is attached (or built into) a portable terminal, and a standard telephone handset is then usually placed in rubber cups located on the coupler. The digital pulses produced by the terminal are converted into audible tones that are picked up by the handset receiver. The signals from these tones are sent to the CPU location where another modem converts them back to digital pulses.

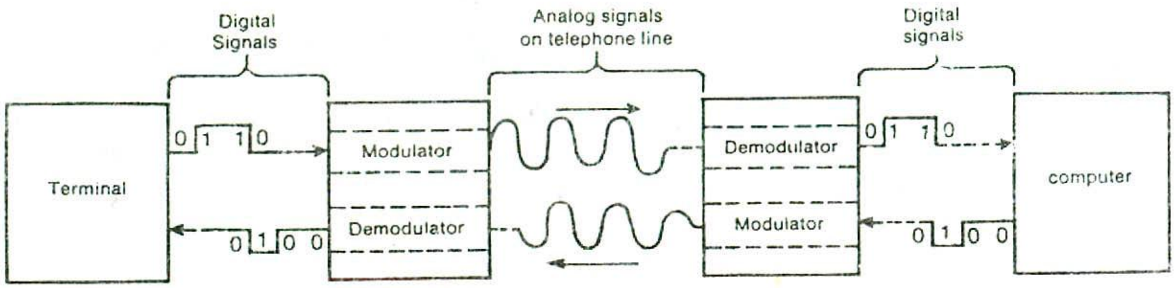


Figure 16.9. Illustrating the use of modems in data communications.

If data is sent over long distances, the analog signal can become weak and distorted. To avoid this, *amplifiers* are used. A communications amplifier is similar to the amplifier used in a home stereo system - it strengthens or amplifies a weak signal. Amplifiers are typically placed along communications lines between modems. Today, signals are also sent in digital mode. In this case modems are not needed. When digital mode of transmission is used over long distances, a ***repeater*** is used to receive and then transmit the signal. Like an amplifier, the purpose of a *repeater* is to strengthen a weak digital signal over long distances.

Digital transmission of digital data is more reliable than analog transmission of digital data. However, digital transmission facilities are currently available only to a limited extent. For example, digital signalling is impossible for satellite and whenever feasible the communication systems are converting to digital. The advantages of digital over analog for data transmission are :

1. Lower cost
2. No modems required
3. Higher transmission speeds possible
4. Lower error rate

It is expected that the years ahead will see ever-increasing digital transmission capabilities.

COMMUNICATIONS PROCESSORS

In a data communications network, the task of network designers is to select and coordinate the network components so that the necessary data are moved to the right place, at the right time, with a minimum of errors, and at the lowest possible cost. A number of communications processors (typical micro - or minicomputers) are used by network designers to achieve their goals. The functions of some of the commonly used communications processors are briefly described here.

MULTIPLEXERS

There are many applications in which several terminals are connected to a computer. If each terminal is operating at 300 bits per second over a communications line (channel) that can operate at 9600 bits per second, then we see a very inefficient operation. It has been found that the capacity of a channel exceeds that required for a single signal. A channel is an expensive resource. Hence, for its optimal utilisation, the channel can be shared in such a way so as to simultaneously transmit multiple signals over it. The method of dividing a physical channel into many logical channels so that a number of independent signals may be simultaneously transmitted on it is known as multiplexing. The electronic device that performs this task is known as a multiplexer.

A multiplexer takes several data communications lines or signals and converts them into one data communications line or signal at the sending location. For example, as shown in Figure 16.10, there may be 4 terminals connected to a multiplexer. The multiplexer takes the signals from the 4 terminals and converts them into 1 large signal which can be transmitted over 1 communications line. Then, at the receiving location, a multiplexer takes the 1 large signal and breaks it into the original 4 signals. Without multiplexers, you would have to have 4 separate communications lines.

Thus, with multiplexing it is possible for a single transmission medium to concurrently transmit data between several transmitters and receivers. There are two basic methods of multiplexing channels. They are frequency division multiplexing and time division multiplexing

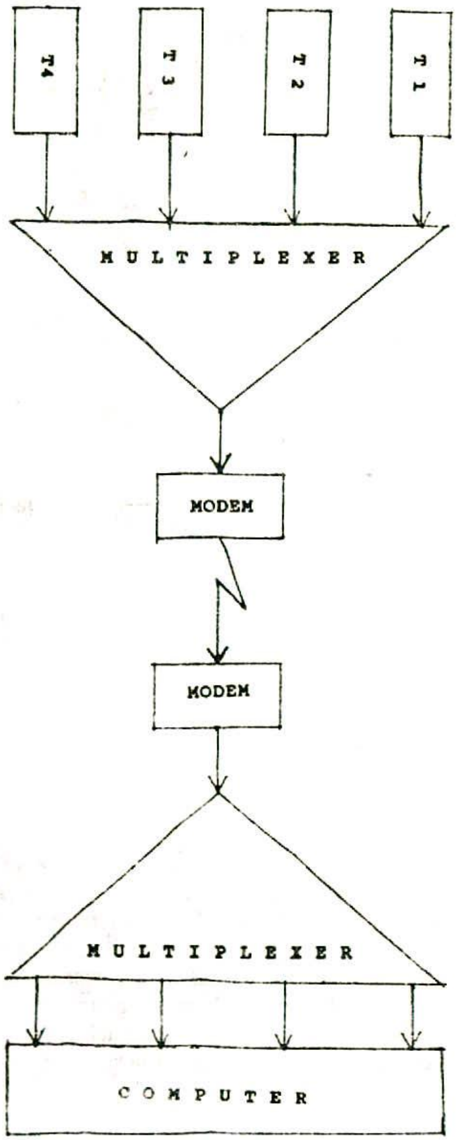


Figure 16.10. A multiplexed system.

1. *Frequency Division Multiplexing (FDM).* The bandwidth or range of a medium exceeds that of any given signal. This fact is utilised for frequency division multiplexing. In FDM, the available bandwidh of a physical medium is split up (divided) into several smaller, disjoint logical bandwidths. Each of the component bandwiths is used as a separate communications line (channel). Figure 16.11 illustrates the process of FDM.
   The best example of FDM is the way we receive various stations in a radio. Each radio station is assigned a frequency range within a bandwidth of radio frequencies. Several radio stations may be transmitting speech signals simultaneously over the physical channel which is "ether" in this case. A radio receiver's antenna receives signals transmitted by all the stations. Finally, the tuning dial in the radio is used to isolate the speech signal of the station tuned. In FDM, the signals to be transmitted must be analog signals. Thus, digital signals must be converted to analog form if they are to use FDM.

2. *Time Division Multiplexing (TDM).* The bit rate of a transmission medium always exceeds the required rate of the digital signal. This fact is utilised for time division multiplexing. In TDM, the total time available in the channel is divided between several users and each user of the channel is allotted a time slice (a small time interval) during which he may transmit a message. The channel capacity is fully utilised in TDM by interleaving a number of data streams belonging to different users into one data stream. Streams of data sent through the physical channel must be demultiplexed at the receiving end. Individual chunks of message sent by each user is reassembled into a full message at the receiving end. The process of TDM is illustrated in Figure 16.12 for multiplexing three different signals. The same idea may be extended for multiplexing several signals.

   TDM may be used to multiplex digital or analog signals. For communications of digital data, it is more convenient to transmit data directly in digital form and thus TDM is more appropriate. Moreover, communication between computers occurs in short fast bursts. Each burst would thus need the full channel bandwidth which is available to a signal in TDM. Besides this, TDM is generally more efficient as more subchannels can be derived because it is upto the network

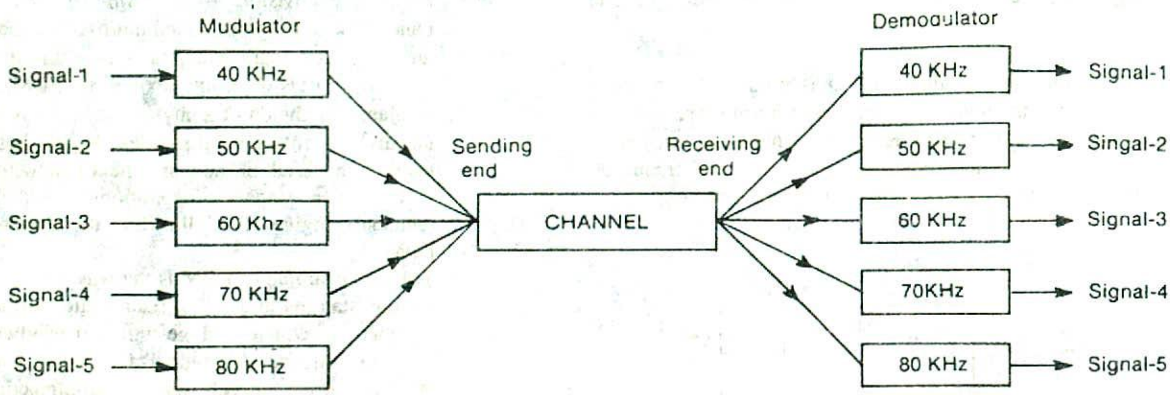


Figure 16.11. Illustrating frequency division multiplexing.

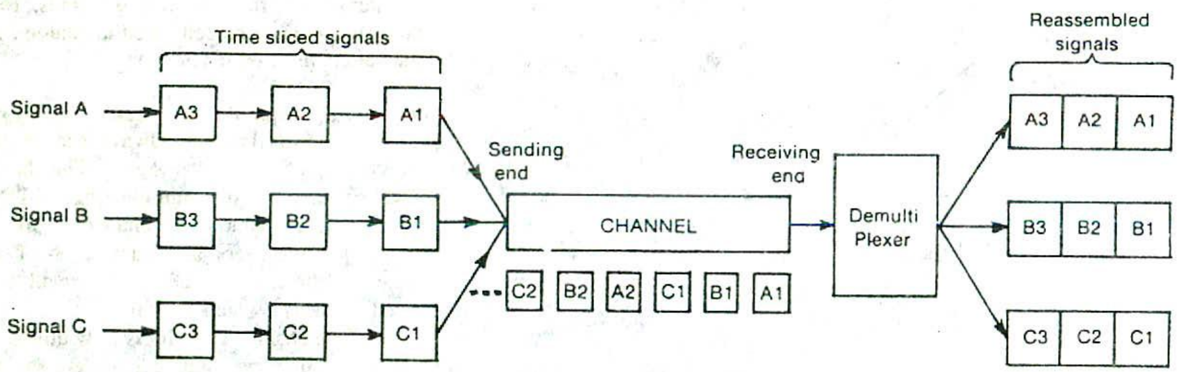


Figure 16.12. Illustrating time division multiplexing.

designers to allocate time slots to different channels. It is common to have 32 low speed terminals connected to one high speed line.

Whether or not to use multiplexing usually depends upon economics. The cost of high-speed modems and multiplexers is very high compared to the cost of low-speed modems. However, if line costs are high due to long distances, then multiplexing is cost effective. One serious disadvantage with multiplexing relates to a transmission line failure. If the line goes out, everything is dead. With individual lines only one terminal is likely to be lost.

CONCENTRATORS

A concentrator performs the same function as a multiplexer, but concentrators have the ability to actually reduce the number of signals. For example, 100 signals from different devices coming into the concentrator could leave as only 70 or 80. The signals are concentrated to form a fewer number of signals. This requires intelligence. This intelligence normally takes the form of microprocessors or even minicomputers. Thus, a concentrator is basically an intelligent multiplexer.

The advantage of using a concentrator is that devices of varying speeds and types are connected to the concentrator which in turn is connected to the host computer by high speed lines. Concentrators are especially useful where data communications cost are high, such as long-distance international communications. In general, concentrators are more expensive than multiplexers. For some long-distance and international data communications applications, however, the use of concentrators is cost justified.

FRONT END PROCESSORS (FEP)

If information is to be moved from point to point in a computer network, then some type of control is necessary. Network processing (also known as communications processing) is the control of information movement between the

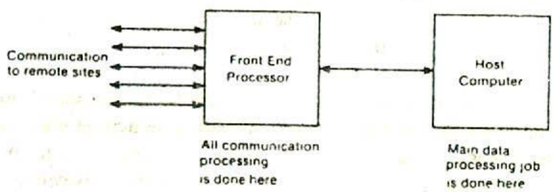


Figure 16.13. Illustrating the use of a front end processor.

various locations of the network. This is a substantial task.

In the early network days, the communications processing job was handled by the main computer. This began to place heavy additional loads on the CPU. Thus, the ability of the computer to do information processing, that is, the job for which it was intended, was seriously degraded. As a result, manufacturers introduced the front end processor. This is a separate CPU designed specifically to handle the network processing task (see Figure 16.13).

A front end processor is usually installed in the same location as the host computer. Its primary purpose is to off-load communications processing task from the host computer, thereby the host computer can be dedicated for applications and data processing jobs. It virtually acts like an intelligent terminal or like a secretary/receptionist to the main processor.

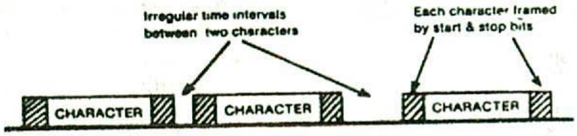
ASYNCHRONOUS AND SYNCHRONOUS TRANSMISSION

Data transmission on a line is normally carried out in two different modes : asynchronous and synchronous. *Asynchronous* transmission is often referred to as *start-stop* transmission because of its nature, that is, the sender can send a character at any time convenient and the receiver will accept it. This is the characteristic of many terminals. When a terminal is connected to a computer and an operator manually pressess keys on the terminal, the time spent between successive keystrokes would vary. Thus in asynchronous transmission, data is transmitted character by character at irregular intervals

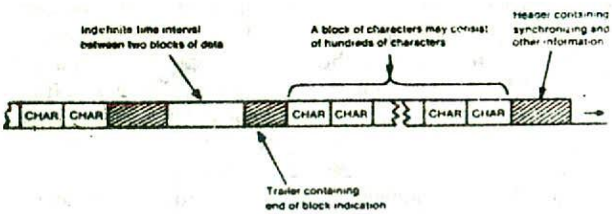
In order to enable the receiver to recognize a character when it arrives, the transmitter "frames" each character. Preceding the character is a *start bit* and following the character will be one or two (depending upon the system) *stop bits*. Thus for the 7-bit ASCII code, for each character the transmitter transmits the seven character bits, one parity bit, one start bit, and one or two stop bits for a total of either 10 or 11 bits. The concept of the character framed by start-stop bits is illustrated in Figure 16.14(a). Note that as each character is "framed" by a distinct start signal and a stop signal, the time taken between transmitting any two characters can be any length or none at all. Thus the computer might send a continuous stream of data to the terminal.

Asynchronous transmission is well suited to many keyboard type terminals and paper tape devices. The advantage of this method is that it does not require any local storage at the terminal or the computer as transmission takes place character by character. Hence it is cheaper to implement. The main disadvantage of asynchronous transmission is that the transmission line is idle during the time intervals between transmitting characters. If the lines are short, this is not bad because line cost would be low and idle time not expensive. Even though less efficient than synchronous transmission, it is also used with devices such as card readers and printers simply to reduce cost.

Synchronous mode of data transmission involves blocking a group of characters in somewhat the same way records are blocked on magnetic tape. Each block is then framed by header and trailer information. The header consists of synchronizing information which is used by the receiving device to set its clock in synchronism with the sending end clock. The header also contains information to identify sender and receiver. Following the header is a block of characters that contains the actual message to be transmitted (see Figure 16.14). The number of characters in a block may be variable and may consist of hundreds of characters. The message characters in the block are terminated by a trailer. The trailer contains an end of message character followed by a check character to aid detection of any transmission error. Thus with synchronous transmission entire blocks of characters are framed and transmitted together.



(a) Asynchronous transmission



(b) Synchronous transmission

Figure 16.14. Modes of data transmission.

Synchronous transmission is well suited to remote communication between a computer and such devices as buffered card readers and printers. Here the logical data block length would be 80 or 132 characters. It is also used with buffered terminals and for computer to computer communication.

The primary advantage of synchronous transmission is its efficiency. Not only does it eliminate the need for individual start-stop bits on each character, but much higher data rates can be used than with asynchronous transmission. The period between blocks is kept small and the block itself is sent at nearly the maximum line speed. This ensures efficient utilisation of the transmission line. The main disadvantage is the need for local buffer storage at the two ends of the line to assemble blocks and also the need for accurately synchronized clocks at both ends. As a result synchronous equipment usually costs more.

SWITCHING TECHNIQUES

In its simplest form, data communication takes place between two devices that are directly connected by some form of transmission medium - twisted wires, coaxial cables, microwave and satellite links. Often however, it is impractical or uneconomical for two devices to be directly connected. Instead, communication is achieved by transmitting data from source to destination through a network of intermediate nodes. These nodes provide a switching facility that moves data from node to node until the destination is reached. There are three different methods of establishing communication links between data sources and receivers in a communication network. These are: circuit switching, message switching and packet switching.

CIRCUIT SWITCHING

It is the simplest method of data communication in which a dedicated physical path is established between the sending and the receiving stations through the nodes of the network. This method is used to connect two subscribers in a telephone. Network computers and terminals connected to a telephone network also use this method of establishing communication path among them.

The method of circuit switching is illustrated in Figure 16.15. Each rectangle represents a switching node of the communication network. When a message is to be communicated, a physical path is established between the sending station and the receiving station by physically connecting the incoming and outgoing line of each of the intermediate switching nodes that fall on the path. Once a circuit is established between the two stations, it is exclusively used by the two parties and the dedicated physical link between both ends continues to exist until the call is terminated either by the sender or the receiver. As soon as the connection is terminated by one of the two stations, the dedicated resources are deallocated and can now be used by other stations also.

Thus circuit switching involves three phases - circuit establishment, data transfer and circuit disconnection.

Advantages

1. The main advantage of circuit switching is that once the circuit is established, data is transmitted with no delay other than the propagation delay which is negligible (typically of the order of 6msec. per 1000 km).

2. It is suitable for low speed communication between

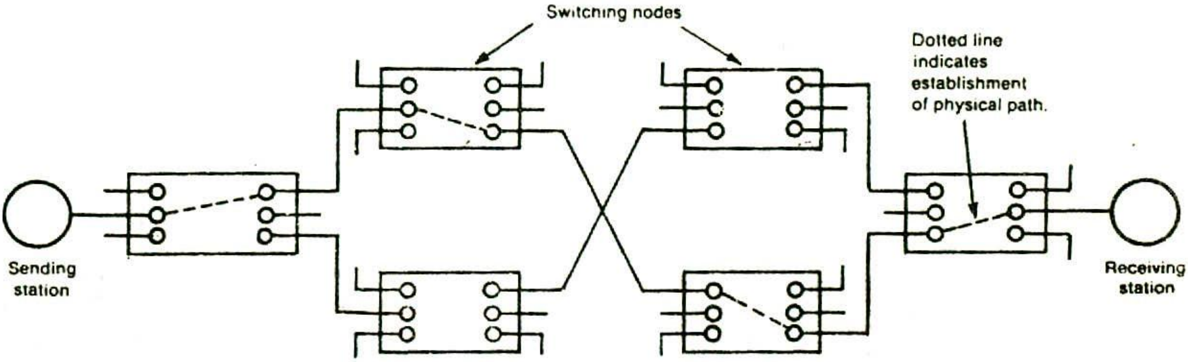


Figure 16.15. Illustrating the method of circuit switching.

a terminal and a computer because the method is simple and requires no special facilities.

3. Since a dedicated continuous transmission path is established, the method is suitable for long continuous transmission.

Disadvantages

1. Prior to actual data transfer, the time required to establish a physical link between the two stations is of the order of 10 secs or more depending on the distance. For many computer applications e.g. point of sale verification, this elapse time is too large and unsuitable because communication among computers occur in bursts for short period with long silent period in between, during which the communication line is not used.

2. Since the physical link is a dedicated one, the channel capacity is dedicated to one source for the entire duration of a connection. Hence the network resources are not properly utilised.

3. The method proves to be very uneconomical when used for communication between computers that are connected using expensive high speed transmission lines.

MESSAGE SWITCHING

A message is a logical unit of information and can be of any length. In this method, if a station wishes to send a message to another station, it first appends the destination address to the message. After this, the message is transmitted from the source to the destination either by store-and-forward method or broadcast method.

As shown in Figure 16.16, in the store-and-forward method, the message is transmitted from the source node to an intermediate node. The intermediate node stores the complete message temporarily, inspects it for errors, and transmits the message to the next node based on an available free channel and its routing information. The actual path taken by the message to its destination is dynamic as the path is established as it travels along. When the message reaches a node, the channel on which it came is released for use by another message. In Figure 16.16, if a message is to be transmitted from station A to station B, it may take either path 1-2-3-4 or 1-5-4 depending on the availability of a free output path at that particular moment.

As shown in Figure 16.17, in the *broadcast* method, the message is broadcasted over a common medium known as broadcast channel. All the stations check the destination address of each message as they pass by and accept only those addressed to them. The routing delays inherent in store and forward method are eliminated in this method. However, this method requires that all stations must be connected to the broadcast channel.

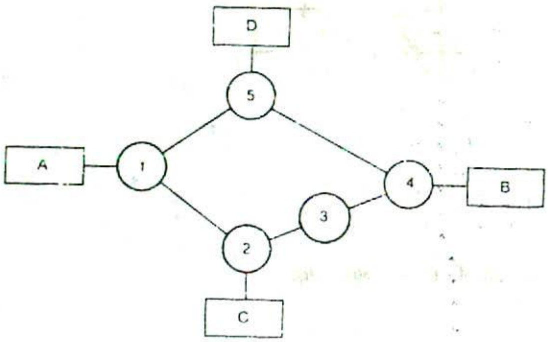


Figure 16.16. Illustrating store-and-forward method of message switching.

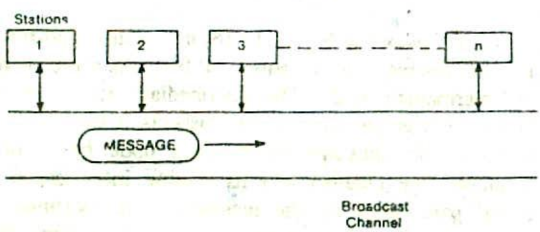


Figure 16.17. Illustrating broadcast method of message switching.

Advantages

1. In message switching, no physical connection is required between the source and the destination as it is in circuit switching.

2. As channels are used only when messages are transmitted, this method uses the channels very effectively.

Disadvantages

1. As the message length is unlimited, each switching node must have sufficient storage to buffer messages. In many cases this storage space may be under-utilised.

2. In message switching, a message is delayed at each node for the time required to receive the message plus a queuing delay waiting for an opportunity to retransmit the message to the next node.

3. The method is too slow for interactive/real time applications. Hence it is used when message delays are not critical.

PACKET SWITCHING

This method works in a similar fashion as message switching. However, it overcomes the disadvantages of message switching technique because in this method routing is done on 'packet' basis and not on 'message' basis.

A message is split up into 'packets' of a fixed size (of the order of one or few thousand bits). Besides the block of data (part of a message) to be sent, a packet has a header that contains destination and source addresses, control information, message number, number of current and last packet, synchronisation bits, acknowledgement and error checking bytes, etc. Like message switching, the packets may be routed from the sender node to the destination node either by store-and-forward method or by broadcast method. In the store-and-forward method, the packets are stored temporarily at the intermediate nodes for error recovery purposes and is routed to next node based on an available free channel. The actual path taken by the packet to its destination is dynamic as the path is established as it travels along. Thus it is possible that different packets of the same message can be routed across different paths leading to the same destination depending upon line availability and congestion.

Advantages

1. Unlike messages, packets are of small and fixed size. Hence the storage requirement for buffering the packets at intermediate nodes is minimal.

2. Since the routing is done on packet basis, the intermediate nodes do not have to wait for the entire message, hence the transmission in very fast.

3. The method is fast enough for interactive/real time applications. It is thus most suitable for "bursty" computer to computer communication and is widely used in long haul networks.

NETWORK TOPOLOGIES

A network is a logical extension of a data communications system. In a computer network, two or more processors or computers are linked together with carriers and data communications devices for the purpose of communicating data and sharing resources. The term '*topology*', in the context of a communications network, refers to the way in which the end points or stations of a network are linked together. It determines the data paths that may be used between any pair of stations of the network. Although the number of possible network configurations is seemingly limitless, there are three major network configurations. They are the star network, the ring network, and the completely connected network.

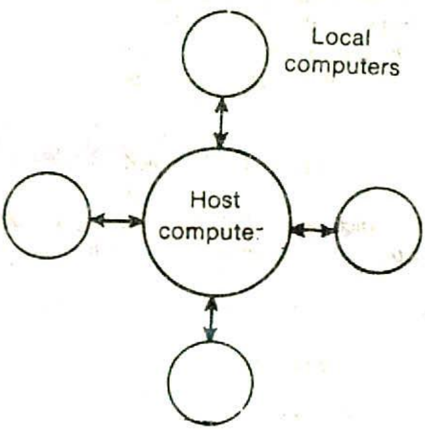


Figure 16.18. A star configuration of computer network.

STAR NETWORK

In a star configuration of computer network, there is a host computer which is attached to local computers through multiple communication lines. As shown in Figure 16.18, the local computers are not linked directly to each other and can communicate only via the host computer. The routing function is performed by the host computer which centrally controls communication between any two local computers by establishing a logical path between them.

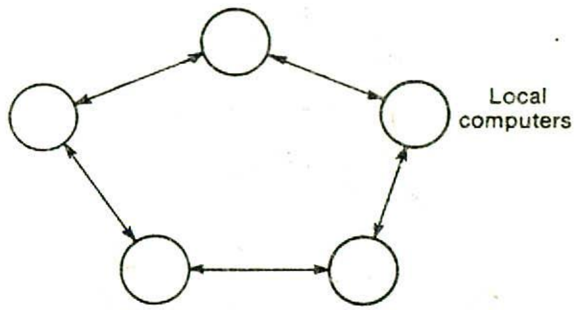


Figure 16.19. A ring configuration of computer network.

Advantages

1. Star topology has minimal line cost because only n-1 lines are required for connecting n nodes.

2. Transmission delays between two nodes do not increase by adding new nodes to the network because any two nodes may be connected via two links only.

3. If any of the local computers fail, the remaining portion of the network is unaffected.

Disadvantage

1. The system crucially depends on the central node. If the host computer fails, the entire network fails.

RING NETWORK

This configuration is a no-host or ring arrangement of communicating equals. That is, there is no main or controlling computer in the network. Figure 16.19

illustrates the circular or ring arrangement of a computer network. Each ring processor has communicating subordinates, but within the ring there is no master computer for controlling other computers.

Thus each node of a ring network must have simple communication capability. A node receives data from one of its two adjacent nodes. The only decision a node has to take is whether the data is for its use or not. If it is addressed to it, it utilises it. Otherwise it merely passes it on to the next node.

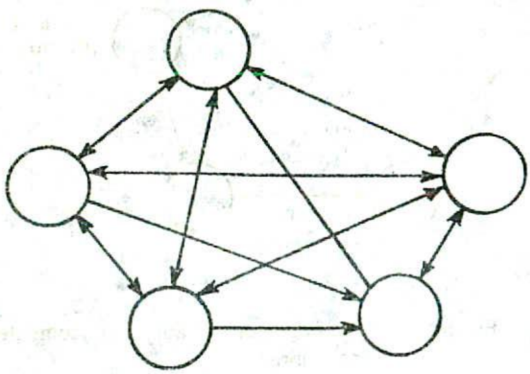


Figure 16.20. A completely connected computer network.

Advantages

1. The ring network works well where there is no central-site computer system. It is a truly distributed data processing system.

2. It is more reliable than a star network because communication is not dependent on a single host computer. If one line between any two computers breaks down, or if one of the computers breaks down, alternate routing is possible.

Disadvantages

1. In a ring network, communication delay is directly proportional to the number of nodes in the network. Hence addition of new nodes in the network increases the communication delays.

2. The ring network is not as popular as star network because of its more complicated control software.

COMPLETELY CONNECTED NETWORK

As shown in Figure 16.20, a completely connected network has a separate physical link for connecting each node to any other node. Thus, each computer of such network has a direct dedicated link, called a point-to-point link with all other computers of the network. The control is distributed with each computer deciding its communication priorities.

Advantages

1. This type of network is very reliable as any line breakdown will affect only communication between the connected computers.

2. Each node of the network need not have individual routing capability.

3. Communication is very fast between any two nodes.

Disadvantage

1. It is the most expensive system from the point of view of line costs. If there are n nodes in the network, then $n(n-1)/2$ links are required. Thus the cost of linking the system grows with the square of the number of nodes.

HYBRID NETWORK

The choice of topology for installing a computer network depends upon a combination of factors such as :

1. reliability of the entire system

2. expandability of the system

3. cost involved

4. availability of communication lines

5. delays involved in routing information from one node to another.

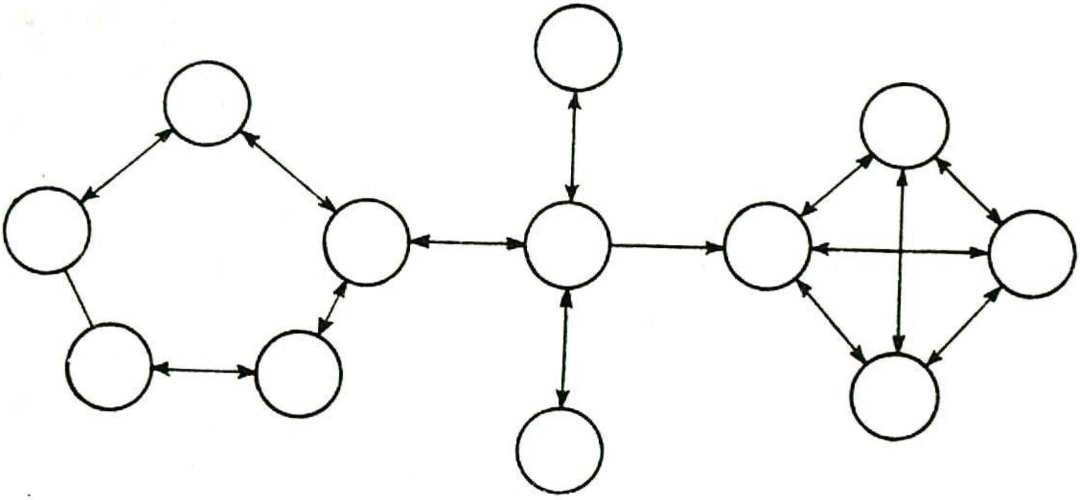


Figure 16.21.

A typical hybrid network having a combination of ring, star, and completely connected network configurations.

Different network configurations have their own advantages and limitations. Hence in reality, a pure star or ring or completely connected network is rarely used. Instead, an organisation will use some sort of hybrid network, which is simply a combination network. The exact shape or configuration of the network depends on the needs and the overall organisational structure of the company involved. In some cases, the hybrid network may have components of star, ring, and completely connected networks. A typical hybrid network of this type is shown in figure 16.21.

MULTIPOINT NETWORK

There is yet another method of linking computers together in a network. In this method, a single transmission medium is shared by all nodes. As shown in Figure 16.22, all the computers are attached to the same line. When a particular computer wants to send a message to another computer, it appends the destination address to the message and checks whether the communication line is free. As soon as the line becomes free, it broadcasts (places) the message on the line. As the message travels on the line, each computer checks whether it is addressed to it. The message is picked up by the addressee computer which sends an acknowledgement to the source computer and frees the line. This method is known as 'multipoint' or 'multidrop' linkage of computers. It is also known as a 'broadcasting' network. This method is appropriate for use in

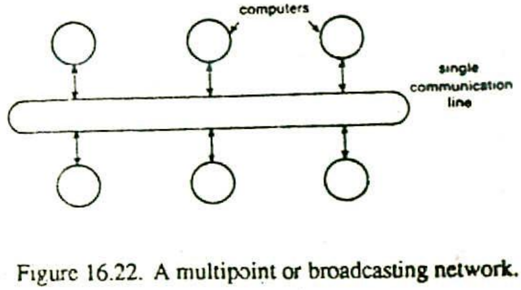


Figure 16.22. A multipoint or broadcasting network.

a local area network where a high speed communication channel is used and computers are confined to a small area. It is also appropriate when satellite communication is used as one satellite channel may be shared by many computers at a number of geographical locations.

Advantages

1. The main advantage of a broadcasting network is the reduction in physical lines.

2. The reliability of network is high because the failure of a computer in the network does not effect the network functioning for other computers.

3. Addition of new computers to the network is easy.

Disadvantages

1. Each computer connected to the line must have good communication and decision making capability.

2. If the communication line fails, the entire system breaks down.

LOCAL AREA NETWORK AND WIDE AREA NETWORK

A *local area network* (LAN) is a digital communication system capable of interconnecting a large number of computers, terminals and other peripheral devices within a limited geographical area, typically under 1 Km across. LANs normally operate within a compact area such as an office building or a campus and is owned by the using organisation. The configuration of a LAN can be a star, a ring, or simply devices attached along a length of cable. In LAN, transmission channels generally use coaxial or fiber optic cables and special interface units rather than telephone lines and modems. Thus the transmission speed is very high. The attached computers may be of different types and be performing a variety of functions such as data processing, word processing, and electronic mail. The two main purposes of the local area network are to link computers within an organisation or campus so that they may share expensive peripheral devices, for example high speed printers or magnetic disks holding the data base, and to allow these computers to communicate with each other.

Ethernet, developed by Xerox Corporation, is a famous example of a LAN. This network uses a coaxial cable for data transmission. Special integrated circuit chips called controllers are used to connect equipment to the cable, and small boxes called transceivers transmit and receive cable data at each station. Each station can exchange data with any other station or group of stations. This particular LAN can tie together Xerox computer systems, copiers, and other devices. Furthermore, devices made by other computer manufacturers can also be made compatible with Ethernet.

Omninet, developed by Corvus systems, is another example of a LAN. This particular network has the ability to interconnect microcomputer systems. Radio Shack, Apple, and other microcomputer systems can be interconnected using Omninet.

A *wide area network* (WAN) is a digital communication system which interconnects different sites, computer installations and user terminals, and may also enable LANs to communicate with each other. This type of communication network may be developed to operate nationwide or worldwide. In a WAN, the transmission medium used are normally public systems such as telephone lines, microwave and satellite links. Packet switching is most effective as public connection services are available for packet switched WANs. A WAN is also known as a *long haul network*.

The *ARPANET* of the Advanced Research Projects Agency of the U.S. Department of Defense is an example of WAN. This network connects about 40 universities and research institutions throughout the United States and Europe with about 50 computers ranging in size from minis to supercomputers. Another example of a WAN is the *INDONET* which is being planned by the Computer Maintenance Corporation, India. It links three IBM/4361 systems one each at Bombay, Calcutta and Madras and a PDP 11/44 system at Delhi. It is a network of large computer centres to give nationwide access and processing facilities.

Differences Between LAN & WAN

1. A LAN is restricted to a limited geographical coverage of a few kilometers, but a WAN spans greater distances and may operate nationwide or even worldwide.

2. The cost to transmit data in a LAN is negligible since the transmission medium is usually owned by the user organisation. However, in case of a WAN, this cost may be very high because the transmission medium used are leased lines or

public systems such as telephone lines, microwave and satellite links.

3. In a LAN, the computers, terminals and peripheral devices are usually physically connected with wires and coaxial cables. Whereas, in a WAN there may not be a direct physical connection between various computers.

4. Data transmission speed is much higher in LAN than in a WAN. Typical transmission speeds in LANs are 0.1 to 100 mega bits per second. On the other hand, in a WAN the data transmission speed is normally of the order of 1800 to 9600 bits per second.

5. Fewer data transmission errors occur in case of a LAN as compared to a WAN. This is mainly because in case of a LAN, the distance covered by the data is negligible as compared to a WAN.

COMMUNICATION PROTOCOLS

In a computer network, how are computers and related devices actually able to send information across data communications lines ? The answer is data *communication software*. In fact, it is the data communication software that is responsible for holding all data communications systems together. It instructs computer systems and devices as to exactly how the data is to be transferred from one place to another. These procedures embedded in software are commonly called *protocols*.

Thus in data communication, a *protocol* is a set of rules and procedures established to control transmission between two points so that the receiver can properly interpret the bit stream transmitted by the sender. It provides a method for orderly and efficient exchange of data by establishing rules for the proper interpretation of controls and data transmitted as raw bits and bytes.

ROLES OF PROTOCOL

In any computer network, data communications software normally performs the following functions for the efficient and error free transmission of data :

1. *Data sequencing*. It refers to breaking a long transmission into smaller blocks and maintaining control. That is, a long message is split up into smaller packets of fixed size. These packets are further fragmented into data frames. This technique is widely used in conjunction with error control techniques to reduce the amount of data that must be retransmitted in case of a detected error.

2. *Data routing*. Routing algorithms are designed to find the most efficient paths between sources and destinations. They can handle varying degrees of traffic on the present network configuration with optimal time utilisation. Normally, they are dynamic enough to accommodate network changes and growth.

3. *Flow control*. A communication protocol also prevents a fast sender from overwhelming a slow receiver. It ensures resource sharing and protection against congestion by regulating the flow of data on the communication lines.

4. *Error control*. Error detecting and recovering routines are also an important element of communications protocols. The most common method for correcting errors is to retransmit a block. This method requires coordination of the two stations that the block having error is discarded by the receiving station and is repeated by the transmitting station.

5. *Precedence and order of transmission*. There are well defined rules to condition all stations about when to transmit their data and when to receive data from other stations. It is ensured that all stations get a chance to use the communication lines and other resources of the network depending upon the priorities assigned to them.

6. *Connection establishment*. When two stations of a network want to communicate with each other, the communication protocol establishes and verifies a connection between the two.

7. *Data security*. Providing data security and privacy is also built into most communications software packages. It prevents access of data by unauthorized users because it is relatively easy to tap a data communications line.

8. *Log information*. Data communications software can also develop log information which consists of all jobs and data communications tasks that have taken place. Such information is normally used for financial purposes and the various users of the network are charged accordingly.

THE OSI MODEL

The initial computer networks had their own set of standards and conventions that were quite hardware oriented. Each manufacturer used to develop their own communications protocols for their networks. For example, IBM launched SNA (Systems Network Architecture) in 1974. Similarly, DEC (Digital Equipment Corporation) launched its network in 1980 for use on the DEC range of computers. The architecture of DECNET (Digital Equipment Corporation Network) is known as DNA

(Digital Network Architecture). Like SNA, it is a private network architecture oriented only to DEC hardware. Other telecommunication protocols are BNA (Burroughs Network Architecture) by Burroughs Incorporation, DSN (Distributed Systems Network) by Hewlett Packard, PRIMENET (Prime Computers Network) by Prime Incorporation, etc. Thus the data communications protocols of one network were not compatible with any other network. Moreover, standards of the same network architecture also kept changing from time to time. For example earlier versions of SNA were not compatible with its subsequent versions. Such incompatibilties started creating bottleneck in the efficient and proper utilisation of network resources.

This problem was recognised by the international Standards Organisation (ISO) which established a sub-committee to develop an international standard on network architectures. The result was the Open System Interconnection (OSI) model, which is a framework for defining standards for linking heterogeneous computers in a packet switched network. Thus the standardized OSI protocols made it possible for any two heterogeneous computer systems, located anywhere in the world, to easily communicate with each other.

CONCEPT OF LAYERING IN OSI MODEL

Most modern computer networks are designed in a modular or structured fashion for easy and efficient handling of the system. They are normally split up into a series of modules and are logically composed of a succession of layers or levels. Each layer offers certain services to the higher layers, shielding those layers from the details of how the offered services are actually implemented. Each layer has its own set of protocols. A particular layer of one machine communicates only with the corresponding layer of another machine using the protocols of this layer.

The OSI model is also designed in a highly structured way. As shown in Figure 16.23, it is a 7-layer architecture and defines a seperate set of protocols for each layer. Thus each layer has a specific independent function which is explained in Figure 16.23.

1. *Physical layer*. The physical layer covers the physical interface between devices. It defines the electrical and mechanical aspects of interfacing to a physical medium for transmitting data. It also defines how physical links are set up, maintained and disconnected. In other words, it deals with the mechanical, electrical, procedural and functional characteristics of transmission. For example, in

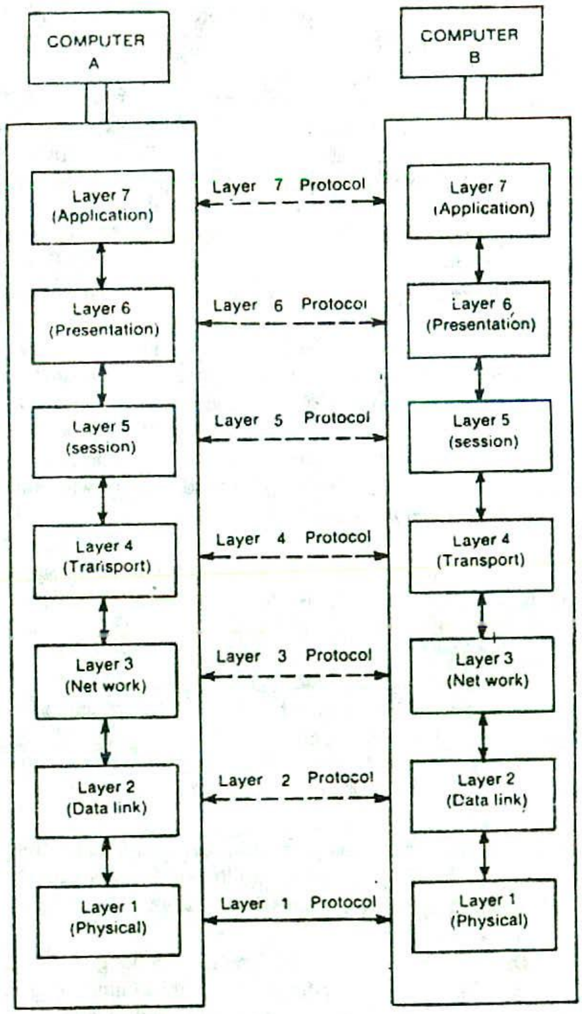


Figure 16.23. OSI network architecture showing layers, protocols and interfaces.

case of RS-232-C interface (used for interconnecting user terminals to computers), the mechanical aspect specifies a 25 pin connector to link the digital device to the modem; electrical characteristics relate to voltage levels and signal transmission rates; functional characteristics specify the functions of each of the pins and procedural characteristics specify the sequence of events for transmitting the data.

Thus, the physical layer transmits the data from the source side to the sink side as raw bits. In reality, data is transferred only between the lowest layers i.e. the physical layers of the source and destination machines . As shown in Figure 16.23, at the lowest (physical) layer, there is physical communication between the two machines as opposed to virtual communication at the higher layers. However, the higher layers are transparent to this.

2. *Data link layer*. The data link layer is responsible for establishing an error-free communications path between computers over the physical channel. It splits packets into data frames which are transmitted sequentially by the sender and the receiver transmits the acknowledgement. It performs checksum Cyclic Redundancy Check (CRC) and horizontal and vertical parity checks to detect and correct errors in the transmission of data. It also multiplexes different messages onto the same transmission channel for optimal line utilisation. It uses synchronous and asynchronous transmission techniques.

3. *Network layer*. The network layer sets up a logical path between the source and the destination computers of the network. The message to be transmitted is first fragmented into packets at this layer. Then it performs sequencing and error control of these packets. Thus the routing decisions are taken at the network layer.

4. *Transport layer*. Once a path is established between the sending and the receiving stations, the transport layer provides control standards for a communication session for enabling processes to exchange data reliably and sequentially.

The transport layer splits the message into smaller units and appends a header to each unit. The headers contain the sequence number of the message block. The transport layer also control essage flow between the sender and the receiver so that a fast sender does not overwhelm a slow receiver with data. It performs this by exchanging 'credit' messages with its peer layer. Moreover, in a multiuser, multiprogrammed environment, the transport layer multiplexes several message streams onto one physical channel.

n layer. The session layer provides means of establishing, maintaining and terminating a dialogue or a session between two end users. It specifies dialogue type - one way, two way alternate, or two way simultaneous and initiates a dialogue if the message is one of connection request i.e. a CALL. Further, it regulates the direction of message flow, i.e. it prevents an incoming message to be taken as an outgoing one.

6. *Presentation layer*. The presentation layer provides facilities to convert encoded transmitted data into displayable form for being displayed on a video terminal or printed on a printer. It may perform text compression, code conversion, or security encryption on the message.

7. *Application layer*. This is a user oriented layer which provides services that directly support the end user of the network. The offered services include file transfers, remote file access, data base management, etc. The application layer also provides network transparancy to the end users so that they are ignorant of the physical distribution of the various network resources being utilized by them.

AN EXAMPLE OF MESSAGE TRANSFER IN OSI MODEL

In order to illustrate the function of the various layers of OSI model, let us consider a simple example of message transfer from the sending station to the receiving station. As shown in Figure 16.24, let us assume that an end user, who is sitting at the sending station, sends a message M that has to be transmitted to the user at the receiving station. The message M invokes the application layer (7) which appends a header (H7) to the message and passes it on to the next layer (6) via the interface between layer 7 and layer 6. The presentation layer (6) performs text compression, code conversion, security encryption, etc. on the message. It appends a header (H6) to it and passes it on to the session layer (5). Depending upon the type of dialogue, the session layer establishes a dialogue between the sender and the receiver. It also regulates the direction of message flow. A header (H5) is appended to the message at this layer. The transport layer (4) now splits the message M into smaller units (M1 and M2) and appends a header (H4) to each unit. These headers contain the sequence number of the message block. The next layer, i.e., the network layer (3) further fragments the message blocks (M1 & M2) into packets and appends a header (H3) to each packet. Then the routing decisions are made for these packets. The network layer performs sequencing and error control of these packets and sets up a logical path between the source and the destination stations. The data link layer (2) once again splits the packets into data frames and attaches a header (H2) and a trailer (T2) to each of these data frames. Cyclic

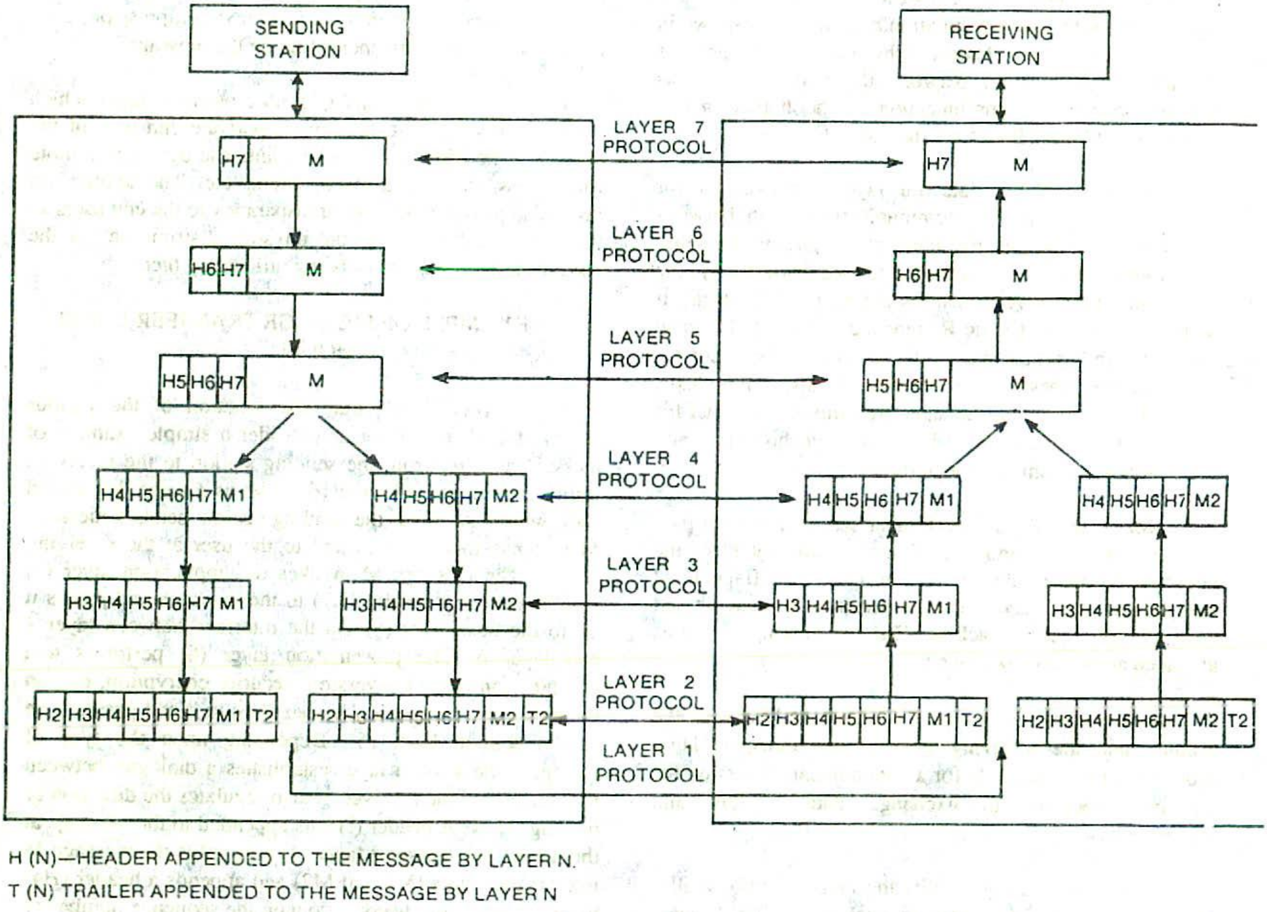


Figure 16.24.

An example illustrating transfer of message M from sending station to the receiving station in OSI model.

Redundancy Check (CRC) and horizontal and vertical parity checks are performed here to detect and correct errors (if any) in the transmission of data. The physical layer (1) now transmits the raw bits of data from the sender side to the receiver side.

On the receiving station side, the message traverses up from the physical layer to the application layer. As the message traverses to higher level layers, the data frames, packets and message blocks are reassembled and the headers and trailers are stripped off at each successive layer to finally obtain the message in its original form (M).

It is important to note here that the peer processes at two adjacent nodes are transparent to this virtual communication. Layer 6 at the source conceptually thinks it is communicating with layer 6 at the destination even though it communicates only with layer 5 at the source end. This abstraction is crucial to network design.

The OSI approach to network design has been adopted by major information standardization bodies including the European Computer Manufacturers Association (ECMA), the American National Standards Institute (ANSI) and the US National Bureau of Standards (NBS). The main advantage of the layered approach is that each one can be improved and modified independent of other layers. This facilitates easy adoption of the changes in communication technology and standards. The X.25 protocol standard, recommended by the Consultative Committee on International Telegraphy and Telephony (CCITT), defines the lower three layers (i.e. the physical, data link and network) of the OSI model. This standard is gaining wide popularity and has already been integrated in the network architecture of many vendors.

DISTRIBUTED DATA PROCESSING

Computers are a business tool, and the rapid developments in small computers have made them increasingly cost effective. Distributed data processing is a management concept that tries to increase the usability of computers by bringing them closer to the end user and by integrating them into daily business activities at the locations at which these activities take place. Advances in both computer and communications hardware and software are increasing the feasibility of placing data processing power throughout all the departments or locations of a business firm.

We define *distributed data processing system* as a configuration in which many geographically dispersed or distributed independent computer systems are connected by a telecommunications network, and in which messages, processing tasks, programs, data, other resources are transmitted between cooperating processors and terminals. Such an arrangement enables the sharing of many hardware and significant software resources among several users who may be sitting far away from each other.

Advantages of a Distributed Data Processing System

1. A distributed data processing system attempts to capture the advantages of both a centralized and a decentralized system. Each computer can be used to process data like a decentralized system. In addition, a computer at one location can also transfer data and processing jobs to and from computers at other locations.

2. It allows greater flexibility in placing true computer power at the location where it is needed.

3. Better computer resources are easily available to the end users. For example, users can use small mini or micro computer systems for processing small jobs. However, for complex jobs they can easily access large sophisticated computer systems. The same is true for other resources like mass storage devices, plotters, data base and even a growing library of applications programs.

4. It facilitates quick and better access to data and information especially where distance is a major factor.

5. Network users can develop their own specialized applications with the help of skilled computer/communications specialists.

6. The availability of multiple processor in the network permits peak load sharing and provides backup facilities in the event of equipment failure.

7. Telecommunication costs can be lower when much of the local processing in handled by on-site mini and micro computers rather than by distant central mainframe computers.

8. Users with access to nearby computer and data bases may be able to react more rapidly to new developments, and they may be able to interact with the other network resources to seek solutions to unusual problems.

Disadvantages of a Distributed Data Processing System

1. There is lack of proper security controls for protecting the confidentiality and integrity of the user programs and data that are stored online and transmitted over network channels. It is relatively easy to tap a data communication line. One technique used to protect security and privacy over data communications lines is encryption. Basically, *encryption* is a coding device placed on either end of the data communications line, putting a very complex code on the data. This code is extremely difficult to break, although any code can be broken. At the other end of the data communications line, another encryption device is used to decode the signal into a meaningful message. However, encryption and other techniques are generally ineffective today in providing reliable security and privacy of confidential data and programs.

2. Due to lack of adequate computing/communications standards, it is not possible to link different equipments produced by different vendors into a smoothly functioning network. Thus, several good resources may not be available to the users of a network.

3. Due to decentralization of resources at remote sites, management from a central control point becomes very difficult. This normally results in increased complexity, poor documentation, and non-availability of skilled computer/communications specialists at the various sites for the proper maintenance of the system.

4. System reliability, flexibility, response time, vendor support, and the cost of telecommunications facilities used are some of the important factors that may disappoint network users in some cases.

QUESTIONS

1. Why are computing and communications technologies merging ? What are likely to be some of the effects of this ?

2. Identify the basic elements of a communication system and the purpose of each.

3. Differentiate between simplex, half-duplex, and full-duplex modes of data transmission.

4. Which mode of data transmission is suitable for communication between a terminal and a computer ?

5. "A full-duplex line is faster since it avoids the delay that occurs in a half-duplex circuit." Explain this statement.

6. Explain the terms "bandwidth" and "baud".

7. Why are the transmission mode and the bandwidth of communication channels of concern to an analyst designing a data communication system ?

8. Differentiate between narrowband, voiceband, and broadband communication channels. Give a practical application of each.

9. What is a wire pair ? In what situations are they suitable for use in data transmission ?

10. What is a coaxial cable ? Give some of its practical uses.

11. Explain how microwave systems can be used for communication between two distant stations.

12. How are communications satellites used ? What are the possible advantages and limitations of using a communications satellite ?

13. What is an optical fiber ? How is it used for data communications ? What are its advantages ?

14. Differentiate between analog and digital transmission of data. Give their relative advantages and disadvantages.

15. What do you understand by modulation and demodulation ?

16. Why is modulation used in signal transmission ? Describe the three different forms of modulation used in signal transmission.

17. What are modems ? What purpose do they serve in data communication systems ?

18. What is an acoustic coupler ?

19. What is a repeater ?

20. When are public telephone lines used to connect

a terminal to a computer ? Are modems required for this purpose ? Why ?

21. What is a multiplexer ? Explain its function with the help of a diagram.

22. A company has a computer at its main office in Delhi linked to a terminal in each of its branch offices situated in the state capitals. It would like to use multiplexing for these terminals to reduce transmission costs. Is that possible ? Explain your answer.

23. Describe the two basic methods of multiplexing. Give use of both methods.

24. List out the differences between FDM and TDM. Which method is suitable for communication between computers and why ?

25. What is a concentrator ? Justify its use in a data communication system.

26. What is a FEP ? Illustrate its use .

27. Describe the asynchronous and synchronous modes of data transmission.

28. List out the relative advantages and disadvantages of asynchronous and synchronous modes of data transmission.

29. Explain how circuit switching method is used to link the sender and the receiver in a communication network. What are the advantages and disadvantages of this method of switching ?

30. Explain the store-and-forward method of message switching. Give the advantages and disadvantages of this message switching technique.

31. What is packet switching ? Why is this method used for digital data communication between computers ?

32. What is meant by network topology ? Describe three commonly used network topologies with their relative advantages and disadvantages.

33. What is a hybrid network ? Why are they used ?

34. Write a short note on multipoint network.

35. What is a LAN ? What are its main objectives ?

36. What is a WAN ?

37. Differentiate between a LAN and a WAN. Give one example of each.

38. What is a communication protocol ? What are the normal functions performed by these protocols ?

39. Why is layring used in the design of communication networks ?

40. Describe the layring concept in OSI model of network architecture with the functions of each layer.

41. What is meant by distributed data processing ?

42. What are the possible advantages and limitations of a distributed data processing system ?

43. What is encryption and why is it important for sensitive data ?