UNIT 9

DATA COMMUNICATION CONCEPTS

Objectives

The objectives of this unit are to :

- understand the concept of data communication as applied to computers
- inform about the hardware and software required for data communication in computers.

Structure

9.1. INTRODUCTION

Personal computers are forcing the world into the information age, which is characterised by computers and the networks that connect them. The need for such connectivity is emphasised by the fact that information is required for initiating, executing and monitoring of a project. In today's world, every activity needs to be optimised to get the maximum cost-effectiveness.

This scenario is similar to the early part of this century where automobiles forced the development of highways for free accessibility and communicability,. Similarly, widespread use of computers (ranging from PCs to Mainframes) are forcing us to build up the information highways, namely the networks, to facilitate access, common utilities and common services. Fundamental to these goals is data communication.

By data communication we mean the transportation of information from one point to another through a communication media. Data communication facilitates efficient use of large computers, improves the day-to-day monitoring of projects and provides a variety of services like Electronic Mail, Credit Card Checking, Videotex, etc. These services on networks are called value-added services. This is becoming a new commercial business proposition.

9.2. BASICS OF DATA COMMUNIICATIONS

The main components of data communication are data source, data sink and communication media (Figure 9.1). The source is the originator of information, while sink is the receiver of information. The media is the path through which the information is transported to the sink from the source. This media could be a telephone wire, a micorwave system or a satellite circuit of a fibre optic line. Usually, the media is provided by one or more common communication carriers. In india, the common communication carrier is the Department of Telecommunications. The carrier agency lays down the rules and regulations on how to use communication media and also specifies the type of equipment that canbe connected to the carrier. The source usually is a computer of a computer terminal. The computer equipment is connected to the communication media through a piece of equipment called Modem. This piece of equipment converts the digital signal to the analog signal and passes it on to the communication media through which they are propagated towards the sink. The sink is similarly connected to the communication media through a Modem and receives the propagated signals.

Figure 9.1

The source and sink could both be computers; or one could be a CRT terminal and the other a computer, or one could be a terminal and the other may be a printer, or any other computer resource. The source and sink can be connected in a variety of ways.

9.3. FUNDAMENTAL COMMUNICATION CONCEPTS

Types of Electronic Signals

The electronic signals actually represent reality. For example, the temperature or pressure can be represented as "equivalent" electronic signals. Such representations are of two basic types. These are Analog and Digital.

Analog Signals

Analog signals are continuous in nature. Figure 9.2 shows an analog signal called sinusoidal signal. Analog signals are ideally suited to represent the natural phenomena which are continuous. There is no discontinuity in nature! It is not possible to say that the pressure can only be measured as 100,200.... 10,000 psi.

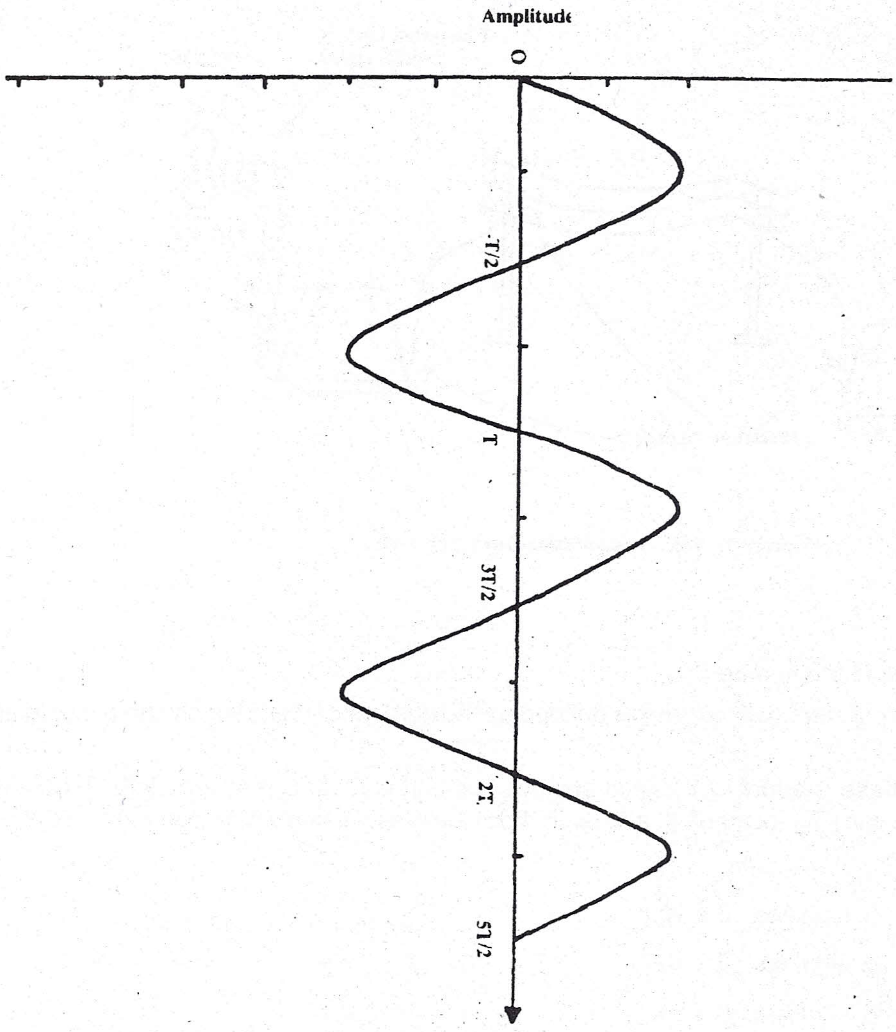


Figure 9.2: Sinusoidal Signal

You can always have 100.3 or 100.39 or 100.39421789. This is what we mean by continuous signals. There is no break anywhere. Let us consider another example, say, speech. When you speak using the telephone, the microphone in the handset near your mouth converts your speech or voice into analog electronic signals. It is this analog signal that gets transmitted through the public switched Telephone Network to the called party. At the other end the analog electronic signal is converted back to speech signals by using a speaker which is part of the telephone handset near the ear. This is depicted in Figure 9.3. This is an example of analog signal transmission.

Digital Signals : Digital Signals are the basis of modern computer. In the digital system, there are only two states to the signal - Present and Not Present. TRUE and FALSE, 1 or 0. Any other quantity has to be represented in terms of these. What we use in everyday life is the decimal number system, that is the numbers (or should we say digits) run from 0 to 9. The digits that we deal with are only 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. Any number that we want to represent in this decimal numbers system, can be composed of these ten digigs. A number is made up of individual digits (egg., 803 consists of the digits 8, 0 and 3). The value of each digit in a number is determined by three considerations:

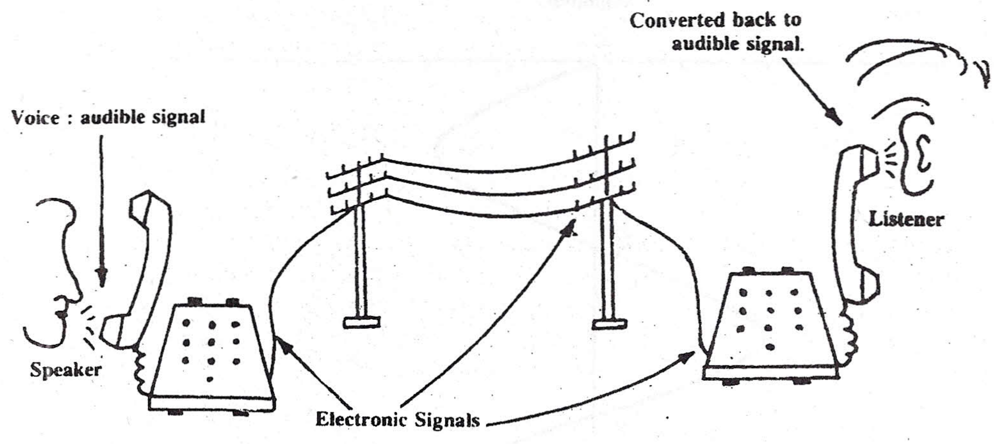


Figure 9.3: Voice Transmission-Block Schematic

a) the digit itself
b) the position of the digit in the number
c) the base of the number system (where base is defined as the number of digits which can occur in any one position).

In the decimal system the base is equal to 10 since any position can contain one to ten digits (0123456789). The system therefore has a carrying factor of 10 and each digit indicates a value which depends on the position it occupies:

In 6,421 the digit 6 signifies 6 x 1000

In 4,621 the digit 6 signifies 6 x 100

In 4,261 the digit 6 signifies 6 x 10

In 4,216 the digit 6 signifies 6

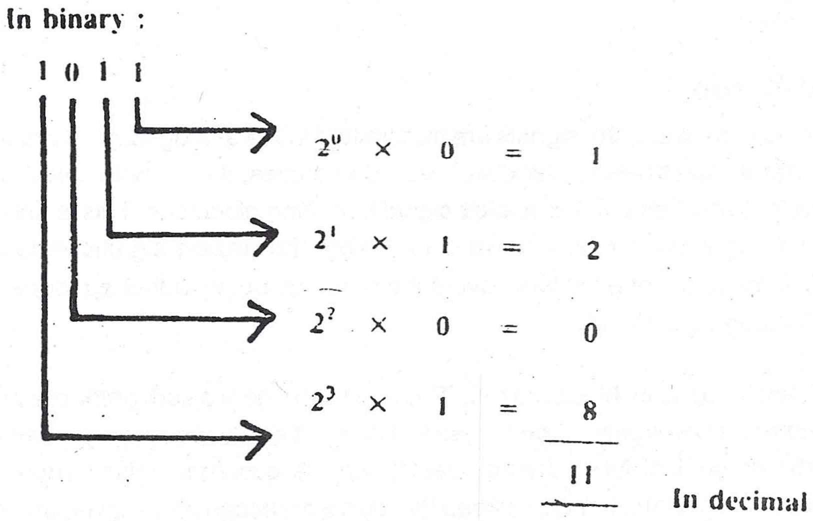
On the contrary, in the case of digital signals, there are only two levels. That is the ability to represent a ZERO or a ONE. Any other number has to be represented only as a combination of these. Here 0 and 1 are called binary digits or bits. We use the binary number system for this purpose. In binary, the base is equal to 2 and the two digits are 0 and 1. This system is ideal for coding purposes for the computer because of the two-State nature i.e., ON or OFF of the electrical components that are used.

Remember we only have two digits, 0 and 1, and therefore the binary equivalent of the decimal number 2 has to be stated as 10 (a 0 with a 1 carry, read as 'one, zero').

Binary	Decimal Equivalent
0	0
1	1
10	2
11	3
100	4
101	5

110	6
111	7
1000	8
1001	9
1010	10
1011	11 and so on.

This system has carry factor of 2 and each bit has a value which depends on the position it occupies:



In our 36-bit word, numeric data can be represented by upto 35 bits with the 33th bit always reserved to indicate whether the number is positive or negative.

Numbering the bit positions from the right, we can assign each bit a value based on two times the value of the previous bit. The number 1,208,747 is represented in the computer by the unique pattern of 1's and 0's as shown below. It is the total value of those bits (reading from right to left marked with a 1 that gives us the number in decimal figures, i.e.,

Bit number from right	value		
1	1	=	$2^0 \times 1$
2	2	=	2×1
4	8	=	$2^3 \times 1$
6	32	=	$2^5 \times 1$
8	128	=	$2^7 \times 1$
9	256	=	$2^8 \times 1$
13	4096	=	$2^{12} \times 1$
14	8192	=	$2^{13} \times 1$
15	16384	=	$2^{14} \times 1$
18	131072	=	$2^{17} \times 1$
21	1048576	=	$2^{20} \times 1$
	1208747		

Types of Transmission

In the previous section we tried to explain the types of electronic digital signals. Also, we noted that the computers use only digital signals. But when we consider an application like office automation, both types of signals may be present because the signals may originate from several independent sources, e.g., computers, Fax machine, Video conferencing machines etc. It, is often necessary to pass the information at application level from one system to another. The information becomes electronic signals when it passes through a communication medium. Most often, the systems that act as source and destination could be far apart, even thousands of miles apart. A little insignt into the transmission of analog signals and digital signals will put these in proper perspective.

Analog Transmission

In the popular telophone network, the signals are transmitted in the analog form. By nature, without ant special effort, the analog signals can travel longer distances. Sometimes, it is easy to convert a digital signal, 0 or 1, to an analog equivalent and transmit the analog signal over long distances. This is known as *modulation*. The receiving end can recover the digital form of 0 to 1 from the analog signals received. This is known as *demodulation*. Since the telephone system covers the entire globe, by adhering to the analog signal, we can transmit signals all around the globe.

There are some disadvantages in this approach. The most prominent disadvantage is noise. Noise in electrical parlance is yet another analog signal. When noise interferes, it easily mixes with the analog signal that is being transmitted, disturbs its original form, thereby destroying the contents. Also, when the signal travels long distances, it may lose its strength; hence, to keep the signal at recognisable level, amplifiers (or boosters) are required. These device not only increase (or boost) the signal but also increase the noise content. Hence, recognition of the signal at the receiving end is an involved affair.

Digital Transmission

On the contrary, the digital transmission is less error prone. But, without a booster, it cannot travel long distances like analog counterparts. Incidentally the digital signal cannot be simply amplified. It has to be absorbed and regenerated at regular intervals. Because it is absorbed and regenerated, the noise signals are completely eliminated. Therefore, the digital transmission is always preferred because of its high quality as compared to analog transmission. But then all the real world or natural signals are analog. Voice and video are excellent examples of analog signals. To make use of high quality associated with the digital transmission for analog signals, the analog signals have to be converted into their digital equivalents. As we all know, intuitively, no translation can be 100% perfect. But there are several techniques developed over a period of time for converting signals from one form into another with fairly high fidelity.

Bits and Baud

Bit is the basic unit of information. Bits are combined to farm characters. In contrast, Baud is a measure of signalling speed. In fact baud should not be used to experss the capacity of a line. However, these two are used synonymously. It (baud) refers to the number of times the line condition changes in each second. If the line condition represents the presence or absence of one bit, then the signalling speed in baud is the same as the line's capacity in bits per second. Baud describes the rate of change of the signal on the line, that is, how many times (per second) the signal changes its pattern.

In figure 9.5, the sending device assembles the bits into groups of two and then modifies the oscillating wave form (i.e. changes the signal state) to one of the four amplitudes to represent any combination of 2 bits (00,01,10,11).

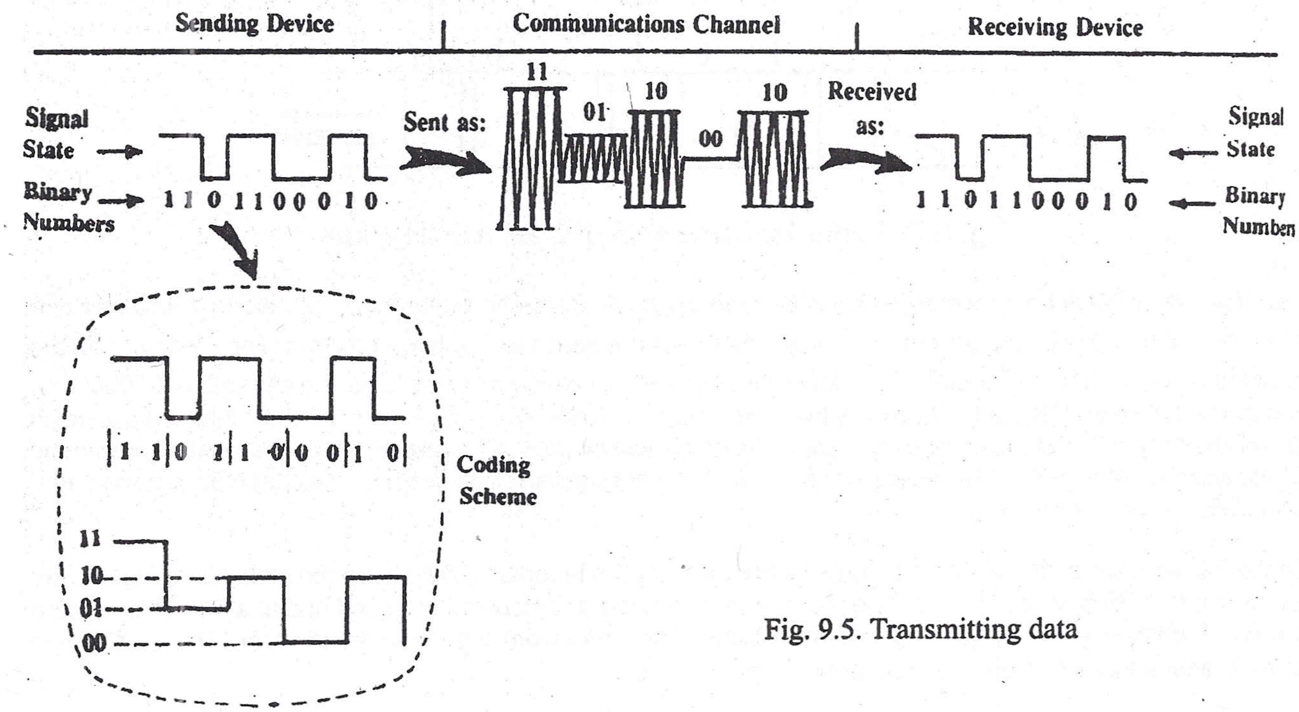


Fig. 9.5. Transmitting data

Source : Black D. Uyless Data Communications and Distributed Networks (Second Edition). 1987. A Reston Book. Prentice. Hall Inc. Englewood Cliffs. New Jersey).

Mode of Transmission

The computer system transmits data to its devices in two modes-serial and parallel.

Serial Transmission Mode

The transmission of a stream of data bit by bit over the communication line is called serial transmission. This is illustrated in Figure 9.6. In this, initially, the sender trasmits the first bit. Then after some time (machine cycle) the second bit is transmitted and then the third and so on till all the bits are transmitted. The receiver receives the data exactly in the same format bit by bit.

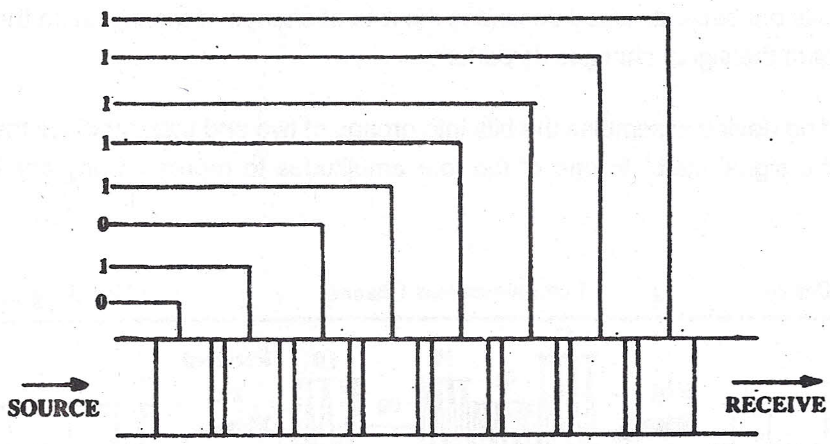


Fig. 9.6. Serial Transmission of 8-Bit ASCH code

The objective of serial data transmission is to send the bytes from one point to another along a single line or channel. That is, the bits representing a given character are sent serially, one at a time. The medium has the ability to carry only one digital signal i.e., only a bit at a time. For example, to transmit the charater A (01000001), first the digital level '1' is sent followed by five digital level '0', followed by digital level '1' and then a digital level '0'. Incidentally, in the charater representation, the right most bit position is referred to as the least significant bit (LSB) and the left most bit position is referred to as the most significant bit (MSB). The chatacter is transmitted with LSB first and MSB last.

As the bits sent are digital electronic signals, consequently the receiver should have the ability to recognise the serial stream of bits as characters. The receiver must be able to detect the start and end of a character. There are two techniques for recognising and separating characters from the serial bit stream. They are called asynchronous transmission and synchronous transmission.

Parallel Transmission Mode

In this transmission mode, all the bits of information are transmitted in a single cycle. For example, in the 8-bit ASCII code, all the 8 bits are transmitted over the communication media in one single cycle. This is illustrated in Figure 9.7.

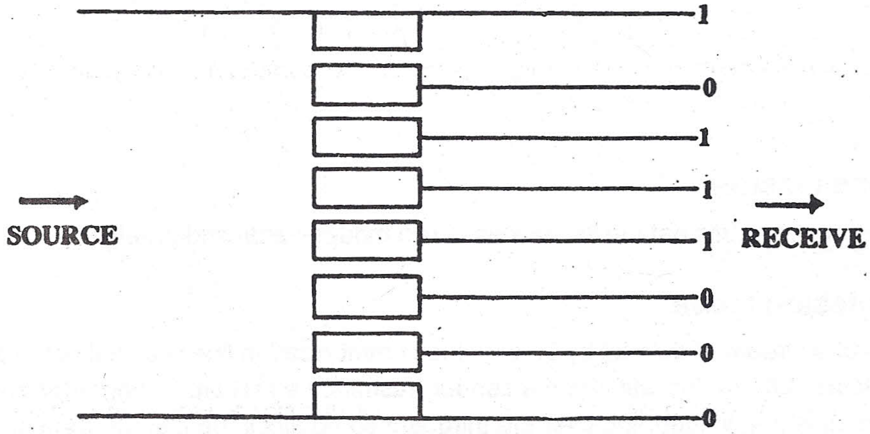


Figure 9.7 : Paralel Transmission of 8-Bit ASCII Code

It is clear that if there are 8 bits the serial mode transmission would require 8 machine cycles while the parallel mode transmission would require only one cycle.

In parallel transmission, as the name implies, the bits of a chartacter are sent in parallel (simultaneously) using as many signal carrying lines as there are bits. For example, to transfer an eight bit character from one subsystem to another, eight separate signal carrying lines are required. As you can see, the entire character can be transferred in one bit time. That is an eight- fold increase in transmission speed as compared to serial transmission.

But such an increase is not without its share of problems and limitations. First of all the sender and receiver have to agree on the exchange of one or more characters. this necessitates a protocol or prior understanding between them. Protocol is a communication control methodology which defines the content and the sequence of exchange of units of information (bits,bytes or groups of bytes called packets) between any two systems. This can be implemented either through hardware or software. At high speeds of tranfer using parallel transmission, protocols will be in the form of hardware signal exchanges. Therefore, systems capable of such high speed transfer will be complex and are expensive to build. They are used typically for exchanges between subsystems of a computer system. The high speed also limits the distance and hence parallel transfers are confined to shorter distance of the order of a few feet. The parallel mode is used to achieve high transmission speeds between the devices and the CPU.

Serial transmission is achieved in three ways. These are asynchronous, synchronous and iso-synchronous.

Asynchronous Transmission

Asynchronous is the most commonly used transmission mode. In asynchronous transmission of characters, each character to be transmitted is preceded by a start bit and terminated by one or two stop bits. Because of this, the asynchronous transmission is sometimes referred to as "start /stop" transmission. The function of the start bit is to tell the receiver where the new character starts and the function of the stop bit is to tell the receiver that the character has ended, so that the next start bit will be perceived as the start of a new character. The receiver can know the end of the character by counting the number of bits.

Asynchronous character framing is designed for a situation where the charactes are transmitted intermittently. Ths is typical when a person is sitting at the keyboard of a terminal that is connected to a computer. Whenever a key is pressed, the binary code corresponding to that character is generated and sent to the computer system immediately.

Typical applications of asynchronous transmission are computer to terminal communication, communication with slow printers, and sometimes even between computer to computer. The main disadvantages of this approach are the overhead transmission is generallly slow (at 1200 bits per second) using a telephone line. With dedicated point-to-point lines one can go up to a speed of 9600 bits per sencond or even 19200 bits per second. For example, 1200 bits per second means that the communication channel has a capacity to transfer 1200 bits of information in one second.

Always, the two devices (terminal and computer for example), have to agree upon the number of bits in a character and the bit time. The ASCII character set, which uses 7 bits, is the most widely used. The bit time is set by deciding how many bits per second to transmit. The bit time refers to the duration for which the digital signal remains either at "0" leverl or at "1" level.

Let us refer to Figure 9.8. Which depicts the waveform of the signal where the character whose ASCII represenation is 1100111 is transmitted. Here it is assumed that the LSB will be transmitted first and the MSB at the end followed by a bit called parity bit. Here we assume odd parity. That is, there will be an odd number of 1 s in the character. There are 7 character bits + 1 odd parity bit + 1 start bit 2 stop bits = a total of 11 bits for every 7 bit characcter, 4 bits overhead for 7 bits of data. The idle state of the line is "high state" or "1 state". A drop suddenly for a one-bit period means that start bit is on the line. This is followed by the 7 bits belonging to the character in the order 1,1,1,0,0,1 and 1. Then the parity bit is sent. Since in this case the character already has odd number (s) of 1 bits, the parity bit sent is actually '0'. Then the 2 stop bits ar sent.

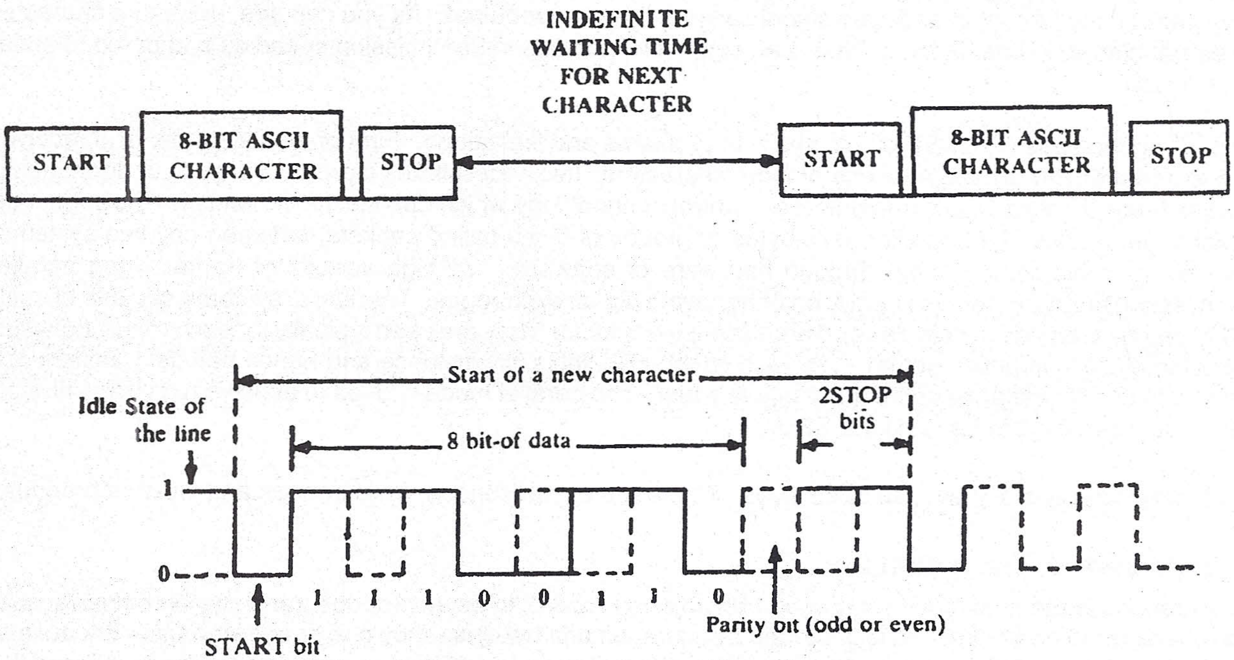


Figure 9 .8 : Asynchronous Transmission

Asynchronous or start/stop transmission is relatively simple to implement. But it results in inefficient use of channel capacity because ten bits are transmitted to convey the characters consisting of only 7 bits - approximately 20% to 30% overhead. This is mainly because each character is a separate entity by itself in the start/stop case.

Synchronous Transmission

synchronous transmission is used to achieve high speed of data-transmission. In this the sender transmits a block of characters together in one single transmission.

The synchronisation between the transmission device (sender) and the receiver device is achieved by transmission of a pre-determined group of bits known as synchronous bits (figure 9.9). These synchronous bits inform the receiver that the data is following and he can determine the time frame between each of the bits. The receiving device based on the synchronous bits starts receiving the bits and starts interpreting them bit by bit into character form as per code and transmits the characters to the computer. In the case of 8-bit ASCII, it counts 8 bits interprets the character and then transmits it to the computer. There are at least three SYN characters, followed by number of data characters and then finally the checksum character:

Asynchronous vs Synchronous Transmission

As can be seen, asynchronous transmission is less efficient compared to synchronous transmission as, for every character, there is a start bit and stop bit in the former system. However, in asynchronous transmission, if an error occurs during transmission, only one character is destroyed. On the other hand, the same error in synchronous transmission may destroy the whole block (set) of characters.

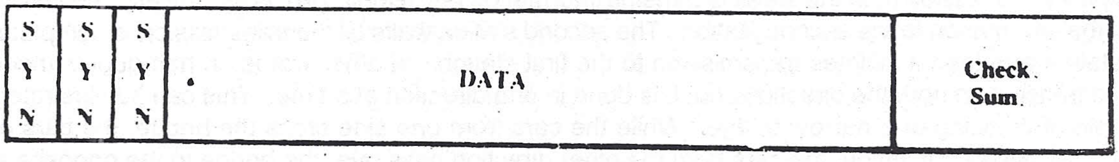


Figure 9.9 : Synchronous Transmission

The equipment required for receiving synchronous transmission will obvioulsy be more expensive than that used for asynchronous transmission.

Both the asynchronous and synchrounous transmission methods are widely used in terminals. While terminals of microcomputers and minicomputers support asynchronous connection to terminals, the mainframes still support synchronous communication between the computer and the terminals. One reason in favour of asynchronous approach is the simplicity and significantly low cost of realisation. On the other hand, synchronous communication terminals and interfaces are complex by an order or magnitude and are significantly more expensive to implement. But synchronous mode terminals are favoured in situations where fast query/ response times are desirable. One must also take cognizance of the fact that the **population of devices** using the asynchronous method has increased dramatically due to the spectacular growth of personal computers. The PCs almost exclusively use asynchronous transmission for communication lines and for printer interfaces. It is really a matter of balancing between response time, communication channel cos'ts and the cost of implementation.

Iso-chronous

Iso-chronous is a technique which makes use of both synchronous and asynchronous modes. In this, each character starts with a star-bit and ends with a stop-bit. In addition, the time interval between the transmission of two characters will always be an integer multiple of the length of time required to transmit one character. That is, all periods of non-transmission consist of one or more character time intervals. This common timing allows higher precision than asynchronous transmission between the end devices. Iso-chronous transmission is generally used to achieve higher rate of transmission compared to asynchronous transmission and also to retain the advantages of asynchronous transmission.

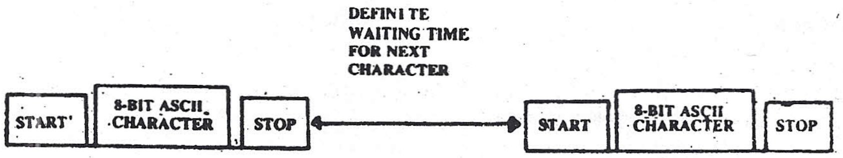


Figure 9.10 : Isosynchronous Mode

A circuit is a path for transmission of electrical signals between two or more points. The terms channel, line, circuit, link or a path are synonymously used.

There are three types of transmissions. These are simplex, half-duplex and full-duplex.

In a simplex transmission, signals are transmitted in one direction only from one point to another. The roles of the transmitter and the receiver are well defined. An example of this is remote control of VCR or a Television. Here, the remote control unit sends a signal to the television or VCR to perform a particular function. Here the role of the remote control is to direct the action at the television or the VCR. Another example is a one way road.

In half-duplex transmission both the stations transmit information but in their own turns. Initially, the first station transmits the information to the second station. The second station waits till the transmission is complete from the first station and then it initiates transmission to the first station. In other words, in half-duplex mode it is possible to transmit in both the directions but it is done in one direction at a time. This can be illustrated with the example of crossing of a narrow bridge. While the cars from one side cross the bridge, the cars on the other side wait. After completion, the cars from the other direction pass over the bridge to the opposite side.

In full-duplex transmission both the sides can transmit information simultaneously. A two-way road is a simple example of full duplex transmission. The concepts mentioned above are illustrated in Figure 9.11.

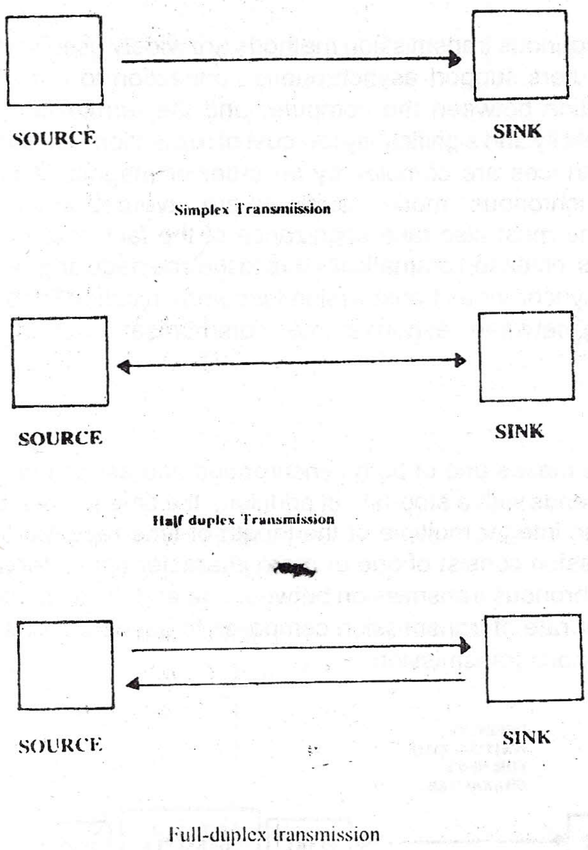


Fig. 9.11 Modes of Transmission

Half-dujplex operation is possible on both two-wire and four-wire circuits. In a two-wire circuit, only one wire is used for transmission. The second one is for grounding. However, on two-wire, the user must deal with turn around time, i.e., 'the time required to change the direction. During that time there is no transmission. In full-duplex there is no turn around time. It generally requires four-wires. However, some sophisticated modems can handle full duplex transmission on two-wire circuits.

9.4. HARDWARE REQUIREMENTS

Till now we have been discussing the transmission of data on the communication lines. In this section we will be discussing the interface between the computer lines. In this section we will be discussing the interface between the computer and communication equipment, i.e., how to get onto the communication media. As has been spelt out earlier the communication media deals with the digital signals. Further, the commuication media is comparatively slower than the data processing equipment. These differences make it necessary to have an additional equipment which establishes the linkage between the data processing equipment and the communication media. It is something similar to providing an interface between the two of them to facilitate movement from a high level to a low level and from a low level to a high level. Similarly, the data communication hardware facilitates linkage between the communication media and the data processing equipment.

If you look at Figure 9.1 you will see that we have identified three elements, i.e., source, media and the sink. In this section, we will be talking about the equipment which interfaces between the EDP equipment and the media. There are three possible locations where these equipments can be located. The two obvious places are at the two terminal ends of the communication lines (Figure 9.12). In between the two terminal ends, a lot of equipment is also deployed to facilitate, maintain and monitor the communication link between the source and the sink. In this course, we will be exploring only the equipment located at the first two palces.

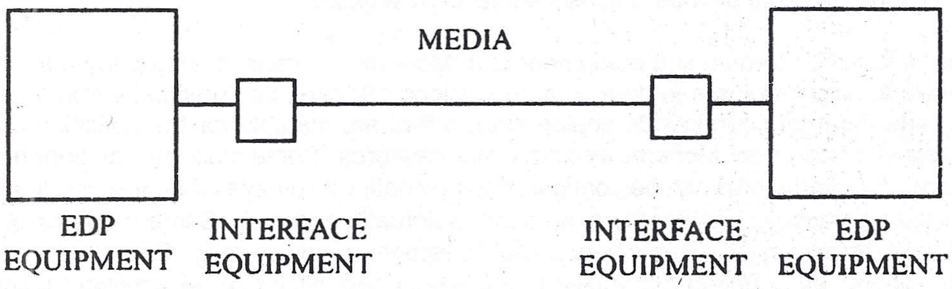


Fig. 9.12. Interface Equipment

The equipment at the end of the communication lines are generally called data circuit terminating equipment. Each of these equipments performs certain functions. Some of these equipments have very sophisticated functions.

Some of the major functions of the Data circuit terminating equipments are:

a) establishment of the physical connection between the two end points;

b) transmission and receipt of all digital information through the physical circuit;

c) conversion from digital to analog and analog to digital;

d) error detection and correction;

e) monitoring and diagnosing of equipment faults.

Lines for Data Transmission

So far, we have referred to communication channles as lines, without being precise as to their physical nature. In fact, the most commonly used medium for transmission, both nationally and internationally, is the telephone system. Links may be established by dialing on the Public Switched Telephone Network (PSTN) or by using private circuits leased from telecommunication administration or by using privately installed wires.

In none of these cases does a physical line exist in the sense of copper wires joining any two arbitrarily chosen points. Telephone channels for transmission other than the "local leads" are grouped together in carrier systems using coaxial cable, microwave, fiber - optic or even satellite links. The coper wires exist only at the ends called"local leads" and, ironically, these relatively short "tails" or "local loops" are the one which are subject to electrical interference. Such interference produces noise and consequent errors in data transmission using the telephone channels.

Naturally so, because the telephone network was designed for voice communication and not for data communication. The Telecommunications authority provides leased lines which are equalised or "conditioned", so that improved quality of data transmission is possible. but little can be done to improve the quality of channels established by dialing on the public switched telephone network. Moreover, the communication equipment at the exchange cannot tolerate the variability and correct the transmission errors. the communication lines are available either as "4-wire" or "2-wire" circuits. The former provides, in effect, two independent channles, one in each direction, while the latter provides one channel, usable in either direction. In practice, most lines are 2-wire only at the local loop.

The lines may be of two operational types :

* **Switched** (i.e., public Switched Telephone Network - PSTN) with world - wide availability and connectivity.

* **Leased**, specially engineered circuits between (usually) two points only. The signalling is not required and the line is conditioned to provide a consistent level of service.

The most common data circuit terminating equipment is a 'Modem'. Modem is an acronym for modulator / demodulator. It plays an important role in data communications. It takes binary signals from the computer/ terminals and converts them into contiguous analog signals that are suitable for transmission on the voice communication media and vice versa. Modems also have other features. Some modems can perform automatic dialing to remote stations. Some also can be configured to be continuously available or in ready state so that they can be accessed at any time. This feature is called "automatic answer". Some modems also allowed alternate data and voice transmission. This is very useful for remote troubleshootig. Some also have "reverse channel" capability, where by a limited full duplex transmission capability can be achieved using two-wire circuits.

Modems are calssified as low speed or high speed. Modems with speed less than 1800 bps are referred to as low speed and ones with more than 1800 bps as high speed. The cost of the modem accordingly varies with the functions and speed. For any two data terminal equipments to communicate with each other over a communication line / medium, the associated modems should also be able to communicate with each other. For this, the two modems should follow the same procedures and techniques. Recognising this, standards for modems have been prescribed. The CCITT an international organisation dealing with telecommunications has published a series of recommendations known as V-series for the modems. As long as the modem manufacturer conforms to the standards the modems of different manufacturers will be able to communicate with each other over the communication lines.

The modems can be interconnected by a variety of ways with the use of leased point to point circuits or dial up circuits. Some of the simple connections are given in Figure 9.13.

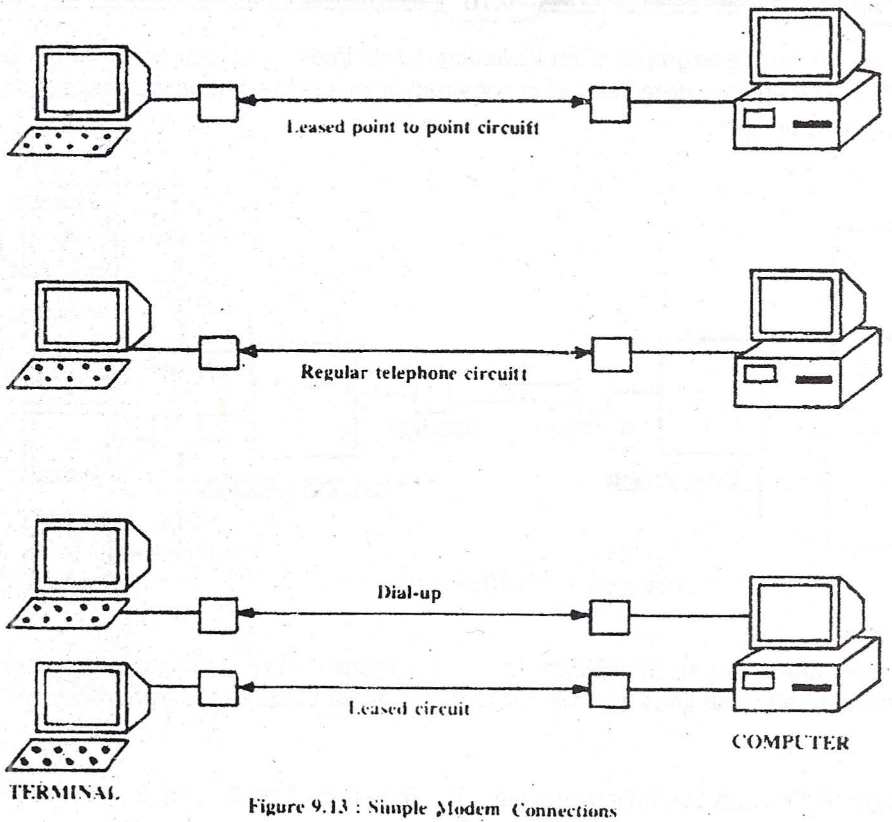


Figure 9.13 : Simple Modem Connections

Multiplexor

In the approach given above (Figure 9.13) each communication line with a modem would facilitate one data terminal equipment to communicate. The efficiency of utilisation of the line will very much depend upon the usage. There are many ways links can be used to interconnect data processing equipment for higher utilisation of line. One method might be to have a common communication line, for several terminals, with the computer. Each terminal communicates with the computer as long as the line is available. If a terminal wants to communication to the computer it must wait until the data line is free. This can be illustrated with the example of a telephone with two or more extensions. When one of the extensions is busy, the other extension cannot make a call. Only one terminal on the data-link can transmit at one time. The criteria for choosing a modem are speed, error rate, reliability, maintainability (like loop-back) turn around time and cost.

The other methods of line sharing use devices of various types to interconnect data terminal equipments with each other. Instead of connecting several terminals to the mainframe using a multi-point data-like, we can think of (as described in the above paragraph) a mechanism of combining all the links at one end and transmit them on a single line with the facility of recovering all of them at the other end. This method is called multiplexing and the equipment is called multiplexor.

The multiplexor's main job is to combine the data being transmitted over a number of low speed data links for transmission over a common long distance line. This would mean that the low speed lines will be able to achieve their speed over the communication lines media. Here we gain the cost of the lines against the cost of multiplexing equipment.

The end effect of the multiplexing is to combine several low speed transmissions into a single high speed transmission. Because of the economics, a single communication line is nearly always cheaper than an equal number of smaller lines. A simple example of multiplexing is multiplexing of four small roads over a river by constructing a single four lane bridge. Here the cost of construction of a single bridge is cheaper than construction of four separate single lane bridges.

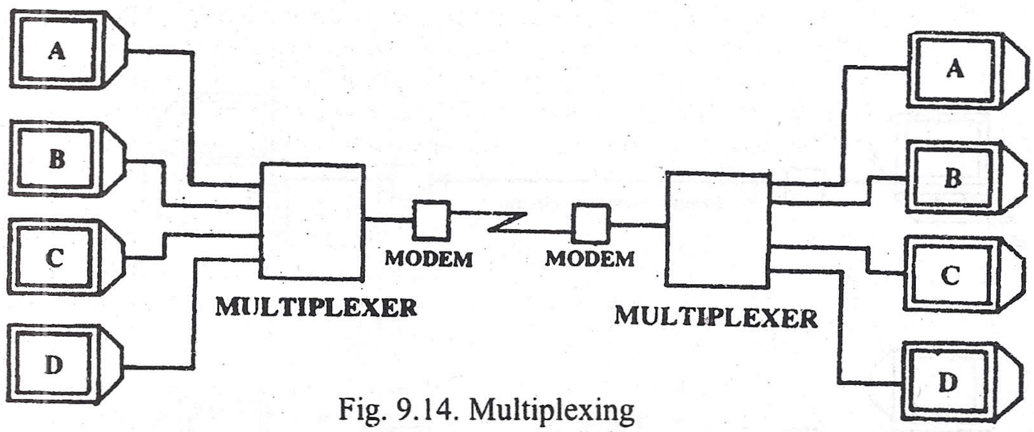


Fig. 9.14. Multiplexing

The most often quoted reason to use multiplexor is to save money. The savings are realized through the reducation in the number of physical lines and the number of modems required to transmit data from a number of terminals.

The multiplexors only multiplex and demultiplex the signals. They are relatively simple, rugged and transparent to the user.

Simple multiplexors techniques generally provide a "transparent" connection between terminals located remotely from the computer and the computer ports to which these terminals are individually attached. the word "transparent" means that the multiplexor system does not in any way interfere with the flow of data. Neither the computer nor the terminal knows that the multiplexor system is being used. Thus, neither terminal equipment nor the computer software need to be changed when a multiplexor system is installed. The use of multiplexors can result in substantial savings in telephone line rentals or in long - distance call charges.

It should be noted that multiplexors are normally required at both ends of the "shared" telephone line, so that a given number of channels multiplexed at one end may be demultiplexed back into the same number of channels at the other end, thus providing the transparent connection between each of the points on either side. In data communication, characters may be multiplexed in different ways. Three main methods are used : Frequency Division Multiplexing, Time Division Multiplexing and Statistical Multiplexing.

Frequency Division Multiplexing (FDM) is the oldest type of multiplexing. It takes advantage of the fact that the bandwidth of a voice-grade telephone line is significantly greater than that required by a low speed channel. Using different centre frequencies, several channels can share the same line. Typically, up to a maximum of 24 low speed channels can be derived from one voice grade line. However, due to its relative inefficiency and inflexibility, FDM is now rarely used for general purpose data multiplexing

Time Division Multiplexing (TDM) is a digital technique. **TDM** interleaves bits (called bit TDM) or characters (called character TDM), from low speed channels attached to it and then transmits the combined data stream serially using a high speed line. The multiplexer at the other end, demultiplexes the data stream, presenting one bit or character to the corresponding low-speed channel. If we observe the low - speed channels both at the transmitting and at the receiving end, they will be identical. Each low-speed channel is allocated a fixed time duration or time slot on the high speed line. Character interleaving is more widely used than bit interleaving primarily because of its efficiency when multiplexing asynchronous channels. Because a character multiplexer stores a complete character before transmitting it down the high speed line, it is possible to remove the start and stop bits during demultiplexing at the other end. Thus, it is only necessary to transmit eight bits for every ten bits (8 bit data plus one start plus one stop bit) received. The net result is that the high speed line is used more efficiently and channel capacity for a given speed of a high speed line is greater when character TDM is used as opposed to the bit TDM. However, the character storage required in character TDM results in longer delays than with bit TDM. As a result, bit TDM is usally preferred for the multiplexing of synchronous channels. Since there are no redundant start and stop bits in synchronous transmission, character TDM offers no advantages in efficiency. Modern Time Division Multiplexers accommodate a wide range of terminal speeds and codes. Typically, speeds from 50 to 9600 baud and any combination of ASCII, IBM and Baudot codes may be mixed.

It may be noted that the channel in a Time Division Multiplexer is allocated to a fixed time slot on the high speed line. A slot is allocated to a channel whether it is active or not, idle characters are inserted if a channel is not active. Therefore, even when a channel has sporadic or low use, the time slot must be allocated. This leads to inefficient use of the high speed line.

Another deficiency of conventional TDMs is that errors occurring on the high speed line cannot be corrected and will cause corruption of the characters received by one or more channels. This does not matter of the terminals connected to the multiplexer have their own built-in error correction features, but a large proportion of terminals in use are simple asynchronous devices without this capacity.

Lack of error correction effectively limits the application for which the conventional TDMs can be used. Also on all lines except the very best, the error rates experienced are unacceptable to the user. This is especially true if the high speed line is operated at 9600 bps or faster in order to squeeze the maximum number of channels into the line.

Statistical Time Division Multiplexer (STDM) overcomes the problems associated with the conventional TDM. The STDM operates on the principle that at any one instant only some of the channels will be transmitting data. The TDM "frame"is "collapsed" with no idle characters being inserted. Instead, addressing infomation is included to indicate for which channels data characters are present. Using STDM an improvement of 2 to 4 times can be achieved in a typical application. The STDM can be safely used at high speeds to provide very efficient use of the lines even in highly sensitive applications where data loss or corruption unacceptable.

Concentrators : The Concentrator, as the name implies, helps in concentrating a set of terminals at a site. Once the concentrator is used, individual communication lines between the terminals and the computers are no longer required. The concentrator works based on the following simple principle. It collects all the data to be passed in one direction (say from terminal to the computer), tags it to identify the source and then puts it out on one of the serial lines. Obviously, the concentrator should have its counterpart as an integral part of the computer. This part (may be in hardware and software but typically in firmware) will separate the data to its original form and feed it to the computer for further processing. At this point, the data looks similar to the one received from the local terminals which are connected via dedicated cables.

The exact differences between multiplexers and concentrators can be brought out as follows. While a multiplexer codifies several low speed lines into a single high speed line, the concentrator enables several lines to share a few lines.

In general concentrators can be used for connecting a groups of serial devices to a remote computer. That is, the terminal in Figure 9.15 can be replaced with any input/output device, viz., a printer or even a microcomputer itself. When only terminals are used with such an equipment, then, it is called terminal concentrator.

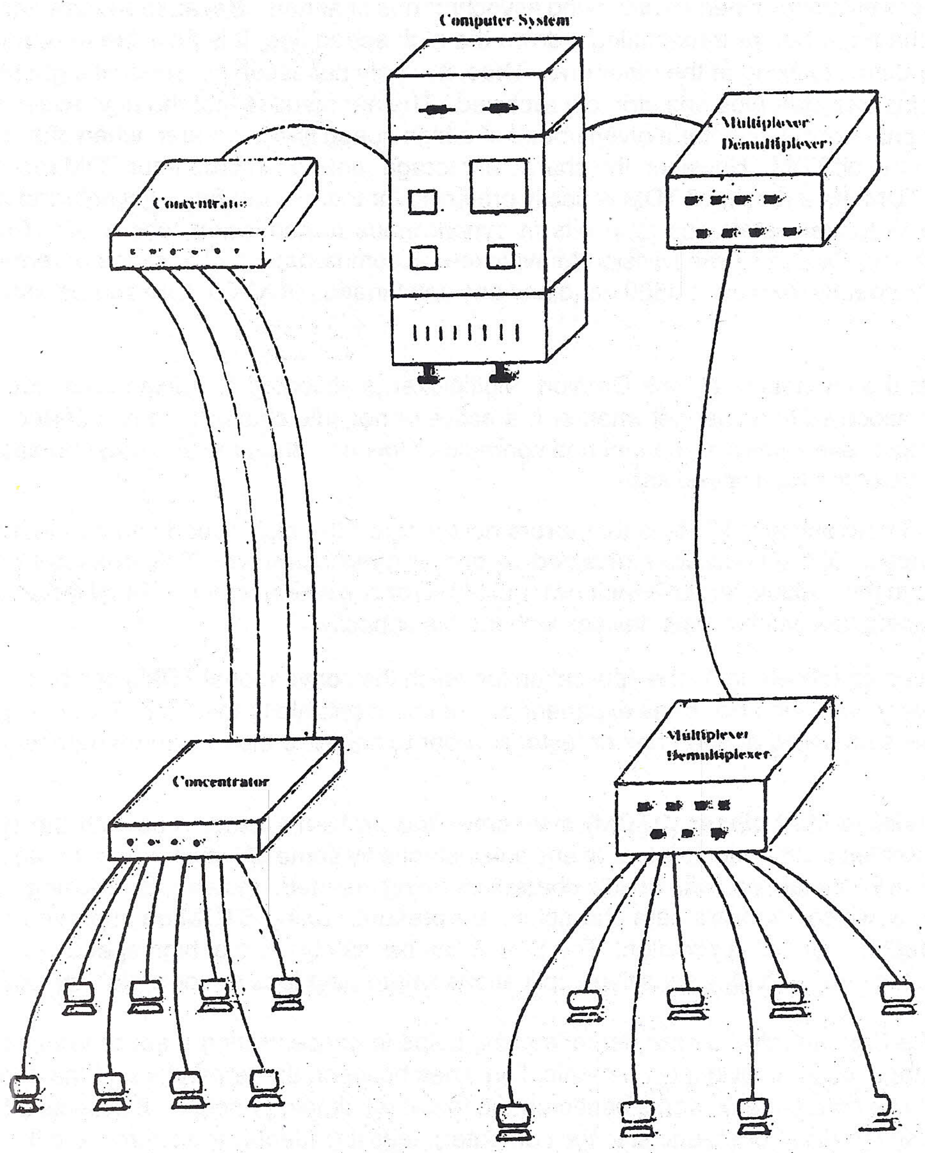


Fig. 9.15. Concentrator and Multiplexer

There are certain other devices which combine the functions of both multiplexers and the concentrators, they are called statistical multiplexers,

Communication Controllers

The most important device which controls the functions of data transmission is the communication controller. The main purpose of this equipment is not to optimise the use of transmission facilities but to optimise the usage of the host computer to which it is attached. As we have stated earlier the transmission takes place byte by byte or bit by bit. These bits are sent to the computers at the speed of the line, they are assembled to form the characters and also checked for the transmission errors. The communication controller is used to remove these functions from the host computer. These communication controllers are also called transmission control or line control computers. These controlling equipment feed information to the main computer (Figure 9.16). It thus maintains the discipline on the communication line and relieves the host computer from these jobs. The communication controller has its own instruction set that is different from the conventional computers.

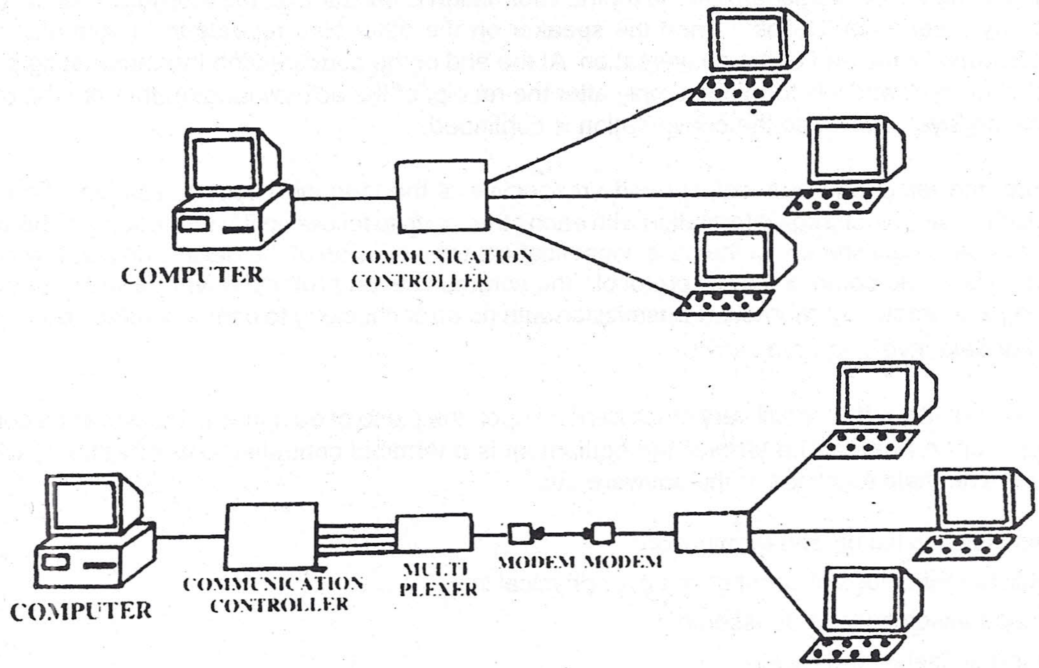


Fig. 9.16. Use of Communication Controller

To overcome the problems of interfacing, the hardware manufacturers have come up with standards for interfacing. The most commonly used interface is the RS-232 interface. This clearly defines the physical and logical standards for connecting devices, such as, connecting terminals, modems.

Personal computers

The personal computers have proliferated in all activities. This becomes one of the most common data terminal equipment which is used in many data communication systems.

The personal computers usually have two ports: one serial and other called parallel port. The parallel port is mostly used for connecting the line printer. The 25 pin DIN is the most common connector used for the line printer connection. However, the standardised interface is the centronics interface which uses a 36-pin connector.

The serial port is used most oftem in connecting the personal computer to the remote mainframe using modems. This interface is mostly known as RS-232-C. Most of these adaptors terminate in the standard 25-pin connector. A notable exception is the PC-AT (in some cases) P which has a 9-pin connector of 25-pin connector.

9.5. DATA COMMUNICATION SOFTWARE

In the preceding two sections we have discussed the communication media and the interface between the communication media and the computer equipment. In this section, we will be discussing the software that is required on the terminal equipment (computer) to bridge the gaps and interpret the bits/bytes that are transmitted via the communication media through the interface. This is illustrated by the following example:

When people use a telephone they follow a particular procedure or a protocol. First, the disired telephone number is dialled. Then the establishment of the physical link to the disired number is confirmed with telephone bell sound. The receiver acknowledges the call by saying 'Hello'. This is confirmed with a return 'Hello' from the speaker. Subsequently, the parties identify each other. Only after this identification process, the information is exchanged. During the conversation, whenever the information is not audible, the listeners request repetition of information by a series of 'Hellos'. Then the speaker on the other side repeats the information and this process is continued till the end of the conversation. At the end of the conversation the terminating process is initiated by saying 'bye'; and it is terminated only after the receipt of the acknowledgement from the other side by a reciprocating 'bye', otherwise the conversation is continued.

This procedure, the telephone protocol, is used irrespective of the language communication. Similarly, the computers which have to exchange information with each other have to follow similar procedures. This collection of rules for physical establishment of the calls, identification, transmission of the data, non acknowledgement and terminattion is called communication protocol. the communication protocol covers a wide spectrum and range from single character by character transmission with no error checking to complex rules about moving of large amount of data involving many devices.

The requirements of the software will very much depend upon the piece of equipment that would be connected. It would depend upon whether the terminating equipment is a terminal controller, concent-ator, a switch or a host computer. The main functions of the software etc.

- transmission initiation and termination,
- establishment of logical connections over physical line,
- message assembly and deassembly,
- data transmission and receipt,
- code conversion,
- error detection,
- data editing,
- control character recognition,
- data delivery,
- data output,
- transmission monitoring and maintenance.

In addition to these the system also has to schedule and monitor the resources.

The software that fulfils these functions may completely reside on the central computer or part of it may be located on the front end communication computers, a concentrator or remote concentrators or in the intelligent terminals.

The desingner of data-communication software faces some unique problems. The most basic of these is time dimension. In a normal batch processing system the software may be designed so as not to accept any inputs until all the stipulations/conditions are met. Whereas, in a data-communication environment data/users arrives in time and sequence beyond the control of the desingner. It also has to face the errors that may be caused by the media or the equipment connected to it, for example, major breakdowns like line failures, of interruptions lasting as long as one or more message. Because of these and other reasons the communication software is different from other software.

For this reason while developing the communication software the principles of software design and development namely: modularity, hierarchy and generality-are comprehensively and completely followed.

The software of advanced computers is always developed in layers. Different layers perform different functions and provide services. This applies to any major software like operating system of database. Similar technique is also applied to data-communication software. These layers of software have to ensure that the data is physically transmitted and the user receives it with no errors. Whatever, necessary storage, error correction, monitoring and security that have to be provided will have to be embedded between various layers of communication software. For advanced computer separate computers are made to perform these tasks. By these processes the activities are made transparent to the user while accessing or delivering the services.

It is evident that computers of different vendors, having different operating systems, should have a common communication protocol to facilitate their communication with each other. Towards establishment of standards the International Standard Organisation (ISO) has defined a seven layer architecture called Reference Model of Open System International (OSI). This International standard 7498 provides the source of documentation with OSI reference model. This model is also now documented in the CCITT X.200 series. The ISO and CCITT versions of the model are essentailly the same. This model provides a basis for coordinating the development of a standard that would facilitate a flexible interconnection of systems using data-communication facilities.

The seven layers of the OSI are:

- physical layer,
- data link layer,
- network layer,
- transport layer,
- session layer,
- presentation layer and
- application layer.

Each of these layers performs certain specific tasks. The physical layer's objective is to support a wide variety of physical media for interconnection by using suitable control procedures. This is the lowest layer in architecture.

Data link layer: provides methods for error-free transmission over the physical layer. The layer is above the physical layer.

Network layer: performs the delivery of data through certain protocols such as routing. It provides a communication path between the two end- points.

Transport layer: forms the uppermost layer of data transport service. It isolates higher level entities from any concern of transport of data from one system to another. It makes the network transparent to the users.

Session layer: mainly performs the job of the controller and synchronises the dialogue session between the systems.

Presentation layer: also provides a general service not unique to a specific application. It mainly concerns a represeniation and manipulation of data. It provides service to the application layer.

Application layer: makes use of the service provided by the lower layers by providing interface to the user processes.

The four main principles in the layering are:

a) to define as few layers as possible while ensuring that each layer performs a specified task.

b) Each layer performs a small job but at the same time ensures that the number of interactions between the layers is minimised. Each layer is independent of the other to facilitate complete predesign and to facilitate maximum advantage of the architecture. Each layer will provide a service to the upper layer and derive service from the lower layer.

c) Each layer can be modified without affecting the other layers.

d) The interface between the layers should be clearly defined so that the other layer can be independently developerd. Each layer will communicate to its next lower and its next upper layers only.

Type of Protocol

The data-communication protocols are either bit-oriented or byte-oriented. Bit-orinted protocol transmit data in blocks of any length up to a specified number. In this, acknowledgement takes place after one or several blocks have been sent; depending upon the protocol, the normal size is 18 to 512 characters of bytes. In a byte-oriented protocol the data is transmitted in 8 bit blocks. The acknowledgement is effected after each transmission. By this we mean transmission on a block. The complexity of the communication protocol very depends upon the complexity of the network. In a simple host terminal exchange it is not necessary to identify and verify the communication as it has been established physically. However, it will be required when several terminals are made use of as a single line or a concentrator.

The most commonly used data communication protocols are synchronous (STIC) and by-synchronous (BSC), Higher Level Data Link Controller (HDLC), multipoint poll select, etc. Recently, efforts have been made to evolve a common communication protocol which would facilitate different vendor machines to communicate with each other. One of such protocols, which has wide accessibility, is the CCITTS x.25 recommendation.

9.6 DATA TRANSMISSION ERROR AND RECOVERY

Data, while it is being transmitted, may suffer some damage. This can be due to the characteristics of the transmission medium or due to external disturbances. In either case, the data bit 1 or 0 that is transmitted will be recieved as 0 or 1, as the case may be. Please note that for a given bit the error is either 0% or 100% and nothing in between! When a bit is received erroneously the character 'A' sent by the transmitter will not be received by the receiver as 'A' but as something else. If we consider a communication channel capable of transmitting 9600 bits per second or approximately 960 characters per second, then we need to estimate as to what percentage of these characters are transmitted correctly. This can be a measure of the quality of the communication channel. For example, to arrive at such a quantifier, one can transmit a million bits and see how many of them are received correctly. This will give the Bit Error Rate (BER) of the channel. One need not count patienly up to a million. There are standard test equipment available that transmit a large number of bits and measure the quality of the line. Similarly, blocks of data can be transmitted and the quality can be assessed by measuring the percentage of good blocks in the receiving side. These are called Block Error Rates (BLER) of a channel.

Since the channels are error prone, recovery mechanisms are a must. For example, even if a single bit is lost, the whole character consisting of eight bits is lost! One would like to capture at that level and request the transmitter to retransmit the lost character. For doing this a prior understanding between the sender and receiver is required. Such an understanding is called the "protocol". Protocol between two communicating systems essentialy determines who can talk what and when. In fact, the asynchronous character transmission is based on "start-stop" protocol, which helps in restricting the transmission loss to a character. Recovery from the loss of a character will require that the receiver is able to signal back to sender. This leads us naturally to the need for a higher level of protocol.

"Protocol" has two main purposes: (1) to ensure that the information is transmitted when and only when the communication channel is free and the appropriate terminal devices are ready to receive; and (2) to prevent corruption or loss of information during transmission.

The term "protocol" is used to describe the set of rules governing information flow in a communication system. What is required is a method of checking the transmission of data and, if an error occurs, of informing the transmitting node or computer so that the transmission of the same data may be repeated. The solution is to break up the transmission into blocks containing a convenient number of characters and to add to each block a check character or characters, computed from the data characters according to a predetermined algorithm. By recomputing the check character (s) at the receiving end, it can be determined, to a certain level of probability, whether an error has occurred.

The receiving terminal can then send a character to indicate either that the block was error free or that an error occurred and a retransmission is required. These two responses are sometimes designated as ACK for "acknoledgement" (i.e. all correct) and NAK for "negative acknowledgement" (i.e. an error has been detected). Such a simple protocol is illustrated in Figure 9.17 with the application called file transfer.

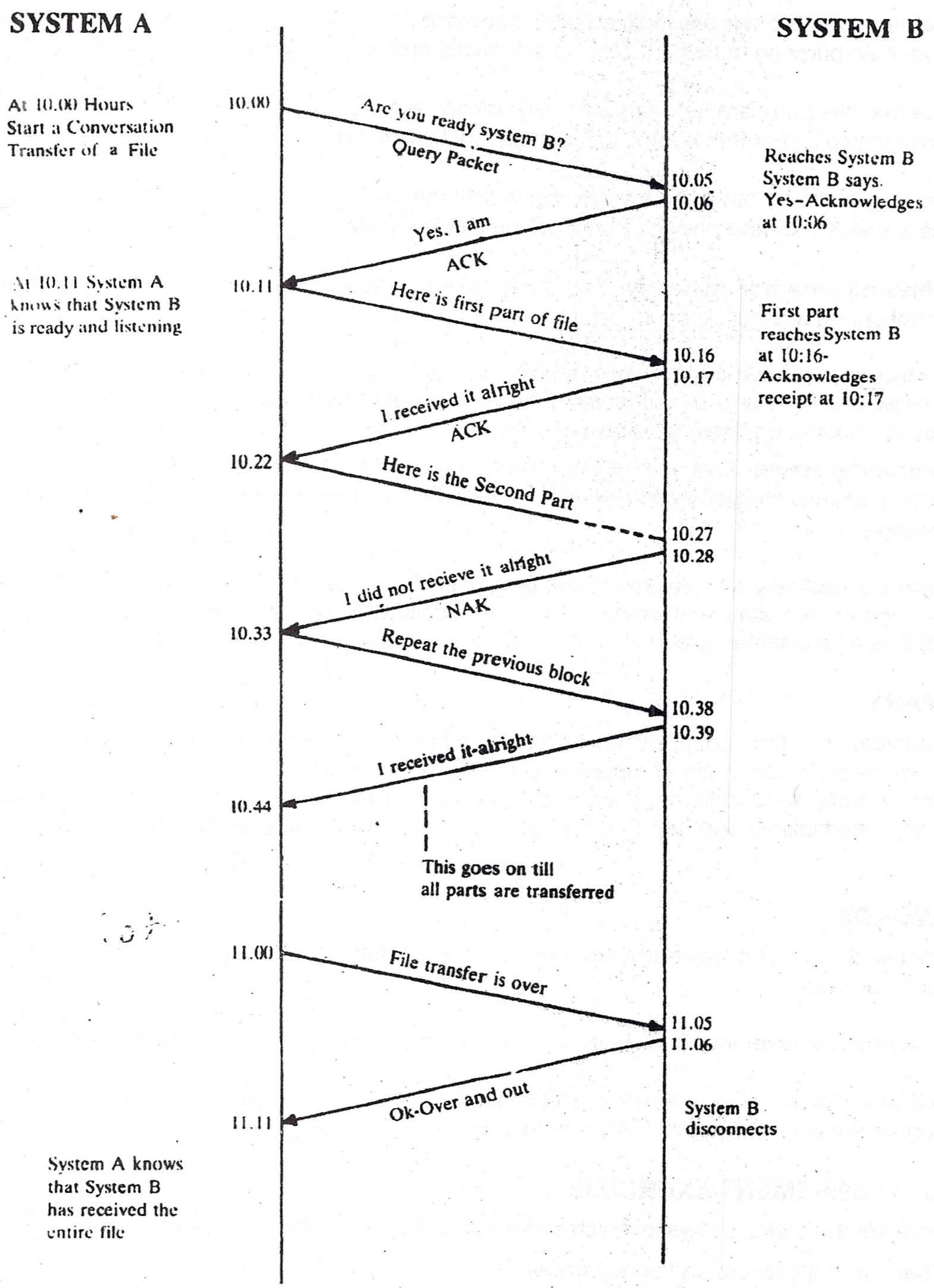


Figure 9. 17 An Illustration of a Sample Protocol

The protocol just described also guards to a high degree against loss of data: if the terminal receives nothing or becomes inoperatinve it will respond with neither ACK nor NAK: the computer can be programmed to take appropriate action in such a case. Such an error control system is also known as ARD (Automatic Repeat Request) system.

9.7. DATA COMMUNICATION PROTOCOLS

At the lowest level (or should we say the first level), hardware protocols, like asynchronous transmission protocol, operate. The main purpose of these protocols is to synchronise between transmission and reception.

To make sure that bits (or characters) are securely transmitted through the channel or line, we need a link level protocol between two computers. Some of the main functions to be performed by such a link level protocol are:

- Ensuring that the data to be transmitted is split into data blocks with beginning and ending markers. This is called **framing** and the transmission block is called a frame.
- **Achieving data transparency**. This allows a link to treat a bit pattern, including normally restricted control characters, just as pure data.
- **Controlling the flow of data across the link**. It is essentail not to transmit bits faster than they can be received at the other end. Otherwise, the receiver overflows and the data is overrun, or all buffering capacity is used up, leading to loss of data.
- **Controlling errors.** This involves detection of errors using some kind of redundancy check. It also involves acknowledgement of correctly received messages and requests for retransmission of faulty message.

There are basically two classes of link protocols. They are BInary SYNchronous protocols (BISYNC) and High Level Data Link Control (HDLC) protocols. BISYNC is based on character control, whereas HDLC is a bit-oriented protocol. In fact, HDLC is widely used in most link protocols of computers.

9.8 SUMMARY

Data Communication is the transportation of data from one point to another through a communication media. In data communication, the main components are data source, data sink and communication media. The concept of baud, serial and parallel modes of transmission, hardware equipment required for data communication, error recovery mechanisms and the requisite data communication software have also been dealt with in this unit..

9.9 KEY WORDS

Data Communications : The transmission and reception of data, often including such operations as coding, decoding and validation.

RS-232C : A Physical layer interface standard for the interconnection of equipment, established by EIA.

Two Wire (2Wire) Circuits : Circuits comprising two conductors insulated to each other. This circuit provides a go and return channel for the signals of same frequency.

9.10 SELF-ASSESSMENT EXERCISES

1) What are the various ways in which serial transmission can be achieved ? Explain each way in detail.
2) What are multiplexers and concentrators ?
3) What are the main functions of data communication software ?

9.11 FURTHER READINGS

Black Uyless D., *Data Communications and Distributed Networks* (Second Edition); A Reston Book, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Hunt, Roger and Shelley, John, *Computers and Common Sense* (Fourth Edition). Prentice- Hall, of India Private Limited, New Delih, 1989.

Indira Gandhi National Open University , School of Engineering and Technology; DCO-5: *Modern Office, Block - I : Communication in the Office,* Unit 2A.