Indira Gandhi
National Open University
School of Computer and
Information Sciences

BCS-041
Fundamental of Computer Networks

Block

1

CONCEPTS OF COMMUNICATION AND NETWORKING

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COURSE INTRODUCTION

Computer networking is the practice of connecting two or more computing devices for the purpose of communication and sharing data. These networks are designed with a set of computer hardware and computer software. The various communication functions and services of networking are grouped into seven layers according to OSI reference model. These layers are called Physical, Data Link, Network, Transport, Session, Presentation and Application Layer. This course introduces the basics of data communication and networking. Students will develop an understanding of the general principles of data communication and networking as used in networks. It also includes an activity of setting up a small local area network. The objective of this course is to enable students in developing an understanding of the structure of network, its elements and how these elements operate and communicate with each other. Along with this course material of BCS-041, you must read the book and study material suggested you in the last of each unit. This course on fundamentals of computer networks is divided in the following four blocks:

Block 1: Concepts of Communication and Networking gives an introduction of data communication and networking. It covers basic details of techniques, methods and schemes used at the physical and data link layer of OSI model.

Block 2: Networks and Devices is an introduction to the various hardware devices and wires used for designing different networks. Most of these hardware devices are used at physical, data link and network layer of OSI model.

Block 3: Network, Transport & Application Layer covers the details of various protocols used in the top three layers Network, Transport and Application Layer of the OSI model.

Block 4: Network Design & Security will give you the fundamental details for setting up a small local area network including wired and wireless setup. This block will also cover the foundational details of network security protocols and wireless networking.

BLOCK 1 INTRODUCTION

This block named **Concepts of Communication and Networking** gives an introduction of data communication and networking. It covers basic details of techniques, methods and schemes used at the physical and data link layer of OSI model. This block is divided into the following four units:

Unit 1: **Basics of Data Communication.** It will introduce you some of the basic concepts of data communication and computer networking. In other words, though this unit we would like to explain the "What, Why, When, How, Where" of data communication.

Unit 2: **Modulation and Encoding**. In this unit, we will discuss about different modulation and encoding techniques. Further, this unit we will explore how analog signals are converted into digital system and vice-versa.

Unit 3: **Multiplexing and Switching**. Multiplexing and Switching are two most important techniques being employed for this purpose in the present day communication systems and have been discussed in this unit.

Unit 4: **Communication Mediums**, This unit will discuss about various communication mediums and cables used in wired and wireless networking.

UNIT 1 BASICS OF DATA COMMUNICATION

Structure **Page No.**

1.0 INTRODUCTION

This is the first unit of our course on Fundamentals of Computer Networks. It will introduce you to some of the basic concepts of data communication and computer networking. In other words, though this unit we would like to explain the "What, Why, When, How, Where" of data communication. In the beginning, you will be introduced with the concept of communication and "communication system". Once you understand the communication system and its components, we think other areas will be simpler for you. Different forms of data communication are further introduced to you in this unit. Next, we will discuss about various modes of communications. This unit will eventually cover an introduction to computer networking, networking protocols and standards, those are necessary for any effective communication. In the end of our unit, we will discuss various applications of data communication and computer networking.

1.1 OBJECTIVES

After going through this unit, you should be able to:

- Know the concept of communication system
- Understand the communication system and its components
- Differentiate between analog and digital Communication
- Know data communication modes
- Differentiate between synchronous and asynchronous transmission
- Differentiate among Simplex, half-duplex, full duplex communication
- Understand the need of protocols and standards
- Know the functions of OSI layers
- Understand the concepts of encapsulation and End-to-end argument
- Know the different protocol design issues

- Know the applications of computer network

1.2 CONCEPT OF COMMUNICATION SYSTEM

Before we discuss about "communication system" and its components, let us understand "communication". Can you define it, what definition will come first in your mind? When we asked some students, answers were like:

- Delivery of message
- Proper way of passing a signal to the intended user
- Right message, to right person, at right time through right way.

So many "rights"! and all seems to be 'Right'. Let me inform you about some definitions of communication:

- " Communication is transfer of information from one person to another, whether or not it elicits confidence. But the information transferred must be understandable to the receiver – G.G. Brown.
- The imparting or exchanging of information by speaking, writing, or using some other medium.-Oxford Dictionary

After going though these definitions, I am sure now we can list the components required for some communication:

- **Sender**: who is trying to send a message to the receiver?
- **Message or Signal**: the message is the actual content for communication
- **Communication Medium**: The medium is what the message is transmitted on. The phone system, it is wire. Television and radio use air
- **Receiver**: The receiver is the target of the message.

There is something missing in this list, can you guess? That is encoding and decoding. Try to conceptualize a discussion with your friend. While talking with your friend you encode your message in a speaking language and on the other side your friends (receiver) decodes your language and understand the message. In the same way, if you are talking to your friend over telephone, it is not possible to actually transmit voice across the wire for any distance. The telephone set converts the sound into electrical pulses, which can be transmitted by wires. The decoder takes the encoded message and converts it to a form the receiver understands, in continuation of our previous example phone system convert electrical pulses into voice.

Let's see a block diagram for a communication system as depicted in the Figure 1.

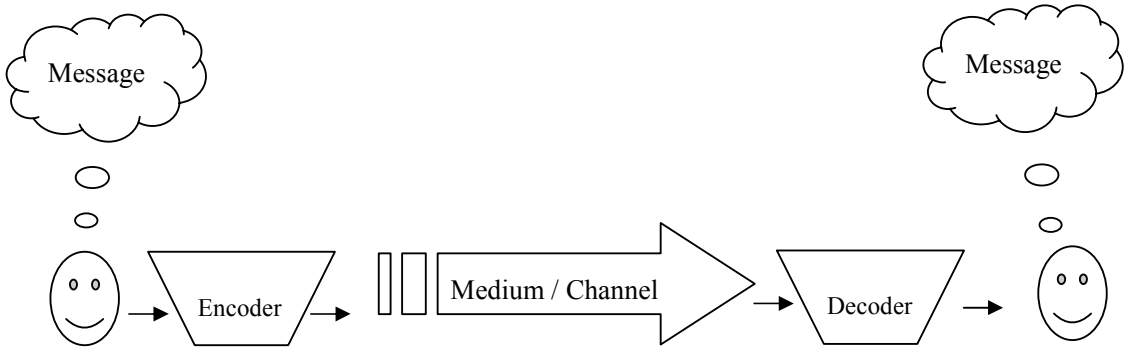

Figure 1: Block Diagram of Communication System

Now, can you try to explore some communication systems around us? Ok, let's list some:

- Human communications operate through speech, signs, gestures, body language, etc. Note that the communication mediums are air and light.

- Telephone system are a kind of communications system which we use in day to day basis, it is a collection of individuals, telephone handsets for transforming voice into electrical signals), wires (communication medium), some controlling and call management devices, Telephone exchange, etc. Remember that the components of a communications system serve a common purpose, are technically compatible, use common procedures, respond to controls, and operate in unity.

- A radio or television communication system is composed of several communications subsystems that give exterior communications capabilities. These are also known as public broadcasting systems, because they broadcast the messages/signals in the air and any one in the coverage area with a receiver can receive the signals. Such systems comprises of a large transmitting station for converting and transmitting the audio/video into the air, and on the other side if signals are public can be decoded and converted again into the same audio/video.

By now, you must be curious to know the mechanism used for converting a message (text, video, audio, etc) into some electrical signals. How does it function in a system?

Let us understand the communication from the technical or mathematical point of view, C.E. Shannon [Claude Elwood Shannon (April 30, 1916 – February 24, 2001) was an American mathematician, electronic engineer, and cryptographer known as "the father of information theory".] had worked on some of the fundamentals in the communication, like:

- How the symbols of communication are transmitted between sender and receiver?

- How the meaning is conveyed through the transmitted symbols?

- What is the effect of the received meaning?

According to Shannon, following are the essential elements of communication also shown in the Figure 2 below:

1. Information source: Source that produces a message

2. Transmitter: An element that functions on the message to generate a signal which can be delivered through a medium/channel

3. Communication Channel: that is a medium over which the signal (carrying the information that composes the message) is sent.

4. Receiver: An element that intercept the signal and converts it back into the message

5. Destination: It can be a person/machine, for whom / which the message is intended.

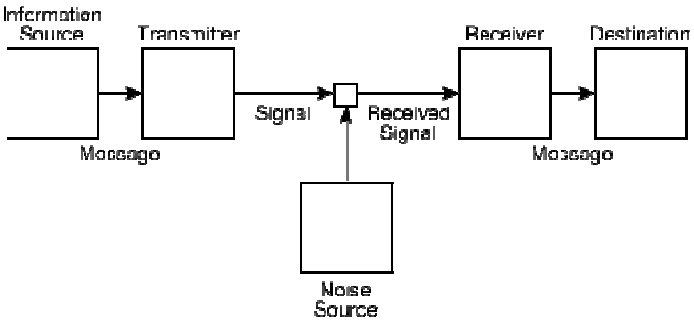

Figure 2: Shannon's diagram of a general communications system

Here, the noise is considered as an error or undesired disturbance that occurs during the transmission (before receiver and after transmitter), from natural and sometimes man-made sources.

1.3 ANALOG AND DIGITAL COMMUNICATION

We all have heard these terms several times, like analog signal, digital signal, digital TV, analog radios, etc. In this section, we will explore the basic definitions and differences of analog and digital communication. Two main types of signals encountered in practice are analog and digital. The figure 3 shows analog, discreet and digital signals, digital signals outcome from approximating an analog signal by its values at particular time moments. Digital signals are discrete and quantized, while analog signals possess neither property.

Technically, if we observe the elements and processes of any communication system, you may notice that all the components and processes of a communication system should be aligned, compatible and work as a unit. Try to remember our example where telephone system is converting voice into electrical signal, in this case receiver instrument must be compatible and convert the electrical signal or voice signal in the similar way, otherwise your message will never be delivered.

Here, we have to address one important point that is how does the message is being converted? We have two options one is analog and another is digital.

- As you may know that an analog is something continuous, which is having time varying feature (variable). Analog signal is a representation of some time varying quantity. For example, Human voice can be considered as an analog signal. In analog signals data are represented by continuously variable, measurable, physical quantities, such as current, voltage, or pressure.
- A digital signal is a physical signal that is a representation of a sequence of discrete values, for example of a bit stream. In digital technology, generally a signal is converted into a bit form represented by a series of "1"s and "0"s. Please note here that "1"s and "0"s are nothing but two states usually represented by some measurement of an electrical property: Voltage is the most common, but current is used in some logic families. A threshold is designed for each logic family.

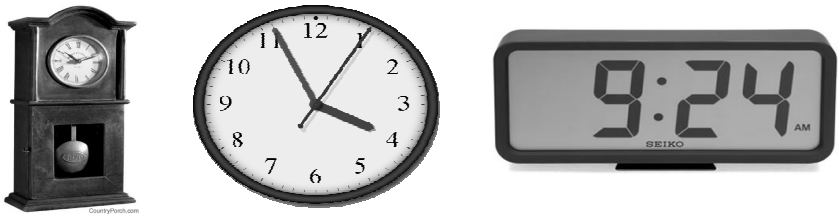

Figure 3: Analog, Discrete and Digital Clocks

In a communication system, data signals are propagated from one point to another by means of electrical signals. An analog signal (Figure 4a) is a continuously varying voltage signal that may be propagated over a variety of media. A digital signal (Figure 4b) is a sequence of discrete values for example any bit stream.

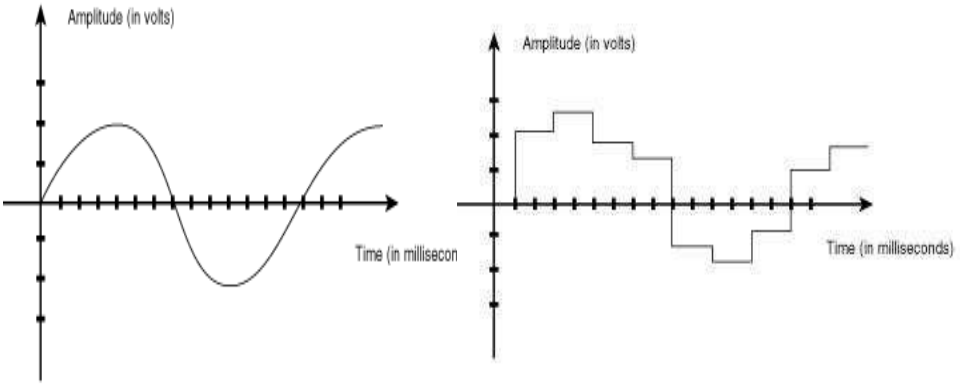

Figure 4 a): Analog Signal **Figure 4 b): Digital Signal**

Analog and **digital** signals are used to transmit information, usually through electric signals. In both these systems, the information, such as any text, audio or video, is transformed into electric signals. Let us see some of the differences between analog and digital systems below in table 1.

Table 1: Comparison between Analog and Digital system

Analog	Digital
Signals are records waveforms as they are. Signal occupies the same order of spectrum as the analog data.	Converts analog waveforms into set of numbers and records them. The numbers are converted into voltage stream for representation. In case of binary it is converted in 1's and 0's.
In analog systems electronic circuits are used for transformation of signals.	In this transformation is done using logic circuits.
About Noise analog signals are more likely to get affected and results in reducing accuracy	Digital signals are less affected, because noise response are analog in nature
Analog signal is a continuous signal which transmits information as a response to changes in physical phenomenon.	Digital signals are discrete time signals generated by digital modulation.
Data transmission is not of high quality	Data transmission has high quality.
Analog devices are not very precise.	Digital systems are very precise.

Can you explore the reasons why digital signals are seems to be better? Let us see why digital communication having high quality? Because, digital devices decode and reconstruct data, due to which loss of quality of data as compared to analog devices is much higher. But analog signal are affected by noise. While amplifying the signal noise also gets amplified. Therefore it becomes difficult to filter out noise from the signal and the message gets corrupted. Digital signal are least affected by noise. And further

computer advancement has enabled use of error detection and error correction techniques to remove disturbances artificially from digital signals and improve quality. Now days, digital signals has been most proficient in cellular phone industry. Analog phones have become superfluous even though sound clarity and quality was better.

☞ Check Your Progress 1

1. List the essential elements of communication system. Also, draw and explain the Shannon model of communication system.

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2. Write any four differences between analog and digital communication.

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1.4 DATA COMMUNICATION MODES

In this section, we will learn about some modes of data communication used in computer networking. Because we are going to study computer networking, we assume all data communication is digital. Digital communications is the physical transfer of data/bits over a communication channel. As you may know, data are represented as an electromagnetic signal, such as an electrical voltage, radio-wave, microwave, or infrared signal. The channel or medium could be air (for wireless/mobile communication), copper wires, or optical-fibers. Remember, the data transmitted can be pure digital messages generated from a digital-data source, like a computer or a keyboard. However, it may also be an analog signal such as a human voice over phone call, which could be digitalized.

Serial and parallel transmission

In digital communication, serial transmission of data refers to sequential transmission of bits, where a group of bits over a single channel represents a character. It requires less processing and fewer chances for error. The start and stop of a communication is specified by LSB (lowest significant bit) and MSB (most significant bit) as shown in the Figure 5.

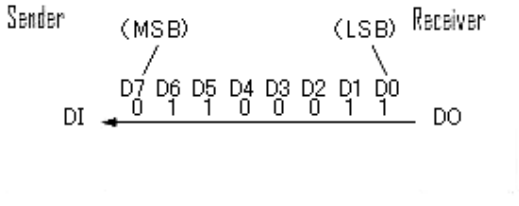

Figure 5: Serial Communication

Parallel transmission refers to simultaneous transmission of the bits over two or more separate channels. Here, we can transmit multiple bits simultaneously as given in Figure 6, which allows for higher data transfer rates than that can be achieved with serial

transmission. For example, for internal data communication in a computer system this method of parallel transmission is used. Parallel data transmission is less reliable for long distances because error correction is not very simple and economical in this case.

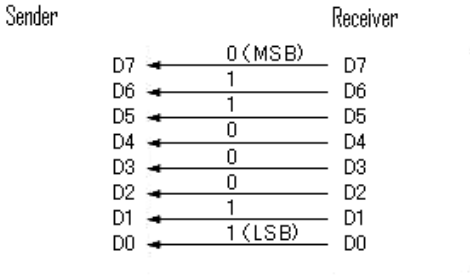

Figure 6: Parallel data transmission

In serial transmission, the byte plus the parity bit are transmitted one bit after another in a continuous line. In parallel transmission, 8 bits (a byte) plus a parity bit are transmitted at the same time over nine separate paths. Thus, parallel transmission is generally faster than serial transmission.

1.4.1 Synchronous and Asynchronous Transmission

Synchronous transmission means both receiver and sender has an agreement (or aware) about timing for the sending data, so that both sender and receiver can coordinate (synchronize) their data signals. Asynchronous means "not synchronous", or no coordination between sender and receiver before transmission. Can you try to explore some examples of Synchronous and asynchronous communication that occurs in your day to day life?

The asynchronous transmission uses start and stop bits to signify the beginning bit. For example, if sender wants to send some data "**11100001**", it will be appended with the start and stop bit and look like "1 **11100001** 0". Where, we have assumed that '0' is start bit and '1' is stop bit. Asynchronous transmission works well where the characters are transferred at irregular intervals e.g. data entry from the keyboard.

Asynchronous transmission has some advantages and disadvantages, like:

- Each individual character is complete unit, hence if there is an error in a character, other sequence of characters are not affected. However, Error in start and stop bit(s) may cause serious problems in data transfer.
- Doesn't require synchronization of both communication sides.
- It is cost effective
- The speed of transmission is limited.
- Large relative overheads, a high proportion of the transmitted bits are uniquely used for control purposes

In case of synchronous transmission, we do not use any start and stop bits, but instead of that clock signal end (clock is built into each end of transmission) is being used for synchronizing the data transmission at both the receiving and sending. A constant stream of bits is sent between the sender and receiver. As clock synchronization may disturbed the possibility of error increases in synchronous transmission. Synchronous transmission has following advantages and disadvantages:

- In comparison to asynchronous communication it has higher speeds, because the system has lesser possibility of error. But, if an error takes place, the complete set of data is lost instead of a single character.
- Serial synchronous transmission is principally used for high-speed communication between computers but is unsuitable where the characters are transferred at irregular intervals.
- It is gives lower overheads and thus, greater throughput.
- Process is more complex
- It is not very cost effective as hardware are more expensive

1.4.2 Simplex, Half-Duplex, Full Duplex Communication

The data transmission mode on the channel, can be classified into three ways simplex, half-duplex and full-duplex as given below in Figure 7.

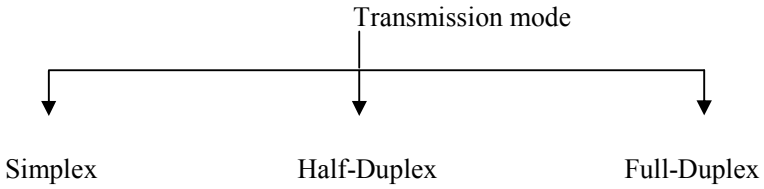

Figure 7: Transmission mode

In simplex transmission (Figure 8a), signals are transmitted in only one direction; one station is a transmitter and the other is the receiver. In the half-duplex operation (Figure 8b), both stations may transmit, but only one at a time. In full-duplex operation (Figure 8c), both stations may transmit simultaneously. In the latter case, the medium is carries signals in both directions at same time.

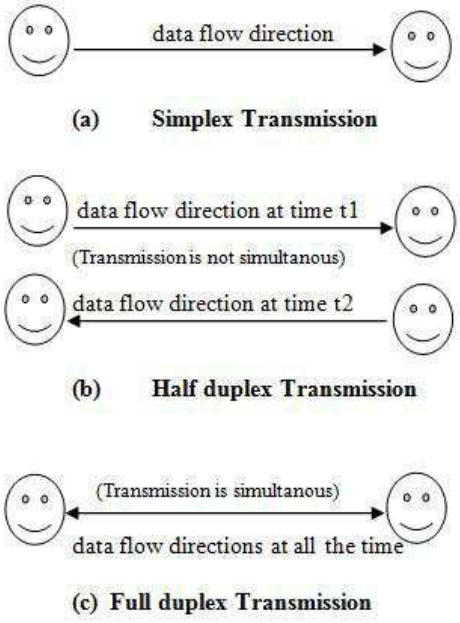

Figure 8(a) (b) (c): Directions of data transmission in Simplex 8(a), half-duplex 8(b), full duplex 8(c) communication

Simplex Transmission

Simplex transmission is one-way transmission. As the name implies, is simple in term of process and hardware. It is also called unidirectional because the signal travels in **only**

one direction. For example, Radio or TV broadcasting system, which are always in one direction from Radio/TV station to our radio or TV sets.

Half-Duplex Transmission

In half-duplex transmission data transmission can be take place in both directions, but not at the same time. This means that only one side can transmit at a time. For example, walky-talky devices used by security agencies are half-duplex as only one person can talk at one time.

Full-Duplex Transmission

Full-duplex (also known as Duplex) transmission can take place in both directions at the same time. For example, telephone or mobile conversation is an example of full-duplex communication, where both sender and receiver can hear each other at the same time.

☞ **Check Your Progress 2**

1. Differentiate between Synchronous and asynchronous transmission.

   ……

   ……

2. Give an example of each communication system based on:
   - Simplex communication,
   - half-duplex communication,
   - full duplex communication

   ……

   ……

   ……

1.5 NETWORKING PROTOCOLS AND STANDARDS

All modes of communication described above follow some 'set of rules' or protocol. Protocol is set of rules that governs communication between the entities engaged in conversation, for example in railways, if a green colour flag is shown a train can start, and if red colour flag is shown train will stop, this is a set of rule and we can say it is a protocol. When we write a letter or talk to someone we follow protocol(s). In case of computer communication also both sender computer and receiver computer should agree on some set of rules like communication language/syntax, scheme of acknowledgement, rules for data control, error control, and other mechanism. Thus, we can say that the conversation is governed by some set of rules known to both the parties. This set of rules is called protocol and it necessary for proper and disciplined conversation/communication.

Problems in Computer Communication

When protocols are implemented for computer communication, we encounter some challenges due to the infrastructure and machines used in computer network may not be compatible and aligned with one another. The concept of Internetworking though, highly desirable, is not easily achievable. Let us see one simple example to understand the compatibility problem, any two networks, cannot directly communicate by connecting a wire between the networks. For example, one network could represent a binary 0 by-5 volts, another by +5 volts. Similarly, one could use a packet size of 128 bytes, whereas other could use 256 byte packets. The method of acknowledgement or error detection

could be different. There could be many such differences. The incompatibility issues are handled at two levels:

i) **Hardware Issues**

At the hardware level, an additional component called router is used to connect physically distinct networks. A router connects to the network in the same way as any other computer. Any computer connected to the network has a Network Interface Card (NIC), which has the address (network id+ host id), hard coded into it. A router is a device with more than one NICs. Router can connect incompatible networks as it has the necessary hardware (NIC) and protocols.

ii) **Software Issues**

The routers must agree about the way information would be transmitted to the destination computer on a different network, since the information is likely to travel through different routers, there must be a predefined standard to which routers must confirm. Packet formats and addressing mechanism used by the networks may differ. One approach could be to perform conversion and reconversion corresponding to different networks. But this approach is difficult and cumbersome. Therefore, the Internet communication follows one protocol suite, the TCP/IP. The basic idea is that it defines a packet size, routing algorithms, error control, flow control methods universally.

It would be unwise to club all these features in a single piece of software ─ it would make it very bulky. Therefore, all these features are logically sub-grouped and then the sub-groups are further grouped into groups called layers. Each layer has an interface with the adjacent layers, and performs specific functions.

1.5.1 Layering

Since it is difficult to deal with complex set of rules, and functions required for computer networking, these rules and functions are divided into logical groups called layers. Each layer can be implemented interdependently with an interface to other layers providing with services to it or taking its services like data, connection and error control functions are grouped together and make a layer. A. Speech in telephone conversation is translated, with electrical segments and vice-versa. Similarly in computer system the data or pattern are converted into signals before transmitting and receiving. These function and rules are grouped together and form a layer.

1.5.2 OSI Reference Model

The OSI model is based on a proposal developed by the International Standards Organization as a first step towards international standardization of the various communication functions and services. Here, communication functions are grouped into logical layers. The model is called the ISO - OSI (International Standard Organisation - Open Systems Interconnection) Reference Model because it deals with connecting open systems — that is, systems that follow the standard are open for communication with other systems, irrespective of a manufacturer. Its main objectives were to allow manufacturers of different systems to interconnect equipment through standard interfaces globally. Allow software and hardware to integrate well and be portable on different systems. The OSI model has seven layers shown in Figure 9. The principles

that were applied to arrive at the seven layers are as follows:

1. Each layer should perform a well-defined function.

2. The function of each layer should be chosen with an eye toward defining internationally standardized protocols.

3. The layer boundaries should be chosen to minimize the information flow across the interfaces.

4. A layer serves the layer above it and is served by the layer below it.

The set of rules for communication between entities in a layer is called protocol for that layer. The seven layers of ISO OSI reference model as shown in the Figure 9 are following:

i) Physical Layer

ii) Data Link Layer

iii) Network Layer

iv) Transport Layer

v) Session Layer

vi) Presentation Layer

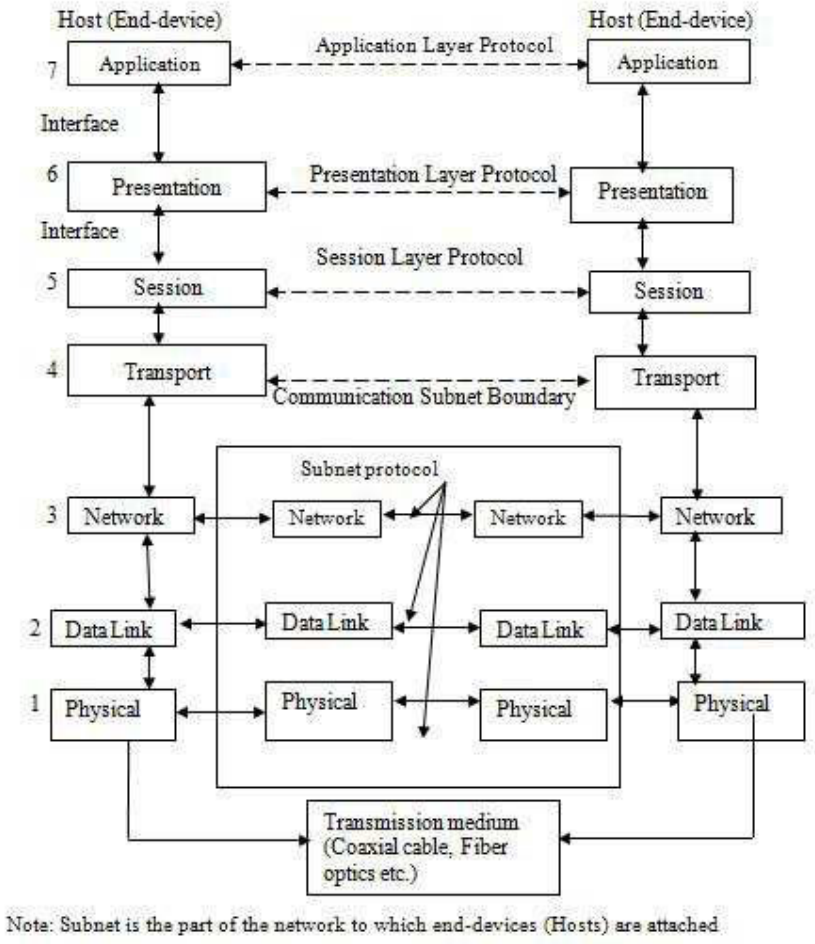

Figure 9: OSI Reference Model

a) **The Physical Layer**

Physical Layer defines functional, electrical and mechanical specifications of signaling, cables, and connectors options that physically link two nodes on a network.

b) **The Data Link Layer**

The main task of data link layer is to provide error free transmission. It accomplishes this task by having the sender configure input data into data frames, transmit the frames sequentially, between network devices and process the acknowledgement frames sent back by the intermediate receiver. The data link layer creates and recognises frame boundaries. This can be accomplished by attaching special bit patterns to the beginning and end of the frame. Since these bit patterns can accidentally occur in the data, special care is taken to make sure these patterns are not incorrectly interpreted as frame boundaries.

c) **The Network Layer**

The network layer ensures that each packet travels from its sources to destination (both in different networks) successfully and efficiently. A key design issue is determining how packets are routed from source to destination. Routes can be based on static tables that are "wired into" the network and rarely changed. They can also be determined at the start of each conversation, for example, a terminal session. Finally, they can be highly dynamic, being determined anew for each packet, to reflect the current network load. When a packet has to travel from one network to another to reach its destination, many problems can arise. The addressing mechanism is used by the second network may be different from the first one. The second network may not accept the packet at all because it is too large. The protocols may differ, and so on. It is up to the network layer to overcome all these problems to allow heterogeneous networks to be interconnected.

d) **The Transport Layer**

The basic function of the transport layer is to accept data from the session layer, split it up into smaller units if need be, pass these to the network layer, and ensure that the pieces all arrive correctly at the other end. Furthermore, all this must be done efficiently, and in a way that isolates the upper layers from the inevitable changes in the hardware technology.

Transport Layer provides location and media independent end-to-end data transfer service to session layer.

e) **The Session Layer**

The main tasks of the session layer are to provide:

- Session Establishment
- Session Release – Orderly or abort
- Synchronization
- Data Exchange
- Expedited Data Exchange.

The session layer allows users on different machines to establish sessions between them. A session allows ordinary data transport, as does the transport layer, but it also provides enhanced services useful in some applications. A session might be used to allow a user to log into a remote timesharing system or to transfer a file between two machines.
One of the services of the session layer is to manage dialogue control. Sessions can allow traffic to go in both directions at the same time, or in only one direction at a time. If traffic can only go one way at a time (analogous to a single railroad track), the session layer can help in keeping track of whose turn it is.

A related session service is token management. For some protocols, it is essential that both sides do not attempt the same operation at the same time. To manage these activities, the session layer provides tokens that can be exchanged. Only the side holding the token may perform the desired operation.

Another session service is synchronization. Consider the problem that might occur when trying to do a 2 hour file transfer between two machines with a one hour mean time between crashes. After each transfer was aborted, the whole transfer would have to start over again and would probably fail again the next time as well. To eliminate this problem, the session layer provides a way to insert markers after the appropriate checkpoints.

f) **The Presentation Layer**

Unlike all the lower layers, which are just interested in moving bits reliably from here to there, the presentation layer is concerned with the syntax and semantics of the information transmitted.

A typical example of a presentation service is encoding data in a standard agreed upon format. Most user programs do not exchange random binary bit strings, they exchange things such as people's names, dates, amounts of money and invoices. These items are represented as character strings, integers, floating-point number, and data structures composed of several simpler items. Different computers have different codes for representing character strings (e.g., ASCII and Unicode), integers (e.g., one's complement and two's complement), and so on. In order to make it possible for computers with different representations to communicate, the data structure to be exchanged can be defined in an abstract way, along with a standard encoding to be used. The presentation layer manages these abstract data structure and converts from the representation used inside the computer to the network standard representation and back. It also performs the task of encryption and decryption.

g) **Application Layer**

Application Layer supports functions that control and supervise OSI application processes such as start/maintain/stop application, allocate/deallocate OSI resources, accounting, check point and recovering. It also supports remote job execution, file transfer protocol, message transfer and virtual terminal.

1.5.3 Encapsulation

Encapsulation is a technique of implementing layered architecture of a communication system. In OSI model we have separated all the communication functions/services into seven layers. We know that a layer serves the layer above it and is served by the layer below it, so to make it possible encapsulation techniques is followed for sending/receiving data between and through layers. In encapsulation we add some control information or "Header/Trailer" to a Data Unit by a communications protocol. This data along with header/trailer is known as Protocol Data Unit (PDU). This header/trailer actually creates an envelope for the PDU which has its address and addressee.

The Figure 10 shows the header associated with each of the N layers of some communication model. When a packet of data (we are saying it as PDU because packets is relevant to some protocol at some layer) is passed by any layer, attach a header (control information) of its layer and passes the packet (along with header) to the layer below. Each layer appends a new header to the PDU received from upper layer. Each layer considers the PDU of upper layer as data, and does not worry about headers in the PDU. This process continues until the packet reaches the lowest layer, which is the communication channel.

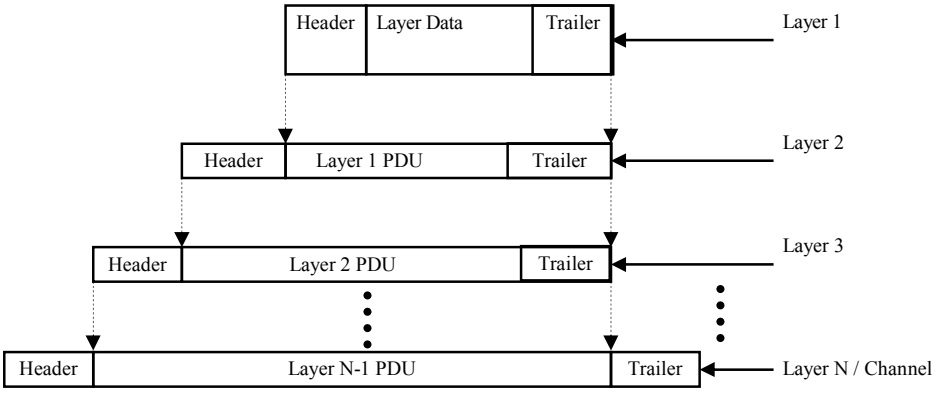

Figure 10: Encapsulation

This lowest layer is considered as physical layer by OSI model, which also add its control information. As you know that physical layer is final end or beginning of any side of communication. It converts PDU+control information into a series of bits and sends it across a cable or telecommunications circuit to the destination. Generally, due to this physical layer add control information at both ends of PDU for management point of view. At the receiver side, the Layer N of receiver reassembles the series of bits to form a packet and forwards the packet for processing by the upper (N-1) layer. This removes the N-1 layer header, and passes it to the next upper layer. The processing continues until finally the original packet data is sent to the program/application running at Layer 1.

1.5.4 End-To-End Argument

Assume we want to transfer some important file or information from a machine available on a network to a machine on other network. In case of a reliable communication we will establish a connection. If connection is available we send the data. Before accepting the data we will ensure the reliability of data at each step or each layer. But at the final stage at receiver (application layer) reliability check have to be performed. If we have to perform a final reliability check at application layer, can we say that we do not require reliability checks at lower layers? Is there any need to implement reliability at lower layers? Yes, it can be implemented but only for improving the performance in case the link quality is poor.

The end-to-end principle states that application-specific functions must be implemented in the end hosts of a network instead of intermediary nodes, provided these functions are “completely and correctly" implemented at the end hosts. The basic concept behind the end-to-end principle is that for two processes communicating with each other via some communication channel, the reliability obtained from that means cannot be expected to be absolutely associated with the reliability requirements of the processes. To be specific we can say, obtaining a very high ‘reliability’ requirements of communicating processes in a small network is more costly than obtaining that ‘reliability’ by end-to-end acknowledgements and retransmissions.

A system should consider only functions that can be completely and correctly implemented within it. We needs to be careful before implementing a functionality that we believe that is useful to an application at a lower layer. If the application can implement a functionality correctly, implement it a lower layer only as a performance enhancement. If implementation of function in higher levels is not possible due to technological/economic reasons then it may be placed at lower levels.

1.5.5 Protocol Design Issues

For communication to take place, protocols have to be agreed upon. Data are sent and received on communicating systems to establish communications. Protocols should therefore specify rules governing the transmission. In general, the following issues should be addressed for designing these protocols:

- Data formats: The format of data should be well defined, how the bit strings are divided in fields and in which format. Here, the packet size and format, PDU format, header size and format should be defines properly for proper communication. Let us assume a postal system, in which we specify, where the address of sender/ receiver should be written. Different kind of letters are represented by different methods like speed post, telegraph, registered post, book post, post card, etc.
- Address formats: Addresses are used to recognize both the sender and the proposed receiver. Mostly, addresses (also a bit string) are stuffed in the header field of the packet, to find whether the packet/data are intended for someone or not. The rules explaining the purpose of the address value are called an addressing scheme. For example, in the postal system, the method and sequence of writing an address is well formulated like name, father's name, house number, street, city, country, pin code, etc.
- Address mapping. Sometimes protocols need to map addresses of one scheme on addresses of another scheme. When the address formats are different than mapping is needed. For example, physical address of a computer need to be mapped with network address of a computer.
- Routing. When systems are not directly connected, intermediary systems along the route to the intended receiver(s) need to forward messages on behalf of the sender. In the postal system, we can see the post offices are selecting and sorting the letter according to the given addresses.
- Acknowledgements Scheme: In connection-oriented communication (communication systems where connection is not established before communication like email or SMS), acknowledgement of correct reception of packets is required. Acknowledgements are sent from receivers back to their respective senders, in the same way of registered posts. connection-oriented communication ensure the reliability by acknowledgement.
- Data Loss and damage: There is a possibility that data is lost or get corrupted (changed from 0 to 1 or vice versa). To address the data loss, protocols may implement acknowledgement scheme. Protocols may use timeout mechanism, in which if data is not received within a time frame sender is requested to retransmit the data. If data is corrupted, different error correction and detection mechanisms can be used.
- Sequence control: In this we wants to ensure that the packets (chunk of bits) are received in a correct sequence or not. The packets are sent on the network individually, so some packets may get lost or delayed or take different routes to their destination on some types of networks. As a result pieces may arrive out of sequence. necessary scheme should be implemented for retransmissions and reassemble the packets in right order to get the original message.
- Flow control is needed when the sender transmits faster than the receiver can process the transmissions. Flow control can be implemented by various schemes, which you will study further in the course.

1.6 APPLICATIONS OF COMPUTER NETWORKING

The main reason is that each computer network is designed with a specific purpose. Due to advancement in Computer Networks field we are now moving from personalized

computing to network computing. Therefore, its application is increasing every day. For example, a computer network in an office is used to connect computers in a smaller area, and it provides fast communication between the office persons/machines. The following is the list of some general application of computer network:

Resource sharing

Using networks we can share any resource, CPU processing power, peripherals like printers, scanners, etc, information like files and data and even software. This sharing is done by communicating the machine through whom we want to share.

Personal communication

There are many examples available with us for personal communication through computer networks, like email, chatting, audio/video conferencing, etc

Information Broadcasting and Search

This is also a mostly used application like website, blogs, social networking website, search engines, etc. Computer network provide us tremendous opportunity for information broadcasting, display, searching and information retrieval. Apart from these commonly used applications of computer networks we have following specific applications of computer networking.

Some Specific end applications

- Campus-wide computing and resources sharing
- Collaborative research and development
- Integrated system for design + manufacturing + inventory
- Electronic commerce, publishing and digital libraries
- Multimedia communication (tele-training, etc.)
- Health-care delivery (remote diagnosis, telemedicine)
- Video-on-demand.
- On-line learning.

☞ Check Your Progress 3

1. Explain the need of layering in the data communication protocols stack.

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2. List and explain any two functions of each OSI layer.

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1.7 SUMMARY

We hope you must have understood the concept of communication and communication system. As we discussed communication system is comprised of Information Source, Transmitter, Communication Channel, Receiver and the Destination. The information could be sent in the various forms like analog and digital. The concept of analog and digital transmission deals with form in which information is available and the way it is transmitted. Analog data is represented by continuous signals. The other type of signal is digital, which uses a bit steam. In this unit we have studied various modes and mechanism of communication like synchronous and asynchronous communication, simplex, half and full duplex communication. We studied that in simplex the data/signals are transmitted in one direction by a station i.e., by the sender, in half duplex the transmission can be done in one direction at a time whereas in full duplex the transmission can take place in both directions simultaneously. Further, in the unit we have explored the computer networking systems, its difficulties in data communication and the need of protocols and standards for these systems. We have also studied the details of OSI reference model and functions of OSI layers. In the end of this unit we have discussed different protocol design issues and listed some of the applications of computer networks. In the next unit, you will be introduced with various modulation techniques and there advantages. These modulation techniques are used to convert the message signal into a different form(s) so that it can be communicated through computer networks.

1.8 REFERENCES/FURTHER READING

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1.9 SOLUTIONS/ANSWERS

☛ Check Your Progress 1

1. Following are the essential elements of communication system.
   a) Information source: Source that produces a message
   b) Transmitter: An element that functions on the message to generate a signal which can be delivered through a medium/channel
   c) Communication Channel: that is the medium over which the signal (carrying the information that composes the message) is sent.
   d) Receiver: An element converts the signal back into the intended message.

e) Destination: It can be a person/machine, for whom / which the message is intended.

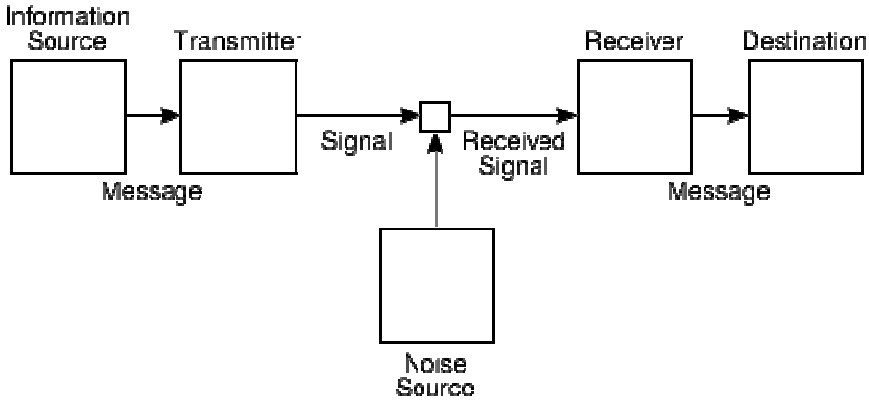

Diagram: Shannon's diagram of a general communications system

Here, the noise is considered as an error or undesired disturbance occurs during the transmission (before receiver and after transmitter), from natural and sometimes man-made sources.

2. Following are some differences between analog and digital communication:

Analog	Digital
Signals are records waveforms as they are. Signal occupies the same order of spectrum as the analog data.	Converts analog waveforms into set of numbers and records them. The numbers are converted into voltage stream for representation. In case of binary it is converted in 1's and 0's.
In analog systems electronic circuits are used for transformation of signals.	In this transformation is done using logic circuits.
About Noise analog signals are more likely to get affected and results in reducing accuracy	Digital signals are less affected, because noise response are analog in nature
Data transmission is not of high quality	Data transmission has high quality.

☞ Check Your Progress 2

1. Following are the main differences between Synchronous and asynchronous transmission.

Asynchronous transmission has following advantages and disadvantages:

- Each individual character is complete unit, hence if there is an error in a character, other sequence of characters are not affected. However, Error in start and stop bit(s) may cause serious problems in data transfer.
- Doesn't require synchronization of both communication sides.
- It is cost effective
- The speed of transmission is limited.
- Large relative overhead, a high proportion of the transmitted bits are uniquely for control purposes

Synchronous transmission has following advantages and disadvantages:

- In comparison to asynchronous communication it has higher speeds, because the system has lesser possibility of error. But, if an error takes place, the complete set of data is lost instead of a single character.
- Serial synchronous transmission is principally used for high-speed communication between computers but is unsuitable where the characters are transferred at irregular intervals.
- Lower overhead and thus, greater throughput.
- Process is more complex
- It is not very cost effective as hardware are more expensive

2. Following are the example for each:
   - Simplex communication: Radio/ Television Broadcasting System
   - half-duplex communication: walky-talky System
   - full duplex communication: Mobile or telephone system

☞ Check Your Progress 3

1. Explain the need of layering in the data communication protocol stack.

   The data communication follows protocols or protocols stack like OSI reference model. Since it is difficult to deal with complex set of rules, and functions required for computer networking, these rules and functions are divided with logical groups called layers. Each layer can be implemented interdependently with an interface to other layers providing with services to it or taking its services like data, connection and error control functions are grouped together into a layer. Speech in telephone conversation is translated, with electrical segments and vice-versa. Similarly in computer system the data or pattern are converted into signals before transmitting and receiving. These function and rules are grouped together into a layer.

2. List and explain any two functions of each OSI layer.

   The seven layers of ISO OSI reference model are:

   i) Physical Layer
   ii) Data Link Layer
   iii) Network Layer
   iv) Transport Layer
   v) Session Layer
   vi) Presentation Layer
   vii) Application Layer.

   a) **The Physical Layer**
      - Physical Layer defines electrical and mechanical specifications of cables and connectors.
      - Specify signaling options for sending control information between two nodes on a network.

   b) **The Data Link Layer**
      - The main task of the data link layer is to provide error free transmission.

- The data link layer creates and recognises frame boundaries. This can be accomplished by attaching special bit patterns to the beginning and end of the frame.

c) **The Network Layer**

- The network layer ensures that each packet travels from its sources to destination successfully and efficiently. It determining how packets are routed from source to destination.
- Addressing is another important task of this layer. The addressing used by the second network may be different from the first one. The second network may not accept the packet at all because it is too large. The protocols may differ, and so on. It is up to the network layer to overcome all these problems to allow heterogeneous networks to be interconnected.

d) **The Transport Layer**

- The basic function of the transport layer is to accept data from the session layer, split it up into smaller units if need be, pass these to the network layer, and to ensure that the pieces all arrive correctly at the other end.
- Transport Layer provides location and media independent end-to-end data transfer service to session and upper layers.

e) **The Session Layer**

- Session Establishment and Session Release – Orderly or abort
- Synchronization, Data Exchange and Expedited Data Exchange.

f) **The Presentation Layer**

- Presentation layer is concerned with the syntax and semantics of the information transmitted.
- The presentation layer manages these abstract data structure and converts from the representation used inside the computer to the network standard representation and back.

g) **Application Layer**

- Application Layer supports functions that control and supervise OSI application processes, such as start/maintain/stop application, allocate/deallocate OSI resources, accounting, check point and recovering.
- It also supports remote job execution, file transfer protocol, message transfer and virtual terminal.

UNIT 2: MODULATION AND ENCODING

Structures **Page No.**

2.0 INTRODUCTION

Electronic communication has become an analogy for the communication in the present era of electronic gadgets. As a general concept, we can say that transfer of information from one place to another is communication. A significant point about communication is that it involves a sender (transmitter) and a receiver. Only a sender or a receiver can not complete the process of communication. Therefore dual process of "transmitting and receiving" or "coding and decoding" information can be called as communication making it a two way process. In this unit we will discuss about different modulation and encoding techniques. In this unit both analog and digital modulation will be discussed. Further, this unit we will explore how analog signal are converted into digital system and vice-versa.

2.1 OBJECTIVES

After going through this unit, you should be able to:

- Know the concept of modulation
- Understand the different Analog Modulation techniques
- Differentiate between analog and digital modulation
- Know process of analog to digital signal conversion
- Understand the sampling and quantization process
- Know the digital to analog signal conversion process
- Understand the Digital Modulation techniques

2.2 NEED FOR MODULATION

Normal communication signals loose strength as they travel to the large distances. Hence, we often transmit the signals through electromagnetic waves and we use antennas to recover them at a remote point. To send transmitting message signals effectively for long distances, we use Modulation. At the receiver end, after receiving the signal, we need to "move" them back to the original frequency band (baseband) through demodulation. Therefore, we can see the modulation task as "giving wings"

to the information message. However, the original information is retrieved at the receiver end.

2.3 MODULATION

Often, the message being communicated is itself a signal, e.g., an audio signal, and to produce a signal that is suitable for transmission through the channel, we effect some transformation on the message signal. Modulation is the Process by which a property or a parameter of a signal is varied in proportion to another signal. The original signal is normally referred as the modulating signal and the high frequency signal, whose properties are changed, is referred as the carrier signal. The resulting signal is finally referred as the modulated signal.

For example in case of the amplitude modulation, the amplitude of the carrier wave is varied in accordance with the amplitude of the message signal, whereas in the angle modulation, phase angle of the carrier is varied with respect to the message signal.

Benefits of Modulation

1. Modulation can shift the frequency spectrum of a message signal into a band which is better suited to the channel. Antennas only efficiently radiate and admit signals, whose wavelength is similar to their physical aperture. Hence, to transmit and receive, say, voice, by radio we need to shift the voice signal to a much higher frequency band.
2. Modulation permits the use of multiplexing. Multiplexing means allowing simultaneous communication by multiple users on the same channel. For instance, the radio frequency spectrum must be shared and modulation allows users to separate themselves into bands.
3. Modulation can provide some control over noise and interference. For example the effect of noise can be controlled to a large extent by frequency modulation.

Modulation can be classified into two categories Analog Modulation and Digital Modulation. Let's see what are these Analog Modulation and Digital Modulation in detail.

Analog Modulation

Analog modulation is the simplest form of the modulation. In analog modulation, the modulation is applied continuously in response to the analog information signal. The process of the analog modulation has been shown in the Figure 1, below. Here the original signal at the baseband frequency has been shifted to the broadband frequency (F_c) .

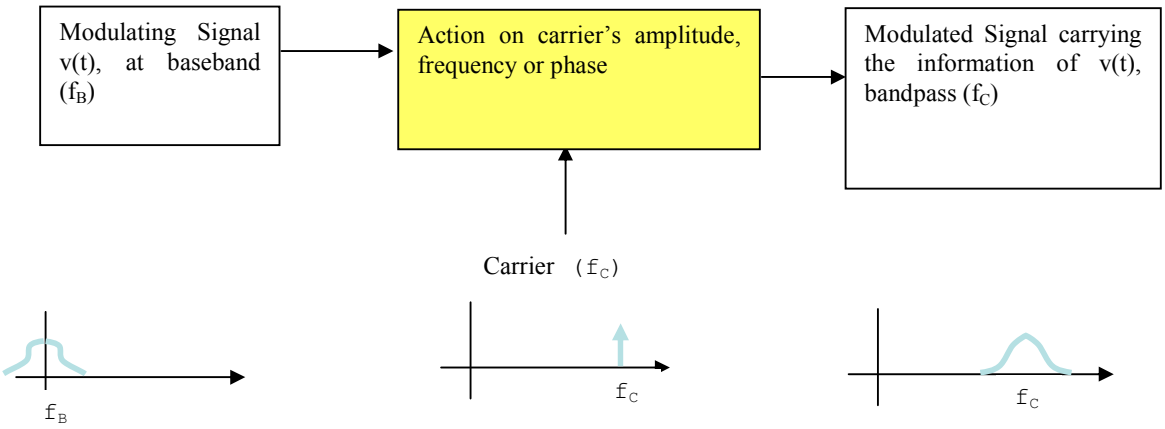

Figure 1: Process of the Analog Modulation

Common analog modulation techniques are:

1. Amplitude Modulation (AM): Here the amplitude of the carrier signal is varied in accordance to the instantaneous amplitude of the modulating signal.

2. Angle Modulation: Here the frequency or phase of the carrier signal is varied in accordance with the strength of the modulating signal. Consequently, the Analog Modulation has two forms:

   i) Frequency Modulation (FM): In this case, the frequency of the carrier signal is varied in accordance to the instantaneous frequency of the modulating signal)

   ii) Phase Modulation (PM): In this case, the phase of the carrier signal is varied in accordance to the instantaneous phase of the modulating signal)

2.4 AMPLITUDE MODULATION

Amplitude modulation (AM) is a technique used in electronic communication, most commonly for transmitting information via a high frequency carrier wave. AM works by varying the strength of the transmitted signal in relation to the information being sent. For example, changes in signal strength may be used to specify the sounds to be reproduced by a load speaker, or the light intensity of television pixels. "Undulatory currents" are the initial implementations of the Amplitude modulation. These were the first method to successfully produce quality audio over telephone lines in 1870's. The Figure 2 illustrates the process of modulation, by showing the modulating, carrier and modulated signals. Figure 3, further illustrates the Amplitude modulation process by varying the amplitudes of the modulating (input signal) and plotting the corresponding modulated signal.

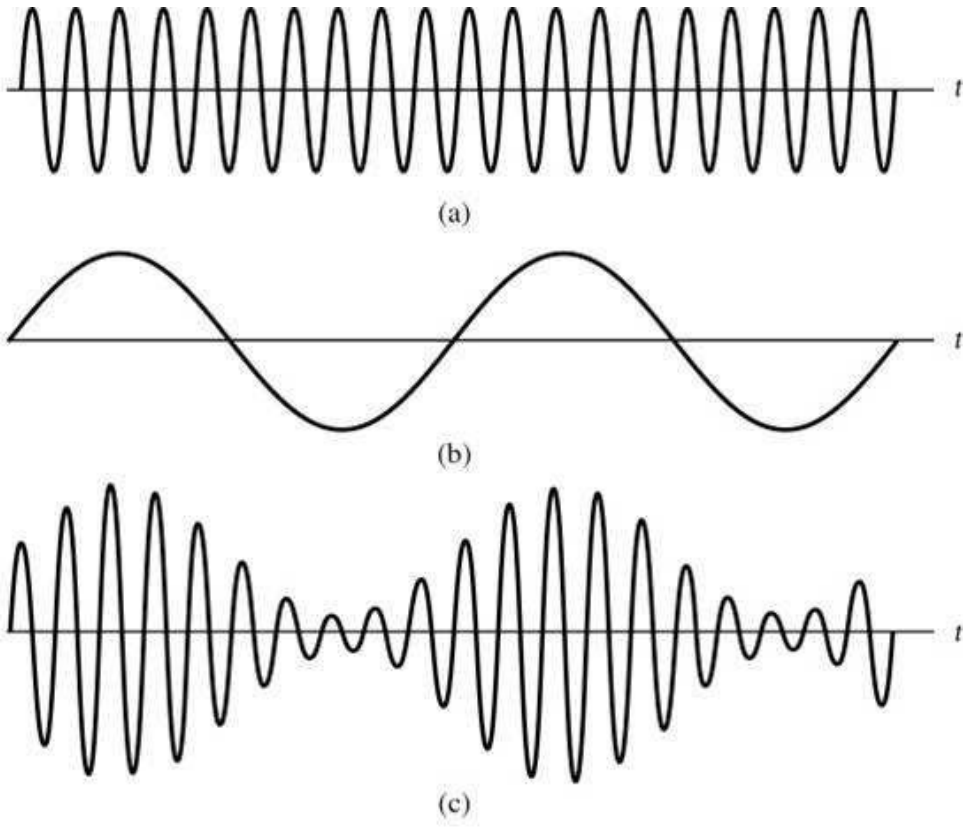

Figure 2: a) Carrier Signal, b) Modulating Signal, c) Modulated Signal

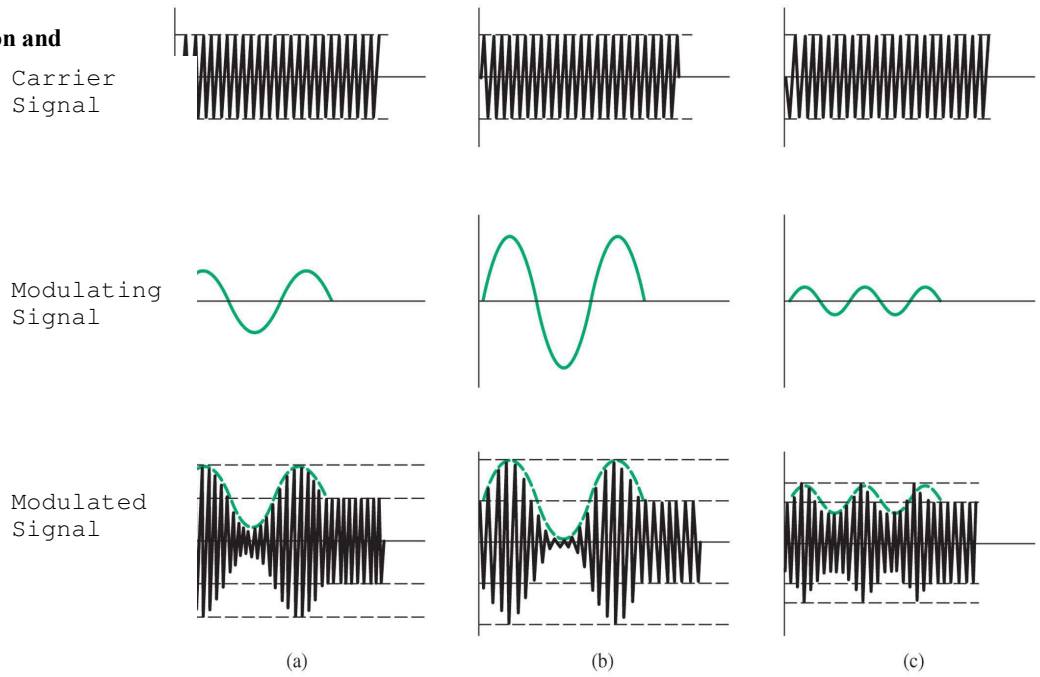

Figure 3: AM Modulation with varying amplitudes of the input signal

Advantages and Disadvantages

Advantages of Amplitude Modulation

1. Coverage area of AM Receiver is wider than FM because atmospheric propagation
2. AM is long distance propagation because of its high power.
3. AM Circuit is the cheapest and least complex,
4. AM can be easily demodulated using a Diode Detector.

Disadvantages of Amplitude Modulation

1. Amplitude modulation is very much sensitive to noise and hence the performance is very weak.
2. Signal of AM is not stronger than FM when it propagates through and obstacle.
3. Only one sideband of AM transmits Information Signal, so it loses power on other sideband and Carrier. Hence the power efficiency of the Amplitude Modulation is very poor.
4. Noise mixes AM Signal in amplitude when it propagates in free space that it makes it difficulty to recover the original signal at receiver in a highly noisy environment.

☛ Check Your Progress 1

1. What is the need for modulation?

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2. What are Analog modulation techniques?

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3. Define amplitude modulation.

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4. What are the limitations of amplitude modulation?

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2.5 FREQUENCY MODULATION

Frequency modulation, FM is widely used for a variety of radio communications applications. FM broadcasts on the VHF bands still provide exceptionally high quality audio, and FM is also used for a variety of forms of two way radio communications, and it is especially useful for mobile radio communications, being used in taxis, and many other forms of vehicle. in view of its widespread use, frequency modulation, FM, is an important form of modulation, despite many forms of digital transmission being used these days. Since its first introduction the use of frequency modulation, FM has grown enormously. Now wideband FM is still regarded as a very high quality transmission medium for high quality broadcasting. FM, is also widely used for communications where it is resilient to variations in signal strength.

Frequency Modulation is the technique in which, the frequency of the carrier wave is changed in accordance with the Amplitude of the modulating signal. The process is shown in the Figure 4 below.

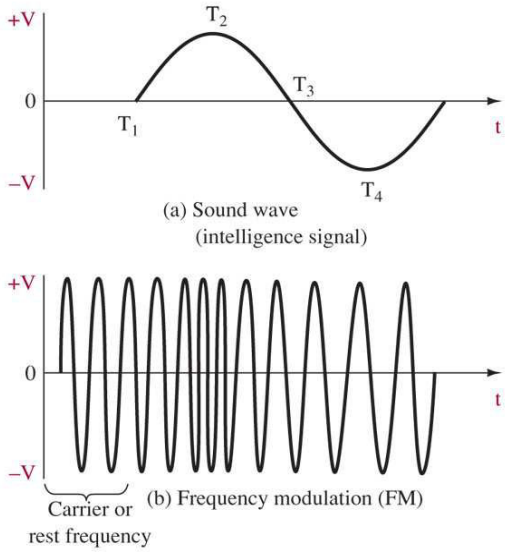

Figure 4: FM representation.

Advantages of Frequency Modulation

There are many advantages of using frequency modulation. These have been widely used for many years, and will remain in use for many years.

- Resilient to noise: One of the main advantages of frequency modulation is that it has been utilised by the broadcasting industry to take care of noise. As most noise is amplitude based, this can be removed by running the signal through a limiter so that only frequency variations appear. This is provided that the signal level is sufficiently high to allow the signal to be limited.

- Resilient to signal strength variations: Signal variations are reduced since noise effect is eliminated. This means that one of the advantages of frequency modulation is that it does not suffer amplitude variations as the signal level varies, and it makes FM ideal for use in mobile applications where signal levels constantly vary. This is provided that the signal level is sufficiently high to allow the signal to be limited.

- Does not require linear amplifiers in the transmitter: As only frequency changes are required to be carried, any amplifiers in the transmitter do not need to be linear.

- Enables greater efficiency than many other modes: The use of non-linear amplifiers, e.g. class C, etc. means that transmitter efficiency levels will be higher - linear amplifiers are inherently inefficient.

Disadvantages of Frequency Modulation

There are a number of dis-advantages to the use of frequency modulation. Some are can be overcome quite easily, but others may mean that another modulation format is more suitable.

- Requires more complicated demodulator: One of the minor dis-advantages of frequency modulation is that the demodulator is a little more complicated, and hence slightly more expensive than the very simple diode detectors used for AM. Also requiring a tuned circuit adds cost. However this is only an issue for the very low cost broadcast receiver market.

- Some other modes have higher data spectral efficiency: Some phase modulation and quadrature amplitude modulation formats have a higher spectral efficiency for data transmission that frequency shift keying, a form of frequency modulation. As a result, most data transmission system uses the digital transmission techniques such as PSK and QAM.

- Sidebands extend to infinity either side: The sidebands for an FM transmission theoretically extend out to infinity. To limit the bandwidth of the transmission, filters are used, and these introduce some distortion of the signal.

Comparison of FM and AM Transmission

Both the Amplitude and Frequency Modulation have their own advantages and disadvantages. However a comparison of the general performance is shown in the table 1 below:

Table 1: Comparison of AM and FM

S. No.	AM Broadcasting	FM Broadcasting
1.	It requires smaller transmission bandwidth	It requires larger bandwidth.
2.	It can be operated in low, medium and high frequency bands.	It needs to be operted in very high and high frequency bands.
3.	It has wider coverage.	Its range is restricted to 50 km.
4.	The demodulation is simple.	The process of demodulation is complex.
5.	The stereophonic transmission is not possible.	In this, stereophonic transmission is possible.
6.	The system has poor noise performance.	It has an improved noise performance.
7.	The AM signal reception does not have any threshold in the useful range of signal noise ratio (SNR).	The FM signal recepition exhibits a three the useful range of signal noise ratio (SM, SNR value should be higher than the ????

2.6 PHASE MODULATION

Frequency Modulation and the Phase Modulation are the two forms of the angle modulation. The main characteristic of the angle modulation is that the amplitude of the carrier frequency is maintained constant, whereas the frequency or phase is changed. In the phase modulation, the phase of the carrier wave is shifted in accordance with the amplitude of the modulating frequency. Phase modulation is a form of modulation that can be used for radio signals used for a variety of radio communications applications. As it will be seen later that phase modulation and frequency modulation are closely linked together and it is often used in many transmitters and receivers used for a variety of radio communication applications from two way radio communications links, mobile radio communications and even maritime mobile radio communications. Phase modulation is also the basis for many forms of digital modulation based around phase shift keying, PSK which is a form of phase modulation. As various forms of phase shift keying are the favored form of modulation for digital or data transmissions, this makes phase modulation particularly important.

Before looking at phase modulation it is first necessary to look at phase itself. A radio frequency signal consists of an oscillating carrier in the form of a sine wave is the basis of the signal. The instantaneous amplitude follows this curve moving positive and then negative, returning to the start point after one complete cycle - it follows the curve of the sine wave. This can also be represented by the movement of a point around a circle, the phase at any given point being the angle between the start point and the point on the wave.

Phase modulation works by modulating the phase of the signal, i.e. changing the rate at which the point moves around the circle. This changes the phase of the signal from what it would have been if no modulation was applied. In other words the speed of rotation around the circle is modulated about the mean value. To achieve this, it is necessary to change the frequency of the signal for a short time. In other words when phase modulation is applied to a signal there are frequency changes and vice versa. Phase and frequency are inseparably linked as phase is the integral of frequency. Frequency modulation can be changed to phase modulation. The information

regarding sidebands, bandwidth and the like also hold true for phase modulation as they do for frequency modulation, bearing in mind their relationship.

Unlike its more popular counterpart, i.e. frequency modulation (FM), PM is not very widely used for radio transmissions. This is because it tends to require more complex receiving hardware and there can be ambiguity problems in determining whether, for example, the signal has changed phase by +180° or -180°. PM is used, however, in digital music synthesizers such as the Casio CZ synthesizers, or to implement FM Synthesis in digital synthesizers such as the Yamaha DX7. The Phase modulation signals have been illustrated in the Figure 5 and Figure 6 below.

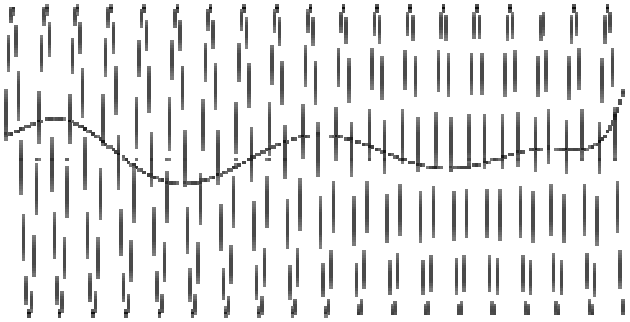

Figure 5: Modulating Signal and the Carrier Wave

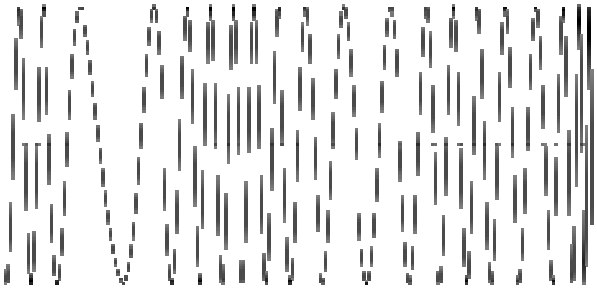

Figure 6: Modulated Wave

☞ Check Your Progress 2

1. Define Frequency Modulation.

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2. What do you know by angle modulation?

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3. What are limitations of AM?

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2.7 DIGITAL COMMUNICATION

Digital communication is the process of communication in which, the signals are transferred in the form of discrete formats rather than the continuous analog forms. Digital communication is very common in the present day communication systems and the signals are normally transmitted in binary formats. It is always easy to process the digital information as compared to the analog signals, because of their discrete nature and hence they have become more popular in the electronic communication. However, the voice based communication is Analog in nature, the signals needs to be converted into the digital formats to process in through the digital communication systems. The opposite process happens, while reconstructing the voice signal at the receiver end. A device called Modem (Modulator + demodulator) in the process. A modem (modulator-demodulator) is a device that modulates an analog carrier signal to encode digital information, and also demodulates such a carrier signal to decode the transmitted information. The goal is to produce a signal that can be transmitted easily and decoded to reproduce the original digital data. The basic process is depicted in the Figure 7 below.

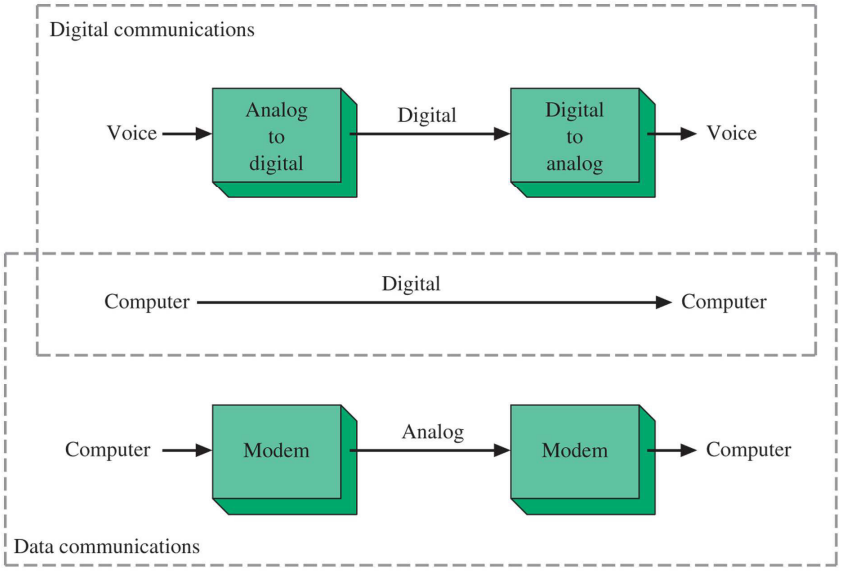


Figure 7: Digital Communication System

Advantages of Digital Communication

1. Reliable communication
2. Less sensitivity to changes in environmental conditions (temperature, etc.)
3. Easy multiplexing
4. Easy signaling
5. Voice and data integration
6. Easy processing like encryption and compression

7. Easy system performance monitoring
8. Quality of Service monitoring
9. Better Signal to Noise Ratio
10. Easy Regeneration of signals

Disadvantages

1. Increased bandwidth requirement for the communication channels.
2. Need for precision timings (Bit, character, frame synchronization needed)
3. Need for the Analog to Digital and Digital to Analog conversions
4. Higher complexity of the system design

Sampling

Digital communication uses the discrete signals; hence the natural analog signals needs to be converted to the discrete signals, in order to process them digitally. For this, purpose a technique known as sampling is employed. In electronic signals, sampling is the reduction of a continuous signal to a discrete signal. A sample refers to a value or set of values at a point in time and/or space. The process is illustrated in the Figure 8 below.

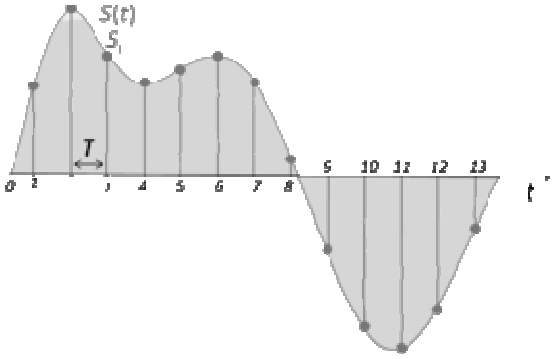


Figure 8: Sampling from the Analog Signals

Sampling is the first step towards the digitization. However, in order to codify these samples, the flat top sampling is most widely used. The block diagram of the natural and flat top sampling has been shown in the Figure 9 below.

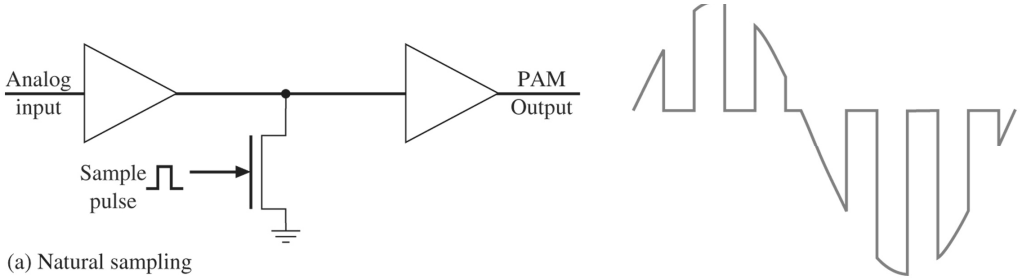


Figure 9: a) Natural sampling

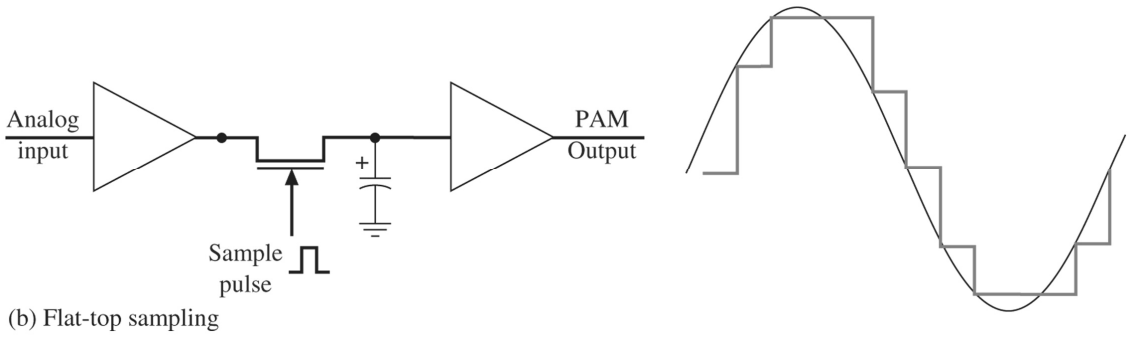


Figure 9: b) flat-top sampling

Once we get the samples, these samples are then quantized as per the voltage levels and finally converted to the binary codes to process them digitally. This process along with corresponding voltage levels and binary codes are shown in the Figure 9 b above.

Analog to Digital Conversion

An analog-to-digital converter (ADC, A/D) is a device that converts the input continuous physical quantity to a digital number that represents the quantity's amplitude. Instead of doing a single conversion, an ADC often performs the conversions ("samples" the input) periodically. The result is a sequence of digital values that have converted a continuous-time and continuous-amplitude analog signal to a discrete-time and discrete-amplitude digital signals. The most commonly employed A/D converter is the Ramp based circuit. It uses a comparator to compare the voltage levels

Digital to Analog Conversion

Digital to analog converter is the electronic circuit, which takes digital input and converts this into an analog waveform. A common use of digital-to-analog converters is generation of audio signals from digital information in music players. Digital video signals are converted to analog in television and cell phones to display colors and shades

2.8 DIGITAL MODULATION TECHNIQUES

There are three major classes of digital modulation techniques used for transmission of digital data:

- Amplitude Shift Keying
- Frequency Shift Keying(FSK)
- Phase-shift keying (PSK)

All of these processes convey the data by changing some aspect of a carrier wave, in response to a data signal.

2.9 AMPLITUDE SHIFT KEYING (ASK)

Amplitude-shift keying (ASK) is a form of modulation that represents digital data as variations in the amplitude of a carrier wave.

Any digital modulation scheme uses a finite number of distinct signals to represent digital data. ASK uses a finite number of amplitudes, each assigned a unique pattern of binary. Usually, each amplitude encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular amplitude. The demodulator, which is designed specifically for the symbol-set used by the modulator,

determines the amplitude of the received signal and maps it back to the symbol it represents, thus recovering the original data. Frequency and Phase of the carrier are kept constant.

Like Amplitude Modulation, ASK is also linear and sensitive to atmospheric noise, distortions, propagation conditions on different routes in PSTN (Public Switched Telephone Network) etc. Both ASK modulation and demodulation processes are relatively inexpensive. The ASK technique is also commonly used to transmit digital data over optical fiber. For LED transmitters, binary 1 is represented by a short pulse of light and binary 0 by the absence of light. Laser transmitters normally have a fixed "bias" current that causes the device to emit a low light level. This low level represents binary 0, while a higher-amplitude light wave represents binary 1. The simplest and most common form of ASK operates as a switch, using the presence of a carrier wave to indicate a binary one and its absence to indicate a binary zero. This type of modulation is called on-off keying, and is used at radio frequencies to transmit Morse code.

More sophisticated encoding schemes have been developed which represent data in groups using additional amplitude levels. For instance, a four-level encoding scheme can represent two bits with each shift in amplitude; an eight-level scheme can represent three bits; and so on. These forms of amplitude-shift keying require a high signal-to-noise ratio for their recovery, as by their nature much of the signal is transmitted at reduced power.

2.10 FREQUENCY SHIFT KEYING

Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave. The simplest FSK is a binary FSK (BFSK). BFSK uses a pair of discrete frequencies to transmit binary (0s and 1s) information. With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency.

FSK Transmitter

The block diagram of the FSK modulator is shown below in Figure 10. The modulating signal and the carrier frequency are fed to the frequency modulator circuitry and correspondingly the output is transmitted in the form of a signal with varied frequency.

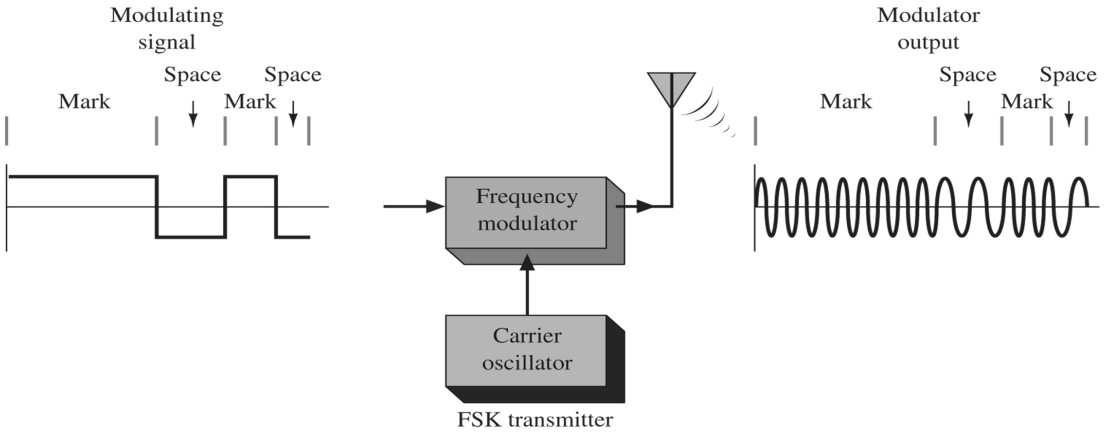


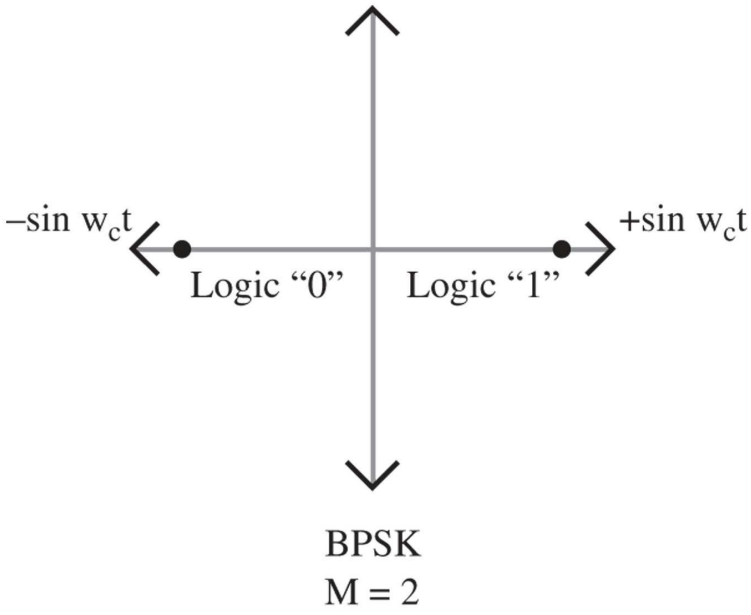
Figure 10: FSK Modulator

2.11 PHASE SHIFT KEYING

Phase-shift keying (PSK) is a digital modulation scheme that communicates the data by changing, or modulating, the phase of the carrier wave. Any digital modulation scheme uses a finite number of distinct signals to represent digital data. PSK uses a finite number of phases, each assigned a unique pattern in the form of a binary code. Each pattern of bits forms the symbol that is represented by the particular phase. On the other hand, the demodulator is designed specifically for the symbol-set used by the modulator. It determines the phase of the received signal and maps it back to the symbol it represents, thus recovering the original data. This requires the receiver to be able to compare the phase of the received signal to a reference signal. Another simple way of operation is that instead of operating with respect to a constant reference wave, the broadcast can operate with respect to itself. Changes in phase of a single broadcast waveform can be considered the significant items. In this system, the demodulator determines the changes in the phase of the received signal rather than the phase (relative to a reference carrier wave) itself. Since this scheme depends on the difference between successive phases, it is termed differential phase-shift keying (DPSK). DPSK can be significantly simpler to implement than ordinary PSK since there is no need for the demodulator to have a copy of the reference signal to determine the exact phase of the received signal.

Like any form of shift keying, there are defined states or points that are used for signaling the data bits. The basic form of binary phase shift keying is known as Binary Phase Shift Keying (BPSK) or it is occasionally called Phase Reversal Keying (PRK). A digital signal alternating between +1 and -1 (or 1 and 0) will create phase reversals, i.e. 180 degree phase shifts as the data shifts state. This has been illustrated in the Figure 11 below.

The problem with phase shift keying is that the receiver cannot know the exact phase of the transmitted signal to determine whether it is in a mark or space condition. This would not be possible even if the transmitter and receiver clocks were accurately linked because the path length would determine the exact phase of the received signal. To overcome this problem PSK systems use a differential method for encoding the data onto the carrier. This is accomplished, for example, by making a change in phase equal to a one, and no phase change equal to a zero. Further improvements can be made upon this basic system and a number of other types of phase shift keying have been developed. One simple improvement can be made by making a change in phase by 90 degrees in one direction for a one, and 90 degrees the other way for a zero. This retains the 180 degree phase reversal between one and zero states, but gives a distinct change for a zero. In a basic system not using this process it may be possible to loose synchronization if a long series of zeros are sent. This is because the phase will not change state for this occurrence. There are many variations on the basic idea of phase shift keying. Each one has its own advantages and disadvantages enabling system designers to choose the one most applicable for any given circumstances. Other common forms include QPSK (Quadrature phase shift keying) where four phase states are used, each at 90 degrees to the other, 8-PSK where there are eight states used and so forth. For an example the output of a BPSK modulator circuit for a 1010101 input is shown in figure 11.



A BPSK signal

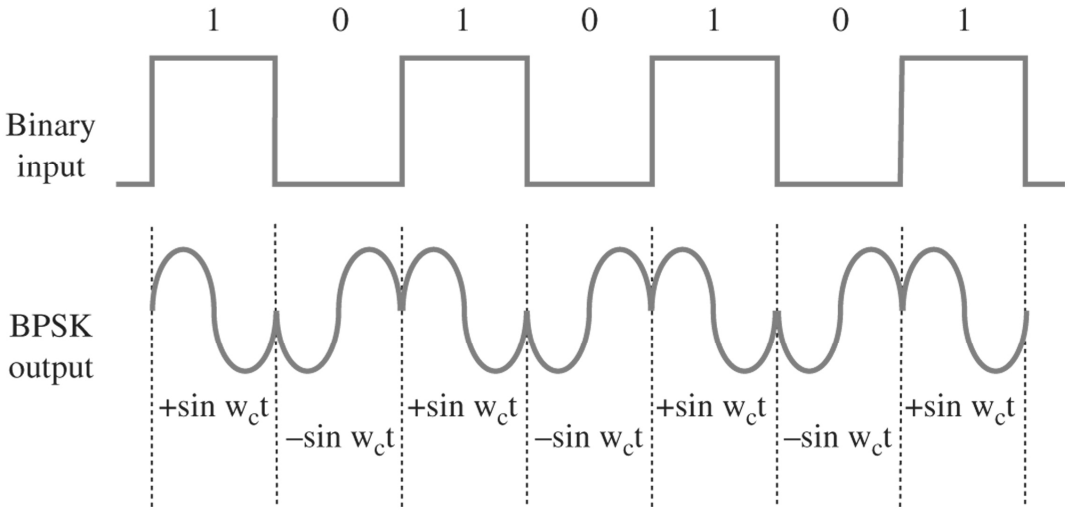


Figure 11: The output of a BPSK modulator circuit for a 1010101 input.

☛ Check Your Progress 3

1. What are the different digital modulation techniques?

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2. How many different phase states are used in BPSK and QPSK?

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3. Why digital modulation is better than the Analog Modulation?

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2.12 SUMMARY

After completing this unit we are sure that you have understood the term modulation. Why modulation is need in out communication systems. In this unit we have studied about different modulation techniques both analog and digital modulation type. We have also discussed different techniques for converting the analog signals into digital system and vice-versa.

2.13 REFERENCES/FURTHER READING

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3. *Computer Networking*, J.F. Kurose & K.W. Ross, A Top Down Approach Featuring the Internet, Pearson Edition, 2003.
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2.14 SOLUTIONS/ANSWERS

☞ **Check Your Progress 1**

1. To send transmitting message signals effectively for long distances, we use Modulation.

2. The Analog modulation techniques are:
   a) Amplitude modulation
   b) Angle modulation
      i) Frequency modulation
      ii) Phase modulation.

3. This is defined as the modulation, in which amplitude of carrier is changed in accordance to the amplitude of the modulating signal.

4. The amplitude modulation suffers from the following limitations

i) The useful power is contained in the sidebands and even at 100% modulation the and contain only 33% of the total power and hence the modulation efficiency is poor.

ii) Due to poor efficiency, the transmitters employing amplitude modulation have very poor range.

iii) The reception in this modulation is noisy. The radio receiver picks up all the surrounding noise along with the signal.

☞ Check Your Progress 2

1. Frequency Modulation is the technique in which, the frequency of the carrier wave is changed in accordance with the Amplitude of the modulating signal.

2. It is possible to convey or transmit information by varying its frequency as well as angle of phase. These are known as frequency and phase modulations respectively and both collectively are known as "Angle Modulation". The frequency and phase modulation systems have similar characteristics with minor differences.

   Briefing we can say angle modulations of two types:

   i) Frequency modulation

   ii) Phase modulation

3. Limitations of AM:

   i) Power of carrier and of one side band is useless.

   ii) The AM reception is noisy.

   iii) The BW is much less.

   iv) Only two S.Bs are available.

☞ Check Your Progress 3

1. There are three major classes of digital modulation techniques used for transmission of digitally represented data:

   - Amplitude Shift Keying
   - Frequency Shift Keying(FSK)
   - Phase-shift keying (PSK)

2. BPSK uses two different phase states and each one differs by 180^o , whereas the QPSK uses four different phases and each one differs by 90^o.

3. i) It is easy to process the digital information.

   ii) Digital systems are less prone to noise.

   iii) Digital signals can be easily re-transmitted.

UNIT 3: MULTIPLEXING AND SWITCHING

Structure **Page No.**

3.0 INTRODUCTION

The most fundamental need of any communication system design is to cater to large number of users. But this requires a large number of resources and large bandwidths supporting multiple channels. Requirement for large number of resources can be met if the resources are available, but this makes it cost ineffective. Therefore, the aim is always to use minimum number of resources and make their utilisation to their fullest potential. Bandwidth always remains a critical resource due to its limited availability and therefore, communication systems try to harness its fullest potential. Networks always require us to accommodate multiple signals utilizing a single piece of cabling to make it cost effective and reduce complexity. This need is seen throughout networking whether we are talking about local area networks or wide area ones. Modern telephone systems must place a large number of calls over a limited amount of bandwidth (i.e. a trunk). Broadband LANs must have several different types of data on a single wire at once. For these applications, we need to share the resources and in particular the bandwidth. Multiplexing and Switching are the two most important techniques being employed for this purpose in the present day communication systems and have been discussed in the present unit.

3.1 OBJECTIVES

After going through this unit, you should be able to:

- Know the concept of Multiplexing and Switching in computer networks
- Understand the basic multiplexing techniques like FDM, TDM, CDM and SDM
- Differentiate between different types of multiplexing techniques
- Know the switching mechanisms
- Differentiate between packet, circuit and message switching
- Understand the different packet switching mechanisms

3.2 MULTIPLEXING CONCEPT

In general, a medium can carry only one signal at any moment in time. For multiple signals to share one medium, the medium must somehow be divided, giving each signal a portion of the total bandwidth. Multiplexing (also known as MUXing) is a method by which multiple analog message signals or digital data streams are combined into one signal over a shared medium. The basic aim of the Multiplexing is to share an expensive resource by putting-up multiple signals on the same channel. For example, in telecommunications, several telephone calls may be carried using one wire. Multiplexing originated in telegraphy in the 1870s, and is now widely applied in different streams of communications. When several communication channels are needed between the same two points, significant economies may be realized by sending all the messages on one transmission facility – called multiplexing. As shown in Figure 1, n number of signals from the low speed channels have been combined to one sigh speed link using a n:1 multiplexer. Whereas the opposite process is carried out at the other end, where the signals are further separated into n number of low speed channels. This opposite process is referred as demultiplexing.

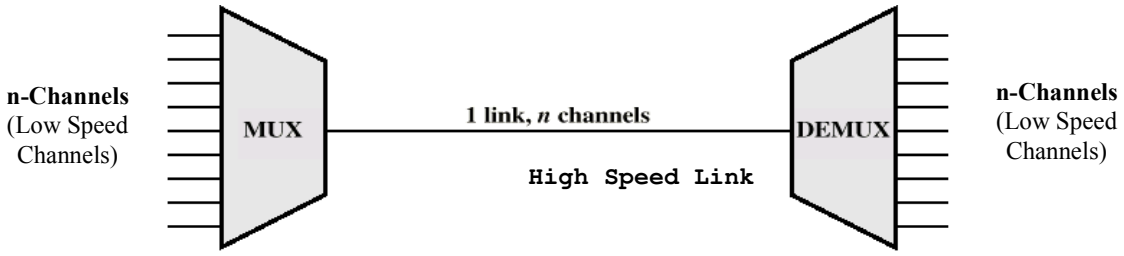

Figure 1: Multiplexing and De-Multiplexing

Thus, Multiplexing refers to the ability to transmit data coming from several pairs of equipment (transmitters and receivers) called *low-speed channels* on a single physical medium (called the *high-speed channel*). Whereas, a *multiplexer* is the multiplexing device that combines the signals from the different transmitters and sends them over the *high-speed channel*. A *demultiplexer* is the device which separates signal received from a *high-speed channel* into different signal and sends them to receivers.

There are four basic multiplexing techniques:

- Frequency division multiplexing (FDM)
- Time division Multiplexing (TDM)
- Code division Multiplexing (CDM)
- Space-division Multiplexing (SDM)
- Frequency division Multiplexing: Bandwidth is divided into different smaller frequency bands (range).
- Time division Multiplexing (TDM) (Time slots are allocated to message signals in an non overlapping manner in the time domain so that individual messages can be recovered from time synchronized switches)
- Quadrature Carrier/amplitude Multiplexing (QAM): Two message signals are transmitted in the same frequency band. The recovery is possible due to the carrier signals being orthogonal)

- Code division Multiplexing (CDM) users occupy the same frequency band but modulate their messages with different codes TDMA FDMA CDMA when used for multiple access TDMA, FDMA, e.g., GSM, FM, AM, Wireless networks

☞ Check Your Progress 1

1. Define multiplexing.

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2. State the importance of multiplexing.

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3. What are the multiplexing techniques?

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3.3 FREQUENCY-DIVISION MULTIPLEXING

Frequency division multiplexing (FDM) is the technique used to divide the available bandwidth into a number of smaller independent logical channels with each channel having a small bandwidth. The method of using a number of carrier frequencies each of which is modulated by an independent speech signal is in fact frequency division multiplexing. The following Figure 2 depicts the basic process of frequency division multiplexing, in which the total bandwidth has been divided into n-number of different channels and each one of them working with a specific bandwidth.

The following figure 2 depicts how three voice-grade telephone channels are multiplexed using FDM. When many channels are multiplexed together, 4000Hz is allocated to each channel to keep them well separated. First the voice channels are raised in frequency, each by a different amount. Then they can be combined, because no two channels can occupy the same portion of the spectrum. Notice that even though there are gaps (guard bands) between the channels, there is some overlap between adjacent channels, because the filters do not have sharp edges. This overlap means that a strong spike at the edge of one channel will be felt in the adjacent one as non-thermal noise.

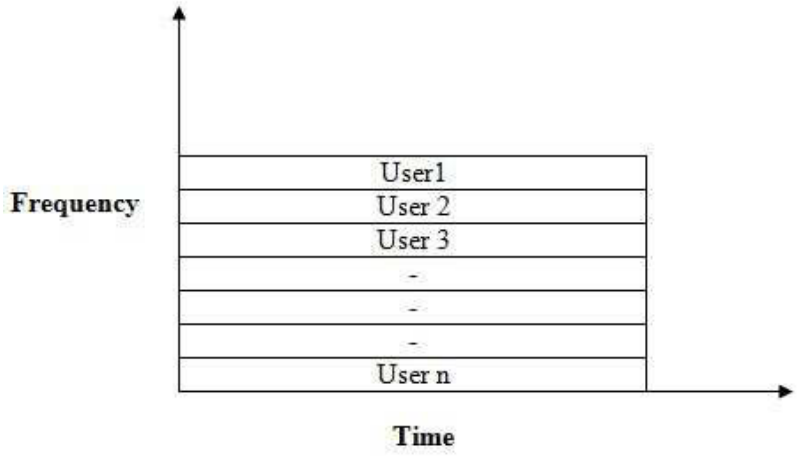

Figure 2: Frequency Division Multiplexing

In the telecommunication technology, the total bandwidth available in a communication medium is divided into a series of non-overlapping frequencies sub-bands using the frequency division multiplexing. Each one of these sub-bands then carries a separate signal. This allows a single transmission medium such as a cable or optical fiber to be shared by many signals. An example of a system using FDM is cable television, in which many television channels are carried simultaneously on a single cable. FDM is also used by telephone systems to transmit multiple telephone calls through high capacity trunk lines, communications satellites to transmit multiple channels of data on uplink and downlink radio beams, and broadband DSL modems to transmit large amounts of computer data through twisted pairs telephone lines, among many other uses.Frequency-division multiplexing works best with low-speed devices. The frequency division multiplexing schemes used around the world are very standardized. A wide spread standard is 12, 4000-Hz each voice channels (3000Hz for user, plus two guard bands of 500Hz each) multiplexed into the 60 to 108 KHz band. Many carriers offer a 48 to 56 kbps leased line service to customers, based on the group. The frequency band division has been illustrated in the Figure 3 taking some example frequencies.

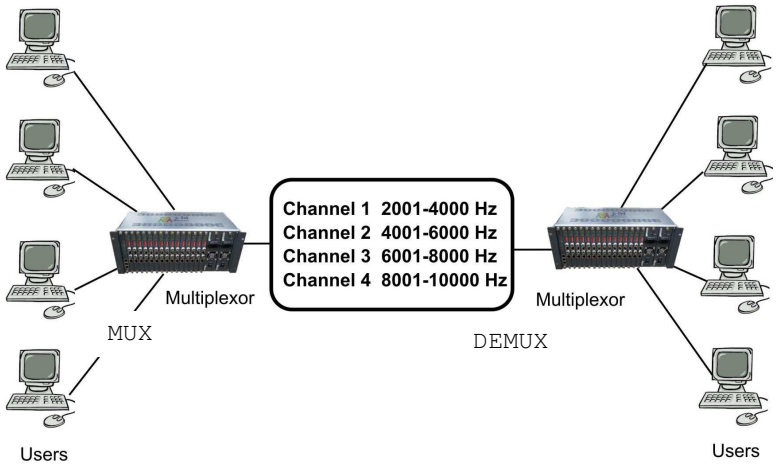

Figure 3: Illustration of FDM using four different channels

In Telephony, the most widely used method of modulation in FDM is single sideband modulation, which, in the case of voice signals, requires a bandwidth that is approximately equal to that of the original voice signal. Each voice input is usually assigned a bandwidth of 4 KHz. The bandpass filters following the modulators are used to restrict the band of each modulated signal to its prescribed range. The

resulting bandpass filter outputs are combined in parallel to form the input to the common channel. At the receiving terminal, a bank of band pass filters, with their inputs connected in parallel, is used to separate the message signals on a frequency-occupancy basis. The original message signals are recovered by individual demodulators

Frequency division multiplexing (FDM) is also referred as the Wavelength division multiplexing (WDM), where we are using the optical communications focusing on the wavelength rather than the frequency.

Advantages of FDM:

1. The users can be added to the system by simply adding another pair of transmitter modulator and receiver demodulators.
2. FDM system support full duplex information (Both side simultaneous Communication) flow which is required by most of application.

Disadvantages of FDM:

1. In FDM system, the initial cost is high. This may include the cable between the two ends and the associated connectors for the cable.
2. A problem with one user can sometimes affect the others.
3. Each user requires a precise carrier frequency for transmission of the signals.

3.4 TIME-DIVISION MULTIPLEXING

Time Division Multiplexing (TDM) is another popular method of utilizing the capacity of a physical channel effectively. Each user of the channel is allotted a small time interval during which it may transmit a message. Thus the total time available in the channel is divided and each user is allocated a time slot. Data from each user is multiplexed into a frame which is transmitted over the channel. In TDM, user's messages are buffered as they received and read from the buffer during its time slot to make a frame. Therefore each user can use the full channel bandwidth. The channel capacity is fully utilized in TDM by interleaving a number of messages belonging to different users into one long message. This message sent through the physical channel must be separated at the receiving end. Individual chunks of message sent by each user should be reassembled into a full message. The process of the Time division multiplexing has been shown in Figure 4.

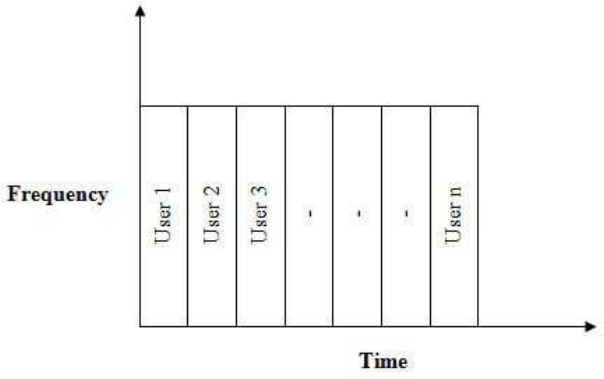

Figure 4: Time Division Multiplexing

Sharing of the signal is accomplished by dividing available transmission time on a medium among users. For example, in some countries, the individual stations have two logical sub channels: music and advertising. These two alternate in time on the same frequency first a burst of music, then a burst of advertising, then more music and

so on. This situation is time division multiplexing. Unfortunately, TDM can only be used for digital data multiplexing. Since local loops produce analog signals, a conversion is needed from analog to digital in the end office. Where all the individual local loops come together to be combined onto outgoing trucks. The TDM process is further illustrated in Figure 5 with the digital data stream.

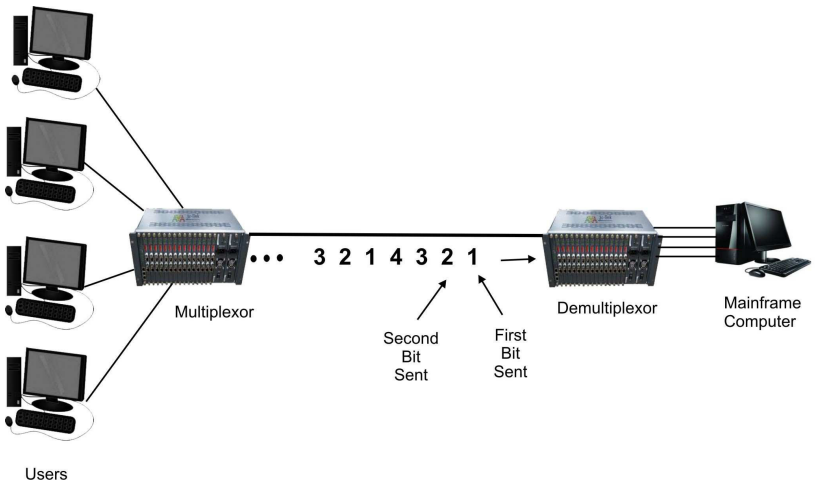

Figure 5: Digital Transmission using TDM

Applications of TDM

- The PDH (Plesiochronous Digital Hierarchy) system, also known as the PCM (Pulse Code Modulation) systems
- The synchronous digital hierarchy (SDH) / synchronous optical networking (SONET) network transmission standards.
- TDM can be further extended into the time division multiple Channel (TDMA) scheme, where several stations connected to the same physical medium, for example sharing the same frequency channel, can communicate. Application examples include the widely used GSM telephone system

Advantages of TDM

1. It uses a single link
2. It does not require precise carrier matching at both end of the links.
3. Use of the channel capacity is high.
4. Each to expand the number of users on a system at a low cost.
5. There is no need to include identification of the traffic stream on each packet.

Disadvantages of TDM

1. The sensitivity to other user is very high and causes problems
2. Initial cost is high
3. Technical complexity is more

3.5 CODE DIVISION MULTIPLEXING

As you may know, the concept of multiple access where we can allow several transmitters to send information simultaneously over a single communication channel and it allows several users to share a band of frequencies (or you can say bandwidth).

CDMA uses spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code generally pseudorandom code) to allow multiple users to be multiplexed over the same physical channel. By contrast, time division multiple access (TDMA) divides access by time, while frequency-division multiple access (FDMA) divides it by frequency. CDMA is a form of spread-spectrum signalling, since the modulated coded signal has a much higher data bandwidth than the data being communicated. This allows more users to communicate on the same network at one time than if each user was allotted a specific frequency range. Remember that CDMA is a digital technology, so analog signals must be digitized before being transmitted on the network.

3.6 SPACE DIVISION MULTIPLEXING

When we want to transmit multiple messages through any of the communication media, the ultimate goal is to maximize the use of the given resources (e.g. time and frequency in general). It involves grouping many separate wires into a common cable enclosure. A cable that has, for example, 50 twisted pairs inside it can support 50 channels. SDM has the unique advantage of not requiring any multiplexing equipment. It is usually combined with other multiplexing techniques to better utilize the individual physical channels. For example, if there are six persons in the office and all of them want to talk at the same time, this will give rise to interference between the conversations. To reduce the interference they may divide themselves into three groups of two, such that the conversation is between each pair of people. If the pairs continue talking whilst sitting next to each other, the interference would still be present. The best way for each pair to converse with minimal interference would be to sit a few feet away from the other pairs (within the same room) and converse. They would still be sharing the same medium for their conversations but the physical space in the room would be divided for each conversation. This is the simplest example of Space Division Multiplexing. The concept of SDM has been illustrated in Figure 6.

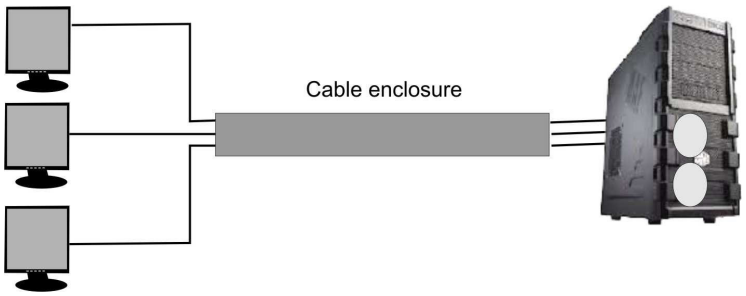

Figure 6: Space Division Multiplexing

Space Division Multiplexing is the multiplexing technique in which both the time and frequency can be reused by transmitting our information through a parallel set of channels.

In wired communication, space-division multiplexing simply implies different point-to-point wires for different channels. Examples include an analogue stereo audio cable, with one pair of wires for the left channel and another for the right channel, and a multipair telephone cable usually employed to provide PSTN connections in different homes. Another example is a switched star network such as the analog telephone access network (although inside the telephone exchange or between the exchanges, other multiplexing techniques are typically employed). In wireless communication, space-division multiplexing is achieved by multiple antenna elements forming a phased array antenna. Examples are multiple-input and multiple-output (MIMO), single-input and multiple-output (SIMO) and multiple-input and single-output (MISO) multiplexing.

3.7 SWITCHING

Switching forms a very important process in a communication system. A switch is used to connect the incoming link to the desired outgoing link and directs the incoming message to the appropriate outgoing link. Let us understand the concept of switching with the help of a simple illustrative example.

Consider a group of 8 people with telephones. If we were to use direct lines between all the people, we would need 28 duplex (wires that allow simultaneous two-way conversation) lines. The arithmetic is pretty simple - to connect **n** subscribers directly, we need **n(n-1)/2** lines. This is alright as long as the number of subscribers is less and the distances are also small. But in the present day electronic communication systems, we are talking about connecting the entire world - obviously direct connections are not the answer. We need to design a system, which can connect the people from anywhere. Now, if we were to use a switch instead, we could reduce the number of lines needed to just 4, because with 8 subscribers, there would at the most be just 4 conversations simultaneously. The switch would have 4 lines internally and it would use the each line to connect a pair of subscribers. This has been illustrated in Figure 7 below.

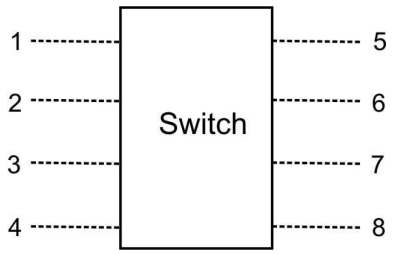

Figure 7: A simple switch with 4-input and 4-output lines

Let us assume the switch in the above diagram has 4 internal lines A, B, C and D. Say A is being used to connect 1 to 7 and B to connect 4 to 5. Now if 3 were to wish to get connected to 8, the switch would 'patch' the ends of C so that 3 and 8 are connected. Instead, if 6 had lifted the phone before the 3 and tried to get connected to 2, the switch would use C to 'patch' a connection between 6 and 2. We assume that the order in which the lines A, B, C and D are used is in accordance with their alphabetical order. This assumption is valid and any other order would not have any bearing upon the concept of switching. The fact remains that the lines A, B, C and D are not fixed. Their end-points change from time to time. *Thus they are* switched *circuits.*

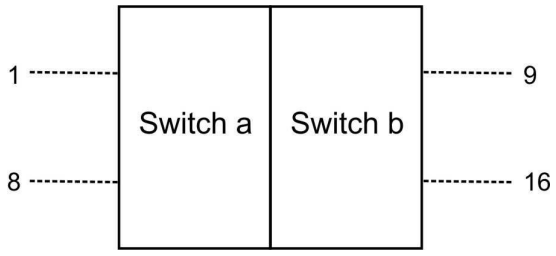

Figure 8: Two Switches with 8-subscribers

Consider 2 such 8-subscriber switches as shown in the Figure 8. They are seemingly connected by just one line. But this line is a multiplexed line, and is not switched. It is called a trunk. It is not switched because it always carries traffic from switch a switch b. Let us assume the multiplexer is capable of sending 4 simultaneous conversations over one line. Then the trunk could be carrying conversations between 1-15, 4-9, 8-11 and 5-12. The lines internal to switch a would connect 1,4,8 and 5 to the multiplexer /

demultiplexer (remember the line is duplex) and therefore the trunk. Similarly, the lines internal to switch b would connect 15, 9, 11 and 12 to the multiplexer/ demultiplexer. The switched circuits are inside the switches a and b. But the trunk between a and b is multiplexed with 4 conversations. So in a sense, the trunk is not switched. But if you had more than one trunk between switches a and b, then the trunks would also be switched. Why, because a call from 1 to 15 could go on either trunk 1 or trunk 2 (assuming there are two trunks each capable of carrying 4 conversations). Thus, the trunks are now switched, in addition to being multiplexed.

It is very important to understand the difference between switching and multiplexing. In simple terms, multiplexing is done to maximize the use of a communications channel. Whereas, the switching is the manipulation of the ends of the communications channel and is used to make the connections. The purpose of an electrical switch is to close /open a circuit to allow/stop flow of current. A communication switch is similarly used to allow/stop flow of message through the path connecting the receiver and the transmitter. Two users, one can be called sender and the other receiver, can be connected by a medium like a conducting wire over which messages in the form of electrical signals can be transmitted from one user to the other. A switch inserted in the electrical path between the two users facilitates connection/disconnection of the users as desired by controlling the switch. The path need not be on all the time. It needs to be switched on only when the users need to communicate. The role of such a switch becomes more important when there are a large number of users and a particular user at one time may want to communicate with another user and wants to communicate still another user at a different time. Thus the same user has to be connected to two different users at two different times. This can be done by a controlled switch. Thus in a set of say n users, different users may like to communicate with different users at different time. The simple 2 X 2 switch has been illustrated in the Figure 9 below.

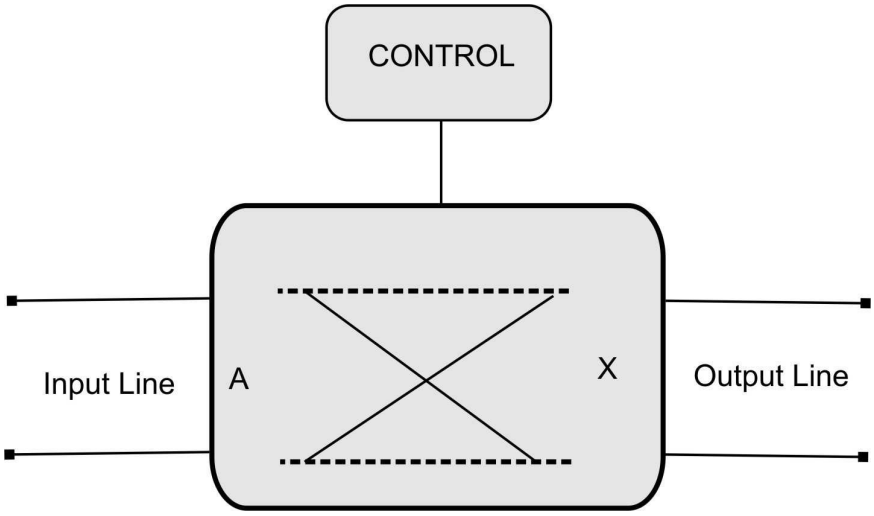

Figure 9: A Simple 2 X 2 Switch

Switching plays a very important role in telecommunication networks. It enables any two users to communicate with each other. Basically, there are three categories of Switching

a) Message Switching

b) Circuit Switching

c) Packet Switching

A circuit switch closes a circuit between the incoming and the outgoing paths so that the incoming message can go to the output link. The circuit between any two desired paths is closed by a control signal applied to the switch. In message and packet switching, the incoming message/packet to the node is stored in a memory location. Then the stored message/packet is transferred to another desired memory location, from where the message/packet can be delivered/forwarded to the next node or the receiver. The transfer from the incoming bin to the outgoing bin is done with a control/command signal.

3.8 MESSAGE SWITCHING

Message switching is one of the initial mode of switching, which helped a lot in the proliferation of the electrical communication. It is interesting to know that electrical communication in the form of Telegraph arrived earlier than the Telephone. Let us try to understand the working of the Telegraph system to build the concept of message switching. Consider the Figure 10 as a working model of the Telegraph Network. As an example of message switching: A, B, ….F are the message switching nodes/telegraph offices.

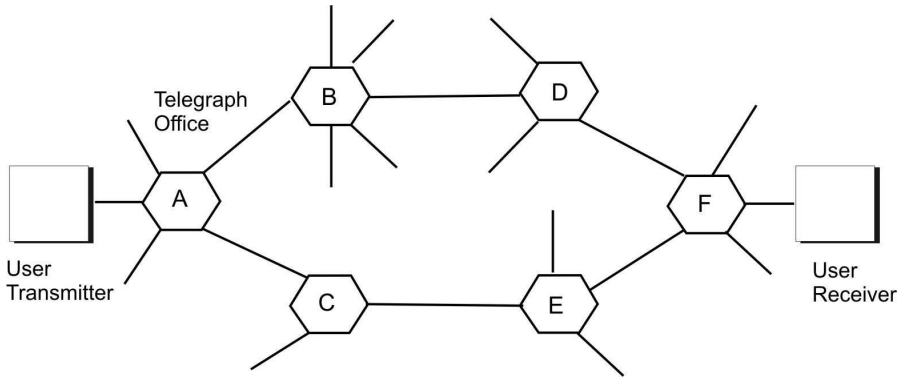

Figure 10: Working Model of the Telegraph Systems

The User who wants to send a telegraph comes to a Telegraph office with his message and hands it over to the counter operator. Now the following sequences of events occur:

- This message is sorted on the basis of the receiver's address and clubbed with other messages moving in the same direction, i.e., if in the Delhi's telegraph office the operator receives 10 messages for addresses in Mumbai, then they are bundled and are sent.
- The operator in this case does not bother if the entire path (to Mumbai) is available or not. He just forwards this message to the next node (Telegraph Office) in the path (generally predetermined).
- The operator at the next node receives all these messages, stores, sorts and forwards them.

In the olden days, the storage was done by manually. Human beings then did the sorting. Later on the storage process was automated using paper tapes. The advantage of using paper tapes is that the incoming signal is punched onto it automatically and the same tape can be directly fed into the telegraph machine for further transmission. In the Telegraph system, unlike telephones, no circuits are switched. Information is transmitted as discrete messages. So this method of switching is known as Message Switching. The important context is *'Store and Forward'*. At each node (telegraph office) the message that arrives from the previous node in the path is stored for some time, sorted, and depending on the availability of the path from this node to the next in the path, the message is forwarded.

There were central telegraph offices which acted like nodes of telegraph network and performed the task of message switching. as the teleprinters came, Morse code was replaced by machine telegraphy resulting in faster operations. Later computers were introduced to do the function of message switching. Computer based message switching is still used many organizations having many locations of working. However, if we compare the cost, the telegraph is less costly than the telephone due to the following reasons:

- Better utilization of transmission media
- The message switching is done over distributed time.
- Hogging (Capturing the entire path) does not occur in message switching. Only one of the links in the entire path may be busy at a given time.

However, message switching requires storage and this may raise-up the cost of the systems.

3.9 CIRCUIT SWITCHING

Circuit switching is defined as a mechanism applied in telecommunications (mainly in PSTN) whereby the user is allocated the full use of the communication channel for the duration of the call. That is if two parties wish to communicate, the calling party has to first dial the numbers of the called party. Once those numbers are dialed, the originating exchange will find a path to the terminating exchange, which will in turn find the called party. After the circuit or channel has been set up, then communication will take place, then once they are through the channel will be cleared. This mechanism is referred to as being connection-oriented.

Voice being a very vital medium of human communication, telephone was invented. It permitted long distance voice communication. The need of a user to talk to a desired person out of many persons on a real time basis leads to the concept of establishing a direct path between the caller and the called users. Circuit switching was conceived to be an appropriate technique for the purpose. Telephone systems use circuit switching largely to date because it serves the purpose very well. However, a major drawback of circuit switching is the requirement of a dedicated path between the calling and the called parties. This means reserving resources like the chain of switches and transmission media over the entire path. This is obviously a costly proposition. The circuit switching process has been illustrated in the Figure 11, for the telephone network. In which, the physical connections are made by the switching offices to connect the call of two users.

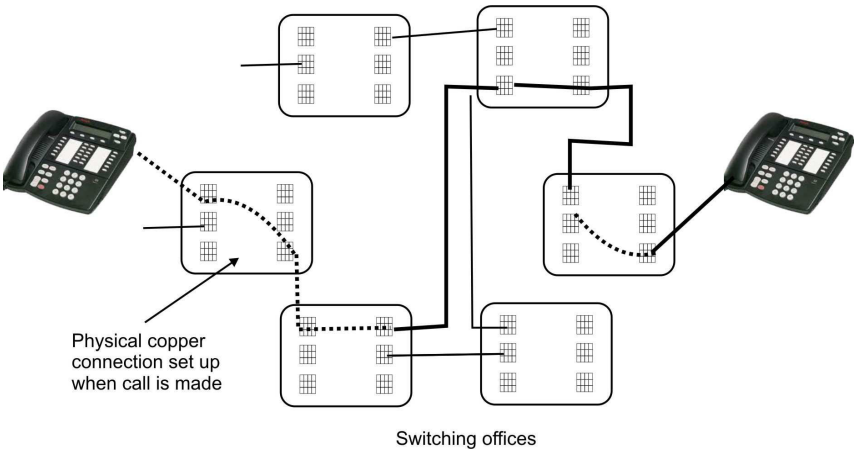

Figure 11: Circuit Switching in the Telephone Network

For each connection, physical switches are set in the telephone network to create a physical "circuit" – That's the job of the switching office Switches are set up at the beginning of the connection and maintained throughout the connection. Network resources reserved and dedicated from sender to receiver. However this is not a very efficient strategy as a connection "holds" a physical line even during "silence" periods (when there is nothing to transmit)

Advantages of Circuit Switching:

- Once the circuit has been set up, communication is fast and without error.
- It is highly reliable

Disadvantages:

- Involves a lot of overhead, during channel set up.
- Waists a lot of bandwidth, especial in speech whereby a user is sometimes listening, and not talking.
- Channel set up may take longer.

To overcome the disadvantages of circuit switching, packet switching was introduced, and instead of dedicating a channel to only two parties for the duration of the call it routes packets individually as they are available. This mechanism is referred to as being connectionless packet switching as discussed in the next section.

☞ Check Your Progress 2

1. Write differences between FDM and TDM.

   ……..

   ……..

   ……..

2. What is CDMA?

   ……..

   ……..

   ……..

   ……..

3. What is Circuit Switching?

   ……..

   ……..

   ……..

3.10 PACKET SWITCHING

Packet Switching is the backbone of the present day communication systems. The packet switching works on the principle that the long messages are fragmented into small size units, known as *packets*. It is these packets that are transmitted instead of the single long message. This method is slightly different from **Message switching** and is called **Packet switching**. Figure12 shows a message broken down into small sized packets P_1, P_2 …P5.

P1
P2
P3
P4
-
-
Pn

Figure 12: A Message broken into n number of packets

These packets are now transmitted over the network in the same manner as the messages in message switching. The model is just like Sharing by taking turn and is analogous to the conveyor belt in a warehouse. In this case, the Items are picked from the storage room and placed on the conveyor belt every time a customer makes an order. In this model, this is important that Different customers may request a different number of items and Different users' items may be interspersed on the conveyor belt (they are "multiplexed"). Similarly in the Packet Switching, packetizes the data to transfer and Multiplex it onto the wire. Thus packets from different connections share the same link

The packets are stored and forwarded at every node. Obviously every packet now has to have the source and destination addresses. Even in message switching repeated transmission of addresses at every node consumes network bandwidth. In packet switching the overhead/wastage is more because every packet is now required to carry the addresses on their head. Thus each packet is composed of the payload (the data we want to transmit) and a header. The header contains information useful for transmission, such as:

- Source (sender's) address
- Destination (recipient's) address
- Packet size
- Sequence number
- Error checking information

The header introduces overheads, that is, additional bits to be sent. Therefore, it is not wise to have packets that are too small. In the packet switching, each computer attached to a network is assigned a unique number (called address). A packet contains the address of the computer that sent it and the address of the computer to which it is sent. In general, packets need not be of the same size, The Internet Protocol specifies the maximum size in the form of Maximum transmission unit (MTU) and does not give the No minimum size. But, header size is fixed (e.g., 20 bytes for TCP/IP in the IP version 4). Packets are generated by the network hardware, however the application (e.g., email) does not know that the data to be transmitted is packetized. When packets are received, they are put together before the application accesses the data. The process is shown in the Figure 13 below, where A and B are the sender and C and D are the receiver.

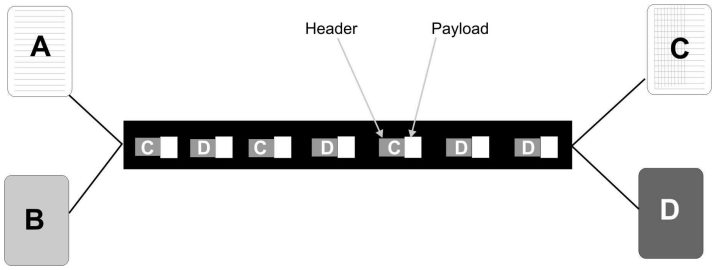

Figure13: Packet Switching Example

So with the user message in a packet with the header is to be transmitted also. From this point of view network bandwidth consumed is maximum in packet switching and minimum in circuit switching. Packets of the same message are launched into the network in parallel over different available forward links at a node. These packets would travel through different paths to arrive at the destination. This simultaneous transmission of packets over different paths results in further improvement of the link utilization compared to the message switching. Another advantage is that no link is engaged for a long time since the packets are of smaller size than the single message.

This permits better sharing of the links amongst multiple users. However the scheme just discussed has two major drawbacks. Firstly, the packets of the same message traveling through different paths may arrive at the destination at different times due to different delays encountered in different paths. Thus the packets may arrive out of order. In order to deliver them to the destination, they need to be ordered which requires extra processing and so more delay. They need to be given sequence numbers for reordering them. The sequence number increases the overhead and requires more network bandwidth. Secondly, some of the paths may not be very good and some packets may get lost. This worsens the quality. To improve quality, they require retransmission which in turn requires more processing time and more bandwidth. In spite of these drawbacks the packet switching is the most favored technique in the present day communication systems. The basic reasons behind this choice are:

a) Computer traffic being mostly text is non real time (in the beginning of the networking)

b) Computer data traffic is highly bursty in nature

Considering these features it becomes obvious that circuit switching was not the right kind of switching. Message switching can do the job but for better line utilization packet switching is preferable. Thus computer networks used packet switching. The difference between the packet switching and the circuit switching has been outlined in the Table 1.

Table 1: Difference between the packet switching and Circuit Switching

S.No.	Packet Switching	Circuit Switching
1	Bandwidth is allocated dynamically.	Fixed bandwidth allocation.
2	Packets has header, FCS.	Don't deal with data content and error-checking
3	Better buffering. System can be operated at different bit rate to inter-network.	Simple buffering
4	May be more economical as not needed dedicated circuit.	Costs more for hardware.
5	The packet needs to be re-transmitted every time when it gets lost, damaged before it is received in this method.	Once connection is established, communication is fast and almost errorless.
6.	Useful for bursty applications	Useful for delay sensitive applications

Categories of Packet Switching

The packet switching is basically, categorized in the following two categories:

a) Connection Less Packet Switching

b) Connection Oriented Packet Switching

3.10.1 Connection Less Packet Switching

In this mode of transmission, packets from a source machine to a destination machine are transmitted as per-packet basis, meaning that each packet is transmitted and routed independently from all other packets. So, even if the source and destination machines do not change, routers in the middle may decide to change the routes that different packets follow , resulting in the different packets reaching their destination in a different order from the sender because of the different transmission path length , difference in transmission rates, and the amount of congestion in the different paths. This is illustrated in the following Figure 14.

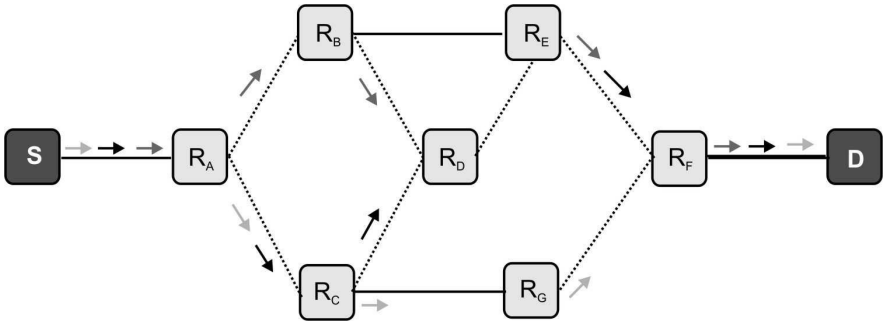

Figure 14: Connection less Packet Switching

In the figure 14, S denotes the source and D denotes the destination. R represents the router, whereas the packets have been shown by the arrow. Three packets are transmitted from the same source machine heading towards the same destination machine. Each route of the network shows the packets that have travelled over it. It is clear that the packets may arrive at the destination machine in an order different from the transmission order. Since the details of this routing table change with the movement of the packets, the routing of different packets often changes. The transmission process involves the following steps:

- Transmit Packet 1
- Transmit Packet 2
- ……
- ……..
- Transmit Packet N

Examples:

- POTS (Plane Old Telephone Systems)
- ATM (Asynchronous Transmission Mode)
- Frame Relay
- MPLS (Multi Protocol Label Switching)

Disadvantages of connectionless packet switching:

1. Extra processing power is required at the nodes for attaching source and destination addresses with every packet which also increases the required time of transmission.
2. Connectionless Packet switching requires overhead bits for indexing/numbering the packets.

3. Packets may arrive at the destination in a random manner. This requires that all the arriving packets are stored and rearranged.
4. Some packets may be lost in the network.

3.10.2 Connection Oriented Packet Switching

In this mode of transmission, packets from a source machine to a destination machine are moved as per the source destination pair basis, meaning that all packets from the same source going to the same destination are transmitted over the same routes and through the same routers. This results in having almost a constant delay of transmission for the different packets and the different packets reaching their destination in order

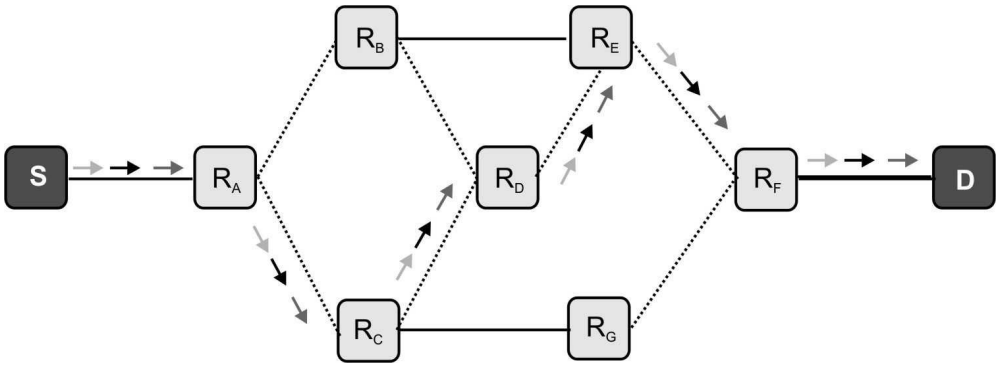

Figure 15: Connection Oriented Packet Switching

It is clear from the above Figure 15 that a circuit - like connection has been established. The process of transmission in the above case is also called Virtual - Circuit Packet Switching as it involves the establishment of a fixed path called Virtual Circuit or Virtual Connection between the source and destination prior to the transfer of packets. The transmission of packets involves the following steps:

1. Connection Request
2. Connection Confirm \
3. Transmit Packet 1
4. Transmit Packet 2
5. ……
6. ……
7. Transmit Packet N
8. Connection Release

Example:

ATM Networks

☞ Check Your Progress 3

1. Define the difference between switched and leased lines.

……..

……..

2. What are switched communications networks?

……..

……..

3. Discuss the advantages of packet switching over circuit switching.

……..

……..

3.11 SUMMARY

We hope you must have understood the concept of multiplexing and switching. As we discussed Multiplexing refers to the ability to transmit data coming from several pairs of equipment (transmitters and receivers) called *low-speed channels* on a single physical medium (called the *high-speed channel*). Whereas, A *multiplexer* is the multiplexing device that combines the signals from the different transmitters and sends them over the *high-speed channel*. Further in this unit you have studied four basic multiplexing techniques are frequency division multiplexing (FDM), Time division Multiplexing (TDM), Code division Multiplexing (CDM) and Space-division Multiplexing (SDM). As you have studied that Switching plays a very important role in telecommunication networks. It enables any two users to communicate with each other. Basically, there are three categories of Switching like Message Switching, Circuit Switching and Packet Switching.

3.12 REFERENCES/FURTHER READING

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3.13 SOLUTIONS/ANSWERS

☞ Check Your Progress 1

1. Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link.

2. To make efficient use of high speed telecommunications lines, some form of multiplexing is used. Multiplexing allows several transmission sources to share a larger transmission capacity.

A common application of multiplexing is in long-haul communications. Trunks on long-haul networks are high capacity fiber, coaxial or microwave links. These links can carry large numbers of voice and data transmission simultaneously using multiplexing.

3. Four basic multiplexing techniques are frequency division multiplexing (FDM), Time division Multiplexing (TDM), Code division Multiplexing (CDM) and Space-division Multiplexing (SDM).

☞ Check Your Progress 2

1. Frequency-Division Multiplexing (FDM) is a form of signal multiplexing where multiple baseband signals are modulated on different frequency carrier waves and added together to create a composite signal.

   Time-Division Multiplexing (TDM) is a type of digital multiplexing in which two or more signals or bit streams are combined into different slots of a frame. Transmission of frame carries simultaneously data from sub-channels in one communication channel, but are physically taking turns on the channel.

2. What is CDMA?

3. Circuit switching is defined as a mechanism applied in telecommunications hereby the user is allocated the full use of the communication channel for the duration of the call and hence a physical connection is set-up between the caller and the receiver.

☞ Check Your Progress 3

1. In switched line communications, a link that is established in a switched network, such as the international dial-up telephone system.

   A leased line is a symmetric dedicated service (the same upstream and downstream bandwidth) creating a permanent connection between your premises and the Internet.

2. In the switched communications networks data entering the network from a station are routed to the destination by being switched from node to node. For example in the Figure 16 data from station A intended for station F are send to node 4. They may then be routed via nodes 5 and 6 or nodes 7 and 6 to the destination. This is called switched communication networks.

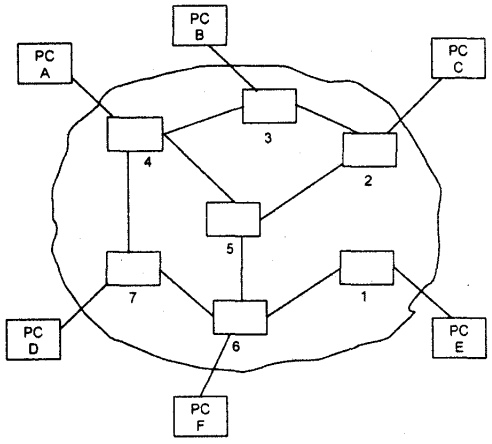

Figure 16: Simple Switching Network

3. i) Line efficiency is greater, because single node to node link can be dynamically shared by many packets over time. in other hand in circuit switching time on a node to node link is pre-allocated using synchronous time division multiplexing.

   ii) A packet switching network can perform data rate conversion.

   iii) When traffic becomes heavy on a circuit switching network, some caller are blocked, on the packet switching network, packets are still accepted, hut delivery delay increases.

   iv) Priorities can be used. Thus it can transmit higher priority packet first.

UNIT 4 COMMUNICATION MEDIUMS

Structure **Page No.**

4.0 DIGITAL DATA TRANSMISSION

The term digital refers to the way it is conveyed: usually by a binary code consisting of a long string of 1s and 0s. Digital transmission or digital communications is a literal transfer of data over a point to point (or point to multipoint) link using transmission medium –such as copper wires, optical fibers, wireless communications media, or storage media. The data that is to be transferred is often represented as an electro-magnetic signal (such as a microwave). Digital transmission transfers messages discretely. These messages are represented by a sequence of pulses via a line code. Digital data transmission can occur in two basic modes: serial or parallel. The serial and parallel transmission is shown in Figure 1 below. Data within a computer system is transmitted via parallel mode on buses with the width of the parallel bus matched to the word size of the computer system. Data between computer systems is usually transmitted in bit serial mode. Consequently, it is necessary to make a parallel-to-serial conversion at a computer interface when sending data from a computer system into a network and a serial-to-parallel conversion at a computer interface when receiving information from a network. The type of transmission mode used may also depend upon distance and required data rate.

4.1 OBJECTIVES

After going through this unit, you should be able to:

- Know the concept of communication mediums
- Differentiate between Serial and Parallel Transmission
- Differentiate between Guided and Unguided Mediums
- Know the features and limitations of different wired mediums
- Understands the use of Twisted Pair, Coaxial and Fiber Optic Cables
- Know the functions of Unguided Mediums
- Understand the use of different connectors

4.2 SERIAL AND PARALLEL TRANSMISSION

Serial Transmission: In serial transmission, bits are sent sequentially on the same channel (wire) as shown in Figure 1, which reduces costs for wire but also slows the speed of transmission. Also, for serial transmission, some overhead time is needed since bits must be assembled and sent as a unit and then disassembled at the receiver. Serial transmission can be either synchronous or asynchronous. In synchronous transmission, groups of bits are combined into frames and frames are sent continuously with or without data to be transmitted. In asynchronous transmission, groups of bits are sent as independent units with start/stop flags and no data link synchronization, to allow for arbitrary size gaps between frames. However, start/stop bits maintain physical bit level synchronization once detected.

In parallel transmission, multiple bits (usually 8 bits or a byte/character) are sent simultaneously on different channels (wires, frequency channels) within the same cable as shown in Figure 1, or radio path, and synchronized to a clock. Parallel devices have a wider data bus than serial devices and can therefore, transfer data in words of one or more bytes at a time.

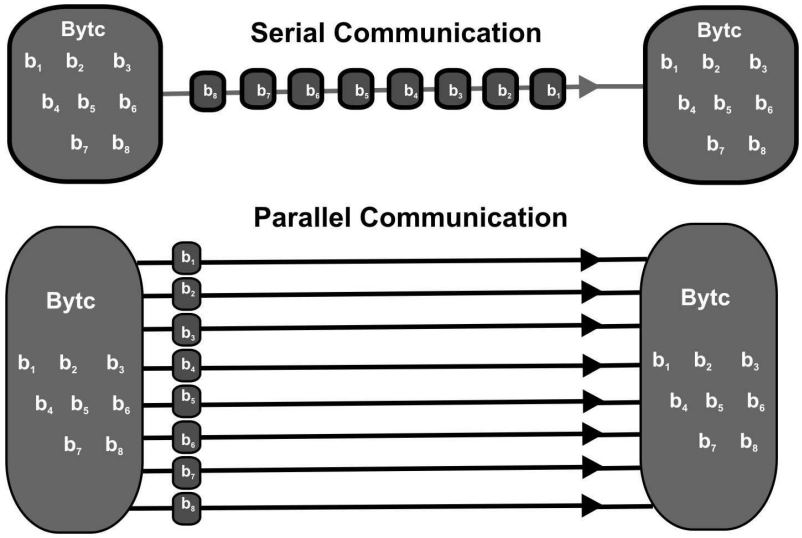

Figure 1: Serial and parallel communication

As a result, there is a speedup in parallel transmission bit rate over serial transmission bit rate. However, this speedup is a tradeoff versus cost since multiple wires cost more than a single wire, and as a parallel cable gets longer, the synchronization timing between multiple channels becomes more sensitive to distance. The timing for parallel transmission is provided by a constant clocking signal sent over a separate wire within the parallel cable; thus parallel transmission is considered synchronous.

4.3 GUIDED AND UNGUIDED MEDIUMS

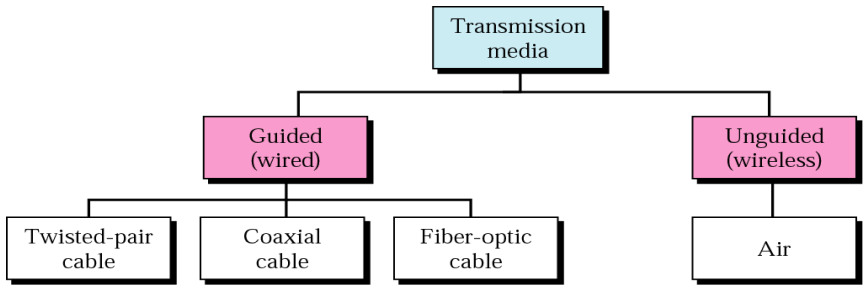

Figure 2: Classification of Transmission Mediums

Transmission Media: The transmission medium is the physical path between transmitter and receiver in a data transmission system. Transmission media can be classified as guided or unguided as depicted in Figure 2. With guided media, the waves are guided along a solid medium, such as twisted pair, coaxial cable, and optical fiber. The atmosphere and outer space are examples of unguided media that provide a means of transmitting electromagnetic signals but do not guide them; this form of transmission is usually referred to as wireless transmission.

The characteristics and quality of a data transmission are determined both by the characteristics of the medium and the characteristics of the signal. In the case of guided media, the medium itself is more important in determining the limitations of transmission.

For unguided media, the bandwidth of the signal produced by the transmitting antenna is more important than the medium in determining transmission characteristics. One key property of signals transmitted by antenna is directionality. In general, signals at lower frequencies are Omni-directional; that is, the signal propagates in all directions from the antenna. At higher frequencies, it is possible to focus the signal into a directional beam.

4.4 TWIATED PAIR

Twisted pair is most widely used media for local data distribution. Twisted-pair cable is a type of cabling that is used for telephone communications and most modern Ethernet networks. A pair of wires forms a circuit that can transmit data. The pairs are twisted to provide protection against crosstalk, and noise generated by adjacent pairs. When electrical current flows through a wire, it creates a small, circular magnetic field around the wire. When two wires in an electrical circuit are placed close together, their magnetic fields are the exact opposite of each other. Thus, the two magnetic fields cancel each other out. They also cancel out any outside magnetic fields. Twisting the wires can enhance this cancellation effect. Using cancellation together with twisting the wires, cable designers can effectively provide self shielding for wire pairs within the network media. The twisted pair cable is shown in Figure 3.

Figure 3: Twisted pair Cable

While twisted-pair cable is used by older telephone networks and is the least expensive type of local-area network (LAN) cable, most networks contain some twisted-pair cabling at some point along the network.

Since some telephone sets or desktop locations require multiple connections, twisted pair is sometimes installed in two or more pairs, all within a single cable. For some business locations, twisted pair is enclosed in a shield that functions as a ground. This is known as shielded twisted pair (STP). Ordinary wire to the home is unshielded twisted pair (UTP).

4.5 UTP CABLE

Unshielded twisted pair is the most common kind of copper telephone wiring. UTP cable is a medium that is composed of pairs of wires. UTP cable is used in a variety of networks. Each of the eight individual copper wires in UTP cable is covered by an insulating material. In addition, the wires in each pair are twisted around each other as shown in Figure 4 (a).

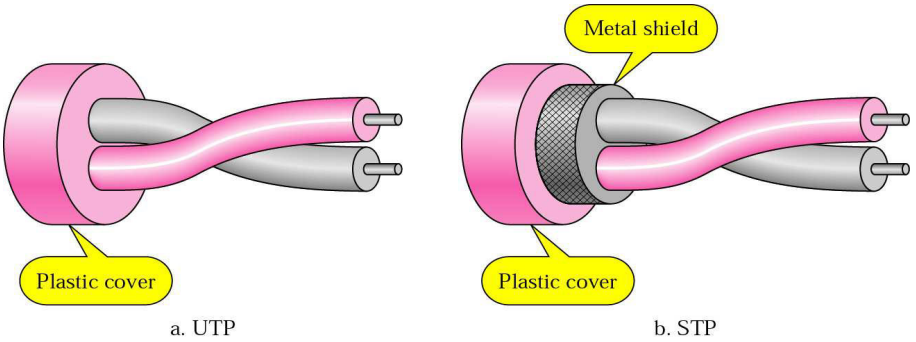

Figure 4: UTP and STP Cables

UTP cable relies solely on the cancellation effect produced by the twisted wire pairs to limit signal degradation caused by electromagnetic interference (EM!) and radio frequency interference (RFI). To further reduce crosstalk between the pairs in UTP cable, the number of twists in the wire pairs varies. UTP cable must follow precise specifications governing how many twists or braids are permitted per meter (3.28 feet) of cable.

4.6 STP CABLE

STP is similar to UTP in that the wire pairs are twisted around each other. STP also has shielding around the cable to further protect it from external interference. The shielding further reduces the chance of crosstalk but the shielding increases the overall diameter and weight of the cable. The maximum segment length of STP cable is 100 meters.

Shielded twisted pair is a special kind of copper telephone wiring used in some business installations. An outer covering or shield is added to the ordinary twisted pair telephone wires; the shield functions as a ground. The STP cable is shown in figure above in Figure 4(b).

Shielded twisted-pair (STP) cable combines the techniques of shielding, cancellation, and wire twisting. Each pair of wires is wrapped in a metallic foil. The four pairs of wires then are wrapped in an overall metallic braid or foil. It is usually a 150-ohm cable, as specified for use in Ethernet network installations. STP reduces electrical noise both within the cable (pair-to-pair coupling, or crosstalk) and from outside the cable (EMI and RFI).

☛ Check Your Progress 1

1. Define parallel transmission.

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2. List guided transmission mediums?

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3. What are the advantages of STP over UTP?

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4.7 COAXIAL CABLE

Coaxial cable like twisted pair, consists of two conductors, but is constructed differently to permit it to operate over a wider range of frequencies. It consists of a hollow outer cylindrical conductor that surrounds a single inner wire conductor. The inner conductor is held in place by either regularly spaced insulating rings or a solid dielectric material. The outer conductor is covered with a jacket or shield. A single coaxial cable has a diameter of from 0.4 to about 1 inch. Because of its shielding, concentric construction, coaxial cable is much less susceptible to interference and cross-talk than is twisted pair. Coaxial cable can be used over longer distances and supports more stations on a shared line than twisted pair.

Coaxial cable is perhaps the most versatile transmission medium and has widespread use in a wide variety of applications; the most important of these are

i) Television distribution

ii) Long-distance telephone transmission

iii) Short-run computer system links

iv) Local Area Networks

Coaxial cable is spreading rapidly as a means of distributing TV signals to individual homes - cable TV. A cable TV system can carry dozens or even hundreds of TV channels ranging up to a few tens of miles.

Coaxial cable has traditionally been an important part of the long-distance telephone network. Today, it is getting replaced by optical fiber, terrestrial microwave, and satellite. Using frequency-division multiplexing, a coaxial cable can carry over 10,000 voice channels simultaneously. Coaxial cable is also commonly used for short-range connections between devices. Using digital signaling, coaxial cable can be used to provide high-speed I/O channels on computer systems. A co-axial cable is shown in Figure 5 below.

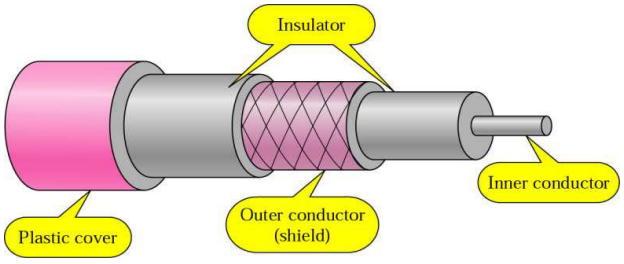

Figure 5: Coaxial cable

Another application area for coaxial cable is local area networks. Coaxial cable can support a large number of devices with a variety of data and traffic types, over distances that encompass a single building or a complex of buildings.

Coaxial cable is used to transmit both analog and digital signals. Coaxial cable has frequency characteristics that are superior to those of twisted pair, and can hence be used effectively at higher frequencies and data rates. The principal constraints on performance are attenuation, thermal noise, and inter modulation noise.

For long-distance transmission of analog signals, amplifiers are needed every few kilometers, with closer spacing required if higher frequencies are used. The usable spectrum for analog signaling extends to about 400 MHz. For digital signaling, repeaters are needed every kilometer or so, with closer spacing needed for higher data rates.

4.8 FIBRE OPTIC CABLES

Now day's optical fiber is widely used as a back bone for network due to its higher data transmission rate, lighter in weight, low interferences, less number of repeaters required, long distance coverage etc. An optical transmission system has three components; the light source, the transmission medium, and the detector.

Conventionally, a pulse of light indicates a bit 1 and absence of light indicates bit 0. Transmission medium is an ultra-thin fiber of glass. The transmitter generates the light pulses based on the input electrical signal. The detector regenerates the electrical signal based on the light signal it detects on the transmission medium. By attaching a light source to one end of an optical fiber and a detector to the other, we have an unidirectional data transmission system that accepts an electrical signal, converts and transmits it by light pulse, and then reconverts the output to an electrical signal at the receiving end. Figure 6 given blow shows optical fiber cable.

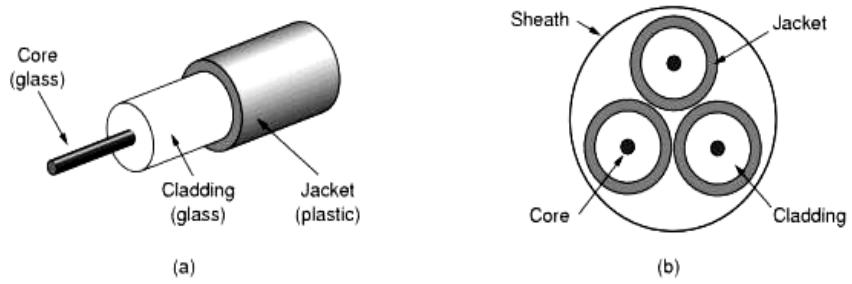

Figure 6: Optical Fiber Cable

An optical fiber is a thin (2 to 125 nm – nano meter – 10-9 meter), flexible medium capable of conducting an optical ray. Various glasses and plastics can be used to make optical fibers. The lowest losses have been obtained using fibers of ultrapure fused silica. Ultrapure fiber is difficult to manufacture; higher-loss multi-component glass fibers are more economical and still provide good performance. Plastic fiber is even less costly and can be used for short-haul links, for which moderately high losses are acceptable.

An optical fiber cable has a cylindrical shape and consists of three concentric sections: the core, the cladding, and the jacket. The core is the innermost section and consists of one or more very thin strands, or fibers, made of glass or plastic. Each fiber is surrounded by its own cladding, a glass or plastic coating that has optical properties different from those of the core. The outermost layer, surrounding one or a bundle of cladded fibers, is the jacket. The jacket is composed of plastic and other

material layered to protect against moisture, abrasion, crushing and other environmental dangers.

One of the most significant technological breakthroughs in data transmission has been the development of practical fiber optic communications systems. Optical fiber already enjoys considerable use in long-distance telecommunications. The continuing improvements in performance and decline in prices, together with the inherent advantages of optical fiber, have made it increasingly attractive for local area networking and metropolitan networks. Optical fiber is of two types.

i) Single mode optical fiber.

ii) Multimode Optical Fiber.

Single mode optical fiber: Single mode uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal. The fiber itself is manufactured with a much smaller diameter than that of multimode fibers, and with substantially lowers density (index of refraction). The decrease in density results in a critical angle that is close enough to 90 degrees to make the propagation of beams delays are negligible. All of the beams arrive at the destination "together" and can be recombined without distortion to the signal as depicted in Figure 7 (c).

Multi-Mode: Multimode is so named because multiple beams from a light source move through the core in different paths. How these beams move within a cable depends on the structure of the core. Multi-mode is categorized into step-index multimode and graded index mode.

1. **Step-index Mult-mode:** In step-index multimode, the density of the core remains constant from the center to the edges. A beam of light moves through this constant density in a straight line until it reaches the interface of the core and the cladding. At the interface there is an abrupt change to a lower density that alters the angle of the beam's motion. The term step-index refers to the suddenness of this change. Figure 7 below shows various beams (or rays) traveling through a step-index fiber. Some beams in the middle travel in straight lines through the core and reach the destination without reflecting or refracting. Some beams strike the interface of the core and cladding at an angle smaller than the critical angle; these beams penetrate the cladding and are lost. Still others hit the edge of the core at angles greater than the critical angle and reflect back into the core and off the other side, bouncing back and forth down the channel until they reach the destination.

   Every beam reflects off the interface at an angle equal to its angle of incidence as shown in Figure 7(a). The greater the angle of incidence, the wider the angle of refraction. A beam with a smaller angle of incidence will require more bounces to travel the same distance than a beam with a larger angle of incidence. Consequently, the beam with the smaller incident angle must travel farther to reach the destination. This difference in path length means that different beams arrive at the destination at different times. As these different beams are recombined at the receiver, they result in a signal that is no longer an exact replica of the signal that was transmitted. Such a signal has been distorted by propagation delays. This distortion limits the available data rate and makes multimode step-index cable inadequate for certain precise applications.

2. **Graded-index Mode:** A second type of fiber, called graded-index, decreases this distortion of the signal through the cable. The word index here refers to the index of refraction. As we saw above, index of refraction is related to density. A graded-index fiber, therefore, is one with varying densities. Density is highest at

the center of the core and decreases gradually to its lowest at the edge. Figure 7(b) shows the impact of this variable density on the propagation of light beams.

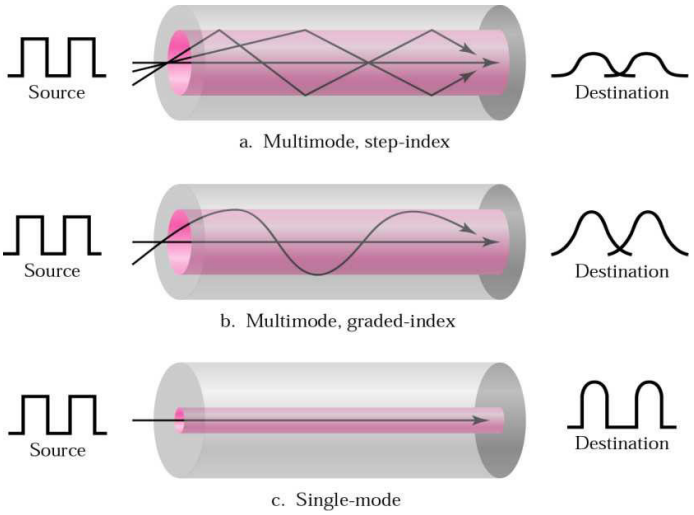

Figure 7: Types of Optical Fiber Cables

☞ Check Your Progress 2

1. List the applications of Coaxial cable.

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2. What is Single mode optical fiber?

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4.9 UNGUIDED MEDIUMS

Unguided Media: Unguided media transport electromagnetic waves without using a physical conductor. Signals are broadcast though air or water, and thus are available to anyone who has a device capable of receiving them. The EM spectrum covers frequencies from 3 Hz (ELF) to gamma rays (30 ZHz, Zetta Hertz - 10^{21} Hz) and beyond (cosmic rays). But only frequencies ranging from 3 KHz to 900 THz are used for wireless communication.

Propagation of Radio Waves: Radio technology considers the earth as surrounded by two layers of atmosphere: the troposphere and the ionosphere. The troposphere is the portion of the atmosphere extending outward approximately 30 miles from the earth's surface. The troposphere contains what we generally think of as air. Clouds, wind, temperature variations, and weather in general occur in the troposphere. The ionosphere is the layer of the atmosphere above the troposphere but below space. Unguided signals can travel from the source to destination in several ways. There is

ground propagation, sky propagation, and line-of-sight propagation. In ground propagation, radio waves travel through the lowest portion of the atmosphere, hugging the earth. These low-frequency signals emanate in all directions from the transmitting antenna and follow the curvature of the earth. The distance depends on the power of the signal. In Sky propagation, higher-frequency radio waves radiate upward into the ionosphere where they are reflected back to earth. This type of transmission allows for greater distances with lower power output. In Line-of-Sight Propagation, very high frequency signals are transmitted in straight lines directly from antenna to antenna. Antennas must be directional, facing each other and either tall enough or close enough together not to be affected by the curvature of the earth.

Radio Waves: Radio wave frequencies are between 3 KHz to 1 GHz, and uses omnidirectional antenna. Omniderectional antenna propagates signal in all direction. This means that the sending and receiving antennas do not have to be aligned. But it has disadvantage too, it is susceptible to interference wherein a radio wave transmitted by one antenna may be interfered by another antenna that may send signals using the same frequency or band.

Radio waves are used for multicast communications, such as radio (AM and FM radio), maritime radio, television, cordless phones and paging systems.

Microwaves: Frequencies between 1 and 300 GHz are called microwaves. Microwaves are unidirectional. When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned. Its advantage is that a pair of antennas can be aligned without interfering with another pair of aligned antennas.

The propagation of microwave is line-of-sight. The problem with this propagation is that towers that are far apart from each other need to be very tall. The curvature of the earth as well as other blocking obstacles does not allow two short towers to communicate. For long distance communication, repeaters are often needed. Another disadvantage is that very high frequency microwaves cannot penetrate walls.

In a unidirectional antenna, there are two types: the parabolic dish and the horn. A parabolic dish antenna is based on the geometry of the parabola. Every line parallel to the line of symmetry reflects off the curve at angles such that all the lines intersect in a common point called focus. The parabolic dish works as a funnel, catching a wide range of waves and directing them to a common point.

A horn antenna on the other hand looks like a gigantic scoop. Outgoing transmissions are broadcast up a stem and deflected outward in a series of narrow parallel beams by the curved head. Received transmissions are collected by the scooped shape of the horn, in a manner similar to the parabolic dish, and are deflected down into the stem.

There is another type of microwave transmission with the use of satellite relay. It requires geo-stationary orbit with the height of 35,784km to match the earth's rotation. It has uplink that receives transmission on one frequency and a downlink that transmits on a second frequency. It Operates on a number of frequency bands known as transponders.

It can operate in two ways:

a) Point to point- Ground station to satellite to ground station

b) Multipoint (Broadcast link)- Ground station to satellite to multiple receiving stations.

Microwaves are used in unicast communication such as cellular telephones, satellite networks, and wireless LANs.

Infrared Waves: Infrared signals with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 700 nm), can be used for short-range communication. high frequencies cannot penetrate walls. This characteristic prevents interference between one system and another; a short-range communication cannot be affected by another system in the next room. The same characteristic makes infrared signals useless for long range communication. Infrared waves cannot be used outside a building because the sun's rays contained infrared waves can interfere with the communication. The infrared band, almost 400 THz, has an excellent potential for data transmission. Such a wide bandwidth can be used to transmit digital data with a very high data rate. The infrared Data Association (IrDA), an association for sponsoring the use of infrared waves, has established a standard for using these signals for communication between devices such as the keyboard, mice, PCs, and printers. Infrared signals defined by the IrDA transmit through line of sight; the IrDA port on the keyboard needs to point to the PC for transmission occurs.

4.10 CONNECTORS

The connectors are the interface for communication between computers/ computers to hub, switch, router etc. In LAN basically used connector are discussed as follows:

1. **RJ-45 Connector:** RJ stands for registered jack. RJ45 is a standard type of connector for network cables. RJ45 connectors are most commonly seen with Ethernet cables and networks. RJ45 connectors feature eight pins to which the wire strands of a cable interface electrically. Standard RJ-45 pin-outs define the arrangement of the individual wires needed when attaching connectors to a cable. RJ-45 connectors are of two types: male RJ-45 and female RJ-45. The Figure 8 shows RJ -45 connector.

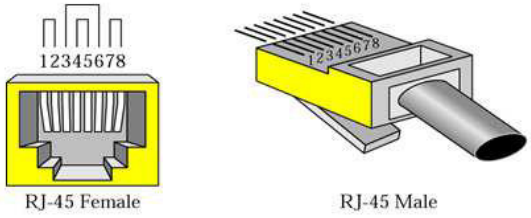

Figure 8: RJ-45 connectors

2. **BNC connector:** The BNC connector (Bayonet Neill–Concelman) is miniatures quick connect/disconnect RF connector used for coaxial cable. It features two bayonet lugs on the female connector; mating is achieved with only a quarter turn of the coupling nut. BNCs are ideally suited for cable termination for miniature-to-subminiature coaxial cable (e.g., RG-58, 59, to RG-179, RG-316). It is used with radio, television, and other radio-frequency electronic equipment, test instruments, video signals, and was once a popular computer network connector. BNC connectors are made to match the characteristic impedance of cable at either 50 ohms or 75 ohms. It is usually applied for frequencies below 3 GHz and voltages below 500 Volts.

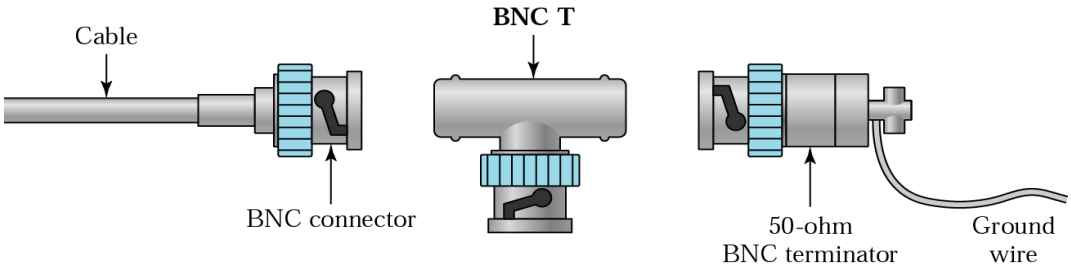

Figure 9: BNC connectors

Fiber optic cable connector: Fiber optic cable connectors are hardware installed on fiber cable ends to provide cable attachment to a transmitter, receiver or other cable. In order for information to be transmitted efficiently, the fiber cores must be properly aligned. They are usually devices that can be connected and disconnected repeatedly. There are many types of fiber optic cable connectors also shown in Figure 10:

1. **ST Connectors:** ST stands for Straight Tip. Slotted bayonet type connector with long ferrule, a common connector for multi-mode fibers. The ST connector has been the main stay of optical fiber connectors for many years. It can be found in almost every communications room worldwide, but used mainly in data communications systems. The simple to use bayonet locking mechanism reduces the risks of accidental disconnection of fiber connections.

2. **SC (Standard Connector) Connectors:** Push/pull connector that can also be used with duplex fiber connection. The SC connector comprises a polymer body with ceramic ferrule barrel assembly plus a crimp over sleeve and rubber boot. These connectors are suitable for, 900µm and 2-3mm cables. The connector is precision made to demanding specifications. The combination of a ceramic ferrule with precision polymer housing provides consistent long-term mechanical and optical performance.

3. **MT Connector:** The MT-RJ connector is a development of the now legendary MT ferrule. MT stands Multi-fiber Connector. The MT ferrule in its various designs has the ability to connect anything from 2 fibers in the MTRJ to 72 fibers in the latest versions of the MPO connector.

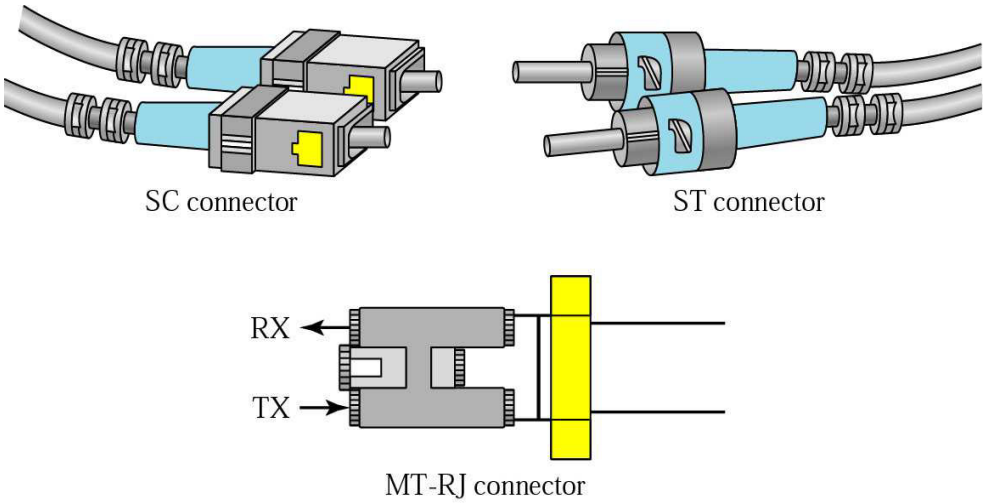

Figure 10: Fiber optic cable connector

☞ **Check Your Progress 3**

1. What are microwaves? Explain their properties.

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2. What is BNC connector?

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3. Explain the use of SC Connectors.

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4.11 SUMMARY

After completing this unit, you must have knowledge of different transmission mediums, cables and connectors. In the beginning serial and parallel communication is explained. In serial transmission, bits are sent sequentially on the same channel (wire). In parallel transmission, multiple bits (usually 8 bits or a byte/character) are sent simultaneously on different channels (wires, frequency channels) within the same cable. In this unit, we have seen that transmission media can be classified as guided or unguided. Twisted-pair cable is a type of cabling that is used for telephone communications and most modern Ethernet networks. Coaxial cable like twisted pair, consists of two conductors, but is constructed differently to permit it to operate over a wider range of frequencies. Today's optical fiber is widely used as a back bone for network due to its higher data transmission rate, lighter in weight, low interferences, less number of repeaters required, long distance coverage etc.. Optical fiber is of two types i.e. Single mode optical fiber and Multimode Optical Fiber. Further medium of communication is unguided. Unguided media transport electromagnetic waves without using a physical conductor. Signals are broadcast though air or water, and thus are available to anyone who has a device capable of receiving them. The connectors are the interface for communication between computers/ computers to hub, switch, router etc. In LAN basically used connector.

4.12 REFERENCES/FURTHER READING

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4.13 SOLUTIONS/ANSWERS

☞ Check Your Progress 1

1. In parallel transmission, multiple bits (usually 8 bits or a byte/character) are sent simultaneously on different channels (wires, frequency channels) within the same cable

2. Following are the guided transmission mediums
   i) twisted pair,
   ii) coaxial cable,
   iii) optical fiber

3. STP is similar to UTP in that the wire pairs are twisted around each other. STP also has shielding around the cable to further protect it from external interference. The maximum segment length of STP cable is 100 meters. Shielded twisted-pair (STP) cable combines the techniques of shielding, cancellation, and wire twisting. Each pair of wires is wrapped in a metallic foil.

☞ Check Your Progress 2

1. Following are the main applications of Coaxial cable.
   i) Television distribution
   ii) Long-distance telephone transmission
   iii) Short-run computer system links
   iv) Local Area Networks

2. Single mode uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal. The fiber itself is manufactured with a much smaller diameter than that of multimode fibers, and with substantially lowers density (index of refraction). The decrease in density results in a critical angle that is close enough to 90 degrees to make the propagation of beams delays are negligible.

☞ Check Your Progress 3

1. Frequencies between 1 and 300 GHz are called microwaves. Microwaves are unidirectional. When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned. Its advantage is that a pair of antennas can be aligned without interfering with another pair of aligned antennas.

   The propagation of microwave is line-of-sight. The problem with this propagation is that towers that are far apart from each other need to be very tall. The curvature of the earth as well as other blocking obstacles does not allow two short towers to communicate. For long distance communication, repeaters are often needed. Another disadvantage is that very high frequency microwaves cannot penetrate walls.

2. The BNC connector (Bayonet Neill–Concelman) is miniatures quick connect/disconnect RF connector used for coaxial cable.
3. This is a fiber optics cable connector. Push/pull connector that can also be used with duplex fiber connection. The SC connector comprises a polymer body with ceramic ferrule barrel assembly plus a crimp over sleeve and rubber boot. These connectors are suitable for, 900μm and 2-3mm cables. The connector is precision made to demanding specifications.