Module 1

Module 1:Introduction and Physical Layer

- Overview of Computer Network, OSI and TCP/IP Reference Models, Guided and Unguided Transmission Media, Analog and Digital Communication, Encoding and Modulation, Nyquist Theorem, Shannon’s capacity, Switching techniques- TDM, FDM.

Overview of Computer Network

- **Computer Network** is a group of computers connected with each other through wires or wireless, optical fibres or optical links so that various devices can interact with each other through a network.
- The **aim** of the computer network is the sharing of resources among various devices.
- A computer network is a system that connects numerous independent computers in order to share information (data) and resources. The integration of computers and other different devices allows users to communicate more easily.
- A computer network is a collection of two or more computer systems that are linked together. A network connection can be established using either cable or wireless media. Hardware and software are used to connect computers and tools in any network.

- **How Does a Computer Network Work?**

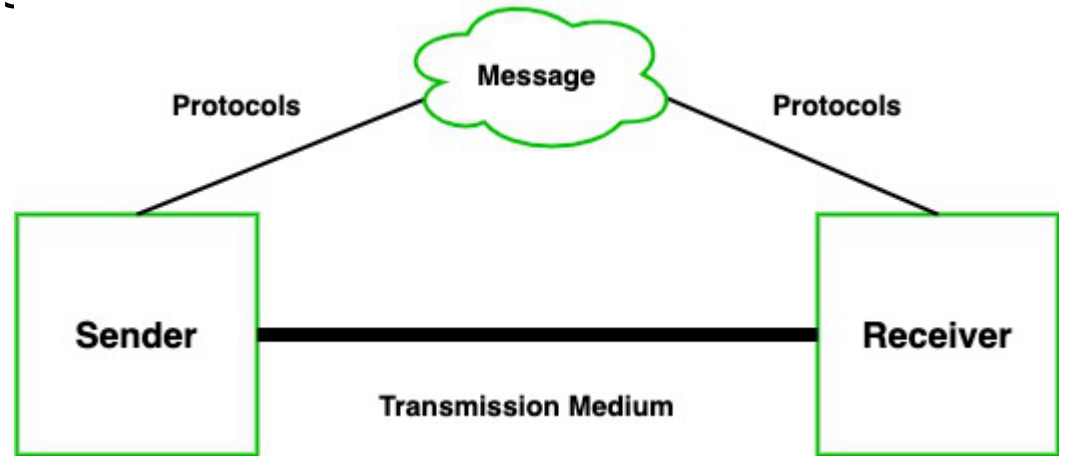
Computer Networks simply work using nodes and links. Data Communication Equipment is simply termed as Nodes. For example, Modems, Hubs, Switches, etc. whereas links in Computer networks can be referred to as a connection between two nodes. We have several types of links like cable wires, optical fibers, etc.

- The **purpose** of having computer network is to send and receive data stored in other devices over the network. These devices are often referred as nodes.
- There are five basic components of a computer network

- **Components of Data Communication**

A communication system is made up of the following components:

1. **Message:** A message is a piece of information that is to be transmitted from one person to another. It could be a text file, an audio file, a video file, etc.
2. **Sender:** It is simply a device that sends data messages. It can be a computer, mobile, telephone, laptop, video camera, or workstation, etc.
3. **Receiver:** It is a device that receives messages. It can be a computer, telephone mobile, workstation, etc.
4. **Transmission Medium / Communication Channels:** Communication channels are the medium that connect two or more workstations. Workstations can be connected by either wired media or wireless media.
5. **Set of rules (Protocol):** When someone sends the data (The sender), it should be understandable to the receiver also otherwise it is meaningless. For example, Sonali sends a message to Chetan. If Sonali writes in Hindi and Chetan cannot understand Hindi, it is a meaningless conversation.



- Therefore, there are some set of rules (protocols) that is followed by every computer connected to the internet and they are:
- **TCP(Transmission Control Protocol)**: It is responsible for dividing messages into packets on the source computer and reassembling the received packet at the destination or recipient computer. It also makes sure that the packets have the information about the source of the message data, the destination of the message data, the sequence in which the message data should be re-assembled, and checks if the message has been sent correctly to the specific destination.
- **IP(Internet Protocol)**: Do You ever wonder how does computer determine which packet belongs to which device. What happens if the message you sent to your friend is received by your father? Scary Right. Well! IP is responsible for handling the address of the destination computer so that each packet is sent to its proper destination.

- **Type of data communication**
- As we know that data communication is communication in which we can send or receive data from one device to another. The data communication is divided into three types:

1. **Simplex Communication:** It is one-way communication or we can say that unidirectional communication in which one device only receives and another device only sends data and devices uses their entire capacity in transmission. For example, IoT, entering data using a keyboard, listing music using a speaker, etc.
2. **Half Duplex communication:** It is a two-way communication or we can say that it is a bidirectional communication in which both the devices can send and receive data but not at the same time. When one device is sending data then another device is only receiving and vice-versa. For example, walkie-talkie.
3. **Full-duplex communication:** It is a two-way communication or we can say that it is a bidirectional communication in which both the devices can send and receive data at the same time. For example, mobile phones, landlines, etc.

- **Communication Channels**
- Communication channels are the medium that connects two or more workstations. Workstations can be connected by either wired media or wireless media. It is also known as a transmission medium. The transmission medium or channel is a link that carries messages between two or more devices. We can group the communication media into two categories:
- Guided media transmission
- Unguided media transmission

I - Guided Media: In this transmission medium, the physical link is created using wires or cables between two or more computers or devices, and then the data is transmitted using these cables in terms of signals. Guided media transmission of the following types:

- **1. Twisted pair cable:** It is the most common form of wire used in communication. In a twisted-pair cable, two identical wires are wrapped together in a double helix. The twisting of the wire reduces the crosstalk. It is known as the leaking of a signal from one wire to another due to which signal can corrupt and can cause network errors. The twisting protects the wire from internal crosstalk as well as external forms of signal interference. Types of Twisted Pair Cable :
- **Unshielded Twisted Pair (UTP):** It is used in computers and telephones widely. As the name suggests, there is no external shielding so it does not protects from external interference. It is cheaper than STP.
- **Shielded Twisted Pair (STP):** It offers greater protection from crosstalk due to shield. Due to shielding, it protects from external interference. It is heavier and costlier as compare to UTP.

2. Coaxial Cable: It consists of a solid wire core that is surrounded by one or more foil or wire shields. The inner core of the coaxial cable carries the signal and the outer shield provides the ground. It is widely used for television signals and also used by large corporations in building security systems. Data transmission of this cable is better but expensive as compared to twisted pair.

3. Optical fibers: Optical fiber is an important technology. It transmits large amounts of data at very high speeds due to which it is widely used in internet cables. It carries data as a light that travels inside a thin glass fiber. The fiber optic cable is made up of three pieces:

1. **Core:** Core is the piece through which light travels. It is generally created using glass or plastic.
2. **Cladding:** It is the covering of the core and reflects the light back to the core.
3. **Sheath:** It is the protective covering that protects fiber cable from the environment.

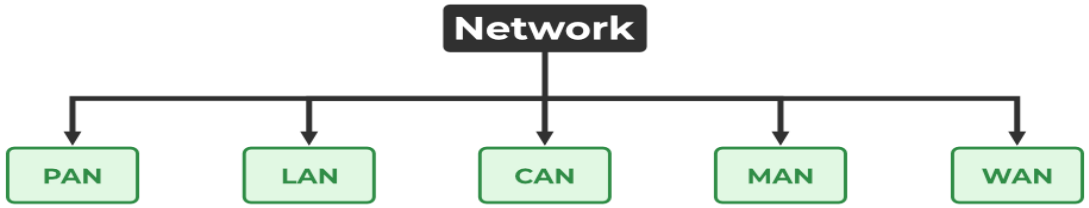
II- Unguided Media: The unguided transmission media is a transmission mode in which the signals are propagated from one device to another device wirelessly. Signals can wave through the air, water, or vacuum. It is generally used to transmit signals in all directions. Unguided Media is further divided into various parts :

- **1. Microwave:** Microwave offers communication without the use of cables. Microwave signals are just like radio and television signals. It is used in long-distance communication. Microwave transmission consists of a transmitter, receiver, and atmosphere. In microwave communication, there are parabolic antennas that are mounted on the towers to send a beam to another antenna. The higher the tower, the greater the range.
- **2. Radio wave:** When communication is carried out by radio frequencies, then it is termed radio waves transmission. It offers mobility. It is consists of the transmitter and the receiver. Both use antennas to radiate and capture the radio signal.
- **3. Infrared:** It is short-distance communication and can pass through any object. It is generally used in TV remotes, wireless mouse, etc.

Type of Computer Networks

- A computer network is a cluster of computers over a shared communication path that works to share resources from one computer to another, provided by or located on the network nodes.
- **Uses of Computer Networks**
- Communicating using email, video, instant messaging, etc.
- Sharing devices such as printers, scanners, etc.
- Sharing files.
- Sharing software and operating programs on remote systems.
- Allowing network users to easily access and maintain information.
- **Types of Computer Networks**
- There are mainly five types of Computer Networks

1. Personal Area Network (PAN)
2. Local Area Network (LAN)
3. Campus Area Network (CAN)
4. Metropolitan Area Network (MAN)
5. Wide Area Network (WAN)



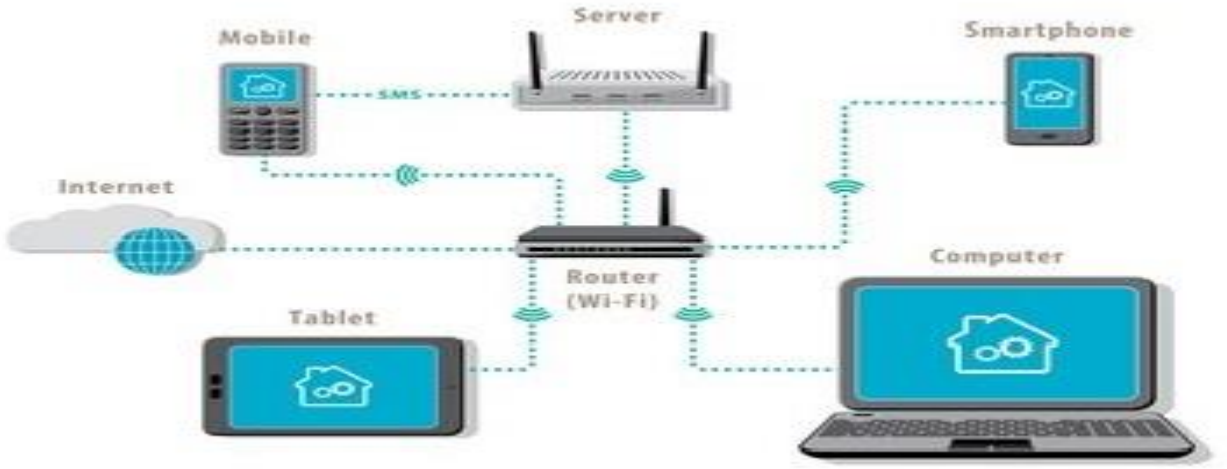
- **Different Types of Computer Networks**

A computer network can be defined as a group of computers that utilize a set of common communication protocols over digital interconnections to share resources over the network. A network can be a small one including a handful of systems to a one with millions of devices spread all across the world.

The various types of networks are listed as below:

- **Local Area Network (LAN)**

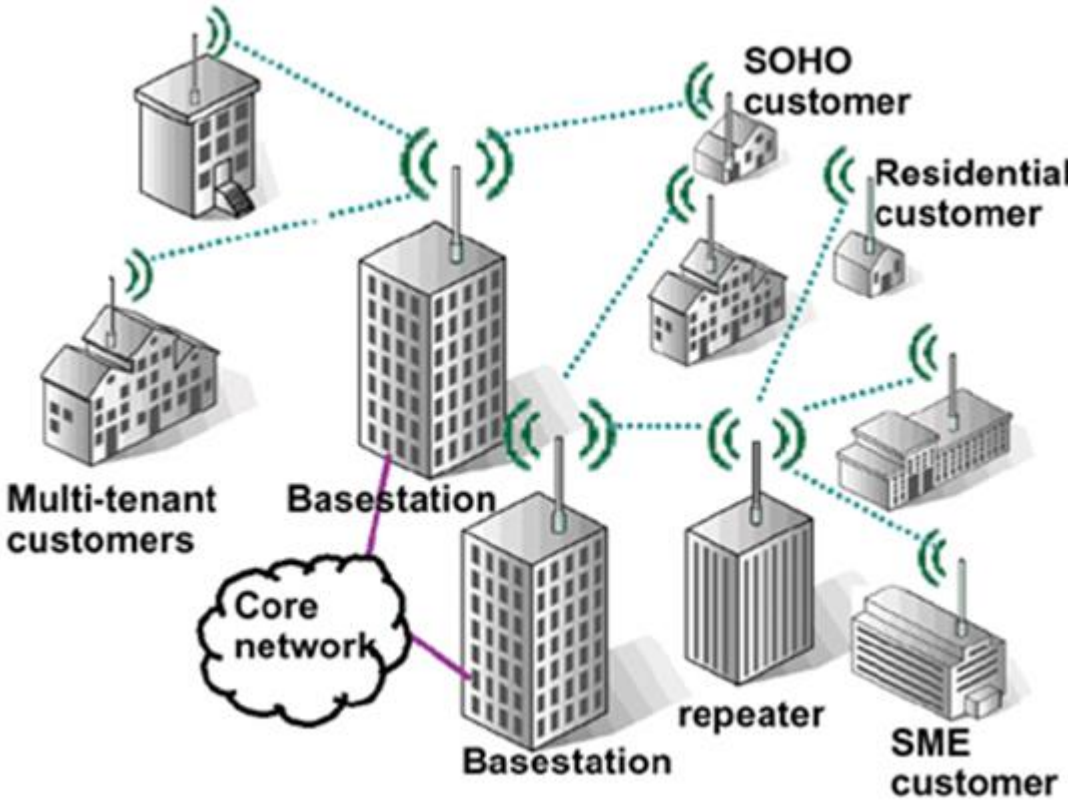
This is one of the original and very basic types of network, and also one of the simplest. LAN networks group computers together over comparatively small distances, such as within a single building or a small group of buildings, schools, offices, colleges, universities, etc to share resources such as printers, file servers, scanners, and the interne‘



- **Personal Area Network (PAN)**
- The smallest and most primary type of network, a PAN is composed of a wireless modem, a computer or two, phones, laptops, Bluetooth-enabled devices or infrared-enabled devices, media player, printers, tablets, etc., and revolves around one individual in one building.
- This may also incorporate a wireless computer keyboard and mouse, Bluetooth-enabled headphones, wireless printers, and TV remotes. These types of networks are typically observed in small offices or residences and are controlled by one person or organization from a single device.
- PAN possesses a connectivity span of up to 10 meters. There are two types of Personal Area Network: Wired Personal Area Network and Wireless Personal Area Network.

- **Metropolitan Area Network (MAN)**
- MAN is a kind of network which is bigger than a LAN but smaller than a WAN and incorporates properties of both. It typically covers a town or city and is controlled by a single person or company, such as a local council or a large company. The most extensively used protocols in MAN are RS-232, ATM, Frame Relay, ISDN, ADSL, OC-3, etc. It has a longer range than Local Area Network(LAN).

This type of network can be applied to connect citizens with various Organisations for example communication between the banks in a city, employed in college within a city, Government and private organizations use MAN to connect all its offices within the city.



- **Wide Area Network (WAN)**
- This is another kind of the original category of network and is Slightly more complex than a LAN. WAN networks encapsulate computers together over huge physical distances, remotely connecting them over a network and allowing them to communicate even when far apart.
- The Internet is an example of WAN which connects computers all around the world together. WANs are generally too large to be controlled by one administrator, and so generally have collective ownership, or in the case of the internet, is publicly owned. WAN is a general connection between LANs and MANs, that is not restricted to a single location, but it traverses over a large geographical area through a telephone line, fibre optic cable, microwaves, or satellite links.
- A Wide Area Network is extensively applied in the field of business, government, and education. The data communication is slowest in WAN due to the largest distance. The installation cost of WAN is very high and utilizes advanced technologies such as Asynchronous Transfer Mode (ATM), Frame Relay, and Synchronous Optical Network (SONET).

Other Types of Network

There are also other types of network users may encounter. Some of these are distinct, but most are developed from LAN and WAN networks to have slight variation and adapt to different user needs. These include:

- **Campus Area Network (CAN)**

This is a network that is bigger as compared to a LAN, but smaller than a MAN. This is very common in areas like a university, large school, or small business. CAN spread over several buildings which are reasonably local to each other. It can have an internal Ethernet along with the capability of connecting to the internet. Its also referred to as a "Corporate Area Network".

- **Wireless Local Area Network (WLAN)**

This is a LAN that is implemented with the use of wireless network technology such as Wi-Fi. This kind of network is becoming more popular these days as wireless technology is further developed and is used commonly in the home and small businesses. In other words, devices do not need to be dependent on physical cables and wires as much and can organize their spaces more effectively.

- **System Area Network (SAN)**

System area network combines computers on an especially high-speed connection, in a configuration known as a cluster(server-to-server applications). It means computers that are linked in a group to work as a single system, and can be implemented as a result of very high-speed computers and new low-cost microprocessors. They are generally used to enhance performance and for cost-effectiveness.

- **Storage Area Network (SAN)**

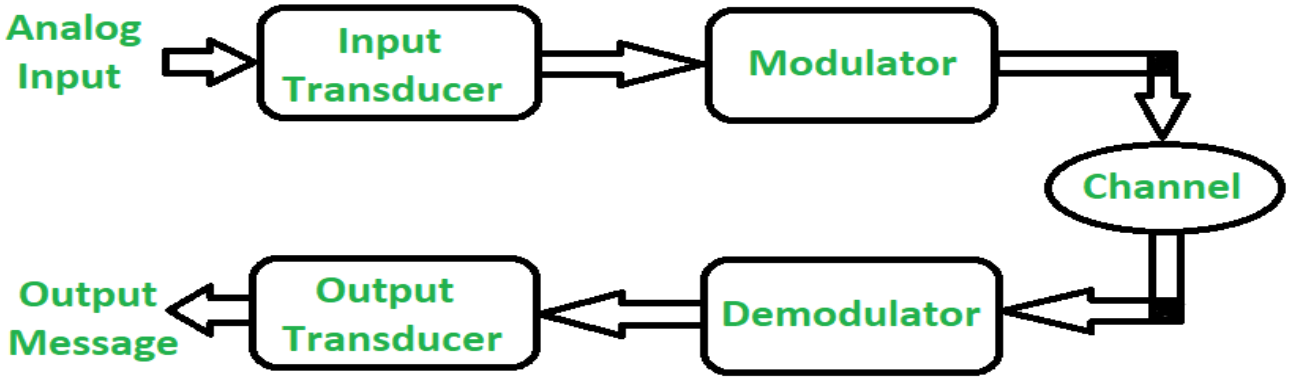
This network links servers directly to devices which store large amounts of data without depending on a LAN or WAN network to do so. This can include another type of connection known as Fibre Channel, a structure similar to Ethernet which manages high-performance disk storage for applications on a variety of professional networks. Types of storage-area networks include virtual, converged, and unified SANs.

- **Virtual Private Network (VPN)**

A Virtual Private Network or VPN is a private network that lets its users transmit and accept data as if their devices were connected to the private network and even if they are not. These systems use encryptions and other security tools to guarantee authorized user's access. Through a virtual point-to-point link, users can enter a private network remotely.

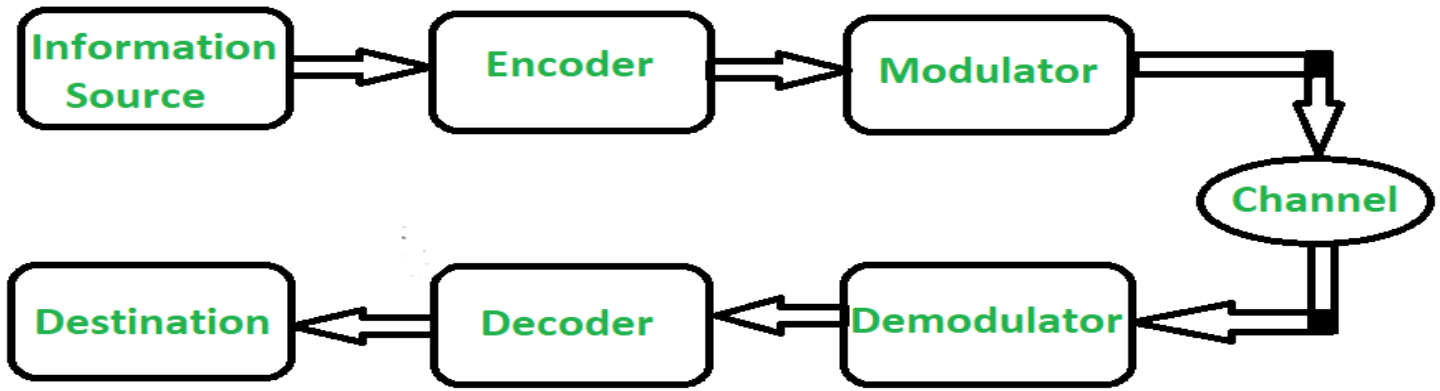
Analog (continuous) and Digital (Discrete) Communication, Encoding and Modulation

- **Analog Communication:**
  In analog communication the data is transferred with the help of analog signal in between transmitter and receiver. Any type of data is transferred in analog signal. Any data is converted into electric form first and after that it is passed through communication channel. Analog communication uses a continuous signal which varies in amplitude, phase, or some other property with time in proportion to that of a variable.
- The below figure illustrates the **Analog Communication System:**



Analog Communication System

- **Digital Communication:**
  In digital communication digital signal is used rather than analog signal for communication in between the source and destination. The digital signal consists of discrete values rather than continuous values. In digital communication physical transfer of data occurs in the form of digital bit stream i.e 0 or 1 over a point-to-point or point-to-multipoint transmission medium. In digital communication the digital transmission data can be broken into packets as discrete messages which is not allowed in analog communication.



Digital Communication System

DATA & SIGNALS

To be transmitted, data must be transformed to electromagnetic signals.

1. Data can be Analog or Digital:

-Analog data refers to information that is continuous;

For example. sounds made by a human voice

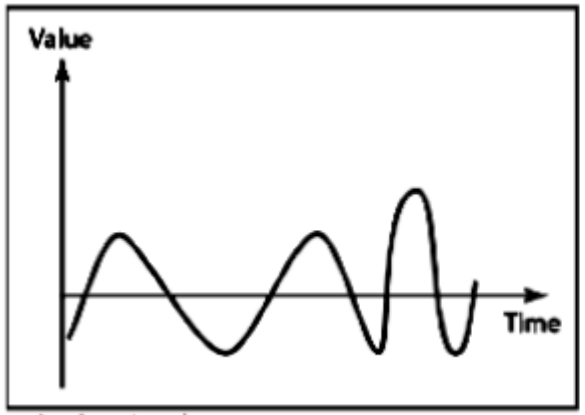
- Digital data refers to information that has discrete states. Digital data take on discrete values.

For example, data are stored in computer memory in the form of 0's and 1's

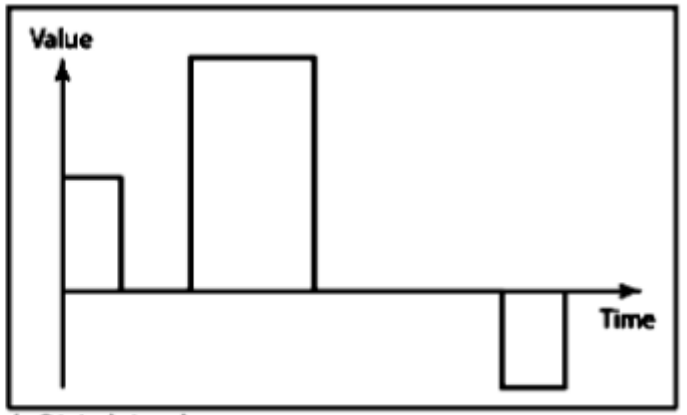
2. Signals can be of two types:

- Analog Signal: They have infinite values in a range.
- Digital Signal: They have limited number of defined values

For example,



a. Analog signal



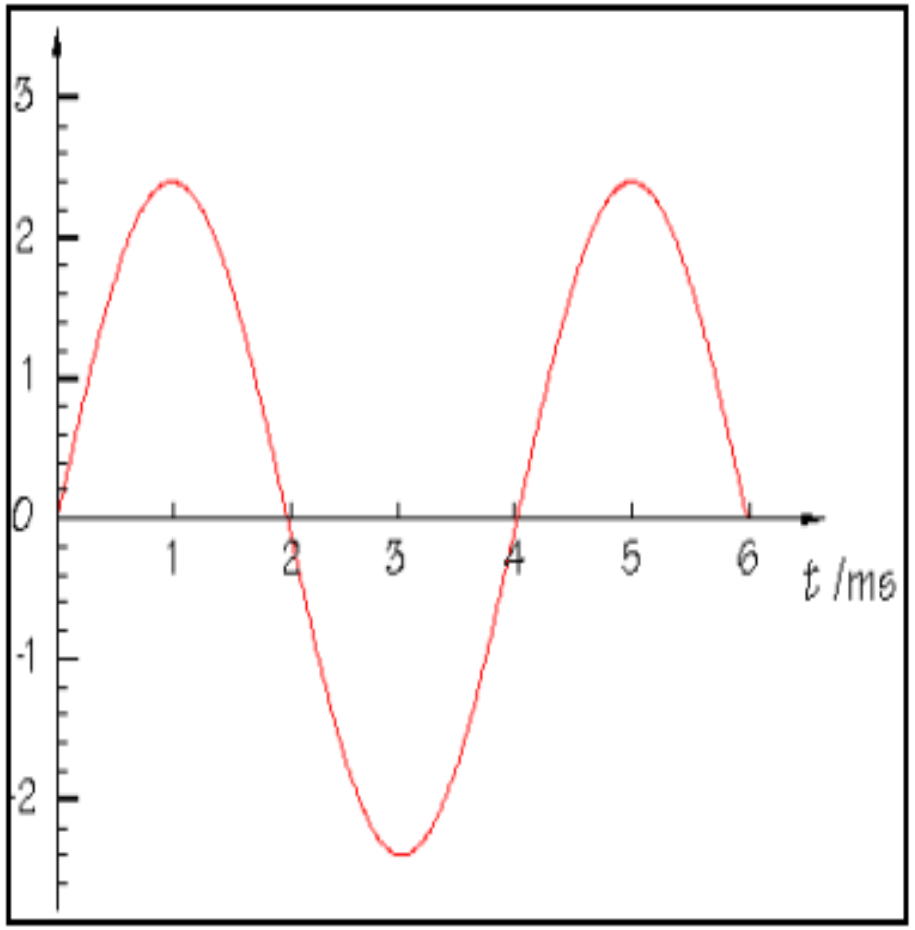
b. Digital signal

ANALOG SIGNAL

- An analog signal has infinitely many levels of intensity over a period of time.
- As the wave moves from value A to value B, it passes through and includes an infinite number of values along its path as it can be seen in the figure below.
- A simple analog signal is a sine wave that cannot be further decomposed into simpler signals.

A sine wave is characterized by three parameters:

1. Peak Amplitude
2. Frequency – inversely proportional to time period
3. Phase



Peak

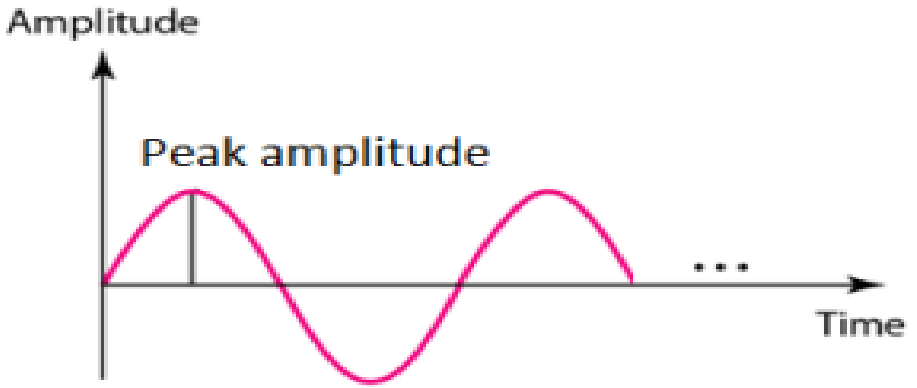


Fig.
Signal with high peak amplitude

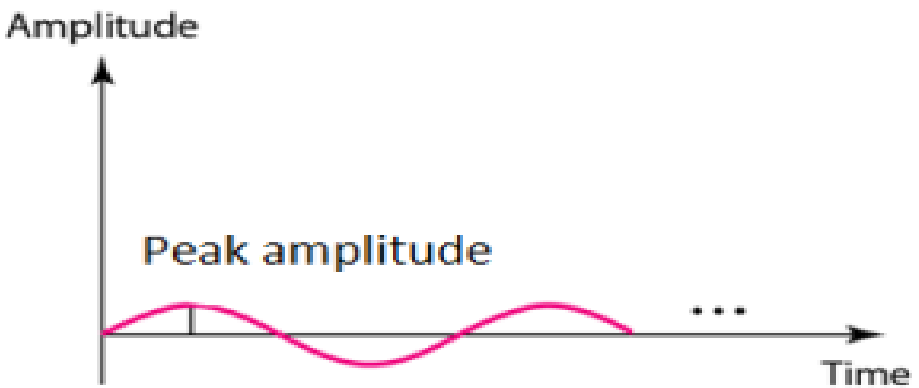
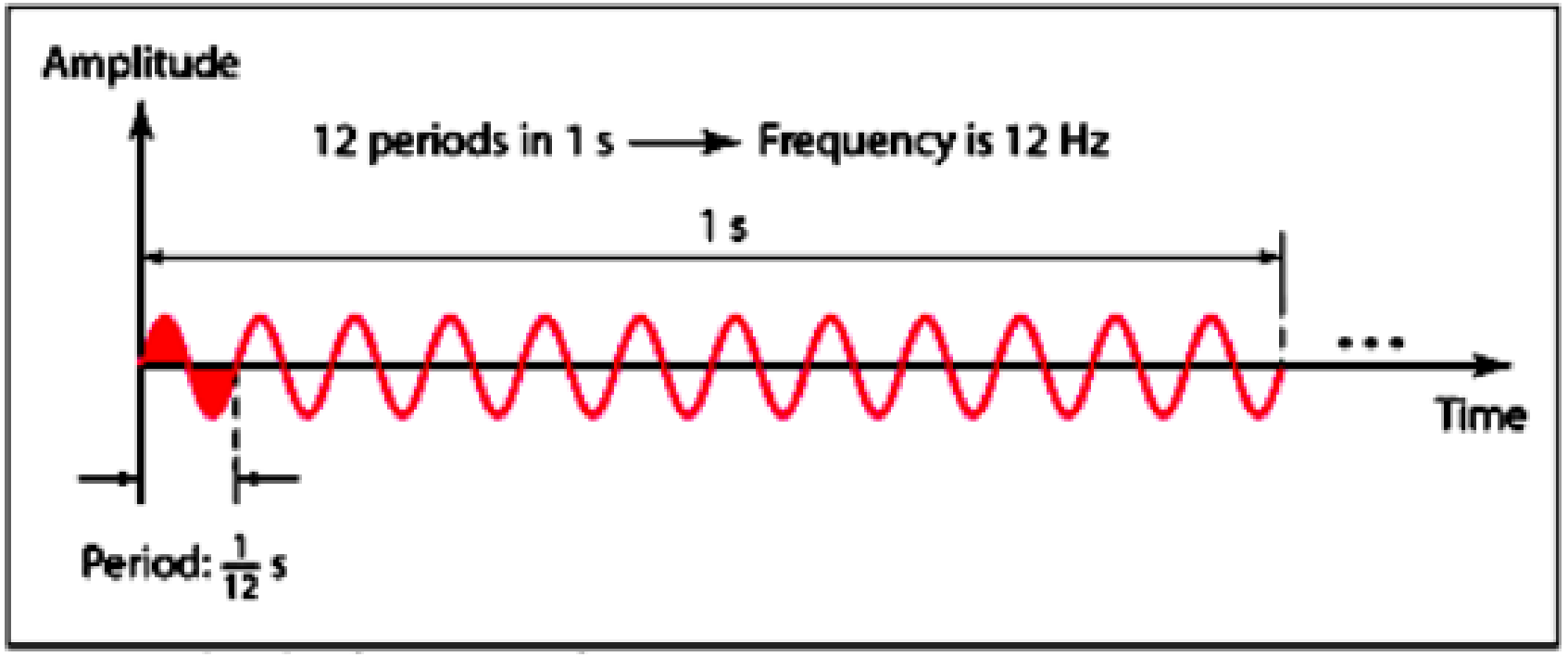
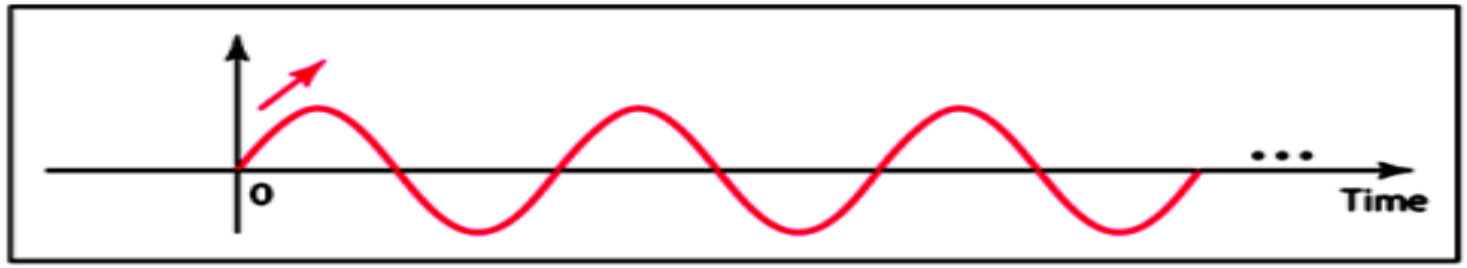


Fig.
Signal with low peak amplitude

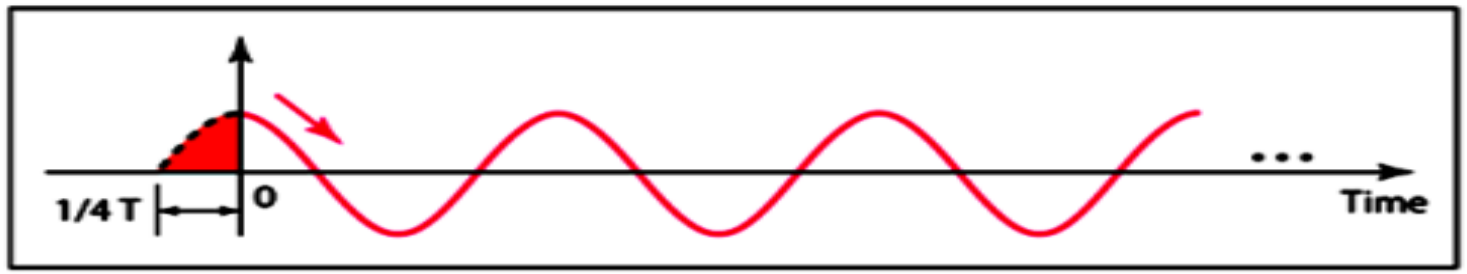
Frequency


Amplitude
12 periods in 1 s
Frequency is 12 Hz
1 s
Time
Period: 1/12 s

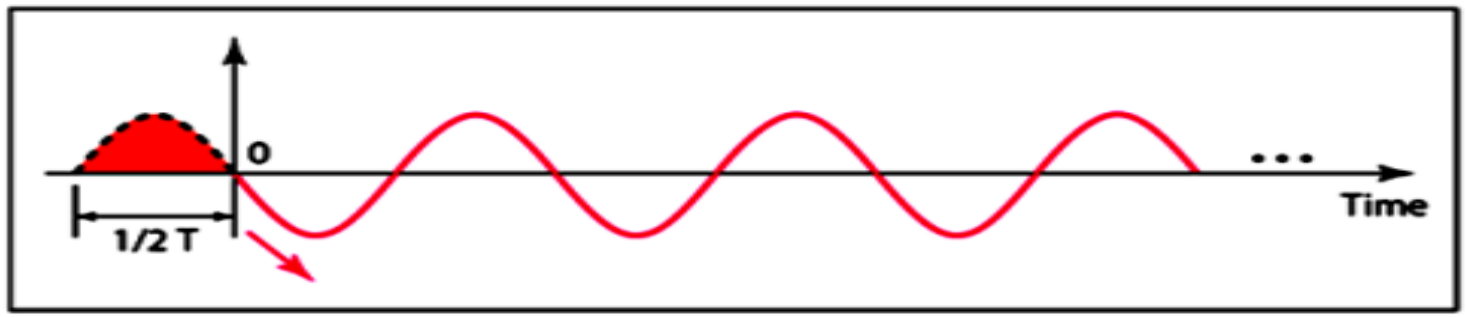
Phase



a. 0 degrees



b. 90 degrees



c. 180 degrees

Relation between Frequency & Period

Frequency & Period are inverse of each other. It is indicated by the following formula:

$T=1/f$

$F=1/t$

Example1. A wave has a frequency of 100hz. Its period(T) is given by

$T = 1/ F = 1/ 100 = 0.01$ sec

Example2. A wave completes its one cycle in 0.25 seconds. Its frequency is given by

$F = 1 / T = 1 / 0.25 = 4$ Hz

Wavelength

The wavelength of a signal refers to the relationship between frequency (or period) and propagation speed of the wave through a medium.

The wavelength is the distance a signal travels in one period.

It is given by

$$\text{Wavelength} = \text{Propagation Speed} \times \text{Period}$$

OR

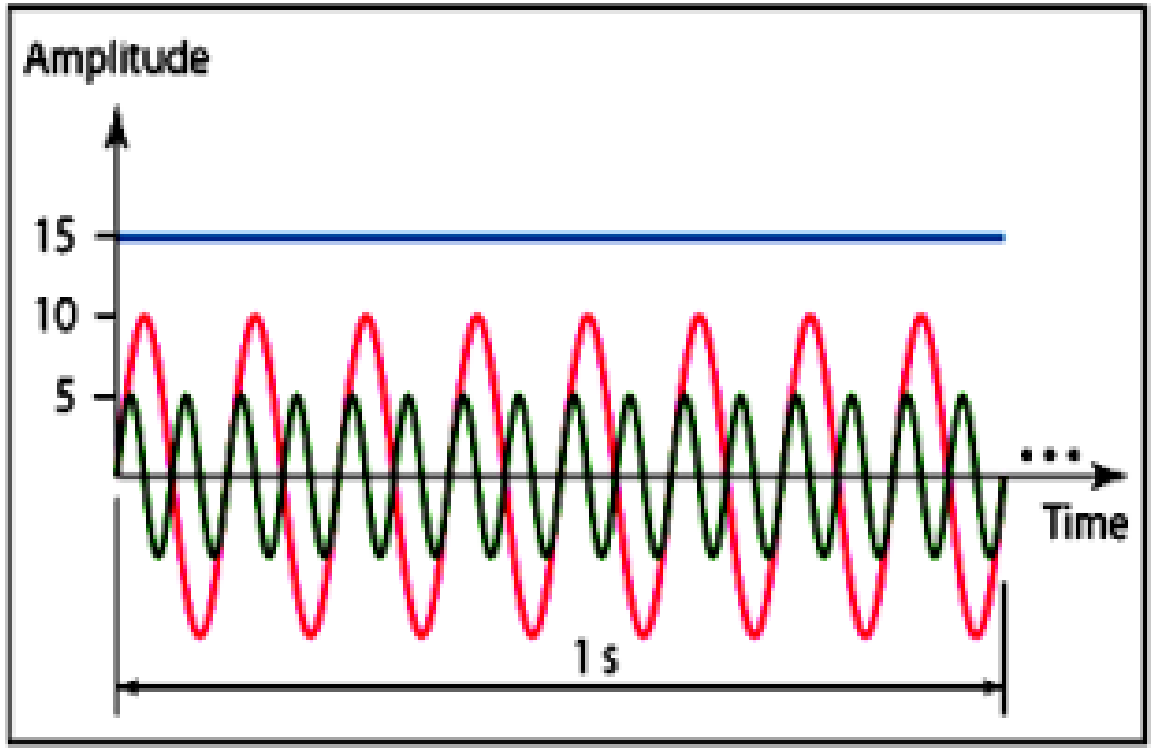
$$\text{Wavelength} = \text{Propagation Speed} \times \frac{1}{\text{Frequency}}$$

-It is represented by the symbol : λ (pronounced as lamda)

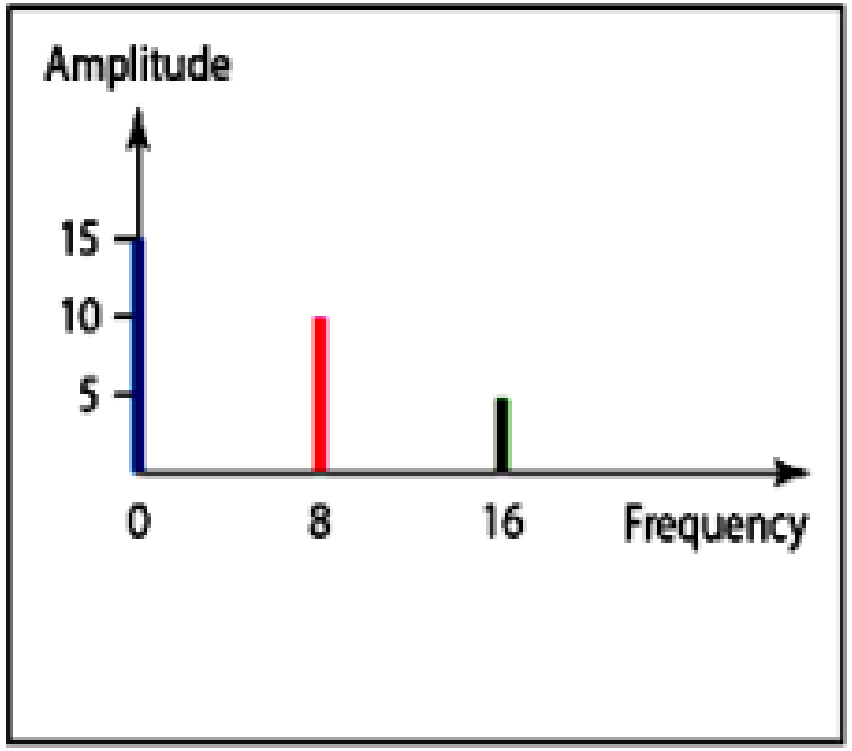
-It is measured in meters

-It varies from one medium to another.

Time Domain and Frequency domain representation of signals



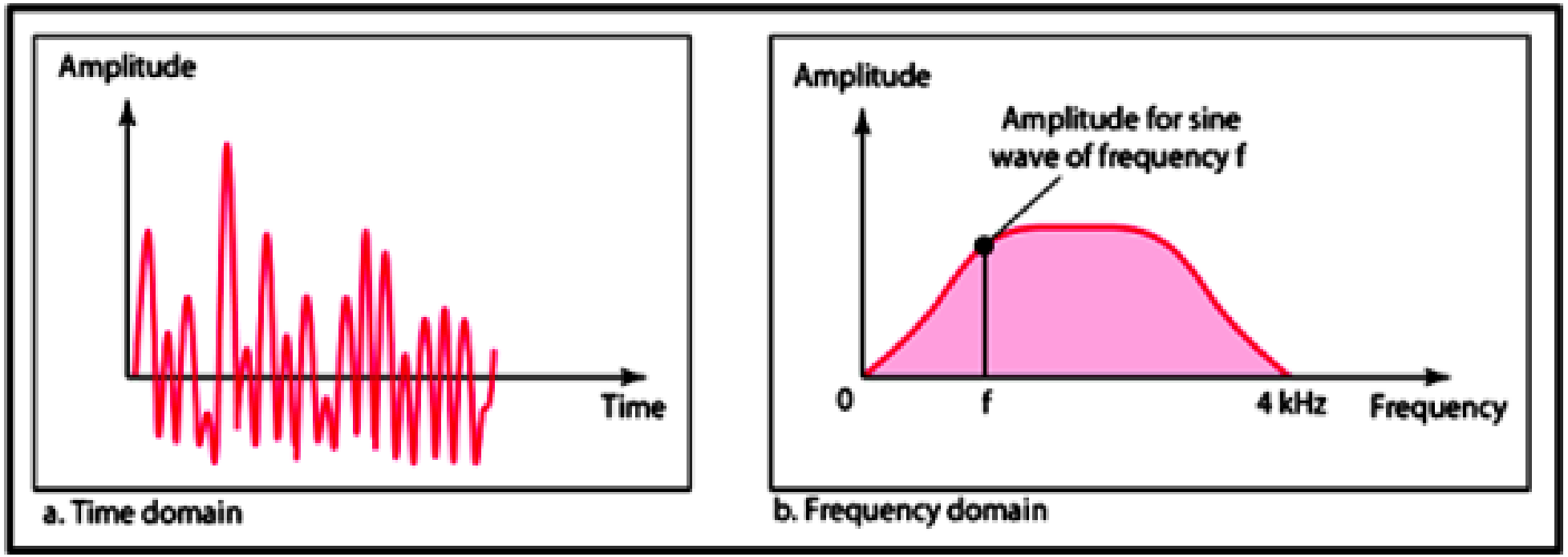
a. Time-domain representation of three sine waves with frequencies 0, 8, and 16



b. Frequency-domain representation of the same three signals

Composite signals can be periodic or non periodic

- A periodic composite signal can be decomposed into a series of signals with discrete frequencies.
- A non-periodic signal when decomposed give a combination of sine waves with continuous frequencies.



Digital Signal

Definition:- A digital is a signal that has discrete values. The signal will have value that is not continuous.

LEVEL-> Information in a digital signal can be represented in the form of voltage levels.

Ex. In the signal shown below, a ‘1‘ is represented by a positive voltage and a ‘0‘ is represented by a Negatives voltage.

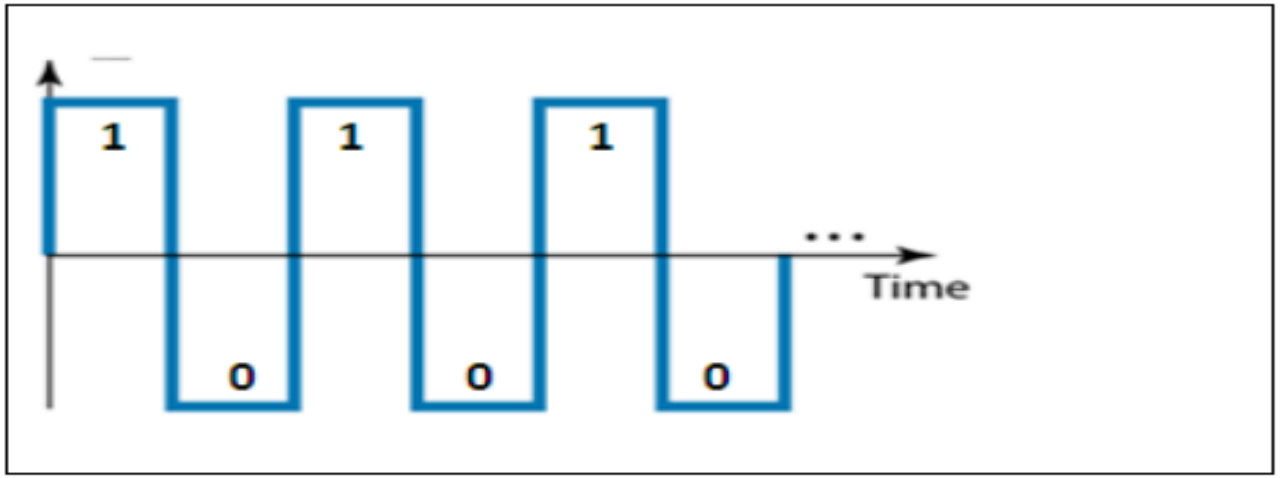


Fig: A digital signal with Two levels. ‘1’ represented by a positive voltage and ‘0’ represented by a negative voltage

A Signal can have more than two levels

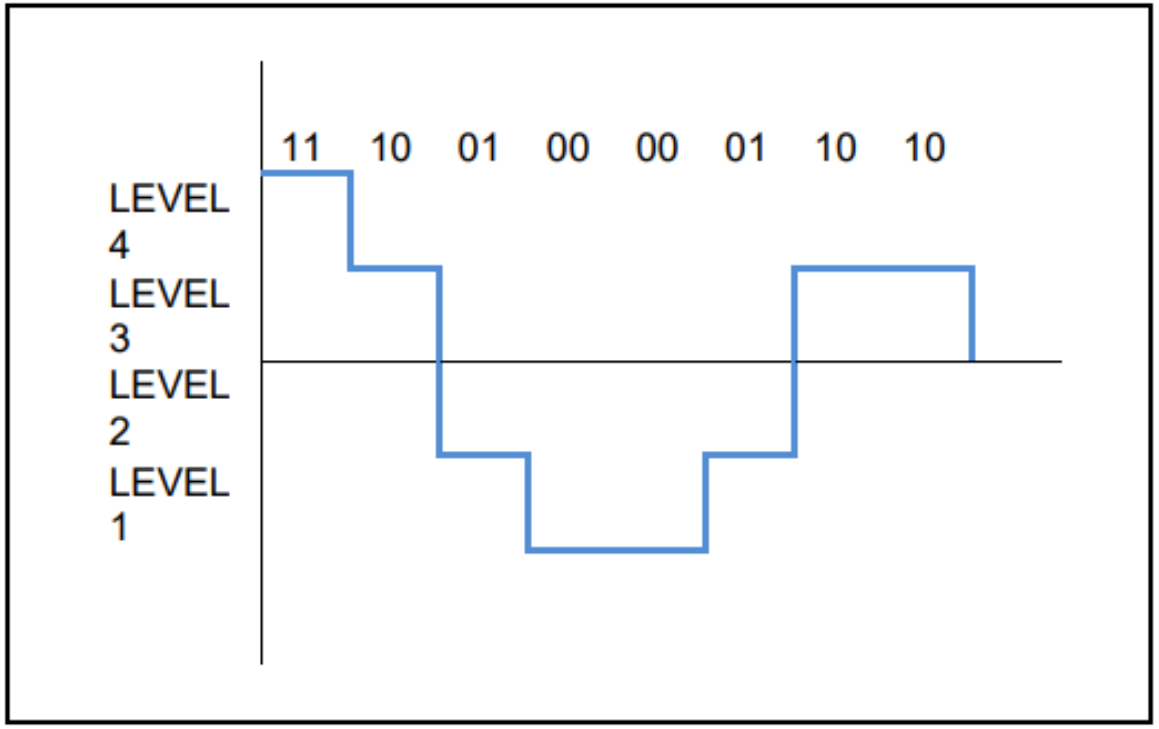


Fig: A digital signal with four levels

In general, if a signal has L levels then, each level need $\mathbf{Log_2 L}$ bits.

Example: Consider a digital Signal with four levels, how many bits are required per level?

Answer:

Number of bits per level = $Log_2 L = Log_2 4 = 2$

Hence, 2 bits are required per level for a signal with four levels.

BIT LENGTH or Bit Interval (Tb)

- It is the time required to send one bit.
- It is measured in seconds.

BIT RATE

- It is the number of bits transmitted in one second.
- It is expressed as bits per second (bps).
- Relation between bit rate and bit interval can be as follows

Bit rate = 1 / Bit interval

- **Encoding vs Modulation**

- Encoding and Modulation are two techniques used to provide the means of mapping information or data into different waveforms such that the receiver (with the help of an appropriate demodulator and decoder) can recover the information in a reliable manner. Encoding is the process by which the data is converted into digital format for efficient transmission or storage. Modulation is the process of converting information (signals or data) to an electronic or optical carrier, so that it can be transmitted to comparatively large distance without getting affected by noise or unwanted signals.
- **What is Encoding?**
- Encoding is mainly used in computers, and the process includes arranging a sequence of characters such as letters, punctuation, numbers and certain other symbols into a specialized format for the purpose of efficient transmission and storage. This is a common operation done in most wireless communication systems.

- **What is Modulation?**
- Modulation can be simply defined as a way of facilitating the transfer of information over a certain medium. For example, sound generated from our lungs, transmitted through the air can only travel for a limited distance depending on the amount of power we consume.

Encoding

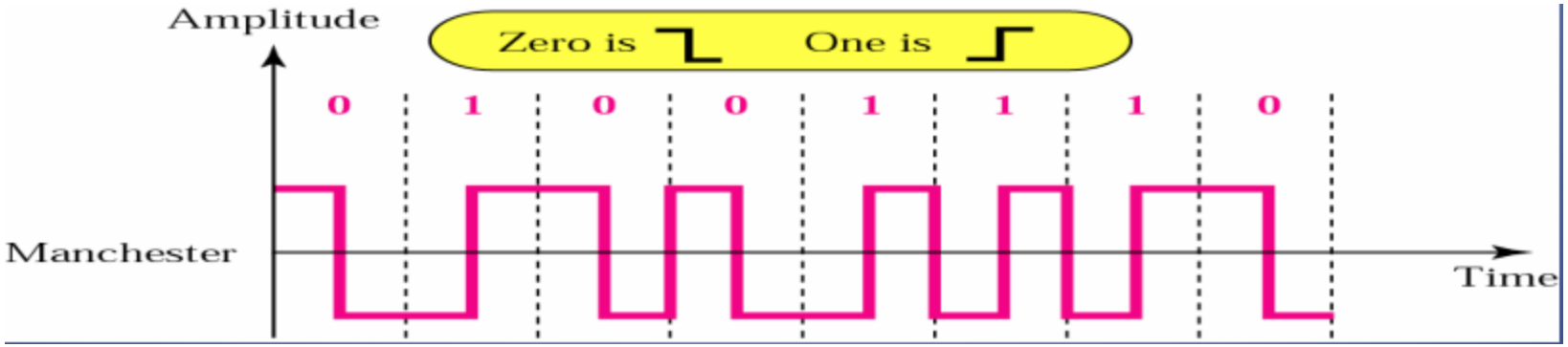
- **Encoding** is the process of converting the data or a given sequence of characters, symbols, alphabets etc., into a specified format, for the secured transmission of data.
- **Decoding** is the reverse process of encoding which is to extract the information from the converted format.

Manchester Encoding

- There is **always** a mid-bit transition
- The **direction** of the mid-bit transition represents the digital data.

1 ⇔ **low-to-high** transition

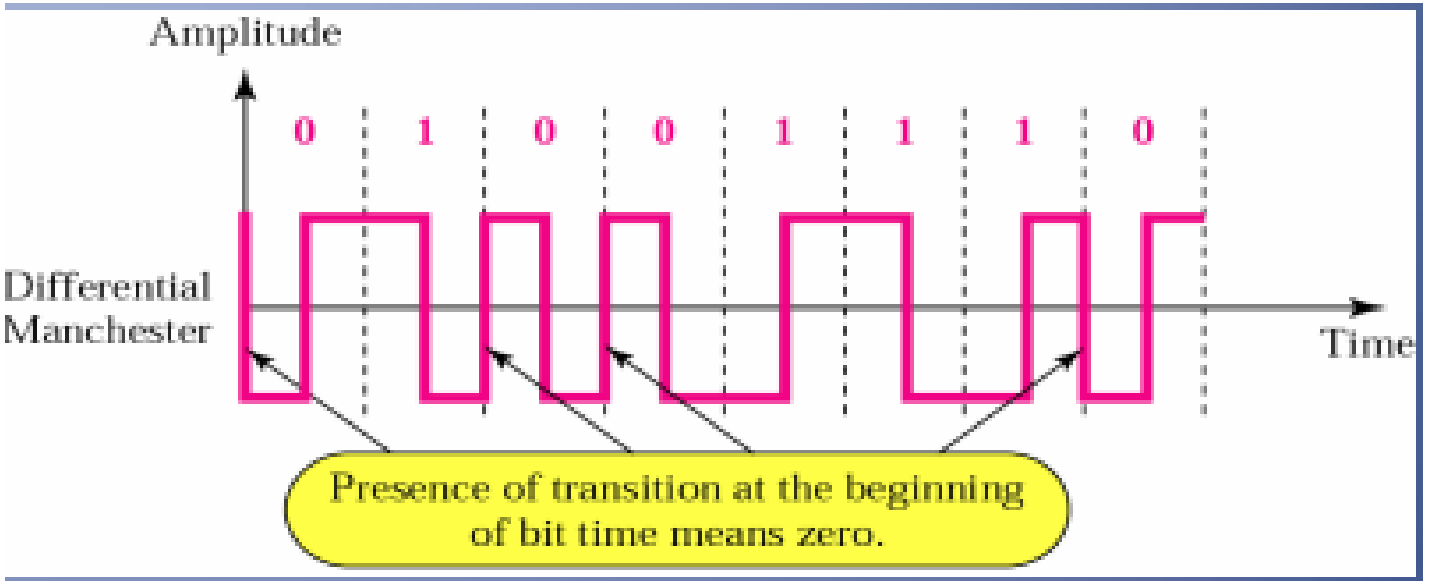
0 ⇔ **high-to-low** transition



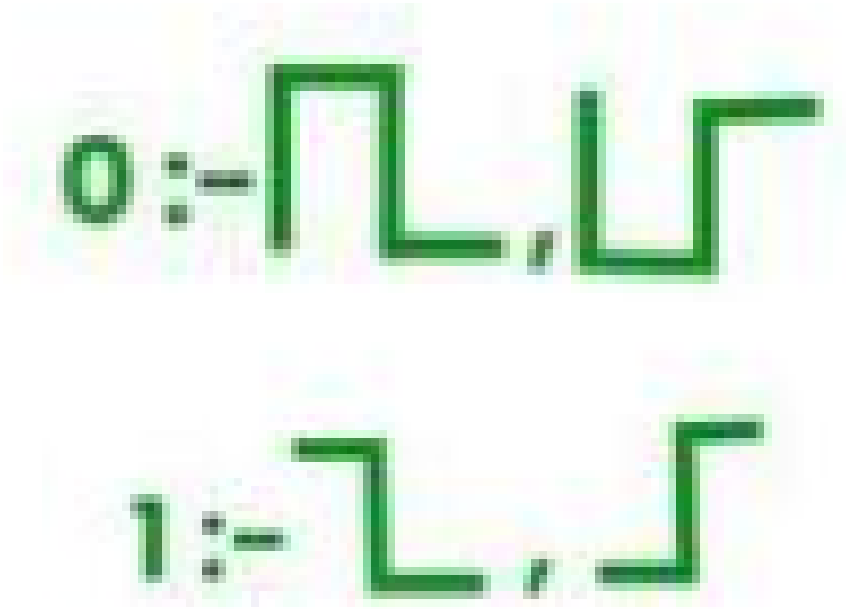
Differential Manchester Encoding

1 ⇔ **absence** of transition at the beginning of the bit interval

0 ⇔ **presence** of transition at the beginning of the bit interval



0 – transition should happen at the beginning
starting and ending should be same



Modulation

Modulation can be digital or analog. Input wave of analog scheme varies continuously like a sine wave. Voice is sampled at some rate then compressed and turned into a bit-stream then superimposed on the carrier signal, in digital modulation. This all happens because the communication systems have used a powerful and beautiful technique called Modulation.

- **Modulation:**
- The process by which data/information is converted into electrical/digital signals for transferring that signal over a medium is called **modulation**. It increases strength for maximum reach of the signals. The process of extracting information/data from the transmitted signal is called **demodulation**. A Modem is a device that performs both modulation and demodulation processes. The various forms of modulation are designed to alter the characteristic of carrier waves. The most commonly altered characteristics of modulation include amplitude, frequency, and phase.
- **Carrier signal:** The signals which contain no information but have a certain phase, frequency, and amplitude are called carrier signals.
- **Modulated signals:** The signals which are the combination of the carrier signals and modulation signals are modulated signals. The modulated signal is obtained after the modulation of the signals.

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)

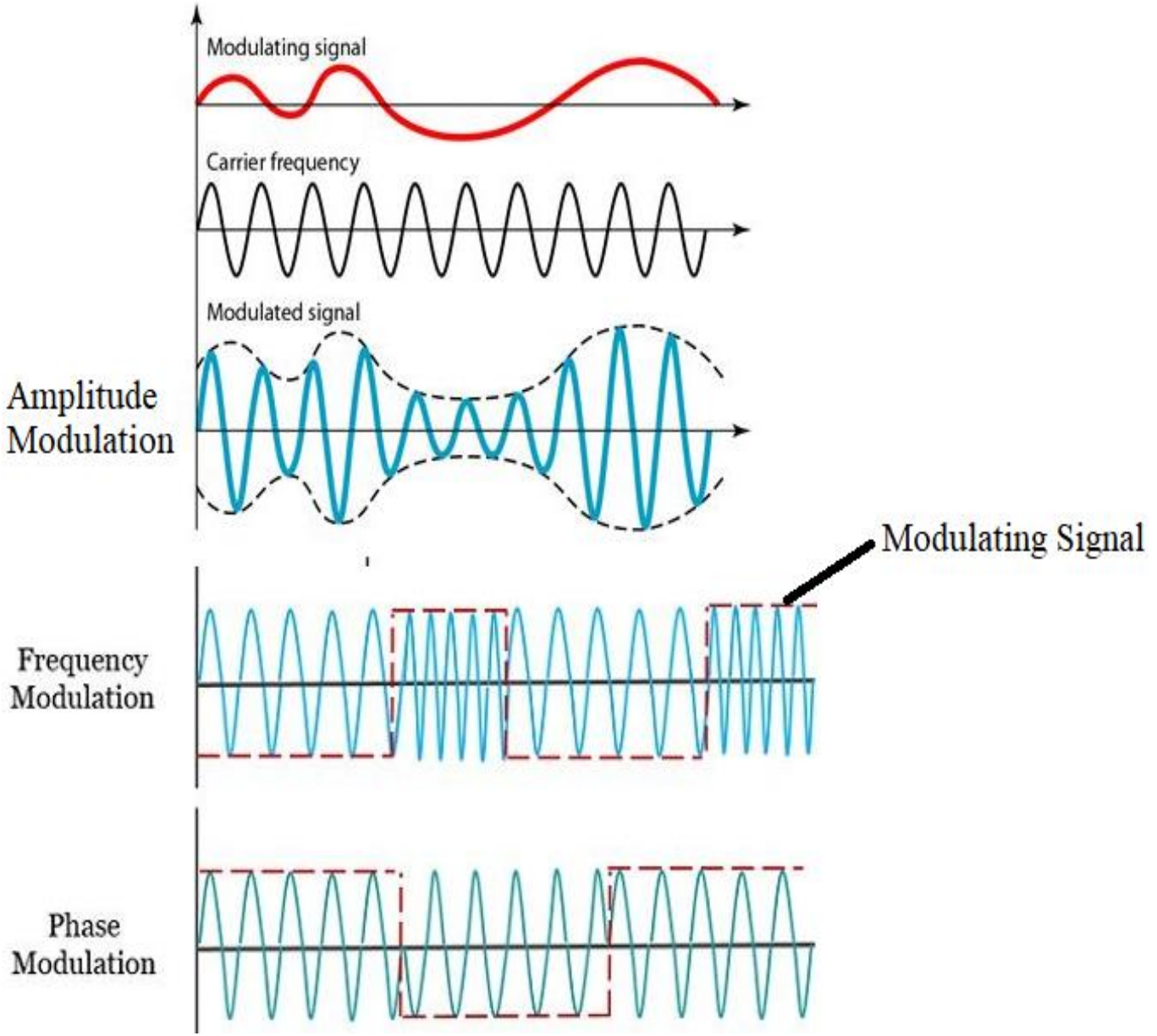
ii) *Phase Modulation (PM):* In this case, the phase of the carrier signal is varied in accordance to the instantaneous phase of the modulating signal)

Types of modulation:

1. **Amplitude modulation:** It is a type of modulation in which only the amplitude of the carrier signal is varied to represent the data being added to the signals whereas the phase and the frequency of the signal are kept unchanged.

2. **Frequency modulation:** It is a type of modulation in which only the frequency of the carrier signal is varied to represent the frequency of the data whereas the phase and the amplitude of the signals are kept unchanged.

3. **Phase modulation:** It is a type of modulation in which the phase of the carrier signal is varied to represent the data being added to the signal. Different information values are represented by different phases. For example: '1' may be represented by 0° while '0' by 180°.



- **What is the need for modulation?**
- **Size of antenna:** As we know that the size of the antenna is inversely proportional to the frequency of the radiated signal and antenna size must be 1/10th of the wavelength. If the frequency signals are more than 5KHz in that case it is quite impossible to set up an antenna of that size. So, by using the modulation technique the size of the antenna is reduced.
- **Wireless communication:** Modulation provides a wireless connection to transmit the signals to a longer distance. Earlier we used wire systems (like the telephone) to transfer information with the help of telephonic wires but it was not possible to spread the wires all over the world for communication. By using the modulation technique, the cost of wire is saved and even information can be transferred to longer distances faster.

Advantages of modulation:

- It reduces the size of the antenna.
- It reduces the cost of wires.
- It prohibits the mixing of signals.
- It increases the range of communication.
- It improves the reception quality.
- It easily multiplexes the signals.
- It also allows the adjustment of the bandwidth.

Disadvantages of modulation:

- The cost of the equipment is higher.
- The receiver and the transmitter are very complicated.
- For better communication, the antennas for the FM system must be kept closed.
- It is not efficient for large bandwidth.
- Power wastage takes place.

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.

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.

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.

Nyquist Bit Rate

The Nyquist bit rate formula defines the theoretical maximum bit rate for a noiseless channel

Bitrate = 2 x Bandwidth x $\log_2$ L

Where,

- Bitrate is the bitrate of the channel in bits per second
- Bandwidth is the bandwidth of the channel
- L is the number of signal levels.

- Example:

What is the maximum bit rate of a noiseless channel with a bandwidth of 5000 Hz transmitting a signal with two signal levels.

Solution: The bit rate for a noiseless channel according to Nyquist Bit rate can be calculated as follows:

BitRate = 2 x Bandwidth x $\log_2$ L

= 2 x 5000 x $\log_2$ 2

=**10000 bps**

$\text{Log}_2 8 = \log_2 2^3 = 3 \log_2 2 = 3$

The Shannon's Capacity

The Shannon Capacity defines the theoretical maximum bit rate for a noisy channel
Capacity=bandwidth X $\log_2$ (1 +SNR)

- Where,
- Capacity is the capacity of the channel in bits per second
- Bandwidth is the bandwidth of the channel
- SNR is the Signal to Noise Ratio

Shannon Capacity for calculating the maximum bit rate for a noisy channel does not consider the number of levels of the signals being transmitted as done in the Nyquist bit rate.

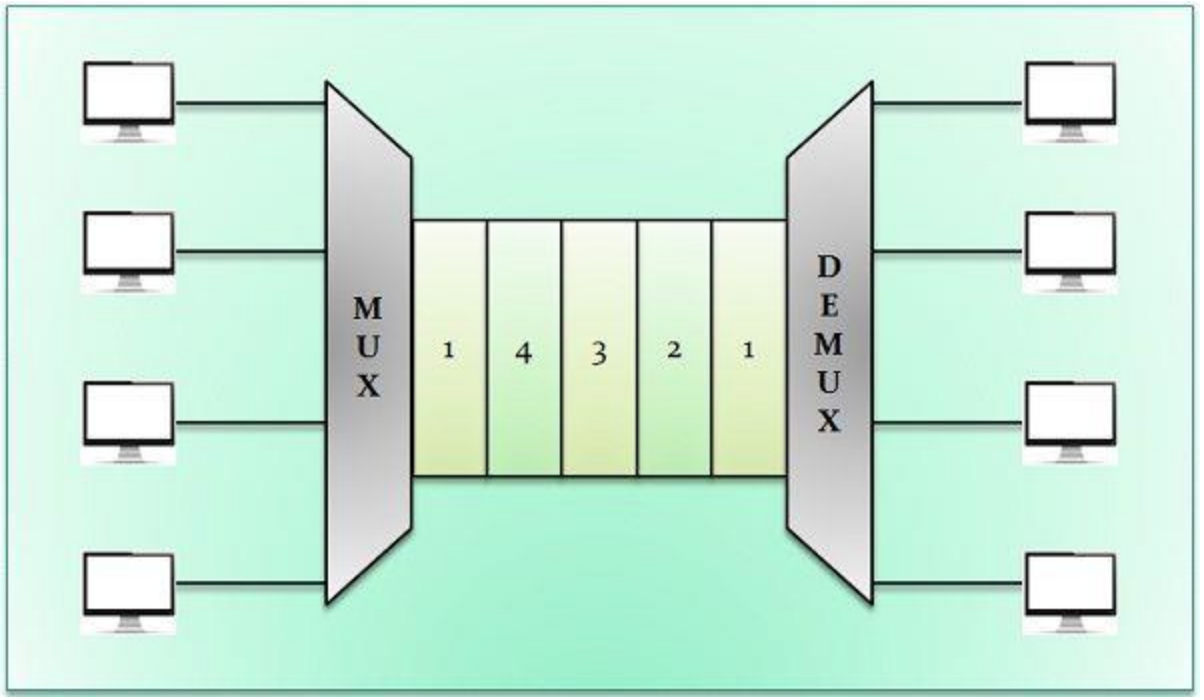
Example: Calculate the bit rate for a noisy channel with SNR 300 and bandwidth of 3000Hz Solution: The bit rate for a noisy channel according to Shannon Capacity can be calculated as follows:
Capacity=bandwidth X $\log_2$ (1 +SNR) = 3000 x $\log_2$ (1 + 300) = 3000 x $\log_2$ (301) = 3000 x 8.23 = **24,690bps=24.69kbps**

Circuit Switching in Computer Network

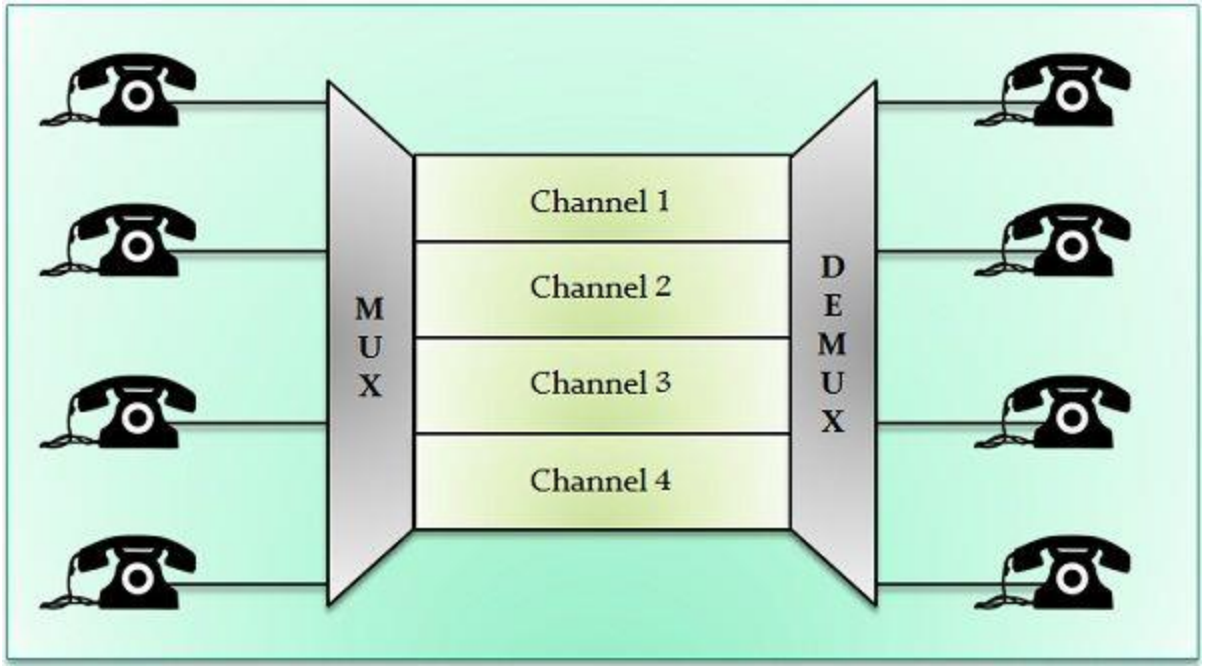
- In circuit switching network resources (bandwidth) are divided into pieces and bit delay is constant during a connection. The dedicated path/circuit established between sender and receiver provides a guaranteed data rate. Data can be transmitted without any delays once the circuit is established.
- Telephone system network is one of the example of Circuit switching. **TDM (Time Division Multiplexing) and FDM (Frequency Division Multiplexing)** are two methods of multiplexing multiple signals into a single carrier.
- **Frequency Division Multiplexing :** *Divides into multiple bands*
  Frequency Division Multiplexing or FDM is used when multiple data signals are combined for simultaneous transmission via a shared communication medium. It is a technique by which the total bandwidth is divided into a series of non-overlapping frequency sub-bands, where each sub-band carry different signal. Practical use in radio spectrum & optical fiber to share multiple independent signals.

- **Time Division Multiplexing :** *Divides into frames*
  Time-division multiplexing (TDM) is a method of transmitting and receiving independent signals over a common signal path by means of synchronized switches at each end of the transmission line. TDM is used for long-distance communication links and bears heavy data traffic loads from end user.
  Time division multiplexing (TDM) is also known as a digital circuit switched.

- **Time-division multiplexing (TDM)** is considered to be a digital procedure which can be employed when the transmission medium data rate quantity is higher than the data rate requisite of the transmitting and receiving devices. In TDM, corresponding frames carry data to be transmitted from the different sources. Each frame consists of a set of time slots, and portions of each source is assigned a time slot per frame.
- Type of TDM: **1.** Synchronous TDM **2.** Asynchronous TDM

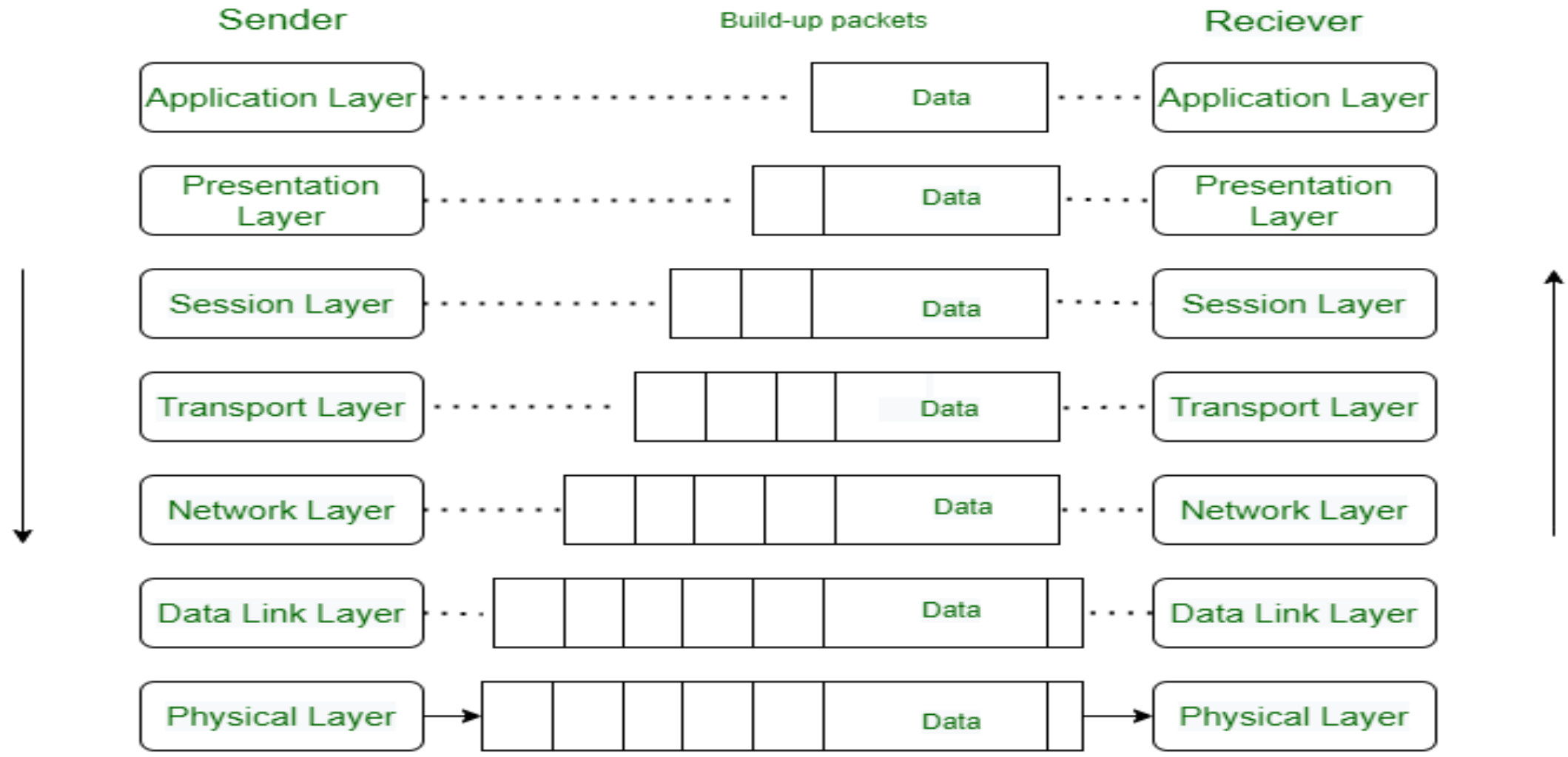


- **Frequency-division multiplexing (FDM)** is an analog technique which is implemented only when the bandwidth of the link is higher than the merged bandwidth of the signals to be transmitted. Each sending device produces signals which modulate at distinct carrier frequencies. To hold the modulated signal, the carrier frequencies are isolated by adequate bandwidth.

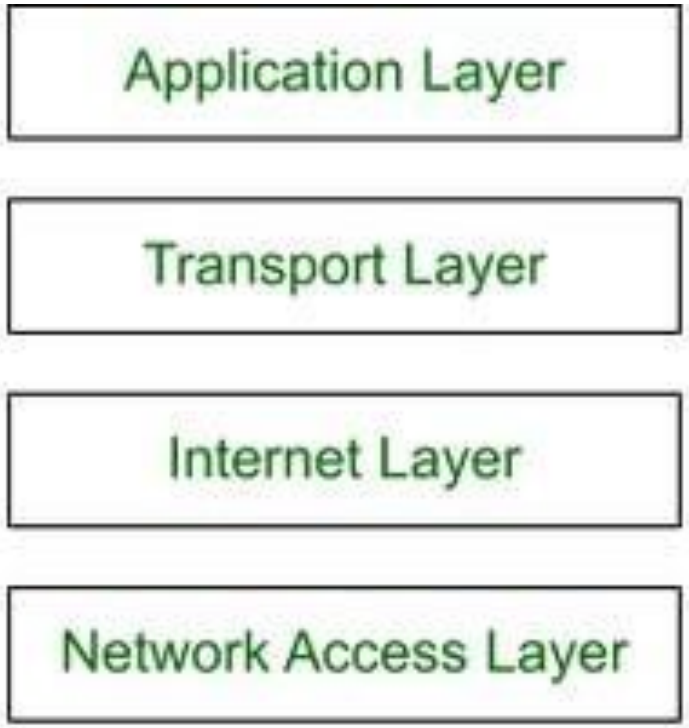


BASIS FOR COMPARISON	TDM	FDM
Basic	Times scale is shared.	Frequency is shared.
Used with	Digital signals and analog signals	Analog signals
Necessary requirement	Sync Pulse	Guard Band
Interference	Low or negligible	High
Circuitry	Simpler	Complex
Utilization	Efficiently used	Ineffective

OSI Model


Sender
Build-up packets
Reciever
Application Layer
Data
Application Layer
Presentation Layer
Data
Presentation Layer
Session Layer
Data
Session Layer
Transport Layer
Data
Transport Layer
Network Layer
Data
Network Layer
Data Link Layer
Data
Data Link Layer
Physical Layer
Data
Physical Layer

TCP/IP model



Various Layers of the TCP/ IP Model

7	Application Layer	Human-computer interaction layer, where applications can access the network services
6	Presentation Layer	Ensures that data is in a usable format and is where data encryption occurs
5	Session Layer	Maintains connections and is responsible for controlling ports and sessions
4	Transport Layer	Transmits data using transmission protocols including TCP and UDP
3	Network Layer	Decides which physical path the data will take
2	Data Link Layer	Defines the format of data on the network
1	Physical Layer	Transmits raw bit stream over the physical medium

7. Application Layer: The application layer is used by end-user software such as web browsers and email clients. It provides protocols that allow software to send and receive information and present meaningful data to users. A few examples of application layer protocols are the Hypertext Transfer Protocol (HTTP), File Transfer Protocol (FTP), Post Office Protocol (POP), Simple Mail Transfer Protocol (SMTP), and Domain Name System (DNS).

6. Presentation Layer: The presentation layer prepares data for the application layer. It defines how two devices should encode, encrypt, and compress data so it is received correctly on the other end. The presentation layer takes any data transmitted by the application layer and prepares it for transmission over the session layer.

5. Session Layer: The session layer creates communication channels, called sessions, between devices. It is responsible for opening sessions, ensuring they remain open and functional while data is being transferred, and closing them when communication ends. The session layer can also set checkpoints during a data transfer—if the session is interrupted, devices can resume data transfer from the last checkpoint.

4. Transport Layer: The transport layer takes data transferred in the session layer and breaks it into "segments" on the transmitting end. It is responsible for reassembling the segments on the receiving end, turning it back into data that can be used by the session layer. The transport layer carries out flow control, sending data at a rate that matches the connection speed of the receiving device, and error control, checking if data was received incorrectly and if not, requesting it again.

3. Network Layer: The network layer has two main functions. One is breaking up segments into network packets, and reassembling the packets on the receiving end. The other is routing packets by discovering the best path across a physical network. The network layer uses network addresses (typically Internet Protocol addresses) to route packets to a destination node.

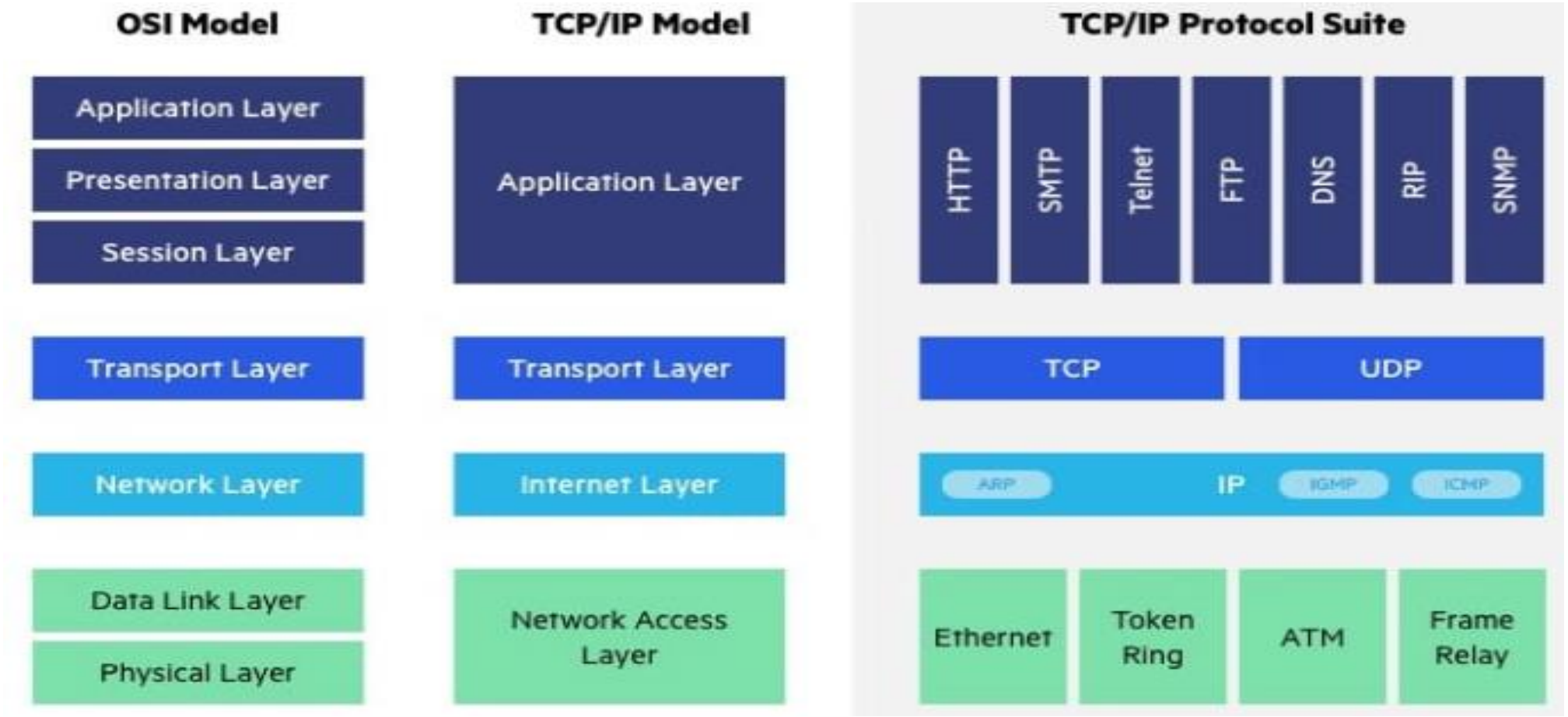
2. Data Link Layer: The data link layer establishes and terminates a connection between two physically-connected nodes on a network. It breaks up packets into frames and sends them from source to destination. This layer is composed of two parts—Logical Link Control (LLC), which identifies network protocols, performs error checking and synchronizes frames, and Media Access Control (MAC) which uses MAC addresses to connect devices and define permissions to transmit and receive data.

1. Physical Layer: The physical layer is responsible for the physical cable or wireless connection between network nodes. It defines the connector, the electrical cable or wireless technology connecting the devices, and is responsible for transmission of the raw data, which is simply a series of 0s and 1s, while taking care of bit rate control.

Advantages of OSI Model

- **The OSI model helps users and operators of computer networks:**
- Determine the required hardware and software to build their network.
- Understand and communicate the process followed by components communicating across a network.
- Perform troubleshooting, by identifying which network layer is causing an issue and focusing efforts on that layer.
- **The OSI model helps network device manufacturers and networking software vendors:**
- Create devices and software that can communicate with products from any other vendor, allowing open interoperability
- Define which parts of the network their products should work with.
- Communicate to users at which network layers their product operates – for example, only at the application layer, or across the stack.

OSI vs. TCP/IP Model



TCP/IP

- The Transfer Control Protocol/Internet Protocol (TCP/IP) is older than the OSI model and was created by the US Department of Defense (DoD). A key difference between the models is that TCP/IP is simpler, collapsing several OSI layers into one:
- OSI layers 5, 6, 7 are combined into one Application Layer in TCP/IP
- OSI layers 1, 2 are combined into one Network Access Layer in TCP/IP – however TCP/IP does not take responsibility for sequencing and acknowledgement functions, leaving these to the underlying transport layer.

Other important differences:

- TCP/IP is a functional model designed to solve specific communication problems, and which is based on specific, standard protocols. OSI is a generic, protocol-independent model intended to describe all forms of network communication.
- In TCP/IP, most applications use all the layers, while in OSI simple applications do not use all seven layers. Only layers 1, 2 and 3 are mandatory to enable any data communication.

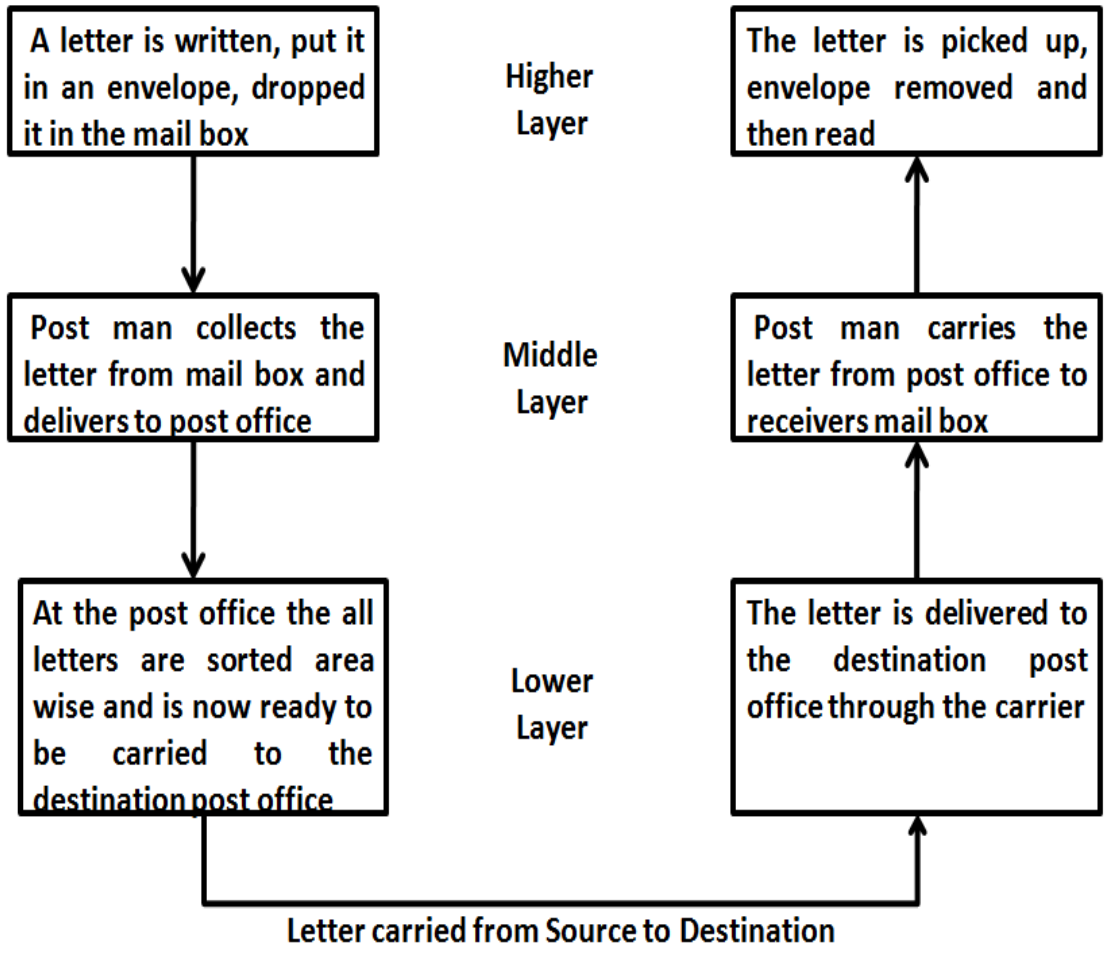
CONCEPT OF LAYERED TASK

i. The main objective of a computer network is to be able to transfer the data from sender to receiver. This task can be done by breaking it into small sub tasks, each of which are well defined.

ii. Each subtask will have its own process or processes to do and will take specific inputs and give specific outputs to the subtask before or after it. In more technical terms we can call these sub tasks as layers.

iii. In general, every task or job can be done by dividing it into sub task or layers. Consider the example of sending a letter where the sender is in City A and receiver is in city B.

iv. The process of sending letter is shown below:



v. The above figure shows

a. Sender, Receiver & Carrier

b. Hierarchy of layers

vi. At the sender site, the activities take place in the following descending order:

a. Higher Layer: The sender writes the letter along with the sender and receivers address and put it in an envelope and drop it in the mailbox.

b. Middle Layer: The letter is picked up by the post man and delivered to the post office

c. Lower Layer: The letters at the post office are sorted and are ready to be transported through a carrier.

vii. During transition the letter may be carried by truck, plane or ship or a combination of transport modes before it reaches the destination post office.

viii. At the Receiver site, the activities take place in the following ascending order:

a. Lower Layer: The carrier delivers the letter to the destination post office

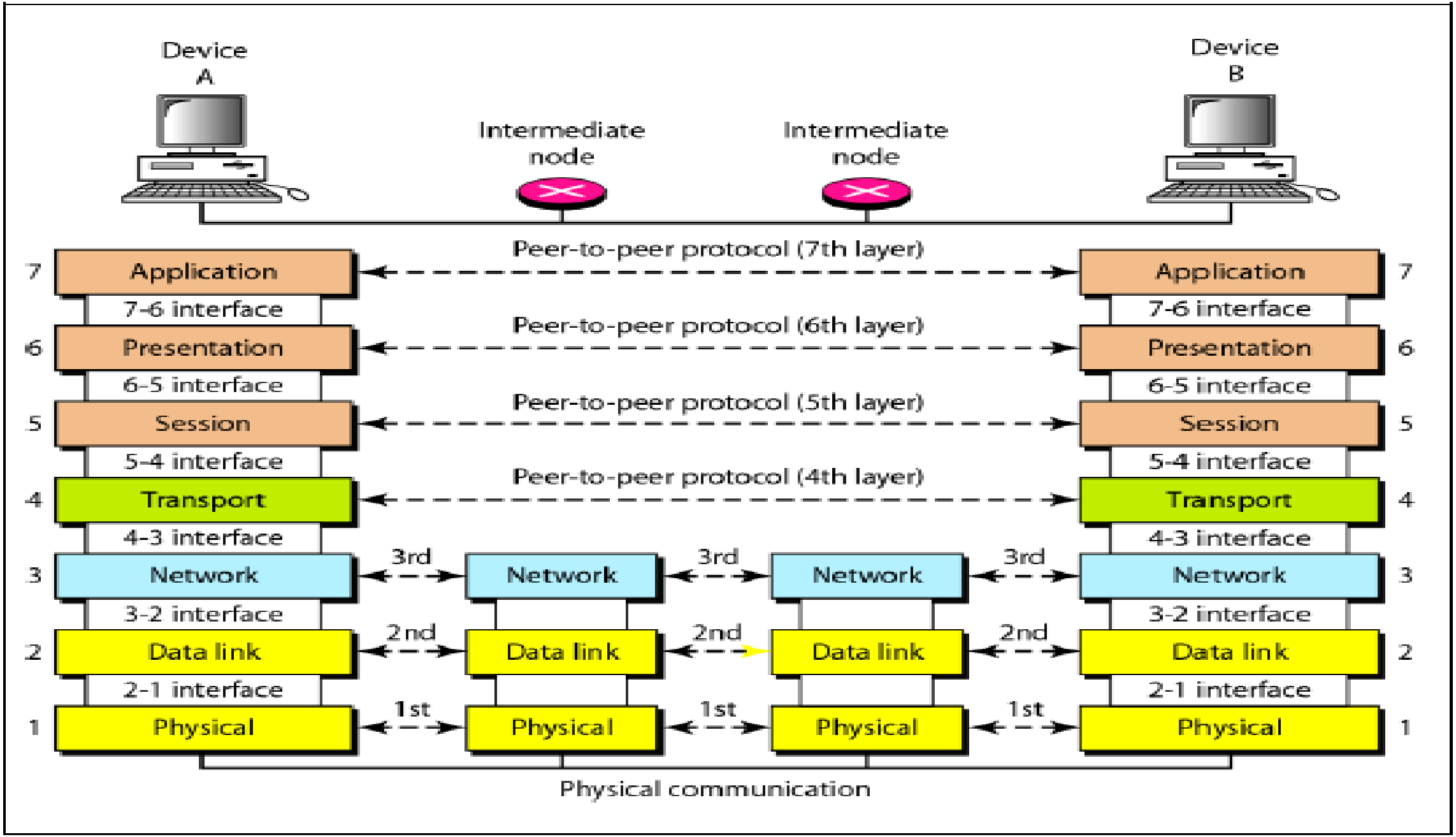
b. Middle Layer: After sorting, the letter is delivered to the receivers mail box

c. Higher Layer: The receiver picks up the letter, opens the envelope and reads it.

ix. Hierarchy of layers: The activities in the entire task are organized into three layers. Each activity at the sender or receiver side occurs in a particular order at the hierarchy.

x. The important and complex activities are organized into the Higher Layer and the simpler ones into middle and lower layer.

- **The Open Systems Interconnection (OSI)** Model was developed by International Organization for Standardization (ISO).
- ISO is the organization, OSI is the model
- It was developed to allow systems with different platforms to communicate with each other. Platform could mean hardware, software or operating system.
- It is a network model that defines the protocols for network communications.
- It is a hierarchical model that groups its processes into layers. It has 7 layers as follows: (Top to Bottom)
- 1. Application Layer
- 2. Presentation Layer
- 3. Session Layer
- 4. Transport Layer
- 5. Network Layer
- 6. Data Link Layer
- 7. Physical Layer
- Each layer has specific duties to perform and has to co-operate with the layers above and below it.


Device A
Device B
Intermediate node
Intermediate node
Peer-to-peer protocol (7th layer)
Peer-to-peer protocol (6th layer)
Peer-to-peer protocol (5th layer)
Peer-to-peer protocol (4th layer)
7
Application
7-6 interface
6
Presentation
6-5 interface
5
Session
5-4 interface
4
Transport
4-3 interface
3
Network
3-2 interface
2
Data link
2-1 interface
1
Physical
3rd
2nd
1st
Physical communication

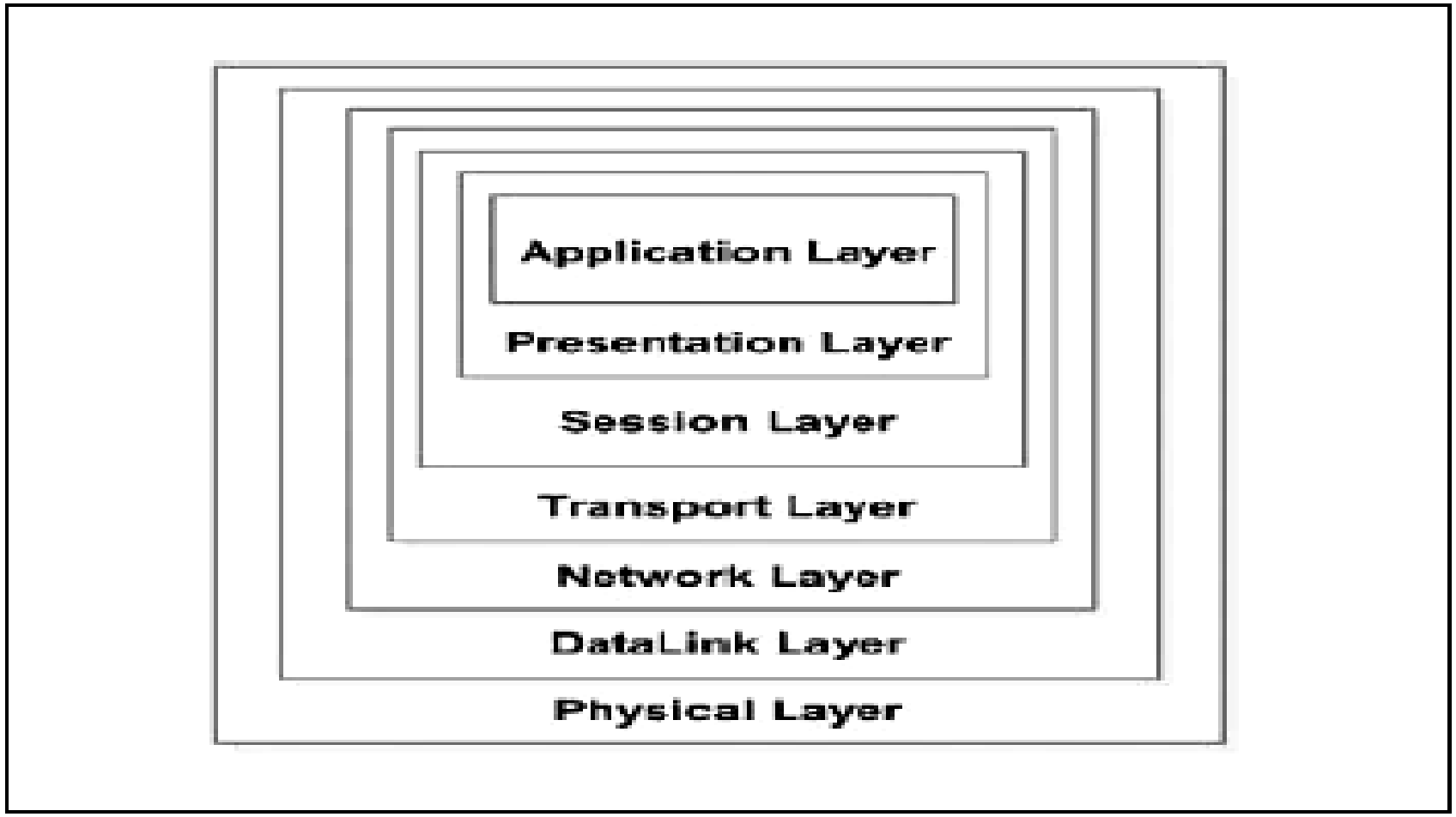


Fig: Encapsulation

Encapsulation of Data

- As shown in the figure above the data at layer 7 i.e the Application layer along with the header added at layer 7 is given to layer 6, the Presentation layer. This layer adds Its header and passed the whole package to the layer below.

- The corresponding layers at the receiving side removes the corresponding header added at that layer and sends the remaining data to the above layer.

- The above process is called encapsulation