The Physical Layer

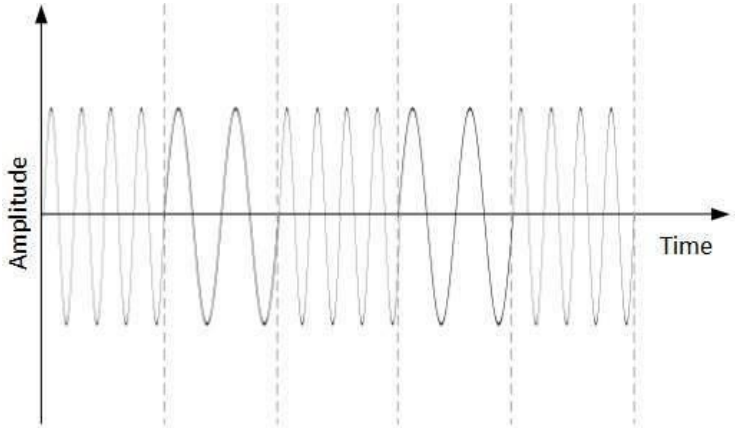
Transmission media is a pathway that carries the information from sender to receiver. We use different types of cables or waves to transmit data. Data is transmitted normally through electrical or electromagnetic signals.

An electrical signal is in the form of current. An electromagnetic signal is series of electromagnetic energy pulses at various frequencies. These signals can be transmitted through copper wires, optical fibres, atmosphere, water and vacuum Different Medias have different properties like bandwidth, delay, cost and ease of installation and maintenance. Transmission media is also called ***Communication channel***.

Analog data transmission

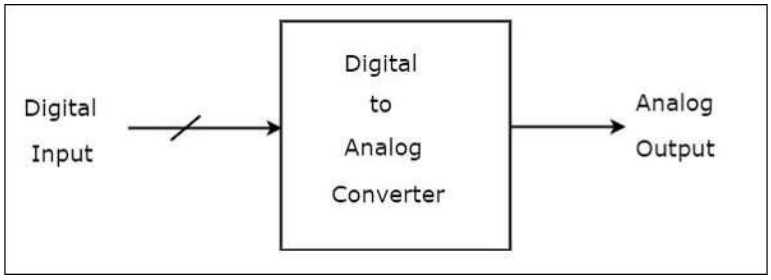
An analogue network is a network that uses analog technology to connect users with each other. an analog network is based on circuit-switching. Which means that the connection is set up before and maintained during the whole conversation. Analog signal are in the form of continues data.

The best known example of an analog network is the plain old telephone system. Although this network is now digitized. The first generation of mobile networks was also analog.



A **Digital to Analog Converter (DAC)** converts a digital input signal into an analog output signal. The digital signal is represented with a binary code, which is a combination of bits 0 and

The **block diagram** of DAC is shown in the following figure −



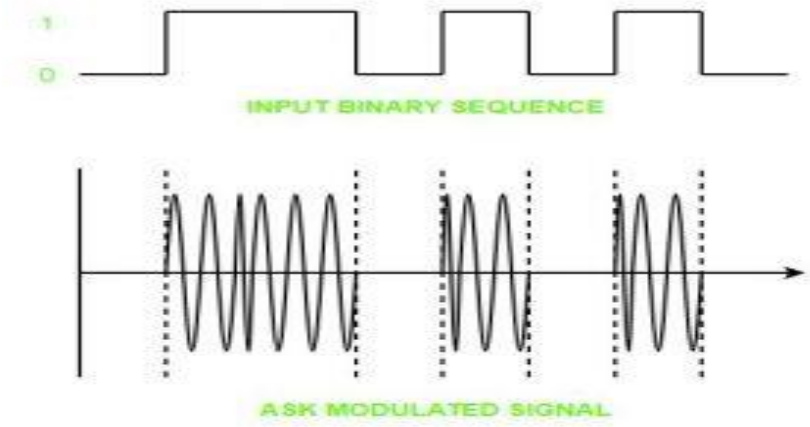
A Digital to Analog Converter (DAC) consists of a number of binary inputs and a single output. In general, the **number of binary inputs** of a DAC will be a power of two.

Digital to Analog Conversion

The following techniques can be used for Digital to Analog Conversion:

1. **Amplitude Shift keying**
2. **Frequency Shift keying**
3. **Phase Shift keying**

1. **Amplitude Shift keying**– Amplitude Shift Keying is a technique in which carrier signal is analog and data to be modulated is digital. The amplitude of analog carrier signal is modified to reflect binary data.
   The binary signal when modulated gives a zero value when the binary data represents 0 while gives the carrier output when data is 1. The frequency and phase of the carrier signal remain constant.



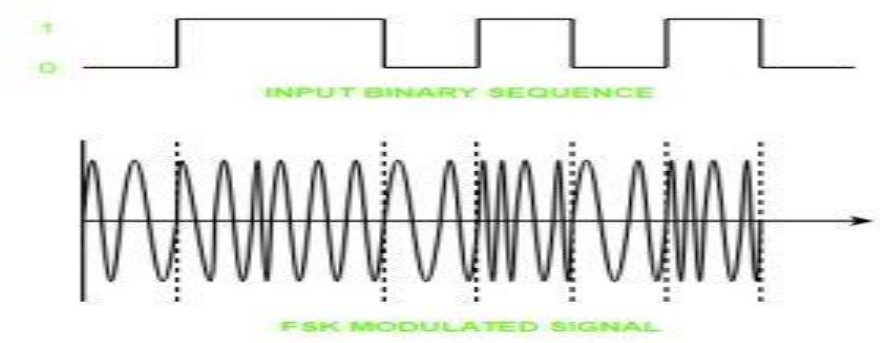
Advantages of amplitude shift Keying –

- It can be used to transmit digital data over optical fiber.
- The receiver and transmitter have a simple design which also makes it comparatively inexpensive.
- It uses lesser bandwidth as compared to FSK thus it offers high bandwidth efficiency.

Disadvantages of amplitude shift Keying –

- It is susceptible to noise interference and entire transmissions could be lost due to this.
- It has lower power efficiency.

2. **Frequency Shift keying**– In this modulation the frequency of analog carrier signal is modified to reflect binary data.
   The output of a frequency shift keying modulated wave is high in frequency for a binary high input and is low in frequency for a binary low input. The amplitude and phase of the carrier signal remain constant.



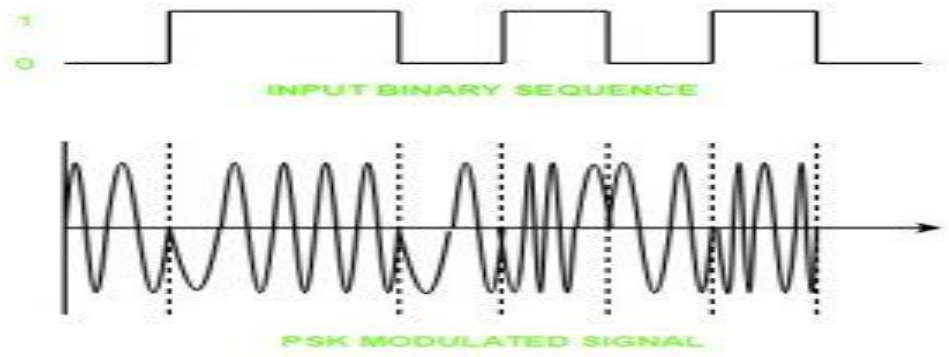
Advantages of frequency shift Keying –

- Frequency shift keying modulated signal can help avoid the noise problems beset by ASK.
- It has lower chances of an error.
- It provides high signal to noise ratio.
- The transmitter and receiver implementations are simple for low data rate application.

Disadvantages of frequency shift Keying –

- It uses larger bandwidth as compared to ASK thus it offers less bandwidth efficiency.
- It has lower power efficiency.

3. <u>Phase Shift keying</u> – In this modulation the phase of the analog carrier signal is modified to reflect binary data.The amplitude and frequency of the carrier signal remains constant.



Advantages of phase shift Keying –

- It is a more power efficient modulation technique as compared to ASK and FSK.
- It has lower chances of an error.
- It allows data to be carried along a communication signal much more efficiently as compared to FSK.

Disadvantages of phase shift Keying –

- It offers low bandwidth efficiency.
- The detection and recovery algorithms of binary data is very complex.
- It is a non coherent reference signal.

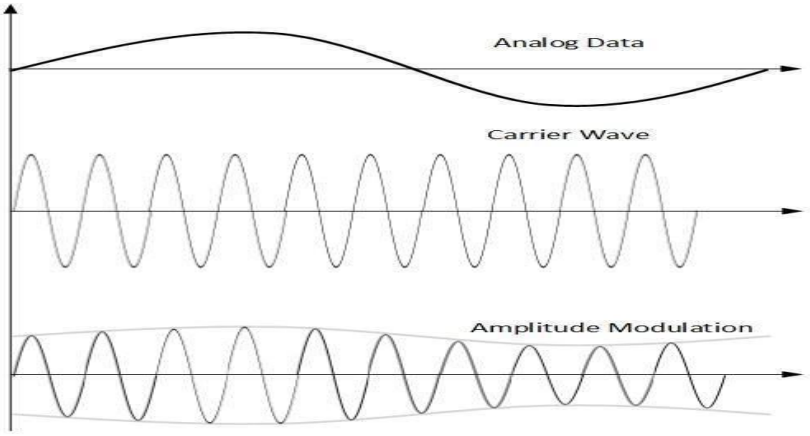
Analog-to-Analog Conversion

Analog signals are modified to represent analog data. This conversion is also known as Analog Modulation. Analog modulation is required when band pass is used. Analog to analog conversion can be done in three ways:

1. Amplitude Modulation
2. Frequency Modulation
3. Phase Modulation

1. Amplitude Modulation

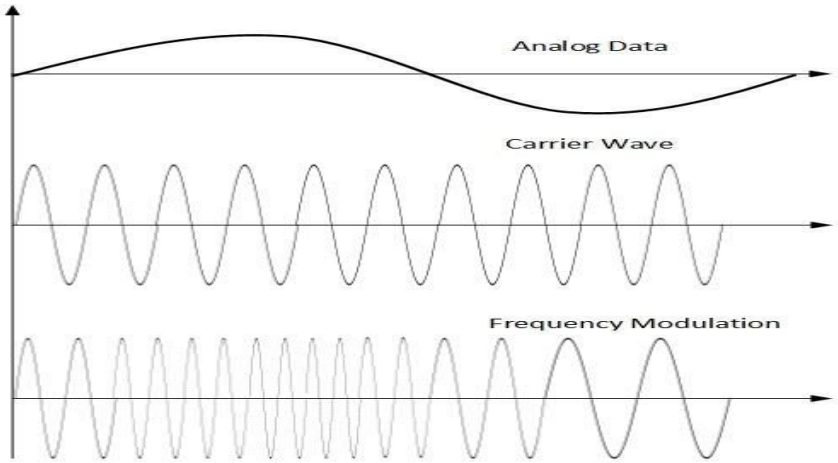
In this modulation, the amplitude of the carrier signal is modified to reflect the analog data.



Amplitude modulation is implemented by means of a multiplier. The amplitude of modulating signal (analog data) is multiplied by the amplitude of carrier frequency, which then reflects analog data. The frequency and phase of carrier signal remain unchanged.

2. Frequency Modulation

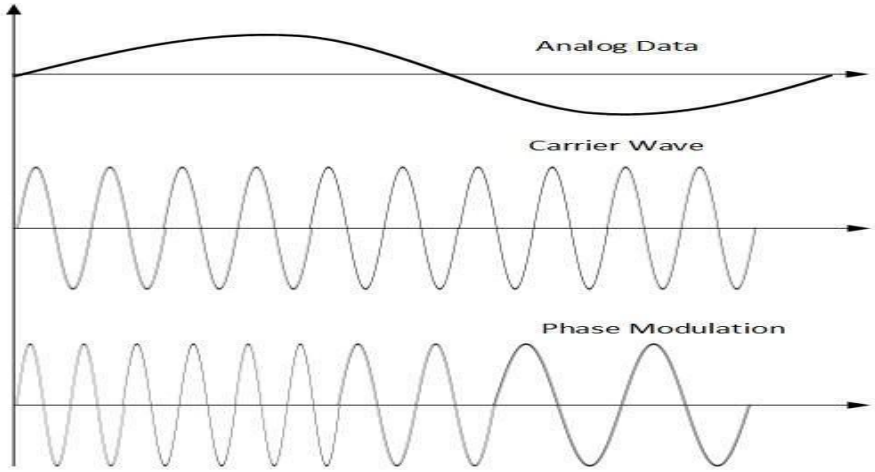
In this modulation technique, the frequency of the carrier signal is modified to reflect the change in the voltage levels of the modulating signal (analog data).



The amplitude and phase of the carrier signal are not altered.

3. Phase Modulation

In the modulation technique, the phase of carrier signal is modulated in order to reflect the change in voltage (amplitude) of analog data signal.



Phase modulation is practically similar to Frequency Modulation, but in Phase modulation frequency of the carrier signal is not increased. Frequency of carrier is signal is changed (made dense and sparse) to reflect voltage change in the amplitude of modulating signal.

The data transmission capabilities of various Medias vary differently depending upon the various factors. These factors are:

1. **Bandwidth :** It refers to the data carrying capacity of a channel or medium. Higher bandwidth communication channels support higher data rates.

2. **Radiation :** It refers to the leakage of signal from the medium due to undesirable electrical characteristics of the medium.

3. **Noise Absorption :** It refers to the susceptibility of the media to external electrical noise that can cause distortion of data signal.

4. **Attenuation :** It refers to loss of energy as signal propagates outwards. The amount of energy lost depends on frequency. Radiations and physical characteristics of media contribute to attenuation.

5. **Channel :**In communication channel refers to path of communication between two nodes of the network.

6. **Baud :**It is the number of signaling elements that occur per unit time during transmission.
   Ex : 300 baud means 300 bits of data is transferred every second through a medium and is read as 300 bps.

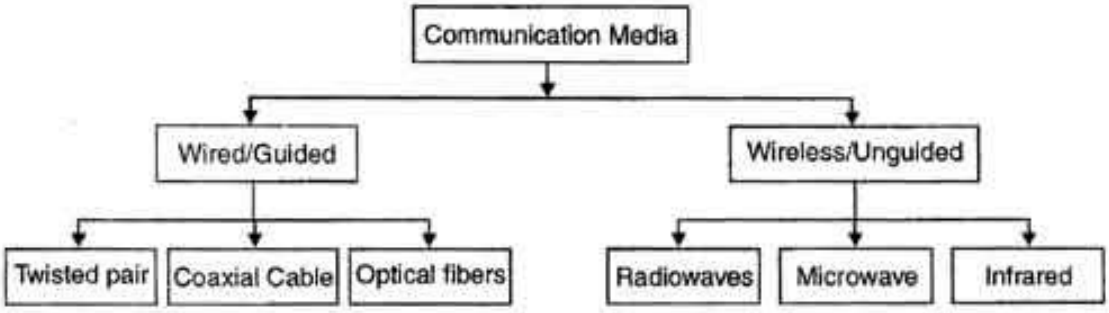
7. **Frequency :**It is the number of cycles within a unit time throughout the complete transmission. The unit of measuring frequency is hertz.

PROPERTIES OF MEDIA AND DIGITAL TRANSMISSION SYSTEMS:

- **Transmission medium is the physical path between sender and receiver that conveys the energy of a signal.**
- The transmitter and receiver equipment is placed at both the ends of the medium to form the communication channel.

There are 2 types of transmission media: Guided and UnGuided.

- In guided media, the data signals are guided along a physical path (wires).
- In unguided media, the data signals are transmitted using air, vacuum, sea water , but are not guided.



There are 3 types of commonly used guided (wired) media:

1) Twisted Pair
2) Coaxial cable
3) Optical fiber

There are 3 types of commonly used unguided (wireless) media:

1) Radio
2) Microwave
3) Infrared

WIRED MEDIA:

1) Twisted Pair:

- A twisted pair consists of **two parallel conductors** (normally copper wires) twisted together where in each pair has its own colour plastic insulation.
- One of these wires carries **signals to the receiver** and the other is used as **ground reference**.
- The receiver uses the voltage difference between the two to detect the information signal.
- **Twisting helps to reduce crosstalk and interference** when multiple pairs are placed within one cable.

- The bandwidth of twisted pair decreases with distance.

- Twisted Pair is of two types:

  a) Unshielded Twisted Pair (UTP) – This is a simple twisted pair of unshielded copper wires.

  b) Shielded Twisted Pair (STP) - This cable has a metal foil or braided-mesh covering for each pair of insulated conductors to reduce crosstalk and noise.

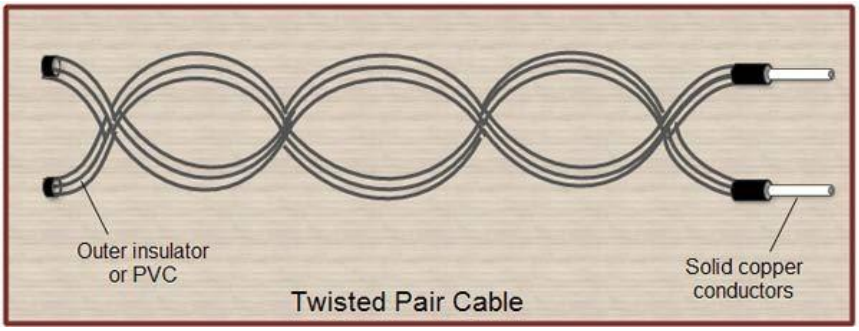


Figure: **Unshielded Twisted Pair (UTP)**

- **Advantages:**
  - Easier to install and terminate
  - Inexpensive.
  - Flexible: can be used for analog or digital transmission.
  - Crosstalk is less, since the wires are twisted.
- **Disadvantages:**
  - It easily picks up noise
  - Attenuation is very high.
  - It supports lower bandwidth as compared to other media.
  - very poor security and is relatively easy to tap.
  - Breaks easily.
- **Applications of Twisted Pair Cables:**
  - In telephone lines to carry voice and data channels.
  - In the local loop.
  - In the Digital Subscriber loops (DSL)
  - Local area networks (ETHERNET)
  - In the ISDN (Integrated Services Digital Network).
  - Security cameras

2) Coaxial Cable:

- In a coaxial cable, there is a solid conductor at the centre which is located coaxially within a cylindrical braided outer conductor.
- The two conductors are separated by a dielectric material.

- The outer conductor is covered with a plastic sheath.
- The coaxial arrangement provides protection to crosstalk and interference as compared to twisted pair.
- Two types of coaxial cables : Baseband and Broadband

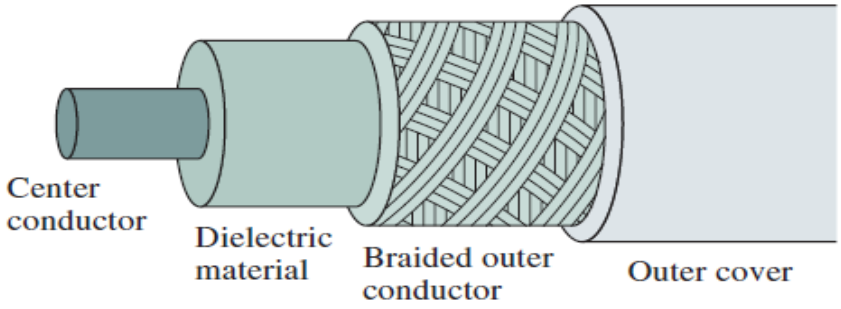


Figure: Coaxial Cable

- **Advantages:**
  - offers much higher bandwidth.
  - preferred for long distance telephone lines.
  - Provides better shield
  - data transmission without any distortion.
  - quite higher noise immunity.
- **Dis-Advantages:**
  - Single cable failure can fail the entire network.
  - Difficult to install and expensive when compared with twisted pair.
  - If the shield is imperfect, it can lead to grounded loop.
- **Applications of Coaxial Cables:**
  - Cable television
  - Cable Modem
  - Ethernet LAN
  - Analog Telephone network

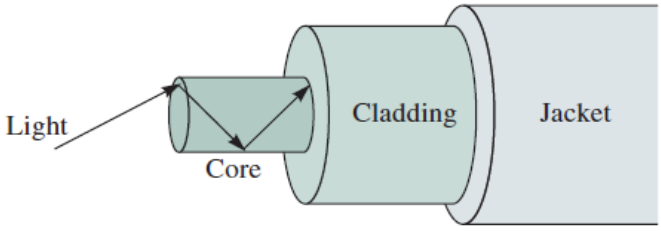
3) Optical Fiber:

- An optical fiber consists of a very fine cylinder of glass core surrounded by a concentric layer of glass called as cladding.
- The information is transmitted through the glass core in form of fluctuating beam of light.
- The core has a slightly high optical density (index of refraction) than the cladding.
- When a ray of light from the core reaches the cladding at the angle less than a critical angle, it is reflected (guided) back to the core.
- LED and laser are used as light sources.
- There are two types: single mode and multimode

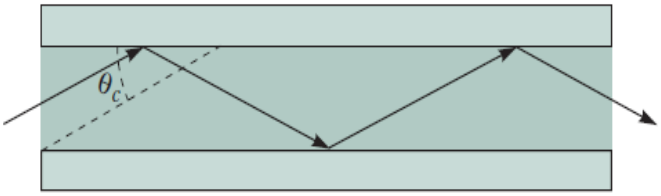
1) **Single mode.**
2) **Multi-mode**

- **Wave Division Multiplexing** is used in optical fiber to carry multiple information streams on the same fiber and hence best utilize its bandwidth.

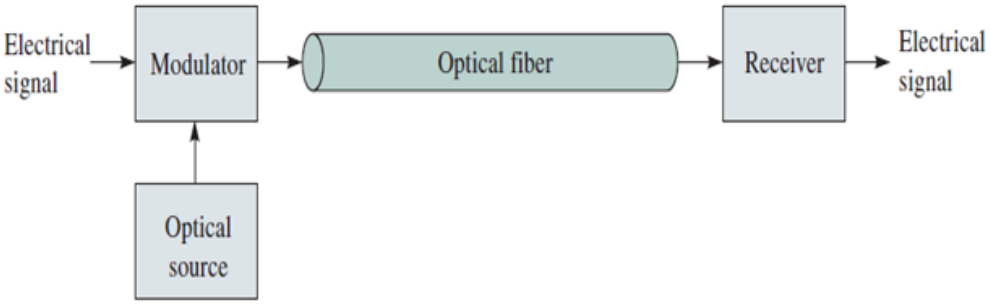
(a) Geometry of optical fiber



(b) Reflection in optical fiber



- **Working:**
  - The optical fiber transmission system consists of a transmitter that modulates the input electrical current into a light beam which is inserted into a fiber.
  - The binary information is mapped into sequence of on /off light pulses at some particular wavelength.
  - An optical detector at the receiver end converts the received optical signal into electrical signal from which the original information is detected.



Optical transmission system

- **Advantages:**
  - Have maximum regenerator spacing (from hundreds to thousands of kilometres)

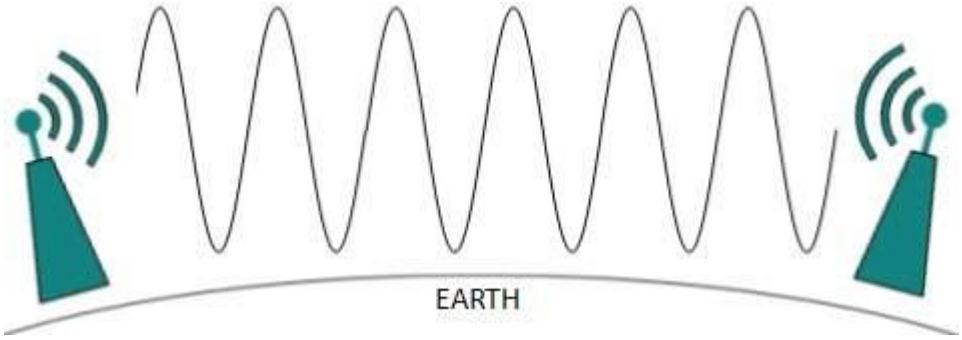
- High speed transmission
- Reduced cost of digital transmission
- Reduced space required to hold cables
- Thinner in size
- Do not radiate significant energy
- More immune to crosstalk and interference from external sources
- More secure from tapping
- Works for both analog as well as digital signals.

- **Dis-Advantages:**
  - Installation and maintenance
  - Unidirectional light propagation
  - High Cost
- **Applications:**
  - Access and backbone networks
  - LAN
  - 10-GB Ethernet networks
  - Cable TV

WIRELESS TRANSMISSION MEDIA:

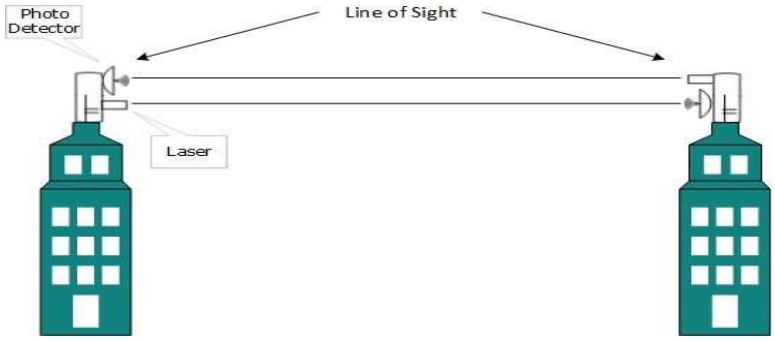
1) RADIO TRANSMISSION:

- In radio communication, the signal is transmitted into air or space using antenna that radiates energy at some carrier frequency.
- Information is embedded in carrier signal using modulation.
- The propagation is either unidirectional or omni directional.
- In unidirectional, a properly aligned antenna receives the modulated signal from which the receiver recovers the original information.
- In omni directional, any receiver with an antenna in the area of coverage can pick up the signal.
- Radio communication faces variety of transmission issues like attenuation, multipath fading and interference.
- The range of various frequency bands supported by radio waves are called radio spectra and are classified according to wavelengths..
- Radio frequencies below 1GHz are suitable for omni directional applications like Pagers, cordless phone, Cellular phone, Personal communication services, Wireless LAN etc.
- **Applications** : Cellular communications, Wireless LAN, point to point and multipoint radio systems, satellite systems etc.



2) INFRARED

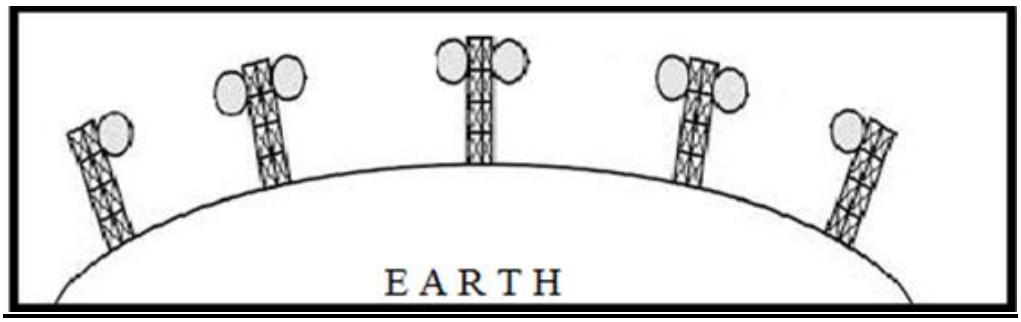
- Infrared light communication is suitable for transmission of data within a room because the infrared light does not penetrate the walls of the room.
- Therefore there is less interference and frequency band can be reused in different rooms.
- IR communication operates in the region of 850nm to 900nm wavelengths.
- IR can have interference from the sun's IR rays.
- **Applications**: Cordless devices like remote controls, mice, keyboard, joysticks, handheld computers, high speed wireless LAN.



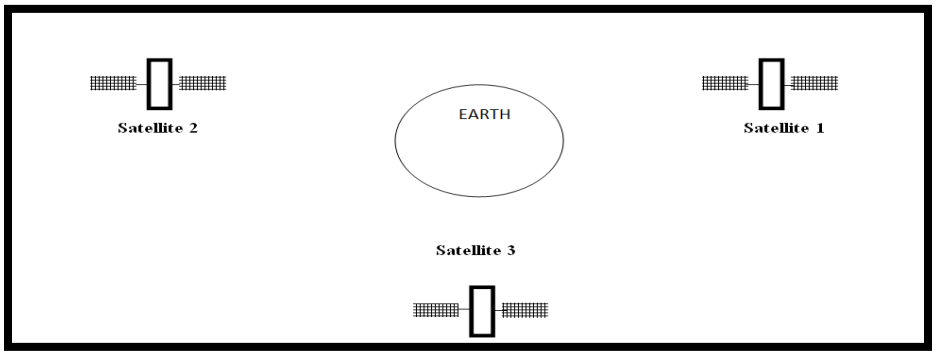
3) MICROWAVES

- A microwave link is a communications system that uses a beam of radio waves in the microwave frequency range to transmit information between two fixed locations on the earth.
- A simple one-way microwave link includes four major elements: a transmitter, a receiver, transmission lines, and antennas.
- Microwaves travel in a straight line and are narrowly focused using a parabolic antenna to give a higher SNR ratio.
- Here the transmitter and receiver antennas must be accurately aligned with each other.
- Microwaves need repeaters for transmission between transmitter and receiver.

- Microwaves are broadband and hence they can transmit large amounts of information at high speeds.
- **Applications:** Microwaves are used for long distance communication like telephones, mobiles, television broadcasting, high speed wireless internet access etc.



Terrestrial microwave transmission



Satellite microwave transmission

Multiplexing

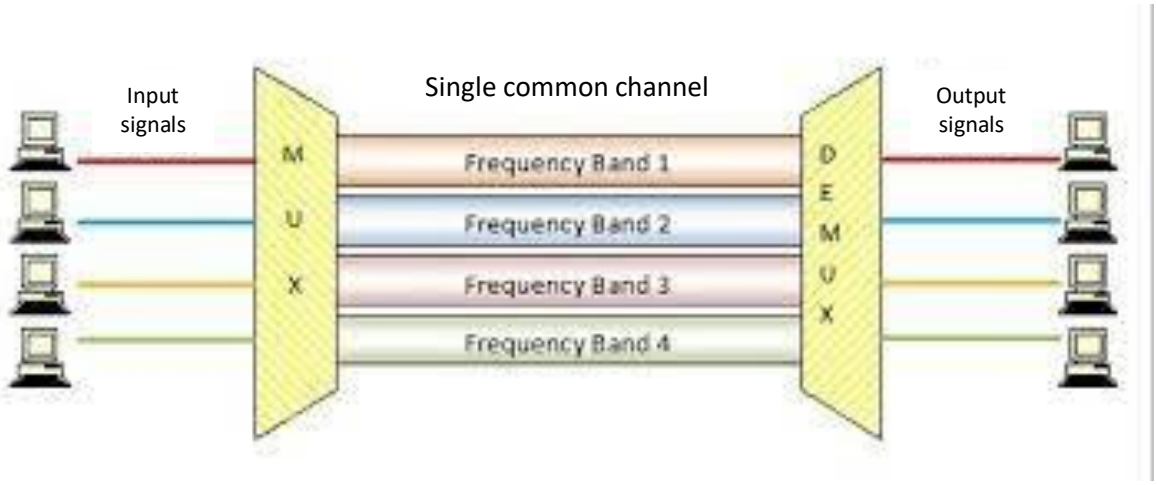
The technique to combine two or more data streams in one session is called Multiplexing.
Multiplexing is a technique by which different analog and digital streams of transmission can be simultaneously processed over a shared link. Multiplexing divides the high capacity medium into low capacity logical medium which is then shared by different streams.When multiple senders try to send over a single medium, a device called Multiplexer divides the physical channel and allocates one to each. On the other end of communication, a De-multiplexer receives data from a single medium, identifies each, and sends to different receivers.
Different types of multiplexing are :

1. Frequency Division Multiplexing(FDM)
2. Time Division multiplexing(TDM)
3. Wavelength Division Multiplexing(WDM)
4. Code Division Multiplexing(CDM)

Frequency Division Multiplexing(FDM)

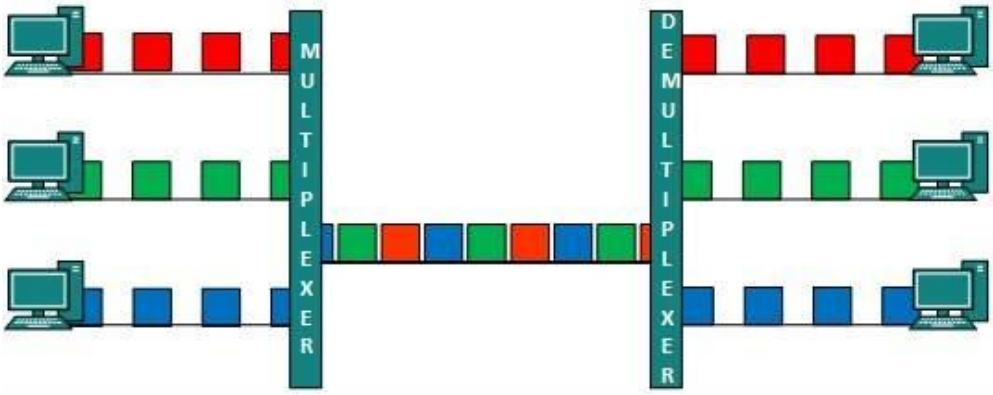
When the carrier is frequency, FDM is used. FDM is an analog technology. FDM divides the spectrum or carrier bandwidth in logical channels and allocates one user to each channel.

Each user can use the channel frequency independently and has exclusive access of it. All channels are divided in such a way that they do not overlap with each other. Channels are separated by guard bands. Guard band is a frequency which is not used by either channel.



Time Division Multiplexing

TDM is applied primarily on digital signals but can be applied on analog signals as well. In TDM the shared channel is divided among its user by means of time slot. Each user can transmit data within the provided time slot only. Digital signals are divided in frames, equivalent to time slot i.e. frame of an optimal size which can be transmitted in given time slot.TDM works in synchronized mode. Both ends, i.e. Multiplexer and De-multiplexer are timely synchronized and both switch to next channel simultaneously.

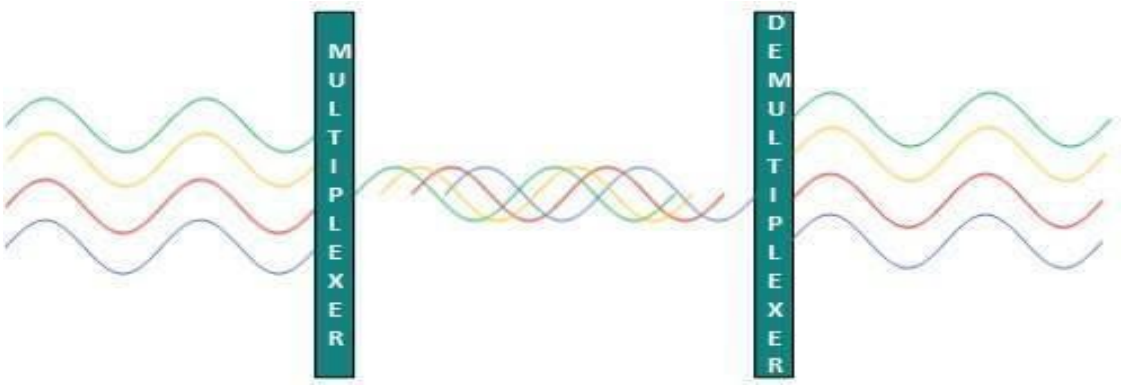


When channel A transmits its frame at one end,the De-multiplexer provides media to channel A on the other end.As soon as the channel A's time slot expires, this side switches to channel B. On the other end, the De-multiplexer works in a synchronized manner and provides media to channel B. Signals from different channels travel the path in interleaved manner.

Wavelength Division Multiplexing

Light has different wavelength (colours). In fiber optic mode, multiple optical carrier signals are multiplexed into an optical fiber by using different wavelengths. This is an analog

multiplexing technique and is done conceptually in the same manner as FDM but uses light as signals.



Code Division Multiplexing

Multiple data signals can be transmitted over a single frequency by using Code Division Multiplexing. FDM divides the frequency in smaller channels but CDM allows its users to full bandwidth and transmit signals all the time using a unique code. CDM uses orthogonal codes to spread signals.Each station is assigned with a unique code, called chip. Signals travel with these codes independently, inside the whole bandwidth.The receiver knows in advance the chip code signal it has to receive.

SWITCHING

Switching is process to forward packets coming in from one port to a port leading towards the destination. When data comes on a port it is called ingress, and when data leaves a port or goes out it is called egress. A communication system may include number of switches and nodes. At broad level, switching can be divided into two major categories:

- **Connectionless:** The data is forwarded on behalf of forwarding tables. No previous handshaking is required and acknowledgements are optional.
- **Connection Oriented:** Before switching data to be forwarded to destination, there is a need to pre-establish circuit along the path between both endpoints. Data is then forwarded on that circuit. After the transfer is completed, circuits can be kept for future use or can be turned down immediately.

Types of switching techniques

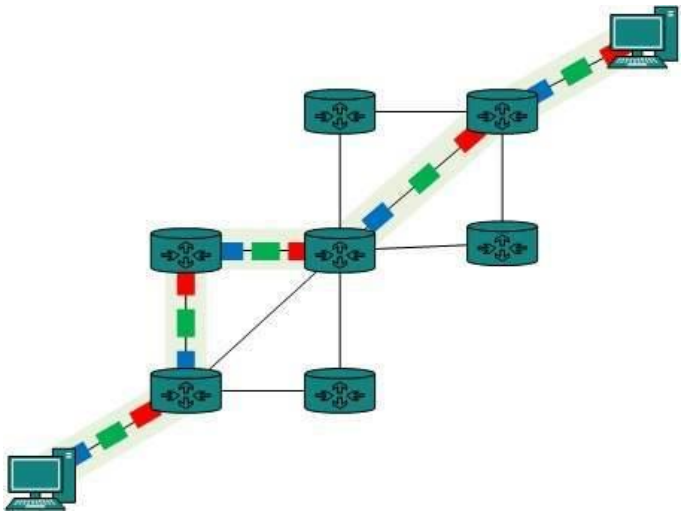
1. Circuit Switching
2. Message Switching
3. Packet Switching

1. Circuit Switching

When two nodes communicate with each other over a dedicated communication path, it is called circuit switching.There 'is a need of pre-specified route from which data will travel and no other data is permitted.In circuit switching, to transfer the data, circuit must be established so that the

data transfer can take place. Circuits can be permanent or temporary. Applications which use circuit switching may have to go through three phases:

- Establish a circuit
- Transfer the data
- Disconnect the circuit

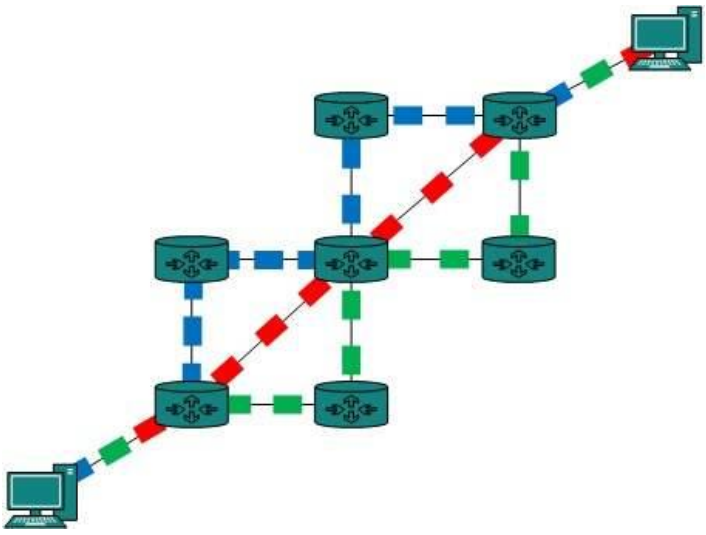


Circuit switching was designed for voice applications. Telephone is the best suitable example of circuit switching. Before a user can make a call, a virtual path between caller and callee is established over the network.

2. Packet Switching

Shortcomings of message switching gave birth to an idea of packet switching. The entire message is broken down into smaller chunks called packets. The switching information is added in the header of each packet and transmitted independently.

It is easier for intermediate networking devices to store small size packets and they do not take much resources either on carrier path or in the internal memory of switches.

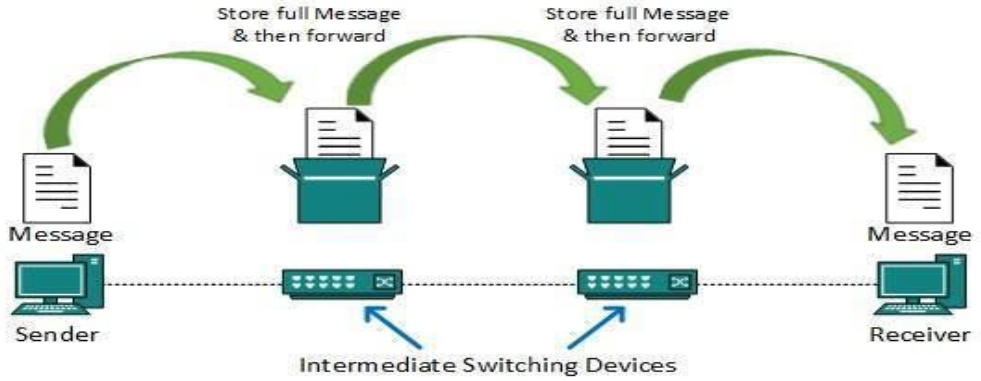


Packet switching enhances line efficiency as packets from multiple applications can be multiplexed over the carrier. The internet uses packet switching technique. Packet switching enables the user to differentiate data streams based on priorities. Packets are stored and forwarded according to their priority to provide quality of service.

3. Message Switching

This technique was somewhere in middle of circuit switching and packet switching. In message switching, the whole message is treated as a data unit and is switching / transferred in its entirety.

A switch working on message switching, first receives the whole message and buffers it until there are resources available to transfer it to the next hop. If the next hop is not having enough resource to accommodate large size message, the message is stored and switch waits.



This technique was considered substitute to circuit switching. As in circuit switching the whole path is blocked for two entities only. Message switching is replaced by packet switching. Message switching has the following drawbacks:

- Every switch in transit path needs enough storage to accommodate entire message.
- Because of store-and-forward technique and waits included until resources are available, message switching is very slow.
- Message switching was not a solution for streaming media and real-time applications.