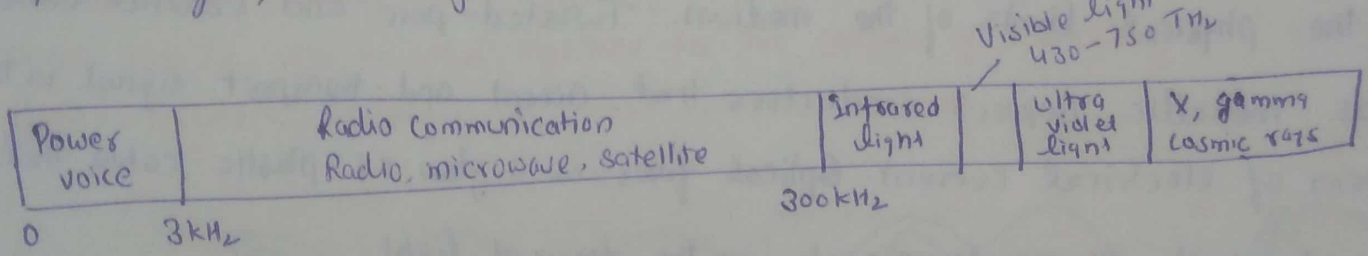
Transmission media: Guided & Unguided, Network Topologies

Transmission media:

Computers and other telecommunication devices use signals to represent data. These signals are transmitted from one device to another in the form of electromagnetic energy. Electromagnetic signals can travel through a vacuum, air or other transmission media.

Electromagnetic energy, a combination of electrical and magnetic fields vibrating in relation to each other, includes power, voice, radio waves, infrared light, visible light, ultraviolet light and X, gamma and cosmic rays.



Electromagnetic spectrum

voice-band frequencies are generally transmitted as current over metal cables, such as twisted-pair or coaxial cable.

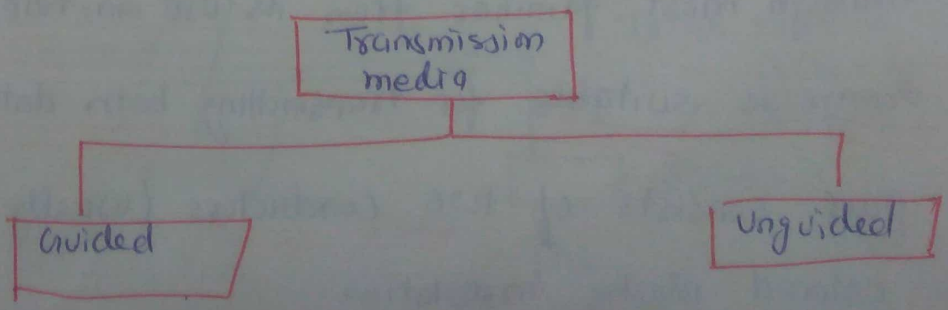
Radio frequencies can travel through air or space but require specific transmitting and receiving mechanisms.

Visible light, the third type of electromagnetic energy currently used for communications is harnessed using fiber-optic cable.

Transmission media can be divided into two broad categories

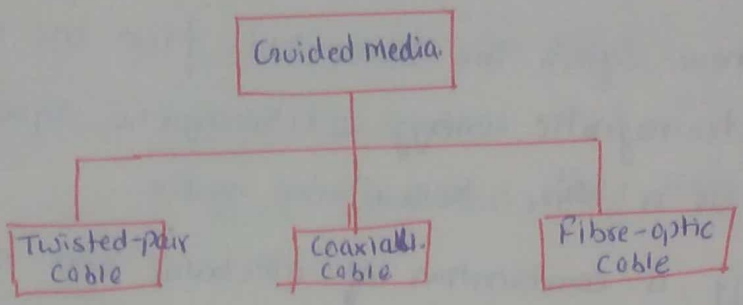
① Guided

② Unguided



Guided media ↓

Which are those that provide a conduit (passage) from one device to another include twisted pair cable, coaxial cable and fiber-optic cable



A signal travelling along any of these media is directed and contained by the physical limits of the medium. Twisted-pair and coaxial cable use metallic (copper) conductors that accept and transport signal in the form of electrical current. Optical fiber is a glass or plastic cable that accepts and transports signals in the form of light.

Twisted-Pair Cable ↓

Twisted-pair cable comes in two forms

① unshielded ② Shielded.

Unshielded Twisted-pair Cable (UTP) ↓

UTP is most common type of telecommunication medium in use today. Although most familiar from its use in telephone systems. its frequency range is suitable for transmitting both data and voice. A twisted pair consists of two conductors (usually copper), each with its own colored plastic insulation.

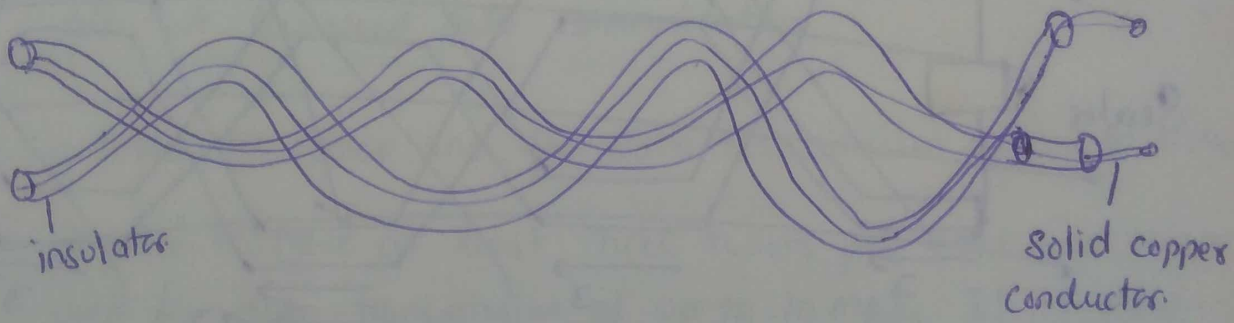
Twisted-pair cable

100 Hz — 5 MHz

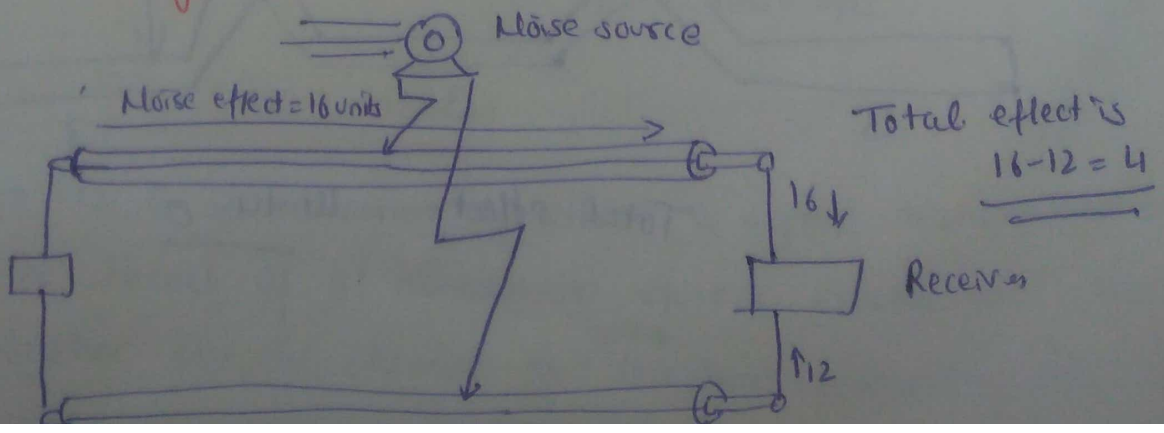
Frequency range for twisted-pair cable

The plastic insulation is color-banded for identification. Colors are used both to identify the specific conductors in a cable and to indicate which wires belong in pairs and how they related to other pairs in a large bundle.

Twisted pair cabling is a type of wiring in which two conductors of a single circuit are twisted together for the purpose of canceling out ~~electromagne~~ electromagnetic interference from external sources.

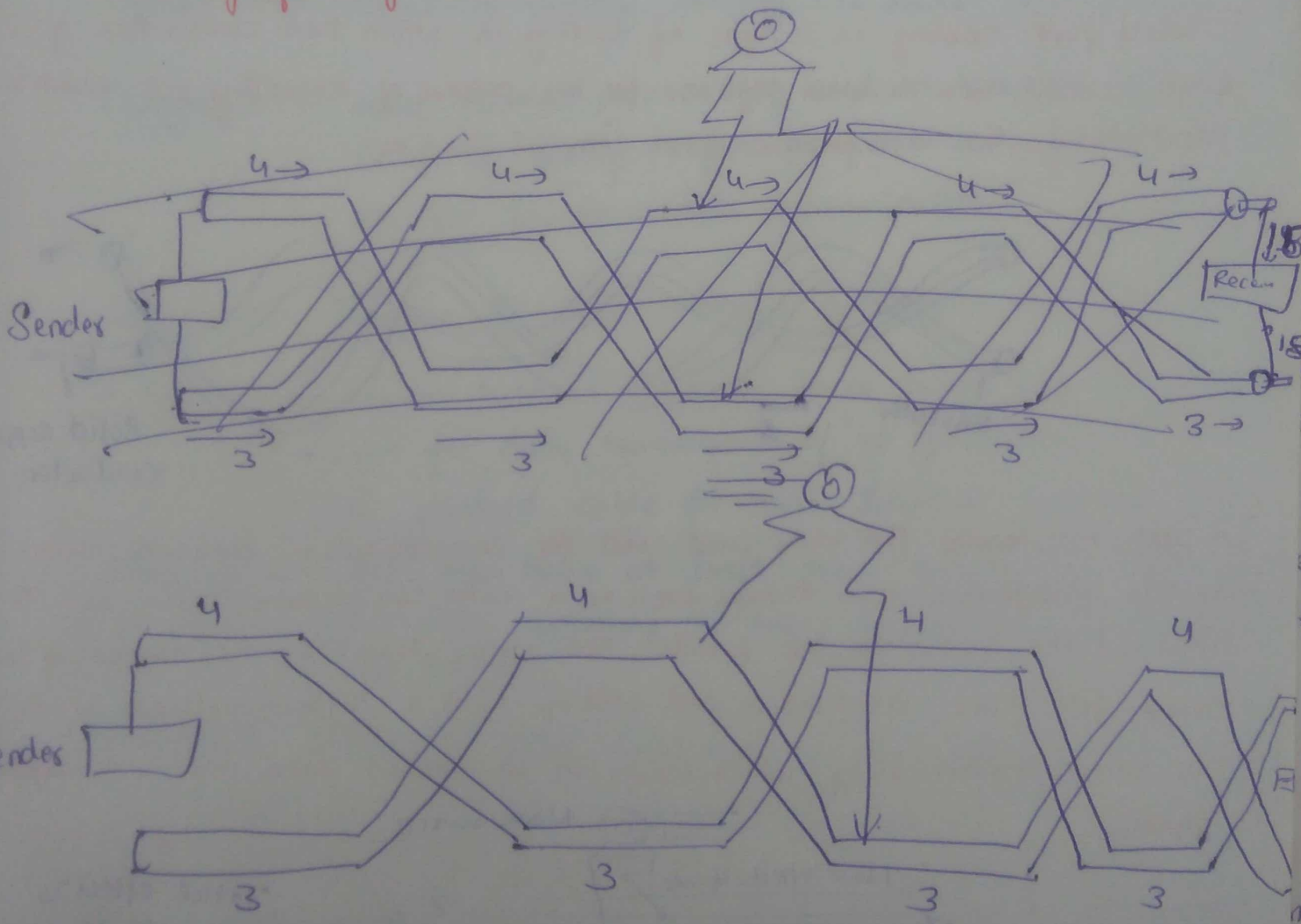


In past, two parallel flat wires were used for communication. However, electro-magnetic interference from devices such as a motor can create noise over those wires. If the two wires are parallel, the wire closest to the source of the noise gets more interference and ends up with a higher voltage level than the wire farther away, which results in an uneven load and a damaged signal.



If, however, the two wires are twisted around each other at regular intervals (between 2 and 12 twists per foot), each wire is closer to the noise source for half the time and farther away for the other half. With twisting, therefore the cumulative effect of the interference is equal on both wires. Each section of wire has a "load" of 4 when it is on the top of the twist and 3 when it is on the bottom. The total effect of the noise at the receiver is therefore 0.

Twisting does not always eliminate the impact of noise, but it does significantly reduce it.



Total effect- 14-14=0

Advantages of UTP

1. Easy to handle and install
2. UTP is cheap, flexible
3. Crosstalk is minimized
4. Electrical noise going into or coming from the cable can be prevented.

Standards to grade UTP

Electronic Industries Association (EIA) has developed standards to grade UTP cables by quality. Category 1 is lowest and 5 as the highest.

Category 1 :- basic twisted-pair cabling used in telephone systems. This level of quality is fine for voice but inadequate for all but low-speed data communication

Category 2 :- Suitable for voice and for data transmission of up to 4 Mbps

Category 3 :- Require to have at least three twists per foot and can be used for data transmission of up to 10 Mbps. It is now the standard cable for most telephone systems

Category 4 :- Must also have at least three twists per foot as well as other conditions to bring the possible transmission rate to 16 Mbps.

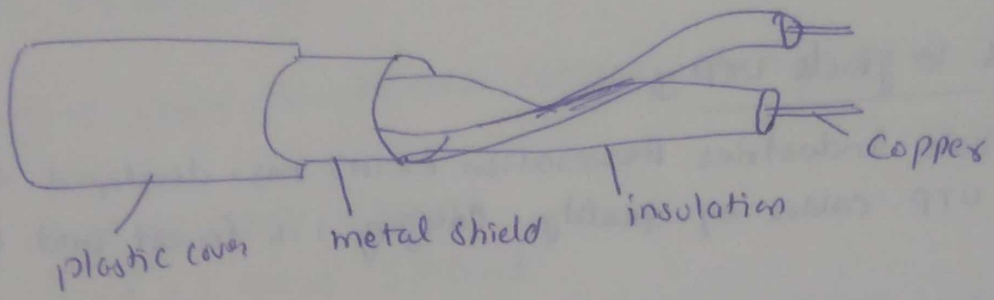
Category 5. Used for data transmission up to 100 Mbps.

Shielded Twisted-Pair (STP) cable →

Cross talk → is a phenomenon by which a signal transmitted on one ckt or channel of a transmission system creates an undesired effect in another ckt or channel. ex ^ during telephone conversations when one can hear other conversations in the background.

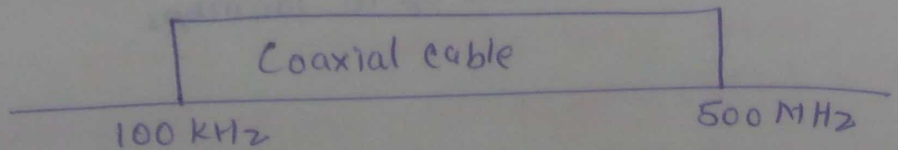
Shielded twisted-pair (STP) cable has a metal foil or braided-mesh covering that encases each pair of insulated conductors. The metal casing prevents the penetration of electromagnetic noise. It also can eliminate a phenomenon called crosstalk.

Materials and manufacturing requirements make STP more expensive than UTP but less susceptible to noise.

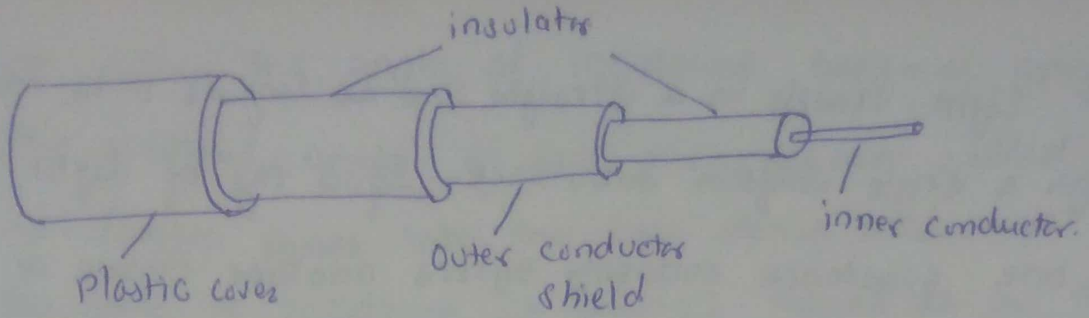


Coaxial Cable ↓

Coaxial Cable carries signals of higher frequency ranges than twisted pair cable. because the two media are constructed quite differently. Instead of having two wires, coax has a central core conductor of solid or stranded wire (copper) enclosed in an insulating sheath, which is in turn encased in an outer conductor of metal foil, braid or a combination of the two The outer conductor is also enclosed in an insulating sheath and the whole cable is protected by a plastic cover.



frequency range of Coaxial cable



Coaxial Cable

Coaxial Cable Standards ↓

Different coaxial cable designs are categorized by their radio government rating.

RG-8 -	Used in thick Ethernet
RG-9	Used in thick Ethernet
RG-11	Used in thick Ethernet
RG-58	Used in thin Ethernet
RG-59	Used in TV.

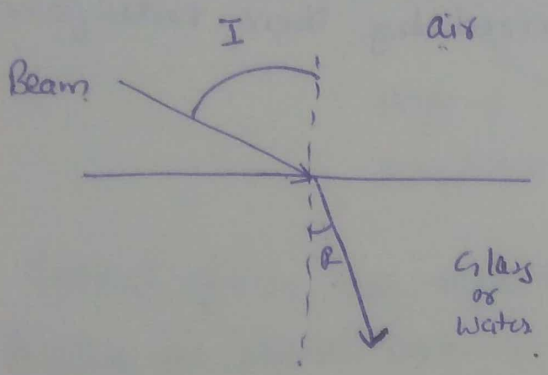
Connectors – T-connectors and Terminators.

Optical Fiber :↓ Optical fiber is made of glass or plastic and transmits signals in the form of light.

For understanding optical fiber we first need to know nature of light

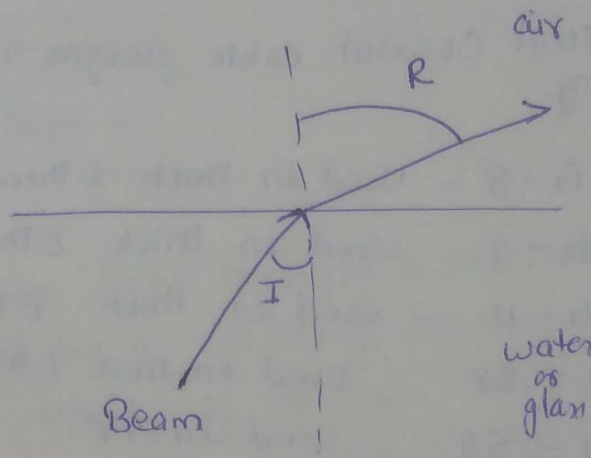
Light, a form of electromagnetic energy, travels at 300,000 kilometers/sec or approximately 186000 miles/second in a vacuum. This speed decreases as the medium through which the light travels becomes denser.

Refraction → Light travels in a straight line as long as it is moving through a single uniform substance. If a ray of light travelling through one substance suddenly enters another (more or less dense) its speed changes abruptly, causing the ray to change direction. This change is called refraction.



(a) From less dense to more dense

$R < I$

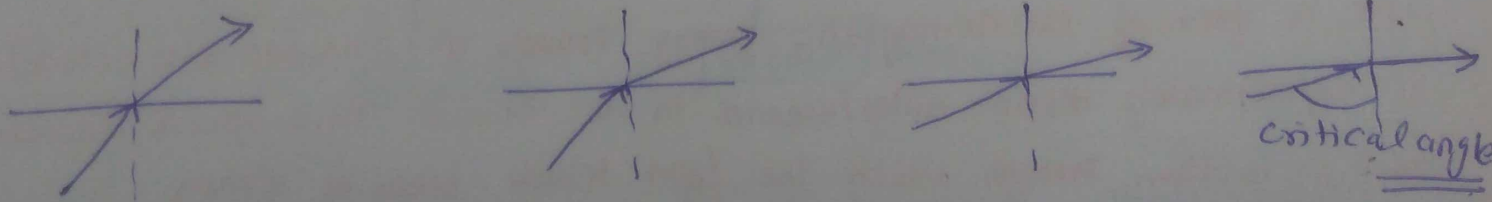


(b) From more dense to less dense

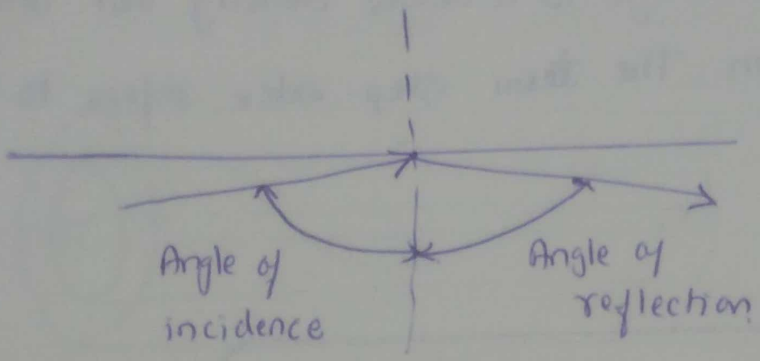
$I < R$

I- angle of incidence R- angle of refraction.

Critical Angle → At some point the change in the incident angle results in a refracted angle of 90° degree with the refracted beam now lying along the horizontal. The incident angle at this point is known as the critical angle.

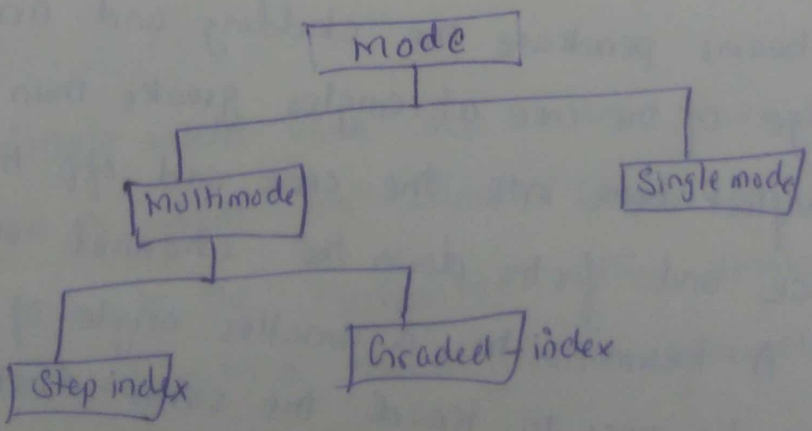


Reflection → When the angle of incidence becomes greater than the critical angle a new phenomenon called reflection. Light no longer passes into the less dense medium at all. In this case the angle of incidence is always equal to the angle of reflection.



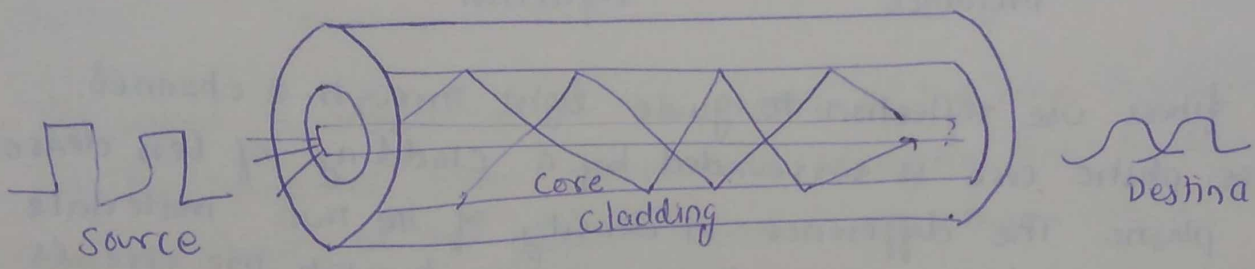
Optical fibers use reflection to guide light through a channel. A glass or plastic core is surrounded by a cladding of less dense glass or plastic. The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being refracted into it. Information is encoded onto a beam of light as a series of on-off flashes that represent 1 and 0 bits.

Propagation Mode



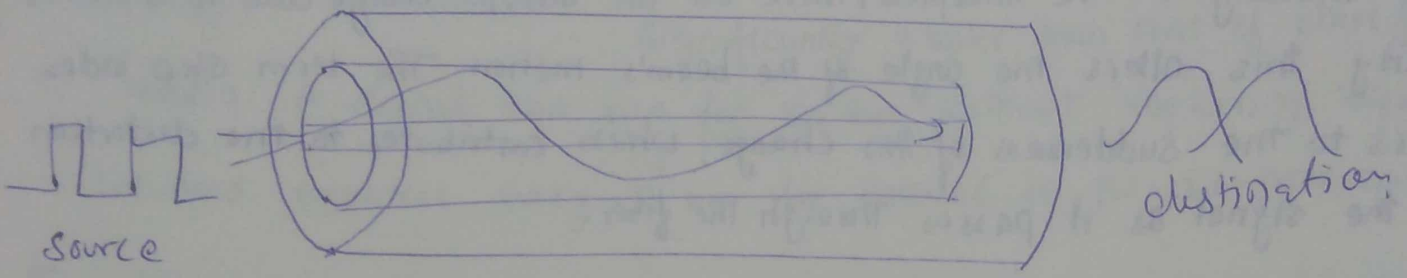
Multimode :- multimode is so named because multiple beams from a light source move through the core in different paths.

In multimode step-index fiber, the density of the core remains constant from the center to the edge. 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.



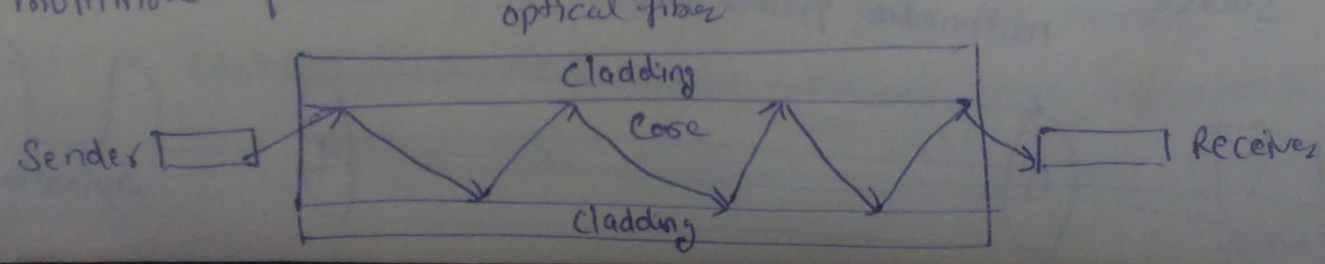
Various beams traveling through a step-index fiber. Some beams in the middle travel in straight lines through the core and reach the destination without reflecting or refracting. Some beams strike the interface of the core and cladding at an angle smaller than the critical angle; these beams penetrate 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. 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 incidence angle must travel farther to reach the destination.

A second type of fiber called multimode graded-index fiber decreases this distortion of the signal through the cable. The word index here refers to the index of refraction. A graded-index fiber is one with varying densities. Density is highest at the center of the core and decrease gradually to its lowest at the edge.



The signal is introduced at the center of the core. From this point only the horizontal beam moves in a straight line through the constant density at the center. Beams at other angles move through a series of constantly changing densities. Each density difference causes each beam to refract into a curve. In addition varying the refraction varies the distance each beam travels in a given period of time.

Single mode :- 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 single mode fiber itself is manufactured with a much smaller diameter than that of multimode fibers



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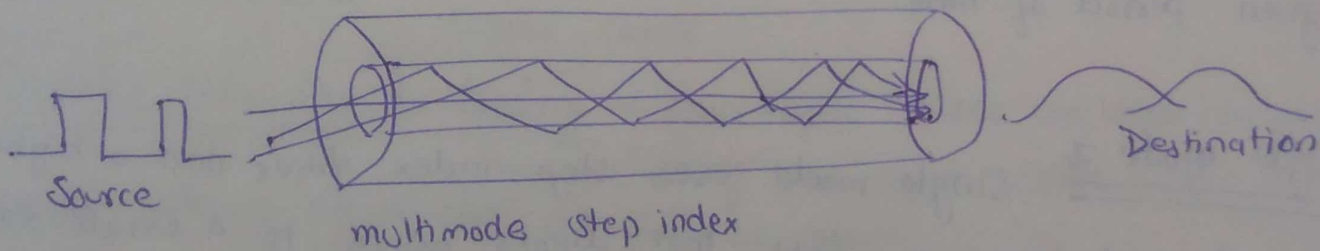
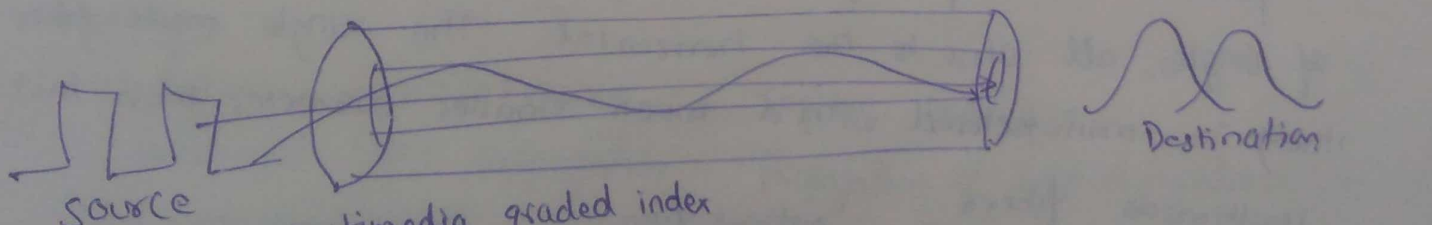
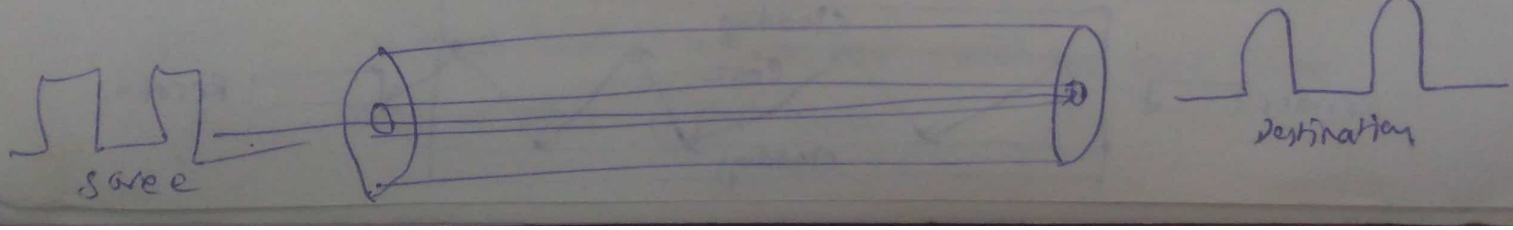
Second type of fiber, called multimode graded-index fiber, decreases this distortion of the signal through the cable. The word index here refers to the index of refraction. Index of refraction is related to density. A graded-index fiber therefore is one with varying densities. Density is highest at the center of the core and decreases gradually to its lowest at the edge.



multimode step index



multimedia graded index



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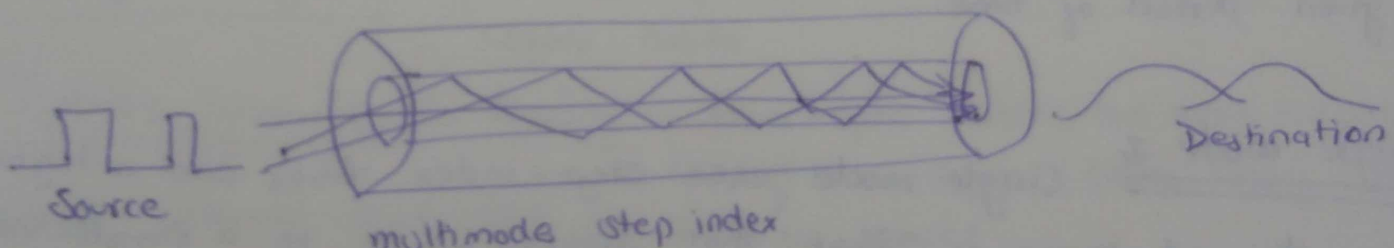

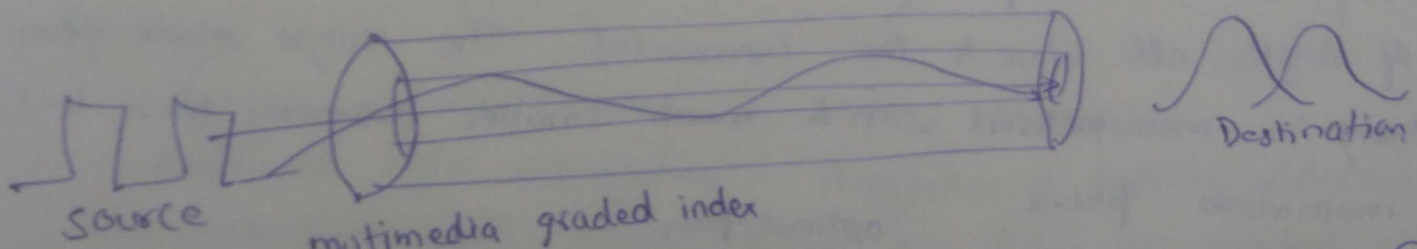

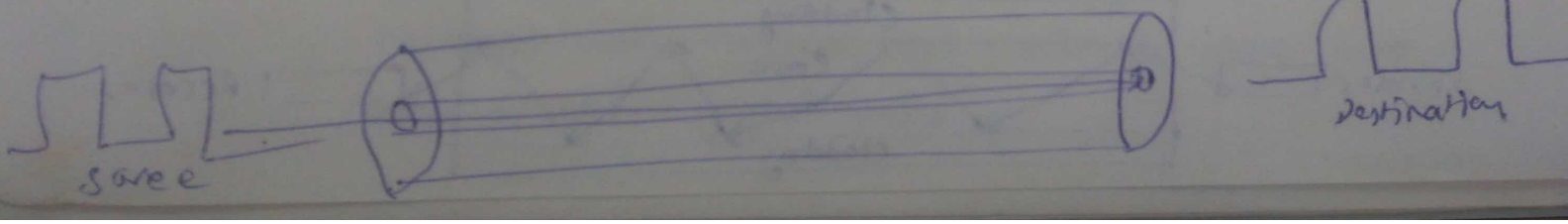

Advantages & Disadvantages of optical fiber

Advantages

① Higher bandwidth — Fibers-optic cable can support dramatically higher bandwidths than either twisted-pair or coaxial cable.

② Less signal attenuation :- Fibers-optic transmission distance is significantly greater than that of other guided media. A signal can run for 50 km without requiring regeneration we need repeaters every 5 km for coaxial or twisted-pair cable.

③ Immunity to electromagnetic interference :- Electromagnetic noise cannot affect fibers-optic cables

④ Resistance to corrosive materials :- Glass is more resistant to corrosive materials than copper.

⑤ Light weight :- Fiber optic cables are much ~~m~~ lighter than copper cables.

⑥ Greater Immunity to tapping :- Fiber-optic cables are more immune to tapping than copper cables. Copper cables create antenna effects that can easily be tapped.

Disadvantages

① Installation and maintenance :- require expertise

② Unidirectional light propagation :- Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.

③ Cost :- Cable ~~and~~ and interfaces are relatively more expensive than those of other guided media.

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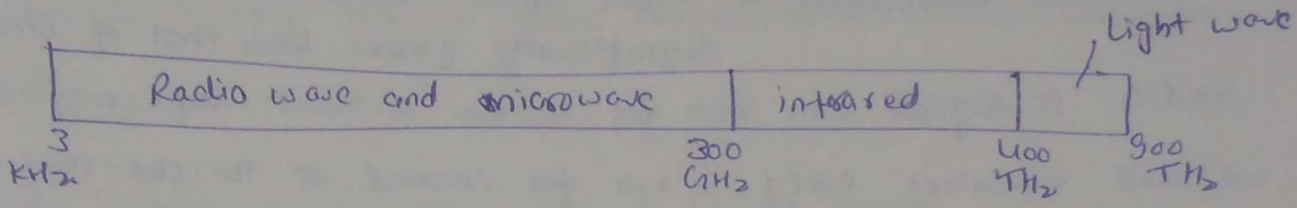
Unguided media: Unguided media transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication. Signals are normally broadcast through free space and thus are available to anyone who has a device capable of receiving them.



Unguided signals can travel from the source to destination in several ways.

- Ground propagation
- Sky propagation
- line-of-sight propagation

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 planet. Distance depends on the amount of power in the signal. The greater the power, the greater the distance.

Sky propagation :- higher frequency radio waves radiate upward into the ionosphere (layer of atmosphere where particles exist as ions) where they are reflected back to earth. This type of transmission allows for greater distances with lower output power.

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 together not to be affected by the curvature of the earth. Line-of-sight propagation is tricky because radio transmissions cannot be completely focused.

We can divide wireless communication into 3 broad groups

- Radio waves
- micro waves
- infrared waves

Radio waves:- Electromagnetic waves ranging in frequencies between 3kHz and 1 GHz are normally called radio waves. Radio waves are omnidirectional when an antenna transmits radio waves, they are propagated in all directions. This means that the sending and receiving antennas do not have to be aligned. Disadvantage of omnidirectional property is radio waves transmitted by one antenna are susceptible to interference by another antenna that may send signals using the same frequency or band. Radio waves particularly those of low and medium frequencies can penetrate walls. This characteristics can be both advantage and disadvantage.

Radio waves are used for multicast communications such as radio and television and paging system.

Microwaves :- Electromagnetic waves having frequencies between 1 and 300 GHz are called microwaves. microwaves are unidirectional. Sending and receiving antennas need to be aligned. Unidirectional property has an advantage A pair of antennas can be aligned without interfering with another pair of aligned antennas. Some ~~properties are~~ characteristics are

① microwave propagation is line-of-sight
② Very high-frequency microwaves cannot penetrate walls
③ microwave band is relatively wide almost 299 GHz
④ Use of certain portions of the band requires permission from authorities.

microwaves are used for unicast communications such as cellular telephones, satellite network and wireless LANs.

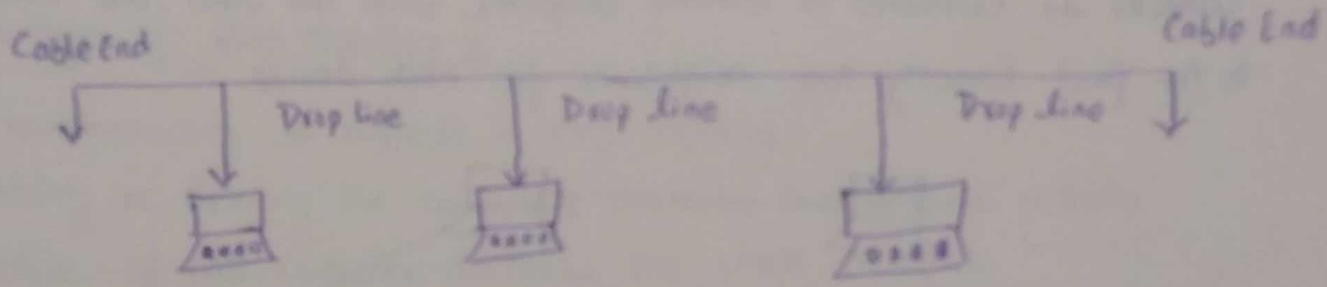
Infrared :- Infrared waves, with frequencies from 300 GHz to 400 THz can be used for short-range communication. Infrared waves having high frequencies, cannot penetrate walls. This advantageous characteristic prevents interference between one system and another. that's why we cannot use infrared signals useless for long-range communication. We cannot use infrared waves outside a building because the sun's rays contains infrared waves that can interfere with the communication.

Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

Network Topology :-

Network topology is the schematic description of a network arrangement connecting various node (senders and receivers) through lines of connection.

Bus Topology :- Bus topology is a network type in which every computer and network device is connected to single cable. When it has exactly two endpoints, then it is called Linear Bus topology.



Features of Bus topology

1. It transmits data only in one direction.
2. Every device is connected to a single cable.

Advantages of Bus Topology

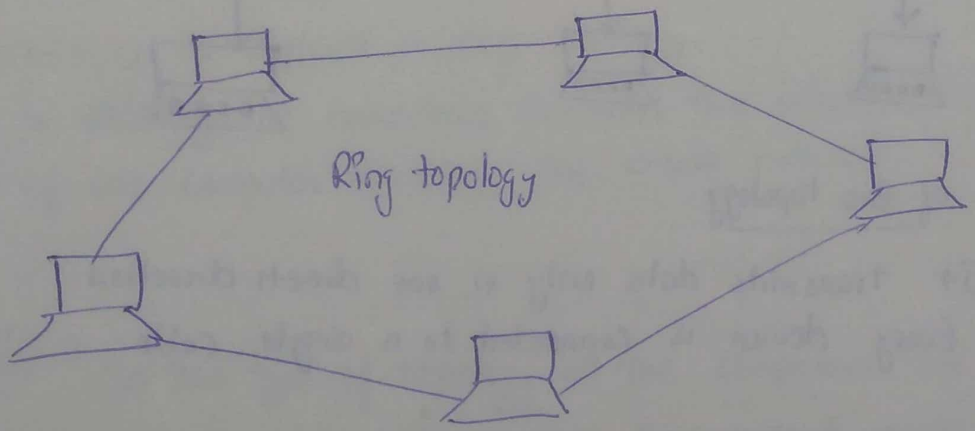
1. It is cost effective.
2. Cable required is least compared to other network topology.
3. Used in small networks.
4. It is easy to understand.
5. Easy to expand joining two cables together.

Disadvantages of Bus Topology :-

1. Cables fails then whole network fails
2. If network traffic is heavy or nodes are more the performance of the network decreases.
3. Cable has a limited length
4. It is slower than the ring topology

RING Topology :-

It is called ring topology because it forms a ring as each computer is connected to another computer, with the last one connected to the first. Exactly two neighbours for each device.



Features of Ring topology :-

1. A number of repeaters are used for Ring topology with large number of nodes, because if some one wants to send some data to the last node in the ring topology with 100 nodes, then the data will have to pass through 99 nodes to reach 100th node. Hence to prevent data loss repeaters are used in the network.
2. The transmission is unidirectional, but it can be made bidirectional by having 2 connections b/w each network node. It is called Dual Ring topology.

(3) In dual Ring topology, two ring networks are formed and data flow is in opposite direction in them. Also if one ring fails, the second ring can act as a backup, to keep the network up.

(4) Data is transferred in a sequential manner that is bit by bit. Data transmitted has to pass through each node of the network till the destination node.

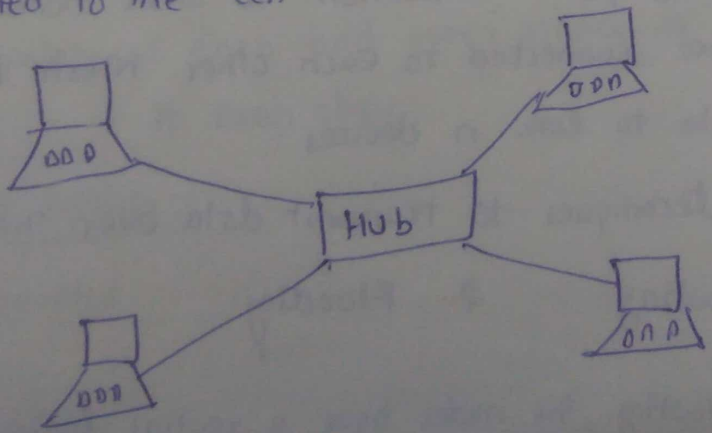
Advantages of Ring Topology :-

1. Transmitting network is not affected by high traffic or by adding more nodes, as only the nodes having tokens can transmit data.
2. Cheap to install and expand.

Disadvantages of Ring topology :-

1. Troubleshooting is difficult in ring topology.
2. Adding or deleting the computers distrubs the network activity.
3. Failure of one computer disturbs the whole network.

STAR Topology :- In this type of topology all the computers are connected to a single hub through a cable. This hub is the central node and all others nodes are connected to the central node.



Features of star Topology :-

1. Every node has its own dedicated connection to the hub.
2. Hub acts as a repeater for data flow.
3. Can be used with twisted pairs, optical fibre or coaxial cable.

Advantages of star Topology :-

1. Fast performance with few nodes and low network traffic.
2. Hub can be upgraded easily
3. Easy to troubleshoot.
4. Easy to setup and modify
5. Only that node is affected which has failed, rest of the nodes can work smoothly.

Disadvantages of star Topology

1. Cost of installation is high
2. Expensive to use.
3. If the hub fails then the whole network is stopped because all the nodes depends on the hub.
4. Performance is based on the hub that is it depends on its capacity.

MESH Topology :-

It is a point-to-point connection to other nodes or devices. All the network nodes are connected to each other. Mesh has $n(n-2)/2$ physical channels to link n devices.

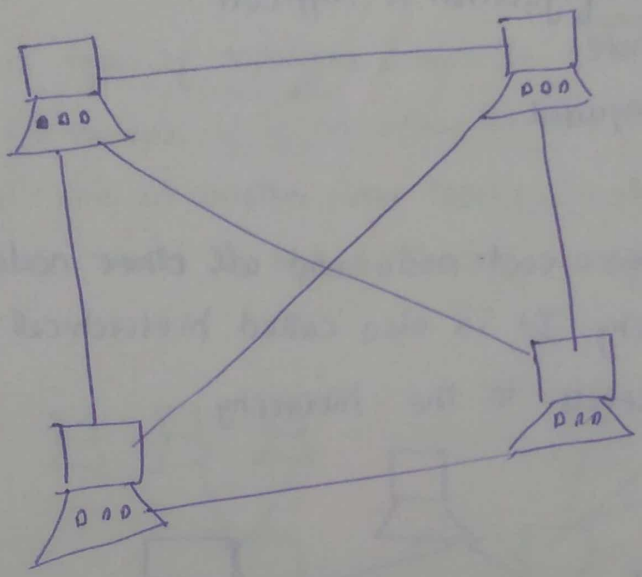
There are two techniques to transmit data over the mesh topology they are

1. Routing
2. Flooding

Routing :- In routing, the nodes have a routing logic as per the network requirements. Like routing logic to direct the data to reach the destination using the shortest distance.

or routing logic which has information about the broken links and it avoids those node etc. We can even have routing logic to re-configure the failed nodes.

Flooding:- In flooding, the same data is transmitted to all the network nodes, hence no routing logic is required. The network is robust and the its very unlikely to lose the data. But it leads to unwanted load over the network



Types of mesh topology :-

1. Partial mesh topology : in this topology some of the systems are connected in the same fashion as mesh topology but some devices are only connected to two of three devices
2. Full Mesh topology :- Each and every nodes or devices are connected to each other.

Features of mesh topology :-

1. Fully connected
2. Robust
3. Not Flexible

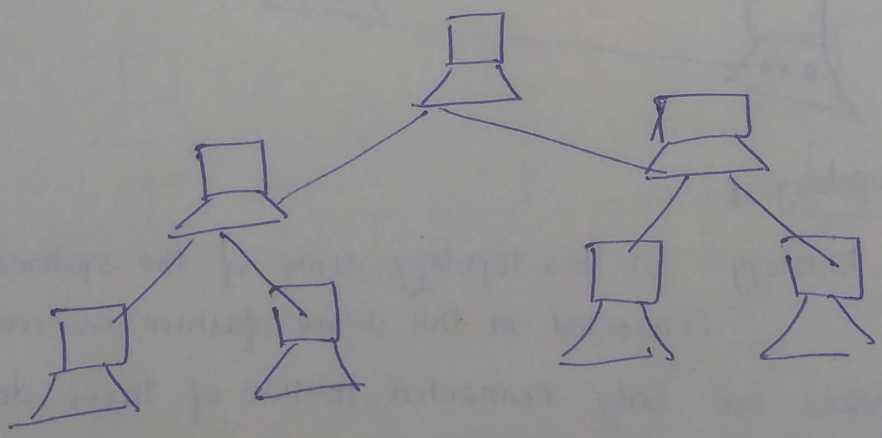
Advantages of Mesh topology :

1. Each connection can carry its own data load.
2. It is robust
3. Fault is diagnosed easily
4. Provides security and privacy

Disadvantages of Mesh Topology :

1. Installation and configuration is difficult
2. Cabling cost is more
3. Bulk wiring is required.

TREE Topology : It has a root node and all other nodes are connected to it forming a hierarchy. It is also called hierarchical topology. It should at least have three levels to the hierarchy.



Features of Tree topology

1. Ideal if ~~works~~ workstations are located in groups
2. Used in wide Area Network.

Advantages of Tree topology

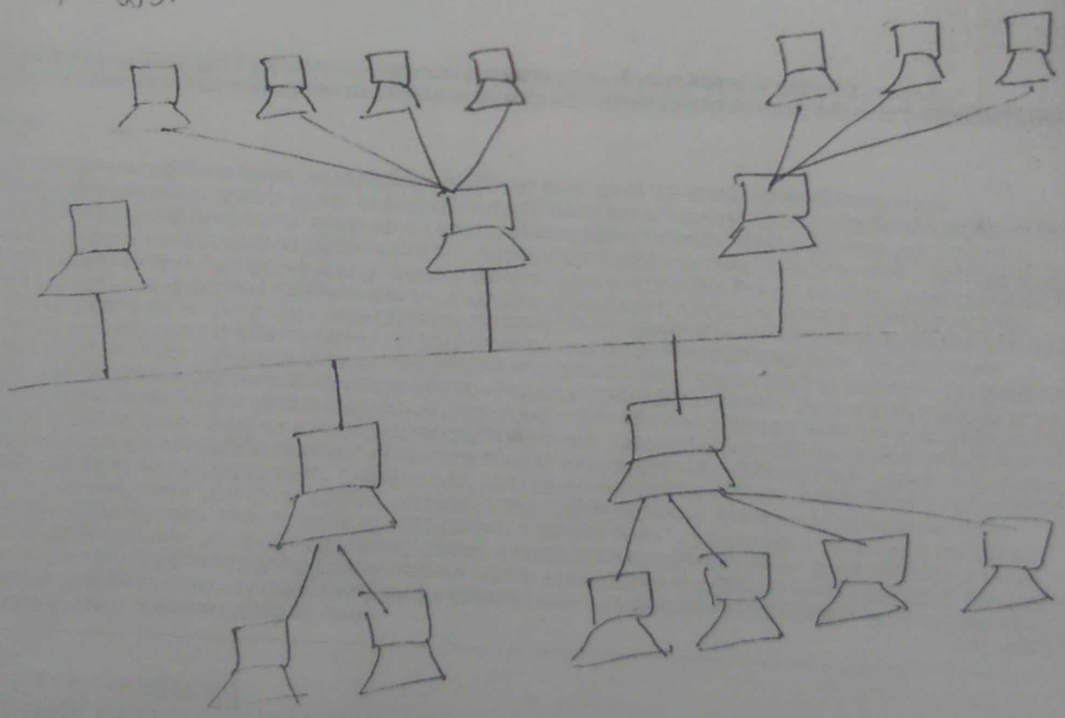
1. Extension of bus and star topologies
2. Expansion of nodes is possible and easy
3. Easily managed and maintained.
4. Error detection is easily done.

Disadvantages of Tree Topology :-

1. Heavily cabled.
2. Costly
3. If more nodes are added maintenance is difficult
4. Central hub fails, network fails

Hybrid topology :-

It is two different types of topologies which is a combination mixture of two or more topologies. For example if in an office in one department ring topology is used and in another star topology is used, connecting these topologies will result in Hybrid Topology (ring topology and star topology).



Features of hybrid topology :-

1. It is a combination of two or more topologies.
2. Inherits the advantages and disadvantages of the topologies included

Advantages of Hybrid Topology :

1. Reliable as Error detecting and trouble shooting is easy
2. Effective
3. Scalable as size can be increased easily
4. Flexible.

Disadvantages of Hybrid Topology :

1. Complex in design
2. Costly.