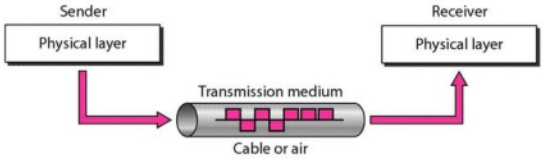
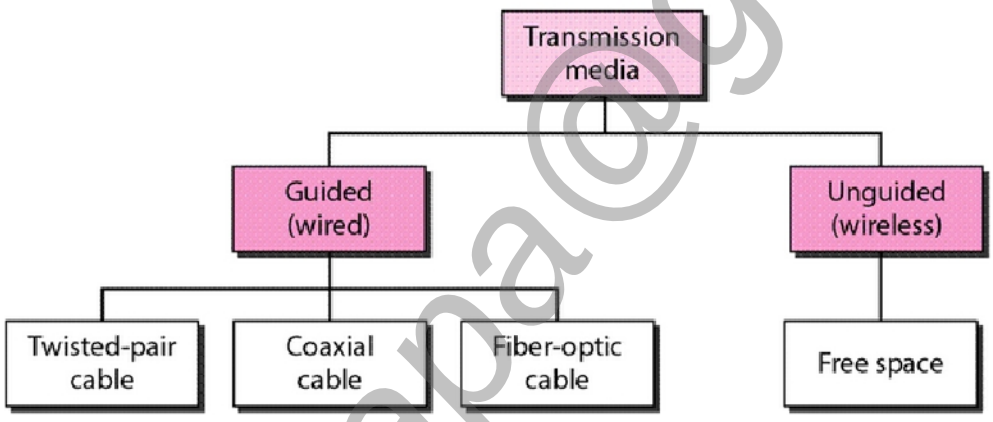
Chapter-3
The Physical Layer

Transmission Media

- Transmission media are actually located below the physical layer and are directly controlled by the physical layer.



- A transmission medium can be broadly defined as anything that can carry information from a source to a destination.
- Transmission media can be divided into two broad categories: **guided and unguided**.
- Guided media (Bounded Media) transmits signals by sending electric or light signal over a cable or wire.
- Guided media include twisted-pair cable, coaxial cable, and fiber-optic cable.
- Unguided medium is free space i.e. it transmits data through open air.
- Unguided media (Unbounded Media) include radio wave, infrared signal, earth and satellite based microwave.



Twisted Pair Cable

- Twisted pair cable is one of the most popular transmission media in LAN today.
- It consists of pair of cable twisted around each other inside a protective sheath.
- There are two main types: unshielded twisted pair(UTP) and shielded twisted pair(STP).
- In case of STP, the wires are also encased in an inner sheath of wire mesh.
- The purpose of twisting cable is to protect against electromagnetic interference (EMI) which happens when extraneous signals, either from outside source like power supply or from adjacent wires, leak onto the cable or interfere with communication.
- When EMI is caused by signal from another cable, it creates cross talk.
- Because of shielding STP is less susceptible to EMI than UTP.
- But STP is more expensive than UTP.
- There are different types of TP cable, cat1, cat2, cat3, cat4, cat5, cat6 etc.

- Twisted pair cable uses RJ-45 connector.

Types of TP cable

UTP Category	Data Rate	Max. Length	Cable Type	Application
CAT1	Up to 1Mbps	-	Twisted Pair	Old Telephone Cable
CAT2	Up to 4Mbps	-	Twisted Pair	Token Ring Networks
CAT3	Up to 10Mbps	100m	Twisted Pair	Token Rink & 10BASE-T Ethernet
CAT4	Up to 16Mbps	100m	Twisted Pair	Token Ring Networks
CAT5	Up to 100Mbps	100m	Twisted Pair	Ethernet, FastEthernet, Token Ring
CAT5e	Up to 1 Gbps	100m	Twisted Pair	Ethernet, FastEthernet, Gigabit Ethernet
CAT6	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT6a	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT7	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (100 meters)

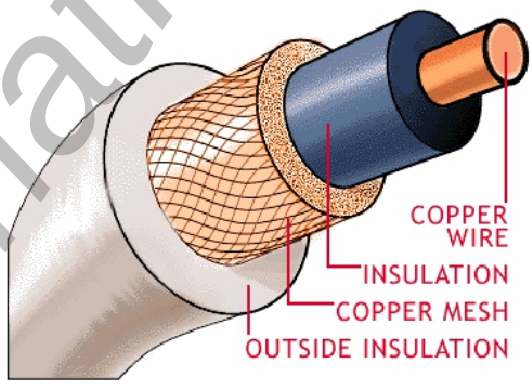
Advantage

1. It is inexpensive.
2. Flexible and light weight
3. Easy to work with
4. Easy to install

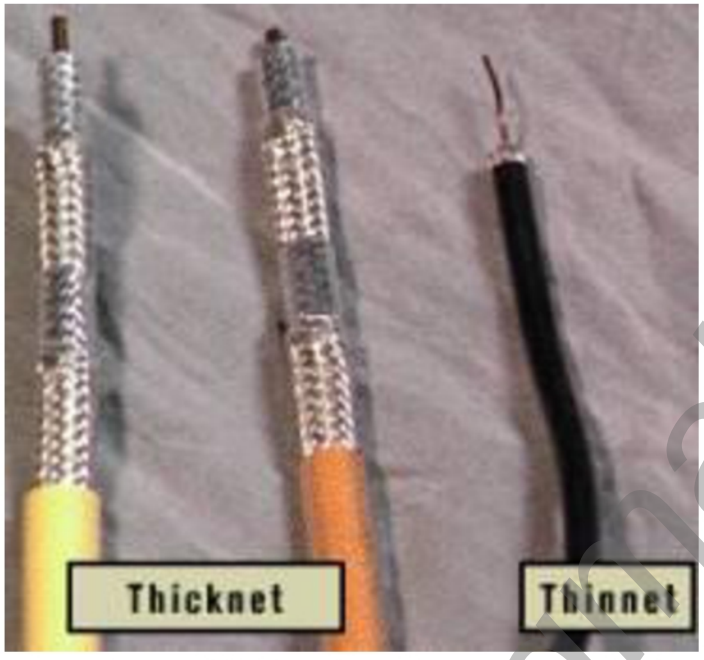
Disadvantage

1. Low data rate as compared to other transmission medium.
2. It is susceptible to EMI.(STP if better than UTP)
3. Can provide data transmission for short range. (STP is faster than UTP)

Co-axial Cable



- Also called as co-ax(common axix) cable.
- It is called so because it is made up of a single inner wire conductor surrounding by a layer of insulation, a wire mesh shield, and another layer of insulation.
- The wire shield against EMI.
- The inner insulator protect the cable against shorting out on contact with the wire shield.
- The outer insulator protects the whole cable.
- Mostly used in Television distribution.
- Coaxial comes into two types: thichnet and thinnet.



- Thicknet can carry signal approximately up to1640 feet while Thinnet can carry signal approximately up to 607 feet.
- Thicknet is about half an inch while Thinnet is of quarter an inch.
- Thicknet is basically used as backbone to connect several thinnets while Thinnet is good for connecting several individual computers.
- Thinnet uses BNC connector and are flexible and easy to work with.
- Thicknet are very difficult to bend and install but not in case of thinnet.

Advantage

1. Light, flexible and easy to work with.
2. Less susceptible to EMI than TP.
3. Relative inexpensive, although more expensive than TP.
4. Better suited for long distance data transmission as it is more resistant to attenuation.

Disadvantage

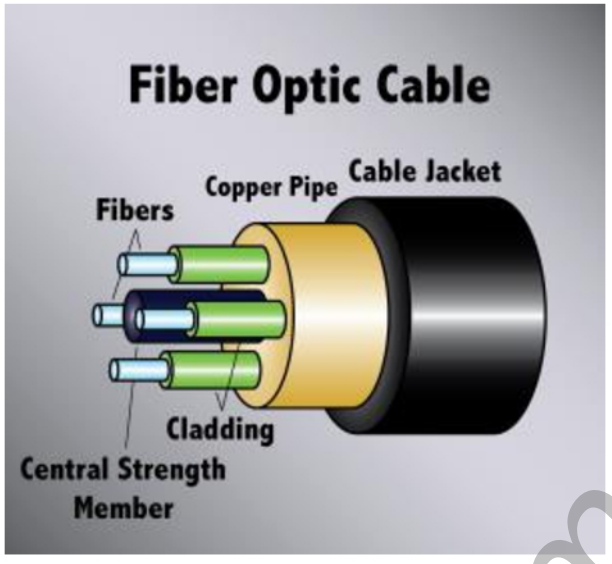
1. More difficult and expensive to install than TP.
2. Still fairly susceptible to EMI.

Baseband and Broadband Coaxial cable

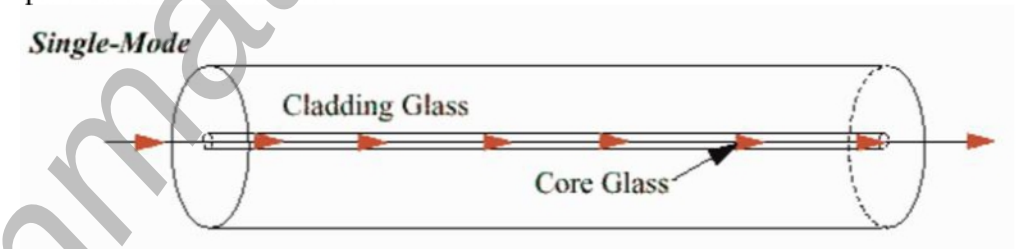
	Baseband	Broadband
Signal type	Digital	Analog
Directions	Bi-directional (but not at the same time)	Unidirectional (two separate channels / frequencies to send/receive)
Number of signals	Only one signal at a time	Multiple signals at a time
Uses	LAN – Ethernet and Token Ring	Many WAN links such as DSL and ISDN are broadband technologies. Cable TVs
Frequency-division multiplexing	Not possible	Possible
Distance	Travels short distances	Signal can travel over long distances

Fiber Optics

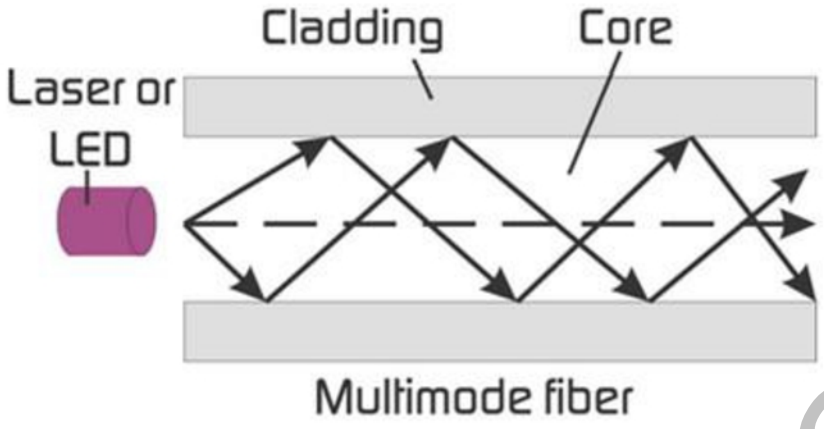
- Fiber optics cable transmits light signals through the strand(very small diameter even less than human hair) of glass or plastic called the core.
- The fiber optics consists of very thin fibers made up of two types of glass, one for the inner core and other for the outer layer.
- Two glasses have different index of refraction.
- A light beam is carried through the glass fiber and is modulated by the network to shape the signal.
- An optical fiber cable has a cylindrical shape and consists of three concentric section, the core, cladding and the jacket.
- The core is the innermost section and consists of one or more very thin fiber, made of glass or plastic. The core has the diameter of 8 to 100µm.
- Each set of fibers is surrounded by its own cladding, a glass or plastic coating that has a optical properties different from those of core.
- The interface between the core and cladding act as reflector to the confine light that would otherwise escape the core.
- The outermost layer is the jacket, which cover the entire fiber. The jacket is composed of plastic to protect against moisture, crushing and other environmental dangers.



- **Types**
  1. Single mode fiber: This uses a highly focused light beam and travel more or less horizontally. Here, fiber core diameter is much smaller and has lower density. Fiber core is reduced to that order so that only fewer angles will reflect i.e. only a single angle or mode can pass. Because there is a single transmission path, the distortion found in multimode can't occur here. Hence single mode is typically used for long distance application including telephone and cable television.

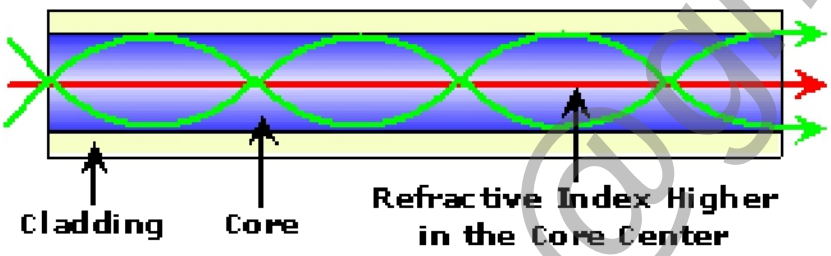


  2. Multi-mode fiber: In multi mode fiber, LED is mostly used as light source. Therefore multiple beam path pass through the core in different path.
     i. Step-index:
     Here, core(higher) and cladding(lower) has different optical properties(density). A beam of light move through this density in straight line until it reaches the interface of the core and cladding. At interface there is sudden change in density. This sudden change to lower density is called step index. Various beam travel through the step index. Some beam in the middle travel in a straight through the core and reach destination without any reflection. Some beam strike the interface of core and cladding at an angle smaller than critical angle, then beam penetrate the cladding and are lost. Some other beam hits the interface at an angle greater than the critical angle an reflect back into the core and continue until they reach the destination. The refractive index of core remain constant from center to edge.



ii. Graded index

In this case, the core is itself made of material at varying densities. The density is highest at the center of core and decreases toward the edge. Therefore, a beam goes through the gradual refraction giving rise to a curve path for beam propagation, however the horizontal beam travels unchanged.



Advantage

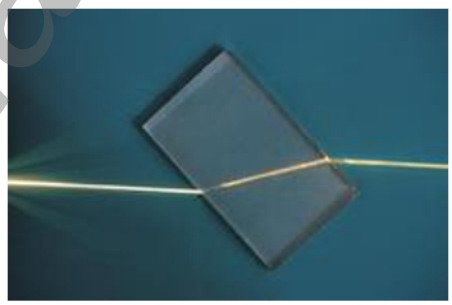
1. Very high speed of transmission.
2. Data can't be trapped from the cable, hence security is extremely high.
3. It uses light rays rather than electrical signal so noise is not an issue here.
4. Provides higher bandwidth than TPC and coaxial cable.

Disadvantage:

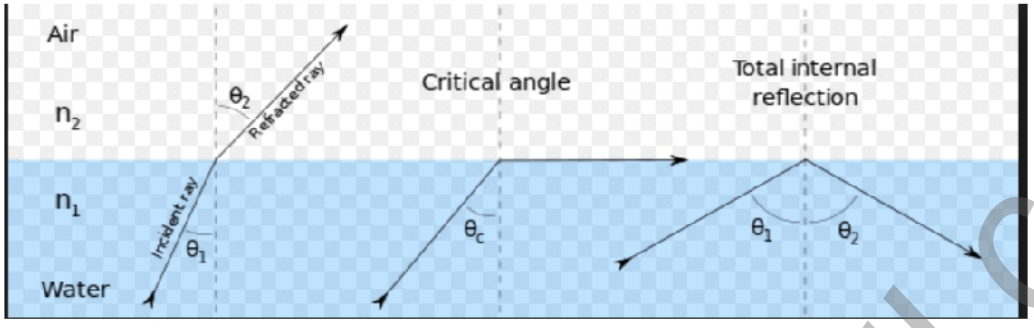
1. High cost of cable and installation.
2. High cost of maintenance.

Note:

- In optics, the refractive index or index of refraction n of a material is a dimensionless number that describes how light propagates through that medium



- Light travel in straight line as long as it is moving through a single uniform substance. So, if a ray of light travelling through one substance (say air) suddenly enter another substance(say water being more denser than previous), then, it causes the ray to change the direction thus forming two angle i.e. incidence and refracted.
- If the beam travel from more dense medium(water) to less dense medium(air) then the incidence angle is smaller than angle of refraction. The beam is bent toward horizontal axis.
- If the beam travel from less dense medium to more dens medium then angle of refraction is smaller than incidence angle. The beam is bent toward vertical axis.



- As the angle of incidence increase while moving the beam from higher dense medium to lower dense medium, the angle of refraction also increases. At some point, the changes in the incident angle result in refracted angle of 90 degree. This incident angle at this point is called critical angle.(same concept is use in optical fiber)

TPC vs Co-axial cable vs optical-fibre cable

Twisted pair cable	Co-axial cable	Optical fiber
1. Transmission of signals takes place in the electrical form over the metallic conducting wires.	1. Transmission of signals takes place in the electrical form over the inner conductor of the cable.	1. Signal transmission takes place in an optical forms over a glass fiber.
2. In this medium the noise immunity is low.	2. Coaxial having higher noise immunity than twisted pair cable.	2. Optical fiber has highest noise immunity as the light rays are unaffected by the electrical noise.
3. Twisted pair cable can be affected due to external magnetic field.	3. Coaxial cable is less affected due to external magnetic field.	3. Not affected by the external magnetic field.
4. Cheapest medium.	4. Moderate Expensive.	4. Expensive
5. Low Bandwidth.	5. Moderately high bandwidth.	5. Very high bandwidth
6. Attenuation is very high.	6. Attenuation is low.	6. Attenuation is very low.
7. Installation is easy.	7. Installation is fairly easy.	7. Installation is difficult.

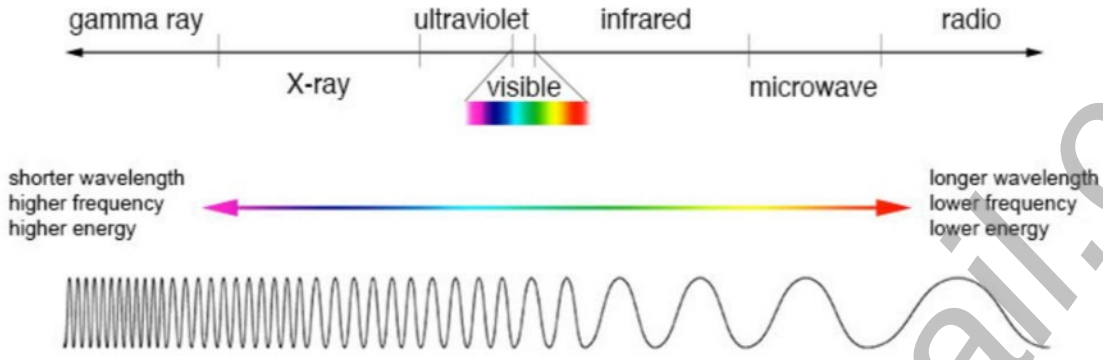
Unguided Transmission media

Unguided media or wireless communication transport electromagnetic wave without physical connection. These signals propagate through air.
For unguided media, transmission and reception are achieved by means of antenna. For transmission, the antenna radiates electromagnetic energy into the medium i.e. air and for reception, the antenna picks up the electromagnetic wave from the surrounding medium. There are two basic configuration for wireless transmission.
i. Directional: Here, the transmitting antenna puts out a focused electromagnetic beam, the transmitting and receiving antenna must be aligned properly.
ii. Omnidirectional: Here, the transmitted signal spread out in all direction and can be received by many antenna.

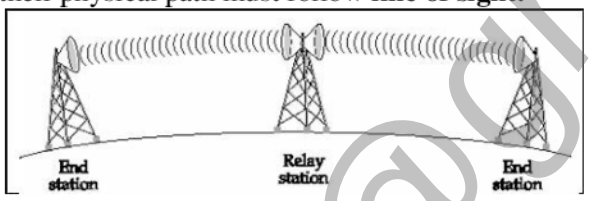
Types of unguided transmission media

- Terrestrial microwave
- Radio transmission

- Satellite Communication



Terrestrial Microwave

- Terrestrial microwave system typically uses directional parabolic antenna to send and receive signal.
- The signal are highly focused and their physical path must follow **line of sight.**
- 

- Terrestrial microwave systems are typically used when cabling is cost-prohibitive.
- Used to relay television broadcasting, long distance telephone calls.

Characteristics

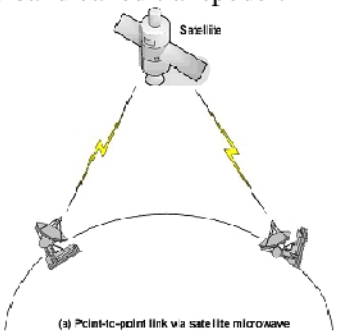
- Frequency range: most terrestrial microwave systems produces signal in the lower giga herz range usually 4 to 6 GHz and 21 to 23 GHz.
- Cost: Shorter distance system can be inexpensive and they are effective in the range of hundreds of meters. Long distance system may be expensive.
- Bandwidth capacity: Depends upon frequency used, data rates vary from 1 to 10Mbps.
- Attenuation: Attenuation is affected by frequency, signal strength and antenna size and atmospheric condition. For short distance attenuation is not significant.
- Installation: LOS requirement for microwave system can make installation difficult. Antenna must be carefully aligned.

Radio transmission

- The primary difference between microwave and radio transmission is that microwave uses directional antenna while radio uses omni directional antenna therefore they travel in all direction from source.
- Frequency characteristics: 30MHz to 1Ghz.
- Radio wave can travel long distance and penetrate building easily so widely used both for indoor and outdoor communication.
- A radio wave acts as a carrier of information-bearing signals; the information may be encoded directly on the wave by periodically interrupting its transmission or impressed on it by a process called modulation.
- The actual information in a modulated signal is contained in its sidebands, or frequencies added to the carrier wave, rather than in the carrier wave itself.
- The two most common types of modulation used in radio are amplitude modulation (AM) and frequency modulation (FM).
- Frequency modulation minimizes noise and provides greater fidelity than amplitude modulation, which is the older method of broadcasting.
- Both AM and FM are analog transmission systems, that is, they process sounds into continuously varying patterns of electrical signals which resemble sound waves.
- In its most common form, radio is used for the transmission of sounds (voice and music) and pictures (television). The sounds and images are converted into electrical signals by a microphone (sounds) or video camera (images), amplified, and used to modulate a carrier wave that has been generated by an oscillator circuit in a transmitter.
- The modulated carrier is also amplified, then applied to an antenna that converts the electrical signals to electromagnetic waves for radiation into space.

Satellite Communication:

- Satellite communication uses the microwave relay station.
- It is used to link transmitter and receiver.
- Satellite communication uses two frequency i.e. satellite receive signal of one frequency band(uplink frequency) , amplifies the signal and then finally transmit it on another frequency (downlink frequency), which means that same satellite operates on number of frequency band called transpoder.

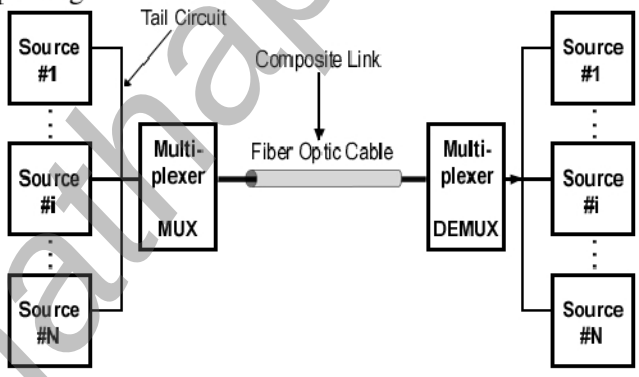


- Two methods are used for satellite communication
    1. Point to point link between two distance ground antenna.
    2. Satellite also provides communication between one ground base transmitter and number of ground based receivers.
- For a communication satellite to function effectively, a satellite must remain stationary with respect to its position over the earth. Otherwise, it wouldn't be within the line of sight of its earth station at all time.
- To remain stationary, the satellite must have a period of rotation equals to the earth period of rotation.

Assignment: Write short notes on VSAT, Bluetooth and WIFI.

Multiplexing

- The method of dividing a single channels into many channels so that a number of independent signals may be transmitted on I known as multiplexing.

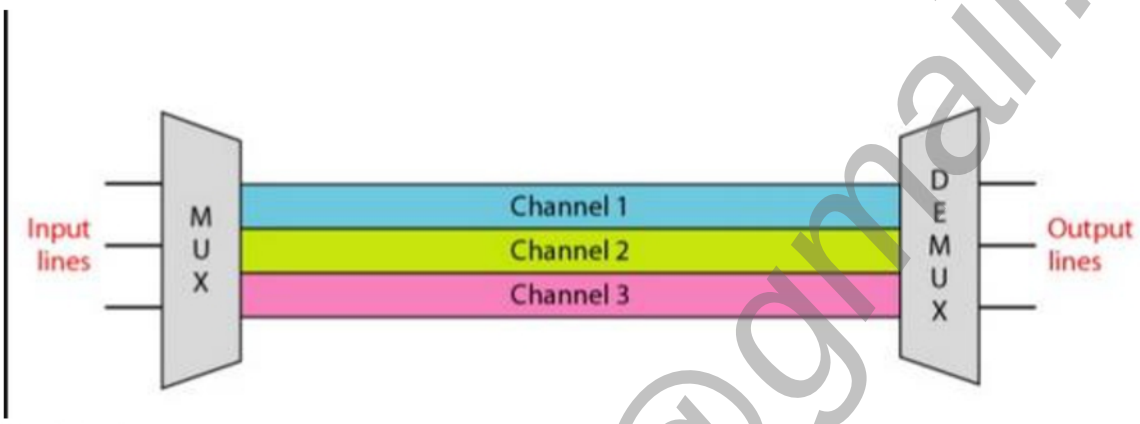


- Multiplexing divides the physical link or a medium into logical segment called channel each carrying different data simultaneously.
- At source, hardware equipment called multiplexer combines the input from different source and load them on different channel of medium.
- At the destination, hardware equipment called de-multiplexer separates the signals and send them to different destination.
- One of the most widely use application of multiplexing is in radio and TV broadcasting.
- Multiplexing provides effective bandwidth utilization and also minimize the cost.

Types of Multiplexing
1. Frequency Division Multiplexing
2. Time Division Multiplexing

1. Frequency Division Multiplexing

- In FDM, Each user or signal is assigned a non-overlapping frequency ranges, thus transmitting all signals at the same time, each using different frequency is called FDM.
- The available bandwidth is divided into different frequency carrier in which different frequency is used by different user.
- So multiplexer accepts inputs and assigns frequency to each input line.
- And De- multiplexer on the other end separates multiplexed signal
- FDM require concept of guard band to keep signal from contaminating or interfering each other.
- They are robust. Failure of one channel doesn't affect the other sub channel
- Production cost is high because of the analog component.



2. Time division Multiplexing

- TDM provides use of full channel bandwidth, but it uses fixed assignment of time slot to the sub channel.
- So in TDM, each channel gets all bandwidth periodically during brief interval of time.
- One complete cycle of time slot is called frame and end and beginning of frame is marked by synchronization.
- The synchronization word enables the de-multiplexer to identify the time slot and their boundaries.
- The first bit of the first time slot follows immediately after the synchronization word.

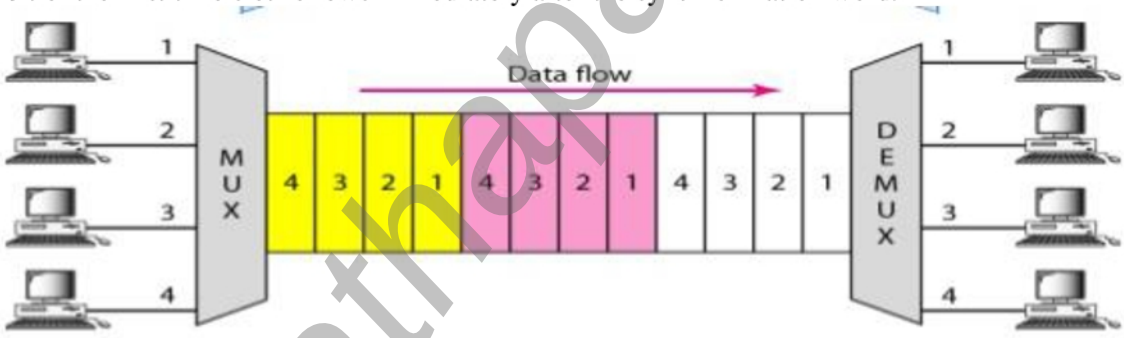


Fig: TDM

..SYN	1	2	3	4	SYN	1	2	3	4	SYN….

Fig: Frame

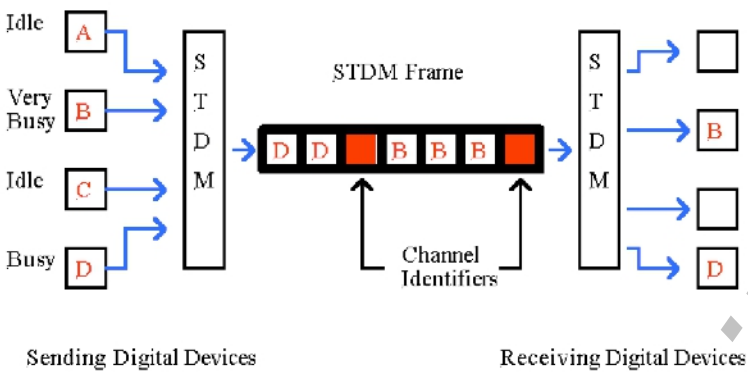
- **Types**

1. Synchronous TDM:

TDM in which the multiplexer accepts the input from the attached devices in a round-robin fashion and transmits the data in never ending pattern. Every line is given T seconds and every cycle is complete in NT seconds where N is the number of input line and each frame is formed by N time slot.

2. Statistical TDM:

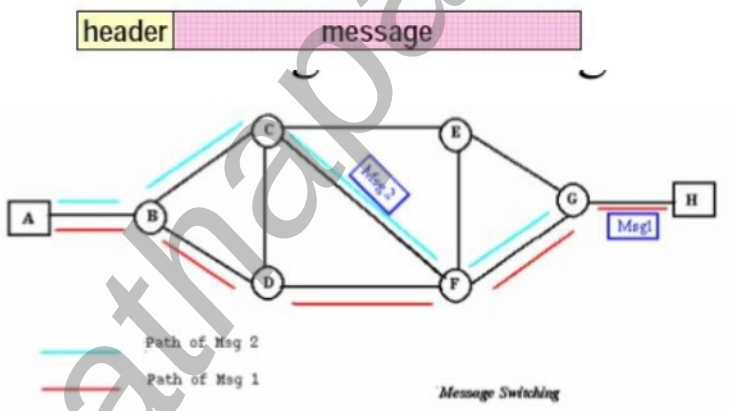
A statistic TDM transmits data only from the active workstation. If the workstation is not active no space is wasted in the multiplexed stream as in synchronous TDM. This allocates the time slot more often to those nodes which produces data more frequently and in greater quantity. So inactive nodes gets less time slot.



Circuit Switching

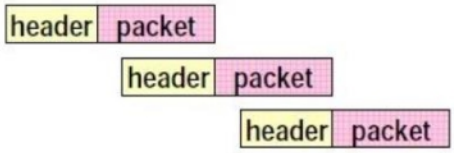
- In circuit switched network, the end to end resources needed along a paths such as buffers, link bandwidth to provide for communication between the end systems are reserved for the duration of the session.
- If a link has N sub channel then each end to end system get 1/N of the links bandwidth for the duration of connection.
- Bandwidth is divided using TDM or FDM.
- Communication via circuit switching involves three phases,
  1. **Circuit Establishment:** Before any signals can be transmitted, an end-to-end (station-to-station) circuit must be established.
  2. **Data Transfer:** The data may be analog or digital, depending on the nature of the network
  3. **Circuit Disconnect:** After some period of data transfer, the connection is terminated, usually by the action of one of the two stations
- Example: Telephone Network

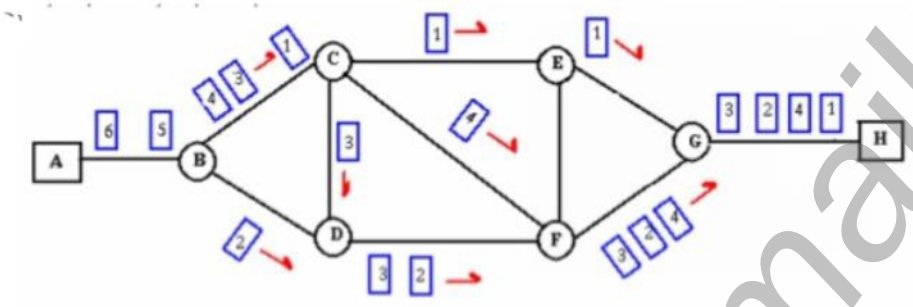
Message switching



- It is a switching strategy in which, no physical path is established in advance between sender and receiver.
- The message is sent to nearest directly connected switching node.
- This node stores the message, checks for error, selects the best available route and forwards the message to the next intermediate node.
- A network that uses this technique is also called as store and forward network.
- In this, more devices can share the network bandwidth as compared to circuit switching technique.
- Temporary storage of message reduces also reduces traffic congestion.
- Higher priority also can be given to urgent message for fast delivery.
  Even under heavy traffic, packets are accepted but possibly with a greater delay in delivery.
- Message of larger size monopolizes the link and storage.
- In message switching system, each router waits until it receives the entire message. Once it receives the complete message it transmits the same over the next link and so on. All the routers over the router does the same.

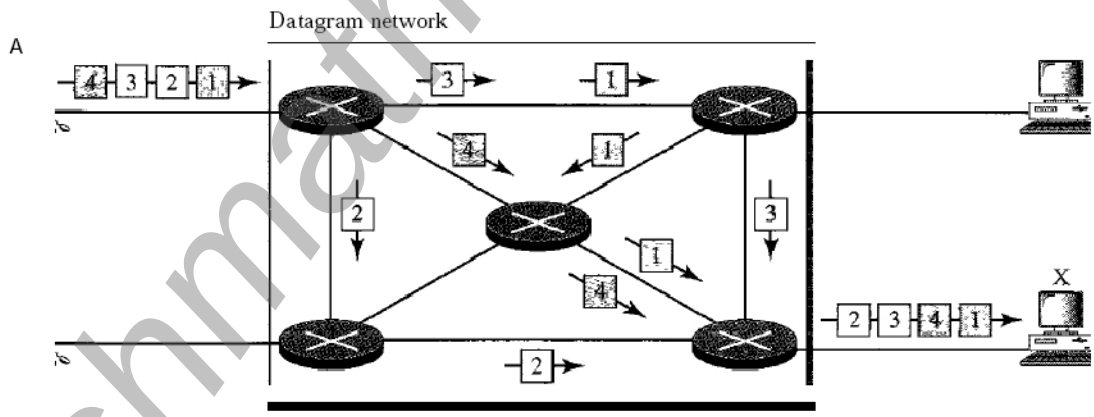
Packet Switching





- Packet Switching is a special case of message switching type.
- In packet switched network, the end to end resources along a path like buffer, link bandwidth to provide for communication between the end systems are not reserved but the session uses the resources on demand so may have to wait for access to communication link.
- So if the link is congested because other packets need to be transmitted over the link at same time, then the current packet must have to wait in buffer at sending side of transmission line and hence suffer a delay.
- In packet switched network, data is transmitted in the form of packets which consists of control information(header) and exact data.
- The long message is broken down into small packets.
- Packets are transmitted over the network at full transmission rate of the link.
- In Packet Switching, different packets can pass through different routes.
- The main implementation of packet switched network is the Internet, which uses the IP network protocol.
- There are two common ways to packet switching.
    1. Datagram Network
    2. Virtual circuit network

1. Datagram Network

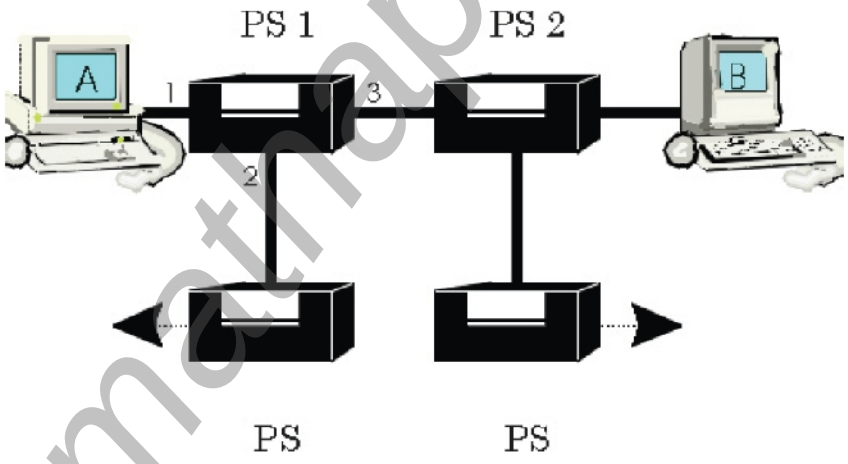


- This approach uses a different, more dynamic scheme, to determine the route through the network links.
- Each packet is treated as an independent entity, and its header contains full information about the destination of the packet.
- The intermediate nodes examine the header of the packet, and decide to which node to send the packet so that it will reach its destination.
- In this method, the packets don't follow a pre-established route, and the intermediate nodes (the routers) don't have pre-defined knowledge of the routes that the packets should be passed through.
- Packets can follow different routes to the destination, and delivery is not guaranteed.
- Due to the nature of this method, the packets can reach the destination in a different order than they were sent, thus they must be sorted at the destination to form the original message.

- This approach is time consuming since every router has to decide where to send each packet.
- The datagram network are also called as connectionless network in which the packet switch doesn't keep the information about connection state. It is because the datagram network makes routing decision for each individual packet.

2. Virtual Circuit network (VCN)

- A virtual-circuit network is a cross between a circuit-switched network and a datagram network. It has some characteristics of both.
- A virtual circuit (VC) consists of
    1. A path (i.e., a series of links and packet switches) between the source and destination hosts
    2. Virtual circuit numbers, one number for each link along the path
    3. Entries in VC-number translation tables in each packet switch along the path.
- Once a VC is established between source and destination, packets can be sent with appropriate VC number.
- Packets arrive at the destination in the correct sequence, and it is guaranteed that essentially there will not be errors.
- This approach is slower than Circuit Switching, since different virtual circuits may compete over the same resources, and an initial setup phase is needed to initiate the circuit.
- As in Circuit Switching, if an intermediate node fails, all virtual circuits that pass through it are lost.
- If a network employs virtual circuits, then the network's switches must maintain state information for the ongoing connections.
- Virtual circuits can be either permanent, called Permanent virtual Circuits (PVC), or temporary, called Switched Virtual Circuits (SVCs).
- A Permanent Virtual Circuit (PVC) is a virtual circuit that is permanently available to the user. A PVC is defined in advance by a network manager. A PVC is used on a circuit that includes routers that must maintain a constant connection in order to transfer routing information in a dynamic network environment.
- A switched virtual circuit (SVC) is a virtual circuit in which a connection session is set up dynamically between individual nodes temporarily only for the duration of a session. Once a communication session is complete, the virtual circuit is disabled.
- The most common implementation of Virtual Circuit networks are **X.25 and Frame Relay.**



- In the above figure, suppose A request that the network establish VC between itself and node B. Supposes the network chooses the paths A-PS1-PS2-B and assigns VC number 12, 22, 32 to three link in a path. Then when a packet as a part of this VC leaves host A, the value of the VC number field is 12, when it leaves the PS1, the value is 22 and when it leaves PS2, the value is 32. The number next to the link of PS1 are the interface number. Each packet switch has a VC number translation table. The VC number translation table in PS1 can be like in below figure . The PS must maintain VC number and each time a connection is released, the entry is removed from the table.

Incoming Interface	Incoming VC#	Outgoing Interface	Outgoing VC#
1	12	3	22
2	63	1	18
3	7	2	17
1	97	3	87
...	...	...	...

Datagram Packet Switching Vs Virtual-circuit Packet Switching:

sno	Datagram Packet Switching	Virtual-circuit Packet Switching
1	Two packets of the same user pair can travel along different routes.	All packets of the same virtual circuit travel along the same path.
2	The packets can arrive out of sequence.	Packet sequencing is guaranteed.
3	Packets contain full Src, Dst addresses	Packets contain short VC Id. (VCI).
4	Each host occupies routine table entries.	Each VC occupies routing table entries.
5	Requires no connection setup.	Requires VC setup. First packet has large delay.
6	Also called Connection less	Also called connection oriented.
7	Examples: X.25 and Frame Relay	Eg. Internet which uses IP Network protocol.

Differences between Circuit Switching and Packet Switching

Circuit switching	Packet switching
1. Call set up is required.	1. Call setup is not required.
2. Dedicated connection between two Hosts.	2. No dedicated connection between two Hosts.
3. Connection/Communication is lost, if any link in the path between the Hosts is broken.	3. Connection/Communication could continue between the Hosts since data have many routes between the Hosts.
4. Information take the same route between the connected Hosts	4. Information could take different routes to reach the destination Host.
5. Information always arrives in order.	5. Information could arrive out of order to the destination
6. Bandwidth available is fixed.	6. Bandwidth available is variable.
7. Congestion is call based.	7. Congestion is packet based.
8. Bandwidth utilization is partial.	8. Bandwidth utilization is full.
9. It does not uses store-and-forward transmission.	9. It uses store-and forward transmission.
10. It is Transparent.	10. Not transparent.
11. Charging is time based.	11. Charging is packet based.

Network Performance

The following measures are often considered important:

- Bandwidth :
  - commonly measured in bits/second is the maximum rate that information can be transferred.
  - It can be measured in terms of herz or bits per second.
- Throughput
  - It is the actual rate that information is transferred. It is the measure of how fast we can send data through the network.
  - Throughput and bandwidth are similar terms. Both have same measurement unit, a bit rate, but bandwidth is the theoretical maximum rate whereas throughput is the actual bit rate received.
- Latency:
  - it is the delay time which defines how long it takes for an entire message to completely arrive at destination from the time the first bit is sent out from source.
  - It might includes the different time required for transmission such as transmission time, queuing time, processing delay etc.
- Bandwidth delay product:
  - Bandwidth and delay are two performance metric on a link.
  - The bandwidth delay product defines the number of bits that can fill the link.
  - This concept is important when we need to send data in bursts and wait for the acknowledgment of each burst before sending the next one.
- Jitter:
  - variation in packet delay at the receiver of the information.
  - It is a problem if different packet of data encounter different delays and the application using the data at the receiver side is time-sensitive such as audio, video.
- Error rate:
  - the number of corrupted bits expressed as a percentage or fraction of the total sent

Assignment:

1. Explain the architecture of ISDN(Integrated Service Digital Network). What are the different application areas of ISDN.