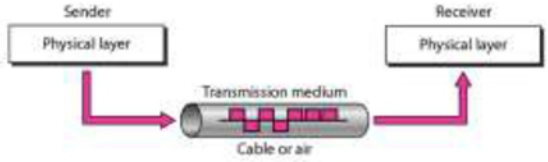
Chapter-2

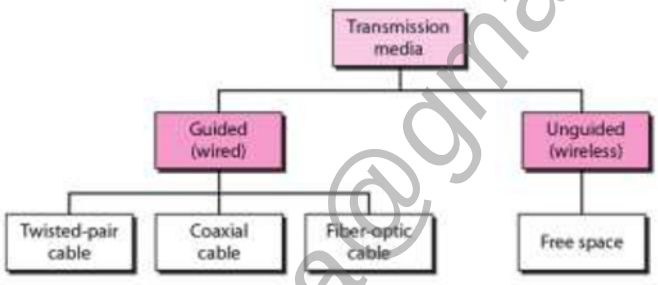
Physical Layer and Network Media

Transmission Media / Physical 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)

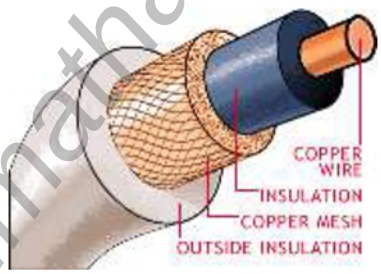
Advantage

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

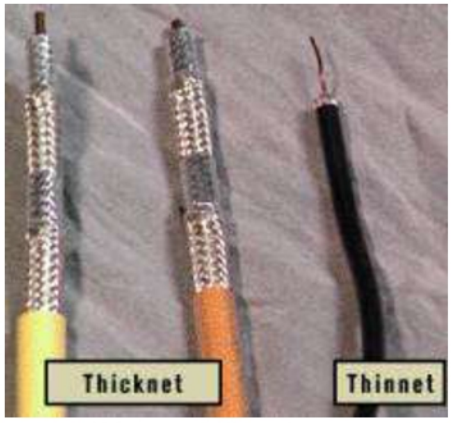
Disadvantage

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 protects 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.

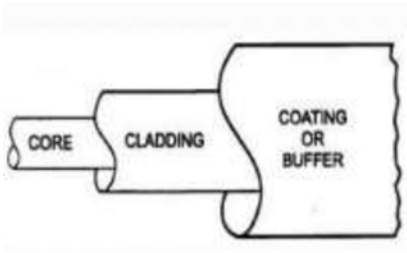
Baseband and Broadband Coaxial cable

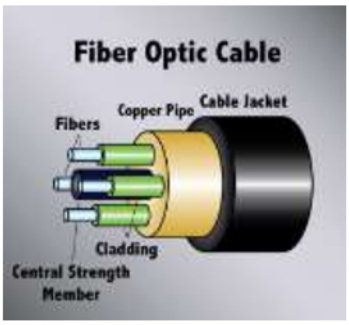
	Baseband	Broadband
Signal type	Digital	Analog
Directions	Bi-directional (but not at the same time)	Unidirectional (two separate channels / frequencies to send/receive)
Number of signals	Only one signal at a time	Multiple signals at a time
Uses	LAN – Ethernet and Token Ring	Many WAN links such as DSL 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

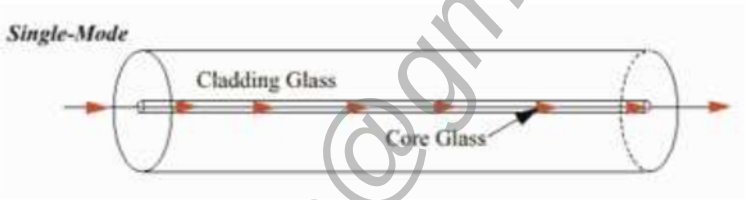
- Fiber optics cable transmits light signals through the strand (very small diameter even less than human hair) of glass or plastic called the core.
- The fiber optics consists of very thin fibers made up of two types of glass, one for the inner core and other for the outer layer.
- Two glasses have 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.

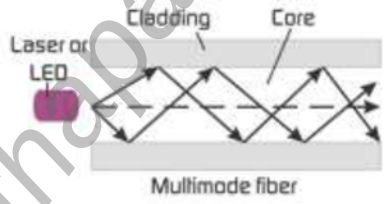




- **Types**
  1. Single mode fiber: This uses a highly focused light beam and travel more or less horizontally. Here, fiber core diameter is much smaller and has lower density. Fiber core is reduced to that order so that only a single angle or mode can pass



  2. Multi-mode fiber: In multi-mode fiber, multiple beam path passes through the core along different path.



Advantage

1. Very high speed of transmission.
2. Less signal attenuation
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.
3. Unidirectional light propagation.

TPC vs Co-axial cable vs optical-fibre cable

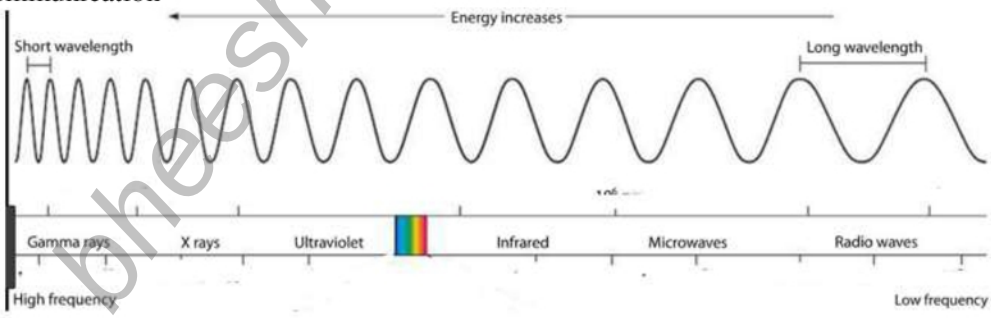
Twisted pair cable	Co-axial cable	Optical fiber
1. Transmission of signals takes place in the electrical form over the metallic conducting wires.	1. Transmission of signals takes place in the electrical form over the inner conductor of the cable.	1. Signal transmission takes place in an optical forms 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

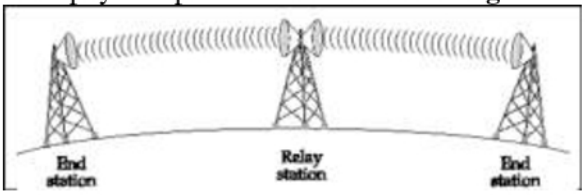
- Unguided media or wireless communication transport electromagnetic wave without physical connection. These signals propagate through air.
- For unguided media, transmission and reception are achieved by means of antenna.
- For transmission, the antenna radiates electromagnetic energy into the medium i.e. air and for reception, the antenna picks up the electromagnetic wave from the surrounding medium.
- There are two basic configurations 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 antennas.

Types of unguided transmission media

- Terrestrial microwave
- Radio wave transmission
- Satellite Communication



Terrestrial Microwave

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

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

Characteristics

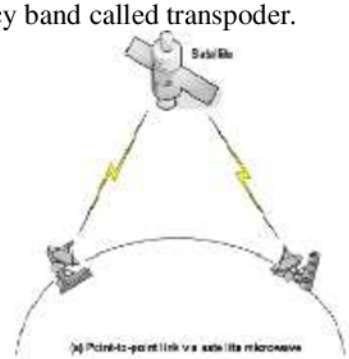
- Frequency range: most terrestrial microwave systems produces signal in the lower giga herz range usually 4 to 6 GHz and 21 to 23 GHz.
- Cost: Shorter distance system can be inexpensive and they are effective in the range of hundreds of meters. Long distance system may be expensive.
- Bandwidth capacity: 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 electromagnetic radio waves that operate at the radio frequency are also used to transmit computer data. This transmission is also known as Radio Frequency (RF) 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.
- Example: Mobile communication uses radio frequency.

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 satellite to communicates 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.

Infrared Transmission

- Infrared transmission refers to energy in the region of the electromagnetic radiation spectrum at wavelengths longer than those of visible light, but shorter than those of radio waves. Correspondingly, infrared frequencies are higher than those of microwaves, but lower than those of visible light.
- Infrared is used in a variety of wireless communications, monitoring, and control applications.
- Here are some examples:
  - Home-entertainment remote-control boxes
  - Wireless (local area networks)
  - Links between notebook computers and desktop computers
  - Night-vision systems

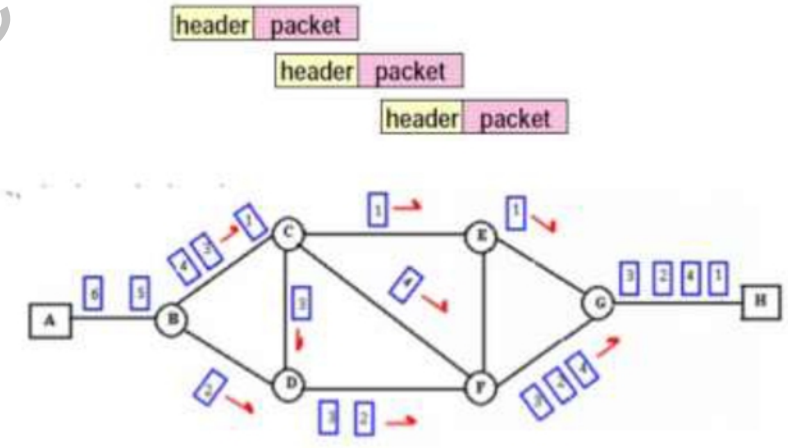
The Network Core

- Network core are the inner components i.e. meshes of the router, of the network.
- End systems in the internet are indirectly connected to each other through intermediate switching devices known as routers.
- Switches are devices capable of creating temporary connections between two or more devices linked to the switch. In a switched network, some of these nodes are connected to the end systems (computers or telephones, for example). Others are used only for routing.
- A router takes information arriving on one of its incoming communication links and then forwards that information on one of its outgoing communication links.
- There are three fundamental approaches towards building a network core: **circuit switching, packet switching and message switching.**

i. Circuit switching

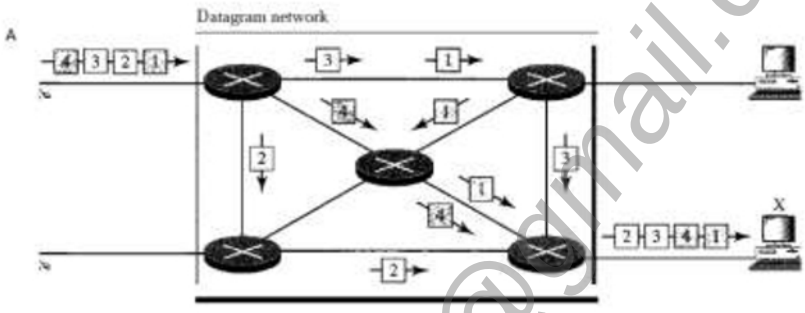
- In circuit switched network, the end to end resources needed along a paths such as buffers, link bandwidth to provide for communication between the end systems are reserved for the duration of the session.
- If a link has N sub channel, then each end to end system get 1/N of the links bandwidth for 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
  4. Example: Telephone Network

ii. Packet switching



- 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 message 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.
- There are two common ways to packet switching.
  1. Datagram Network
  2. Virtual circuit network

1. Datagram Network

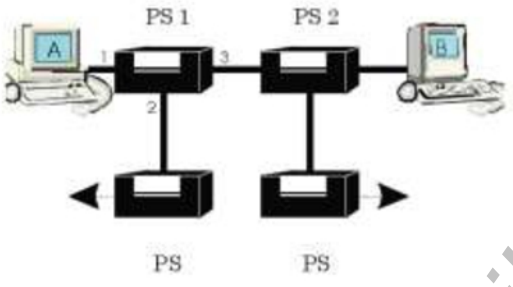


- This approach uses a different, more dynamic scheme, to determine the route through the network links.
- Each packet is treated as an independent entity, and its header contains full information about the destination of the packet.
- The intermediate nodes examine the header of the packet, and decide 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 is 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.
- The main implementation of Datagram Switching network is the Internet, which uses the IP network protocol.

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
  i. A path (i.e., a series of links and packet switches) between the source and destination hosts
  ii. Virtual circuit numbers, one number for each link along the path
  iii. 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 sheqeunce, 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.

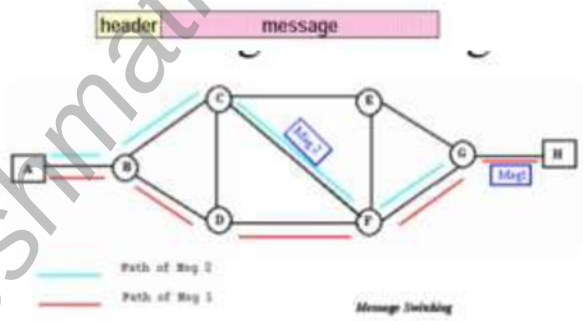
- Virtual circuits can be either permanent, called Permanent Virtual Circuits (PVC), or temporary, called Switched Virtual Circuits (SVCs).
- A Permanent Virtual Circuit (PVC) is a virtual circuit that is permanently available to the user. A PVC is defined in advance by a network manager. A PVC is used 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
...	...	...	...

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.

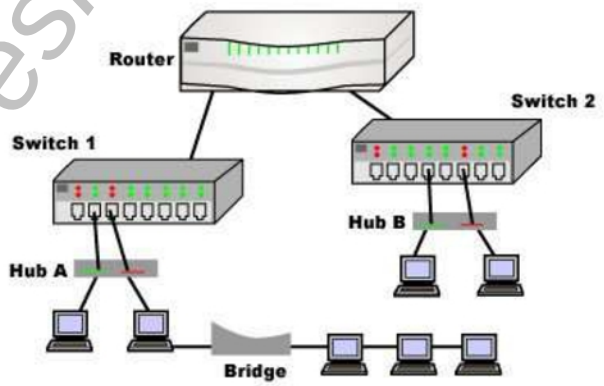
Differences between Circuit Switching and Packet Switching

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.

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.

Repeater, Hub, Bridge, Switch, Router



Repeater

- Every network architecture specification includes a maximum supported cable lengths for different media types because of problem of attenuation-the weakening of signal over distance.
- So we can extend the distance of communication by using repeater.

- A repeater connects two segments of your network cable.
- It receives and regenerates the signals to proper amplitudes and sends them to the other segments.
- When talking about, Ethernet topology, you are probably talking about using a **hub as a repeater**.
- Repeaters require a small amount of time to regenerate the signal.
- This can cause a propagation delay which can affect network communication when there are several repeaters in a row.
- Many network architectures limit the number of repeaters that can be used in a row.
- Repeaters work only at the **physical layer of the OSI network model.**
- Hub, switches, router also act as repeater

Hub

- Also called as multiport repeater
- A hub is just used to connect network segments together.
- Provide half duplex communication.
- Single collision domain
- Work at physical layer of network.
- A Hub is the simplest of these devices. In general, a hub is the central part of a wheel where the spokes come together.
- Hubs cannot filter data so data packets are sent to all connected devices/computers and do not have intelligence to find out best path for data packets.
- This leads to inefficiencies, wastage bandwidth and insecure.
- Hubs are used on small. A hub contains multiple ports.
- When a packet arrives at one port, it is copied or broadcasted to the other ports so that all segments of the LAN can see all packets.
- Almost replaced by switches.

There are many types of hub

1. Passive hub: don't require power and are simple splitter or combiners that group workstations into a single segment.
2. Active hub: require power and include a repeater function and are thus capable of supporting many more connections.

Bridge

- Is smarter networking tool than hub.
- Bridge is a product that connects a local area network (LAN) to another local area network that uses the same protocol.
- Having a single incoming and outgoing port and filters traffic on the LAN by looking at the MAC address, bridge is more complex than hub.
- Bridge looks at the destination of the packet before forwarding unlike a hub.
- When a frame arrives at the bridge, it extracts the destination address from the frame and looks it up in a table to see where the frame is to be sent.
- It restricts transmission on other LAN segment if destination is not found.
- A bridge works at the data-link level of a network, copying a data frame from one network to the next network along the communications path.
- The main advantage of bridge is that it restricts flow of unnecessary traffic between network segments. Bridge forwards a copy of the frame to the other segment, only if necessary. If a frame is meant for a computer on the same segment, then bridge does not forward a copy of the frame to other segment.
- It checks the MAC address of the frame and decides to forward the frame of to discard the frame.
- Almost replaced by switches.
- Work at Data link layer of OSI model.

Switch

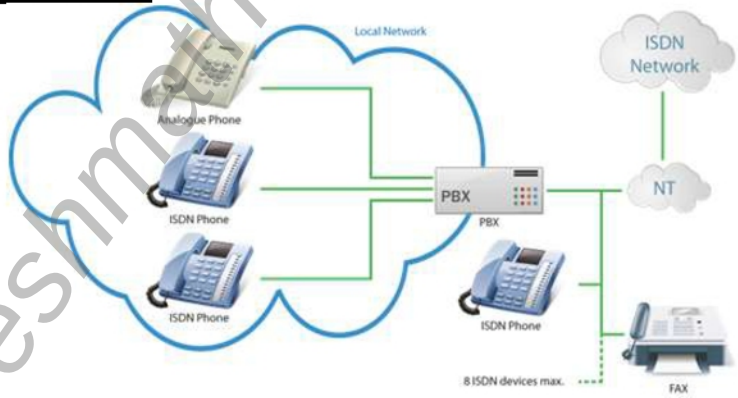
- A switch when compared to bridge is a fast, intelligent multiport bridge that increases the network speed and throughput.

- Switches can perform error checking before forwarding data, which are very efficient by not forwarding packets that error-end out or forwarding good packets selectively to correct devices only.
- Usually large networks use switches instead of hubs to connect computers within the same subnet.
- The main difference between bridge and switch is that, a switch is most often used to connect individual computer so when one host want to send a frame to another host in the same LAN, the bridge gets the frame but just discard it while switch must actively forward the frame between the two hosts.
- The switch maintains a table, MAC address table for each port corresponding to the MAC address learnt when a host connected at a port transmits data.
- Multiple collision domain.
- The switch forwards data based on MAC address table.
- Work at datalink layer of OSI model.
- More expensive than bridge.

Router

- A router, like a switch forwards packets based on address.
- It is an internetworking device that can intelligently use a network address information to decide the best path for the data to take to its destination
- They operate at the network layer of OSI model, router can connect two different network.
- Usually, routers use the IP address to forward packets, which allows the network to go across different protocols.
- Routers try to learn the addresses of all the different network segments in the internetwork, so router maintain a routing table.
- For static router, we will have to manually enter the routing information in the routing table and modify it whenever the network topology changes.
- A dynamic router can use the information on the network packet to builds it routing table dynamically.
- Routers forward packets based on software while a switch forwards using hardware.
- Routers support different WAN technologies but switches do not. Besides, wireless routers have access point built in.
- The most common home use for routers is to share a broadband internet connection.
- As the router has a public IP address which is shared with the network, when data comes through the router, it is forwarded to the correct computer.

ISDN (Integrated Services Digital Network)



- Prior to ISDN, the phone system was viewed as a way to transport voice but ISDN is a **digital telephone service network** that can transmit voice, data and control information over an existing single telephone line.
- So, the major feature of ISDN (Integrated Services Digital Network) is that it put together speech and n on the same line which were not presented in classic telephone system.
- ISDN is a circuit switched telephone network system that also provides access to packet switched network, designed to allow digital transmission of voice and data over ordinary copper telephone line hence provide better voice quality than analog phone.
- It supports very high data rate typically hundreds of Mbps.
- Nowadays, ISDN services are largely being replaced by high speed broadband connection like cable connection, ADSL etc.
- It provides two basic types of interfaces to the users
  1. Basic Rate interface(BRI): BRI is intended for low data rate requirement home users and small business organization
  2. Primary Rate interface(PRI): PRI is intended for users with higher data rate requirement.

Features/Advantage of ISDN

- ISDN connection provides very low error rate transmission.
- It facilitates the user with multiple digital channels. These channels can operate concurrently through the same one copper wire pair.
- The digital signals broadcasting transversely the telephone lines.
- ISDN provides high data rate because of digital scheme which is 56kbps.
- ISDN network lines are able to switch manifold devices on the single line such as faxes, computers, cash registers credit cards readers, and many other devices. These all devices can work together and directly be connected to a single line.
- ISDN takes only 2 seconds to launch a connection while other modems take 30 to 60 second for establishment.

Disadvantage

- The disadvantage of ISDN lines is that it is very costly than the other typical telephone system.
- ISDN requires specialized digital devices just like Telephone Company.

Assignment

1. **Differentiate between baseband and broadband coaxial cable.**