CHAPTER 2
PHYSICAL LAYER AND NETWORK MEDIA

BY ER. ANKU JAISWAL, IOE, PULCHOWK CAMPUS

Unit 2: Physical Layer and Network Media (4Hrs.)

2.1. Network Devices: Repeater, Hub, Switch, Bridge, Router

2.2. Different types of transmission medias (wired: twisted pair, coaxial, fiber optic, Wireless: Radio waves, micro waves, infrared)

2.3. Ethernet Cable Standards (UTP & Fiber cable standards)

2.4. Circuit, Message & Packet Switching

2.5. ISDN: Interface and Standards

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NETWORK DEVICES

A network device is a widely-used term for any hardware within networks that connect different network resources.

Key devices that comprise a network are routers, bridges, repeaters and gateways.

Repeater

- A repeater **connects two segments** of your network cable.
- It **retimes 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.


Wi Fi
AP/REPEATER

Hub

- Hub is one of the basic icons of networking devices which **works at physical layer** and hence connect networking devices physically together.
- Hubs are fundamentally used in networks that use **twisted pair cabling** to connect devices.
- They are designed to transmit the packets to the other appended devices **without altering any of the transmitted packets received.**

- They act as pathways to direct electrical signals to travel along.
- They transmit the information **regardless of the fact if data packet is destined for the device connected or not.**


Kensington

- **Hub falls in two categories:**

Active Hub: They are smarter than the passive hubs.

- They not only provide the path for the data signals in fact **they regenerate, concentrate and strengthen the signals before sending them** to their destinations.
- Active hubs are also termed as ‘repeaters’.

Passive Hub: They are more like point contact for the wires to built in the physical network. They have **nothing to do with modifying the signals.**

Switches

- Hub works by sending the data to all the ports on the device whereas a **switch transfers it only to that port which is connected to the destination device.**
- A switch does so by having an **in-built learning of the MAC address of the devices connected to it.**
- Since the transmission of data signals are well defined in a switch hence the network **performance is consequently enhanced.**

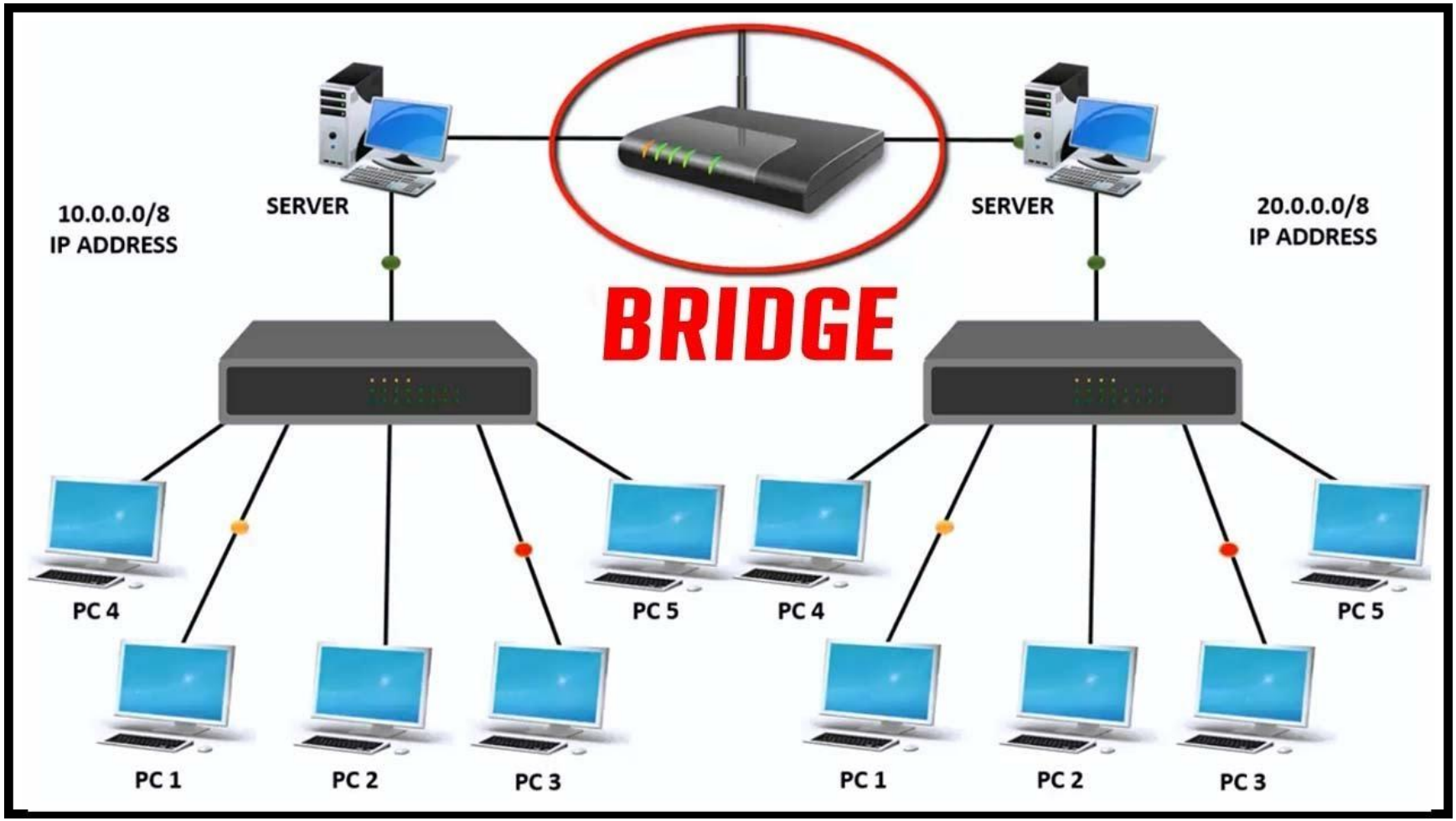
- Switches **operate in full-duplex mode** where devices can send and receive data from the switch at the simultaneously unlike in half-duplex mode.
- The transmission **speed in switches is double than in Ethernet hub** transferring a 20Mbps connection into 30Mbps and a 200Mbps connection to become 300Mbps.
- **Performance improvements** are observed in networking with the extensive usage of switches in the modern days.


HPE OfficeConnect 1920S Series Switch JL385A
10/100/1000BASE-T PoE+ Ports (1-24)
SFP Ports
25
26

Bridges

- A bridge is a computer networking device that builds the **connection with the other bridge networks which use the same protocol**.
- It works at the Data Link layer of the OSI Model and connects the different networks together and develops communication between them.
- It **connects two local-area networks**;

- The bridge does so by placing itself between the two portions of two physical networks and controlling the flow of the data between them.


10.0.0.0/8
IP ADDRESS
SERVER
BRIDGE
SERVER
20.0.0.0/8
IP ADDRESS
PC 4
PC 1
PC 2
PC 3
PC 5
PC 4
PC 1
PC 2
PC 3
PC 5

Routers

- Routers are network layer devices and are particularly identified as Layer- 3 devices of the OSI Model.
- They process logical addressing information in the Network header of a packet such as IP Addresses.
- Router is used to create larger complex networks by complex traffic routing.
- It has the ability to connect dissimilar LANs on the same protocol.

Functionality:

- When a router receives the data, it determines the destination address by reading the header of the packet.
- Once the address is determined, it searches in its routing table to get know how to reach the destination and then forwards the packet to the next hop on the route.
- Routing tables play a very pivotal role in letting the router making a decision.
- Thus a routing table is ought to be updated and complete.

- The two ways through which a router can receive information are:
- **Static Routing:** In static routing, the routing information is fed into the routing tables manually.
- It does not only become a time-taking task but gets prone to errors as well.
- Thus static routing is feasible for tinniest environments with minimum of one or two routers.

- **Dynamic Routing:** For larger environment dynamic routing proves to be the practical solution.
- The purpose of these protocols is to enable the other routers to transfer information about to other routers, so that the other routers can build their own routing tables.


tp-link
AC1750

TRANSMISSION MEDIA

- These are the means by which a communication signal is carried from one system to another.
- These media can carry information from a source to a destination.
- The transmission media can usually be free space such as: satellite, microwave, radio and infrared systems,
- metallic cables such as: twisted pair, or coaxial cable, or fiber-optic cable.

- In telecommunication, transmission media can be divided into two broad categories:
- Guided transmission media
- Unguided transmission media

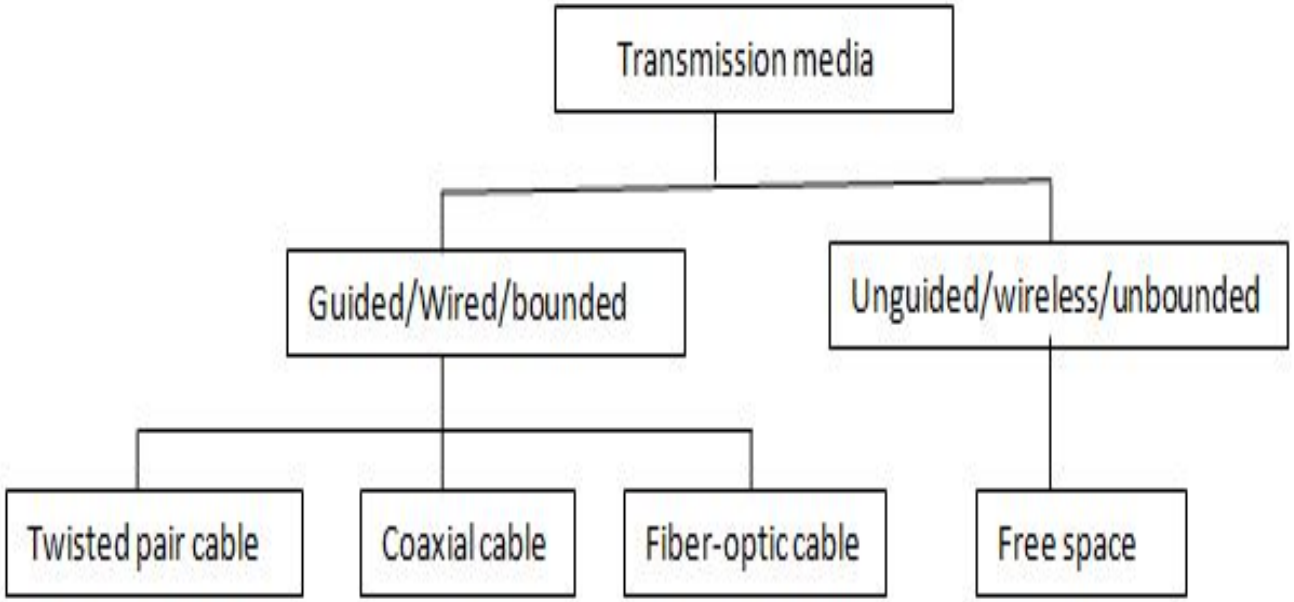


Fig: Classes of transmission media

Guided Transmission Media

- Guided Transmission media uses a cabling system that guides the data signals along a specific path.
- They provide the physical path way for the transmission of the data from the source to the destination.

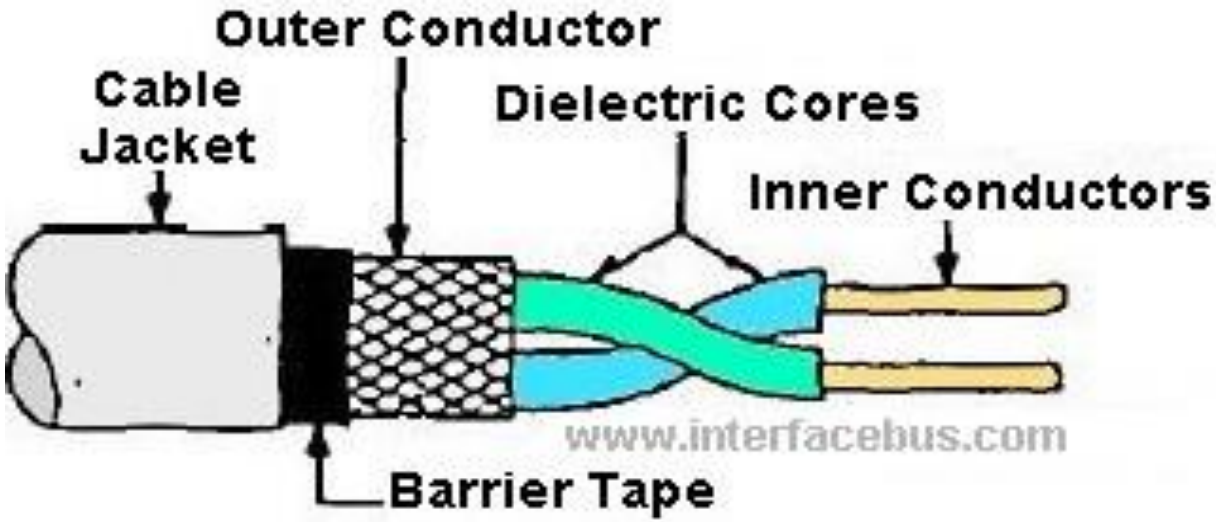
- Twisted-pair and coaxial cable use metallic (copper) conductor that accept and transport signals in the form of electric current.
- Optical fiber is a cable that accepts and transport signals in the form of light.
- Guided Media are also known as Bound media or wired media.

Twisted Pair Cable

- **Twisted pair** cabling is a type of wiring in which two conductors of a single circuit are twisted together
- for the purposes of canceling out electromagnetic interference (EMI) from external sources;
- This cable is the most commonly used and is cheaper than others.
- It is lightweight, cheap, can be installed easily, and they support many different types of network.

Some important points:

- Its frequency range is 0 to 3.5 kHz.
- Typical attenuation is 0.2 dB/Km @ 1kHz.
- Typical delay is 50 µs/km.
- Repeater spacing is 2km.


Outer Conductor
Cable Jacket
Dielectric Cores
Inner Conductors
www.interfacebus.com
Barrier Tape

- Twisted Pair is of two types :
- Unshielded Twisted Pair (UTP)
- Shielded Twisted Pair (STP)

Unshielded Twisted Pair Cable

- It is the most common type of telecommunication when compared with Shielded Twisted Pair Cable which consists of two conductors usually copper, each with its own colour plastic insulator.
- Identification is the reason behind colored plastic insulation.

Shielded Twisted Pair Cable

- This cable has a metal foil or braided-mesh covering which encases each pair of insulated conductors.
- Electromagnetic noise penetration is prevented by metal casing. Shielding also eliminates crosstalk
- It has same attenuation as unshielded twisted pair.
- It is faster the unshielded and coaxial cable.
- It is more expensive than coaxial and unshielded twisted pair.

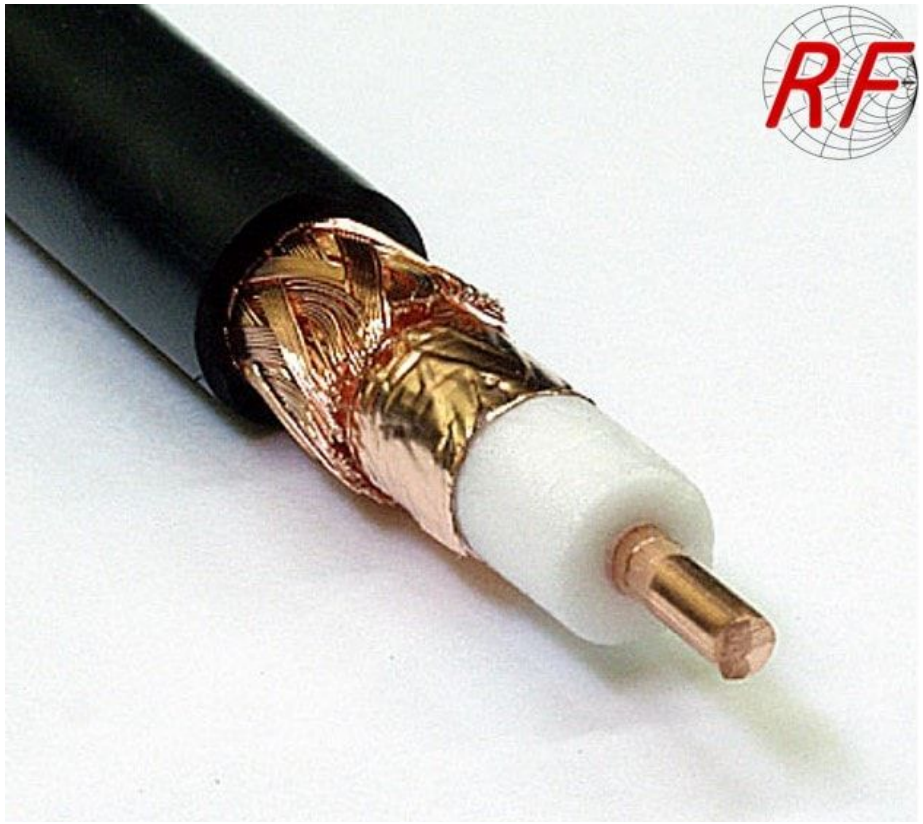

UTP
STP

Coaxial Cable

- Coaxial is called by this name because it contains two conductors that are parallel to each other.
- Copper is used in this as centre conductor which can be a solid wire or a standard one.
- It is surrounded by PVC installation, a sheath which is encased in an outer conductor of metal foil, braid or both.

- Outer metallic wrapping is used as a shield against noise and as the second conductor which completes the circuit.
- The outer conductor is also encased in an insulating sheath.
- The outermost part is the plastic cover which protects the whole cable.

Coaxial Cable



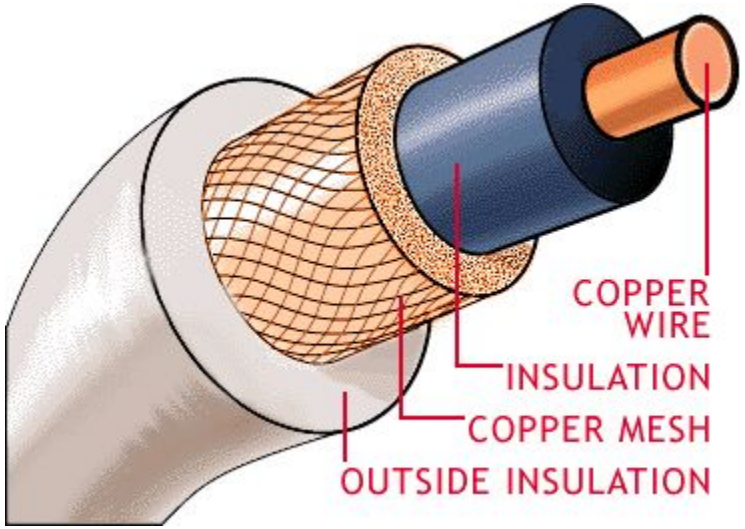
- Here the most common coaxial standards.
- RG(Radio Guide)
- 50-Ohm RG-7 or RG-11 : used with thick Ethernet.
- 50-Ohm RG-58 : used with thin Ethernet
- 75-Ohm RG-59 : used with cable television
- 93-Ohm RG-62 : used with ARCNET(Attached Resource Computer NETwork).

Advantages:

- Bandwidth is high
- Used in long distance telephone lines.
- Transmits digital signals at a very high rate of 10Mbps.
- Much higher noise immunity
- Data transmission without distortion.
- The can span to longer distance at higher speeds as they have better shielding when compared to twisted pair cable

Disadvantages:

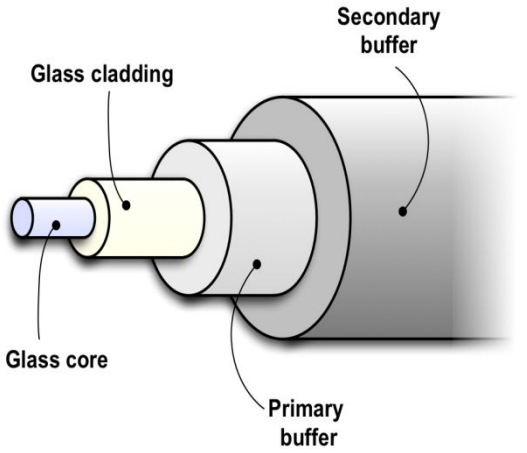
- Single cable failure can fail the entire network.
- Difficult to install and expensive when compared with twisted pair.

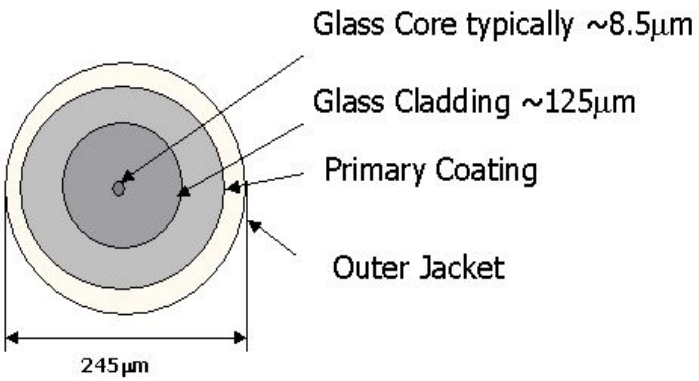

COPPER
WIRE
INSULATION
COPPER MESH
OUTSIDE INSULATION

Fiber Optic Cable

- These are similar to coaxial cable. It uses electric signals to transmit data.
- At the center is the glass core through which light propagates.
- In multimode fibers, the core is 50microns, and In single mode fibers, the thickness is 8 to 10 microns.

- The core in fiber optic cable is surrounded by glass cladding with lower index of refraction as compared to core to keep all the light in core.
- This is covered with a thin plastic jacket to protect the cladding.
- The fibers are grouped together in bundles protected by an outer shield.
- Fiber optic cable has bandwidth more than **2 gbps (Gigabytes per Second)**


Secondary buffer
Glass cladding
Glass core
Primary buffer


Glass Core typically ~8.5μm
Glass Cladding ~125μm
Primary Coating
Outer Jacket
245μm

Advantages:

- Provides high quality transmission of signals at very high speed.
- These are not affected by electromagnetic interference, so noise and distortion is very less.
- Used for both analog and digital signals.

Disadvantages:

- It is expensive
- Difficult to install.
- Maintenance is expensive and difficult.
- Do not allow complete routing of light signals.

Unguided Media

- The unguided media is the wireless media.
- It simply transports electromagnetic waves without using any physical conductor.
- Signals are normally broadcast through the air and thus are available to anyone who has the device capable of receiving them.

Wireless transmission

- Wireless communication is the transfer of information over a distance without the use of electrical conductors or “wires”.
- The distances involved may be short (a few meters as in television remote control) or very long (thousands or even millions of kilometers for radio communication).
- Wireless communication is generally considered to be a branch of telecommunications.
- **Three ways for wireless data propagation**
- **Radio wave**
- **Microwave**
- **Infrared**

Radio Waves

- Radio waves are usually in the frequency range from 500 kHz to 1000 MHz.
- Also, the range of the AM (amplitude modulated) band is between 530 kHz and 1710 kHz.
- Further, shortwave bands use higher frequencies of up to 54 MHz.
- TV waves range from 54 MHz to 890 MHz.
- The FM (frequency modulated) radio band is from 88 MHz to 108 MHz.
- Cellular phones also use radio waves to transmit voice communication in an ultra-high frequency (UHF) band.
- **Generation of Radio Waves**
- The accelerated motion of charges in conducting wires generates Radio waves. Radio and television communication systems widely use these waves.

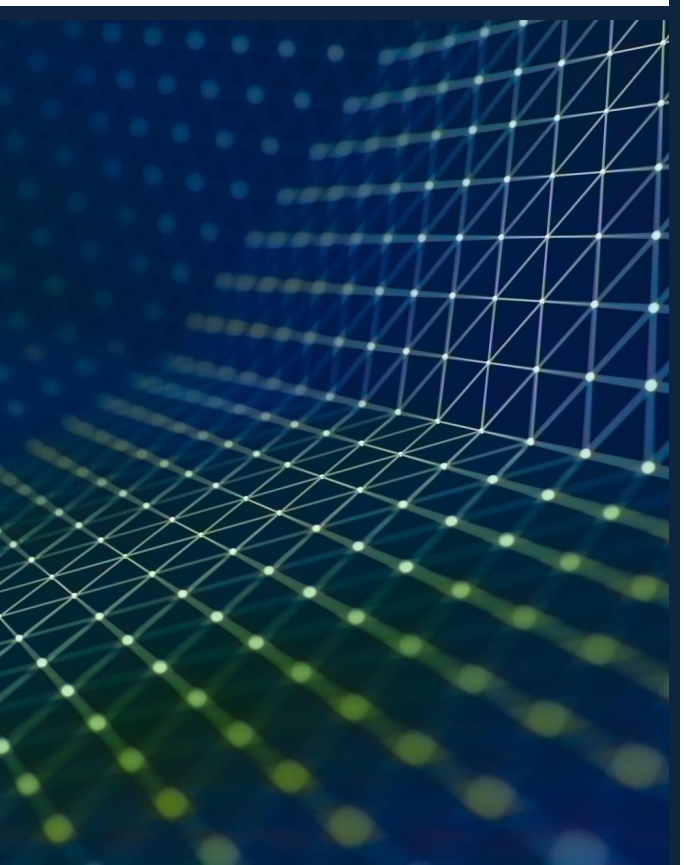
Microwaves

- Microwaves are short-wavelength radio waves with frequencies in the Gigahertz (GHz) range
- Best suited for the radar systems in aircraft navigation
- Another use of Radars is as speed-guns. These speed guns help time fastballs, tennis serves and automobiles.
- These waves form the basis of microwave ovens. In microwave ovens, the frequency of the microwaves is selected to match the resonant frequency of water molecules.
- This results in a direct transfer of energy from the waves to the kinetic energy of the water molecules raising the temperature of any food containing water.
- **Generation of Microwaves**
- Special vacuum tubes called klystrons, magnetrons and Gunn diodes generate microwaves.

Infrared Rays

- ‘Heat Waves’ is another name for Infrared rays.
- Water molecules present in most materials readily absorb these rays.
- After absorption, their thermal motion increases which increases their heat and that of their surroundings.
- Many physical therapy treatments use Infrared lamps.
- These rays also play an important role in maintaining the earth’s average temperature through the greenhouse effect.
- Earth Satellites deploy Infrared detectors for military purposes and to observe the growth of crops.
- Remote switches of household appliances like TV, video recorders, etc. use infrared rays.
- **Generation of Infrared Rays**
- Hot bodies and molecules generate Infrared rays. Also, the band lies next to the low-frequency or long-wavelength end of the electromagnetic spectrum.

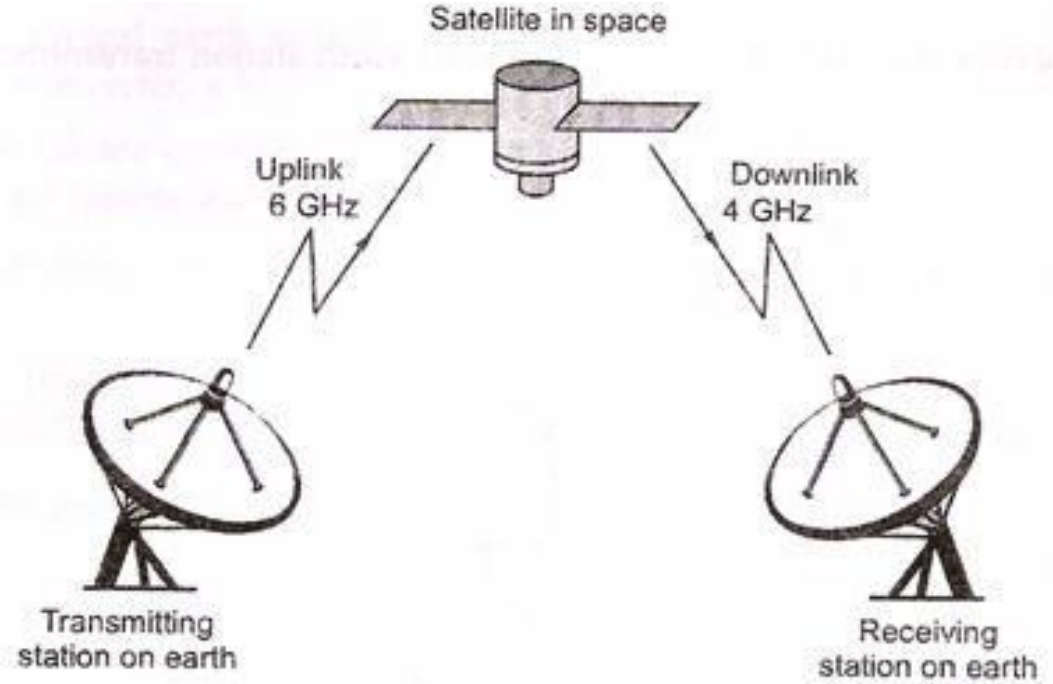
Communication Satellite:



The concept of satellite based networks is to transmit and receive signals from ground stations.

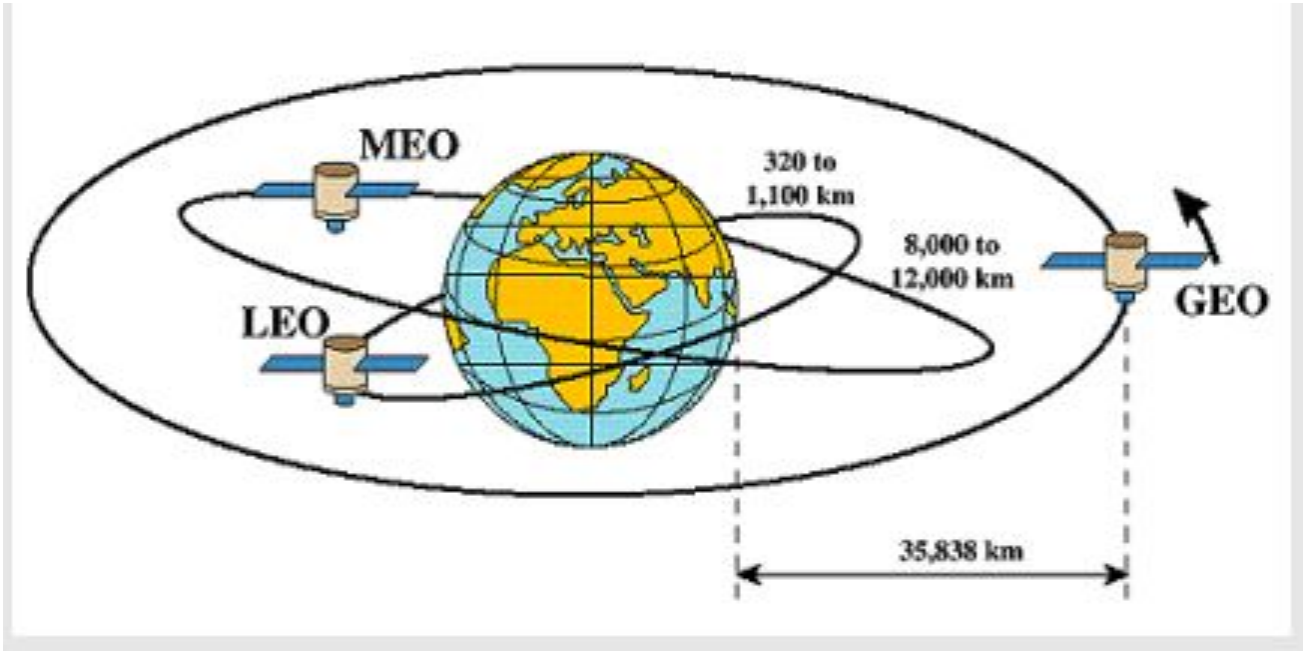
The purpose of satellite communication is to use it for video transmission and sharing.

In simple words a satellite is a device which revolves around the earth either for collecting useful information or for helping transfer of information.


Satellite in space
Uplink
6 GHz
Downlink
4 GHz
Transmitting
station on earth
Receiving
station on earth

- LEO is called Low earth orbit,
- MEO is called Medium Earth Orbit and
- GEO is called Geostationary orbit.
- LEO are about 500 Km to 1500 Km above the earth, so the delay is very small and the losses is small too.

- MEO are installed at 5000 to 12000 km above the earth and generally used for navigation communications like GPS.
- GEO is about 35800 Km above the equator, the delay and losses are greater, but the advantages is more coverage (it covers 40% of the earth) and there no need to track the satellite, so the earth terminal is cheaper.


MEO
320 to
1,100 km
8,000 to
12,000 km
GEO
LEO
35,838 km

Parameter	LEO	MEO	GEO
Satellite Height	500-1500 km	5000-12000 km	35,800 km
Orbital Period	10-40 min.	2-8 hours	24 hours
Number of Satellites	40-80	8-20	3
Satellite Life	Short	Long	Long
Number of Handoffs	High	Low	Least(none)
Gateway Cost	Very expensive	Expensive	Cheap
Propagation Loss	Least	High	Highest

Ethernet Cable Standard

- Ethernet, developed by the Electrical and Electronic Engineers Institute, IEEE Standard 802, is the most popular LAN (local area network) technology used today.
- It defined the number of conductors that are required for a connection, the performance thresholds that can be expected, and provides the framework for data transmission.

Ethernet

Ethernet Type	Bandwidth	Cable Type	Maximum Distanc
10Base-T	10Mbps	Cat 3/Cat 5 UTP	100m
100Base-TX	100Mbps	Cat 5 UTP	100m
100Base-TX	200Mbps	Cat 5 UTP	100m
100Base-FX	100Mbps	Multi-mode fiber	400m
100Base-FX	200Mbps	Multi-mode fiber	2Km
1000Base-T	1Gbps	Cat 5e UTP	100m
1000Base-TX	1Gbps	Cat 6 UTP	100m
1000Base-SX	1Gbps	Multi-mode fiber	550m
1000Base-LX	1Gbps	Single-mode fiber	2Km
10GBase-T	10Gbps	Cat 6a/Cat 7 UTP	100m
10GBase-LX	10Gbps	Multi-mode fiber	100m
10GBase-LX	10Gbp	Single-mode fiber	10Km

UTP Standard

UTP Categories - Copper 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)

Fiber Cable Standard

Cabling Standard	Cabling Type	Max Reach
10GBASE-SR	62.5µm OM3 multimode fiber	300m
	50µm OM4 multimode fiber	400m
10GBASE-LR	9µm single-mode fiber	10km
10GBASE-ER	9µm single-mode fiber	40km
10GBASE-ZR	9µm single-mode fiber	80km
10GBASE-LX4	9µm single-mode fiber	10km
	62.5µm multimode fiber	300m
	50µm multimode fiber	
10GBASE-LRM	9µm single-mode fiber	220m
10GBASE-T	Cat 6, Cat 6a or 7 twisted pair	30m
10G DAC/AOC	Copper RJ45	1-10m/up to 20m

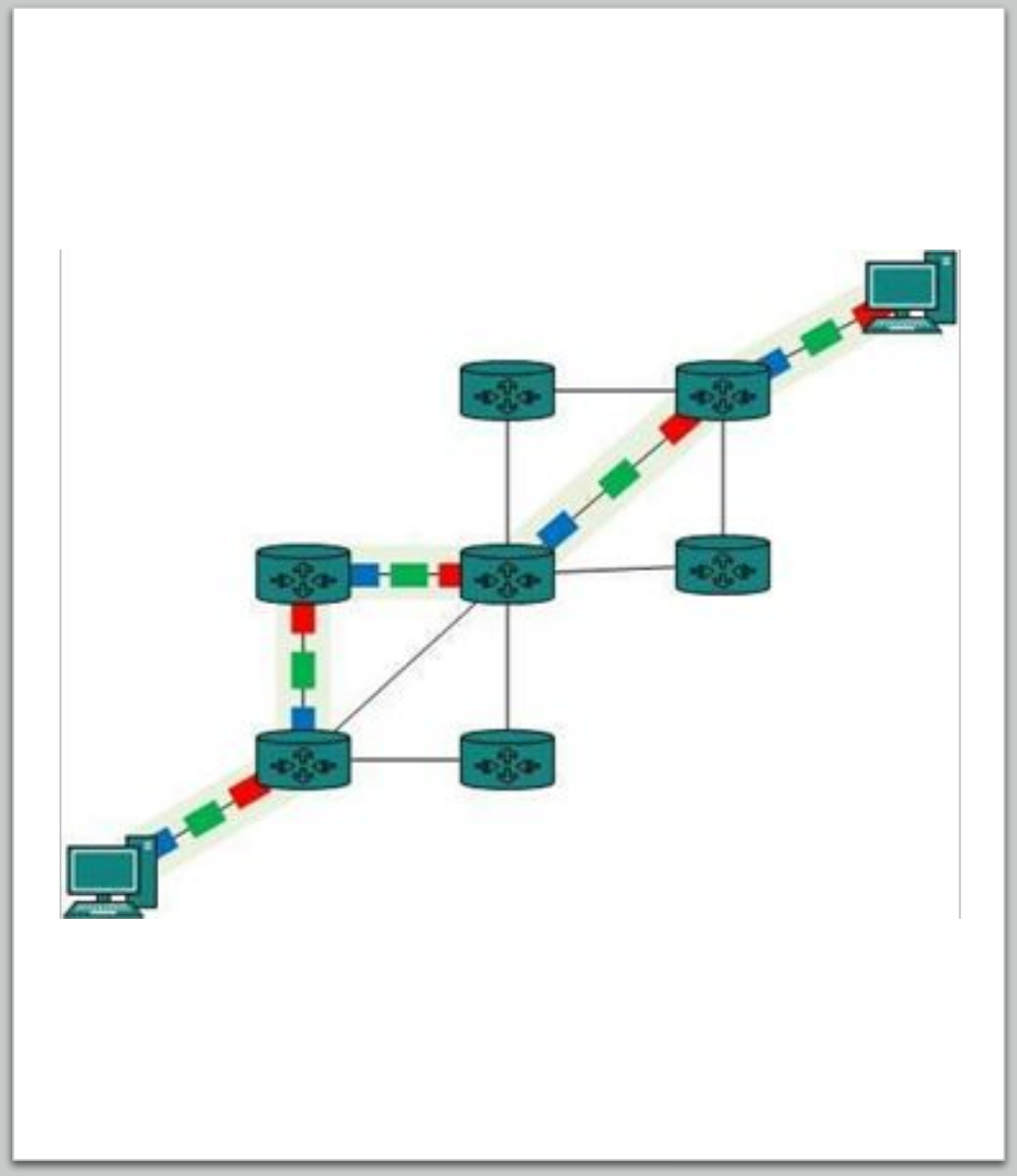
SWITCHING

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

Circuit Switching

- When two nodes communicate with each other over a dedicated communication path, it is called circuit switching.
- There 'is a need of pre-specified route from which data will travel and no other data is permitted.
- In circuit switching, to transfer the data, circuit must be established so that the data transfer can take place.
- Circuits can be permanent or temporary. Applications which use circuit switching may have to go through three phases:
- Establish a circuit
- Transfer the data
- Disconnect the circuit

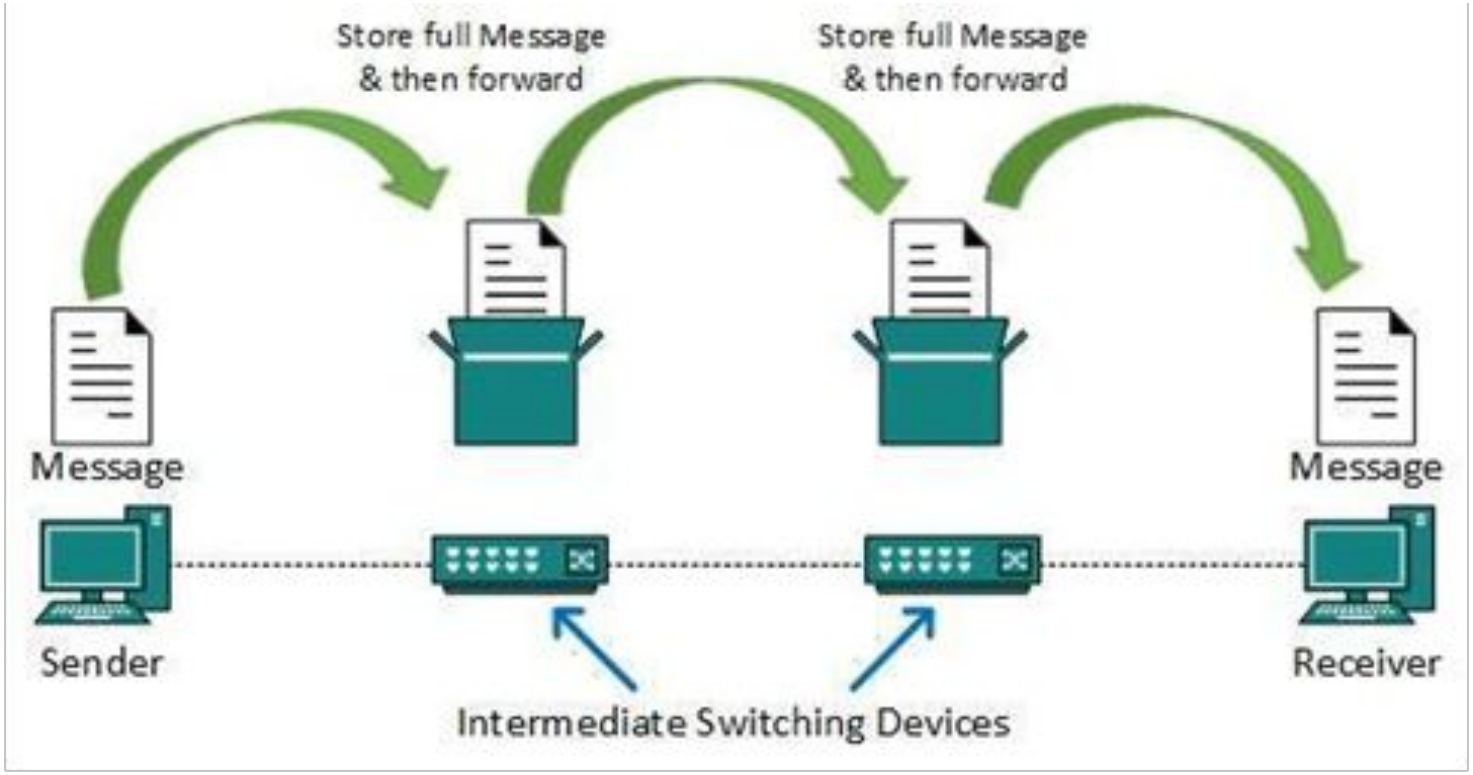
•Circuit switching was designed for voice applications. Telephone is the best suitable example of circuit switching. Before a user can make a call, a virtual path between caller and callee is established over the network.



Message Switching

- This technique was somewhere in middle of circuit switching and packet switching.
- In message switching, the whole message is treated as a data unit and is switching / transferred in its entirety.
- A switch working on message switching, first receives the whole message and buffers it until there are resources available to transfer it to the next hop.
- If the next hop is not having enough resource to accommodate large size message, the message is stored and switch waits.
- This technique was considered substitute to circuit switching.
- As in circuit switching the whole path is blocked for two entities only. Message switching is replaced by packet switching.

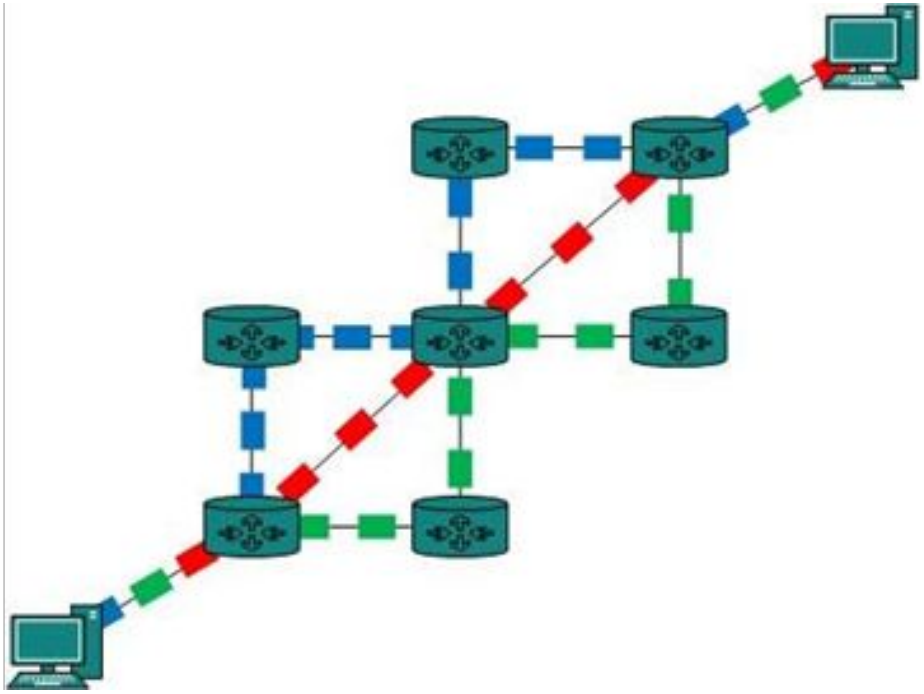
- Message switching has the following drawbacks:
- Every switch in transit path needs enough storage to accommodate entire message.
- Because of store-and-forward technique and waits included until resources are available, message switching is very slow.
- Message switching was not a solution for streaming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


Store full Message
& then forward
Store full Message
& then forward
Message
Message
Sender
Receiver
Intermediate Switching Devices

Packet Switching

- Shortcomings of message switching gave birth to an idea of packet switching.
- The entire message is broken down into smaller chunks called packets.
- The switching information is added in the header of each packet and transmitted independently.
- It is easier for intermediate networking devices to store small size packets and they do not take many resources either on carrier path or in the internal memory of switches.

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



ISDN(Integrated Services Digital Network)

- These are a set of communication standards for **simultaneous digital transmission of voice, video, data, and other network services** over the traditional circuits of the **public switched telephone network.**
- Before Integrated Services Digital Network (ISDN), the telephone system was seen as a way to transmit voice, with some special services available for data.
- The main feature of ISDN is that it can **integrate speech and data on the same lines**, which were not available in the classic telephone system.

- ISDN is a **circuit-switched telephone network** system, but it also provides access to **packet switched networks** that allows **digital transmission of voice and data.**
- This results in potentially better voice or data quality than an analog phone can provide.
- It provides a packet-switched connection for data in increments of **64 kilobit/s.**
- It provided a maximum of 1**28 kbit/s bandwidth** in both upstream and downstream directions.
- A greater data rate was achieved through channel bonding.
- Generally ISDN B-channels of three or four BRIs (six to eight 64 kbit/s channels) are bonded.

ISDN Interfaces:

- The following are the interfaces of ISDN:

Basic Rate Interface (BRI) –

- There are two data-bearing channels (‘B’ channels) and one signaling channel (‘D’ channel) in BRI to initiate connections.
- The B channels operate at a maximum of 64 Kbps while the D channel operates at a maximum of 16 Kbps.

Primary Rate Interface (PRI) –

- Primary Rate Interface service consists of a D channel and either 23 or 30 B channels depending on the country you are in.
- PRI is not supported on the iSeries. A digital pipe with 23 B channels and one 64 Kbps D channel is present in the usual Primary Rate Interface (PRI).
- Twenty-three B channels of 64 Kbps each and one D channel of 64 Kbps equals 1.536 Mbps.
- The PRI service uses 8 Kbps of overhead also.
- Therefore PRI requires a digital pipe of 1.544 Mbps.

ISDN Services

- ISDN provides a fully integrated digital service to users. These services fall into 3 categories- bearer services, teleservices and supplementary services.

Bearer Services –

- Transfer of information (voice, data and video) between users without the network manipulating the content of that information is provided by the bearer network.

Teleservices –

- These services corresponds to layers 4-7 of the OSI model.
- The user need not to be aware of the details of the process.
- Teleservices include telephony, teletex, telefax, videotex, telex and teleconferencing.

Supplementary Service –

- Additional functionality to the bearer services and teleservices are provided by supplementary services. Reverse charging, call waiting, and message handling are examples of supplementary services which are all familiar with today's telephone company services.