Physical Layer

- It is the bottom layer of OSI Model.
- It is responsible for the actual physical connection between the devices. Such physical connection may be made by using twisted pair cable.
- It is concerned with transmitting bits over a communication channel.

Functions of Physical Layer

- Transforming bits into signals
- Provides synchronization of bits by a clock.
- Physical layer manages the way a device connects to network media.
- It defines the transmission rate.
- It defines the way in which the devices are connected to the medium.
- It provides physical topologies
- It can use different techniques of multiplexing.

Networking Devices

- NIC
- HUB
- REPEATER
- SWITCH
- ROUTER
- BRIDGE

NIC

- NIC(Network Interface Card) also called Network Adapter
- It is a part of computer which provide communication
- The network adapter provides one or more ports for the network cable to connect to, and it transmits and receives data onto the network cable
- NIC may be wired or wireless
- Every networked computer must also have a network adapter driver, which controls the network adapter.
- Each network adapter driver is configured to run with a certain type of network adapter

NIC

Functions of NIC:-

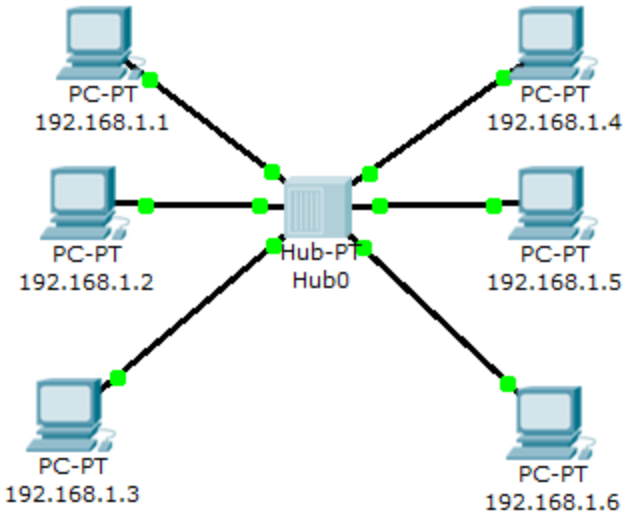
1. Data encapsulation
2. Signal encoding and decoding
3. Transmission and reception
4. Data buffering
5. Serial/parallel conversion
6. Media access control
7. Network protocols

HUB

- Works in physical layer
- Device used to connect different computers to a network(LAN), Only same range of IP is allowed
- Supports simplex and Half duplex data transmission, Only station can transmit at a time
- Hub is based on broadcasting
- Hub will forward the data to all other port, only the receiver will receive and other nodes will drop the data
- Because the hub is broadcasting the Chance of collision is high in HUB
- Easily scalable

LAN Connection With HUB

- *In figure all IP in switch are of same range (192.168.1.0 range)*



SWITCH

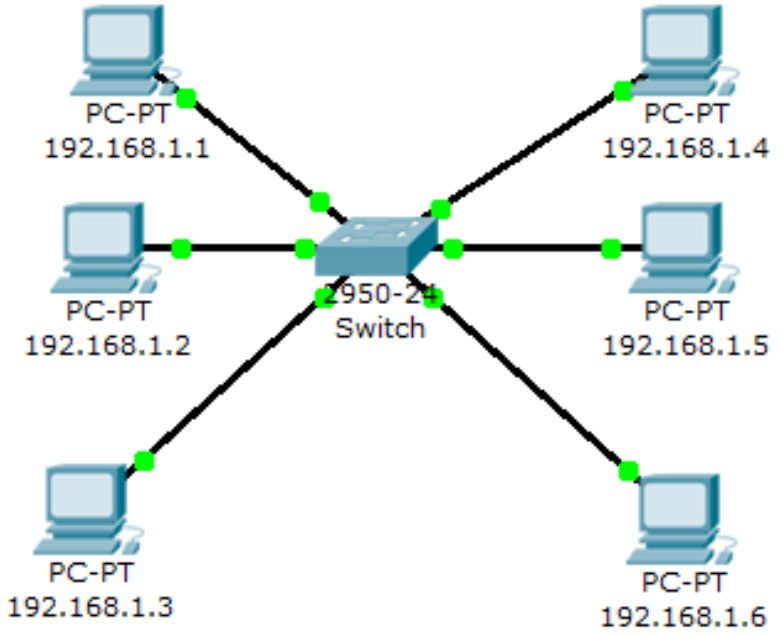
- Works on Layer 2
- Works based on MAC address
- Used to connect computers in Network (LAN), Only same range of IP
- Have MAC address table to store information about ports and MAC address of computer connected in port
- Broadcasting only done initially after that unicasting
- Broadcasting only before learning the mac address of the systems connected

SWITCH

- Switch automatically will learn the MAC Address of the system connected in the port and stores in MAC table
- After learning the address only unicasting is used for data transmission
- It can operate in simple, half duplex and full duplex mode
- Easily Scalable

SWITCH

- There are 4 forwarding methods:
  1. Store and forward
  2. Cut through
  3. Fragment free
  4. Adaptive
- *In figure all IP in switch are of same range (192.168.1.0)*



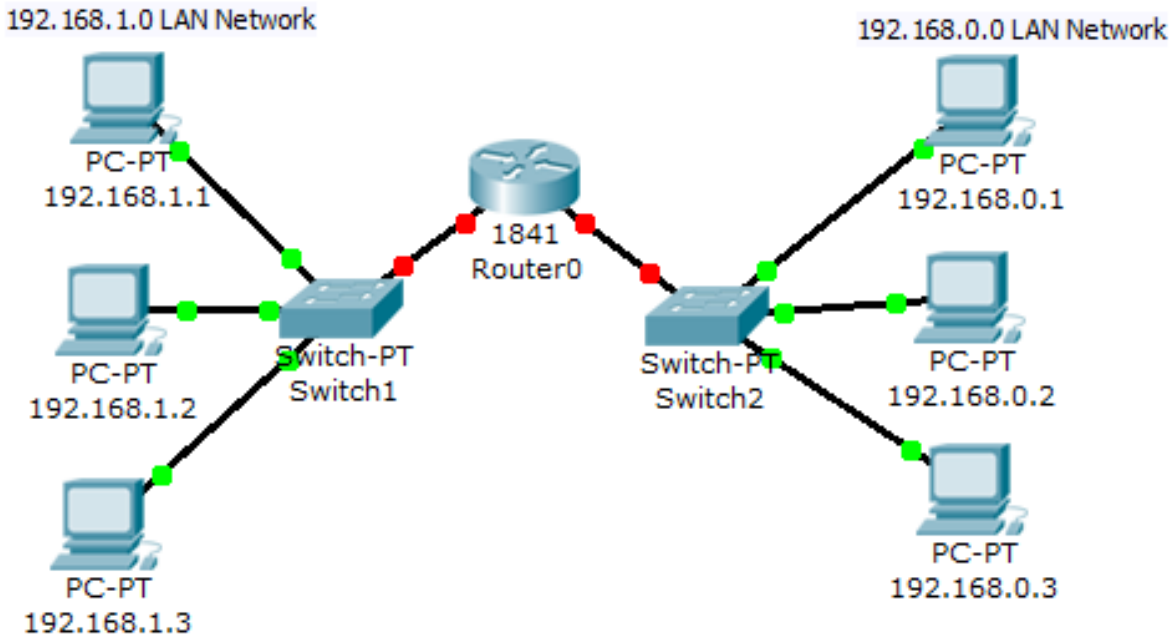
ROUTER

- Router works on Network layer
- It work based on IP address
- It helps in finding route ,best path in Networks
- A router is a device that forwards data packets along networks. A router is connected to at least two networks, commonly two LANs or WANs or a LAN and its ISP's network
- Routers are located at gateways, the places where two or more networks connect each other

ROUTER

- Router Have routing table which stores in formation about IP, interface , best route.
- Routing table will help in routing of the packets in network.
- Router also have some algorithm for finding route and shortest path first such as RIP,OSPF, EIGRP

Connecting 2 Network using Router

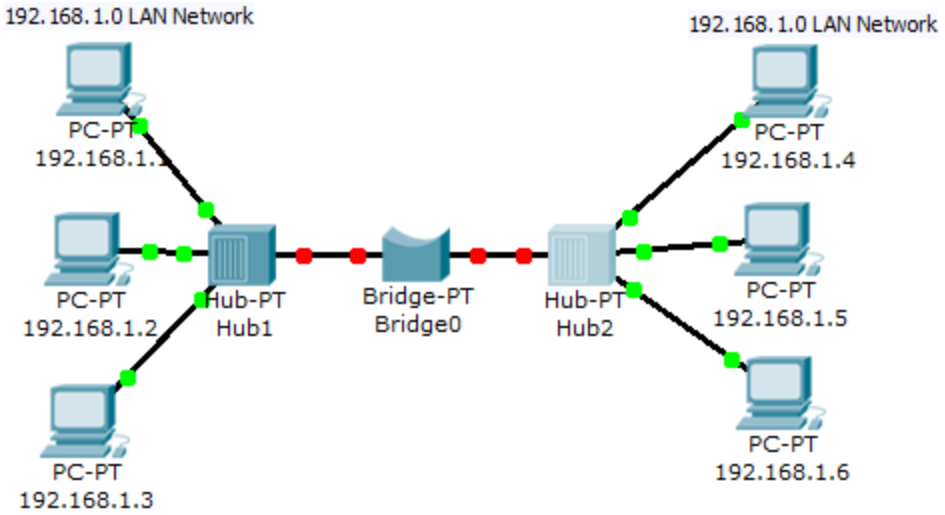


BRIDGE

- Bridge connect 2 segments of same network
- Bridge works on same principle of switch(Layer 2 , MAC table)
- Bridges are used when hub is used in LAN
- HUB have higher no of collision when more devices are the in network
- To avoid the no of collision in network connected using hub
- Network is divided into smaller segments connected using bridge

Connecting 2 segments of one network using Bridge

- 2 segments of same network(192.168.1.0)
- Segment One (LHS) 192.168.1.1-\ to 3
- Segment Two (RHS) 192.168.1.4-\ to 6

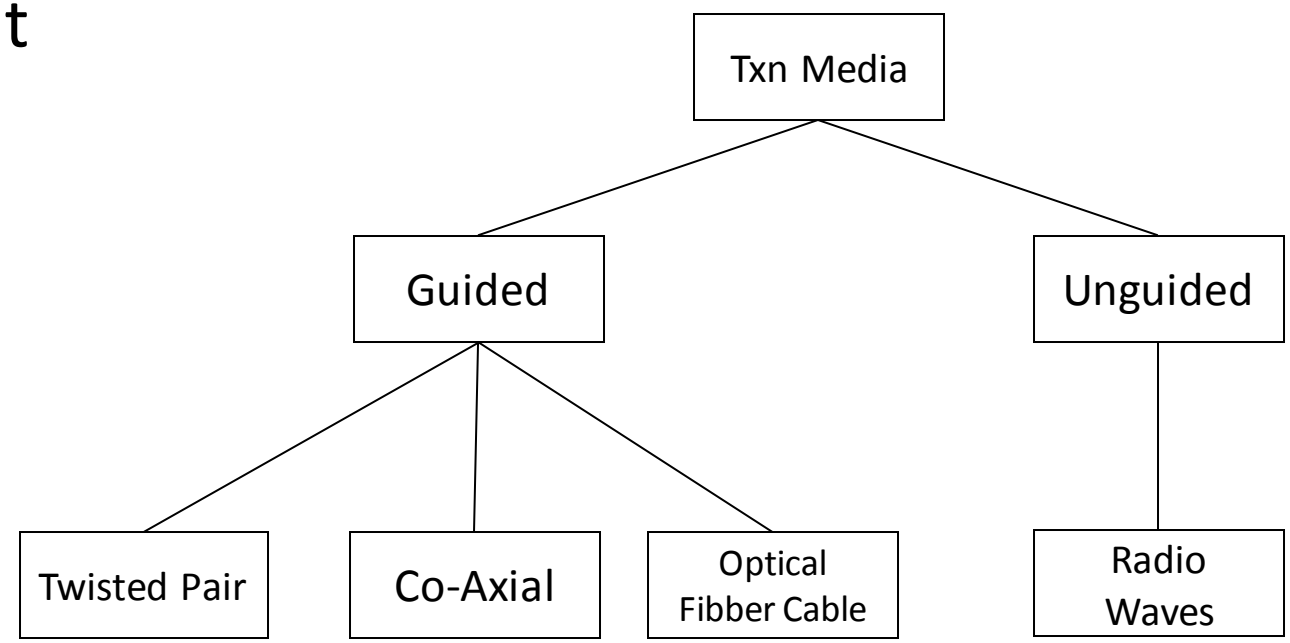


REPEATER

- Works on Layer One of OSI layer
- Device that receives a signal and retransmits it at a higher level or higher power
- In wireless communication, receives a signal and it also retransmits it onto the other side of an obstruction
- It helps signal to cover longer distances
- Also called signal booster

Transmission Media

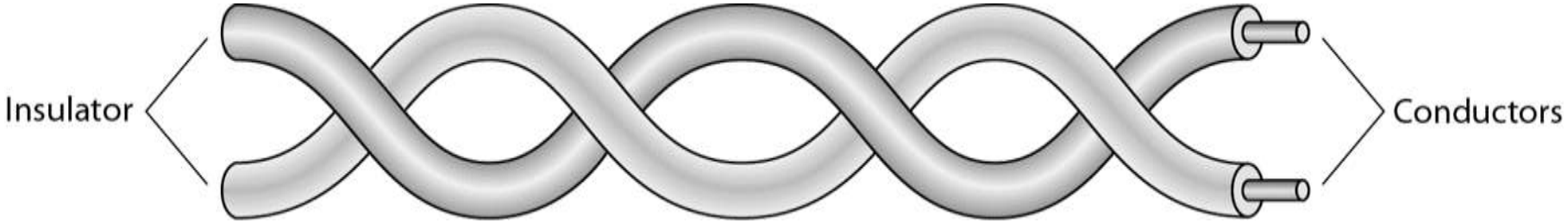
- A transmission medium can be broadly defined as anything that can **carry information** from a **source** to **destination**
- Transmission medium is usually **free space, metallic cable, or fibber-optic cable**
- Information :- Signal that is the result of a conversion of data from another form



Guided Media

- Also called Bounded media/ Wired Media
- Guided media, which are those that provide a conduit from one device to another
    1. **Twisted-pair cable**
    2. **Coaxial cable**
    3. **Fibber-optic cable**
- A signal traveling along any of these media is directed and contained by the **physical limits of the medium**
- Twisted-pair and coaxial cable -- Metallic (copper) conductors -- **signals in the form of electric current**
- Optical fibber -- **transports signals in the form of light**

Twisted Pair

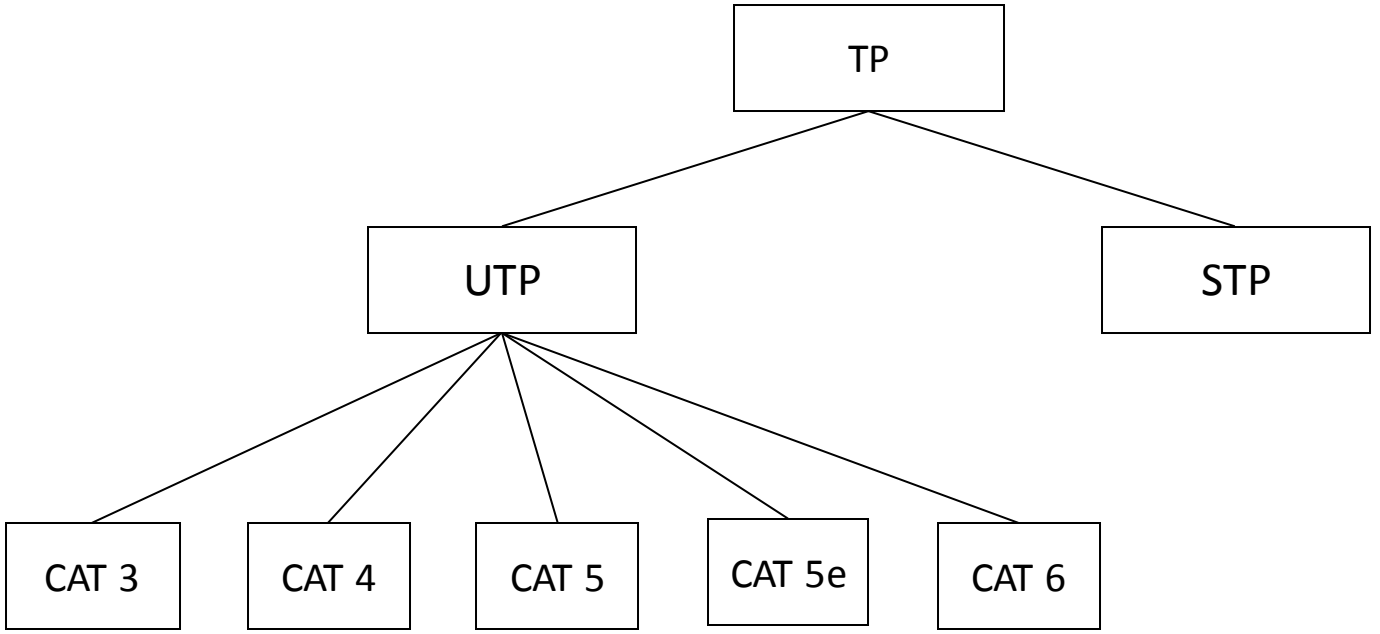


- The wires are twisted together in a helical form.

- A twisted pair consists of two insulated copper wires twisted together regular spiral pattern
- Twisting tends to decrease the crosstalk
- Crosstalk is the interference due to the magnetic filed of 2 wires nearby
- Used to transmit both analog and digital transmission

Twisted pair

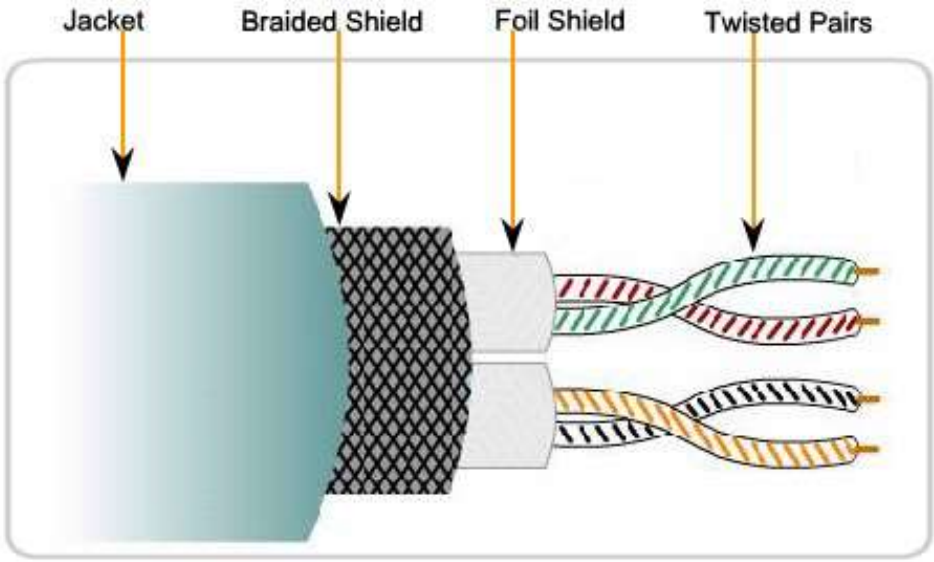
- Twisted pair is limited in distance, bandwidth, and data rate.
- The attenuation for twisted pair is a very strong function of frequency



Shielded Twisted Pair(STP)

- STP uses two or more pairs of wires that are wrapped in an overall metallic braid or foil.
- Shields the entire bundle of wires within the cable as well as the individual wire pairs
- Provides better noise protection
- Higher price

Figure STP Cable



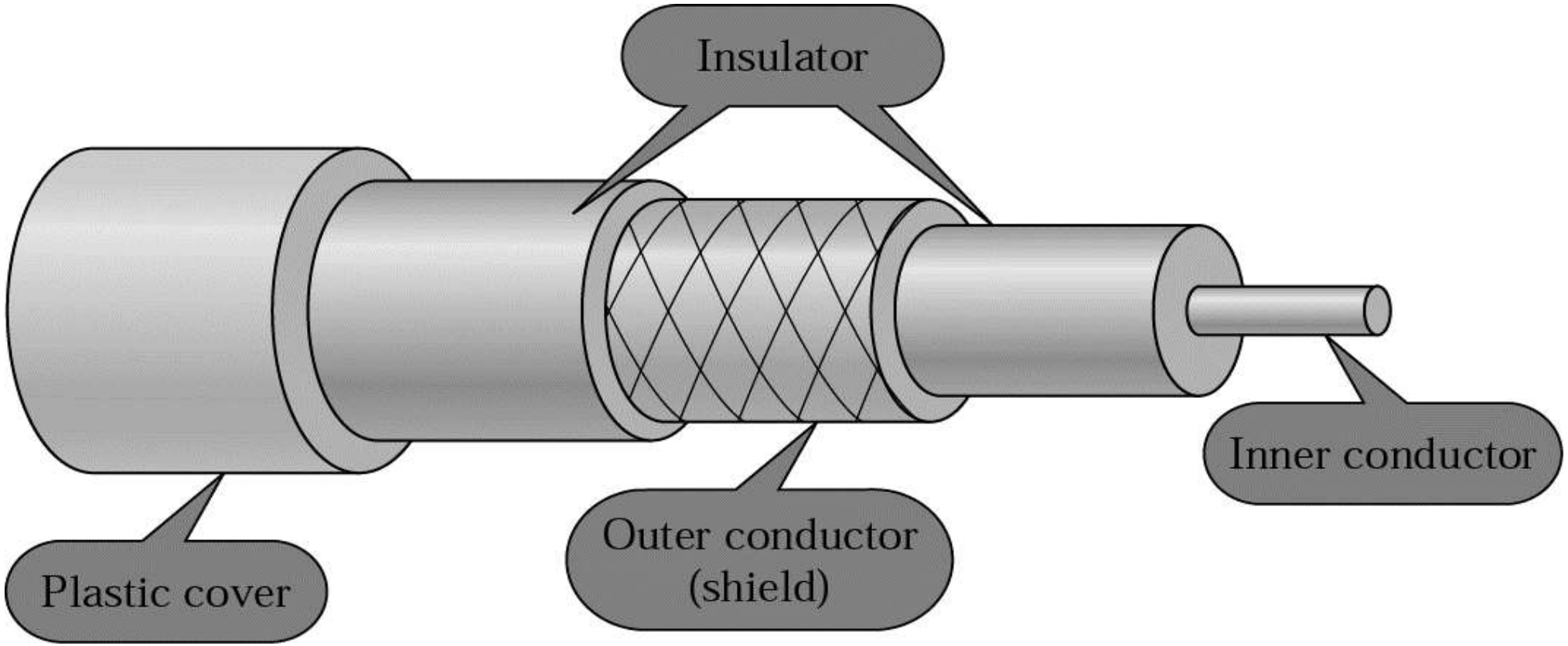
Shielded Twisted Pair(STP)

- More expensive
- Easiest to install
- Harder to handle (thick, heavy)
- Data Rate : 10- 100 Mbps
- Max Cable Length – 100M

Unshielded Twisted Pair(UTP)

- Flexible and cheap cable.
- Category rating based on number of twists per inch and the material used
- CAT 3, CAT 4, CAT 5, Enhanced CAT 5 and now CAT 6.

Co-axil Cable

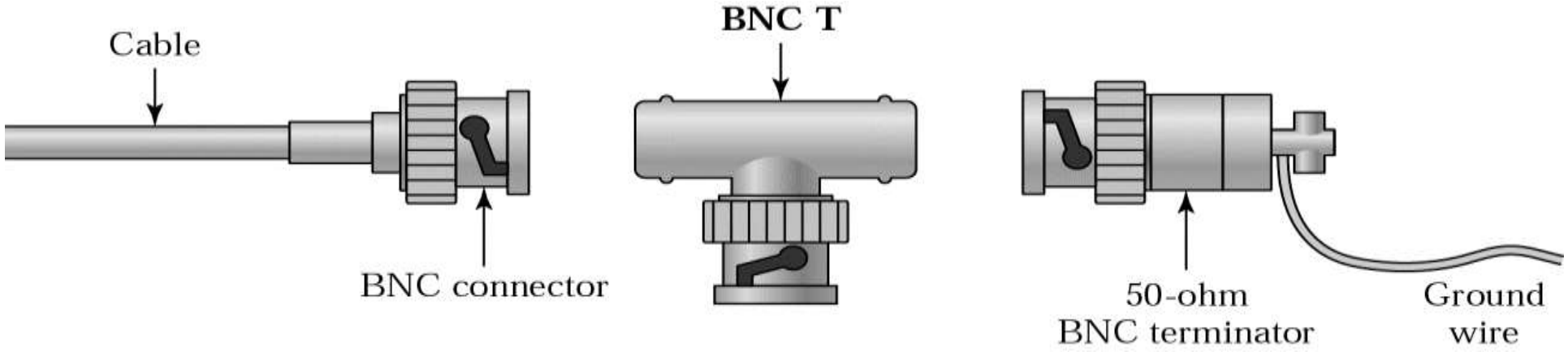


Co-axil Cable

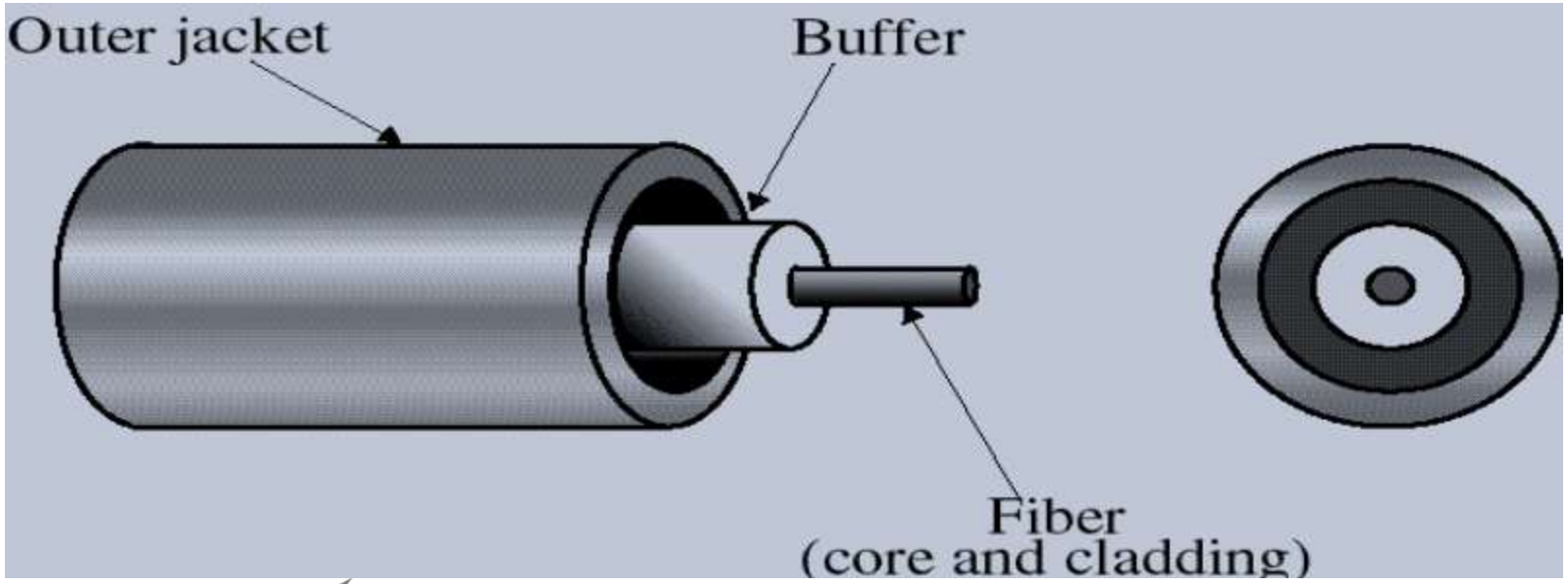
- Both conductors share a common center axial, hence the term “co-axial”
- Coaxial cable consist the followings layers in its construction
  - Copper conductor
  - Insulation layer of plastic foam
  - Second conductor or shield of wire mesh tube or metallic foil
  - Outer jacket of tough plastic
- Coaxial cable can be used over longer distances and support more stations on a shared line than twisted pair
- Coaxial cable is a versatile transmission medium, used in a wide variety of applications, including:
  - Television distribution - aerial to TV systems

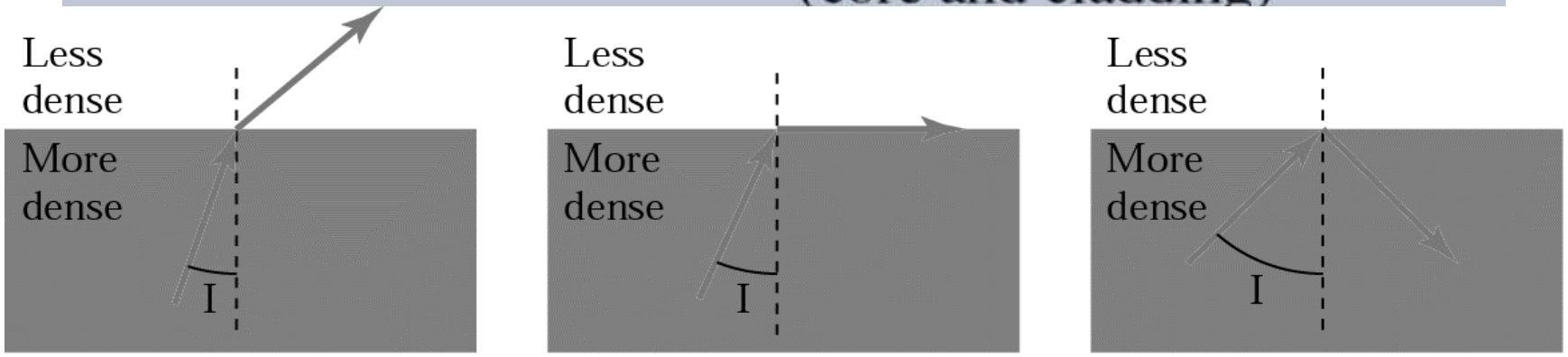
Co-axil Cable

- Characteristics
  - It is comparatively inexpensive
  - Its installation us comparatively simple
  - It must be grounded properly in a network connection
  - Its bandwidth capacity is around 10 Mbps
  - It suffers from data attenuation
- BNC Connectors are used for connecting to co-axial cables



Fibber Optics (Optical Fibber Cable)





Fibber Optics

- Most sophisticated cables used in long distance network connections
- Through this cable data transmission is done through **Light ray signal transmission**
- It has inner core of glass that conducts light
- This inner core is surrounded by cladding
- Cladding is nothing but layer of glass material that reflects light back into the core
- Each fiber is then surrounded by plastic sheath

Optical Fibber - Transmission Characteristics

- Uses total internal reflection to transmit light
  - effectively acts as wave guide for 10^{14} to 10^{15} Hz
- Can use several different light sources
  - Light Emitting Diode (LED)
    - Cheaper, wider operating temp range, lasts longer
  - Injection Laser Diode (ILD)
    - More efficient, has greater data rate
- Relation of wavelength, type & data rate

Optical Fibber Cable

- The bandwidth of the signal produced by the transmitting antenna is more important than the medium in determining transmission characteristics.

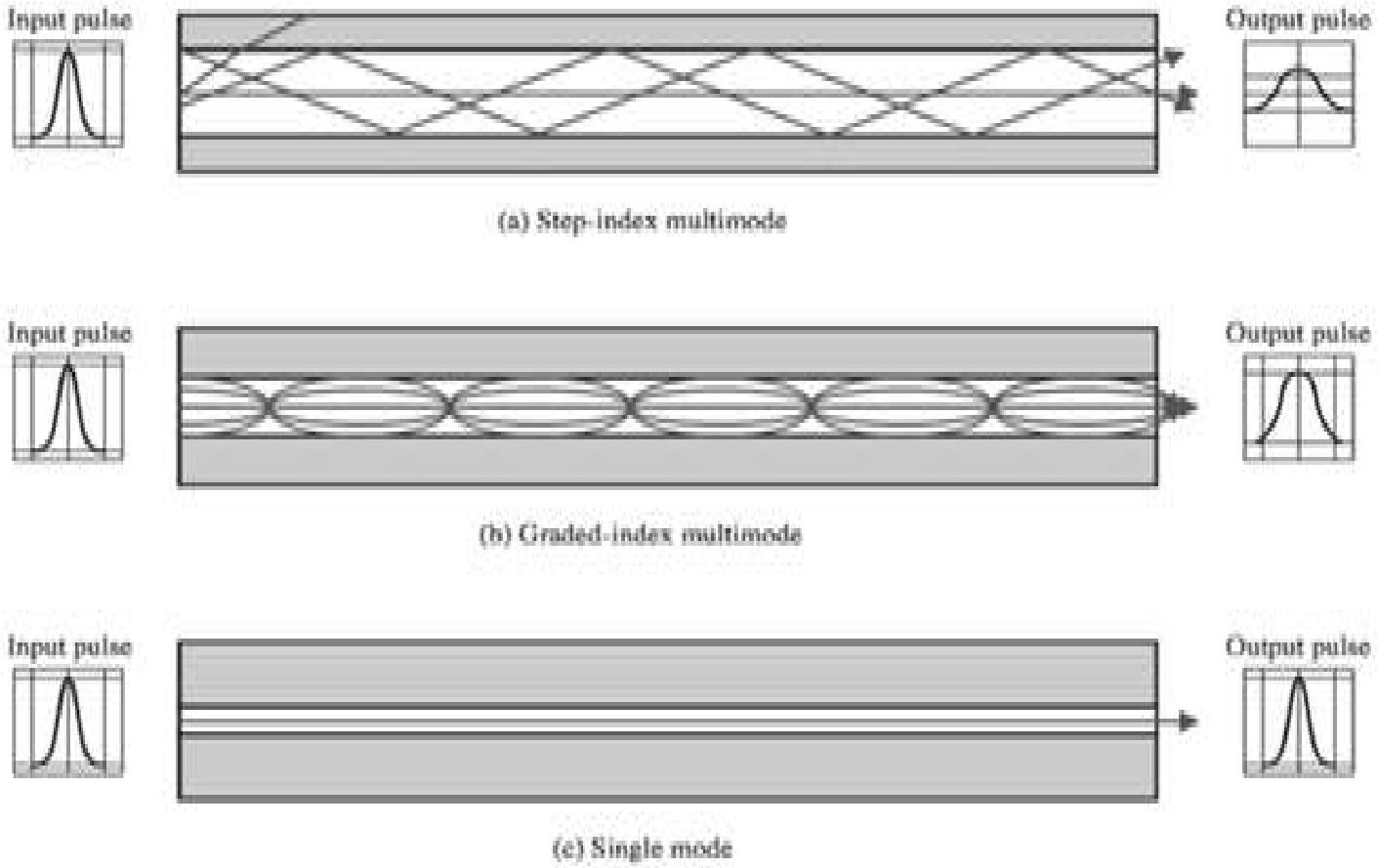
1. Optical Fibber – Benefits
2. greater capacity
3. data rates of hundreds of Gbps
4. smaller size & weight
5. lower attenuation
6. electromagnetic isolation
7. greater repeater spacing
8. 10s of km at least

Optical Fibber Cable Advantages

- **Greater capacity:** Data rates of hundreds of Gbps
- **Smaller size and lighter weight**
- **Electromagnetic isolation**
- **Greater repeater spacing**
- **Lower attenuation**

Optical Fibber Cable Types

- Single Mode
- Multi Mode
    1. Step Index
    2. Graded Index



Unbounded Media(Wireless Media)

- Very useful in difficult terrain where cable laying is not possible
- Provides mobility to communication nodes
- Right of way and cable laying costs can be reduced
- Antenna radiates electromagnetic energy into the medium(air)
- Antenna picks up electromagnetic waves from the surrounding medium

Disadvantages

- Susceptible to rain, atmospheric variations
- Objects in transmission path will reduce the signal strength

Advantages

- **Greater Bandwidth**
- **Low Power Loss**
- **Less Interference**
- **Scalable Size**
- **Safety**
- **Security**
- **Flexibility**

Frequency Bands

Band	Range	Propagation	Application
VLF	3–30 KHz	Ground	Long-range radio navigation
LF	30–300 KHz	Ground	Radio beacons and navigational locators
MF	300 KHz–3 MHz	Sky	AM radio
HF	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF	3–30 GHz	Line-of-sight	Satellite communication
EHF	30–300 GHz	Line-of-sight	Long-range radio navigation

Wireless Technology

Table 6-2 Wireless technologies

wireless technology	transmission distance
Bluetooth	33 feet (10 meters)
WLAN 802.11b	375 feet (112 meters)
WLAN 802.11a	300 feet (90 meters)
WLAN 802.11g	375 feet (112 meters)
Satellite	Worldwide
Fixed broadband	35 miles (56 kilometers)
WAP (cell phones)	Nationwide

Transmission

- Radio Waves 3 KHz to 1 GHz
- Micro Waves 1 GHz to 300 GHz
- Infrared 300 GHz to 400 THz

Infra Red

- Infrared signals have frequencies between 300 GHz to 400 THz.
- They are used for short-range communication.
- Infrared signals have high frequencies and cannot penetrate walls.
- Line of Sight is needed.
- Infrared is used in devices such as the mouse, wireless keyboard and printers.
- Due to its short-range communication system, the use of an infrared communication system in ONE ROOM will not be affected by the use of another system in the next room.

Radio Waves

- Radio waves are normally omnidirectional.
- When an antenna transmits radio waves, they are propagated in all directions
- Sending and receiving antennas do not have to be aligned.
- The omnidirectional characteristics of radio waves make them useful for multicasting, in which there is one sender but many receivers.
- Our AM and FM radio stations, cordless phones and televisions are examples of multicasting.
- Bluetooth ,Wi-Fi, GSM, CDMA

Bluetooth

- Bluetooth is a wireless technology standard for exchanging data over short distances
- Using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz
- Used from fixed and mobile devices, and building personal area networks (PANs)
- It can connect several devices, overcoming problems of synchronization
- Physical range :Typically less than 10 m, upto 100 m

Wi-Fi (Wireless LAN)

- Wi – Fi (Wireless Fidelity) is a standard that certifies that wireless devices (Wireless LAN) can work together.
- Supports IEEE802.11b or IEEE802.11g or IEEE802.11b/g standard
- Wi - Fi high-speed wireless Internet technology is commonly used in the world.
- Uses radio signals to transmit high speed data over the wireless network with the installation of the Access Point to connect to the device, Such as mobile phones, PDAs and notebook
- Range appx 100M
- Mainly uses 2.4GHz radio waves

GSM

- GSM (Global System for Mobile Communications, originally **G**roupe **S**pécial **M**obile)
- Standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation (2G) digital cellular networks
- GSM networks operate in a number of different carrier frequency ranges (separated into GSM frequency ranges for 2G and UMTS frequency bands for 3G),
- Most 2G GSM networks operating in the 900 MHz or 1800 MHz bands

Micro Waves

- Electronic waves with frequencies between 1 GHz to 300 GHz are normally called microwaves.
- Microwaves are unidirectional, in which the sending and receiving antennas need to be aligned.
- Microwaves propagation is line-of-sight therefore towers with mounted antennas need to be in direct sight of each other.
- Due to the unidirectional property of microwaves, a pair of antennas can be placed aligned together without interfering with another pair of antennas using the same frequency.
- High-frequency microwaves cannot penetrate walls. This is why receiving antennas cannot be placed inside buildings.

Satellite Communication

- Because **microwave** restrictions on the landscape that affect obscure wave, satellite is introduced
- A communication satellite is, In fact, Satellite is a microwave station.
- It is used to link two or more ground-based microwave transmitter /receivers, known as earth stations, or ground stations
- Implementing such satellite to orbit above the Earth's surface, only three satellites, it can be cover to communicate to all the world
- The satellite receives transmissions on one frequency band (uplink), amplifies or repeats the signal, and transmits it on another frequency (downlink)

Switching Technologies

- Switching is process to forward packets coming in from one node to a another leading towards the destination
- Communication system may include number of switches and nodes.
- At broad level, switching can be divided into two major categories:

1. **Connection Oriented:** Pre-establish circuit along the path between both endpoints
2. **Connectionless:** No previous handshaking is required and acknowledgements are optional.

- There are 3 main technologies used in Computer Networks

1. Circuit switching
2. Message switching
3. Packet switching

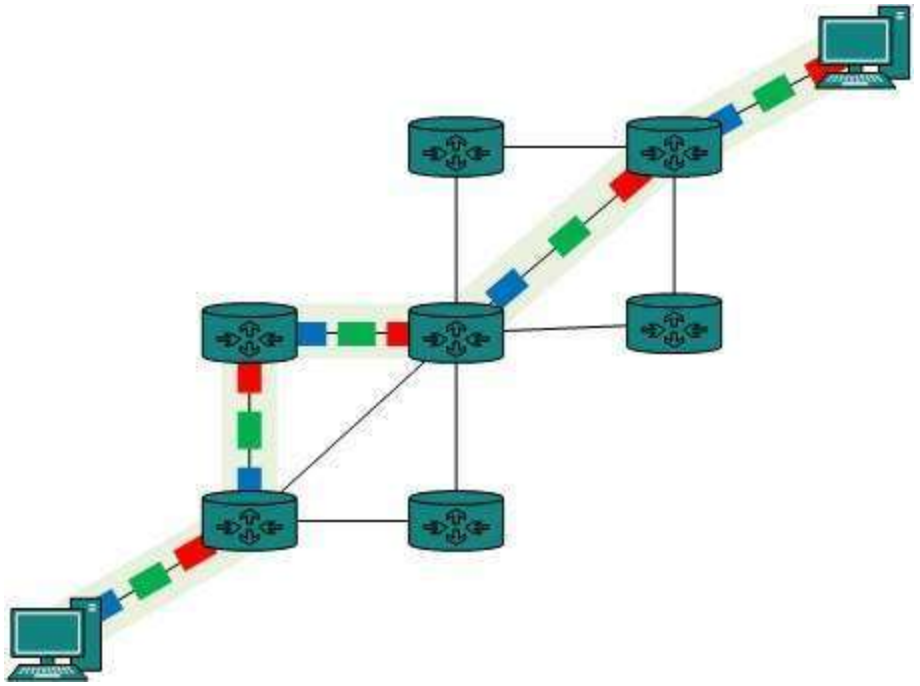
Circuit Switching

- When two nodes communicate with each other over a dedicated communication path, it is called circuit switching (Eg: Telephone Network)
- Need of pre-specified route from which data will travels 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:
    1. Establish a circuit
    2. Transfer the data
    3. Disconnect the circuit

❖Main disadvantage is Path is blocked for 2 nodes only

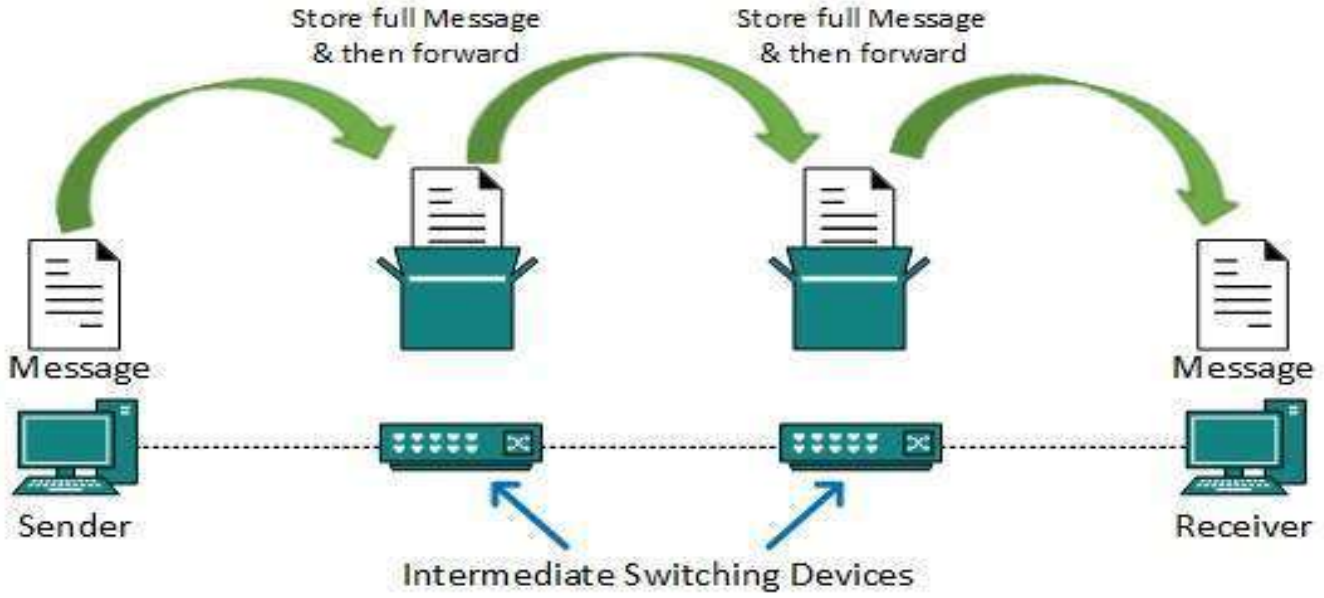
Circuit Switching

- 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.
- In the figure data always passes through same circuit.



Message Switching

- In message switching, the **whole message is treated as a data unit** and is switching / transferred in its entirety.
- This technique was introduced in between circuit switching and packet switc



Message Switching

- 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.

Message Switching

Advantages

1. Channel efficiency can be greater compared to circuit-switched systems, because more devices are sharing the channel.
2. Traffic congestion can be reduced, because messages may be temporarily stored in route.
3. Message priorities can be established due to store-and-forward technique.

Message Switching

Drawbacks:

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

Packet Switching

- Shortcomings of message switching gave birth to an idea of packet switching
- Entire message is broken down into smaller chunks called **packets**
- Switching information is added in the **header(source and destination address)** of each packet and transmitted independently
- It is easier for intermediate networking devices to store small size packets and they do not take much resources either on carrier path or in the internal memory of switches
- Packet switching can be seen as a solution that tries to combine the **advantages of message and circuit switching and to minimize the disadvantages of both.**

Packet Switching

- Packet switching enhances line efficiency as packets from multiple applications can be multiplexed over the carrier
- 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
- There are two types of packet switching methods:
    1. Virtual circuit
    2. Datagram

Packet Switching - Virtual Circuit

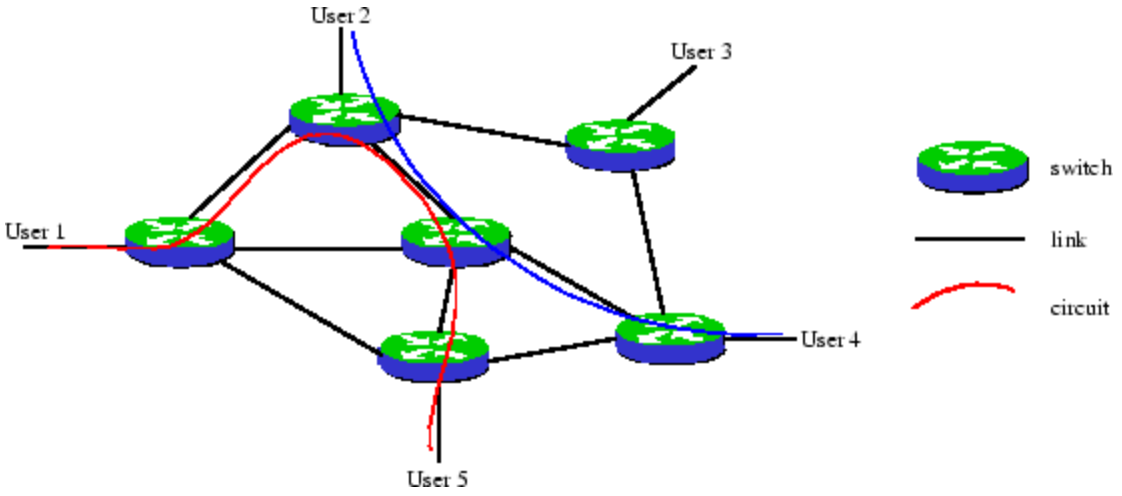
- Virtual circuit switching is a packet switching methodology whereby a logical path is established between the source and destination
- All the packets will go through same path which is called a virtual circuit
- To the user, the connection appears to be a dedicated physical circuit
- Other communications may also be sharing the parts of the same path
- It is connection oriented

Packet Switching - Virtual Circuit

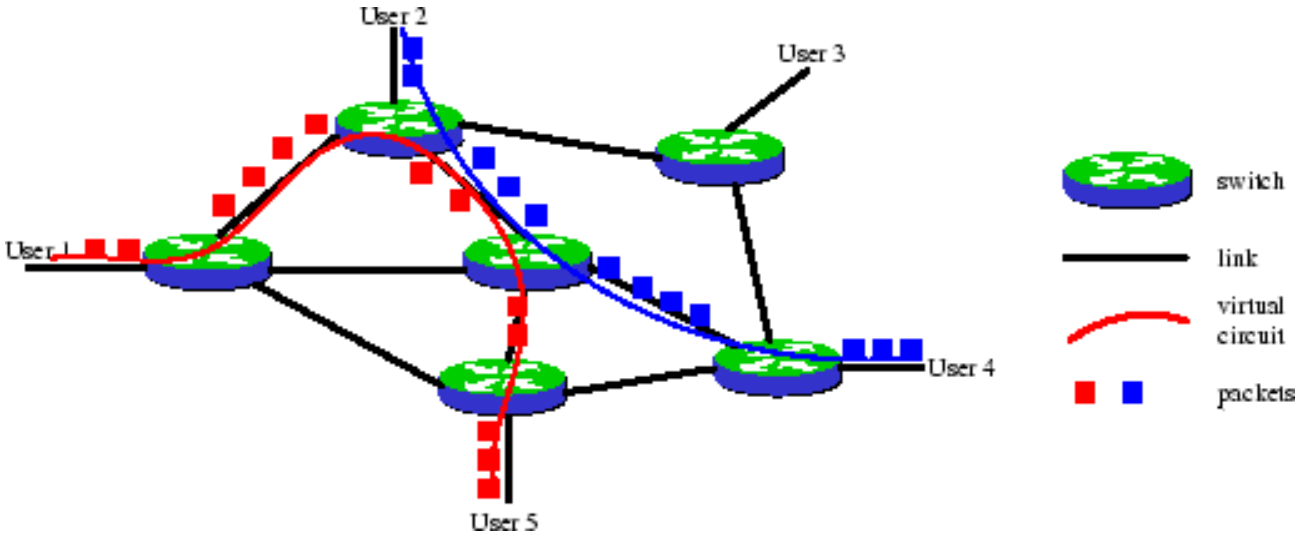
- Before the data transfer begins, the source and destination identify a suitable path for the virtual circuit.
- All intermediate nodes between the two points put an entry of the routing in their routing table for the call
- Additional parameters, such as the maximum packet size, are also exchanged between the source and the destination during call setup
- The virtual circuit is cleared after the data transfer is completed

Packet Switching - Virtual Circuit

- Virtual Circuit Establishment



- Data Transfer



Packet Switching - Virtual Circuit

Advantages

- Packets are delivered in order, since they all take the same route;
- The overhead in the packets is smaller
- The connection is more reliable

Disadvantages

- The switching equipment needs to be more powerful
- Resilience to the loss of a trunk is more difficult, since if there is a failure all the calls must be dynamically re-established over a different route.

Packet Switching - Datagram

- Datagram packet-switching is a packet switching technology by which each packet, now called a datagram, is treated as a separate entity
- Each packet is routed independently through the network
- Therefore packets contain a header with the full information about the destination
- The intermediate nodes examine the header of a packet and select an appropriate link to another node which is nearer to the destination
- Packets do not follow a pre-established route, and the intermediate nodes do not require prior knowledge of the routes that will be used

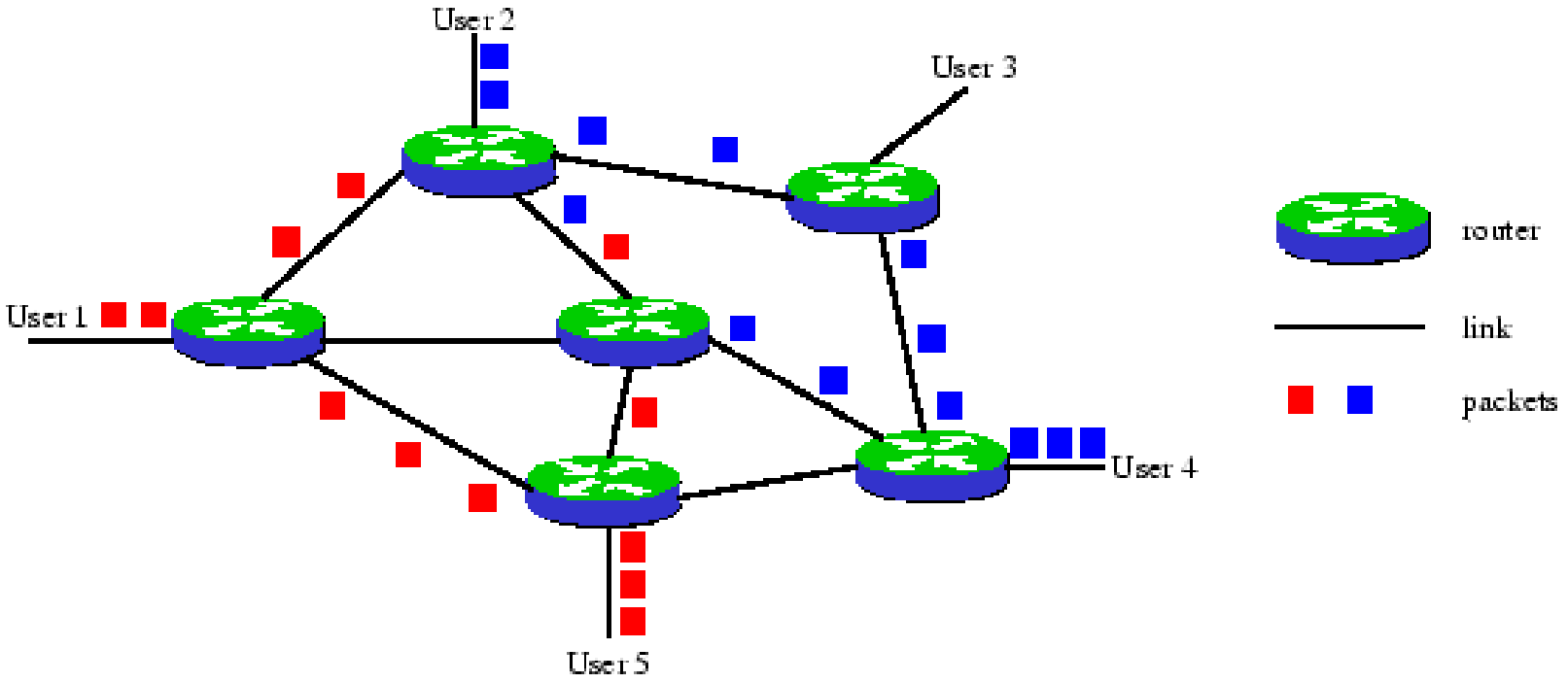
Packet Switching - Datagram

- The individual packets which form a data stream may follow different paths between the source and the destination
- Packets may arrive at the destination out of order
- When this occurs, the packets will have to be reassembled to form the original message.
- Because each packet is switched independently, there is no need for connection setup and no need to dedicate bandwidth in the form of a circuit(Connection less)
- Datagram packet switches use a variety of techniques to forward traffic; they are differentiated by how long it takes the packet to pass through the switch and their ability to filter out corrupted packets.

Packet Switching - Datagram

- A datagram network is a best effort network
- Delivery is not guaranteed
- Reliable delivery must be provided by the end systems (i.e. user's computers) using additional protocols.

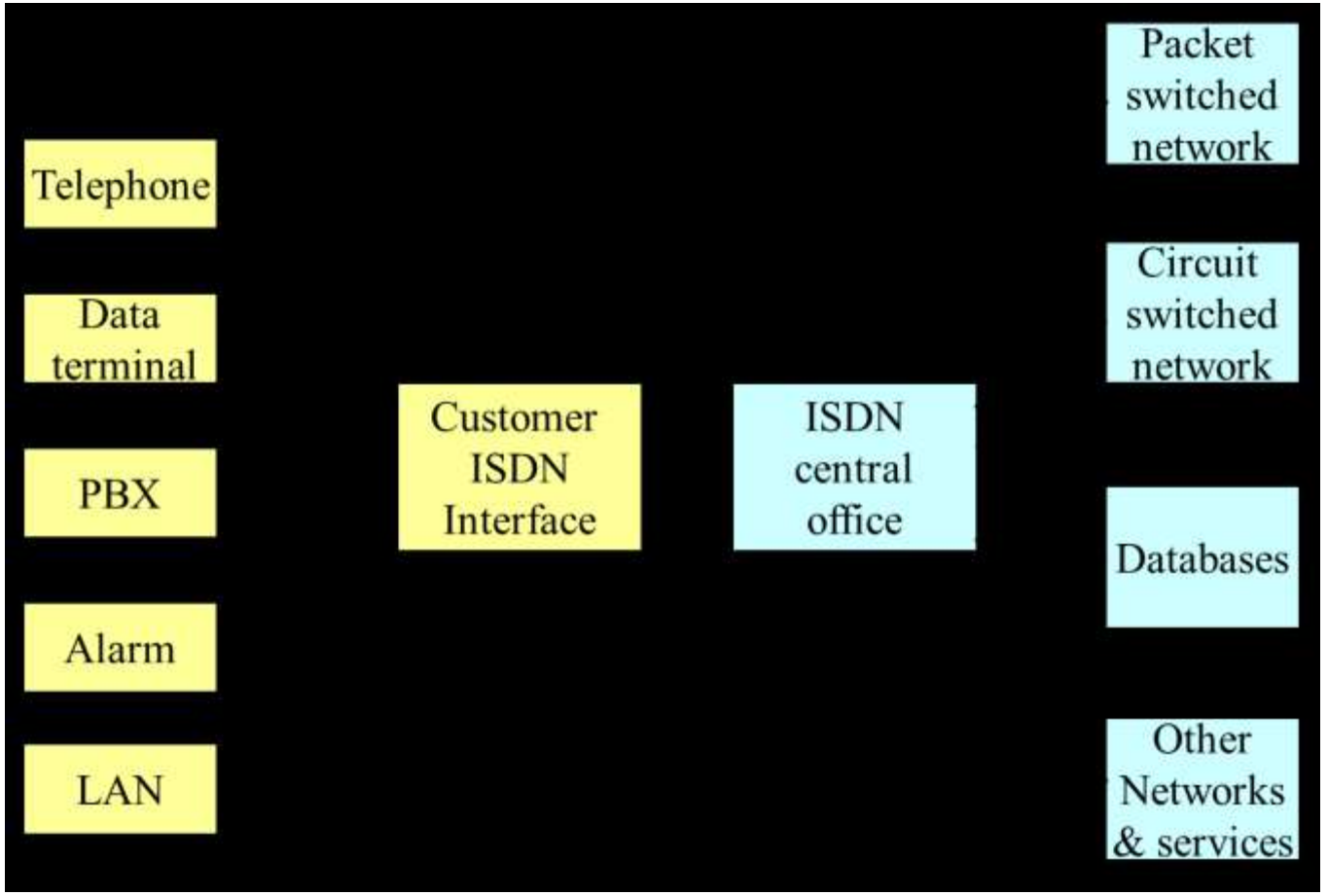
Packet Switching - Datagram



ISDN (Integrated Services Digital Network)

- The Public Switched Telephone network(PSTN) is still analogue from
- The need has arisen to extend the digital network out to subscribers and to provide a single standardised interface to all different users of public networks
- Integrated -> Both transmission and Switching
- Telephone services -> Telecommunication services
- Used for voice, image and data
- In Practice there are multiple networks providing the service nationally , user however sees a single network

ISDN



ISDN Architecture

ISDN Channels

- The Digital pipe is made up of channels - one of three types
  1. B channel
  2. D channel
  3. H channel
- Channels are grouped and offered as a package(Interfaces) to users

B (Basic) Channel

- B channel-64 kbps
- B is basic user channel
  - can carry digital data
  - PCM-encoded voice
  - Mixture of lower rate traffic
- Four kinds of connection possible
  - Circuit-switched
  - Packet-switched (X.25)
  - Frame mode - frame relay (LAPF)
  - Semi permanent - equivalent to a leased line

D Channel

- D Channel - 16 or 64 kbps
- Carries signalling information to control circuit-switched calls on B channels
- Can also be used for packet switching or low-speed telemetry

H Channel

- Carry user information at higher bit rates 384kbps or 1536kbps or 1920kbps
- Can be used as a high-speed trunk
- Can also be subdivided as per user’s own TDM scheme
- Uses include high speed data, fast facsimile, video, high-quality audio

ISDN Channel Grouping

- Channels are grouped into 2 accessing modes or interface
  1. Basic Access (Basic Rate Interface)
  2. Primary Access (Primary Rate Interface)

Basic Service / BRI (Basic Rate Interface)

- Management rate: 192 kbps
- Standard throughput: 144 kbps
- Composition: B + B + D channels, Synch & framing
- 2 B Channel -> Information: Voice, Data
- D Channel -> Signaling: Overhead or telemetry, etc.

Primary Service / PRI (Primary Rate Interface)

- Intended for users with greater capacity requirements
- Rate: 1.544/2.048 Mbps
- Composition:
  1. European Standard 2.048 Mbps: 30 B at 64 kbps each & 2 D at 64 kbps
  2. American Standard 1.544 Mbps: 23 B at 64 kbps each & 1 D at 64 kbps
- B Channels -> PCM voice channels
- D Channel -> Signaling

Network Performance (Parameters)

- Bandwidth
- Throughput
- Latency
- Bandwidth- Delay Product
- Jitter

Bandwidth

- Bandwidth is defined as the amount of data that can be transmitted in a fixed amount of time.
- Bandwidth is also defined as a range within a band of frequencies or wavelengths
- For digital devices, the bandwidth is usually expressed in bits per second(bps) or bytes per second
- For analog devices, the bandwidth is expressed in cycles per second, or Hertz (Hz).

Throughput

- Amount of data transferred from one place to another
- Amount Processed in a specified amount of time
- Data transfer rates for disk drives and networks are measured in terms of throughput.
- Typically, throughputs are measured in kbps, Mbps and Gbps.

Latency

- In networking, the amount of time it takes a packet to travel from source to destination.
- Together, latency and bandwidth define the speed and capacity of a network.

Bandwidth*Delay Product

- The Bandwidth*Delay Product, or BDP for short determines the amount of data that can be in transit in the network.
- It is the product of the available bandwidth and the latency, or RTT.
- BDP is a very important concept in a Window based protocol such as TCP. It plays an especially important role in high-speed / high-latency networks, such as most broadband internet connections.
- It is one of the most important factors of tweaking TCP in order to tune systems to the type of network used.
- BDP (bits) = total_available_bandwidth (bits/sec) x round_trip_time (sec)

Jitter

- Any distortion of a signal or image caused by poor synchronization
- Deviation/Error in normal signal
- In the context of computer networks, jitter is the variation in latency as measured in the variability over time of the packet latency across a network.
- A network with constant latency has no variation (or jitter).
- Packet jitter is expressed as an average of the deviation from the network mean latency. However, for this use
- The standards-based term is "packet delay variation" (PDV).
- PDV is an important quality of service factor in assessment of network performance.