Module - 1 (Introduction and Physical Layer)

Introduction:

- **Uses of computer networks**
- **Network Hardware**- Local Area Networks (LAN), Metropolitan Area Networks (MAN), Wide Area Networks (WAN), Wireless networks, Home networks, Internetworks.
- **Network Software**- Protocol hierarchies, Design issues for the layers. Connection-oriented and Connectionless services, Service primitives, Relationship of services to protocols.
- **Reference models**- The OSI reference model, The TCP/IP reference model, Comparison of OSI and TCP/IP reference models.

Physical Layer:

- **Modes of communication**- Simplex, Half-duplex, and Full duplex
- **Physical topologies** - Mesh, Star, Bus, Ring, Hybrid.
- **Signal encoding**
- **Transmission media overview**- Guided media (twisted pair, coaxial and fiber optic media), Unguided/wireless media (radio, microwave, and infrared).
- **Performance indicators** - Bandwidth, Throughput, Latency, Queuing time, Bandwidth–Delay product.

1. What are the different types of transmission technology widely used in computer networks?

Transmission technologies are divided into two types:

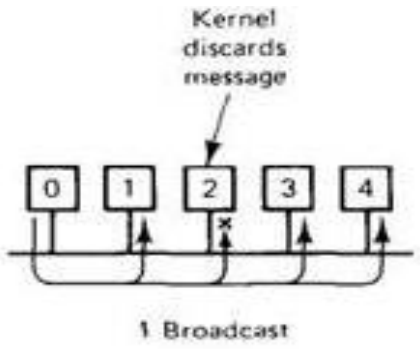
- Broadcast Networks
- Point-to-point Networks

Broadcast Networks

- **Broadcast Networks** have a single communication channel that is shared by all the machines on the network.
- Short messages called **packets**, sent by any machine are received by all the others.
- **Address field** within a packet specifies the **recipient**.
- After receiving the packet, the address field is checked.
- If it is intended for itself, it processes the packet, otherwise it is ignored.

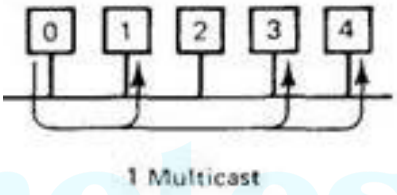
Broadcasting

- Broadcast systems allow the possibility of addressing a packet to all destinations by using special code in the address field.
- When a packet with this code is transmitted, it is received and processed by every machine on the network. This mode of operation is called Broadcasting.
- Smaller localized networks use broadcasting.



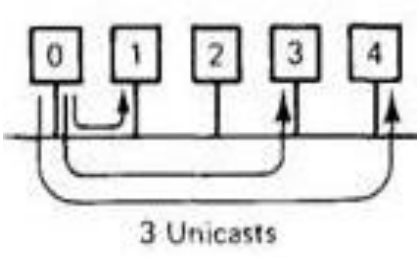
Multicasting

- Some broadcast systems also support transmission to a subset of the machines known as **multicasting**.
- One possible scheme is to reserve one bit to indicate multicasting. The remaining n-1 address bits can hold a group number. When a packet is sent to a certain group,it is delivered to all machines subscribing to that group.



Point-To-Point Networks

- A point-to-point connection provides a dedicated link between two devices. The entire capacity of the link is reserved for transmission between those two devices.
- Point-to-point transmission is sometimes called **unicasting**.
- When you change television channels by infrared remote control,you are establishing a point-to-point connection.
- Point-to-point networks consist of many connections between individual pairs of machines.
- To go from source to destination, a packet has to visit one or more intermediate machines. Often multiple routes of different lengths are possible which leads to the role of routing algorithm for route selection.
- Large networks use point-to-point networks.



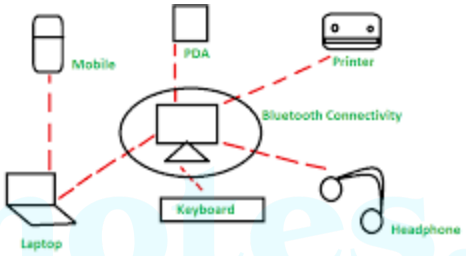
2. How computer networks are categorized based on transmission technology and scale? Explain the features of each network.

Computer networks are divided into five based on scale:

- Personal Area Networks (PAN)
- Local Area Networks (LAN)
- Metropolitan Area Networks (MAN)
- Wide Area Networks (WAN)
- Internetworks or Internet

PAN

- Personal Area Networks are meant for one person.
- This type of network can be wired or wireless.
- It is the smallest and most basic type of network.
- Eg: a wireless network connecting a computer with its mouse,keyboard and printer.



LAN

- These are privately owned networks.
- Inter-processor distance is 10m to 1km.
- LANs are restricted in size.
- LANs may use a transmission technology consisting of a cable to which all the machines are attached,like the telephone lines used in rural areas.
- IEEE 802.3 popularly called Ethernet.

MAN

- Metropolitan Area Network covers a city.
- The Geographical area covered by MAN is larger than LAN but Smaller than WAN.
- MAN delivers fast and effective communication by using a high speed carrier eg: fiber optic cables.
- The best-known example of a MAN is the cable television network available in many cities.

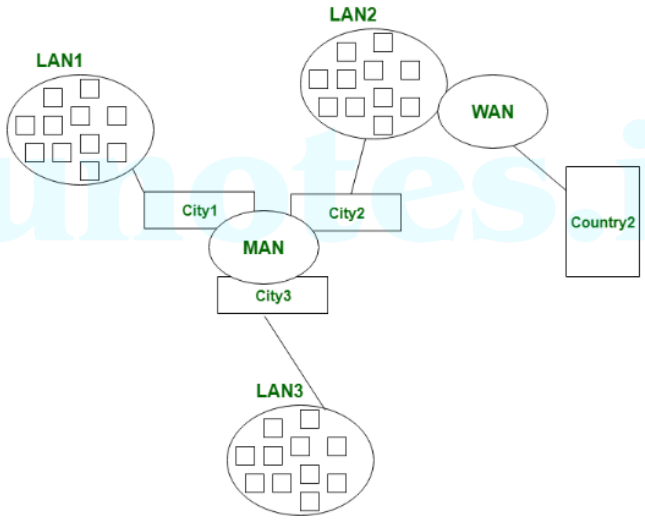
WAN

- Wide Area Network spans a large geographical area, often a country or continent.
- Best example of WAN is the internet.
- The Internet is considered as the largest WAN in the world.

- It contains a collection of machines called hosts intended for running user programs. The hosts are owned by customers.
- The hosts are connected by a communication subnet which is owned and operated by a telephone company or Internet Service Provider.
- The job of the subnet is to carry messages from host to host.

INTERNETWORKS

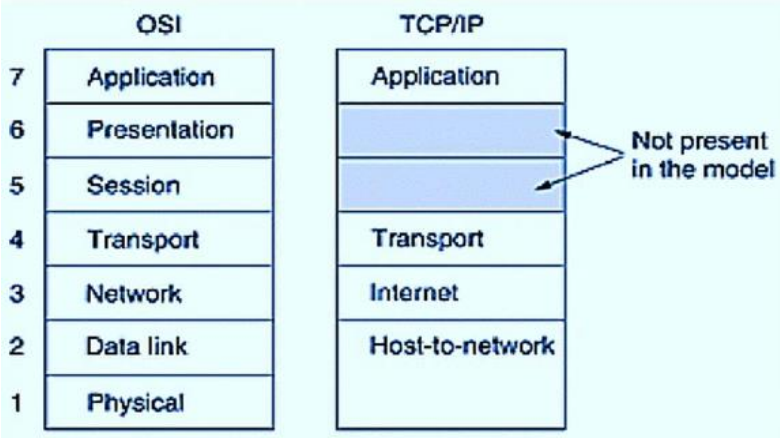
- A collection of interconnected networks is called an internetwork or internet.
- A common form of internet is a collection of LANs connected by a WAN.
- An internetwork is formed when distinct networks are interconnected.
- Advantages:
  - Improved availability
  - Improved dataflow
  - Increased reach
  - Access to knowledge

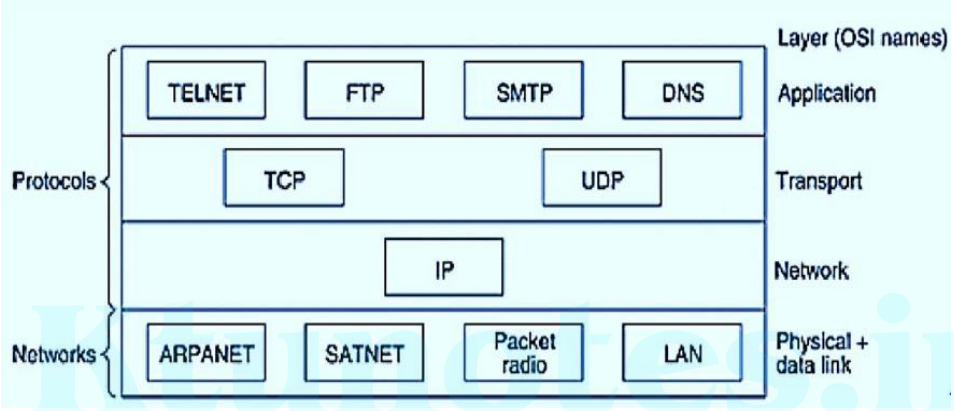


3. What is the TCP/IP reference model? What are the different layers of TCP/IP reference model

TCP/IP Reference Model

- The TCP/IP protocol suite is a 4 layered suite of communication protocols.
- It is named after the 2 main protocols –TCP and IP.
- TCP stands for Transmission Control Protocol and IP stands for Internet Protocol.





1) Host-To-Network Layer

- Host-to-network layer is equivalent to the combination of the physical and data link layers.
- At the physical and data link layer, TCP/IP does not define any specific protocol. It **supports all the standard and proprietary protocols**.
- A network in a TCP/IP internetwork can be a local-area network or a wide-area network.

2) Internet Layer

- TCP/IP supports the Internetworking Protocol.
- The job of the internet layer is to deliver IP packets where they are supposed to go.
- Packet routing & avoiding congestion are the major issues here.
- IP uses four supporting protocols:
  - ARP
  - RARP
  - ICMP
  - IGMP

Address Resolution Protocol (ARP)

- ARP is used to find the physical address of the node when its Internet address (IP address) is known.
- In LAN, each device on a link is identified by a physical or station address, usually imprinted on the network interface card (NIC).

Reverse Address Resolution Protocol (RARP)

- RARP allows a host to discover its Internet address when it knows only its physical address.
- It is used when a computer is connected to a network for the first time or when a diskless computer is booted.

Internet Control Message Protocol (ICMP)

- ICMP is a mechanism used by hosts and gateways to send notification of datagram problems back to the sender.
- CMP sends query and error reporting messages.

Internet Group Message Protocol (IGMP)

- IGMP is used to facilitate the simultaneous transmission of a message to a group of recipients.

3) Transport Layer

- Transport layer was represented in TCP/IP by two protocols: TCP and UDP.
- UDP and TCP are transport level protocols responsible for delivery of a message from a process (running program) to another process.

User Datagram Protocol (UDP):

- It is a process-to-process protocol that adds only port addresses, checksum error control, and length information to the data from the upper layer.

Transmission Control Protocol (TCP):

- TCP is a reliable and connection-oriented transport protocol.
- TCP divides a stream of data into smaller units called segments.
- Each segment includes a sequence number for reordering after receipt, and an acknowledgment number

Stream Control Transmission Protocol (SCTP):

- SCTP provides support for newer applications such as voice over the Internet. It is a transport layer protocol that combines the best features of UDP and TCP.

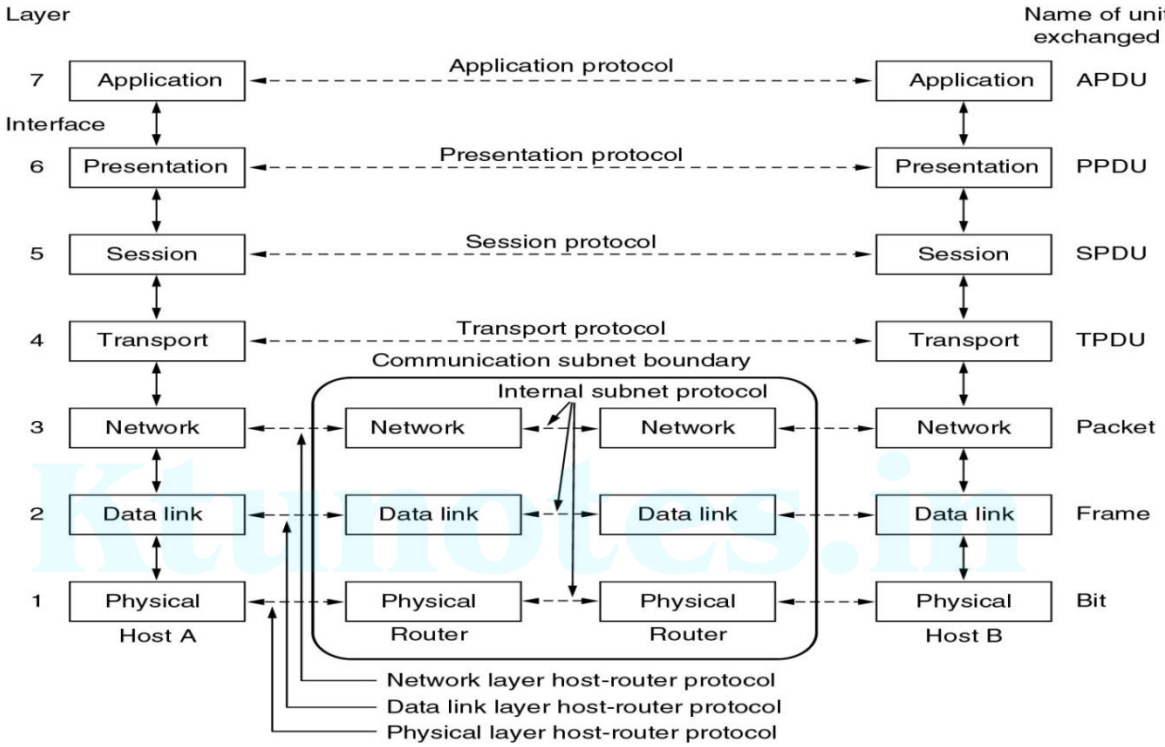
4) Application Layer

- The application layer in TCP/IP is equivalent to the combined session, presentation, and application layers in the OSI model.
- This layer provides services to users
- Many protocols are defined at this layer –
    - File Transfer (FTP)
    - Simple Mail Transfer Protocol(SMTP)
    - Domain Name System (DNS)
    - Terminal network (TELNET)
    - Hyper Text Transfer Protocol (HTTP) etc

4. Draw ISO OSI reference model and explain the functionalities of each layer in the model.

ISO OSI Reference Model

- A networking reference model defined by the ISO (International Organization for Standardization) divides computer-to-computer communications into seven connected layers.
- Such layers are known as protocol stack. Each successively higher layer builds on the functions of the layers below.
- Open Systems Interconnection (OSI) is a reference model that determines the way in which messages should be transmitted between any two points in a network.



Where

APDU-Application Protocol Data Unit
PPDU-Presentation Protocol Data Unit
SPDU-Session Protocol Data Unit
TPDU-Transport Protocol Data Unit

- The different layers layers of the OSI reference are as follows:

1) Physical Layer

- The physical layer is concerned with transmitting **raw bits** over a communication channel.
- **Functions:**
  - Line Configuration:Defines the way in which two or more devices can be connected physically.
  - Data Transmission:Defines the transmission mode between the two devices on the network;
  - Topology:Determines the way in which network devices are arranged.
  - Signals:Determine the type of signal that is used for transmitting information.

2) Data Link Layer

- This layer is responsible for error free transfer of data frames.
- Data Link Layer defines the format of data on the network.
- **Functions:**
  - Framing: DDL encapsulates packets into frames by adding its own header and trailer.
  - Arbitration: Determines how to negotiate access to a single data channel when multiple hosts are attempting to use it at the same time.
  - Physical addressing: Primary form of physical addressing is the media access control (MAC) address.
  - Error Detection: It is the process of determining whether error occurred during the transmission of bits across the wire. The data Link Layer uses a calculated value called CRC (Cyclic Redundancy Check) for this purpose.
  - Encapsulation: DLL identifies encapsulated data.

3) Network Layer

- The network layer is responsible for the delivery of individual packets from the source host to the destination host.
- It determines the physical path that data takes on the basis of network conditions,priority of service and other factors.
- **Functions**:
  - Source-to-Destination delivery: Transfers packet from the source to its destination.
  - Logical addressing: Adds the source and destination address in the header.
  - Routing: Selects the optimal path out of the multiple paths so that a packet can flow.
  - Address Transformation: Interprets the logical address.
  - Multiplexing: Utilizes one physical line for transferring data between several devices at a time.

4) Transport Layer

- The transport layer is responsible for process-to-process delivery of the entire message
- The transport layer is responsible for the delivery of a message from one process to another . A process is an application program running on a host.
- **Functions:**
  - Service-point Addressing: Transport layer includes port address in the header. Using these port addresses ,the transport layer delivers the packets to the correct process.
  - End-End Message Delivery: Ensures that the entire message is transmitted to the destination.
  - Segmentation and Reassembly: Divides each message into segments and assigns a sequence number to these segments which helps to reassemble the message if some error occurs.
  - Connection Control: Decides whether all packets will be sent using a single path or not.

5) Session Layer

- The session layer is responsible for dialog control and synchronization.
- It establishes, maintains, and synchronizes the interaction among communicating systems.
- **Functions**:

- Session Management: Divides the sessions into sub-sessions by inserting checkpoints.
- Synchronization: Selects the order in which the dialog units must pass to the transport layer.
- Dialog Control: Controls which user will send data and at what time.
- Closing the session: Ensures data transfer is completed before the session closes.

6) Presentation Layer

- The presentation layer is concerned with the syntax and semantics of the information exchanged between two systems.
- Different computers use different encoding systems, the presentation layer is responsible for interoperability between these different encoding methods.
- **Functions**:
  - Translation: The presentation layer at the sender changes the information from its sender dependent format into a common format. The presentation layer at the receiving machine changes the common format into its receiver-dependent format.
  - Encryption: Ensures security by using different algorithms for coding,passwords and log-in-codes.
  - Data Compression: Provides efficiency while transmitting data.

7) Application Layer

- The application layer is responsible for providing services to the user.
- It provides user interfaces and support for services such as electronic mail, remote file access and transfer, shared database management, and other types of distributed information services.
- **Functions**:
  - Authentication: Authenticates the sender or receiver of the message or both.
  - File Access, Transfer and Management: Allows the user at remote site to access files on another host.
  - Directory Services: Provides access to global information and database sources.

5. Compare TCP/IP Reference model and OSI Reference model.

Comparison between OSI and TCP/IP Reference Models

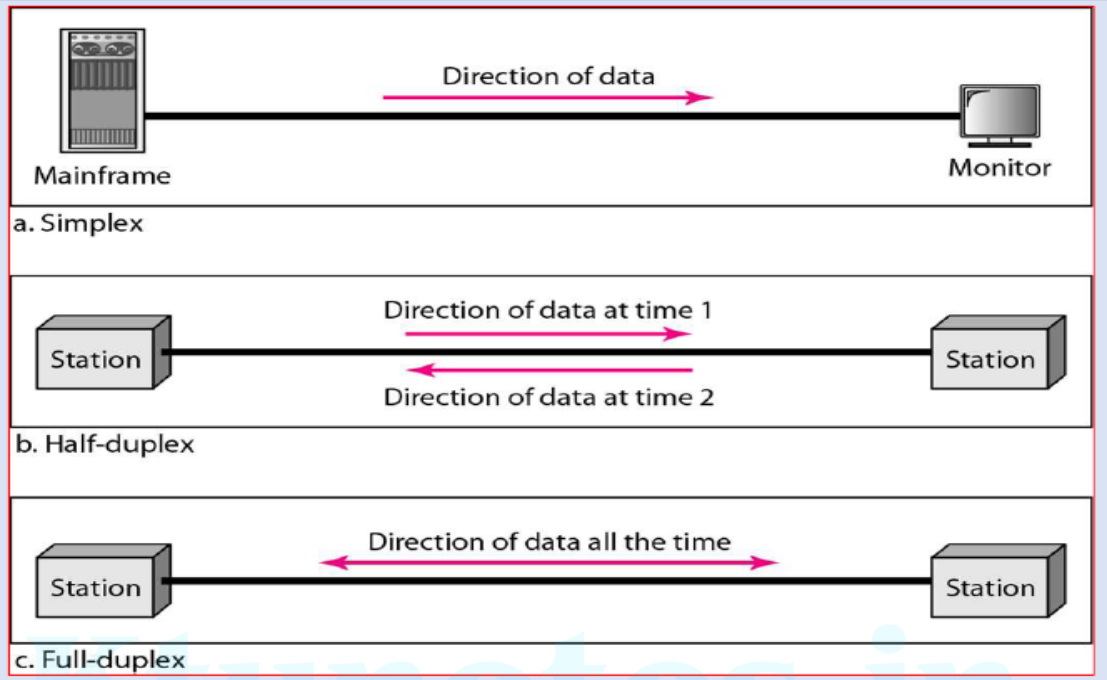
Table 1.3: OSI *vs.* TCP/IP

Basis	OSI	TCP/IP
No. of Layers	7 Layers	4 Layers
Implementation	Model was first defined before implementation takes place.	Model defined after, protocol was implemented.
Model Concepts	OSI model based on three concepts, i.e., service, interface and protocol.	TCP/IP model did not originally clearly distinguish between service, interface and protocol.
Delivery of Packets	OSI model gives guarantee of reliable delivery of packet.	Transport layer does not always guarantee the reliable delivery of packet.
Internet Working	OSI does not support internet working.	TCP/IP support internet working.
Layering	Strict layering	Loose layering
Connection Type	Support connectionless and connection-oriented communication in the network layer.	Support only connection-oriented communication in the transport layer.

6. List and explain various modes of communication

Modes of communication

- Communication between two devices can be simplex, half-duplex, or full-duplex.



Simplex:

- Communication is unidirectional.
- Only one of the two devices on a link can transmit the data; the other can only receive it.
- The simplex mode can use the entire capacity of the channel to send data in one direction.
- Eg : Keyboards and traditional monitors.

Half-duplex:

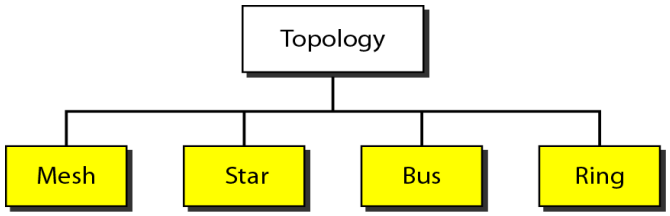
- Each station can both transmit and receive data, but not at the same time.
- When one device is sending, the other can only receive,and vice versa.
- Eg: Walkie-talkies and CB (citizens band) radios.

Full-duplex:

- Both stations can transmit and receive data simultaneously.
- Signals going in one direction share the capacity of the link.
- The full-duplex mode is used when communication in both directions is required all the time
- This sharing can occur in two ways:
  - Either the link must contain two physically separate transmission paths, one for sending and the other for receiving
  - Or the capacity of the channel is divided between signals traveling in both directions.
- Eg: telephone network.

7. Explain various network topologies.

Network Topologies



1) Mesh Topology

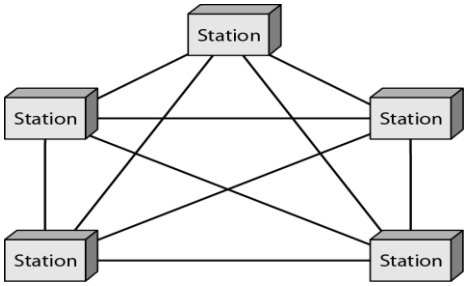
- In Mesh topology, every node has a dedicated point-to- point link with every other node.
- A fully connected mesh with n nodes will have n(n-1)/2 links.
- Eg: Connection of Telephone regional offices.

Advantages:

- Eliminates traffic problem
- Robust
- Privacy or security
- Easy fault identification

Disadvantages:

- More cabling and I/O ports.
- Expensive



2) Star Topology

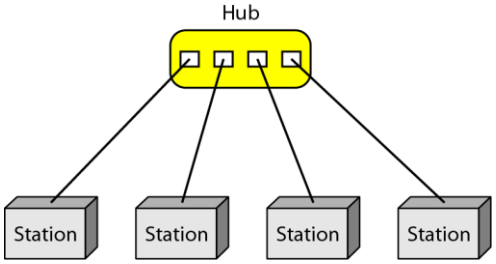
- In star topology, each device has a dedicated point to point link with the central hub.
- The devices are not directly linked to one another.
- Controller acts as an exchange.
- Used in High speed LAN.

Advantages:

- Less expensive than a mesh topology.
- Easy to install and reconfigure.
- Less cabling needs to be housed,
- Robustness - If one link fails, only that link is affected. All other links remain active.
- Easy fault identification

Disadvantages:

- If the hub goes down, the whole system is dead.



3) Bus Topology

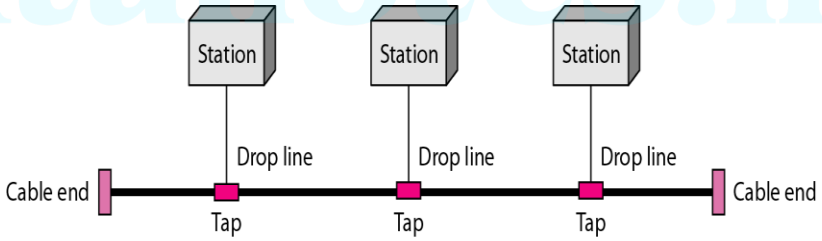
- One long cable acts as the backbone.
- Nodes are connected to the bus cable by drop lines and taps.
- IEEE 802.3 popularly called Ethernet is a bus based broadcast network with decentralized control.

Advantages:

- Ease of installation
- Less cabling

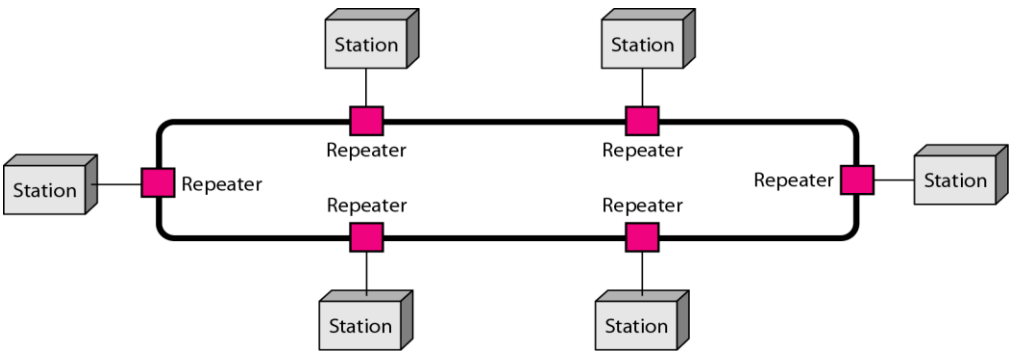
Disadvantages:

- Difficult reconnection and fault isolation.
- Difficult to add new devices.
- Break in the bus cable stops the entire transmission.



4) Ring Topology

- In Ring topology, each device has a dedicated point to point link with its immediate neighbors.
- Signal is passed along only one direction.
- IEEE 802.5 Token Ring.



Ring Network:

- Devices act as repeaters to boost the signal.
- The transmission of data takes place by token passing.
- A token is a special series of bits that contains control information.
- Possession of the token allows a network device to transmit data to the network.
- Each network has only one token.

Advantages:

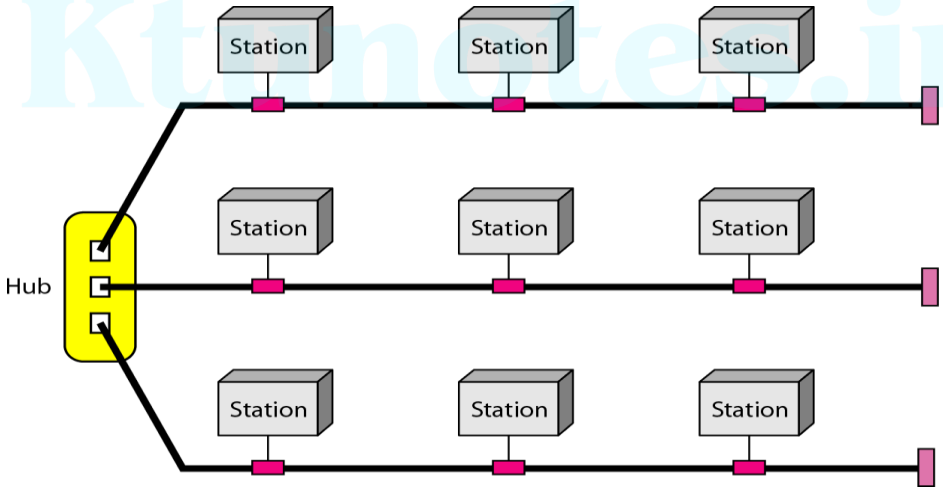
- Ease of installation and reconfiguration.
- Easy fault isolation.
- Easy to add or delete a device.

Disadvantages:

- Unidirectional traffic
- Break in the ring can disable the entire network.

5) Hybrid Topology

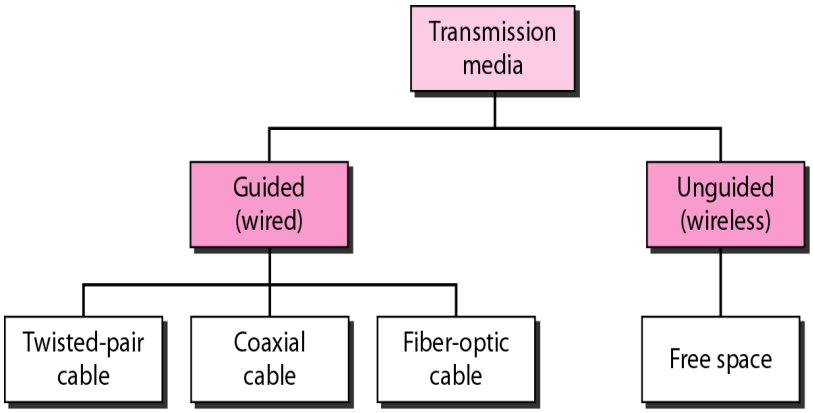
- It is the combination of two or more network topologies
- **Advantages**: reliable, flexible, effective
- **Disadvantages**: complex design , costly infrastructure



8. Compare various transmission media.

Transmission media

- A transmission medium can be defined as anything that can carry information from a source to a destination.



Guided media

- Guided media, which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable.

1) Twisted-pair cable

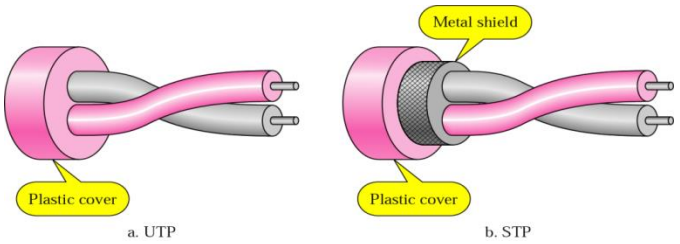
- A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together.
- One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference.
- They are used in point to point and point to multipoint communications.
- 2 types: a) **Shielded Twisted-Pair Cable (STP)**
  b) **Unshielded Twisted-Pair Cable (UTP)**

UTP:

- The most common twisted-pair cable used in communications.
- Very cheap
- Easy to install
- Badly affected by the noise interference.

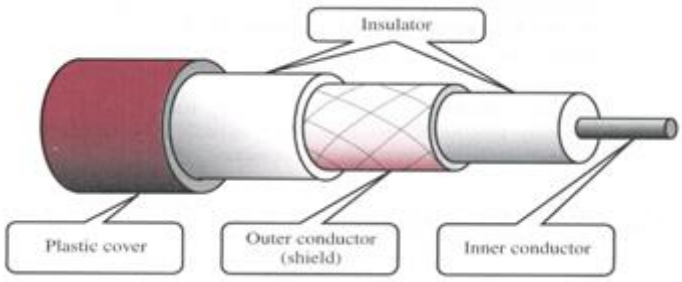
STP:

- STP cable has a metal foil or braided mesh to cover each pair of insulating conductors. This is known as metal shield. It reduces the interference of the noise.
- Metal casing improves the quality of cable by preventing the penetration of noise or crosstalk
- It is bulkier
- More expensive



2) Coaxial cable

- Coaxial cable (or coax) carries signals of higher frequency ranges than those in twisted pair cable.
- Coax has a central core conductor of solid or stranded wire (usually copper) enclosed in an insulating sheath, which is, in turn, encased in an outer conductor of metal foil, braid, or a combination of the two.
- The outer metallic wrapping serves both as a shield against noise and as the second conductor, which completes the circuit.
- This outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover.
- Costlier than twisted-pair cable but cheaper than optical fiber cables.
- **Applications**: i) Analog telephone networks
  ii) Digital telephone networks



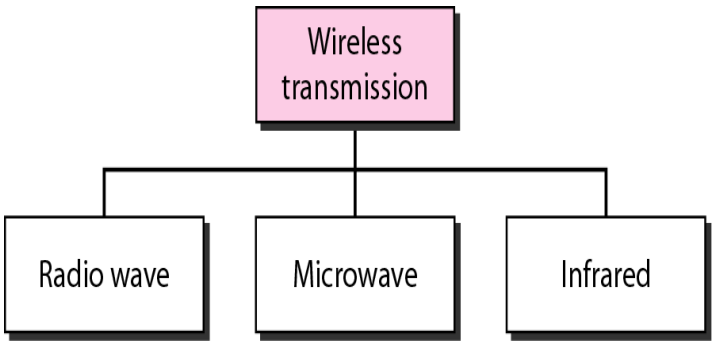
3) Optical fiber

- Optical fiber is a cable that accepts and transports signals in the form of light.
- A fiber-optic cable is made of glass or plastic
- It consist of an inner glass core surrounded by a glass cladding which has lower refractive index
- Optical fibers use reflection to guide light through a channel.
- It's costlier than other 2 types.
- Fiber-optic cable is often found in backbone networks.

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 media

- Unguided media transport electromagnetic waves without using a physical conductor
- Signals are normally broadcast through free space and thus are available to anyone who has a device capable of receiving them.



1) Radio waves

- Electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves
- Radio waves are omnidirectional.
- Radio waves, particularly those waves that propagate in the sky mode, can travel long distances. This makes radio waves a good candidate for long-distance broadcasting such as AM radio.
- Radio waves, particularly those of low and medium frequencies, can penetrate walls.

- **Application**: The omnidirectional characteristics of radio waves make them useful for multicasting, in which there is one sender but many receivers. AM and FM radio, television, maritime radio, cordless phones, and paging are examples of multicasting.

2) Microwaves

- Electromagnetic waves having frequencies between I and 300 GHz are called microwaves.
- Microwaves are unidirectional.
- When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned.
- Very high-frequency microwaves cannot penetrate walls.
- **Application**: cellular telephones
  Satellite networks
  Wireless LANs

3) Infrared

- Infrared waves having frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 770 nm) can be used for short-range communication.
- Infrared waves, having high frequencies, cannot penetrate walls.
- Infrared signals are useless for long-range communication.
- **Application**: Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

9. What are the service primitives

- A service is formally specified by a set of primitives (operations).
- These primitives tell the service to perform some action or report on an action taken by a peer entity.
- The set of primitives available depends on the nature of the service being provided.
- The primitives for connection-oriented service are different from those of connectionless service.
- Primitives used for a request-reply interaction in a client-server environment

Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

10. What is the propagation time if the distance between the two points is 12,000 km? Assume the propagation speed to be 2.4 × 10^8 m/s in cable.

Propagation time = Distance / Propagation speed

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

11. What are the propagation time and the transmission time for a 2.5-kbyte message (an email) if the bandwidth of the network is 1 Gbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at 2.4 × 10^8 m/s.

Propagation time = Distance / Propagation speed

Transmission time= Message size / Bandwidth

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

$$\text{Transmission time} = \frac{2500 \times 8}{10^9} = 0.020 \text{ ms}$$

12. What are the propagation time and the transmission time for a 5-Mbyte message (an image) if the bandwidth of the network is 1 Mbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at 2.4 × 10^8 m/s.

A) Propagation time = Distance / Propagation speed

Transmission time= Message size / Bandwidth

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

$$\text{Transmission time} = \frac{5{,}000{,}000 \times 8}{10^6} = 40 \text{ s}$$