1.1 Data Communication

- **Data communications** is the exchange of data between two devices by means of any transmission medium. The effectiveness of data communication system depends on three fundamental characteristics delivery, accuracy and timeliness.

1. Delivery : The data must be delivered to the intended device or user.

2. Accuracy : The data must be delivered accurately i.e. without alteration.

3. Timeliness : The system must deliver data in a timely manner.

1.1.1 Data Communication System

- A data communication system consists of five components.
  1) Message 2) Sender 3) Receiver
  4) Medium 5) Protocol

Fig. 1.1.1 shows components of data communication system.

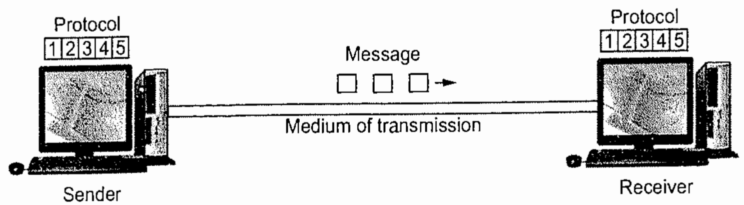


Fig. 1.1.1 Data communication components

1. Message : The message is data or information to be communicated. It can be text, numbers, pictures or sound.

2. Sender : The sender is device that sends data. Various devices can be used to send the data.

3. Receiver : The receiver receives the information/message transmitted by sender.

4. Medium : It is a physical path through which message passes from sender to receiver. The transmission medium can be twisted-pair cable, co-axial cable, fiber-optic cable or radiowaves.

5. Protocol : Protocol is a set of rules that governs data communications. Protocol is a predecided terms for communication.

1.1.2 Direction of Data Flow

- Communication between two devices i.e. sender and receiver can be of three types :
  1. Simplex
  2. Half-Duplex
  3. Full-Duplex

1. Simplex

- In simplex mode of communication, data can flow in one direction only (unidirectional). One device can transmit data and other device accepts the data and works accordingly. Fig. 1.1.2 shows simplex communication mode.

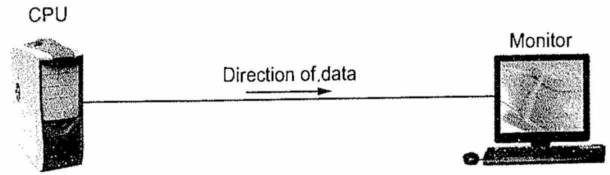


Fig. 1.1.2 Simplex communication

- Typical example of simplex communication is a computer system, data from flow from CPU to monitor or from keyboard to monitor in one direction only.

2. Half-Duplex

- In half-duplex mode of communication each station can transmit or receive the message (data). Fig. 1.1.3 shows half-duplex communication mode.

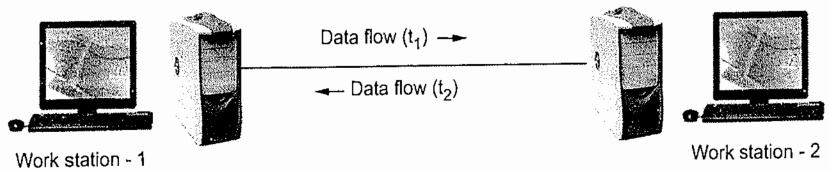


Fig. 1.1.3 Half-duplex communication

- An important condition in half-duplex mode is that both devices cannot transmit at a time. The entire channel capacity is used by any device transmitting at that time.

3. Full-Duplex

- In full-duplex mode, both stations can transmit and receive simultaneously. Fig. 1.1.4 shows full-duplex mode of communication.

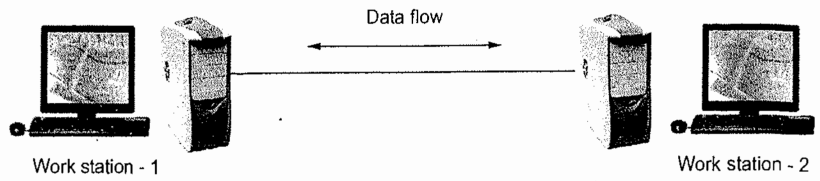


Fig. 1.1.4 Full-duplex communication

- In full-duplex mode of communication, data flow in both directions share the channel capacity. A common example of full-duplex communication is telephone network. Subscriber at both ends can talk and listen at the same time.

1.2 Networks

- A **network** is a set of devices interconnected by a communication medium. Each device is referred to as a **node**. A node can be a computer, printer or any other computing device.

Network criteria

- A network must satisfy following criteria.

a) **Performance** : Performance can be measured by transit time (propagation delay) and response time (speed of operation). Performance is decided by many factors such as number of users, type of transmission medium, hardware and software.

b) **Reliability** : A network reliability is measured by accuracy, failure rate, establishment time and robustness.

c) **Security** : Network security concerned with protection of data from unauthorized access.

1.2.1 Physical Structure

- Physical structure includes some network attributes such as type of connections and topologies.

1.2.2 Type of Connections

- The nodes in computer network are interconnected by some link. The link can be of two types :
  1) Point-to-point 2) Multipoint/multidrop

1. Point-to-point

- In case of point-to-point link, there is a dedicated link between two devices/nodes. Fig. 1.2.1 shows point-to-point link.

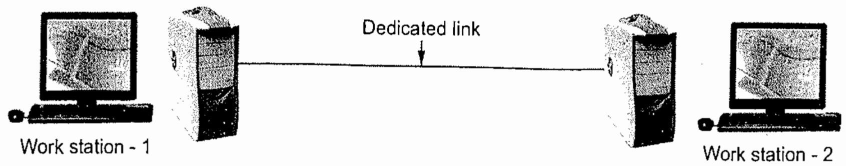


Fig. 1.2.1 Point-to-point connection

- The link capacity is shared between the two nodes only. The link can be a cable or microwave link. Typical example is TV and its remote control.

2. Multipoint

- When two or more devices/nodes share a common link, it is called as multipoint connection. Fig. 1.2.2 shows multipoint connection. It is also called as multidrop.

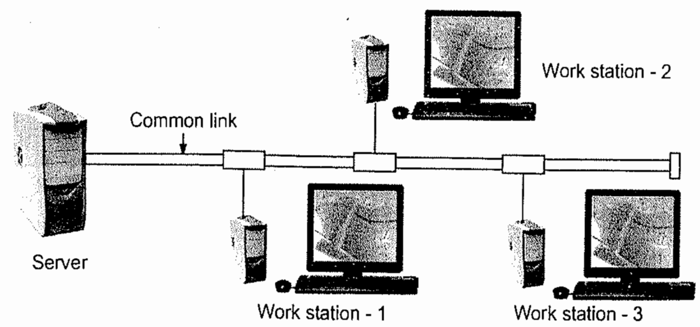


Fig. 1.2.2 Multipoint connection

1.3 Network Topology

SPPU : May-12

- The physical topology of LAN refers to the way in which the stations are physically interconnected.
- Topology is also defined as, the manner in which nodes are geometrically arranged and connected is known as the topology of the network.
- Physical topology of a local area network should have the following desirable features.
  1. The topology should be flexible to accommodate changes in physical locations of the stations, increase in the number of stations and increase in the LAN geographic coverage.
  2. The cost of physical media and installation should be minimum.
  3. The network should not have any single point of complete failures.
- Network topology refers to the physical layout of the network. Each topology has its own strengths and weaknesses.

- Four types of topologies are commonly used in the network. They are bus, star, ring and mesh topology.

1.3.1 Bus Topology

- Bus topology also called horizontal topology.
- In bus topology, multiple devices are connected one by one, by means of connectors or drop cables.
- When one computer sends a signal up (and down) the wire, all the computers on the network receive the information, but only one accepts the information (using address matching). The rest discard the message.
- Bus is passive topology because it requires termination. Cable cannot be left unterminated in a bus network.

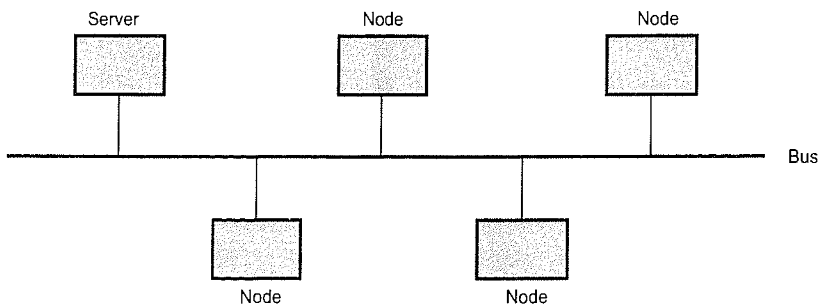


Fig. 1.3.1 Bus topology

Advantages of Bus :

1) Easy to use and easy to install.
2) Needs fewer physical connectivity devices.
3) A repeater can also be used to extend a bus topology network.
4) Low cost.

Disadvantages of Bus :

1) Heavy network traffic can slow a bus considerably.
2) It is difficult to troubleshoot a bus.
3) Failure of cable affects all devices on the network.
4) Difficult to add new node.

1.3.2 Star Topology

- A star topology consists of a number of devices connected by point-to-point links to a central hub.
- Easy to control and traffic flow is simple.
- Data travels from the sender to central hub and then to the receiver.

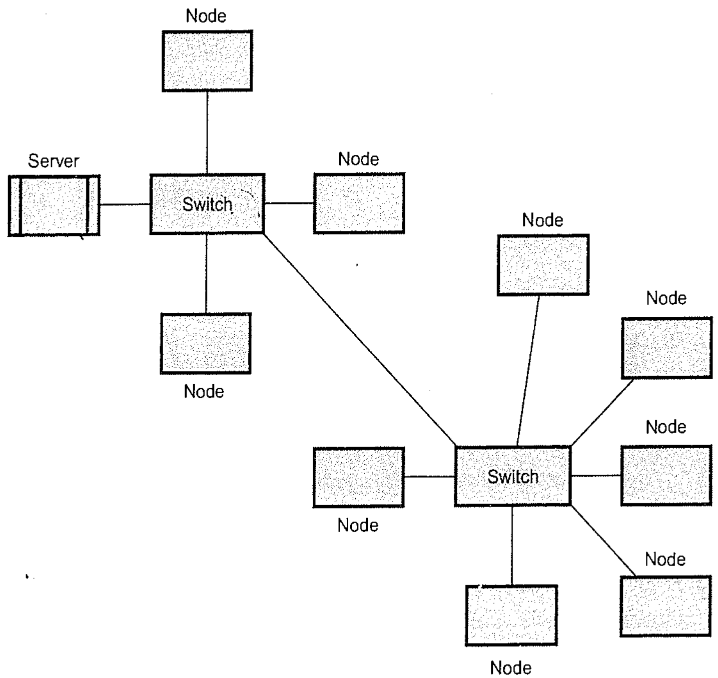


Fig. 1.3.2 Star topology

Advantages of Star Topology :

1) It is easy to modify and add new nodes to a star network without disturbing the rest of the network.
2) Troubleshooting techniques are easy.
3) Failures of any node do not bring down the whole star network.

Disadvantages of Star Network :

1) If the central hub fails, the whole network fails to operate.
2) Each device requires its own cable segment.
3) Installation can be moderately difficult, especially in the hierarchical network.

1.3.3 Ring Topology

- In a ring topology, each computer is connected to the next computer, with the last one connected to the first. The signals travel on the cable in only one direction. Since each computer retransmits what it receives.
- Ring is an active network. Termination is not required.

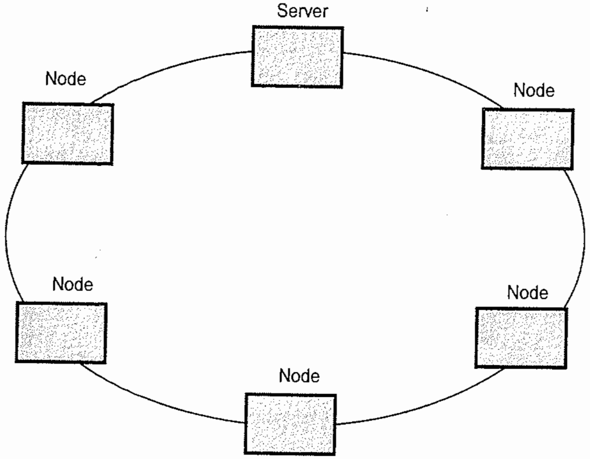


Fig. 1.3.3 Ring topology

Advantages of Ring :

1) Cable failures are easily found.

2) Because every node is given equal access to the token, no one node can monopolize the network.

Disadvantages of Ring :

1) Adding or removing nodes disrupts the network.

2) It is difficult to troubleshoot a ring network.

3) Failure of one node on the ring can affect the whole network.

4) Cost of cable is more in ring network.

1.3.4 Mesh Topology

- The mesh topology has a link between each device in the network. It is more difficult to install as the number of devices increases.
- Mesh networks are easy to troubleshoot.

- Much of the bandwidth available in mesh configuration is wasted.
- Most mesh topology networks are not true mesh networks. Rather, they are hybrid mesh networks, which contain some most important sites with multiple links.

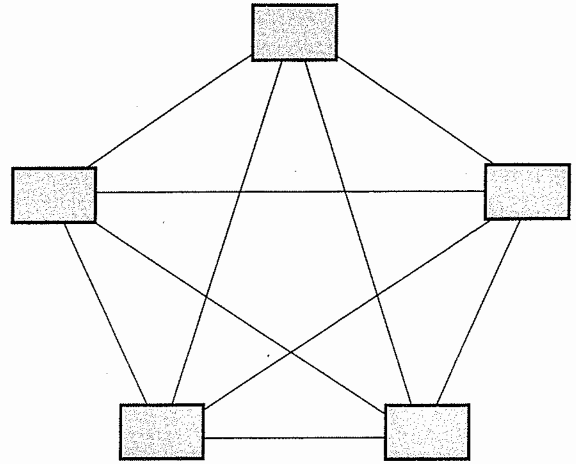


Fig. 1.3.4 True mesh topology

Advantages of Mesh :

1) Troubleshooting is easy. 2) Isolation of network failures is easy.

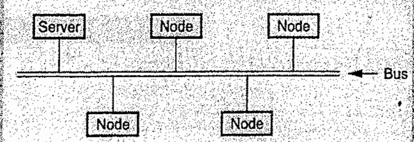
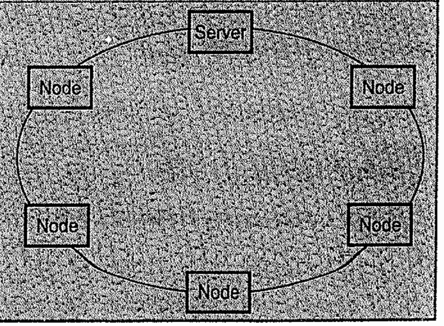
Disadvantages of Mesh :

1) Difficulty of installation.

2) Costly because of maintaining redundant links.

3) Difficulty of reconfiguration.

1.3.5 Comparison between Bus and Ring Topology

Sr. No.	Bus topology	Ring topology
1.		

2.	Bus requires proper termination. Cable cannot be left unterminated.	Termination is not required.
3.	Bus is a passive network topology.	Ring is an active network topology.
4.	There is loss in data integrity as the bus length increases.	Transmission errors are minimized because transmitted signal is regenerated at each node.
5.	It uses point to multipoint communication links.	It uses point-to-point communication links.
6.	Recommended when large number of devices are to be attached.	Recommended when moderate number of devices are to be attached.

1.3.6 Hybrid Topology

A hybrid topology is a combination of two or more topologies. For example, bus topology connected in each branch of star network is shown in the Fig. 1.3.5.

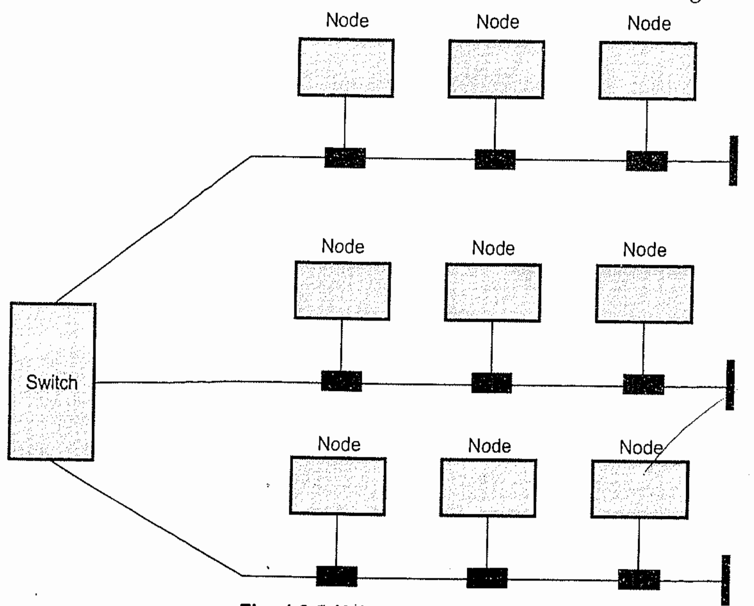


Fig. 1.3.5 Hybrid topology

University Question

1. *State and explain four basic network topologies and write advantages of each type.*

SPPU : May-12, Marks 6

1.4 Network Types

1.4.1 Local Area Network (LAN)

- The IEEE 802 LAN is a popularly used shared medium peer-to-peer communications network that broadcasts information for all stations to receive.

- The LAN enables stations to communicate directly using a common physical medium on a point-to-point basis without any intermediate switching node being required.
- A LAN is a system composed of computer hardware and transmission media and software.
- LANs are privately owned networks within a single building or campus of upto few km in range. It generally use only one type of transmission media.
- Depends upon application and cost, various topology used in LAN. (e.g. star, bus, ring).
- The basic idea of a LAN is to provide easy access to Data Terminal Equipment (DTEs) within the office. These DTEs are not only computers but other devices, such as printer, plotters and electronic files and databases.
- Fig. 1.4.1 shows the local area networks.

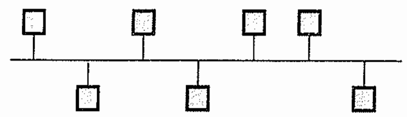


Fig. 1.4.1 LAN

- LAN can provide users
  1) Flexibility
  2) Speed
  3) Reliability
  4) Adaptability
  5) Security
  6) Transparent interface
  7) Access to the other LAN and WAN
  8) Hardware and software sharing
  9) Centralized management
  10) Private ownership of the LAN.
- **Attributes of LAN**
  1) The LAN transmits data amongst user stations.
  2) The LAN transmission capacity is more than 1 Mbps.
  3) The LAN channel is typically privately owned by the organization using the facility.

4) The geographical coverage of LANs is limited to areas less than 5 square kilometers.

- LANs are typically identified by the following properties -

1) Multiple systems attached to shared medium.
2) High total bandwidth (~10 Mbps).
3) Low delay.
4) Low error rate.
5) Broadcast / Multicast capability.
6) Limited geography (1-2 km).
7) Limited number of stations.
8) Peer relationship between stations.
9) Confined to private property.

- The low level protocols used in such environments are different from those used in wide area networks.
- The common forms of LAN are those described by the IEEE standard 802. This standard describes operation upto and including OSI layer 2. Individuals may build what they like on top of these basic protocols.
- A common set of higher level protocols is called TCP/IP which provides OSI layer 3 and 4 functionality, on top of this may be found a set of protocols commonly called Telnet protocols.
- At the lowest level the IEEE 802 specifications split into 3 corresponding to three different but common LAN structures. These are -
802.3, 802.4, 802.5 standards for topology.
- LANs are capable of transmitting data at very fast rates, much faster than data can be transmitted over a telephone line ; but the distances are limited, and there is also a limit on the number of computers that can be attached to a single LAN.
- The following characteristics differentiate one LAN from another :

1. **Topology** : The geometric arrangement of devices on the network. For example, devices can be arranged in a ring or in a straight line.
2. **Protocols** : The rules and encoding specifications for sending data. The protocols also determine whether the network uses a peer-to-peer or client /server architecture.
3. **Media** : Devices can be connected by twisted-pair wire, co-axial cables, or fiber optic cables. Some networks do without connecting media altogether, communicating instead via radio waves.

1.4.2 Metropolitan Area Networks (MAN)

- A MAN, while larger than LAN is limited to city or group of nearby corporate offices. It uses similar technology of LAN.
- The Metropolitan Area Network standards are sponsored by the IEEE, ANSI and the Regional Bell operating companies. The MAN standard is organized around a topology and technique called Distributed Queue Dual Bus (DQDB).
- MAN provides the transfer rates from 34 to 150 Mbps.
- MAN is designed with two unidirectional buses. Each bus is independent of the other in the transfer of traffic. The topology can be designed as an open bus or a closed configuration.
- MANs are based on fiber optic transmission technology and provide high speed interconnection between sites. It can support both data and voice.
- MAN as a special category is that a standard has been adopted for them and this standard is now being implemented. It is called IEEE 802.6.

1.4.3 Wide Area Networks (WAN)

- A WAN provides long distance transmission of data and voice.
- A Network that covers a larger area such as a city, state, country or the world is called **wide area network.**
- The WAN contains host and collection of machines. User program is installed on the host and machines. All the host are connected by each other through communication subnet. Subnet carries messages from host to host.
- Fig. 1.4.2 shows the component of WAN.

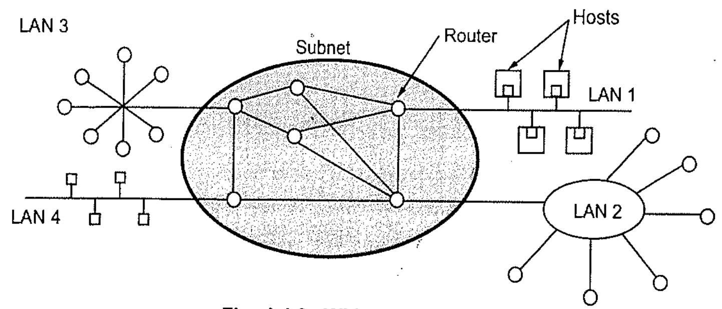


Fig. 1.4.2 Wide area network

- Subnet consists of transmission lines and switching elements. The transmission line is used for data transfer between two machines. Switching elements are used for connecting two transmission lines. Switching elements are specialized computers. It selects the proper outgoing line for incoming data and forward the data on that line.

- The switching elements are basically computers and they are called packet switching nodes, intermediate systems and data switching exchanges. These switching elements are also called routers.
- Each host is connected to a LAN on which a router is present. Sometimes the host can be directly connected to the router. The interconnection of routers forms the subnet.
- In the WAN, when the packet is sent from one router to another via one or more intermediate routers, the packet is received at each intermediate router in its entirety. This packet is stored in that router until the required output line is free. The subnet which uses this principle is called point-to-point, store and forward, or packet switched subnet.
- Almost all the WANs use store and forward subnets.
- If the packets are small and of same size, they are also called cells.
- In the point-to-point subnet, the router interconnection topology becomes important. WANs can also use satellite or ground radio system. The routers have antenna, through which they can send or receive data, they can listen from satellite.
- WAN uses hierarchical addressing because they facilitate routing. Addressing is required to identify which network input is to be connected to which network output.

1.4.4 Comparison between LAN, WAN and MAN

Parameter	LAN	WAN	MAN
Area covered	Covers small area. i.e. within the building.	Covers large geographical area	Covers larger than LAN & smaller than WAN.
Error rates	Lowest.	Highest.	Moderate.
Transmission speed	High speed.	Low speed.	Moderate speed.
Equipment cost	Uses inexpensive equipment.	Uses most expensive equipment.	Uses moderately expensive equipment.

1.4.5 Comparison between LAN and WAN

Sr. No.	LAN	WAN
1.	It covers small area.	WAN covers large geographical area.
2.	LAN operates on the principal of broadcasting.	WAN operates on the principal of point to point.
3.	Used for time critical application.	Not used for time critical application.
4.	Transmission speed is high.	Transmission speed is low.
5.	Easy to design and maintain.	Design and maintenance is not easy.
6.	LAN is broadcasting in nature.	WAN is point-to-point in nature.
7.	Transmission medium is co-axial or UTP cable.	Transmission or communication medium is PSTN or satellite link.
8.	LAN does not suffer form propagation delay.	WAN suffer from propagation delay.

1.4.6 Wireless Networks

- A wireless LAN or WLAN is a wireless local area network that uses radio waves as its carrier. The last link with the users is wireless, to give a network connection to all users in a building or campus. The backbone network usually uses cables.
- Wireless LANs operate in almost the same way as wired LANs, using the same networking protocols and supporting the most of the same applications.

How are WLANs Different ?

1. They use specialized **physical and data link** protocols
2. They integrate into existing networks through **access points** which provide a bridging function
3. They let you stay connected as you **roam** from one coverage area to another
4. They have unique **security** considerations
5. They have specific **interoperability** requirements
6. They require **different hardware**
7. They offer **performance** that differs from wired LANs.

- **Physical Layer :** The wireless **NIC** takes **frames** of data from the link layer, scrambles the data in a predetermined way, then uses the modified data stream to modulate a **radio carrier signal.**
- **Data Link Layer :** Uses Carriers-Sense-Multiple-Access with Collision Avoidance (CSMA/CA).
- Wireless Access Points (APs) is a small device that bridges wireless traffic to your network. Most access point's bridge wireless LANs into Ethernet networks, but Token-Ring options are available as well.

- A family of wireless LAN (WLAN) specifications developed by a working group at the Institute of Electrical and Electronic Engineers (IEEE). It defines standard for WLANs using the following four technologies
  1. Frequency Hopping Spread Spectrum (FHSS)
  2. Direct Sequence Spread Spectrum (DSSS)
  3. Infrared (IR)
  4. Orthogonal Frequency Division Multiplexing (OFDM)
- WLAN versions are : 802.11a, 802.11b, 802.11g, 802.11e, 802.11f, 802.11i

1.5 Protocol Layering

SPPU : May-12, Dec.-13

- A computer network must provide general, cost effective, fair and robust connectivity among a large number of computers. Designing a network to meet these requirements is no small task.
- To deal with this complexity, network designers have developed general blue prints - usually called network architectures. It guides the design and implementation of networks.

1.5.1 Layered Architecture

- Computer network is designed around the concept of layered protocols or functions. For exchange of data between computers, terminals or other data processing devices, there is data path between two computers, either directly or via a communication network.
- Following factors should be considered.
  1. The source system must either activate the direct data communication path or inform the communication network to the identity of the desired destination system.
  2. Provide for standard interface between network functions.
  3. Provide for symmetry in function performed at each node in the network. Each layer performs the same functions as its counter part in the other node of network.
- The network software is now highly structured.

1.5.2 Protocol Hierarchies

- Most of all networks are organized as a series of layers, each one built upon the one below it. Because of layer, it reduces the design complexity.

- In layer protocols, a layer is a service provider and may consists of several service functions. Function is a sub system of a layer.
- Each subsystem may also be made up of entities. An entity is a specialized module of a layer or subsystem.
- Name of the layer, total number of layer, function and content of each layer differ from network to network.
- Protocols are the rules that govern network communication.
- Fig. 1.5.1 shows the five layer network.

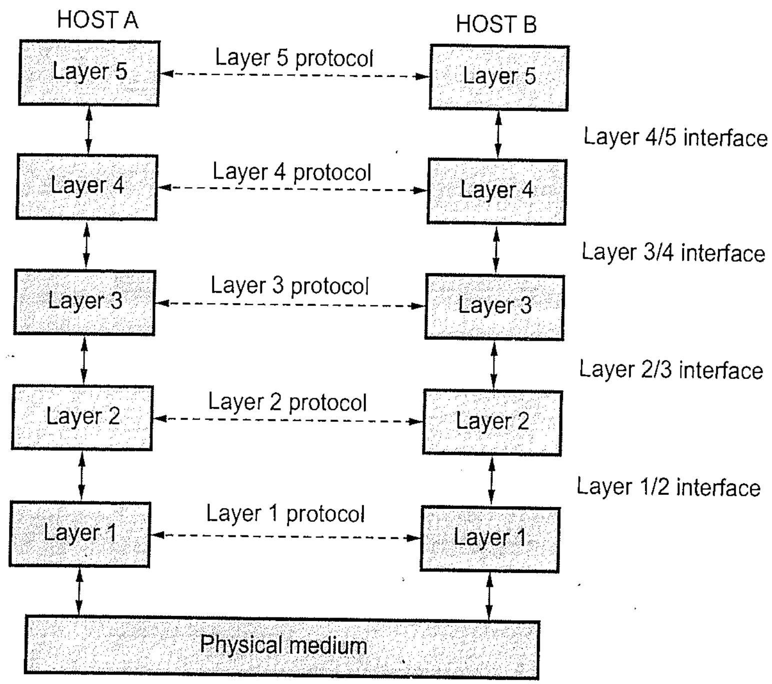


Fig. 1.5.1 Layers, protocols and interfaces

- Layer n on one node carries on a conversation with layer n on other node.
- The entities comprising the corresponding layers on different machine are called **peers.**
- The actual data flow is from upper layer to its below layer and then from physical medium to destination layer.
- Between each pair of adjacent layers is called **interface.** The interface defines which primitive operations and services the lower layer offers to the upper one.
- A set of layers and protocols is called a **network architecture.**

1.5.3 Interfaces and Services

- The process provides a common technique for the layer to communicate with each other. The standard terminology used for layered networks to request services is provided.
- In Fig. 1.5.2 the layers N+1, N and N–1 are involved in the communication process for layer communication, with each other.

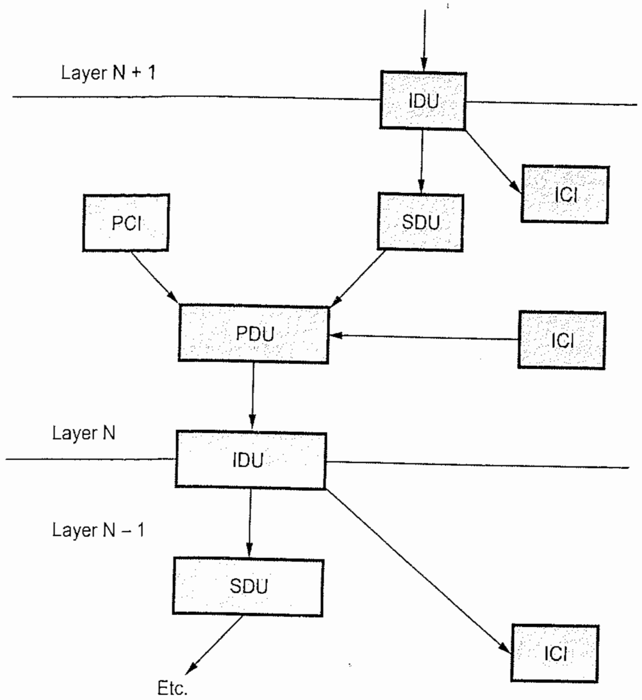


Fig. 1.5.2 Communication between layers

- Following components are involved and their function is as follows :

1. Service Data Unit (SDU)
2. Protocol Control Information (PCI)
3. Protocol Data Unit (PDU)
4. Interface Control Information (ICI)
5. Interface Data Unit (IDU)

Sr. No.	Name	Function
1.	SDU	Transfer user data by layer N+1 to layer N and N-1.
2.	PCI	To perform service function, it is used to exchange information by peer entities at different sites on the network.
3.	PDU	Combination of the SDU and PCI.
4.	ICI	It passes temporary parameter between N and N-1 to invoke service function.
5.	IDU	The total unit of information transferred across the layer boundaries.

- When the IDU from layer N+1 passes to layer N, it becomes the SDU to that layer. PCI is added to SDU at layer N. ICI performs its function and is discarded. Another ICI is added to PDU at layer N and it becomes IDU to layer N–1. Thus a full protocol unit is passed through each layer.
- Each layer adds header to data. This header is used by the peer layer entity at another node of the network to invoke function. This process repeats itself through each layer.
- As each unit traverses through the layer, it has a header added to it i.e. user data and header (SDU and PCI). This full protocol data unit is passed onto the communication path, where it arrives at the receiving site.

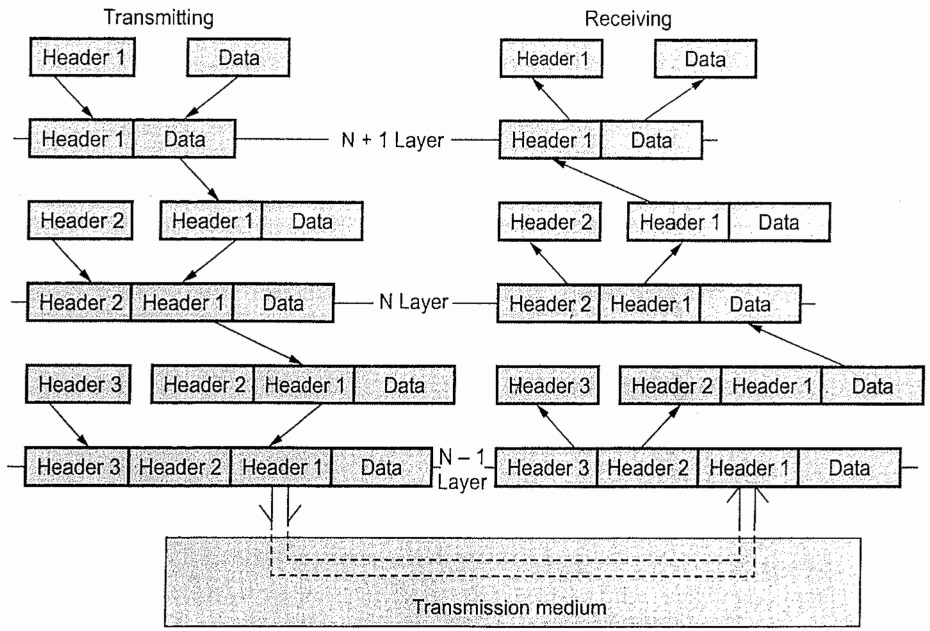


Fig. 1.5.3 Communication between two sites in a network

- In short, each layer added its header to user's data and passes to its next layer. This layer process on that data and adds its own header and provides to next layer for processing. Through transmission channel data passes to receiving site.
- Fig. 1.5.3 shows the communication between two sites in a network.

1.5.4 Connection Oriented and Connectionless Services

- Connection oriented and connectionless are the two types of services, that is offered by the layer.
- In **connection oriented,** direct path is established between source and destination. The telephone system is the example of the connection oriented service. This type of service provides a substantial amount of care for the user data.
- The **connectionless** (also called datagram) service goes directly from an idle condition into a data transfer mode, followed directly by the idle condition.
- The connectionless service is comparable to mailing a letter. Each message carries the full destination address, and each one is routed through the system independent of all the others.
- Each service can be characterized by a quality of service (QOS). Some services are reliable in the sense that they never lose data.
- Usually, a reliable service is implemented by having the receiver acknowledge the receipt of each message, so the sender is sure that it arrived. The acknowledgement process introduces overhead and delays, which are often worth it but are sometimes undesirable.

Fig. 1.5.4 shows the connection oriented and connectionless service operation.

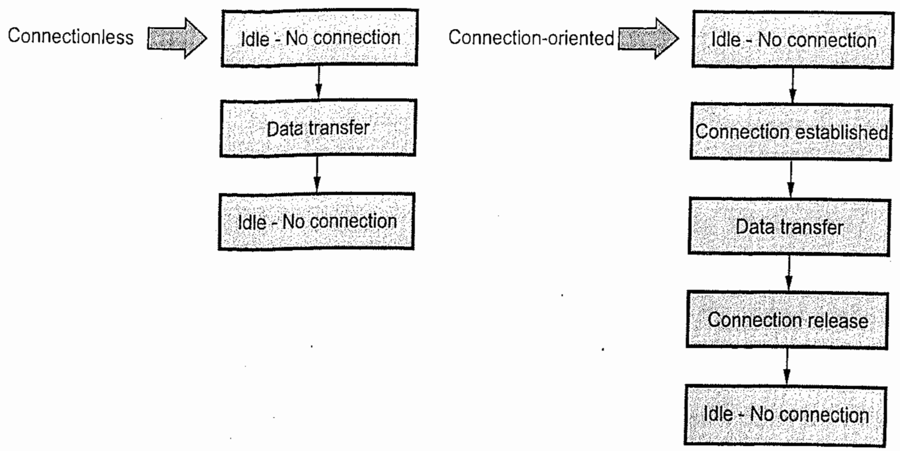


Fig. 1.5.4 Connectionless and connection oriented service

1.5.5 Relationship of Services to Protocols

- Service interface provides an entry point that users use to access the functionality exposed by the application.
- Service interface is usually network addressable.
- Service interface provides a much more coarse-grained interface while preserving the semantics and finer granularity of the application logic. It also provides a barrier that enables the application logic to change without affecting the users of the interface.
- The service interface should encapsulate all aspects of the network protocol used for communication between the user and service. For example, suppose that a service is exposed to consumers through HTTP over a TCP/IP network. User can implement the service interface as an ASP.NET component published to a well-known URL.

University Questions

1. *State and explain the basic service primitives used in client-server model.* **SPPU : May-12, Marks 6**
2. *Explain the terms interfaces, services and protocols.* **SPPU : Dec.-13, Marks 6**

1.6 OSI Model

SPPU : May-12,13

- The ISO was one of the first organizations to formally define a common way to connect computers. Their architecture, called the Open System Interconnection (OSI).
- The International organization for standardization developed the **Open System Interconnection (OSI)** reference model. OSI model is the most widely used model for networking.
- OSI model is a seven layer standard.
- The OSI model does not specify the communication standard or protocols to be used to perform networking tasks.
- OSI model provides following services.
  1) Provides peer-to-peer logical services with layer physical implementation.
  2) Provides standards for communication between system.
  3) Defines point of interconnection for the exchange of information between system.
  4) Each layer should perform a well defined function.
  5) Narrows the options in order to increase the ability to communicate without expansive conversions and translations between products.

Principles in defining OSI layers

- Following principles are used in defining the OSI layers.

1. Do not create so many layers as to make the system engineering task of describing and integrating the layers more difficult than necessary.
2. Create a boundary at a point where the description of services can be small and the number of interrelations across the boundary are minimized.
3. Create separate layers to handle function that are manifestly different in the process performed.
4. Collect similar functions into the same layer.
5. Select the boundaries at a point which past experience has demonstrated to be successful.
6. Create a layer of easily localized functions so that the layer could be totally redesigned and its protocols changed in a major way to take advantage of new advances in architecture, hardware or software technology without changing the services expected from and provided to the adjacent layers.
7. Create a boundary where it may be useful at some points in time to have the corresponding interface standardized.
8. Create a layer where there is a need for a different level of abstraction in the handling of data.
9. Allow changes of functions or protocols to be made within a layer without affecting other layers.
10. Create for each layer boundaries with its upper and lower layer only.

- Fig. 1.6.1 shows the OSI 7 layer reference model.

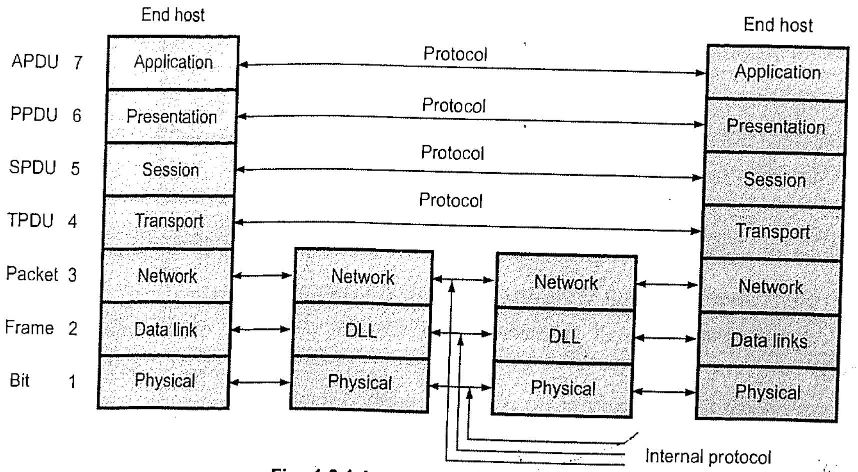


Fig. 1.6.1 Layer of OSI model

1.6.1 Layers in OSI Models

1. Physical Layer

- Physical layer is the lowest layer of the OSI model. Physical layer co-ordinates the functions required to transmit a bit stream over a communication channel. It deals with electrical and mechanical specifications of interface and transmission media. It also deals with procedures and functions required for transmission.
- The position of physical layer with transmission medium and the next layer (data link layer) is shown in Fig. 1.6.2

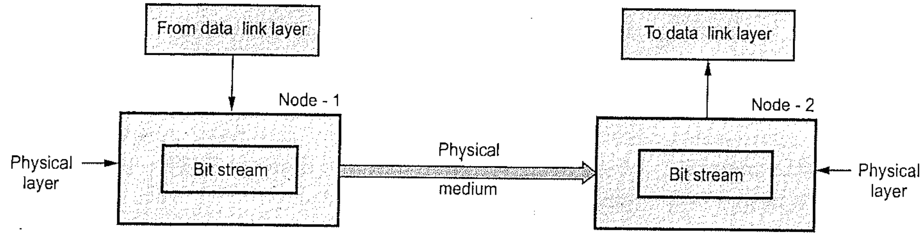


Fig. 1.6.2 Physical layer

Functions of Physical Layer

1. Physical characteristics of interfaces and media : The design issue of physical layer considers the characteristics of interface between devices and transmission media.

2. Representation of bits : Physical layer encodes the bit stream into electrical or optical signal.

3. Data rate : The physical layer defines the duration of a bit which is called as data rate or transmission rate.

4. Synchronization of bits: The transmission rate and receiving rate must be same. This is done by synchronizing clocks at sender and receiver. Physical layer performs this function.

2. Data Link Layer

- The data link layer is responsible for transmitting frames from one node to the next. It transforms the physical layer to a reliable link making it an error free link to upper layer. Fig. 1.6.3 shows data link layer. (See Fig. 1.6.3 on next page.)

Functions of Data Link Layer

1. Framing : The frames received from network layer is divided into manageable data units called frames.

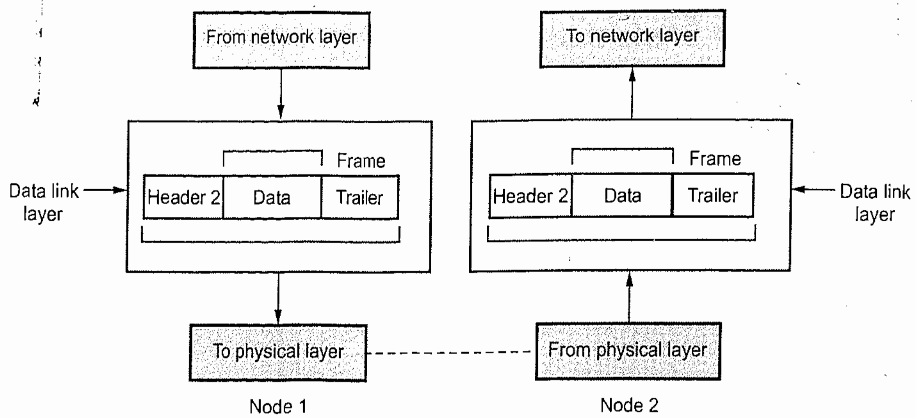


Fig. 1.6.3 Data link layer

2. Physical addressing : When frames are to be sent to different LANs, the data link layer adds a header to the frame to define sender or receiver.

3. Flow control : When the rate of the data transmitted and rate of data reception by receiver is not same, some data may be lost. The data link layer imposes a flow control mechanism to prevent overwhelming the receiver.

4. Error control : Data link layer incorporates reliability to the physical layer by adding mechanism to detect and retransmit damaged or lost frames.

5. Access control : When multiple devices are connected to same link, the data link layer determines which device has control over link.

3. Network Layer : The network layer is responsible for the delivery of packets from the source to destination. Fig. 1.6.4 shows network layer.

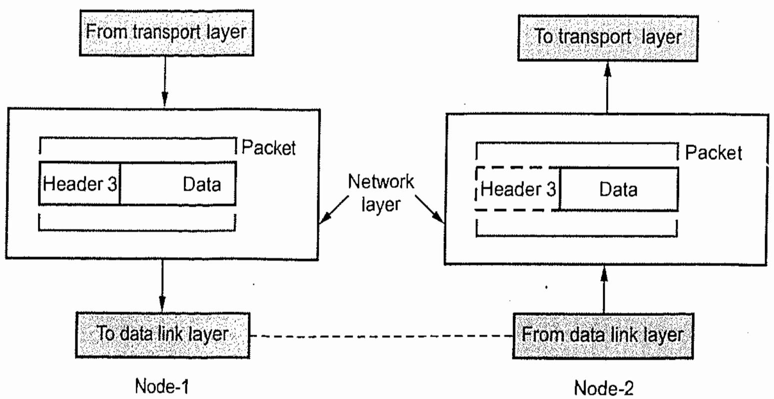


Fig. 1.6.4 Network layer

Functions of Network Layer

1. Logical addressing : Data link layer implements physical addressing. When a packet passes network boundary, an addressing system is needed to distinguish source and destination, network layer performs these function. The network layer adds a header to the packet of upper layer includes the logical addresses of sender and receiver.

2. Routing : Network layer route or switch the packets to its final destination in an internetwork.

4. Transport Layer : The transport layer is responsible for delivery of message from one process to another. The network does the host to destination delivery of individual packets considering it as independent packet. But transport layer ensures that the whole message arrives intact and in order with error control and process control. Fig. 1.6.5 shows transport layer.

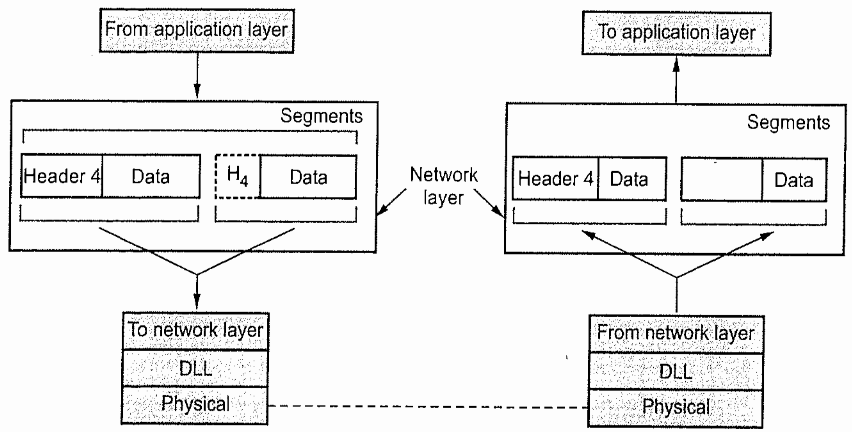


Fig. 1.6.5 Transport layer

Functions of Transport Layer

1. Port addressing :

- Computer performs several operations simultaneously. Process-to-process delivery means specific process of one computer must be delivered to specific process on other computer. The transport layer header therefore include port address.
- Network layer delivers packet to the desired computer and transport layer, gets message to the correct process on that computer.

2. Segmentation and reassembly : A message is divided into segments, each segment contains a sequence number which enables transport layer to reassemble at destination.

3. Connection control : Transport layer performs connectionless or connection oriented services with the destination machine.

4. Flow control : Transport layer performs end-to-end flow control while data link layer performs it across the link.

5. Error control : Error control at this layer is performed on end-to-end basis rather than across the link. The transport layer ensures error free transmission.

5. Session Layer :

- The session layer is network dialog controller i.e. it establishes and synchronizes the interaction between communication system. Fig. 1.6.6 shows session layer.

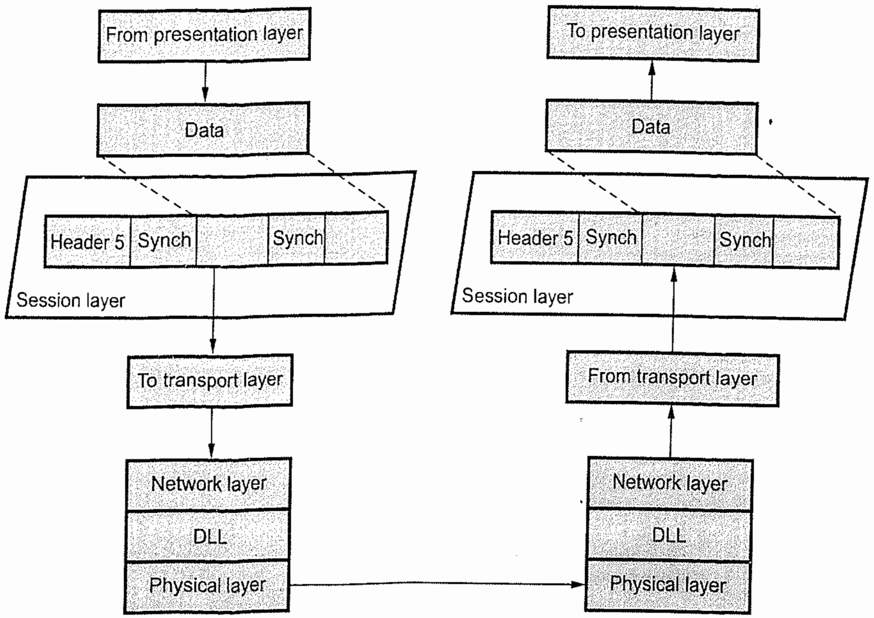


Fig. 1.6.6 Session layer

Functions of Session Layer

1. Dialog control : Communication between two processes take place in either half duplex or full-duplex mode. The session layer manages dialog control for this communication.

2. Synchronization : Session layer adds synchronization points into stream of data.

6. Presentation Layer :

- The presentation layer deals with syntax and semantics of the information being exchanged. Fig. 1.6.7 shows presentation layer.

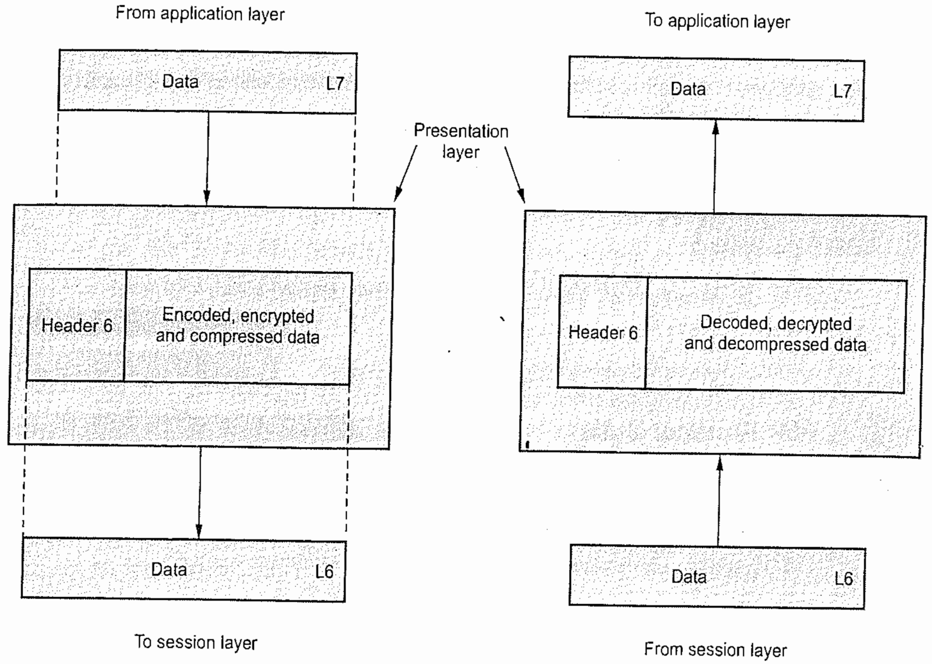


Fig. 1.6.7 Presentation layer

Functions of Presentation Layer

1. Translation : Different computers use different encoding systems. The presentation layer maintains interoperability between the two encoding systems.

2. Encryption : Encryption is transforming sender information to other form to ensure privacy while transmission. Decryption is a reverse process.

3. Compression : Compression is a technique of reducing number of bits required to represent the data.

7. Application Layer

- Application layer is responsible for accessing the network by user. It provides user interfaces and other supporting services such as e-mail, remote file access, file transfer, sharing database, message handling (X.400), directory services (X.500).

Functions of Application Layer

1. **Network virtual terminal** : It is a software version of physical terminal that allows a user to log onto a remote host.
2. **File Transfer, Access and Management (FTAM)** : FTAM allows user to access files in remote hosts, to retrieve files and to manage files in remote computer.
3. **Mail services** : E-mail forwarding, storage are the services under this category.
4. **Directory services** : Directory services include access for global information and distributed database.

University Questions

1. *Draw the neat diagram of OSI model and explain in brief the function of each layer in it.* **SPPU : May-12, Marks 10**
2. *Draw OSI-reference model and explain any three layers.* **SPPU : May-13, Marks 9**

1.7 TCP/IP Protocol Suite **SPPU : Dec-12, 13, 14, May-13, 14**

- The internet architecture, which is also sometimes called the TCP/IP architecture after its two main protocols.
- TCP/IP stands for Transmission Control Protocol / Internet Protocol.
- The TCP/IP reference model is a set of protocols that allow communication across multiple diverse networks.
- TCP/IP is normally considered to be a four layer system. Layers of TCP/IP are Application layer, Transport layer, Internet layer, Host to network layer.
- Host to network layer is also called physical and data link layer.
- The application layer in TCP/IP can be equated with the combination of session, presentation, application layer of the OSI reference model.
- Fig. 1.7.1 shows TCP/IP reference model.
- TCP/IP defines two protocol at transport layer : TCP and UDP.
- **User Datagram Protocol (UDP)** is connectionless protocol.
- UDP is used for application that requires quick but necessarily reliable delivery.

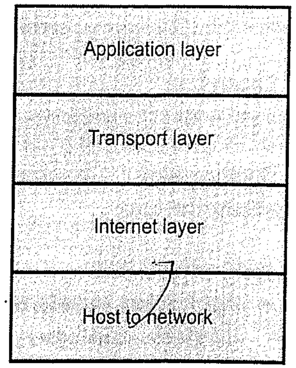


Fig. 1.7.1 TCP/IP reference model

- Internet layer also called **network layer.** Internet layer handles communication from one machine to the other. Routing of packet takes place in internet layer.
- TCP/IP does not define any specific protocol in host to network layer. This layer is responsible for accpeting and transmitting IP datagrams. This layer normally includes the device driver in the operating system.
- Detailed function of each layer is given below.
  1. **Application layer** : Application layer includes all process and services that use the transport layer to deliver data. The most widely known application protocols are : TELNET, File Transfer Protocol (FTP), Simple Mail Transfer Protocol (SMTP) and Simple Network Management Protocol (SNMP). TELNET is the Network Terminal Protocol, which provides remote login over the network. FTP is used for interactive file transfer. SMTP delivers the electronic mail.
  2. **Transport layer** : Application programs send data to the transport layer protocols TCP and UDP. An application is designed to choose either TCP or UDP based on the services it needs.
- The transport layer provides peer entities on the source and destination hosts to carry on a conversation. Both ends protocol is defined in this layer. TCP is reliable connection oriented protocol that allows a byte stream originating on one computer to be delivered without error or any other computer in the internet. It converts the incoming byte stream into discrete message and passes each one onto the internet layer. At the destination side, the receiving TCP reassembles the received data or messages into the output format. TCP also handles flow control. It synchronizes between fast sender and slow receiver. UDP is a connectionless protocol. Sometimes this type of protocol is used for prompt delivery. The relation of the protocols is shown in the Fig. 1.7.2

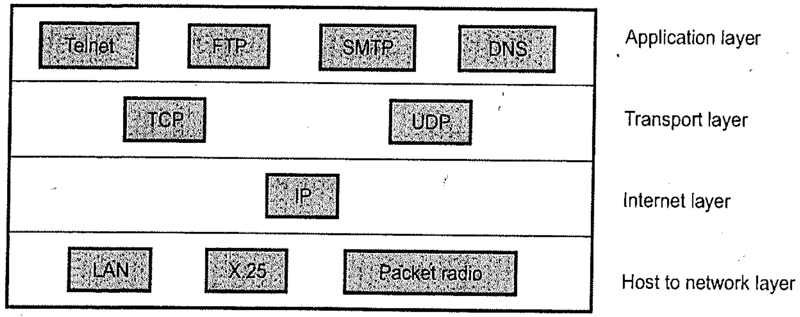


Fig. 1.7.2 Relation of protocol in TCP/IP model

3. **Internet layer** : The Internet network level protocol (IP, ARP, ICMP) handle machine to machine communications.

- These protocols provide for transmission and reception of transport requests and handle network level control. The TCP/IP internet layer moves data from one host to another; even if the hosts are on different networks. The primary protocol used to move data is the Internet Protocol (IP), which provides the following services :
  a. **Addressing** : Determining the route to deliver data to the destination host.

  b. **Fragmentation** : Breaking the messages into pieces if an intervening network cannot handle a large message.
- It provides a connectionless method of delivering data from one host to another. It does not guarantee delivery and does not provide sequencing of datagrams. It attaches a header to datagram that includes source address and the destination address, both of which are unique internet addresses.

4. **Host to network** : This layer is also called network interface layer. This layer is same as **physical and data link layer** of **OSI model. Host to network layer cannot define any protocol.** It is responsible for accpeting and transmitting IP datagrams. This layer may consist of a device driver in the operating system and the corresponding network interface card in the machine.

1.7.1 Comparison of the OSI and TCP/IP Protocol Suite

Sr. No.	OSI	TCP/IP
1.	7 layers	4 layers
2.	Model was first defined before implementation takes place.	Model defined after protocol were implemented.
3.	OSI model based on three concept i.e. service, interface and protocol.	TCP/IP model did not originally clearly distinguish between service, interface and protocol.
4.	OSI model gives guarantee of reliable delivery of packet.	Transport layer does not always guarantee the reliable delivery of packet.
5.	OSI does not support internet working.	TCP/IP support.
6.	Strict layering.	Loosely layered.
7.	Support connectionless and connection-oriented communication in the network layer.	Support only connection-oriented communication in the transport layer.

University Questions

1. *Explain TCP - IP for its relationship of layers and their addresses with an example.* **SPPU : Dec.-12, Marks 8**
2. *Differentiate OSI reference model and TCP/IP.* **SPPU : May-13, Marks 9**
3. *Explain the TCP / IP model with protocols at each layer.* **SPPU : Dec.-13, Marks 8**

4. *Compare OSI and TCP / IP network reference models.* **SPPU : May-14, Marks 4**
5. *Explain TCP / IP reference model with suitable diagram. Compare OSI reference model with TCP / IP.* **SPPU : Dec.-14, Marks 10**

1.8 Addressing

SPPU : May-14

- An Internet employing TCP/IP protocols uses four levels of addresses :
  1. Physical (Link) addresses
  2. Logical (IP) addresses
  3. Port addresses
  4. Specific addresses
- Fig. 1.8.1 shows level of addresses in TCP/IP.

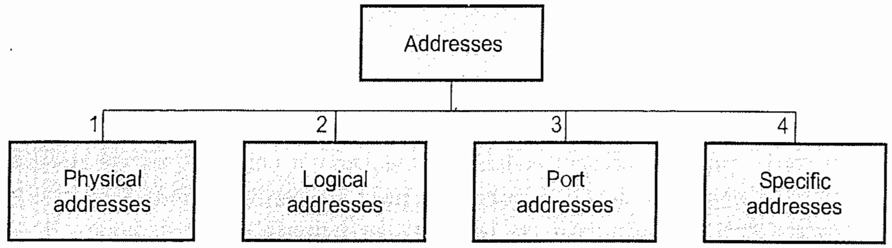


Fig. 1.8.1 Addresses in TCP/IP

- Each address type is related to a specific layer in TCP/IP architecture. Fig. 1.8.2 shows the relationship of layers and addresses in TCP/IP.

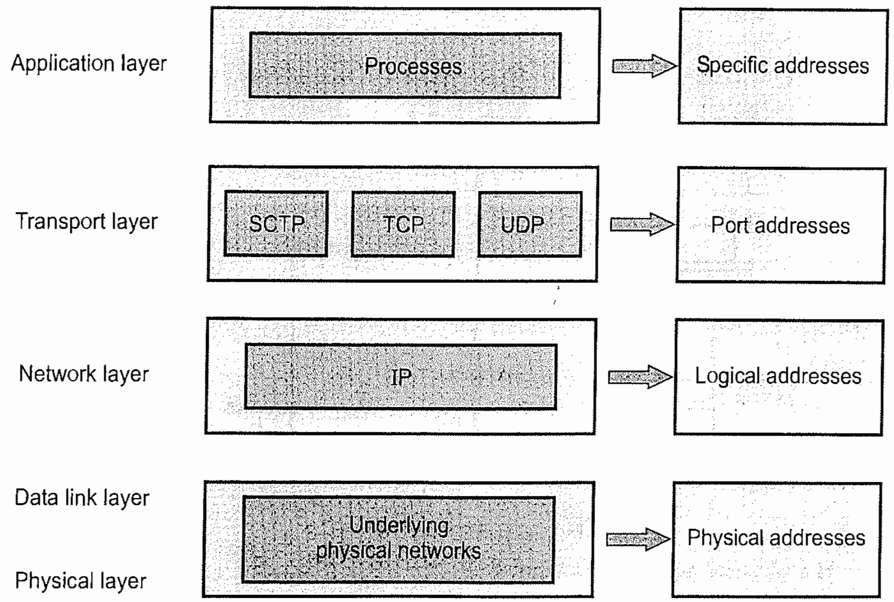


Fig. 1.8.2 TCP/IP layers and associated addresses

1.8.1 Physical Addresses

- The physical address is the lowest level address and is also referred as link address. The physical address of a node is defined by its LAN or WAN. The physical address is included in the frame by the data link layer.
- The size and format of physical addresses vary depending on the network. It has authority over the network. At data link layer, the frame contains physical (link) addresses in the header. The data link layer at sender receives data from upper layer, encapsulates the data in a frame, adds an header and trailer. Only the station having matched address with destination address accepts the frames. The frame is checked, the header and trailer are dropped and data is decapsulated and delivered to upper layer.

1.8.2 Logical Addresses

- Logical addresses are independent of underlying physical networks. Since different networks can have different address formats hence a universal address system is required which can identify each host uniquely irrespective of underlying physical networks. Logical addresses are necessary for universal communications. It is a 32-bit address which uniquely defines host connected to Internet.

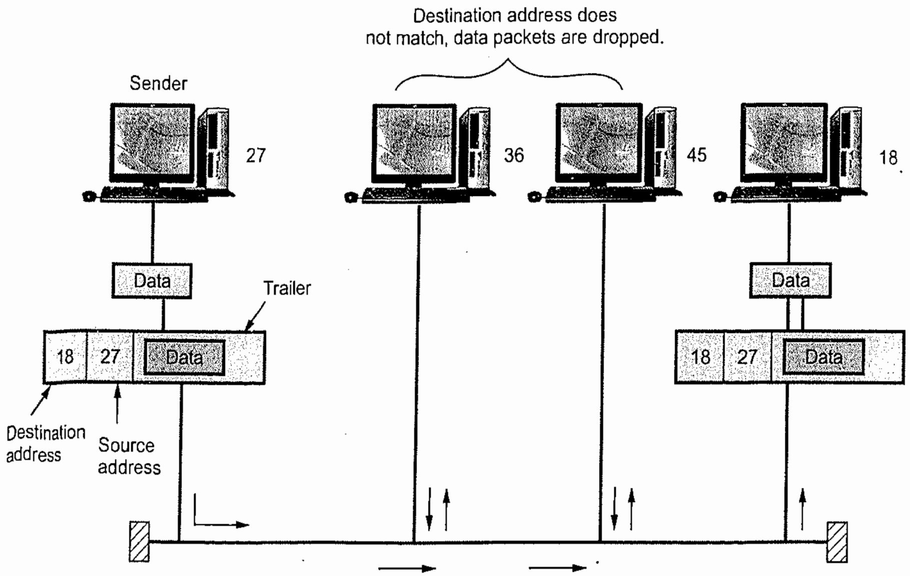


Fig. 1.8.3 Physical addresses

- The physical addresses changes from hop to hop, but the logical address usually remains the same.

1.8.3 Port Addresses

- The IP address and physical address are necessary for data to travel from source to destination. But a communication process involves TELNET and FTP which requires addresses. In TCP/IP architecture, the label assigned to a process is called port address. In TCP/IP the port address is of 16-bit.

1.8.4 Specific Addresses

- Specific addresses are designed by users for some applications. For example, evilaas@in.com and the Universal Resource Locator (URL), www.vtubooks.com. The first example defines the recipient of e-mail and second example is used to find a document on the world wide web.
- The specific addresses gets changed to corresponding port and logical addresses by the station or host who sends it.

University Question

1. *What are the different types of address exists ?* **SPPU : May-14, Marks 4**

1.9 Transmission Media

SPPU : May-14

- **Media** is the general term used to describe the data path that forms the physical channel between sender and receiver. Transmission media can be twisted pair wire such as that used for telephone installation, wire media are referred to as **bounded media** and wireless media are sometimes referred to as **unbounded media**.
- Different types of transmission media is used for different data transfer rates and long distances. Bandwidth, noise, radiation and attenuation are considered while using the different transmission media.
- Higher bandwidth transmission media support higher data rates.
- Attenuation limits the usable distance that data can travel on the media. Noise is related to electrical signal noise that can cause distortion of the data signal and data errors.
- Radiation is the leakage of signal from the media caused by undesirable electrical characteristics of the transmission media.
- The **transmission medium** is the physical path between transmitter and receiver in a data transmission system. In transmission medium, communication is in the form of electromagnetic waves.
- The characteristics and quality of transmission are determined both by the characteristics of the medium and the characteristics of signal.

1.9.1 Classification of Transmission Media

- The transmission medium can be mainly classified into two types.
  1. Bounded or guided media
  2. Unbounded or unguided media.
- **Bounded or guided media**

Depending on the type of transmission medium used the bounded media can be further classified into three types.

1. Twisted pair cable 2. Co-axial cable 3. Fiber optic cable.

The bounded media is also called as wired media.

- **Unbounded or unguided media**

Depending on the method of transmission the unbounded media can be further classified into two types.

1. Microwave links or radio links.
2. Infrared.

Fig. 1.9.1 indicates the classification of transmission media.

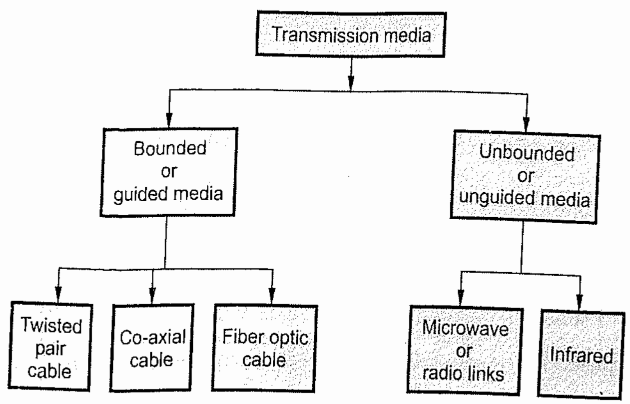


Fig. 1.9.1 Classification of transmission media

1.9.2 Selection of Transmission Media

- The selection of transmission medium depends on following factors
  1. Design factors 2. Guided or unguided media.

1] Design factors :

- The key factors for designing a transmission system is data rate and distance of transmission.

- Following factors determine the data rate and distance -
  1. Bandwidth 2. Transmission impairments
  3. Interference 4. Number of receivers.

1. Bandwidth : The greater the bandwidth of the signal, the higher the data rate can be achieved.

2. Transmission impairments : Transmission impairment such as attenuation, limit the distance (repeater spacing) for guided media. Twisted pair generally suffer more impairment than co-axial cable.

3. Interference : In overlapping frequency bands from competing signals can distort or wipe out a signal. This is an interference which is a problem for both guided and unguided media. For guided media interference is caused by emissions from nearby cables. Since they are bounded together. Proper shielding of guided media can minimize this problem.

4. Number of receivers : A guided media is used either for point-to-point link or a shared link with multiple attachments. In multiple attachments, each attachment introduces some attenuation and distortion on the link, this limits the distance and data rate.

2] Guided or unguided media :

- Depending on the type of application and geographical situation suitable guided or unguided media is chosen.
- For long distance point-to-point transmission guided media are suitable.
- For long distance broadcasting transmission unguided media like microwave links are chosen.

University Question

1. *Compare guided and unguided transmission media.* **SPPU : May-14, Marks 4**

1.10 Guided Media

SPPU : May-12, Dec.-14

1.10.1 Twisted Pair (TP) Cable

- Twisted pair is least expensive and most widely used. A Twisted Pair (TP) consists of two insulated copper wires arranged in a regular spiral pattern. A wire pair acts as a single communication link.

- TP may be used to transmit both analog and digital signals. For analog signals amplifiers are required about every 5 to 6 km. For digital signals, repeaters are required every 2 or 3 km.
- TP is most commonly used medium for in the telephone network. Compared to other commonly used transmission media, TP is limited in distance, bandwidth and data rate when two copper wires conduct electric signal in close proximity, a certain amount of Electromagnetic Interference Occurs (EMI). This type of interference is called cross **talk**. Twisting the copper wire reduces cross talk.
- Twisted pair cable comes in two varieties.
  1. Unshielded Twisted Pair (UTP) cable.
  2. Shielded Twisted Pair (STP) cable.

1.10.1.1 Unshielded Twisted Pair (UTP) Cable

- UTP is a set of twisted pairs of cable within a plastic sheet. UTP is ordinary telephone wire. This is the least expensive of all the transmission media commonly used for LAN, and is easy to work with and simple to install.
- UTP is subject to external electromagnetic interference. Category 3 and category 5 UTP are commonly used in computer networks. UTP can transfer data at 1 to 100 Mbps over a distance of 100 meters. The difference between cat3 and cat5 cable is the number of twists in the cable per unit distance. cat5 is much more tightly twisted.
- Fig. 1.10.1 shows the UTP cable.

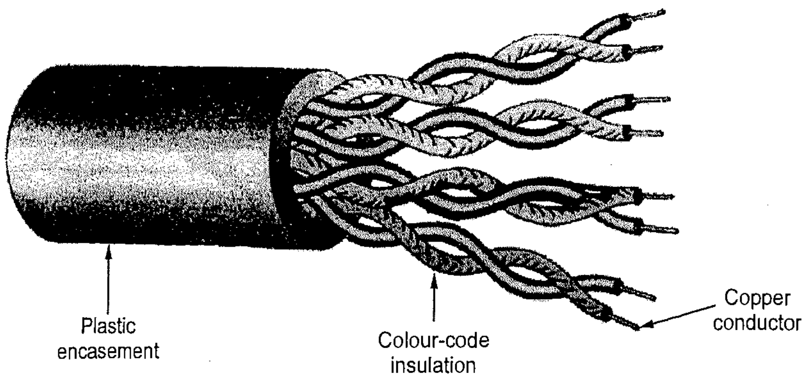


Fig. 1.10.1 Unshielded four pair cable

- The Electronic Industries Association (EIA) has developed standard to grade UTP cable by quality. Category 1 (cat1) as the lowest quality and category 5 (cat5) as the highest quality. Use of each category cable is as follows.

Category 5 : Used in local area network. It support upto 100 Mbps data transmission speed.

Category 4 : It support transmission speed of 16 Mbps and three twist per foot.

Category 3 : It support data transmission speed upto 10 Mpbs. At least three twist per feet and used in telephone system.

Category 2 : It support data transmission speed upto 4 Mbps and suitable for voice data transmission.

Category 1 : Mostly used in telephone system. Cat1 is suitable for voice and low speed data communication.

Characteristics of UTP

- UTP has the following characteristics :
  1. Transmission rate of 10 - 100 Mbps.
  2. UTP is less expensive than FOC and co-axial cable.
  3. Maximum cable segment of UTP is 100 meters.
  4. UTP cable is very flexible and easy to work.
  5. UTP uses RJ - 45 connector.
  6. Most susceptible to electrical interference or cross talk.

Advantages of UTP

1. UTP is easy to terminate.
2. Cost of installation is less.
3. High installed base.

Disadvantages of UTP

1. It is very noisy.
2. It covers less distance.
3. UTP suffers from interference.

1.10.1.2 Shielded Twisted Pair (STP) Cable

- STP offers a protective sheathing around the copper wire. STP provides better performance at lower data rates. They are not commonly used in networks.
- Installation of STP is easy. Special connectors are required for installation. Cost is moderately expensive. Distance is limited to 100 meters to 500 meters. STP suffers from outside interference but not as much UTP. Fig. 1.10.2 shows the STP cable.

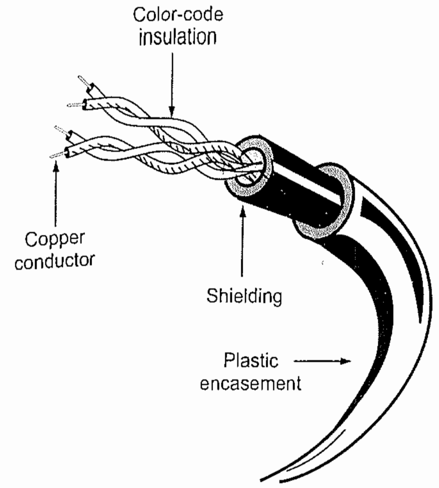


Fig. 1.10.2 Shielded twisted pair (STP) cable

Applications of TP Cable

1) Twisted pair cable used for both analog and digital signals.

2) Twisted pair cable are used in telephone network.

3) In LAN, TP wires are mainly use for low cost, low performance applications.

1.10.1.3 Comparison of UTP and STP

Sr. No.	Parameter	UTP	STP
1.	Data rate	10-100 Mbps	150 Mbps
2.	Cable length	100 meters max.	500 meters max.
3.	Electrical interference	Most susceptible to interference or cross-talk	Less susceptible to interference or cross-talk
4.	Installation	Easy to install	Very easy to install
5.	Cost	Lowest	Little costly

1.10.2 Co-axial Cable

- It is made up of two conductors that share the common axis. It consists of a hollow outer cylindrical conductor that surrounds a single inner wire conductor.
- Co-axial cable is used to transmit both analog and digital signals. Data transfer rate of co-axial cable is used to transmit both analog and digital signals. Data transfer rate of co-axial cable is in between TP and fiber optic cable.

- Co-axial cable is classified by size (RG) and by the cable resistance to direct or alternating electric currents. Following are some co-axial cable commonly used in networking. RG means Government Ratings.
  - 50 ohm, RG - 8 and RG - 11 for thick Ethernet.
  - 50 ohm, RG - 58 used for thin Ethernet.
  - 75 ohms, RG - 59 used for cable TV.
  - 93 ohm, RG - 62 used for ARC net.
- It is relatively inexpensive. The cost for thin co-axial cable is less than STP. Thick co-axial is more expensive than STP. Installation is relatively simple. Co-axial cable must be grounded and terminated.
- A typical data rate for today's co-axial network is 10 Mbps, although potential is higher. It suffers from attenuation. Fig. 1.10.3 shows the co-axial cable.

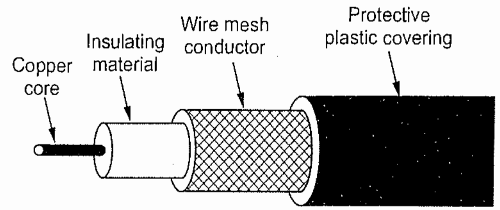


Fig. 1.10.3 Co-axial cable

1. Characteristic of co-axial cable

- Co-axial cable has the following characteristics
  1. 10 Mbps is the transmission rate.
  2. Maximum cable length for thinnet is 185 meters and for thicknet is 500 meters.
  3. Flexible and easy to work with thinnet.
  4. Ethernet designation to 10 base 2 (thinnet) or 10 base 5 (thicknet).
  5. Less expensive than fiber optics cable but more expensive than twisted pair.
  6. Good resistance to electrical interference.

2. Advantages of co-axial cable

1. Co-axial cable used for both data transmission. i.e. analog and digital data transmission.
2. It has higher bandwidth.
3. Easy to handle and relatively inexpensive as compared to fiber optic cables.
4. It uses for longer distances at higher data rates.
5. Excellent noise immunity.

3. Disadvantages of co-axial cable

1. Distance is limited.
2. Number of node connection is limited.
3. Proper connectors and termination is must.

4. Applications of co-axial cable

1. In analog and digital data transmission.
2. In telephone networks.
3. In Ethernet LANs.
4. In cable television network.

1.10.3 Fiber Optic Cable (FOC)

- A fiber optic cable is a light pipe which is used to carry a light beam from one place to another.
- Light is an electromagnetic signal and can be modulated by information. Since the frequency of light is extremely high hence it can accomodate wide bandwidths of information, also higher data rate can be achieved with excellent reliability.
- The modulated light travel along the fiber and at the far end, are converted to an electrical signal by means of a photo electric cell. Thus the original input signal is recovered at the far end.
- FOC transmits light signals rather than electrical signals. Each fiber has a inner core of glass or plastic that conducts light. The inner core is surrounded by cladding, a layer of glass that reflects the light back into core.
- A cable may contain a single fiber, but often fibers are bundled together in the centre of the cable.
- FOC may be multimode or signal mode. Multimode fibers use multiple light paths whereas signal mode fibers allow a single light path and are typically used with laser signaling. It has greater bandwidth.

1.10.3.1 Types of Fiber

- There are three varieties of optical fibers available. All three varieties are constructed of either glass, plastic or a combination of glass and plastic. The three varieties are :
  1. Plastic core and cladding
  2. Glass core with plastic cladding (often called PCS fiber, plastic-clad silica)
  3. Glass core and glass cladding (often called SCS, silica-clad silica)

1. Plastic core and cladding :

- Plastic fibers have several advantages over glass fibers. First, plastic fibers are more flexible and, consequently, more rugged than glass. They are easy to install, can better withstand stress, are less expensive and weigh approximately 60 % less than glass. The disadvantages of plastic fibers is their high attenuation characteristic; they do not propagate light as efficiently as glass. Consequently, plastic fibers are limited to relatively short runs, such as within a single building or a building complex.

2. Glass core with plastic cladding :

- Fibers with glass cores exhibit low attenuation characteristics. However, PCS fibers are slightly better than SCS fibers. Also, PCS fibers are less affected by radiation and are therefore more attractive to military applications.

3. Glass core and glass cladding :

- SCS fibers have the best propagation characteristics and they are easier to terminate than PCS fibers. Unfortunately, SCS cables are the least rugged and they are more susceptible to increase in attenuation when exposed to radiation.
- The selection of a fiber for a given application is a function of specific system requirements. There are always trade-offs based on the economics and logistics of a particular application.
- Presently available fiber cables are with specifications as -
  - 8.3 micron core / 125 micron cladding, single mode
  - 62.5 micron core / 125 micron cladding, multimode
  - 50 micron core / 125 micron cladding, multimode
  - 100 micron core / 140 micron cladding, multimode

1.10.3.2 Modes of Fiber

- Fiber cables can also be classified as per their mode. Light rays propagate as an electromagnetic wave along the fiber. The two components, the electric field and the magnetic field form patterns across the fiber. These patterns are called **modes** of transmission. The mode of a fiber refers to the number of paths for the light rays within the cable. According to modes optic fibers can be classified into two types.

  i) Single mode fiber.

  ii) Multimode fiber.
- Single mode fiber allows propagation of light ray by only one path. And multimode fiber allows multiple paths for light ray to propagate.

  The number of modes (N) is given by the formula.

$$N = \frac{1}{2}\left[\frac{\pi d}{\lambda}\sqrt{n_1^2 - n_2^2}\right]^2$$

$$N = \frac{1}{2}\left[\frac{\pi d}{\lambda} N_A\right]^2 \quad \because \; N_A = \sqrt{n_1^2 - n_2^2}$$

where d = Diameter of core

N_A = Numerical aperture

λ = Wavelength of light ray

1.10.3.3 Fiber Optic Configuration

- Depending on the refractive index profile of fiber and modes of fiber there exist three types of optical fiber configurations. These optic-fiber configurations are -
  i) Single-mode step-index fiber.
  ii) Multimode step-index fiber.
  iii) Multimode graded-index fiber.

Single-Mode Step-Index Fiber

- In **single-mode step-index** fiber has a central core that is sufficiently small so that there is essentially only one path for light ray through the cable. The light ray is propagated in the fiber through reflections. Typical core sizes are 2 to 15 μm. The disadvantage of this type of cable is that because of extremely small size interconnection of cables and interfacing with source is difficult.

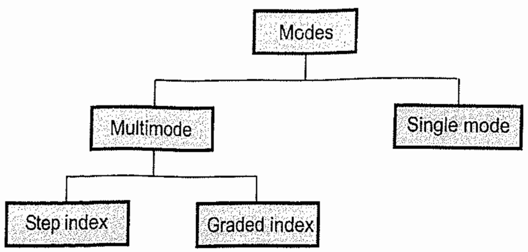


Fig. 1.10.4 Propagation modes

Multimode Step-Index Fiber

- **Multimode step-index fiber** is most widely used type. It is easy to manufacture. Its core diameter is 50 to 1000 μm i.e. large aperture and allows more light to enter the cable. The light rays are propagated down the core in zigzag manner. There are many paths that a light ray may follow during the propagation.

Multimode Graded-Index Fiber

- The core size of **multimode graded-index fiber** cable is varying from 50 to 100 μm range. The light ray is propagated through the refraction. The light ray enters the fiber at many different angles. As the light propagates across the core toward the center it is intersecting a less dense to more dense medium. Therefore the light rays are being constantly being refracted and ray is bending continuously. This cable is mostly used for long distance communication.

1.10.3.4 Characteristics of Fibre Optic Cable

- Fibre optic cable has the following characteristics :

1. Transmission rate of 100 Mbps.
2. Not affected by the electrical interference.
3. Most expensive cable.
4. FOC support cable length of 2 km or more.
5. It supports voice, video and data.
6. It provides most secured media.
7. Commonly used as backbones between buildings and token ring networks.
8. Not very flexible, difficult to work.

1.10.3.5 Advantages and Disadvantages of Optical Fiber

Advantages

1. **Wide bandwidth :** The light wave occupies the frequency range between 2×10^{12} Hz to 3.7×10^{12} Hz. Thus the information carrying capability of fiber optic cables is much higher.
2. **Low losses :** Fiber optic cables offers less signal attenuation over long distances. Typically it is less than 1 dB/km.
3. **Immune to cross talk :** Since fiber optic cables are non-conductors of electricity hence they do not produce magnetic field. Thus fiber optic cables are immune to cross talk between cables caused by magnetic induction.
4. **Interference immune :** Fiber optic cables are immune to conductive and radiative interferences caused by electrical noise sources such as lightening, electric motors, fluorescent lights.
5. **Light weight :** As fiber cables are made of silica glass or plastic which is much lighter than copper or aluminium cables. Light weight fiber cables are cheaper to transport.

6. **Small size :** The diameter of fiber is much smaller compared to other cables, therefore fiber cable is small in size, requires less storage space.
7. **More strength :** Fiber cables are stronger and rugged hence can support more weight.
8. **Security :** Fiber cables are more secure than other cables. It is almost impossible to tap into a fiber cable as they do not radiate signals.

   No ground loops exist between optical fibers hence they are more secure.
9. **Long distance transmission :** Because of less attenuation transmission at a longer distance is possible.
10. **Environment immune :** Fiber cables are more immune to environmental extremes. They can operate over a large temperature variations. Also they are not affected by corrosive liquids and gases.
11. **Safe and easy installation :** Fiber cables are safer and easier to install and maintain. They are nonconductors hence there is no shock hazards as no current or voltage is associated with them. Their small size and lightweight feature makes installation easier.
12. **Long term** cost of fiber optic system is less compared to any other system.

Disadvantages

1. **High initial cost :** The initial installation or setting up cost is very high compared to all other systems.
2. **Maintenance and repairing cost :** The maintenance and repairing of fiber optic systems is not only difficult but expensive also.

1.10.4 Comparison of Performance Characteristics of Guided Media

Sr. No.	Co-axial cable	Twisted pair cable	Fiber optic cable
1.	It uses electrical signal for transmission.	TP uses electrical signal for transmission.	FOC uses optical form of signal over a glass fiber.
2.	Less affect by EMI.	Affected by EMI.	Not affected by EMI.
3.	Bandwidth is moderately high (350 MHz)	Bandwidth is low. (3 MHz)	Bandwidth is very high. (2 GHz)
4.	Support moderately high data rates. (500 Mbps)	Support low data rates. (4 Mbps)	Data rates is very high. (2 Gbps)

5.	Moderately costly.	Cheapest.	Costly.
6.	Repeater spacing is 1-10 km.	Repeater spacing 2 - 10 km.	Repeater spacing is 10-100 km.
7.	It supports all radio frequencies.	Support all radio frequencies.	Frequency range is 902 MHz to 928 MHz.
8.	Low attenuation.	High attenuation.	Very low attenuation.

1.10.5 Connectors for Media

- Connectors are used to connect guided media (cables) to the computers. Varieties of connectors are available for different types of cables. Major categories of connectors are -

  1. UTP cable connectors. 2. Co-axial cable connectors.

  3. Fiber optic cable connectors.

1.10.5.1 RJ-45 (UTP)

- Most commonly used connectors for UTP cable is Registered Jack 45 (RJ - 45). The RJ-45 is a keyed connector i.e. they can be inserted in only one way.

Fig. 1.10.5 shows RJ - 45 male-female connectors.

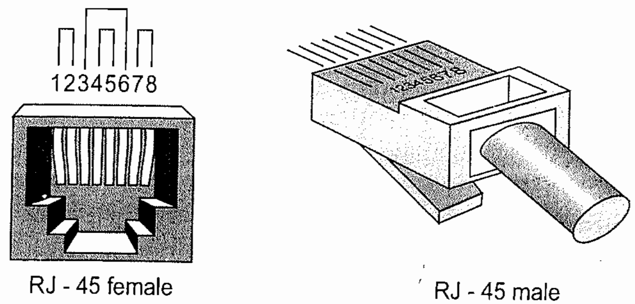


Fig. 1.10.5 RJ-45 connectors

RJ - 45 is a type of connector commonly used for Ethernet networking. Since Ethernet cables have an RJ - 45 connector on each end, Ethernet cables are sometimes also called RJ - 45 cables. The "RJ" in RJ - 45 stands for "registered jack", since it is a standardized networking interface. The "45" simply refers to the number of the interface standard. Each RJ - 45 connector has eight pins, which means an RJ - 45 cable contains eight separate wires.

In Ethernet cable, there are eight wires, which are each a different colour. Four of them are solid colours, while the other four are striped. RJ - 45 cables can be wired in two different ways. One version is called T-568A and the other is T-568B. These wiring standards are listed below :

Sr. No.	T-568A	T-568B
1.	White / Green (Receive +)	White / Orange (Transmit +)
2.	Green (Receive –)	Orange (Transmit –)
3.	White / Orange (Transmit +)	White / Green (Receive +)
4.	Blue	Blue
5.	White / Blue	White / Blue
6.	Orange (Transmit –)	Green (Receive –)
7.	White / Brown	White / Brown
8.	Brown	Brown

The T-568B wiring scheme is by far the most common, though many devices support the T-568A wiring scheme as well. Some networking applications require a crossover Ethernet cable, which has a T-568A connector on one end and a T-568B connector on the other. This type of cable is typically used for direct computer-to-computer connections when there is no router, hub or switch available.

1.10.5.2 Co-axial Cable Connectors

Co-axial cable connectors are also known as BNC connectors. BNC connectors are used in - Cable TVs, Ethernet network. BNC connectors can branch out a cable for connection to a computer or other device. Three different variations of BNC connectors are BNC connector, BNC-T and BNC terminator. Fig. 1.10.6 shows these connectors.

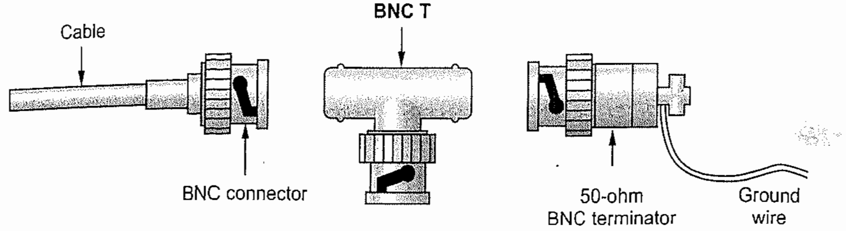


Fig.1.10.6 BNC connectors

1.10.5.3 Fiber Optic Cable Connectors

- Three different types of connectors are used for connecting fiber optic cables. These are -
  1. Subscriber Channel (SC) connector.
  2. Straight Tip (ST) connector.
  3. MT-RJ connector.
- SC connectors are general purpose connectors. It has push-pull type locking system. Fig. 1.10.7 shows SC connector.

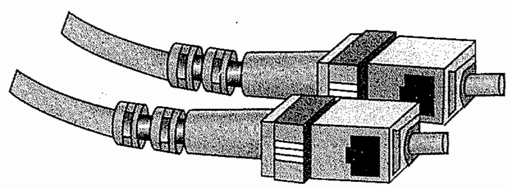


Fig. 1.10.7 SC connector for fiber cable

- ST connectors are most suited for networking devices. It is more reliable than SC connector. ST connector has bayonet type locking system. Fig. 1.10.8 shows ST connectors.

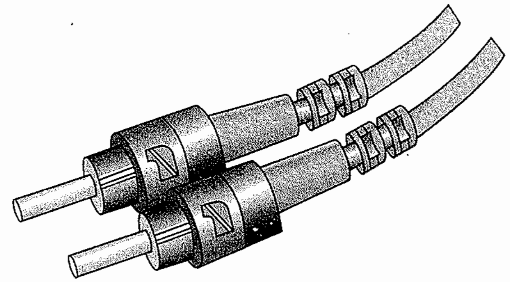


Fig.1.10.8 ST connector for fiber cable

- MT-RJ connector is similar to RJ - 45 connector. Fig. 1.10.9 shows MT-RJ connector.

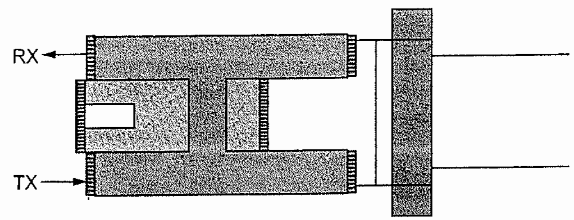


Fig. 1.10.9 MT-RJ connector for fiber cable

University Questions

1. *Explain UTP cable with reference to following :*
   i) Categories ii) Connectors iii) Performance iv) Applications **SPPU : May-12, Marks 8**
2. *Give classification of transmission media. Explain any two guided transmission media.* **SPPU : Dec.-14, Marks 8**

1.11 Unguided Transmission Media

Unguided media transport electromagnetic waves in various ways without using a physical conductor; hence this type of communication is called as wireless communication. The electromagnetic spectrum of wireless communication is shown in the Fig. 1.11.1

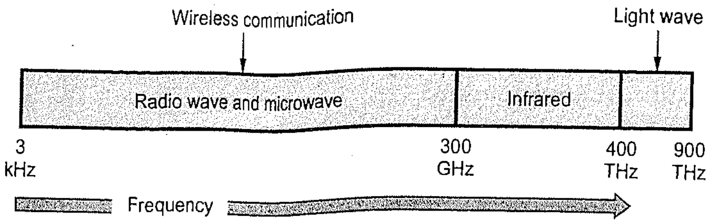


Fig. 1.11.1 Electromagnetic spectrum of wireless communication

- Unguided signals can propagate through several ways such as,
  1. Ground propagation
  2. Sky propagation
  3. Line-of-sight propagation.
- Wireless transmission can be divided into three broad categories : Radio waves, microwave and infrared.

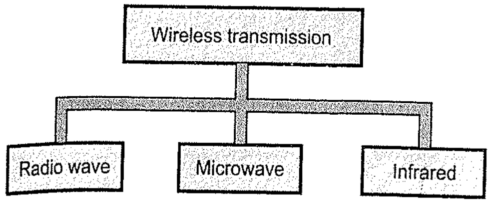


Fig. 1.11.2 Wireless transmission types

1.11.1 Radio Waves

- Radio waves have frequencies between 10 kilohertz (kHz) and 1 gigahertz (GHz). Radio waves include the following types :
  a) Short wave
  b) Very High Frequency (VHF) television and FM radio.
  c) Ultra High Frequency (UHF) radio and television.
- The range of frequency and type of medium used for their transfer is shown in Fig. 1.11.3.
- Radio waves can broadcast omni directionally or directionally. Various kinds of antennas can be used to broadcast radio signals. The power of the Radio Frequency (RF) signal is determined by the antenna and transreceiver (a device that TRANSmits and reCEIVEs a signal over a medium such a copper, radio waves or fiber optic cables).

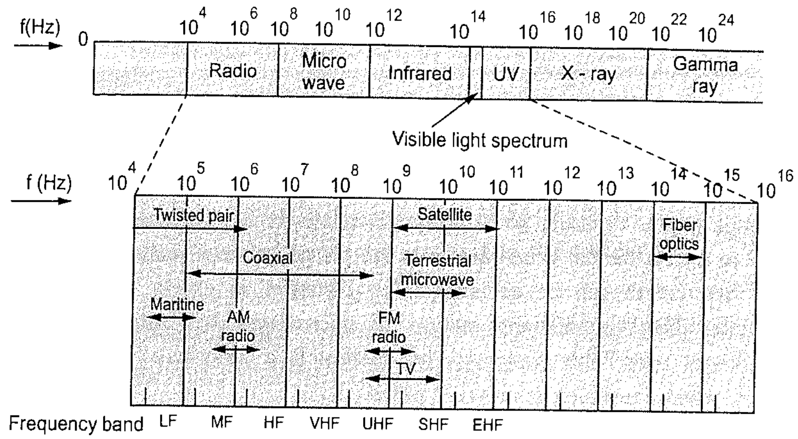


Fig. 1.11.3 Radio frequency and transmission media

1.11.1.1 Radio Wave Characteristics

- Some of the characteristics of radio waves are as follows :
  a) Radio waves are easy to generate.
  b) They can travel long distances.
  c) They can penetrate buildings easily so they are widely used for communications both indoors and outdoors.
  d) Radio waves are omni directional, meaning that they travel in all directions from the source, so that the transmitter and receiver do not have to be carefully aligned physically.
  e) The properties of radio waves are frequency dependent. At low frequencies, radio waves pass through obstacles well, but the power falls off sharply with distance from the source.
- At high frequencies, radio waves are subject to interference from motors and other electrical equipment.
- Low frequency and medium frequency range cannot be used for data transfer because of their very small bandwidth.

1.11.2 Microwaves Transmission

- Above 100 MHz, the waves travel in straight lines and can therefore be narrowly focused. Concentrating all the energy into a small beam using a parabolic antenna (like the satellite TV dish) gives a much higher signal to noise ratio, but the transmitting and receiving antennas must be accurately aligned with each other.

- Before the advent of fiber optics, these microwaves formed the heart of the long distance telephone transmission system.
- In its simplest form the microwave link can be one hop consisting of one pair of antennas spaced as little as one or two kilometers apart or can be a backbone, including multiple hops, spanning several thousand kilometers.
- A single hop is typically 30 to 60 km in relatively flat regions for frequencies in the 2 to 8 GHz bands. When antennas are placed between mountain peaks, a very long hop length can be achieved. Hop distances in excess of 200 km are in existence. The "line-of-sight" nature of microwaves has some very attractive advantages over cable systems. Line-of-sight is a term which is only partially correct when describing microwave paths.
- Atmospheric conditions and certain effects modify the propagation of microwaves so that even if the designer can see from point A to point B (true line of sight), it may not be possible to place antennas at those two points and achieve a satisfactory communication performance.

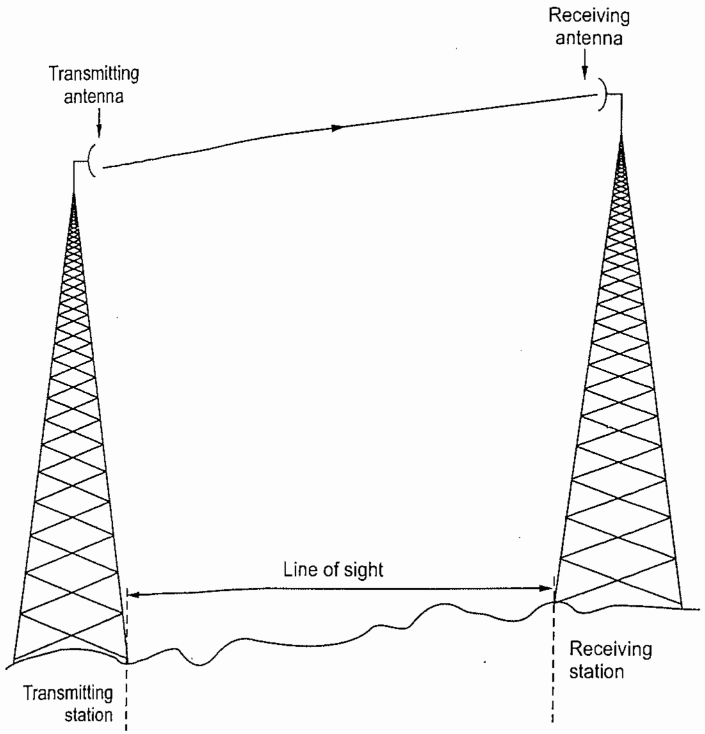


Fig. 1.11.4 Microwave communication

- In order to overcome the problems of line-of-sight and power amplification of weak signals, microwave systems use repeaters at intervals of about 25 to 30 km in between the transmitting receiving stations.
- The first repeater is placed in line-of-sight of the transmitting station and the last repeater is placed in line-of-sight of the receiving station. Two consecutive repeaters are also placed in line-of-sight of each other. The data signals are received, amplified and re-transmitted by each of these stations.
- The objective of microwave communication systems is to transmit information from one place to another without interruption and clear reproduction at the receiver. Fig. 1.11.4 indicates how this is achieved in its simplest form.

1.11.2.1 Microwave Transmitter and Receiver

Fig. 1.11.5 shows block diagram of microwave link transmitter and receiver section.

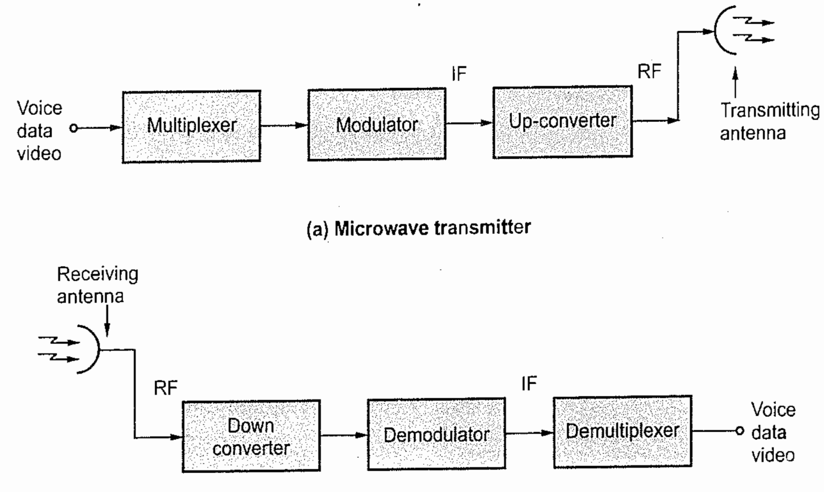


Fig. 1.11.5 Microwave transmitter and receiver

- The voice, video or data channels are combined by a technique known as multiplexing to produce a BB signal. This signal is frequency modulated to an IF and then upconverted (heterodyned) to the RF for transmission through the atmosphere. The reverse process occurs at the receiver. The microwave transmission frequencies are within the approximate range 2 to 24 GHz.
- The frequency bands used for digital microwave radio are recommended by the CCIR. Each recommendation clearly defines the frequency range, the number of channels that can be used within that range, the channel spacing the bit rate and the polarization possibilities.

1.11.2.2 Characteristics of Microwave Communication

- Microwave transmission is weather and frequency dependent. The frequency band of 10 GHz is in the routine use. Microwave communication is widely used for long distance telephone communication, cellular telephones, television distribution and other uses that a severe shortage of spectrum has developed. Following are the important characteristics of microwave communications :

a) Microwave is relatively inexpensive as compared to fiber optics system. For example, putting up two simple towers and antennas on each one may be cheaper than burying 50 km of fiber through a congested area or up tower a mountain, and it may also be cheaper than leasing the telephone line.

b) Microwave systems permit data transmission rates of about 16 Giga (1 giga $=10^9$) bits per second. At such high frequencies, microwave systems can carry 250000 voice channels at the same time. They are mostly used to link big metropolitan cities where have heavy telephone traffic between them.

1.11.2.3 Limitation of Microwave Communication

- Since microwaves travel in a straight line, if the towers are too far apart, the earth will get in the way. Consequently, repeaters are needed periodically. The higher the towers are, the further apart they can be. The distance between repeaters goes up very roughly with the square root of the tower height. For 100 meter high towers, repeaters can be spaced 80 km apart.

1.11.2.4 Applications of Microwave Communication

- Microwave communication is mostly used in following applications.
  1. Mobile telephone network uses microwave communication.
  2. Wireless LAN.
  3. Point-to-point communication between stations.
  4. Line-of-sight communication.

1.11.3 Infrared Light Wave Transmission

- Unguided infrared light (wave) are widely used for short range communication. The remote control used in TV, VCR and stereos all use infrared communication. They are relatively directional, cheap and easy to build, but have a major drawback : They do not pass through solid objects. On the other hand, the fact that infrared waves do not pass through solid walls well is also a plus.
- It means that an infrared system in one room of a building will not interfere with a similar system in adjacent rooms. Security of infrared system against

evasdropping is better than that of radio system precisely for this reason, infrared light is suitable for indoor wireless LAN. For example, the computer and offices in a building can be equipped with relatively unfocused infrared transmitters and receivers. The portable computer with infrared capability can be on the local LAN without having to physically connect to it. Infrared communication cannot be used outdoors because the sun shines as brightly in the infrared as in the visible spectrum.

Applications of Infrared Transmission

1. In remote control of home appliances : e.g. TV, VCR, VCD and DVD players.
2. Indoor wireless LANs.
3. Communication between inhouse electronic gadgets such as keyboard, mouse, printers, scanners and for controlling fan, air conditioners.

1.11.4 Comparison of Guided and Unguided Media

Sr. No.	Guided media	Unguided media
1.	The signal energy propagates within the guided media.	The signal energy propagates through air.
2.	Guided media is mainly suited for point-to-point communication.	Unguided media is mainly used for broadcasting purpose.
3.	The signal propagates in guided media in the form of voltage, current or photons.	The signal propagates in unguided media in the form of electromagnetic waves.
4.	Examples of guided media are - Twisted pair cables - Co-axial cable - Optical fiber cable.	Examples of unguided media are - Microwave or radio links - Infrared.

1.12 University Questions with Answers

(Regulation 2008)

May 2012

Q.1 *State and explain four basic network topologies and write advanatges of each type.* **(Refer section 1.3)** **[6]**

Q.2 *State and explain the basic service primitives used in client-server model.* **(Refer section 1.5)** [6]

Q.3 *Draw the neat diagram of OSI model and explain in brief the function of each layer in it.* **(Refer section 1.6)** [10]

Q.4 *Explain UTP cable with reference to following :*
i) Categories ii) Connectors iii) Performance iv) Applications
(Refer section 1.10) [8]

Dec. 2012

Q.5 *Explain TCP - IP for its relationship of layers and their addresses with an example.* **(Refer section 1.7)** [8]

May 2013

Q.6 *Draw OSI-reference model and explain any three layers.* **(Refer section 1.6)** [9]

Q.7 *Differentiate OSI reference model and TCP/IP.* **(Refer section 1.7)** [9]

Dec. 2013

Q.8 *Explain the terms interfaces, services and protocols.* **(Refer section 1.5)** [6]

Q.9 *Explain the TCP / IP model with protocols at each layer.* **(Refer section 1.7)** [8]

May 2014

Q.10 *Compare OSI and TCP / IP network reference models.* **(Refer section 1.7)** [4]

Q.11 *What are the different types of address exists ?* **(Refer section 1.8)** [4]

Q.12 *Compare guided and unguided transmission media.* **(Refer section 1.9)** [4]

Dec. 2014

Q.13 *Explain TCP / IP reference model with suitable diagram. Compare OSI reference model with TCP / IP.* **(Refer section 1.7)** [10]

Q.14 *Give classification of transmission media. Explain any two guided transmission media.* **(Refer section 1.10)** [8]

❑❑❑

2 Data Link Layer

Syllabus

Introduction to data link layer, DLC services, DLL protocols, HDLC, PPP, Media access control : Random access, Controlled access, Channelization, Wired LAN : Ethernet protocol, Standard ethernet, Fast ethernet, Gigabit ethernet, 10 gigabit ethernet.

Contents