Electronics Engineering

Advanced Communication

Comprehensive Theory

with Solved Examples and Practice Questions

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Prelude to Advanced Communication-I

Every user in telecommunication is interested in higher and higher data rates and need for the high data rates is never ending. For higher data rates, we are going at higher and higher frequencies. The figure shown below shows the electromagnetic spectrum for the telecommunication.

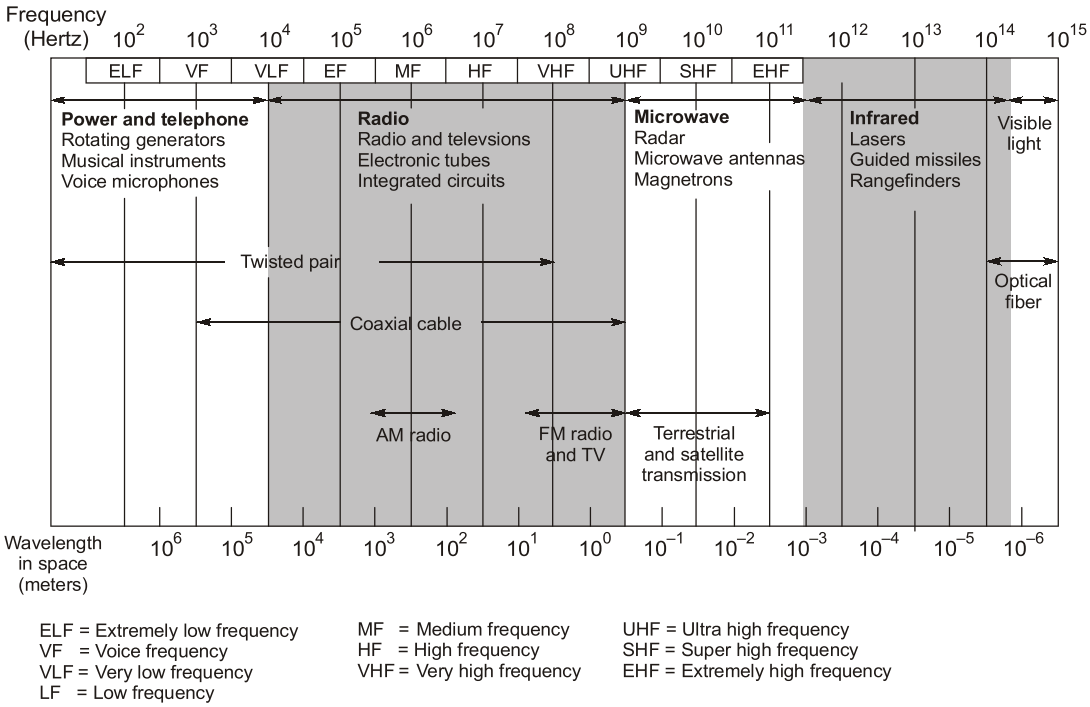

Figure: *Electromagnetic spectrum for telecommunication*

Microwave Line of Sight (LOS) includes both terrestrial and satellite communication. The communication media between the two users depends on the surrounding environment conditions. In the hilly areas, where the optical fibre cable is very difficult to lay down, the satellite communication is preferred over optical fibre.

While, the areas where optical fibre cable is easy to lay down, we prefer optical fibre to microwave LOS system. Also, from the above figure as we see the carrier frequencies of optical fibre is more as compared to that of terrestrial and satellite transmission system, so higher data rates are achievable with the help of optical fibre system.

We have divided this part of book into three parts. Chapter 1 deals with the microwave communication in which we study various types of communication mechanism at different frequencies we have also discussed various types of microwave communication systems.

In chapter 2, we are dealing with orbits of satellite and calculated various losses in satellite communication system alongwith link margin of satellite communication system.

In chapter 3, we have studied the transmission characteristics of optical fibre, different types of optical fibre, sources and detectors in optical fibre system and link margin of the system.

Part-I

CHAPTER 1

Microwave Communication

Introduction

- Microwave frequencies are used for wireless communication as they penetrate through ionosphere, but they get attenuated when used as ground waves as well as surface waves. Due to this reason the microwaves are mainly used for line of sight based communication.
- Microwave communication is further classified into **satellite system and terrestrial system.** Both of these require a transmitter and receiver. The transmitter system converts baseband signal to microwave signal.
- The receiver system converts the microwave signal to baseband signal. The baseband signal is a multiplexed signal which carries a number of individual low bandwidth signals such as voice, data and video.

1.1 Block Diagram of Terrestrial Communication System

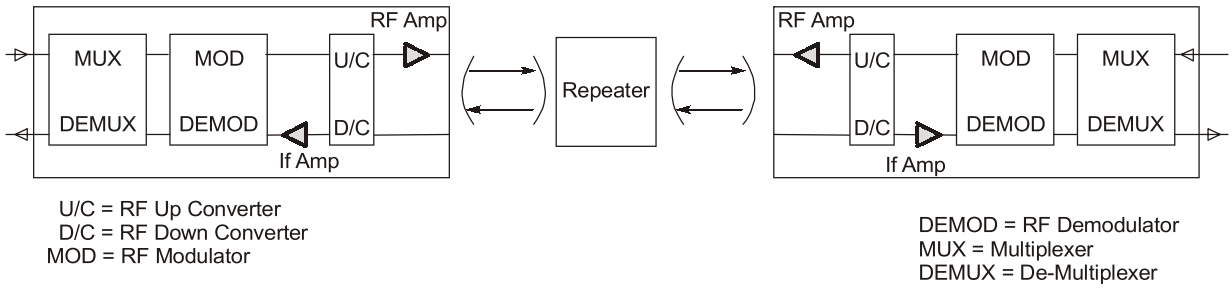

Figure-1.1 : *Terrestrial communication system*

- Microwave signals are attenuated due to geographical locations, atmospheric conditions like rain, dust etc., hence the range is limited. Thus to increase the range of microwave signal, we use repeaters at a certain distance. Repeaters are placed at a distance of about 30 to 80 km, typical value of repeater spacing is 50 km.
- Terrestrial system uses both analog and digital modulation. In analog systems, data information signals are frequency division multiplexed (FDM) and then converted for transmission by RF antenna.
- In digital systems, the information is time division multiplexed (TDM) to form baseband signals. Then it is modulated using either ASK or PSK and up converted for transmission using RF antennas.

1.2 Advantages of Microwave System

Microwave communication has following advantages:

1. It has high bandwidth availability because of high carrier frequency. Microwave frequency ranges from 1 GHz to 1000 GHz.
2. Microwave systems are highly directive because wavelength is small which leads to designing of high gain antennas.
3. Power requirement of transmitter and receiver is low because gain is high.
4. Microwaves have transparency properties i.e. microwave signal can penetrate through ionosphere thus satellite communication is possible.

1.3 Properties of Microwave System

- Microwave systems are mainly point to point systems and generally used for line of sight (LOS) communication system.
- Also, at high frequency conventional tubes do not work satisfactorily due to various reasons like lead inductance effects, transit time limitations etc. Thus, at microwave frequencies devices like Magnetrons, Reflex Klystrons, Gunn diode, Tunnel diode and Avalanche Transit Time devices as oscillator are used.
- Microwave frequency bands are classified as

Band	Frequency range
L	1 - 2 GHz
S	2 - 4 GHz
C	4 - 8 GHz
X	8 - 12 GHz
Ku	12 - 18 GHz
K	18 - 27 GHz
Ka	27 - 40 GHz
V	40 - 75 GHz
W	75 - 110 GHz
mm	110 - 300 GHz

Table-1.1

- At microwave frequency, the design of the component plays a very important role, a small change in length of device leads to huge phase change which is given by:

$$\text{Phase difference} = \frac{2\pi}{\lambda}(\text{Path difference})$$

- Microwave systems are frequency selective devices i.e. they are designed to work at a specific frequency.
- At microwave frequency, the various circuit parameters like *z*-parameters, *y*-parameters cannot be directly measured, we are using **scattering parameters (s-parameters)** to represent any component.
- Microwave communication involves line of sight systems and over the horizon communication systems.

Frequency spectrum can be classified as

1. ELF = Extremely low frequency = 3 Hz - 30 Hz.
2. SLF = Super low frequency= 30 Hz - 300 Hz

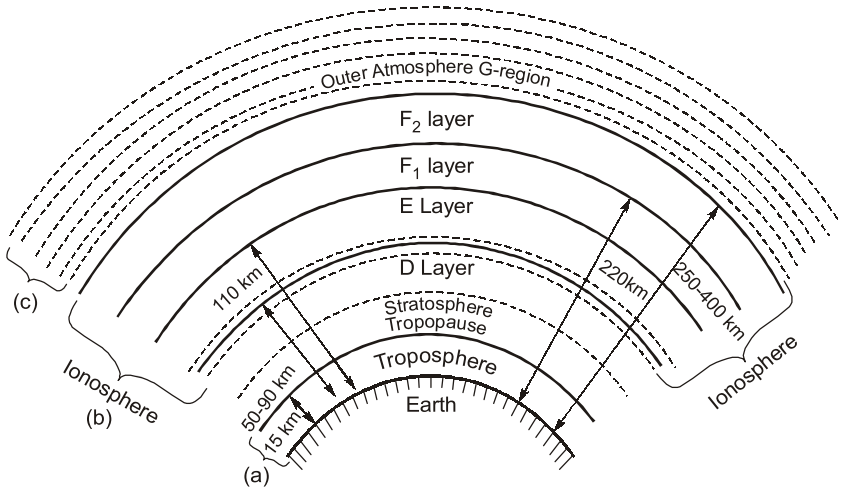

Figure-1.4 : *(a) Troposphere upto 15 km (b) Ionosphere 50-400 km (c) Outer atmosphere above 400 km*

- Above troposphere, tropopause starts and ends at the beginning of 'stratosphere' or region of calm.
- Above a certain height called tropopause the temperature remains uniform through the narrow belt and begins to increase afterwards.

Example - 1.1 Derive an expression of refractive index of ionosphere.

Solution :

- The radio wave passing through the ionosphere is influenced by the electrons and the electric field of radio wave set electrons of the ionosphere in motion.
- These electrons then vibrate simultaneously along paths parallel to the electric field of the radio waves and the vibrating electrons give an AC current proportional to the velocity of vibration.
- Here the effect of earth's magnetic field on the vibrations of ionospheric electrons lags behind the electric field of wave, thus resulting electron current is inductive in nature.
- The actual current flowing through a volume of space consists of the components e.g. capacitive current which leads the voltage by 90° and the electron current which lags the voltage by 90° and hence subtracted from the capacitive current.
- Thus free electrons in the space decreases the current and dielectric constant of space is also be reduced. **The reduction in the dielectric constant due to presence of the electrons in the ionosphere causes the path of radio waves to bend towards earth i.e. from higher electron density to lower electron density.**

  Let the electric field be $E = E_m \sin\omega t$ volts/metre is acting across a cubic metre of space in the ionosphere, where ω is the angular velocity and E_m, the maximum amplitude.

  Force exerted by electric field on each electron is given by

$$F = -eE \quad \text{Newton}$$

  Let us assume there is no collision, then the electron will have an instantaneous velocity v meters/sec.

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

$$-Ee = m\frac{dv}{dt}$$

where, m = Mass of electrons (in kg) ; $\frac{dv}{dt}$ = Acceleration

Integrating both sides, we have

$$\int dv = -\int \frac{eE}{m} dt \; ; \; v = -\frac{e}{m}\int E_m \sin\omega t dt$$

$$v = \frac{eE_m \cos\omega t}{m\omega} = \left(\frac{e}{m\omega}\right) E_m \cos\omega t \qquad ...(i)$$

- If N be the number of electrons per cubic metre, then instantaneous electric current constituted by these N electrons moving with instantaneous velocity v is

$$i_e = -Nev \text{ amp/m}^2 = -Ne\left(\frac{e}{m\omega}\right) E_m \cos\omega t$$

From equation (i)

$$i_e = -\left(\frac{Ne^2}{m\omega}\right) E_m \cos\omega t = \left(\frac{Ne^2}{m\omega}\right) E_m \sin(\omega t - 90°) \qquad ...(ii)$$

which shows current i_e lags behind the electric field E by 90°.

- Besides this inductive current, there is a capacitive current (**or displacement current exists in an unionized air**).

The capacitive or displacement current through the capacitance is

$$i_c = \frac{d}{dt}\vec{D} = \frac{d}{dt}(\epsilon_0 E) = \epsilon_0 \frac{d}{dt}(E_m \sin\omega t)$$

$$i_c = \epsilon_0 E_m \omega \cos\omega t \qquad ...(iii)$$

Thus, total current i that flows through a cubic metre of ionized medium is

$$i = i_c + i_e = \epsilon_0 E_m \omega \cos\omega t - \frac{Ne^2}{m\omega} E_m \cos\omega t$$

$$i = E_m \omega \cos\omega t \left[\epsilon_0 - \frac{Ne^2}{m\omega^2}\right] \qquad ...(iv)$$

From equation (iii) and (iv), the effective dielectric constant of the ionosphere (i.e. ionized space).

$$\epsilon = \epsilon_0 - \frac{Ne^2}{m\omega^2} = \epsilon_0 \left[1 - \frac{Ne^2}{m\omega^2 \epsilon_0}\right]$$

Hence, the relative dielectric constant w.r.t. air

$$\epsilon_r = \frac{\epsilon}{\epsilon_0} = 1 - \frac{Ne^2}{m\omega^2 \epsilon_0}$$

Thus, refractive index (μ) of the ionosphere w.r.t. vacuum or air is given by

$$\mu = \sqrt{\epsilon_r} = \sqrt{\frac{\epsilon}{\epsilon_0}} = \sqrt{1 - \frac{Ne^2}{m\omega^2 \epsilon_0}}$$

Putting, $m = 9.107 \times 10^{-31}$ kg

$e = 1.602 \times 10^{-19}$ Coulombs

$\epsilon_0 = 8.854 \times 10^{-12}$ F/m

So, we get, $$\mu = \sqrt{1 - \frac{81N}{f^2}} \quad \text{...(v)}$$

where, N = Number of electrons per cubic meter or ionic density

f = Frequency in Hz

NOTE

- If N is in cubic cm, then frequency is kHz.
- From equation (v), we can see refractive index of ionosphere is less than one whereas that of unionized medium is one.

1.5.3 Reflection and Refraction of Sky Waves by Ionosphere

- In radio communication, sky wave refers to propagation of radio waves reflected/refracted back towards earth from the ionosphere, an electrically charged layer of upper atmosphere.
- The ionosphere is divided into various layers.
  (i) D-layer (ii) E-layer
  (iii) F_1-layer (iv) F_2-layer
- In night time, D and E layer will disappear and F_1 and F_2 layers will combine into single layer.
- From Snell's law, we can represent

$$\mu = \frac{\sin\theta_i}{\sin\theta_r} = \sqrt{1 - \frac{81N}{f^2}}$$

Since $\mu < 1$ for ionosphere, so $\sin\theta_i < \sin\theta_r$ i.e. angle of refraction will go on deviating from the normal as the wave will encounter rarer medium of atmosphere as shown below:

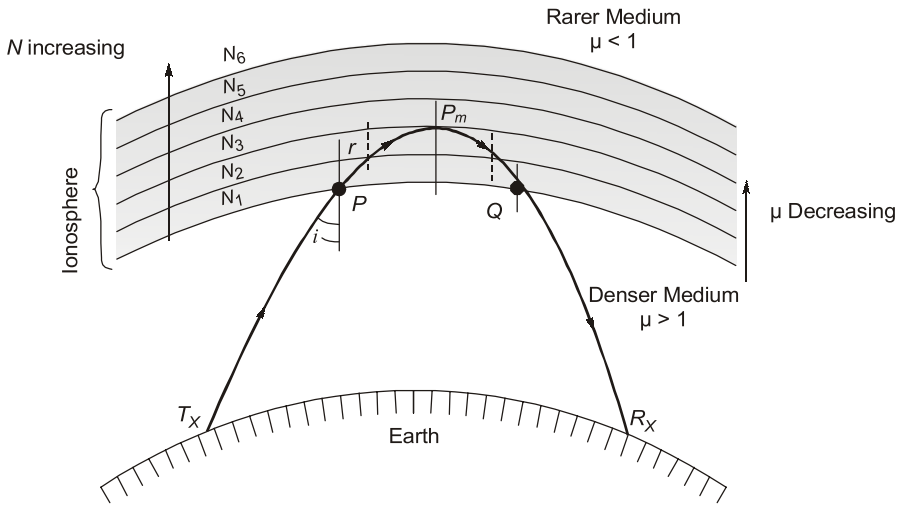

Figure-1.5: *Refraction of the radio wave in the atmosphere*

Remember

1. Rain drop attenuation mainly affects at 11 GHz and is due to absorption of microwave energy by water vapour.
2. To over come rain attenuation, in microwave system path diversity and frequency-diversity scheme are used.
3. Far field of an aperture corresponds to a distance greater than $\frac{2D^2}{\lambda}$.
4. In microwave communication, **circular beams** are generated by **helical antennas**.
5. Microwave antennas like parabolic antenna uses cassegrain feed.
6. In ship to ship communication system to over come fading, we use frequency diversity.
7. Fading/number of fades in any microwave system increases as the frequency increases or the distance between source is increased.
8. Attenuation means decrease in power while fading means decrease in signal strength due to change in phase at receiver end.

Student's Assignments 1

Q.1 In a sky wave with a frequency of 50 MHz is incident on the *D*-region at an angle of 30° then the angle of refraction is
(a) 15° (b) 60°
(c) 30° (d) 5.5°

Q.2 For an aperture antenna of aperture dimension *D* and wavelength of radiation from the antenna λ, the far field distance is greater than
(a) $\frac{D^2}{2\lambda}$ (b) $\frac{2D^2}{\lambda}$
(c) $\frac{D^2}{\lambda}$ (d) $\frac{(2D)^2}{\lambda}$

Q.3 Match **List-I** (medium) with **List-II** (Type of radio waves) and select the correct answer using the code given below the lists:

List-I	List-II
A. Microstrip	1. Surface wave
B. Earth crust	2. Guided wave
C. Troposphere	3. Sky wave
D. Ionosphere	4. Space wave

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	1	2	4	3
(c)	2	1	3	4
(d)	2	1	4	3

Q.4 In free space line of sight propagation case, the transmission losses between transmitter and receiver increases with frequency (f) as
(a) f (b) f^2
(c) f^4 (d) $f^{1/2}$

Q.5 Consider the following statements:
In the case of space wave propagation, the signal strength at the receiver is
1. Directly proportional to transmitter and receiver heights.
2. Inversely proportional to distance between transmitter and receiver.
3. Directly proportional to frequency.

Which of the above statement(s) is/are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 3 only

Q.6 Two microwave signals travelling in the free space have a path length difference of 3 cm when operating at 10 GHz. What is relative phase difference of the signals?
(a) 2π (b) π
(c) 3π (d) 4π

ANSWERS

1. (b) **2.** (b) **3.** (d) **4.** (b) **5.** (b)
6. (a)

Prelude to Communication Networks-II

In today's world, life without communication network is very difficult to imagine. It is used in various daily activities like railway booking counter, internet and mobile telephone network etc. Networking offers various advantages like efficient means to share resources i.e. few licenses for key applications are shared among a large number of users, also it reduces hardware resources like printers and servers as they can be shared.

A communication network is an interconnection of communicating entities, where a communication entity is a stand alone or single entity involved in process of communication. Various communication entities are personal computers, laptops, telephone, pagers and mobile phones.

There is difference between computer network and communication network. In a communication network if computer acts as a networking entity then it is called computer network. Thus, we can say a computer network is one of the forms of communication network i.e. a communication network is used in broader sense. Now a days, world is moving towards the integrated networks, i.e. telephone, intelligent television sets and multimedia networks, which are connected with the same network. Thus, communication networks are becoming very useful.

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Part-II

CHAPTER 1

Building Blocks of Network

1.1 Data

Data is defined as information i.e. stored in the digital form.

1.1.1 Data Communication

Data communication is the process of transferring digital information between two or more points.

Eg. : Telegraph.

1.2 Data communication network architecture

A network is a set of devices interconnected by a communication medium. Each device is referred as an entity. An entity can be a computer, mobile or any other device.

1.2.1 Network Classification

The network can be classified based on

(a) Type of service offered by the network (b) Network topology

(c) Network extent

(a) Type of Service offered by the network

The primary task of a network is to provide the means to transfer the user information from one network entity to another. Based on the way information is transferred, the services offered by a network are classified into two categories.

(i) Connection oriented service (ii) Connection less service

(i) Connection Oriented Service

- Connection oriented service, means establishing a **semi-permanent connection** between communicating entities before data is exchanged. The connection establishment may be at the **physical or at the logical level** and involves some form of signalling.
- In this mode, connection establishment is done by some form of **resource reservation** (e.g. reserving link bandwidth or buffers), which is followed by the exchange of user data. After this, connection is cleared and all resources for the connection are free.

The various characteristics of connection oriented service are:

1. A connection is first established (through signalling), which is followed by some form of resource reservation. After data transfer is over, the connection is released.
2. The services are reliable in the sense that the data loss is minimum.
3. The transfer mode for a connection-oriented service is **circuit-switching** or **virtual-circuit switching**.
4. In case of data based connection-oriented service, the information is delivered in sequence because the data for a connection follow the same path.
5. The scheme is suitable for **long and steady transmission** but it is not suitable for real time services.

Note: **Telephone network** is an example of connection-oriented service, in which a dedicated connection is first set up after which the conversation takes place.

(ii) Connection Less Service

- A connectionless service does not require a connection to be established before the exchange of data. The information is transferred as independent data units, where each data unit carries the complete destination address.
- A connection less service is similar to the way a letter is delivered. Each letter carries a postal address. When a letter reaches the post office, the postal address written on letter is used to forward it to next post office. This process is continued till the mail reaches its destination.

The various characteristics of connectionless services are:

1. A connection does not need to be established before data transfer. Thus, there is **no resource reservation** before transfer.
2. The scheme provides **unreliable or best effort delivery service** because the packets lost or dropped are not retransmitted.
3. Packets may or may not arrive in sequence as the data packets may or may not follow same path.
4. Header size is small because acknowledgement of packets is not required.
5. This scheme is suitable for **bursty transmissions**.

Further, we can differentiate between connection oriented and connection less service on the various basis.

Sl No.	Parameter	Connection Oriented Service	Connection Less Service
1.	Resource Utilization	In connection oriented service, resources are first reserved at setup time, a user is quite likely to get his share of bandwidth.	In connection less service, resources are not reserved for transmission of data.
2.	Service guarantees	Connection oriented service, the delivery of message is guaranteed i.e. it is more reliable.	In connection less service, resources are not reserved for transmission of data. It is not reliable.
3.	Set-up Latency or delay	In certain situations, set-up phase and clearing delays can be time consuming and can take more time than data transfer.	The delay in this service is small as no prior connection is needed for transmission.
4.	Data	Data in connection oriented service may come in sequence as they all travel through dedicated link in sequence.	Data packet in connectionless service may or may not come in order because they travel in random paths.
5.	Header Size	Header size is large because overheads are more.	The header size is small because overheads are less.

Table-1.1 : *Connection Oriented Versus Connectionless Service*

Advantages of connectionless network:

(i) No resource is reserved, the resource utilization is directly linked to the current load, which leads to possibility of **dynamic allocation.**

(ii) There is no connection setup, so there is **no setup latency**.

(iii) There are no connections, no pre-connection state information is maintained.

Disadvantages of connectionless network:

(i) In case of connectionless service, the reliability is less.

(ii) In case of connection less service, a routing table is to be maintained i.e. the information of transmitted packet to receiver node. The size of routing table increases as the number of hosts or networks increases.

Examples of Connection-Oriented (CO)/Connectionless (CL) Protocol

The table below shows the various connection oriented (CO)/Connection less (CL) Services

Name	Type	Description
PSTN	CO	It provides connection-oriented service through dedicated physical connections.
Frame Relay	CO	It provides connection-oriented service through virtual-circuit connections.
ATM	CO	It provides connection-oriented service through virtual-circuit connections.
IP	CL	It provides connection less unreliable service using packet routing.
TCP	CO	It provides connection-oriented reliable service over unreliable IP protocol
UDP	CL	It provides connectionless unreliable service over IP protocol

Table-1.2

where,

PSTN : Public Switched Transport Network

ATM : Asynchronous Transfer Mode

IP : Internet Protocol

TCP : Transmission Control Protocol

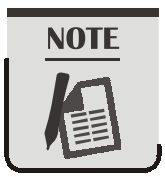
UDP : User Datagram Protocol

Protocol

A protocol is a set of rules that governs data communication. Protocols define the method of communication, how to communicate, when to communicate and what to communicate.

Important elements of protocols are:

1. **Syntax:** Syntax means format of data or the structure how it is presented. e.g. first eight bits are for sender address, next eight bits for receiver address and rest of the bits for message data.
2. **Semantics:** Semantics is the control information. E.g. acknowledgement, sequence number.
3. **Timings:** Timing means, at what time data can be sent and how fast data can be sent. Hence, deals with synchronisation.



1. The semantics of the protocol provides the action to be taken on the basis of received information.
2. The protocols in a communication systems are not organized as individual entity, but as a set of layer, where each layer has well-defined function.

(b) Based on Network Topology

The network topology defines the physical interconnection of its constituent elements. We can say, topology of a network refers to the way nodes (or hosts) are interconnected in a network. The interconnection may be either real or logical. Real interconnection refer to actual (i.e. Physical) connection of a network, whereas logical interconnection refers to the way data is exchanged between the constituent element. The network topology can be classified as

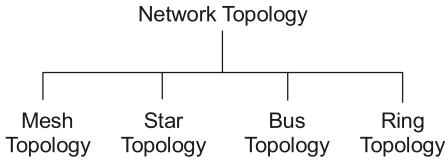


Figure-1.1

Bus Topology

Bus topology is a multipoint topology which is used when a network installation is small. In case of a bus network, the various nodes like computer as shown in the figure below are interconnected through a cable. Cable is one or more wires with no active element to amplify the signal. This type of connection with no active element involved is called as passive bus topology.

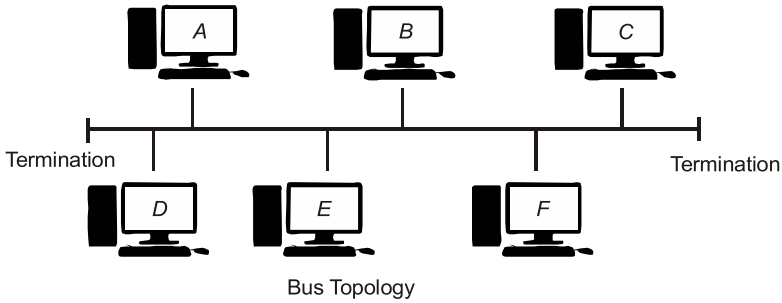


Figure-1.2

- When one computer sends a signal onto the cable, all the computers on the network receive the information, hence security is less.
- The bus topology requires proper termination at both ends of the cable. The generation of standing wave, may distort the signal, to prevent that impedance matching is required.

Advantages of bus topology

(i) The bus topology is easy to understand, install and used for small networks.
(ii) The cabling cost is less.
(iii) The bus topology is easy to expand by joining two cables with a BNC (Bayonet Neill-Concelman) connector.

Disadvantages of Bus Topology

(i) Heavy network traffic slows down the bus speed.
(ii) The BNC connectors for expansion of bus attenuates the signal considerably.
(iii) A cable break or loose BNC connector causes reflection and brings down the whole network causing all network activity to stop. Hence, it is not robust.

Ring Topology

In ring topology, each computer is connected to the next computer, with the last one connected to the first. Rings are used in high performance network where large bandwidth is necessary.

- Computer is connected to next peer on the ring and each retransmits and receives from the previous computer.

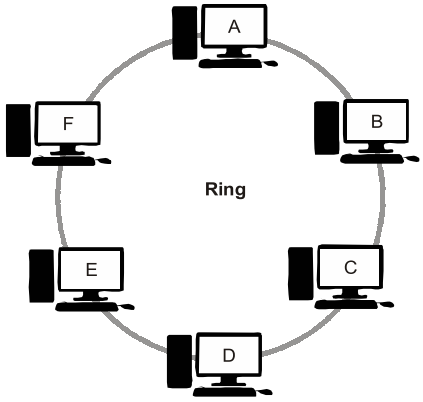


Figure-1.3: *Ring network topology*

- The message flow around the ring is in one direction. There is no termination of the ring because there is no end. A short message called token, is passed around the computers in the ring from one to another. The computer, which transmits the data keeps the token with it otherwise passes the token to the computer, which is next to it in the ring. After transmitting the data, the token is sent to next computer in the ring. Thus, the token circulates until a station is ready to send and capture the token. Hence, token provides traffic management.

Advantages of Ring Topology

(i) No computer can monopolise the network because every computer is given equal access to the token.

(ii) The sharing of the network allows the network to continue function in a useful manner.

Disadvantages of Ring Topology

(i) Initial installation cost is high and hence not preferable for low density traffic.

(ii) If any link breaks or if any repeater fails, then the entire network will be disabled.

(iii) To install a new repeater for supporting a new device, it is necessary to have the identification of two nearby network.

(iv) Closed nature of ring topology makes it necessary to remove the circulating packets.

Star Topology

In a star topology, all computers are connected to a central location through a device **called a hub** as shown below:

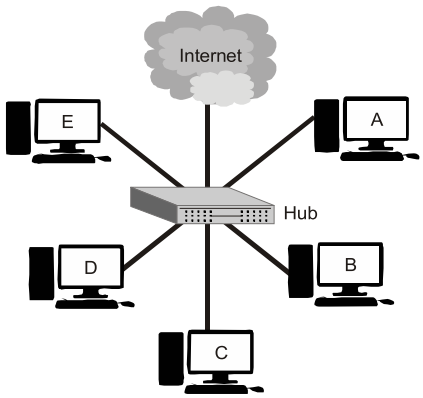


Figure-1.4: *Star network topology*

Each node/computer on a star network communicate with a central hub that resends the message to all computers in a broadcast star network or only to the destination computer in a switched star network. The hub in a broadcast star can be **active or passive**. An active hub generates the electrical signal and sends it to all computer connected to it. Active hubs needs power supply while passive hub do not need it.

Advantages of Star Topology

1. As compared to Bus topology it gives far much better performance, signals do not necessary get transmitted to all the workstation.
2. Easy to connect new nodes or devices. In star topology, new nodes can be added/removed easily without affecting rest of the network.
3. Failure of one node or link does not affect the rest of the network. At the same time it is easy to detect the failure and trouble shoot it.

Disadvantages of Star Topology

1. There is huge dependence on central hub, if it fails, whole network fails to operate.
2. Many star network require a device at the central point to rebroadcast or switch the network traffic.
3. Cabling cost is more since cables are connected to all nodes/computer from central hub.

Mesh Topology

In case of mesh topology, there is a dedicated point to point link from one device to another as shown below:

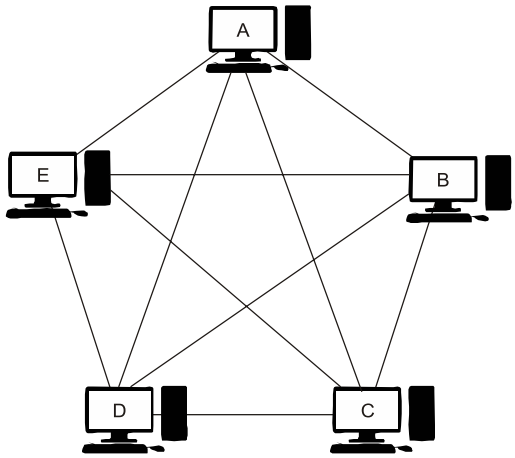


Figure-1.5: *Mesh network topology*

If there are N-devices, then a fully connected network will have $N(N-1)$ physical channels to link devices. The link between the devices in this case are dedicated link i.e. traffic is carried on it between two devices. If the connections are full duplex then number of links will be $N(N-1)/2$.

Advantages of mesh topology

(i) The use of dedicated link guarantees that each connection can carry its own data load, thus eliminates traffic problem.

(ii) In case of mesh topology, failure of one node/computer does not bring down the entire network. Hence, it is robust.

(iii) It provides security and privacy because every message is sent along dedicated line.

(iv) In case of failure, troubleshooting is easy, but fault correction is difficult.

Student's Assignment

Q.1 The topology with highest reliability is
(a) BUS (b) STAR
(c) RING (d) MESH

Q.2 With the use of following device(s) and cables can a LAN based on star topology be setup
(a) router (b) bridge
(c) switch (d) repeater

Q.3 In a topology, if there are n devices in a network, each device has $(n-1)$ ports for cables. Identify it
(a) mesh (b) star
(c) ring (d) bus

Q.4 In a mesh topology, with n devices and half duplex links, if a new device is added, how many new links are added?
(a) $n-1$ (b) n
(c) $n+1$ (d) $2n$

Q.5 _____ used in telephone network for bidirectional, real time transfer between computers.
(a) message switching
(b) circuit switching
(c) packet switching
(d) circular switching

Q.6 _____ is used to optimize the use of channel capacity available in a network, to minimize the transmission latency and to increase robustness of communication.
(a) Message switching
(b) Linear switching
(c) Circuit switching
(d) Packet switching

Q.7 Which one of the following statements is false?
(a) Packet switching leads to better utilization of bandwidth resources than circuit switching
(b) Packet switching results in less variation in delay than circuit switching
(c) Packet switching requires more per -packet processing than circuit switching
(d) Packet switching can lead to reordering unlike in circuit switching

Q.8 With respect to Circuit Switching and Packet Switching, which of the following statement is incorrect?
(a) In circuit switching after data transfer begins, no busy conditions take place
(b) In packet switching, each packet of the same message must follow the same route
(c) In packet switching, each packet must contain the addressing information
(d) In circuit switching, a circuit must be established on the network prior to the data transfer

Q.9 Which of the following is/are correct
1. Circuit switching is designed for voice communication.
2. In Circuit switching network connection provides for transmission at varying data rate
3. Circuit switching sees all transmission are equal.
4. Circuit switching is less suited to data and non-conversation transmission.

(a) Only 3 (b) 2 and 3
(c) Only 4 (d) 1, 3 and 4

ANSWERS

1. (d)	**2.** (c)	**3.** (a)	**4.** (a)	**5.** (b)
6. (d)	**7.** (b)	**8.** (b)	**9.** (d)	

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