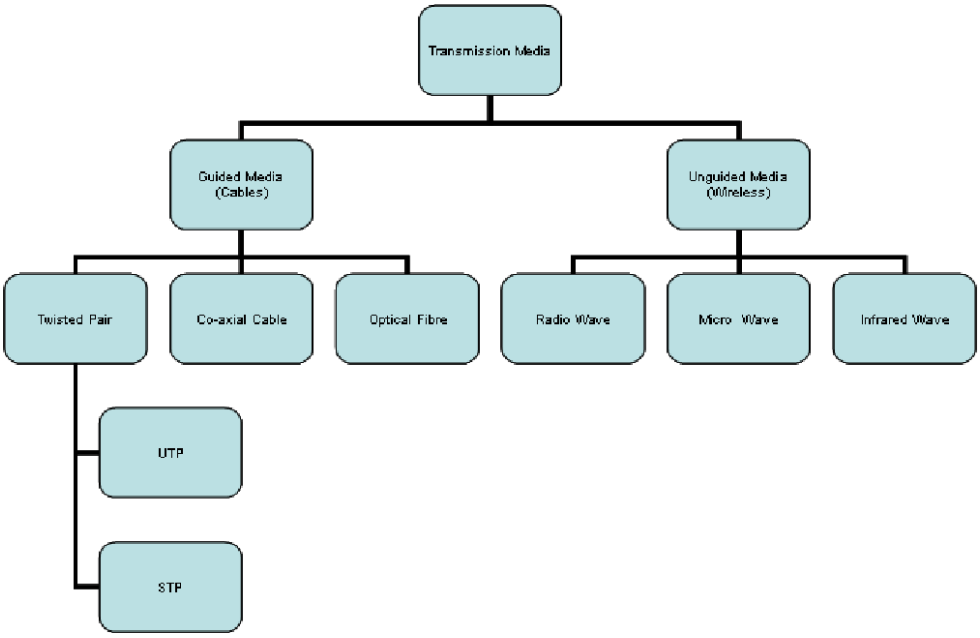
CHAPTER 3 TRANSMISSION MEDIA

3.1 INTRODUCTION

In Computer Networks, the data is transmitted from one place to another using some kind of transmission media. It is the physical path between the sender and receiver. The transmission media can be air, wire or fiber optics. Each medium has its properties and capabilities. In this chapter we will study various types of transmission media in detail.

TRANSMISSION MEDIA AND ITS CHARACTERISTICS

Transmission media is the physical path through which the data travels. Various types of transmission media are wire, fiber optics, air etc... The data travels in the form of signals using the transmission media. For example when two people are talking, air is the transmission media and voice goes in the form of waves from one person's mouth to the other person's ears. In our day to day life telephones are used for communications, they use wired networks whereas mobile phones use wireless networks. The data travels in the form of electric signals, light signals or electromagnetic signals using the transmission media. There are various forms of transmission media, which can be classified into two broad categories viz. Guided media and Unguided media. Some times media word is replaced by words like channel, path, line, link etc. Figure 4.1 illustrates the classification of transmission media.



(Fig 3.1 Classification of Transmission Media)

Each medium has its own properties, advantages and limitations. Depending on the type of medium, the characteristics and quality of data are determined. In the following section we list various characteristics of transmission media that affect the quality and performance of communications:

- **Attenuation** : It refers to the loss of signal strength during transmission. Resistance in wire may absorb energy of electric signals which results in attenuation. As the distance increases, attenuation may increase.
- **Bandwidth** : It refers to the range of frequencies that the medium can support. Higher the bandwidth, more data could travel through the transmission media.
- **Cost**: The cost of installation and operation for a transmission media may vary.
- **Distance** : The range of distance to connect two different hosts. In some media the distance may be 100 meter while some may allow 1 Km.
- **EMI** : Few transmission media are susceptible to Electro-magnetic interference. It is the disturbance caused by the Electrical circuits. When there is EMI, the data travelling though the medium gets damaged. For example you cannot listen to radio if it is placed near the regulator of a fan. The fan regulator causes EMI (disturbance) to the radio signals.
- **Reliability** : If a transmission media can transmit data with less errors, it means the media is more reliable.
- **Linkage**: It refers to connecting the media to host computers or joining two wires into a single.
- **Security**: It is possible that a person can pick up the data from the wire, known as tapping. By insulating the media, we can make it more secure from unauthorized users.
- **Compatibility**: A transmission medium allows two or more computers on a network to communicate. Each transmission medium requires specialized network hardware to transfer information. Network hardware, such as network interface cards, must be compatible with the type of transmission medium used.
- **Combined Media**: There are many different types of transmission media. Smaller networks are usually constructed using only one type of transmission medium. Larger networks may use different types of transmission media in various parts of the network. Networks using a combination of transmission media are more complex and are difficult to build and maintain.

Types of Transmission Media

- **Electric Signals**: Electric signals passing through cable is the oldest and most commonly used type of transmission medium. Cable usually consists of copper wires covered with a protective plastic coating. Cable is inexpensive compared to other types of transmission media. The three main types of cables are coaxial, unshielded twisted pair and shielded twisted pair.
- **Light** : Many larger networks are now using light to transfer information. Fiber-optic cable transmits information by sending light signals through a core made of glass or

plastic. Networks using fibre-optic cable transfer information quickly, but they are expensive and difficult to install.

- **Wireless (Electromagnetic Waves)**: A wireless network is often used when parts of a network cannot be physically connected. For example, a company may use wireless transmission media to connect office buildings that are on opposite sides of a lake. Examples of wireless transmission media included infrared, radio, microwave and satellite systems.

Transmission media makes possible the transmission of the electronic signals from one computer to another. These electronic signals express data values in the form of binary (on/off) impulses, which are the basis for all computer information (represented as 1s and 0s).

These signals are transmitted between the devices on the network, using some form of transmission media (such as cables or radio) until they reach the desired destination computer.

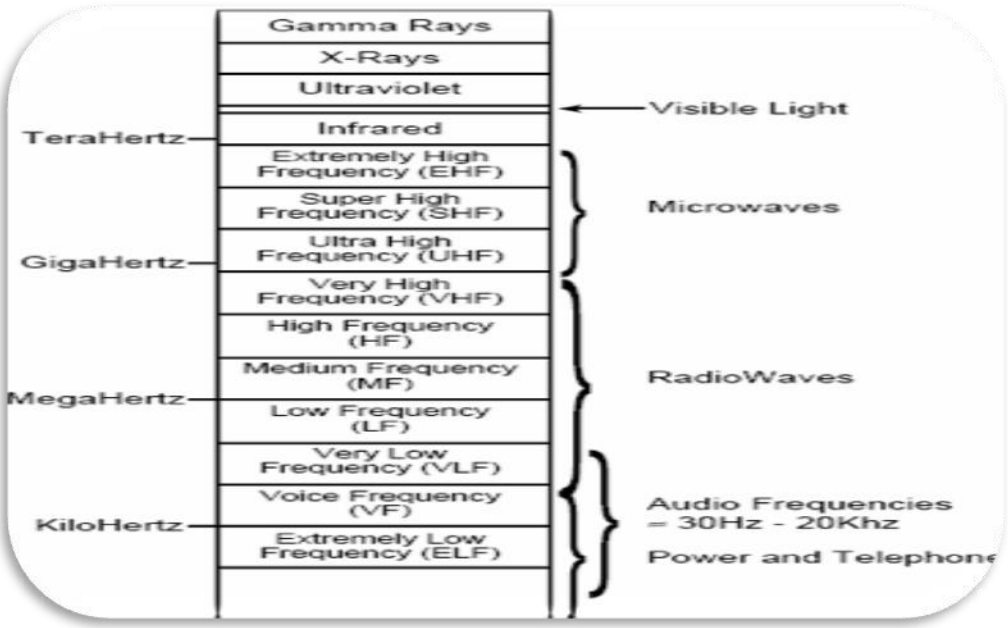
All signals transmitted between computers consist of some form of electromagnetic (EM) waveform, ranging from radio frequencies through microwaves and infrared light.

Different media are used to transmit the signals, depending on the frequency of the EM waveform.

The electromagnetic spectrum consists of several categories of waveforms, including radio frequency waves, microwave transmissions, and infrared light.

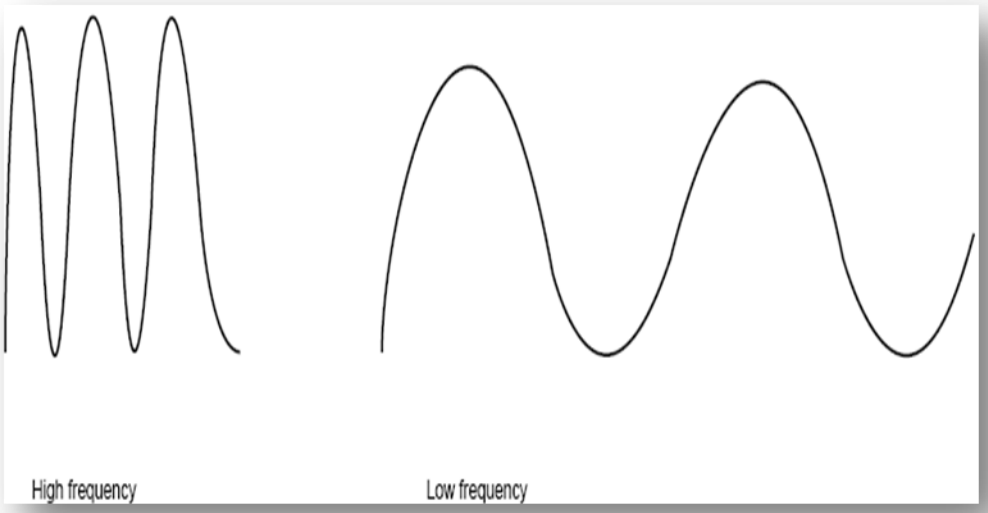
The frequency of a wave is dependent upon the number of waves or oscillations that occur during a period of time.

A high-pitched sound has a very high frequency; in other words, numerous cycles of oscillation (or waves) occur each second.



[Fig 3.2: The electromagnetic spectrum]

Radio frequency waves are often used for LAN signaling. Radio frequencies can be transmitted across electrical cables (twisted-pair or coaxial) or by radio broadcast.



[Fig 3.3: High frequency and low frequency waves]

Microwave transmissions can be used for tightly focused transmissions between two points.

Microwaves are used to communicate between earth stations and satellites, for example, and they are also used for line-of-sight transmissions on the earth's surface.

Infrared light can be transmitted across relatively short distances and can be either beamed between two points or broadcast from one point to many receivers. Infrared and higher frequencies of light also can be transmitted through fiber-optic cables.

Bandwidth:

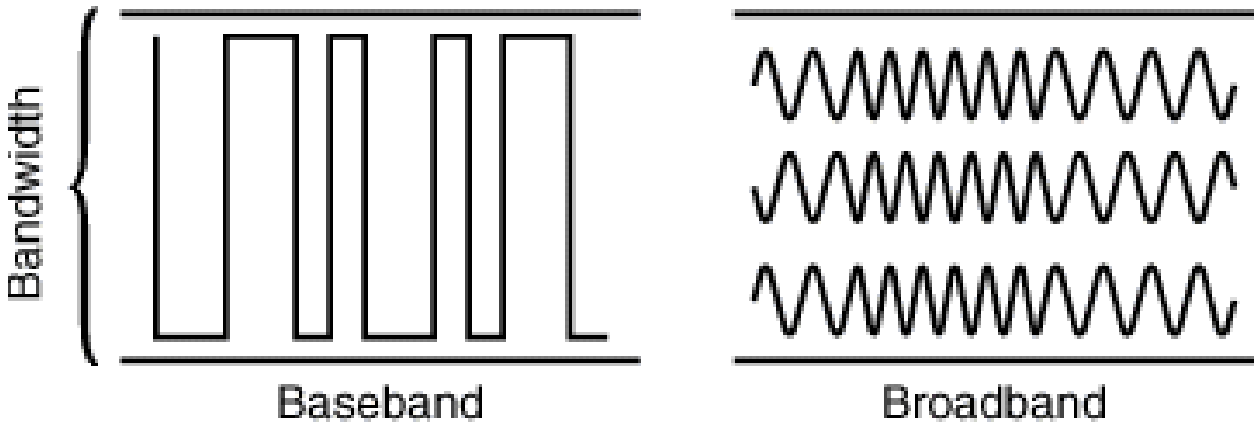
Bandwidth is a measurement of communication data resources in bits or higher units. In other words, bandwidth is a measurement of how much data is being sent or received in a given situation. Bandwidth also acts as a tool to see if either a user is getting the speed he wants, or if too many files are being uploaded or downloaded. The two most common interpretations of bandwidth are for Internet access and for web hosting.

- In computer networking, the term bandwidth refers to the measure of the capacity of a medium to transmit data.
- For example, a medium that has a high capacity has a high bandwidth, whereas a medium that has limited capacity has a low bandwidth.
- Data transmission rates are frequently stated in terms of the bits that can be transmitted per second.
- An Ethernet LAN theoretically can transmit 10 million bits per second and has a bandwidth of 10 megabits per second (Mbps).
- The bandwidth that a cable can accommodate is determined in part by the cable's length.

Baseband and Broadband:

- The two ways to allocate the capacity of transmission media are with baseband and broadband transmissions.
- Baseband refer the entire capacity of the medium to one communication channel.
- Broadband enables two or more communication channels to share the bandwidth of the communications medium.
- Baseband is the most common mode of operation. Most LANs function in baseband mode.
- Baseband signaling can be accomplished with both analog and digital signals.
- Consider the example that the TV cable coming into your house from a cable provider is a broadband medium.
- Many television signals can share the bandwidth of the cable because each signal is modulated using a separately assigned frequency.

- You can use the television tuner to select the frequency of the channel you want to watch.



Attenuation:

- Attenuation is a measure of how much a signal weaker as it travels through a medium.
- When signal strength falls below certain limits, the electronic equipment that receives the signal can be difficult to isolate the original signal from the noise present in all electronic transmissions.
- The effect is exactly like trying to tune in distant radio signals.
- Even if you can lock on to the signal on your radio, the sound generally still contains more noise than the sound for a local radio station.

Electromagnetic Interference:

- Electromagnetic interference (EMI) consists of outside electromagnetic noises that affect the signal in a medium.
- Some network media are more sensitive to EMI than others.

Crosstalk:

- Crosstalk is a special kind of interference caused by adjacent wires.

- Crosstalk occurs when the signal from one wire is picked up by another wire.
- You may have experienced this when talking on a telephone and hearing another conversation going on in the background.

3.2 Guided Media (Cables)

The following sections discuss three types of network cabling media, as follows:

- Coaxial cable
- Twisted-pair cable
- Fiber-optic cable

3.2.1 Co-Axial Cable

Coaxial cables were the first cable types used in LANs. As shown in Figure, coaxial cable gets its name because two conductors share a common axis; the cable is most frequently referred to as a “coax.”

A type of coaxial cable that you may be familiar with is your television cable.

The components of a coaxial cable are as follows:

- A center conductor, although usually solid copper wire, is sometimes made of stranded wire.
- An outer conductor forms a tube surrounding the center conductor. This conductor can consist of braided wires, metallic foil, or both. The outer conductor, frequently called the shield, serves as a ground and also protects the inner conductor from EMI (Electro Magnetic Interface).

- An insulation layer keeps the outer conductor spaced evenly from the inner conductor.
- A plastic encasement (jacket) protects the cable from damage.

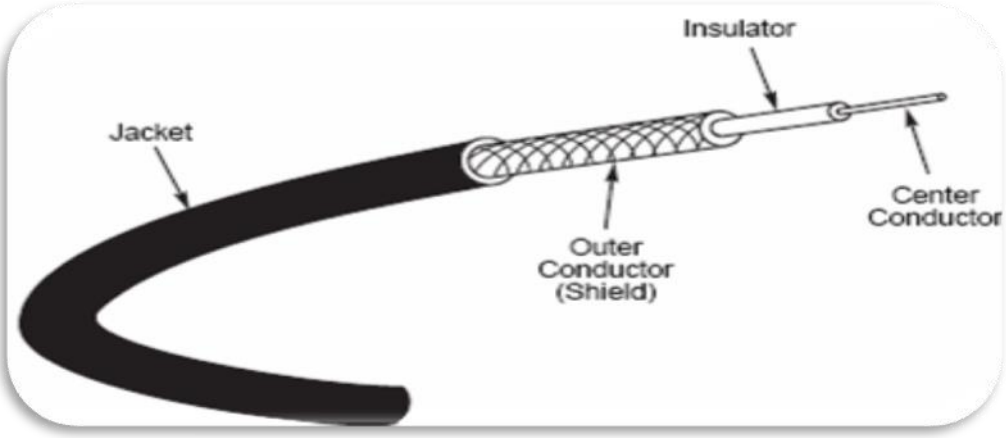
Types of Coaxial Cable

The two basic classifications for coaxial cable are as follows:

- Thinnet
- Thicknet

The following sections discuss Thinnet and Thicknet coaxial cabling.

Thinnet



Thinnet is a light and flexible cabling medium that is inexpensive and easy to install.

[Fig: The structure of coaxial cable consists of four major components]

Note that Thinnet falls under the RG-58 family and Thinnet is approximately .25 inches (6 mm) in thickness.

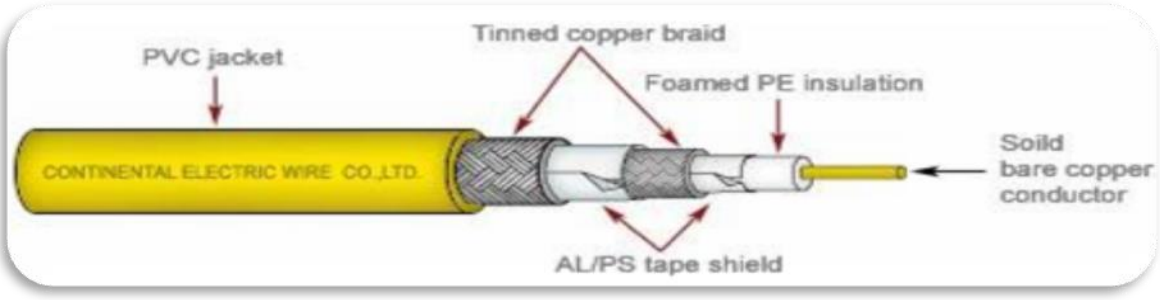
Cable	Description	Impedance
RG-58/U	Solid copper center	50-ohm
RG-58 A/U	Wire strand center	50-ohm
RG-58 C/U	Military version of RG-58 A/U	50-ohm
RG-59	Cable TV wire	75-ohm
RG-62	ARCnet specification	93-ohm

[Table 3.1: THINNET CABLE CLASSIFICATIONS]

Thinnet cable can reliably transmit a signal for 185 meters (about 610 feet).

Thicknet

Thicknet is thicker than Thinnet. Thicknet coaxial cable is approximately 0.5 inches (13 mm) in diameter. Because it is thicker and does not bend as readily as Thinnet, Thicknet cable is harder to work with.



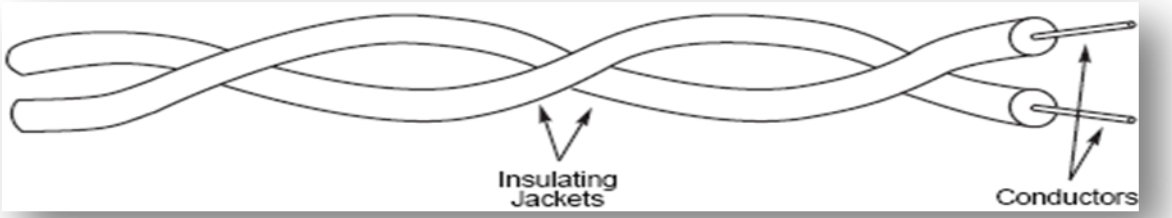
[Fig: Thicknet]

A thicker center core, however, means that Thicknet can carry more signals a longer distance than Thinnet.

Thicknet can transmit a signal approximately 500 meters (1,650 feet). Thicknet cable is sometimes called Standard Ethernet.

3.2.2 TWISTED PAIR CABLE

Twisted-pair cable has become the dominant cable type for all new network designs that employ copper cable. Among the several reasons for the popularity of twisted-pair cable, the most significant is its low cost.



[Fig: Twisted Pair Cable]

Twisted-pair cable is inexpensive to install and offers the lowest cost per foot of any cable type. Your telephone cable is an example of a twisted-pair type cable. A basic twisted-pair cable consists of two strands of copper wire twisted together (see Figure).

Twisting of the wires also controls the tendency of the wires in the pair to cause EMI in each other.

As noted previously, whenever two wires are in close proximity, the signals in each wire tend to produce crosstalk in the other.

Two types of twisted-pair cable are used in LANs: shielded and unshielded, as explained in the following section.

Shielded Twisted-Pair (STP) Cable

Shielded twisted-pair cabling consists of one or more twisted pairs of cables enclosed in a foil wrap and woven copper shielding. the first cable type used with IBM Token Ring that includes two twisted pairs within a single shield.

Early LAN designers used shielded twisted-pair cable because the shield performed double duty, reducing the tendency of the cable to radiate EMI and reducing the cable's sensitivity to outside interference.

Coaxial and STP cables use shields for the same purpose. The shield is connected to the ground portion of the electronic device to which the cable is connected.

A ground is a portion of the device that serves as an electrical reference point, and usually, it is literally connected to a metal stake driven into the ground.

[Fig: A shielded twisted-pair cable]

A properly grounded shield prevents signals from getting into or out of the cable.

Unshielded Twisted-Pair (UTP) Cable

Unshielded twisted-pair cable doesn't incorporate a braided shield into its structure. However, the characteristics of UTP are similar in many ways to STP, differing primarily in attenuation and EMI.

As shown in Figure, several twisted pairs can be bundled together in a single cable. These pairs are typically color-coded to distinguish them.

Telephone systems commonly use UTP cabling. Network engineers can sometimes use existing UTP telephone cabling (if it is new enough and of a high enough quality to support network communications) for network cabling.

Now, however, a clear trend toward UTP is in operation, and all new copper-based cabling schemes are based on UTP. UTP cable is available in the following five grades, or categories:

Categories 1 and 2

These voice-grade cables are suitable only for voice and for low data rates (below 4Mbps). Category 1 was once the standard voice-grade cable for telephone systems.

Category 3

As the lowest data-grade cable, this type of cable generally is suited for data rates up to 10Mbps. Some innovative schemes utilizing new standards and technologies, however, enable the cable to support data rates up to 100Mbps.

Category 3, which uses four twisted pairs with three twists per foot, is now the standard cable used for most telephone installations.

Category 4

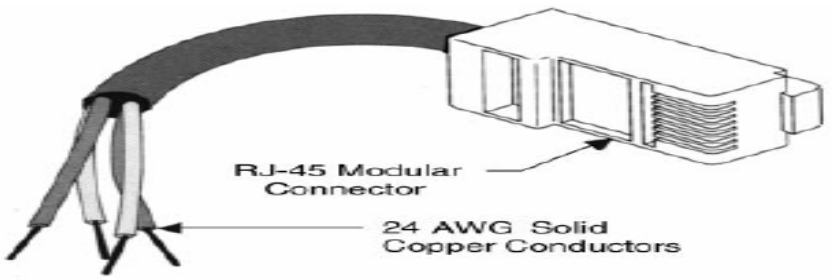
This data-grade cable, which consists of four twisted-pairs, is suitable for data rates up to 16Mbps.

Category 5

This data-grade cable, which also consists of four twisted-pairs, is suitable for data rates up to 100Mbps. Most new cabling systems for 100Mbps data rates are designed around Category 5 cable.

Category 6

Most of the modern networks use category 6 cables. It is a cable standard for Gigabit Ethernet .The price of the grades of cable increase as you moves from Category 1 to Category 6. In a UTP cabling system, the cable is only one component of the system.



[FIG:RJ45 CONNECTOR]

3.2.3 FIBER OPTIC CABLE

In almost every way, fiber-optic cable is the ideal cable for data transmission.

Not only does this type of cable accommodate extremely high bandwidths, but it also presents no problems with EMI and supports durable cables and cable runs as long as several kilometers.

The two disadvantages of fiber-optic cable, however, are cost and installation difficulty.

Despite these disadvantages, fiber-optic cable is now often installed into buildings by telephone companies as the cable of choice.

The center conductor of a fiber-optic cable is a fiber that consists of highly refined glass or plastic designed to transmit light signals with little loss.

A plastic sheath protects the fiber. A fiber-optic network cable consists of two strands separately enclosed in plastic sheaths. One strand sends and the other receives.

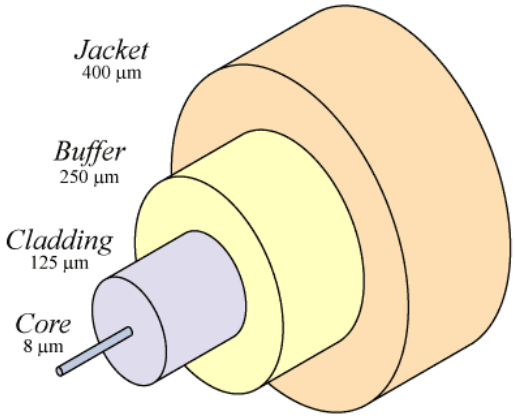
Two types of cable configurations are available: (I) loose and (II) tight configurations. Loose configurations incorporate a space between the fiber sheath and the outer plastic encasement; this space is filled with a gel or other material.

Tight configurations contain strength wires between the conductor and the outer plastic encasement. In both cases, the plastic encasement must supply the strength of the cable, while the gel layer or strength wires protect the delicate fiber from mechanical damage.

Optical fiber cables don’t transmit electrical signals. Instead, the data signals must be converted into light signals. Light sources include lasers and light-emitting diodes (LEDs).

One of the significant difficulties of installing fiber-optic cable arises when two cables must be joined. The small cores of the two cables (some are as small as 8.3 microns) must be lined up with extreme precision to prevent excessive signal loss.

Fiber optics is generally used in back bone of any network.



[Figure: Fibre Optic Cable]

Summary of Guided Transmission

Cable Type	Cost	Installation	Capacity	Range
Coaxial Thinnet	Less than STP	Inexpensive/easy	10Mbps typical	185 m
Coaxial Thicknet	Greater than STP, less than fiber	Easy	10Mbps typical	500 m
Shielded Twisted-Pair (STP)	Greater than UTP, less than Thicknet	Fairly Easy	16Mbps typical up to 500Mbps	100 m typical
Unshielded Twisted-Pair (UTP)	Lowest	Inexpensive/easy	10Mbps typical up to 100Mbps	100 m typical
Fiber-optic	Highest	Expensive/difficult	100Mbps typical	10s of kilometers

3.2.4 CONNECTOR

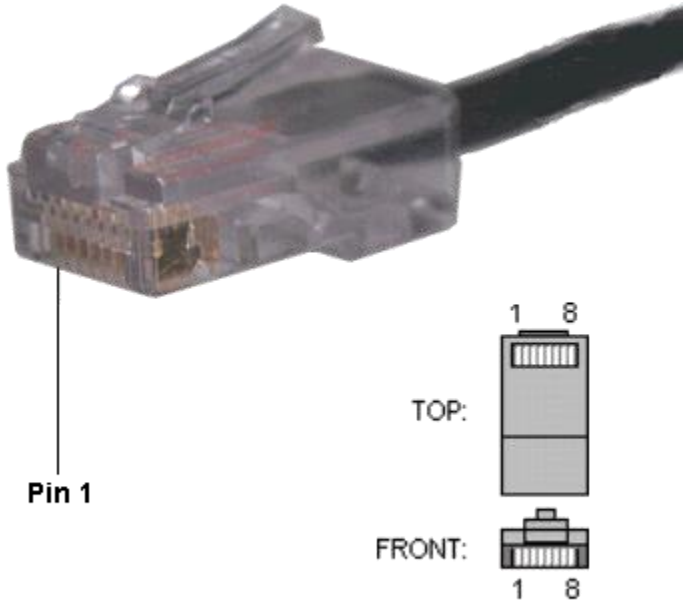
Connector is the part of a cable that plugs into a port or interface to connect one device to another. Most connectors are either male (containing one or more exposed pins) or female (containing holes in which the male connector can be inserted). There are different types of connectors for Twister pair, Co-axial and Fiber optics cable. The following table summarizes the use of connectors.

Cable Type	Connectors
Twister Pair	RJ-45
Co-axial	BNC, RG-58
Fibre Optics	LC & SC, ST Connectors, MT-RJ

RJ-45 : It is a standard type of connector for network cables. RJ45 connectors are most commonly seen with Ethernet cables and networks.

RJ45 connectors feature eight pins to which the wire strands of a cable interface electrically. Standard RJ-45 pinouts define the arrangement of the individual wires needed when attaching connectors to a cable.

Several other kinds of connectors closely resemble RJ45 and can be easily confused for each other. The RJ-11 connectors used with telephone cables, for example, are only slightly smaller (narrower) than RJ-45 connectors.



[FIGURE 1-4 : RG-45 CONNECTOR]

BNC(Bayonet Neill Concelman) Connector: Short for Bayonet Neill Concelman connector, (sometimes erroneously called a British Naval Connector or Bayonet Nut Connector, a type of

connector used with coaxial cables such as the RG-58 A/U cable used with the 10Base-2 Ethernet system. The basic BNC connector is a male type mounted at each end of a cable. This connector has a center pin connected to the center cable conductor and a metal tube connected to the outer cable shield. A rotating ring outside the tube locks the cable to any female connector.

[Figure BNC Connector]

BNC T-connectors (used with the 10Base-2 system) are female devices for connecting two cables to a network interface card (NIC). A BNC barrel connector allows connecting two cables together.

BNC connectors can also be used to connect some monitors, which increases the accuracy of the signals sent from the video adapter.

LC (Lucent Connector) Connector: LC stands for Lucent Connector. The LC is a small form-factor Fiber optic connector.

The LC Connector uses a 1.25 mm ferrule, half the size of the ST. otherwise, it is a standard ceramic Ferrule connector. The LC has good performance and is highly favored for single mode. View all Fiber Optic Connectors.

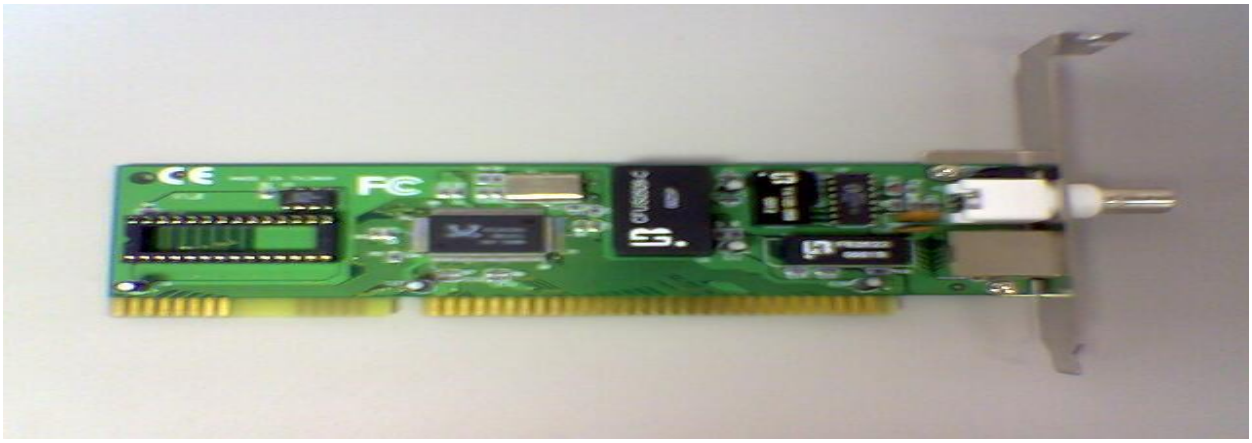
[Figure LC & ST Connectors]

Brief Description of Network lab Equipments

A. Cable Tester (figure 1-1): This device is used to check the connection of a cable.

[Figure : Cable tester]

B. Network Interface Card (NIC) (figure 1-2) :The Interface between computer and physical layer



[Figure : Network Interface card]

C. Hub : Used to connect multiple PCs to the server or in Peer-to-peer Topology.

[Figure: Network Hub]

D. Switch : Used to connect multiple PC's to the server or in peer-to-peer topology.

[FIGURE : Switch]

F Crimping-Tool : Used to attach connector like RJ-45 to UTP Cables

[FIGURE : Crimping Tool]

3.3 CRIMPING OF TWISTED PAIR CABLES

Usually**,** when cables can be purchased that come with connectors or we can attach connectors like RJ-45 to raw cables. The ready to use cables available in market are of 1 meter length, but if we want to create cables of custom length (for example 2.5 meters) then it is required to attached connectors separately to these cables. Crimping tool is a device to attach RJ-45 connector to the UTP cables. Cables are of two types, Straight-Cable and Cross-over Cables. Ethernet network cable is made of 4 pair high performance copper/aluminum cable that consists of twisted pair conductors used for data transmission. Both end of cable is called RJ45 connector.

Straight Cable

Usually use straight cable to connect different type of devices. This type of cable will be used most of the time and can be used to:

1) Connect a computer to a switch/hub's normal port.

2) Connect a computer to a cable/DSL modem's LAN port.

3) Connect a router's WAN port to a cable/DSL modem's LAN port.

4) Connect a router's LAN port to a switch/hub's uplink port. (Normally used for expanding network)

5) Connect two switches/hubs with one of the switch/hub using an uplink port and the other one using normal port.

If you need to check how straight cable looks like, it's easy. Both sides (side A and side B) of cable have wire arrangement with same color.

Crossover Cable

Sometimes you will use crossover cable, it's usually used to connect same type of devices. A crossover cable can be used to:

1) Connect two computers directly.

2) Connect a router's LAN port to a switch/hub's normal port. (Normally used for expanding network)

3) Connect two switches/hubs by using normal port in both switches/hubs.

In you need to check how crossover cable looks like, both side (side A and side B) of cable have wire arrangement with following different color.

This cable (either straight cable or cross cable) has total 8 wires (or we can say lines), i.e. four twisted pairs (4x2=8) with different color codes.

	Hub	**Switch**	**Router**	**Workstation**
Hub	Crossover	Crossover	Straight	Straight
Switch	Crossover	Crossover	Straight	Straight
Router	Straight	Straight	Crossover	Crossover
Workstation	Straight	Straight	Crossover	Crossover

Requirements for crimping a cable

- A reasonable length UTP cable
- Two RJ45 tips (connectors)
- A clip crimping tool

The procedure for crimping:

Strip the cable to 2 cm at each end and separate the strands. Let us call each end as side-A and side-B respectively. The cables are usually divided into 4 twisted pairs of colors:

Orange / orange-white
Green / green-white
Blue / white and blue
Brown / brown-white

Making a straight cable

To make a straight cable, the tips must be crimped typically the same way at each end by respecting the twisted pair size.

In general, the code used for side-A and side-B is:

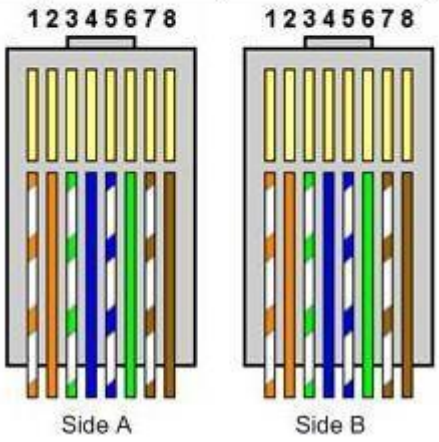
1) orange-white
2) orange
3) green-white
4) Blue
5) blue-white
6) Green
7) brown-white
8) brown

Making a crossover cable

For a crossover cable, side-A is similar to straight cable but in side-B, swap 1 with 3, and 2 with 6, in the list above.

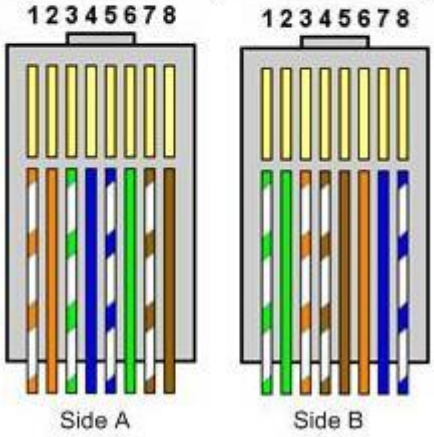
1)green-white
2)green
3)orange-white
4)Blue
5)blue-white
6)orange
7)brown-white
8)brown

Pin ID	Side A	Side B
1	Orange-white	Orange-white
2	Orange	Orange
3	Green-white	Green-white
4	Blue	Blue
5	Blue-white	Blue-white
6	Green	Green
7	Brown-white	Brown-white
8	Brown	Brown



Straight Cable

Pin ID	side A	side B
1	Orange-white	green-white
2	Orange	green
3	green-white	orange-white
4	blue	brown-white
5	blue-white	Brown
6	green	orange
7	brown-white	Blue
8	brown	blue-white



Cross-Over Cable

3.3 UNGUIDED TRANSMISSION MEDIA: (WIRELESS)

Now-a-days, mobile users are increasing. Recent mobile phones and laptops come with networking capabilities. People have started using wireless networks rather than wired networks. Wireless networks use unguided transmission media for communications. Air, Water and Vacuum are considered as unguided transmission media. Signals can travel in the form of waves (Radio wave, Micro wave or Infrared wave).

Let us discuss the advantages and limitations of Unguided Media. Advantages of wireless transmission are :
(a) Signals can travel in long distances
(b) It is cost effective
(c) Transmission media is freely available.

The limitations are :
(a) It is less secure
(b) Signals weaken in presence of obstacles or larger distances
(c) More chances of noise / EMI
(d) Data transmission rates cannot be higher
(e) Climate & weather changes can bring adverse effects on transmission.

Let us understand the concept of electromagnetic spectrum. As you know when we speak, sound waves are generated; they travel in air to the listening person. Similarly light waves travel from source to destination. Now these two waves have different characteristics. Sound waves cannot travel larger distances whereas light waves can travel in larger distances. The main difference between sound wave and light waves is in their frequency and wavelength. Figure illustrates the frequencies of various waves. This is known as Electromagnetic spectrum. All the waves are considered as electromagnetic waves.

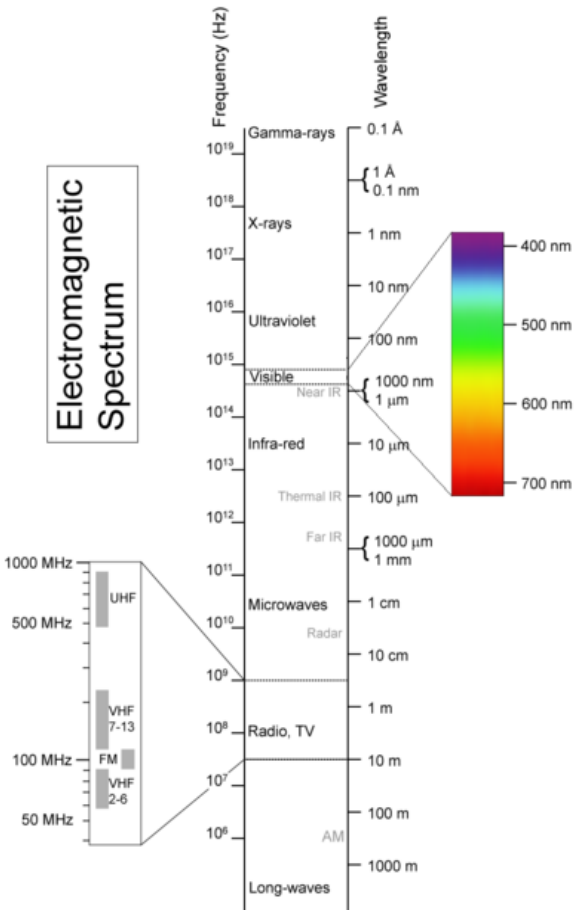


Figure (Electromagnetic Spectrum)

TV and FM Radios use the frequency range between 10^7 to 10^9 Hertz. Gamma Rays have highest frequency range. What we can see (visible light) is found above Infra red frequency and below Ultra Violet frequency. In communications we generally use radio waves, micro waves and infrared waves. Let us study the characteristics of each of these waves.

3.3.1 Infrared Waves and Light Waves

There is very less use of Infrared and Light waves in computer networking. The main reason is that the waves cannot travel large distances and can be easily obstructed. Infrared waves travel in straight line. These waves cannot travel through buildings or walls. Infrared waves are mostly used in Remote Controls and alarm sensor systems.

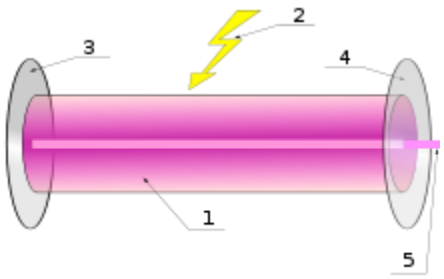
This technology also is used for network communication. Four varieties of infrared communications are as follows:

- Broadband optical telepoint:This method uses broadband technology. Data transfer rates in this high-end option are competitive with those for a cable-based network.
- Line-of-sight infrared:Transmissions must occur over a clear line-of-sight path between transmitter and receiver.
- Reflective infrared:Wireless PCs transmit toward a common, central unit, which then directs communication to each of the nodes.
- Scatter infrared: Transmissions reflect off floors, walls, and ceilings until (theoretically) they finally reach the receiver. Because of the imprecise trajectory, data transfer rates are slow. The maximum reliable distance is around 100 feet.

Infrared transmissions are typically limited to within 100 feet. Within this range, however, infrared is relatively fast. Infrared's high bandwidth supports transmission speeds of up to 10Mbps.

Light Waves

The term "LASER" originated as an acronym for "Light Amplification By Stimulated Emission of Radiation". Laser beams can be focused to very tiny spots, achieving a very high irradiance.



Principal components:

1. Gain medium
2. Laser pumping energy
3. High reflector
4. Output coupler
5. Laser beam

Light amplification in laser means orienting the beams of light from a flash lamp source so that the light waves move parallel to each other. This enhances their energy levels. Laser machines use an optical resonator for this purpose. This is a cylindrical chamber with reflecting mirrors at both ends and an absorbing lining all around (to absorb and eliminate scattering light).

Laser medium (containing atoms with excited electrons), in the form of solids, gases or dyes are filled within the chamber. When the laser machine is put to work, spontaneous emission of laser light occurs, with the lining inside absorbing the scattering lights, and through reflection, the beams are amplified and sent out through a release mechanism from one end of the optical resonator chamber. This, in short, is the origin of the laser light beam.

Difference between Laser Light and Ordinary Light?

There are three distinctive characteristics unique to laser light compared to the normal, natural light:

1. Laser light is collimated: It travels in a single direction without any fluctuation or divergence, even over long distance. Ordinary light waves, in contrast, are scattered in every direction and lose their brightness and intensity within no time.
2. Laser light is monochromatic: This means that the laser light contains only one color or a very narrow range of colors of same frequency. Ordinary light has a wide variety of colors of varying wavelengths. These include the visible light, the ultraviolet light, infra red light etc.
3. Laser light is coherent: The light rays emanating from a laser source are in step, moving together, both in space and time. In ordinary light, the rays are incoherent (out of step with each other) and travel in different directions and are of different frequencies.

Light waves can be used in the form of LASER, they do have limitations like limited distance, cannot pass through obstacles and interference due to weather conditions. Hence such waves do not find any use in Computer Networking.

3.3.2 Radio Waves

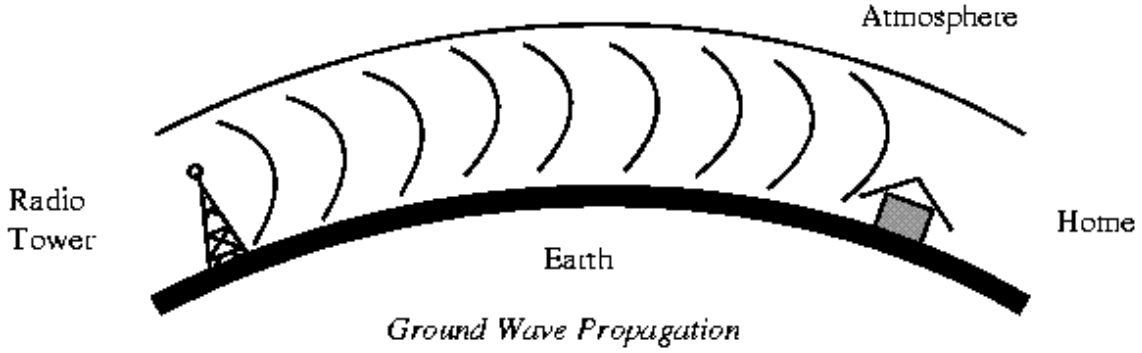
Radio waves operate in the frequency range of 10 Khz to 1 GHz. We can further classify radio waves into (a) Short waves (b) Very High Freq. (VHF) and FM Radio (c) Ultra High Freq. (UHF) and television. The power of radio frequency (RF) is determined by the antenna and the trans-receiver (transmitter + receiver). Few characteristics of radio waves are :

(a) The can be easily generated at low cost.
(b) They can travel long distances
(c) They can penetrate through buildings and walls.
(d) They are omni-directional, it means they can travel in all directions. (For. eg. Light comming out from a bulb/lamp is omni-directional / isotropic but the light comming out from the torch is directional / focussed beam)
(e) They can be absorbed by rain.
(f) At all frequencies, radio waves may suffer from interference from electrical equipments.

Propagation of Radio waves :

Radio waves can travel in different ways depending on the frequency and devices. The following are the different propagation modes of radio waves :

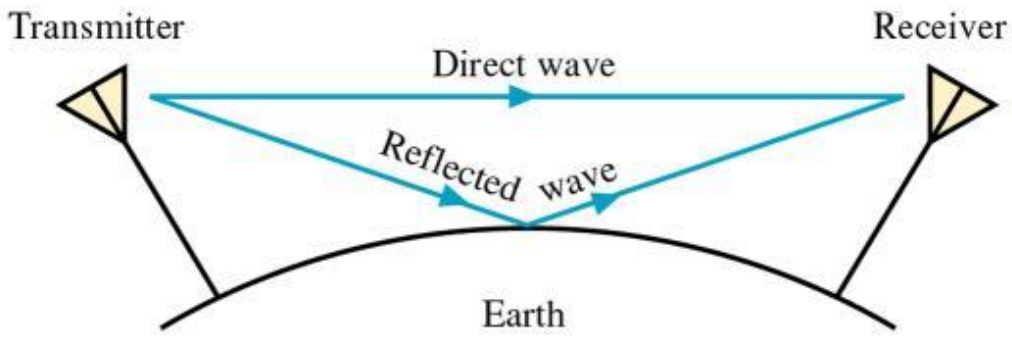
(a) Surface Mode (Ground wave) : Here the radio waves travel on the surface of the earth. The earth has a curve shape, such type of radio waves also follow the curvature of the earth, they tend to cling to the earth's surface. AM Radio is a good example of this kind of propagation. Such radio waves fall in the frequency range of 30 Khz to 3000 Khz. Figure



illustrates the Ground wave propogation.

Figure (Surface mode propogation)

(b) Direct Mode (Line of Sight) : Radio waves at higher frequencies travel in straight line. The sender and receiver must be in the same line. Communication between Satellite and ground antenna is an example of Direct Mode. Radio waves with a frequency above 30 MHz



are used in Direct mode. Figure illustrates Line of Sight communication.
Figure (Direct Mode Propogation)

(c) Ionospheric Mode (Skywave) : Ionosphere is a layer above earth with charged gas particles (ions). It is around 60 to 800 Km above the earth. Ionosphere can reflect the radio waves. This phenomenon can be used to communicate at larger distances. Skywaves can travel at larger distances as they can reflect from the ionosphere. Skywaves operate at a frequency range of 4 MHz to 30 MHz. Fig. illustrates the ionosphere.

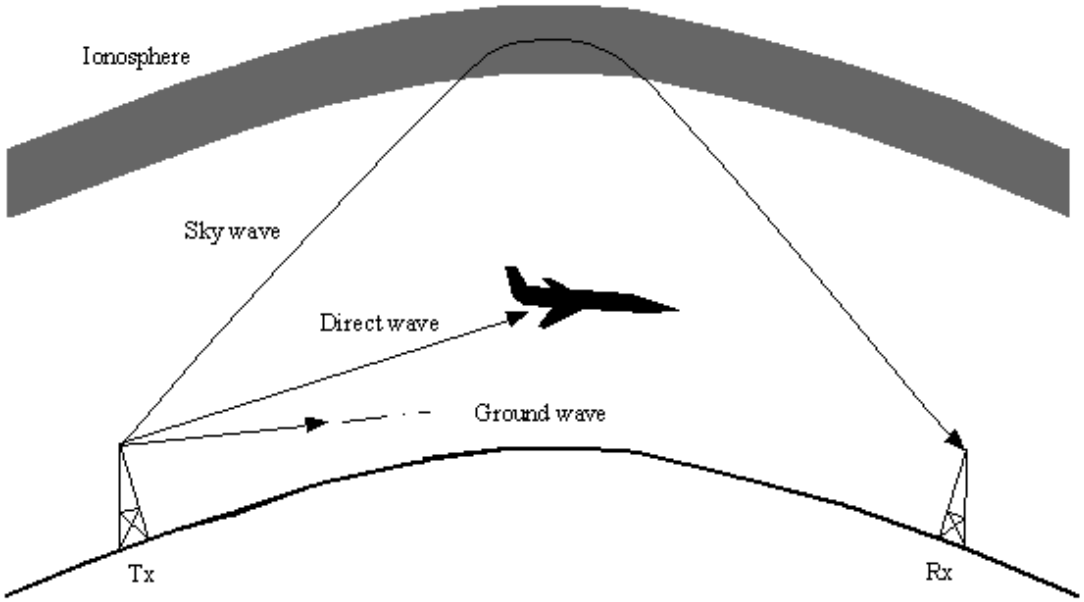


Figure (Ionospheric propogation)

As the radio waves are easy to generate and can travel in any direction, most of the wireless networks use radio waves. Depending on the type of application, radio waves are most suitable in LAN and WAN environments.

3.3.3 Micro Waves

Microwaves are most common waves found in Kitchen devices, they do have a major role in Computer Networking as well. Microwaves operate above 100 MHz frequency. In microwave transmissions, the sender and receiver must be in line of sight. It is a directional transmission. You might have observed microwave towers on roads or highways. Generally the towers are on mountain tops, so that they do not face obstacles between two towers. For example there can be multiple towers between Baroda and Ahmedabad, after every 10 Km they regenerate the signals using repeaters. The main limitation of microwave is that they cannot pass through any obstacles. There are two types of Microwave transmissions:

- Terrestrial Microwave : It is used for land to land communication. Towers are placed at different locations (in line-of-sight), the distance between transmitter and receiver can be around 50-80 km. There may be need of repeaters due to Earth's curvature. Terrestrial microwave communications uses two types of antenna (a) Parabolic dish (b) Horn antenna. Figure 4.13 illustrates terrestrial microwave.

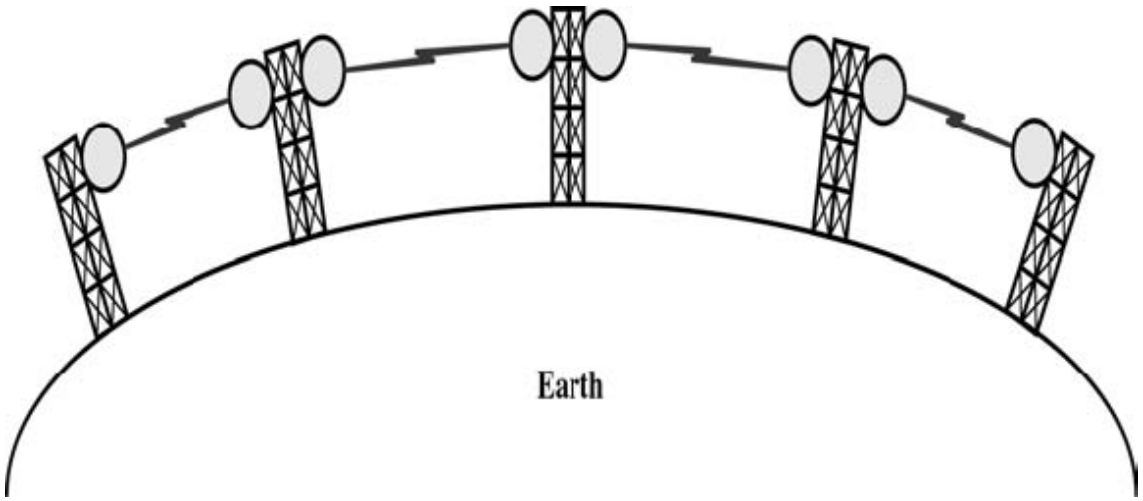


Figure (Terrestial Microwave)

- Satellite Microwave : The limitation of terrestrial microwave is the curvature of Earth. In satellite microwave communication, the transmitter and receiver and be in any part of the earth. The transmitting station will use uplink frequency to send data/voice signals to the satellite, the satellite replays back to receiving station using downlink frequency. Satellite communication requires a special device called transponder at receiving and transmitting stations. Most of the satellites use the frequency of 4-6 Giga Hertz. Figure 4.14 illustrates a point-to-point link for Satellite communications. Figure illustrates Broadcast link, an example of DTH TV connection.

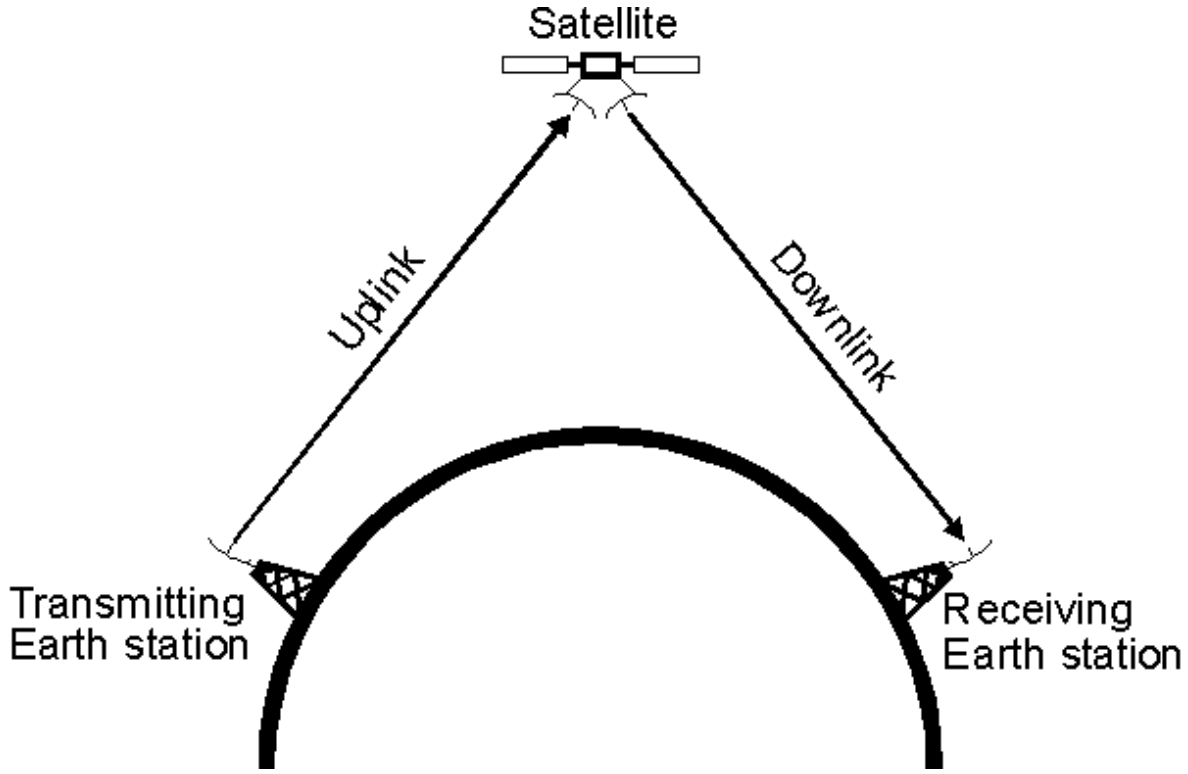


Figure (Point-to-Point Link in Satellite Microwave)

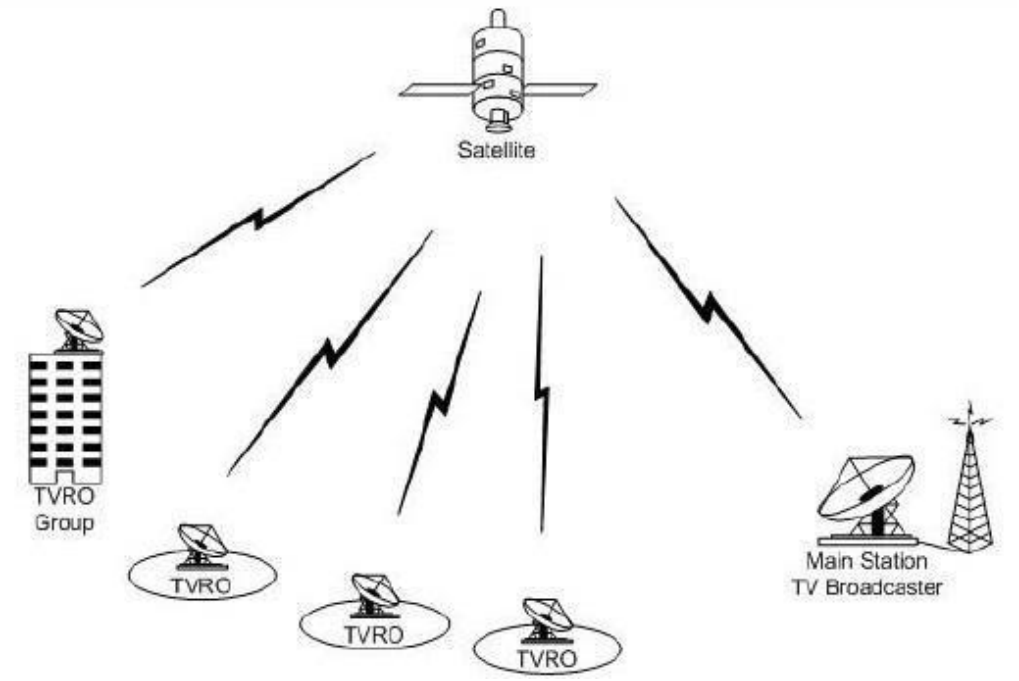
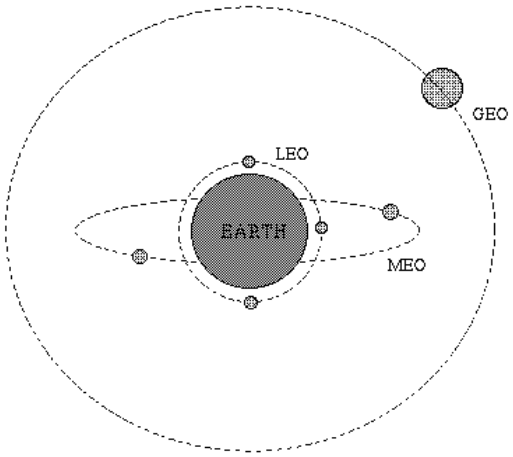


Figure (Broadcast Links in Satellite Microwave)

There are 3 major ways of placing a satellite. It can be installed in an orbit around the earth depending on the type of communication system required, various ways are :

- GEO (GeoStationary/GeoSynchronous Earth Orbit) : Around 36,000 km from Earth, It revolves at the speed of Earth (24 hours for one cycle) and can cover 120 degress of Earth surface. So just 3 satellites can cover the entire Earth.
- MEO (Middle Earth Orbit) : Such satellites are placed at the height of around 1000-5000 km.
- LEO (Low Earth Orbit) : Such satellites are placed at the height of 600-1000 km. They revolve at higher speeds.



Use of Satellite Communications:

- Television Distribution
- Private Business Networks
- Long Distance Telephone Communications

Now let us discuss few advantages and limitations of Satellite Communications. The advantages are :

- They can cover wide geographical area.
- Cost of transmission is constant, whether the stations are near or far the cost remains same.
- Supports a large transmission capacity and high bandwidth.
- Available on lease, no need to purchase entire satellite.
- Helps in designing a switched network.

Limitations of Satellite Communications are :

- Depends on weather conditions, poor weather may disrupt the services.
- Signals can be trapped, so it is less secure.
- Delay in communication due to larger distances.
- Limited number of satellites can be placed in sky.

- Land based communication systems (radio signals) can interfere the Satellite signals.

Frequency Bands for Satellite Communications:
The Satellite communication is divided into different bands. The transmitting frequency is called uplink whereas the receiving frequency is called downlink. The following table summarizes different frequency bands used in Satellite communications:

Band	UpLink (GHz)	Downlink(GHz)	Limitations
L	1.6	1.6	Terrestrial Interferences
Cu	5.925-6.425	3.7-4.2	Terrestrial Interferences
Ku	14.0-14.5	11.7-12.2	Poor Weather
Ka	27.5-30.5	17.7-21.7	Poor Weather, Costly

3.3.4 Bluetooth

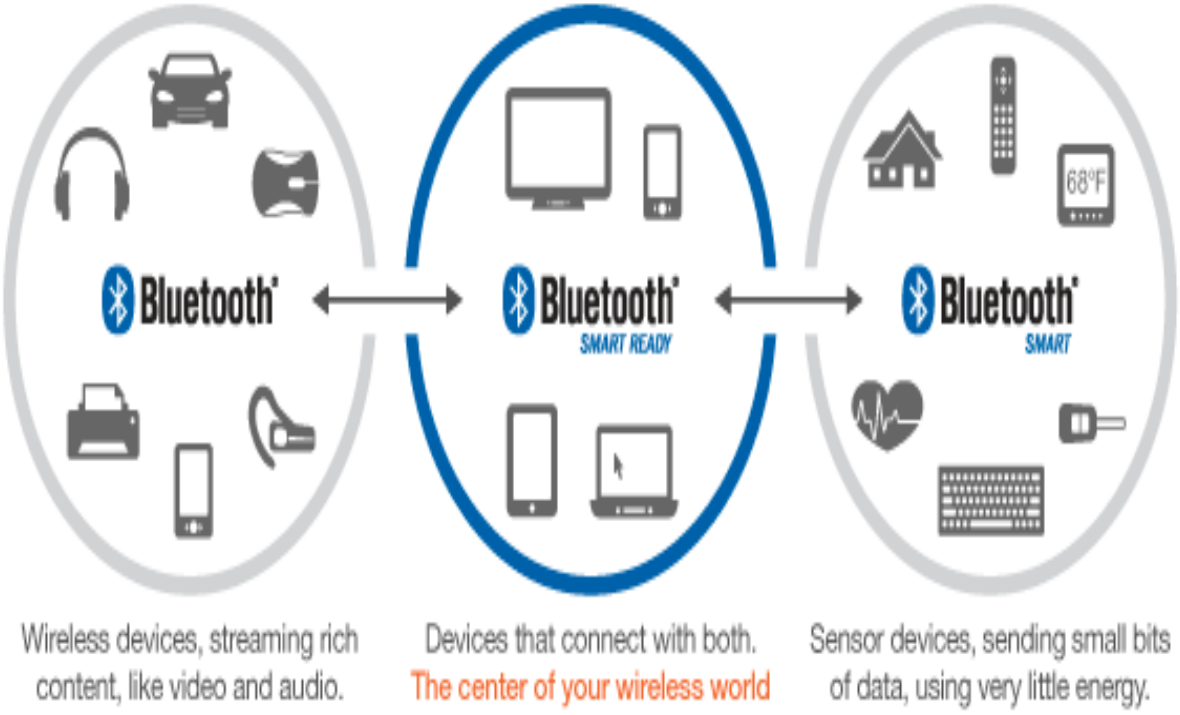
Bluetooth was created by a group of technology companies namely Ericsson, IBM, Intel, Nokia and Toshiba for wireless connectivity between two or more devices.

Named after an ancient Danish King, Bluetooth is a wireless connectivity technology, enabling a range of devices to communicate with each other using radio waves. *Bluetooth* wireless technology is the standard for transmitting information in the form of short range radio waves over distances of up to 30 feet and is used to connect and exchange information between digital devices. The transfer speed of Bluetooth 1.0 is 1 Mbps; Bluetooth 2.0 is 3 Mbps which is faster than conventional IR(infrared) which most cell phones are equipped with. However, the only advantage for Bluetooth is the low power signal it sends which limit the signal range so it won't interfere with any other radio frequecy in the air. For instance, a cellular telephone can connect to a PDA (Personal Digital Assistant) or to a computer in order to update a phonelist or to connect a wireless Bluetooth headset. Bluetooth 2.0 is backward-compatible with 1.0 devices.

One of the ways Bluetooth devices avoid interfering with other systems is by sending out very **weak signals** of about 1 milliwatt. By comparison, the most powerful cell phones can transmit a signal of 3 watts. The low power limits the range of a Bluetooth device to about **10**

meters (32 feet), cutting the chances of interference between your computer system and your portable telephone or television. Even with the low power, Bluetooth doesn't require line of sight between communicating devices. The walls in your house won't stop a Bluetooth signal, making the standard useful for controlling several devices in different rooms.

Bluetooth can connect up to **eight devices** simultaneously. With all of those devices in the same 10-meter (32-foot) radius, you might think they'd interfere with one another, but it's unlikely. Bluetooth uses a technique called **spread-spectrum frequency hopping** that makes it rare for more than one device to be transmitting on the same frequency at the same time. Since every Bluetooth transmitter uses spread-spectrum transmitting automatically, it's unlikely that two transmitters will be on the same frequency at the same time. This same technique minimizes the risk that portable phones or baby monitors will disrupt Bluetooth devices, since any interference on a particular frequency will last only a tiny fraction of a second.



When Bluetooth-capable devices come within range of one another, an electronic conversation takes place to determine whether they have data to share or whether one needs to control the other. The user doesn't have to press a button or give a command -- the electronic conversation happens automatically. Once the conversation has occurred, the devices -- whether they're part of a computer system or a stereo will create a network. Bluetooth systems create a personal-area network (PAN), or **piconet**, that may fill a room or may encompass no more distance than that between the cell phone on a belt-clip and the

headset on your head. Once a piconet is established, the members randomly hop frequencies in unison so they stay in touch with one another and avoid other piconets that may be operating in the same room.

A typical modern living room with typical modern stuff inside. There's an entertainment system with a stereo, a DVD player, a satellite TV receiver and a television; there's also a cordless telephone and a personal computer. Each of these systems uses Bluetooth, and each forms its own piconet to talk between the main unit and peripheral.

Summary of Wavelengths and Corresponding Frequencies

Designation	Abbreviation	Frequencies	Free-space Wavelengths
Very Low Frequency	VLF	9 kHz - 30 kHz	33 km - 10 km
Low Frequency	LF	30 kHz - 300 kHz	10 km - 1 km
Medium Frequency	MF	300 kHz - 3 MHz	1 km - 100 m
High Frequency	HF	3 MHz - 30 MHz	100 m - 10 m
Very High Frequency	VHF	30 MHz - 300 MHz	10 m - 1 m
Ultra High Frequency	UHF	300 MHz - 3 GHz	1 m - 100 mm
Super High Frequency	SHF	3 GHz - 30 GHz	100 mm - 10 mm

Extremely High Frequency	EHF	30 GHz - 300 GHz	10 mm - 1 mm

MCQ of Transmission media

1. Transmission media are usually categorized as _____.
A) fixed or unfixed
B) guided or unguided
C) determinate or indeterminate
D) metallic or nonmetallic

2. Transmission media lie below the _____ layer.
A) physical
B) network
C) transport
D) application

3. _____ cable consists of an inner copper core and a second conducting outer sheath.
A) Twisted-pair
B) Coaxial
C) Fiber-optic
D) Shielded twisted-pair

4. In fiber optics, the signal is _____ waves.
A) light
B) radio
C) infrared
D) very low-frequency

5. Which of the following primarily uses guided media?
A) cellular telephone system
B) local telephone system
C) satellite communications
D) radio broadcasting

6. Which of the following is not a guided medium?
A) twisted-pair cable
B) coaxial cable

C) fiber-optic cable
D) radio waves

7. What is the major factor that makes coaxial cable less susceptible to noise than twisted-pair cable?
A) inner conductor
B) diameter of cable
C) outer conductor
D) insulating material

8. In an optical fiber, the inner core is _____ the cladding.
A) denser than
B) less dense than
C) the same density as
D) another name for

9. The inner core of an optical fiber is _____ in composition.
A) glass or plastic
B) copper
C) bimetallic
D) liquid

10. When a beam of light travels through media of two different densities, if the angle of incidence is greater than the critical angle, _____ occurs.
A) reflection
B) refraction
C) incidence
D) criticism

11. When the angle of incidence is _____ the critical angle, the light beam bends along the interface.
A) more than
B) less than
C) equal to
D) none of the above

12. Signals with a frequency below 2 MHz use _____ propagation.
A) ground
B) sky
C) line-of-sight

D) none of the above

13. Signals with a frequency between 2 MHz and 30 MHz use _____ propagation.
A) ground
B) sky
C) line-of-sight
D) none of the above

14. Signals with a frequency above 30 MHz use _____propagation.
A) ground
B) sky
C) line-of-sight
D) none of the above

15. A parabolic dish antenna is a(n) _____ antenna.
A) omnidirectional
B) bidirectional
C) unidirectional
D) horn

16. A(n) _____ medium provides a physical conduit from one device to another.
A) guided
B) unguided
C) either (a) or (b)
D) none of the above

17. _____ cable consists of two insulated copper wires twisted together.
A) Coaxial
B) Fiber-optic
C) Twisted-pair
D) none of the above

18. _____ cable suffers from highest EMI.
A) Coaxial
B) Fiber-optic
C) Twisted-pair
D) none of the above

19. _____ consists of a central conductor and a shield.
A) Coaxial

B) Fiber-optic
C) Twisted-pair
D) none of the above

20. _____ cable can carry signals of higher frequency ranges than _____ cable.
A) Twisted-pair; fiber-optic
B) Coaxial; fiber-optic
C) Coaxial; twisted-pair
D) none of the above

21. _____ cables are composed of a glass or plastic inner core surrounded by cladding, all encased in an outside jacket.
A) Coaxial
B) Fiber-optic
C) Twisted-pair
D) none of the above

22. _____ cables carry data signals in the form of light.
A) Coaxial
B) Fiber-optic
C) Twisted-pair
D) none of the above

23. In a fiber-optic cable, the signal is propagated along the inner core by _____.
A) reflection
B) refraction
C) modulation
D) none of the above

24. _____ media transport electromagnetic waves without the use of a physical conductor.
A) Guided
B) Unguided
C) Either (a) or (b)
D) None of the above

25. Radio waves are _____.
A) omnidirectional
B) unidirectional
C) bidirectional

D) none of the above

26. Microwaves are _____.
A) omnidirectional
B) unidirectional
C) bidirectional
D) none of the above

27. _____ are used for cellular phone, satellite, and wireless LAN communications.
A) **Radio waves**
B) Microwaves
C) Infrared waves
D) none of the above

28. _____ are used for short-range communications such as those between a PC and a peripheral device.
A) **Radio waves**
B) Microwaves
C) Infrared waves
D) none of the above

29. _____ is made up of light signals.
A) Radio waves
B) Microwaves
C) Infrared waves
D) Laser

30. Remote Controls of Television Sets use :
A) Radio waves
B) Microwaves
C) Infrared waves
D) Laser

31. _____ Connector is used with Twisted pair cables
A) RJ-45
B) BNC
C) LC
D) None

32. _____ Connector is used with Co-axial cables
A) RJ-45
B) BNC
C) LC
D) None

33. _____ Connector is used with Fibre Optic cables
A) RJ-45
B) BNC
C) LC
D) None

34. A straight-through cable can be used to connect
A) One computer to another
B) Connect a router's LAN port to a switch/hub's normal port.
C) Connect 2 switches/hubs by using normal port in both switches/hubs.
D) Connect a computer to a switch/hub's normal port.

35. Bluetooth can connect upto _____ devices simultaneously.
A) 4
B) 8
C) 10
D) 16

36. Piconet is a _____.
A) LAN
B) WAN
C) MAN
D) PAN

37. ____ is the nearest orbit from earth.
A) LEO
B) MEO
C) GEO
D) None

Exercises

1. What do you understand by Guided Media and Unguided Media?
2. Differentiate between Wireless and Wired Networking.
3. Differentiate between Twisted Pair cable and Co-axial Cable.
4. Differentiate between Twisted Pair cable and Fibre Optic Cable
5. Differentiate between straight cable and crossover cable
6. What do you understand by LEO, MEO and GEO
7. Write Short Notes on
    a) Twisted – Pair Cables
    b) Co-axial Cables
    c) Fibre Optics
    d) Microwave Transmission
    e) Radiowave Transmission
8. Define
    a) Electromagnetic Inference
    b) Attenuation
    c) Media
    d) TDM
    e) FDM
    f) Baseband
    g) Broadband
    h) Downlink
    i) Uplink
    j) Frequency

k) Bandwidth