UNIT 4 COMMUNICATION MEDIUMS

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4.0 DIGITAL DATA TRANSMISSION

The term digital refers to the way it is conveyed: usually by a binary code consisting of a long string of 1s and 0s. Digital transmission or digital communications is a literal transfer of data over a point to point (or point to multipoint) link using transmission medium –such as copper wires, optical fibers, wireless communications media, or storage media. The data that is to be transferred is often represented as an electro-magnetic signal (such as a microwave). Digital transmission transfers messages discretely. These messages are represented by a sequence of pulses via a line code. Digital data transmission can occur in two basic modes: serial or parallel. The serial and parallel transmission is shown in Figure 1 below. Data within a computer system is transmitted via parallel mode on buses with the width of the parallel bus matched to the word size of the computer system. Data between computer systems is usually transmitted in bit serial mode. Consequently, it is necessary to make a parallel-to-serial conversion at a computer interface when sending data from a computer system into a network and a serial-to-parallel conversion at a computer interface when receiving information from a network. The type of transmission mode used may also depend upon distance and required data rate.

4.1 OBJECTIVES

After going through this unit, you should be able to:

- Know the concept of communication mediums
- Differentiate between Serial and Parallel Transmission
- Differentiate between Guided and Unguided Mediums
- Know the features and limitations of different wired mediums
- Understands the use of Twisted Pair, Coaxial and Fiber Optic Cables
- Know the functions of Unguided Mediums
- Understand the use of different connectors

4.2 SERIAL AND PARALLEL TRANSMISSION

Serial Transmission: In serial transmission, bits are sent sequentially on the same channel (wire) as shown in Figure 1, which reduces costs for wire but also slows the speed of transmission. Also, for serial transmission, some overhead time is needed since bits must be assembled and sent as a unit and then disassembled at the receiver. Serial transmission can be either synchronous or asynchronous. In synchronous transmission, groups of bits are combined into frames and frames are sent continuously with or without data to be transmitted. In asynchronous transmission, groups of bits are sent as independent units with start/stop flags and no data link synchronization, to allow for arbitrary size gaps between frames. However, start/stop bits maintain physical bit level synchronization once detected.

In parallel transmission, multiple bits (usually 8 bits or a byte/character) are sent simultaneously on different channels (wires, frequency channels) within the same cable as shown in Figure 1, or radio path, and synchronized to a clock. Parallel devices have a wider data bus than serial devices and can therefore, transfer data in words of one or more bytes at a time.

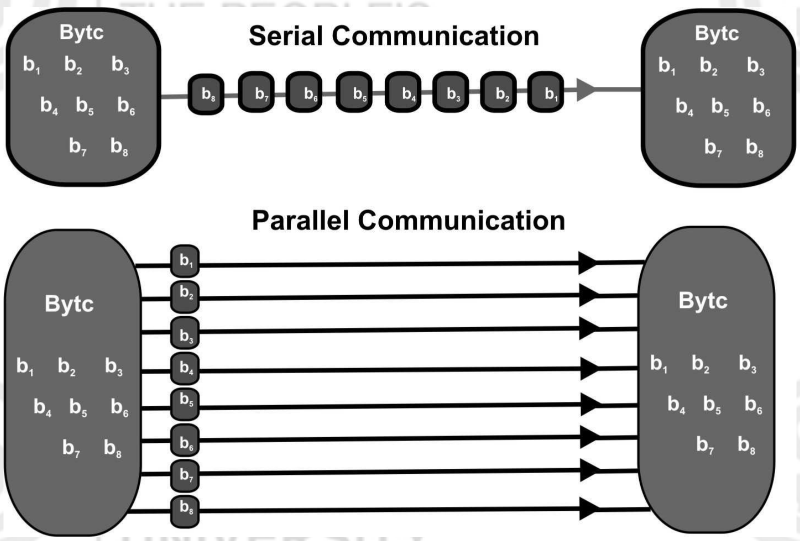

Figure 1: Serial and parallel communication

As a result, there is a speedup in parallel transmission bit rate over serial transmission bit rate. However, this speedup is a tradeoff versus cost since multiple wires cost more than a single wire, and as a parallel cable gets longer, the synchronization timing between multiple channels becomes more sensitive to distance. The timing for parallel transmission is provided by a constant clocking signal sent over a separate wire within the parallel cable; thus parallel transmission is considered synchronous.

4.3 GUIDED AND UNGUIDED MEDIUMS

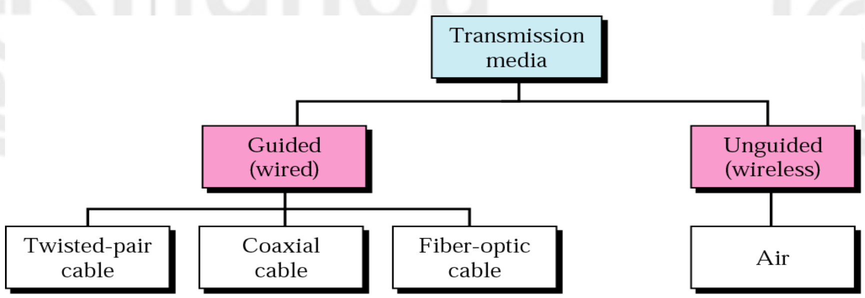

Figure 2: Classification of Transmission Mediums

Transmission Media: The transmission medium is the physical path between transmitter and receiver in a data transmission system. Transmission media can be classified as guided or unguided as depicted in Figure 2. With guided media, the waves are guided along a solid medium, such as twisted pair, coaxial cable, and optical fiber. The atmosphere and outer space are examples of unguided media that provide a means of transmitting electromagnetic signals but do not guide them; this form of transmission is usually referred to as wireless transmission.

The characteristics and quality of a data transmission are determined both by the characteristics of the medium and the characteristics of the signal. In the case of guided media, the medium itself is more important in determining the limitations of transmission.

For unguided media, the bandwidth of the signal produced by the transmitting antenna is more important than the medium in determining transmission characteristics. One key property of signals transmitted by antenna is directionality. In general, signals at lower frequencies are Omni-directional; that is, the signal propagates in all directions from the antenna. At higher frequencies, it is possible to focus the signal into a directional beam.

4.4 TWIATED PAIR

Twisted pair is most widely used media for local data distribution. Twisted-pair cable is a type of cabling that is used for telephone communications and most modern Ethernet networks. A pair of wires forms a circuit that can transmit data. The pairs are twisted to provide protection against crosstalk, and noise generated by adjacent pairs. When electrical current flows through a wire, it creates a small, circular magnetic field around the wire. When two wires in an electrical circuit are placed close together, their magnetic fields are the exact opposite of each other. Thus, the two magnetic fields cancel each other out. They also cancel out any outside magnetic fields. Twisting the wires can enhance this cancellation effect. Using cancellation together with twisting the wires, cable designers can effectively provide self shielding for wire pairs within the network media. The twisted pair cable is shown in Figure 3.

Figure 3: Twisted pair Cable

While twisted-pair cable is used by older telephone networks and is the least expensive type of local-area network (LAN) cable, most networks contain some twisted-pair cabling at some point along the network.

Since some telephone sets or desktop locations require multiple connections, twisted pair is sometimes installed in two or more pairs, all within a single cable. For some business locations, twisted pair is enclosed in a shield that functions as a ground. This is known as shielded twisted pair (STP). Ordinary wire to the home is unshielded twisted pair (UTP).

4.5 UTP CABLE

Unshielded twisted pair is the most common kind of copper telephone wiring. UTP cable is a medium that is composed of pairs of wires. UTP cable is used in a variety of networks. Each of the eight individual copper wires in UTP cable is covered by an insulating material. In addition, the wires in each pair are twisted around each other as shown in Figure 4 (a).

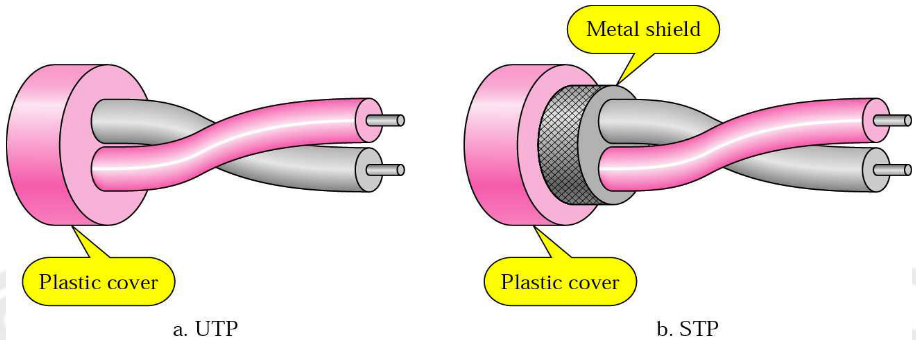

Figure 4: UTP and STP Cables

UTP cable relies solely on the cancellation effect produced by the twisted wire pairs to limit signal degradation caused by electromagnetic interference (EM!) and radio frequency interference (RFI). To further reduce crosstalk between the pairs in UTP cable, the number of twists in the wire pairs varies. UTP cable must follow precise specifications governing how many twists or braids are permitted per meter (3.28 feet) of cable.

4.6 STP CABLE

STP is similar to UTP in that the wire pairs are twisted around each other. STP also has shielding around the cable to further protect it from external interference. The shielding further reduces the chance of crosstalk but the shielding increases the overall diameter and weight of the cable. The maximum segment length of STP cable is 100 meters.

Shielded twisted pair is a special kind of copper telephone wiring used in some business installations. An outer covering or shield is added to the ordinary twisted pair telephone wires; the shield functions as a ground. The STP cable is shown in figure above in Figure 4(b).

Shielded twisted-pair (STP) cable combines the techniques of shielding, cancellation, and wire twisting. Each pair of wires is wrapped in a metallic foil. The four pairs of wires then are wrapped in an overall metallic braid or foil. It is usually a 150-ohm cable, as specified for use in Ethernet network installations. STP reduces electrical noise both within the cable (pair-to-pair coupling, or crosstalk) and from outside the cable (EMI and RFI).

☞ Check Your Progress 1

1. Define parallel transmission.

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2. List guided transmission mediums?

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3. What are the advantages of STP over UTP?

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4.7 COAXIAL CABLE

Coaxial cable like twisted pair, consists of two conductors, but is constructed differently to permit it to operate over a wider range of frequencies. It consists of a hollow outer cylindrical conductor that surrounds a single inner wire conductor. The inner conductor is held in place by either regularly spaced insulating rings or a solid dielectric material. The outer conductor is covered with a jacket or shield. A single coaxial cable has a diameter of from 0.4 to about 1 inch. Because of its shielding, concentric construction, coaxial cable is much less susceptible to interference and cross-talk than is twisted pair. Coaxial cable can be used over longer distances and supports more stations on a shared line than twisted pair.

Coaxial cable is perhaps the most versatile transmission medium and has widespread use in a wide variety of applications; the most important of these are

i) Television distribution

ii) Long-distance telephone transmission

iii) Short-run computer system links

iv) Local Area Networks

Coaxial cable is spreading rapidly as a means of distributing TV signals to individual homes - cable TV. A cable TV system can carry dozens or even hundreds of TV channels ranging up to a few tens of miles.

Coaxial cable has traditionally been an important part of the long-distance telephone network. Today, it is getting replaced by optical fiber, terrestrial microwave, and satellite. Using frequency-division multiplexing, a coaxial cable can carry over 10,000 voice channels simultaneously. Coaxial cable is also commonly used for short-range connections between devices. Using digital signaling, coaxial cable can be used to provide high-speed I/O channels on computer systems. A co-axial cable is shown in Figure 5 below.

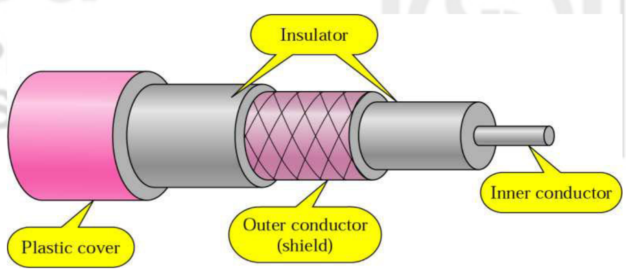

Figure 5: Coaxial cable

Another application area for coaxial cable is local area networks. Coaxial cable can support a large number of devices with a variety of data and traffic types, over distances that encompass a single building or a complex of buildings.

Coaxial cable is used to transmit both analog and digital signals. Coaxial cable has frequency characteristics that are superior to those of twisted pair, and can hence be used effectively at higher frequencies and data rates. The principal constraints on performance are attenuation, thermal noise, and inter modulation noise.

For long-distance transmission of analog signals, amplifiers are needed every few kilometers, with closer spacing required if higher frequencies are used. The usable spectrum for analog signaling extends to about 400 MHz. For digital signaling, repeaters are needed every kilometer or so, with closer spacing needed for higher data rates.

4.8 FIBRE OPTIC CABLES

Now day's optical fiber is widely used as a back bone for network due to its higher data transmission rate, lighter in weight, low interferences, less number of repeaters required, long distance coverage etc. An optical transmission system has three components; the light source, the transmission medium, and the detector.

Conventionally, a pulse of light indicates a bit 1 and absence of light indicates bit 0. Transmission medium is an ultra-thin fiber of glass. The transmitter generates the light pulses based on the input electrical signal. The detector regenerates the electrical signal based on the light signal it detects on the transmission medium. By attaching a light source to one end of an optical fiber and a detector to the other, we have an unidirectional data transmission system that accepts an electrical signal, converts and transmits it by light pulse, and then reconverts the output to an electrical signal at the receiving end. Figure 6 given blow shows optical fiber cable.

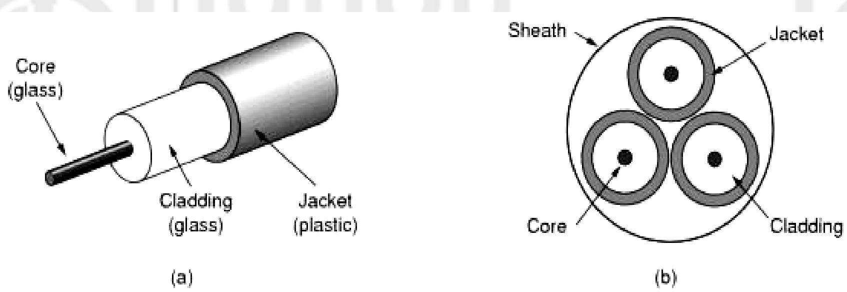

Figure 6: Optical Fiber Cable

An optical fiber is a thin (2 to 125 nm – nano meter – 10-9 meter), flexible medium capable of conducting an optical ray. Various glasses and plastics can be used to make optical fibers. The lowest losses have been obtained using fibers of ultrapure fused silica. Ultrapure fiber is difficult to manufacture; higher-loss multi-component glass fibers are more economical and still provide good performance. Plastic fiber is even less costly and can be used for short-haul links, for which moderately high losses are acceptable.

An optical fiber cable has a cylindrical shape and consists of three concentric sections: the core, the cladding, and the jacket. The core is the innermost section and consists of one or more very thin strands, or fibers, made of glass or plastic. Each fiber is surrounded by its own cladding, a glass or plastic coating that has optical properties different from those of the core. The outermost layer, surrounding one or a bundle of cladded fibers, is the jacket. The jacket is composed of plastic and other material layered to protect against moisture, abrasion, crushing and other environmental dangers.

One of the most significant technological breakthroughs in data transmission has been the development of practical fiber optic communications systems. Optical fiber already enjoys considerable use in long-distance telecommunications. The continuing improvements in performance and decline in prices, together with the inherent advantages of optical fiber, have made it increasingly attractive for local area networking and metropolitan networks. Optical fiber is of two types.

i) Single mode optical fiber.

ii) Multimode Optical Fiber.

Single mode optical fiber: Single mode uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal. The fiber itself is manufactured with a much smaller diameter than that of multimode fibers, and with substantially lowers density (index of refraction). The decrease in density results in a critical angle that is close enough to 90 degrees to make the propagation of beams delays are negligible. All of the beams arrive at the destination "together" and can be recombined without distortion to the signal as depicted in Figure 7 (c).

Multi-Mode: Multimode is so named because multiple beams from a light source move through the core in different paths. How these beams move within a cable depends on the structure of the core. Multi-mode is categorized into step-index multimode and graded index mode.

1. **Step-index Mult-mode:** In step-index multimode, the density of the core remains constant from the center to the edges. A beam of light moves through this constant density in a straight line until it reaches the interface of the core and the cladding. At the interface there is an abrupt change to a lower density that alters the angle of the beam's motion. The term step-index refers to the suddenness of this change. Figure 7 below shows various beams (or rays) traveling through a step-index fiber. Some beams in the middle travel in straight lines through the core and reach the destination without reflecting or refracting. Some beams strike the interface of the core and cladding at an angle smaller than the critical angle; these beams penetrate the cladding and are lost. Still others hit the edge of the core at angles greater than the critical angle and reflect back into the core and off the other side, bouncing back and forth down the channel until they reach the destination.

   Every beam reflects off the interface at an angle equal to its angle of incidence as shown in Figure 7(a). The greater the angle of incidence, the wider the angle of refraction. A beam with a smaller angle of incidence will require more bounces to travel the same distance than a beam with a larger angle of incidence. Consequently, the beam with the smaller incident angle must travel farther to reach the destination. This difference in path length means that different beams arrive at the destination at different times. As these different beams are recombined at the receiver, they result in a signal that is no longer an exact replica of the signal that was transmitted. Such a signal has been distorted by propagation delays. This distortion limits the available data rate and makes multimode step-index cable inadequate for certain precise applications.

2. **Graded-index Mode:** A second type of fiber, called graded-index, decreases this distortion of the signal through the cable. The word index here refers to the index of refraction. As we saw above, index of refraction is related to density. A graded-index fiber, therefore, is one with varying densities. Density is highest at

the center of the core and decreases gradually to its lowest at the edge. Figure 7(b) shows the impact of this variable density on the propagation of light beams.

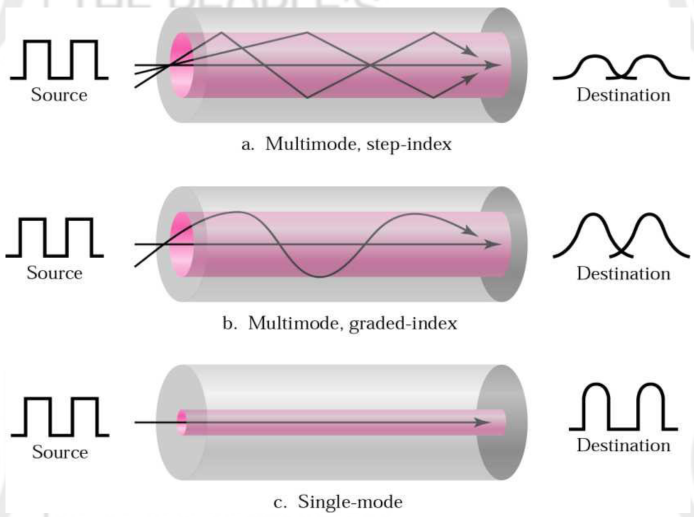

Figure 7: Types of Optical Fiber Cables

☞ **Check Your Progress 2**

1. List the applications of Coaxial cable.

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2. What is Single mode optical fiber?

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4.9 UNGUIDED MEDIUMS

Unguided Media: Unguided media transport electromagnetic waves without using a physical conductor. Signals are broadcast though air or water, and thus are available to anyone who has a device capable of receiving them. The EM spectrum covers frequencies from 3 Hz (ELF) to gamma rays (30 ZHz, Zetta Hertz - 10^{21} Hz) and beyond (cosmic rays). But only frequencies ranging from 3 KHz to 900 THz are used for wireless communication.

Propagation of Radio Waves: Radio technology considers the earth as surrounded by two layers of atmosphere: the troposphere and the ionosphere. The troposphere is the portion of the atmosphere extending outward approximately 30 miles from the earth's surface. The troposphere contains what we generally think of as air. Clouds, wind, temperature variations, and weather in general occur in the troposphere. The ionosphere is the layer of the atmosphere above the troposphere but below space. Unguided signals can travel from the source to destination in several ways. There is ground propagation, sky propagation, and line-of-sight propagation. In ground propagation, radio waves travel through the lowest portion of the atmosphere, hugging the earth. These low-frequency signals emanate in all directions from the transmitting antenna and follow the curvature of the earth. The distance depends on the power of the signal. In Sky propagation, higher-frequency radio waves radiate upward into the ionosphere where they are reflected back to earth. This type of transmission allows for greater distances with lower power output. In Line-of-Sight Propagation, very high frequency signals are transmitted in straight lines directly from antenna to antenna. Antennas must be directional, facing each other and either tall enough or close enough together not to be affected by the curvature of the earth.

Radio Waves: Radio wave frequencies are between 3 KHz to 1 GHz, and uses omnidirectional antenna. Omniderectional antenna propagates signal in all direction. This means that the sending and receiving antennas do not have to be aligned. But it has disadvantage too, it is susceptible to interference wherein a radio wave transmitted by one antenna may be interfered by another antenna that may send signals using the same frequency or band.

Radio waves are used for multicast communications, such as radio (AM and FM radio), maritime radio, television, cordless phones and paging systems.

Microwaves: Frequencies between 1 and 300 GHz are called microwaves. Microwaves are unidirectional. When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned. Its advantage is that a pair of antennas can be aligned without interfering with another pair of aligned antennas.

The propagation of microwave is line-of-sight. The problem with this propagation is that towers that are far apart from each other need to be very tall. The curvature of the earth as well as other blocking obstacles does not allow two short towers to communicate. For long distance communication, repeaters are often needed. Another disadvantage is that very high frequency microwaves cannot penetrate walls.

In a unidirectional antenna, there are two types: the parabolic dish and the horn. A parabolic dish antenna is based on the geometry of the parabola. Every line parallel to the line of symmetry reflects off the curve at angles such that all the lines intersect in a common point called focus. The parabolic dish works as a funnel, catching a wide range of waves and directing them to a common point.

A horn antenna on the other hand looks like a gigantic scoop. Outgoing transmissions are broadcast up a stem and deflected outward in a series of narrow parallel beams by the curved head. Received transmissions are collected by the scooped shape of the horn, in a manner similar to the parabolic dish, and are deflected down into the stem.

There is another type of microwave transmission with the use of satellite relay. It requires geo-stationary orbit with the height of 35,784km to match the earth's rotation. It has uplink that receives transmission on one frequency and a downlink that transmits on a second frequency. It Operates on a number of frequency bands known as transponders.

It can operate in two ways:

a) Point to point- Ground station to satellite to ground station

b) Multipoint (Broadcast link)- Ground station to satellite to multiple receiving stations.

Microwaves are used in unicast communication such as cellular telephones, satellite networks, and wireless LANs.

Infrared Waves: Infrared signals with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 700 nm), can be used for short-range communication. high frequencies cannot penetrate walls. This characteristic prevents interference between one system and another; a short-range communication cannot be affected by another system in the next room. The same characteristic makes infrared signals useless for long range communication. Infrared waves cannot be used outside a building because the sun's rays contained infrared waves can interfere with the communication. The infrared band, almost 400 THz, has an excellent potential for data transmission. Such a wide bandwidth can be used to transmit digital data with a very high data rate. The infrared Data Association (IrDA), an association for sponsoring the use of infrared waves, has established a standard for using these signals for communication between devices such as the keyboard, mice, PCs, and printers. Infrared signals defined by the IrDA transmit through line of sight; the IrDA port on the keyboard needs to point to the PC for transmission occurs.

4.10 CONNECTORS

The connectors are the interface for communication between computers/ computers to hub, switch, router etc. In LAN basically used connector are discussed as follows:

1. **RJ-45 Connector:** RJ stands for registered jack. RJ45 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 pin-outs define the arrangement of the individual wires needed when attaching connectors to a cable. RJ-45 connectors are of two types: male RJ-45 and female RJ-45. The Figure 8 shows RJ -45 connector.

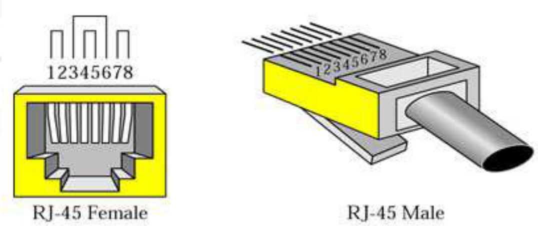

Figure 8: RJ-45 connectors

2. **BNC connector:** The BNC connector (Bayonet Neill–Concelman) is miniatures quick connect/disconnect RF connector used for coaxial cable. It features two bayonet lugs on the female connector; mating is achieved with only a quarter turn of the coupling nut. BNCs are ideally suited for cable termination for miniature-to-subminiature coaxial cable (e.g., RG-58, 59, to RG-179, RG-316). It is used with radio, television, and other radio-frequency electronic equipment, test instruments, video signals, and was once a popular computer network connector. BNC connectors are made to match the characteristic impedance of cable at either 50 ohms or 75 ohms. It is usually applied for frequencies below 3 GHz and voltages below 500 Volts.

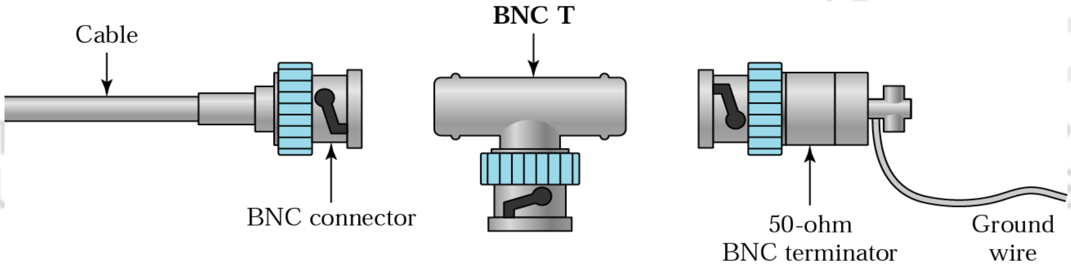

Figure 9: BNC connectors

Fiber optic cable connector: Fiber optic cable connectors are hardware installed on fiber cable ends to provide cable attachment to a transmitter, receiver or other cable. In order for information to be transmitted efficiently, the fiber cores must be properly aligned. They are usually devices that can be connected and disconnected repeatedly. There are many types of fiber optic cable connectors also shown in Figure 10:

1. **ST Connectors:** ST stands for Straight Tip. Slotted bayonet type connector with long ferrule, a common connector for multi-mode fibers. The ST connector has been the main stay of optical fiber connectors for many years. It can be found in almost every communications room worldwide, but used mainly in data communications systems. The simple to use bayonet locking mechanism reduces the risks of accidental disconnection of fiber connections.

2. **SC (Standard Connector) Connectors:** Push/pull connector that can also be used with duplex fiber connection. The SC connector comprises a polymer body with ceramic ferrule barrel assembly plus a crimp over sleeve and rubber boot. These connectors are suitable for, 900µm and 2-3mm cables. The connector is precision made to demanding specifications. The combination of a ceramic ferrule with precision polymer housing provides consistent long-term mechanical and optical performance.

3. **MT Connector:** The MT-RJ connector is a development of the now legendary MT ferrule. MT stands Multi-fiber Connector. The MT ferrule in its various designs has the ability to connect anything from 2 fibers in the MTRJ to 72 fibers in the latest versions of the MPO connector.

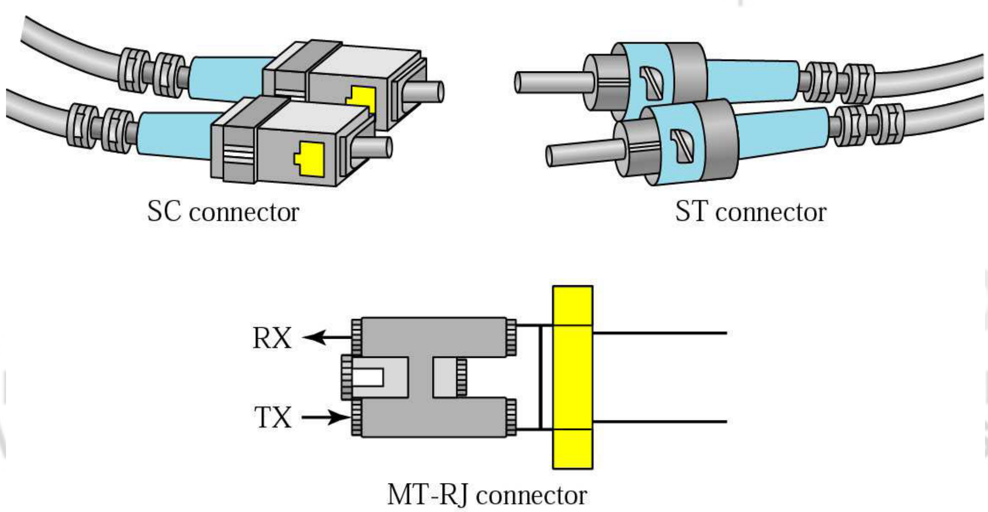

Figure 10: Fiber optic cable connector

☞ **Check Your Progress 3**

1. What are microwaves? Explain their properties.

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2. What is BNC connector?

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3. Explain the use of SC Connectors.

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4.11 SUMMARY

After completing this unit, you must have knowledge of different transmission mediums, cables and connectors. In the beginning serial and parallel communication is explained. In serial transmission, bits are sent sequentially on the same channel (wire). In parallel transmission, multiple bits (usually 8 bits or a byte/character) are sent simultaneously on different channels (wires, frequency channels) within the same cable. In this unit, we have seen that transmission media can be classified as guided or unguided. Twisted-pair cable is a type of cabling that is used for telephone communications and most modern Ethernet networks. Coaxial cable like twisted pair, consists of two conductors, but is constructed differently to permit it to operate over a wider range of frequencies. Today's optical fiber is widely used as a back bone for network due to its higher data transmission rate, lighter in weight, low interferences, less number of repeaters required, long distance coverage etc.. Optical fiber is of two types i.e. Single mode optical fiber and Multimode Optical Fiber. Further medium of communication is unguided. Unguided media transport electromagnetic waves without using a physical conductor. Signals are broadcast though air or water, and thus are available to anyone who has a device capable of receiving them. The connectors are the interface for communication between computers/ computers to hub, switch, router etc. In LAN basically used connector.

4.12 REFERENCES/FURTHER READING

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4.13 SOLUTIONS/ANSWERS

☞ Check Your Progress 1

1. In parallel transmission, multiple bits (usually 8 bits or a byte/character) are sent simultaneously on different channels (wires, frequency channels) within the same cable

2. Following are the guided transmission mediums

   i) twisted pair,

   ii) coaxial cable,

   iii) optical fiber

3. STP is similar to UTP in that the wire pairs are twisted around each other. STP also has shielding around the cable to further protect it from external interference. The maximum segment length of STP cable is 100 meters. Shielded twisted-pair (STP) cable combines the techniques of shielding, cancellation, and wire twisting. Each pair of wires is wrapped in a metallic foil.

☞ Check Your Progress 2

1. Following are the main applications of Coaxial cable.

   i) Television distribution

   ii) Long-distance telephone transmission

   iii) Short-run computer system links

   iv) Local Area Networks

2. Single mode uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal. The fiber itself is manufactured with a much smaller diameter than that of multimode fibers, and with substantially lowers density (index of refraction). The decrease in density results in a critical angle that is close enough to 90 degrees to make the propagation of beams delays are negligible.

☞ Check Your Progress 3

1. Frequencies between 1 and 300 GHz are called microwaves. Microwaves are unidirectional. When an antenna transmits microwave waves, they can be narrowly focused. This means that the sending and receiving antennas need to be aligned. Its advantage is that a pair of antennas can be aligned without interfering with another pair of aligned antennas.

   The propagation of microwave is line-of-sight. The problem with this propagation is that towers that are far apart from each other need to be very tall. The curvature of the earth as well as other blocking obstacles does not allow two short towers to communicate. For long distance communication, repeaters are often needed. Another disadvantage is that very high frequency microwaves cannot penetrate walls.

2. The BNC connector (Bayonet Neill–Concelman) is miniatures quick connect/disconnect RF connector used for coaxial cable.
3. This is a fiber optics cable connector. Push/pull connector that can also be used with duplex fiber connection. The SC connector comprises a polymer body with ceramic ferrule barrel assembly plus a crimp over sleeve and rubber boot. These connectors are suitable for, 900µm and 2-3mm cables. The connector is precision made to demanding specifications.