Chapter Three

Data Communication and Transmission Medias

Data Communication and Computer Networks

(InTc 2112)

Transmission medium

- 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.
- In both cases, communication is in the form of electromagnetic waves.
  - With guided media, the waves are guided along a solid medium, such as copper twisted pair, copper 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.

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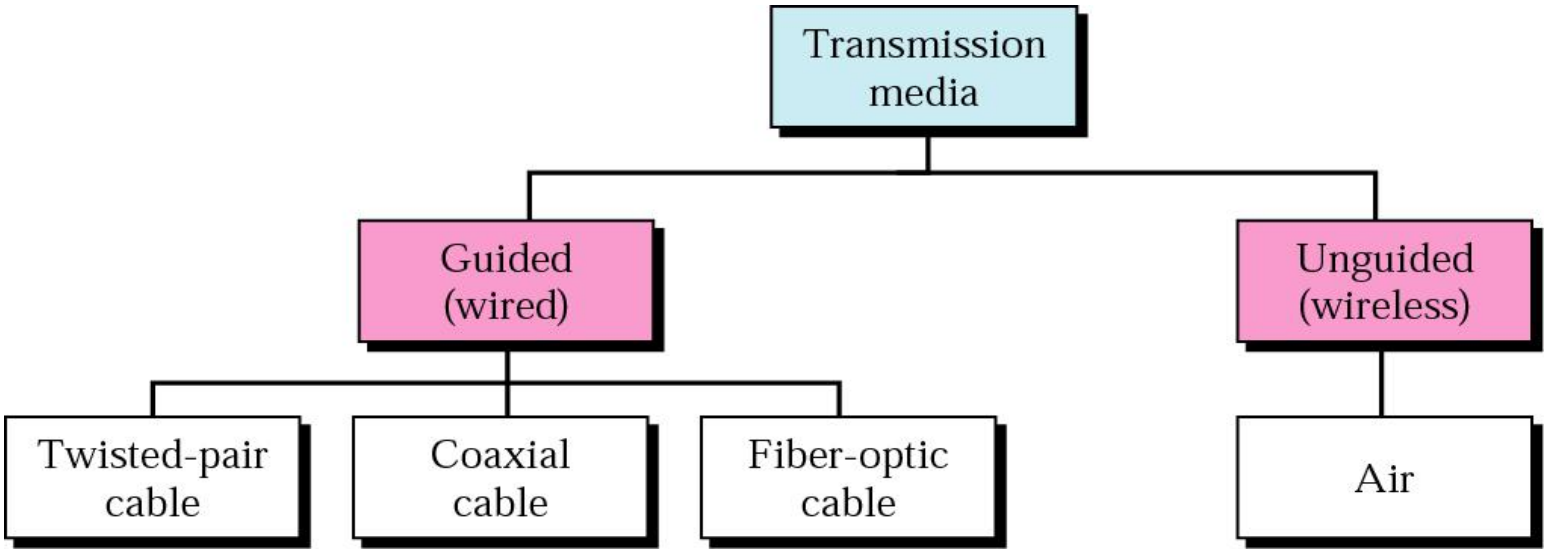

- In considering the design of data transmission systems, a key concern, generally, is data rate and distance: the greater the data rate and distance, the better.
- A number of design factors relating to the transmission medium and to the signal determine the data rate and distance:

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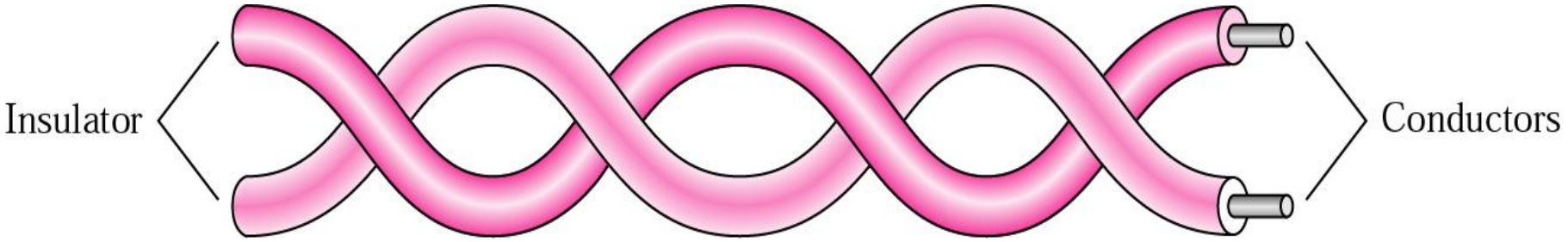
- **Bandwidth:-** All other factors remaining constant, the greater the bandwidth of a signal, the higher the data rate that can be achieved.
- **Transmission impairments:-** Impairments, such as attenuation, limit the distance. For guided media, twisted pair generally suffer more impairment than coaxial cable, which in turn suffers more than optical fiber.
- **Interference:-** Interference from competing signals in overlapping frequency bands can distort or wipe out a signal. Interference is of particular concern for unguided media, but it is also a problem with guided media. For guided media, interference can be caused by emanations from nearby cables. For example, twisted pair are often bundled together, and conduits often carry multiple cables. Interference can also be experienced from unguided transmissions. Proper shielding of a guided medium can minimize this problem.
- **A Number of receivers:-** A guided medium can be used to construct a point-to-point link or a shared link with multiple attachments. In the latter case, each attachment introduces some attenuation and distortion on the line, limiting distance and/or data rate.

GUIDED TRANSMSSION MEDIA

- For guided transmission media, the transmission capacity, in terms of either data rate or bandwidth, depends critically on the distance and on whether the medium is point-to-point or multipoint, such as in a local area network (LAN).
- Guided media, which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable.
- A signal traveling along any of these media is directed and contained by the physical limits of the medium.
- Twisted-pair and coaxial cable use metallic (copper) conductors that accept and transport signals in the form of electric current.
- Optical fiber is a cable that accepts and transports signals in the form of light.

Twisted-Pair Cable

- A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in the figure below



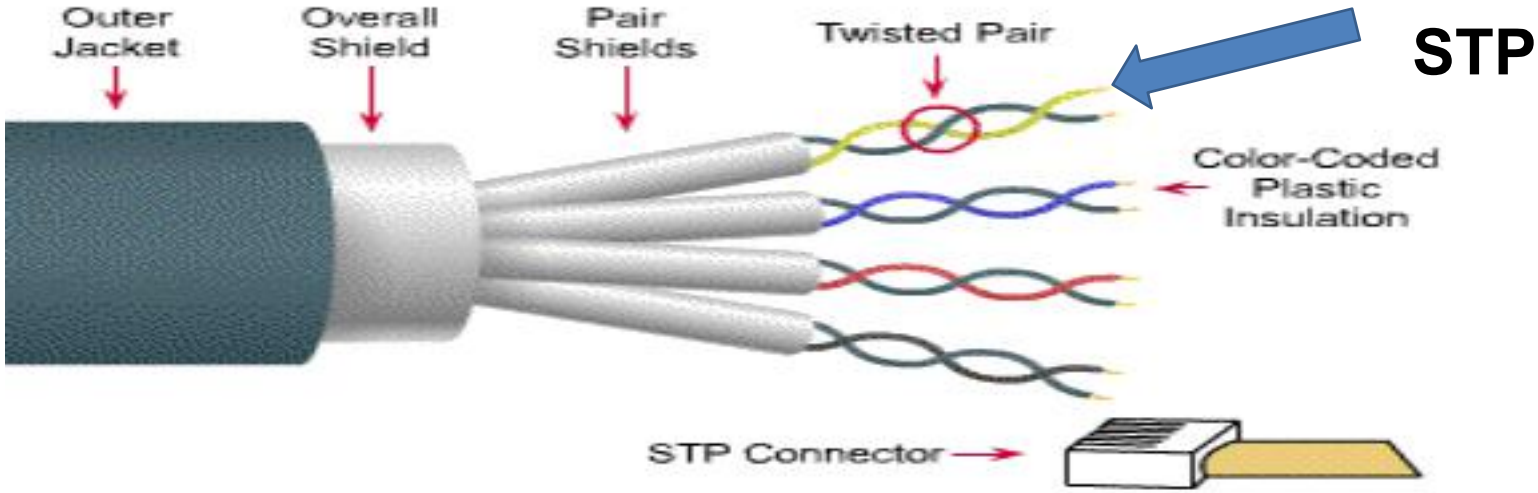
- One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference.
- The receiver uses the difference between the two.
- In addition to the signal sent by the sender on one of the wires, interference (noise) and crosstalk may affect both wires and create unwanted signals.

Contd.

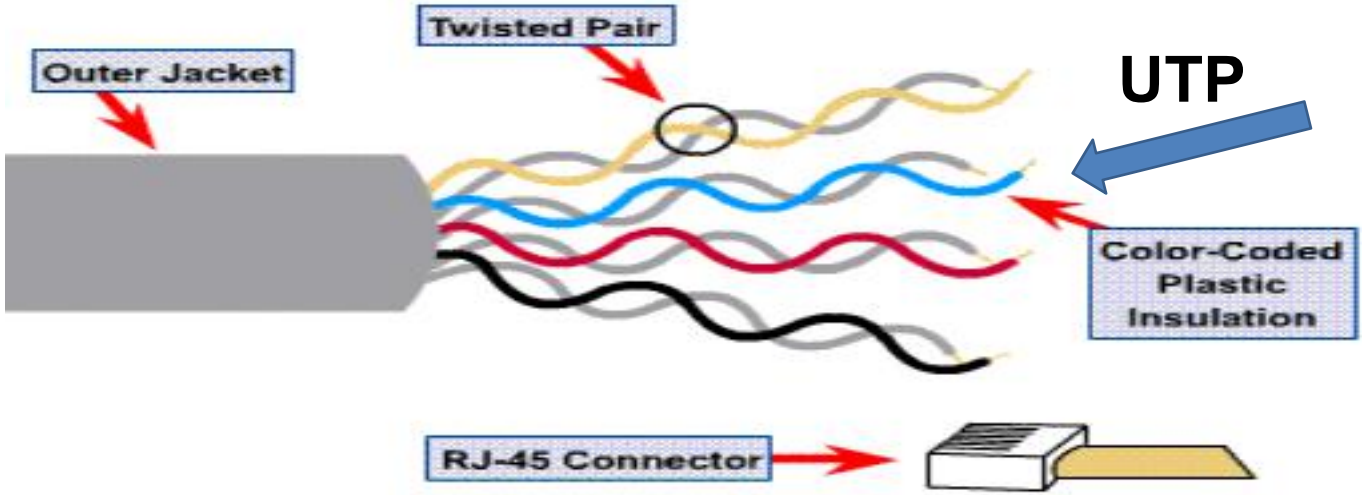
- If the two wires are parallel, the effect of these unwanted signals is not the same in both wires because they are at **different locations** relative to the noise or **crosstalk sources.**
- This results in a **difference at the receiver. By twisting the pairs, a balance is maintained.**
- For example, suppose in one twist, one wire is closer to the noise source and the other is farther; in the next twist, the reverse is true.
- Twisting makes it probable that both wires are equally affected by external influences (**noise or crosstalk**). This means that the receiver, which calculates the difference between the two, receives no **unwanted signals**. The unwanted signals are **mostly canceled out.**
- From the above discussion, it is clear that the **number of twists per unit of length** (e.g., inch) has some effect on the **quality of the cable**.

Unshielded Versus Shielded Twisted-Pair Cable

- The most common twisted-pair cable used in communications is referred to as unshielded twisted-pair (UTP).
- IBM has also produced a version of twisted-pair cable for its use called shielded twisted-pair (STP).
- STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductors.
- Although metal casing improves the quality of cable by preventing the penetration of noise or crosstalk, it is bulkier and more expensive.
- Our discussion focuses primarily on UTP because STP is seldom used outside of IBM.



- Speed and throughput: 10-100 Mbps
- Cost per node: Moderately expensive
- Media and connector size: Medium to Large
- Maximum cable length: 100m (short)



- Speed and throughput: 10-100 Mbps
- Cost per node: Least Expensive
- Media and connector size: Small
- Maximum cable length: 100m (short)

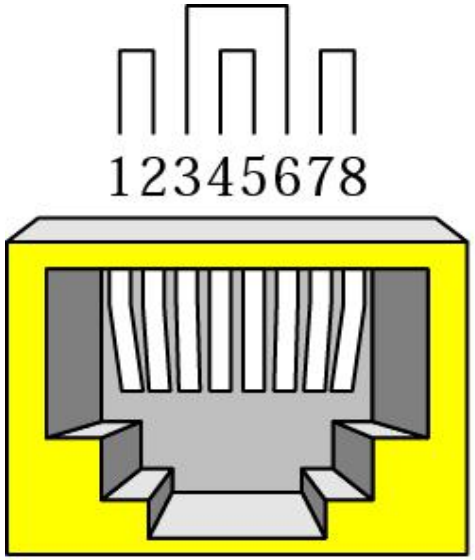
UTP Categories

- The Electronic Industries Association (EIA) has developed standards to classify unshielded twisted-pair cable into seven categories.
- Categories are determined by cable quality, with 1 as the lowest and 7 as the highest.
- Each EIA category is suitable for specific uses.

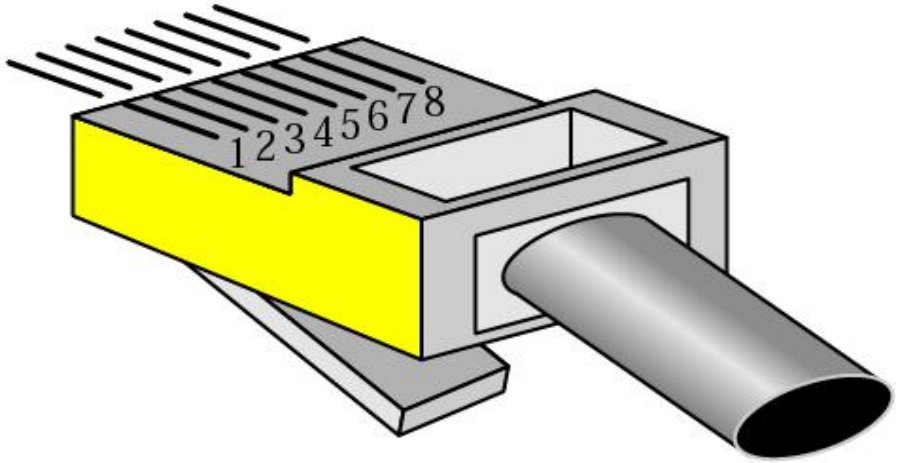
Category	*Specification*	*Data Rate (Mbps)*	*Use*
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
SE	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	LANs
7	Sometimes called SSTP (shielded screen twisted-pair). Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk: and increases the data rate.	600	LANs

Connectors

- The most common UTP connector is RJ45 (RJ stands for registered jack). The RJ45 is a keyed connector, meaning the connector can be inserted in only one way.



RJ-45 Female



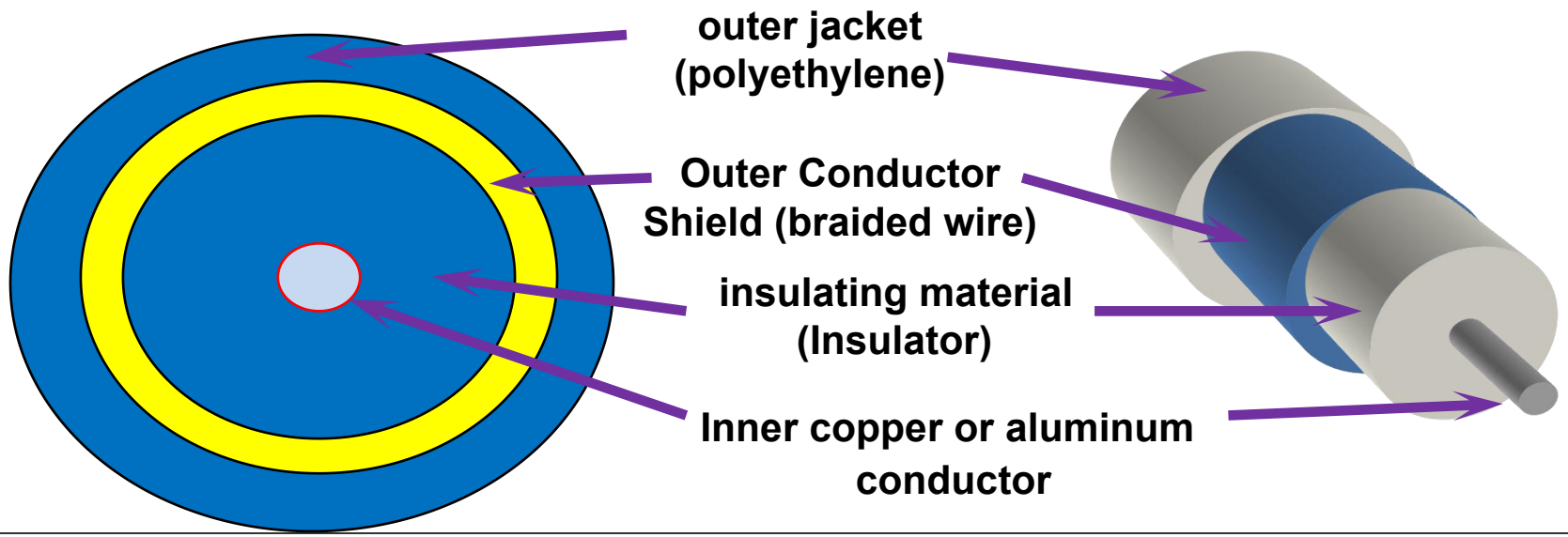
RJ-45 Male

Twisted-pair cable Applications

- Within buildings
- Most common medium
- Twisted-pair cables are used in **telephones lines** to provide voice and data channels.
- The **DSL lines** that are used by the telephone companies to provide high data rate connections also use the high-bandwidth capability of unshielded twisted-pair cables.
- **Local area networks**, such as 10Base-T and 100Base-T, also used UTP cables.

Coaxial Cable

- **Coaxial cable (or *coax*)** *carries signals of* ***higher frequency ranges*** *than those in twisted pair* cable, in part because the two media are constructed quite differently.
- Instead of having two wires, coax has a central core conductor of **solid or stranded wire (usually copper)** enclosed in an insulating sheath, which is, in turn, encased in an **outer conductor of metal foil, braid**, or a combination of the two.
- **The outer metallic wrapping** serves both as a **shield against noise** and as the **second conductor**, which completes the circuit.
- This outer conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover



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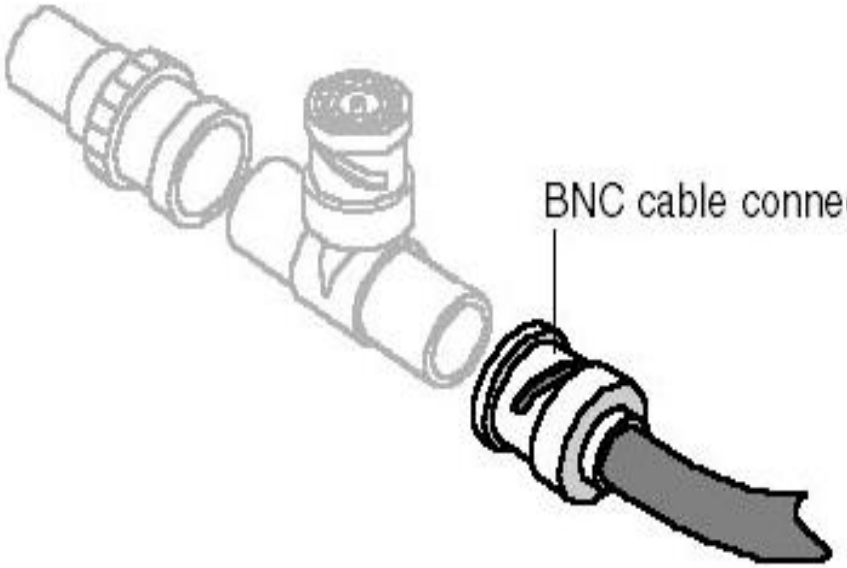
- At one time, coaxial cable was the most widely used network cabling. There were a couple of reasons for coaxial cable's wide usage: it was relatively **inexpensive**, and it was **light**, **flexible**, and **easy to work with**.
- The term **shielding** refers to the **woven or stranded metal mesh** (or other material) that surrounds some types of cabling.
- **Shielding protects transmitted** data by **absorbing stray electronic signals**, called **noise**, so that they do not get onto the cable and distort the data.
- Cable that contains one layer of foil insulation and one layer of braided metal shielding is referred to as **dual shielded**.
- For environments that are subject to **higher interference**, **quad shielding** is available.
- **Quad shielding** consists of two layers of foil insulation and two layers of braided metal shielding.

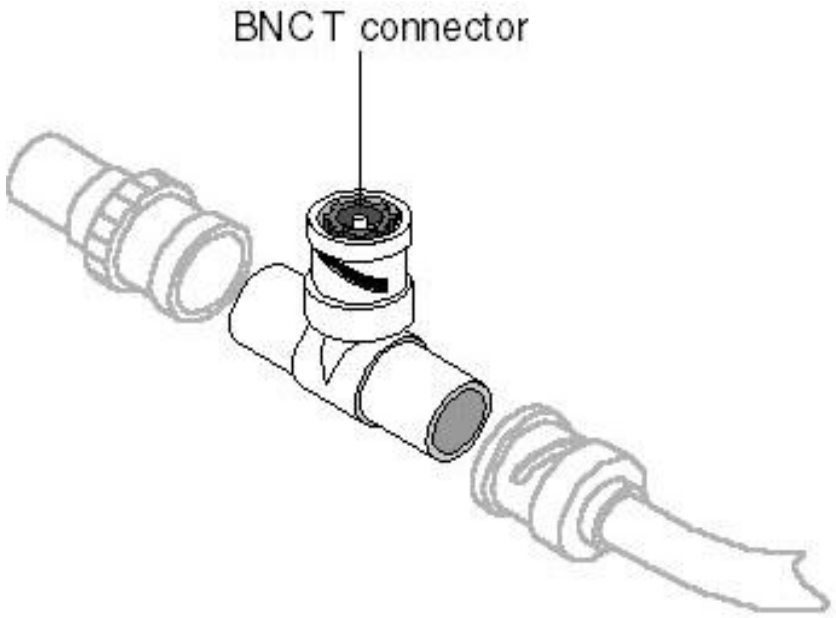
Types of Coaxial Cable

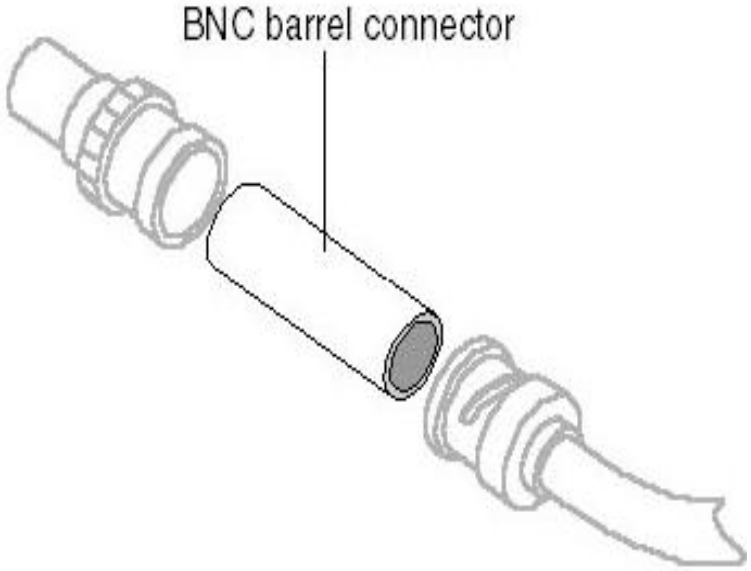
1. **Thin (thinnet) cable**
2. **Thick (thicknet) cable**

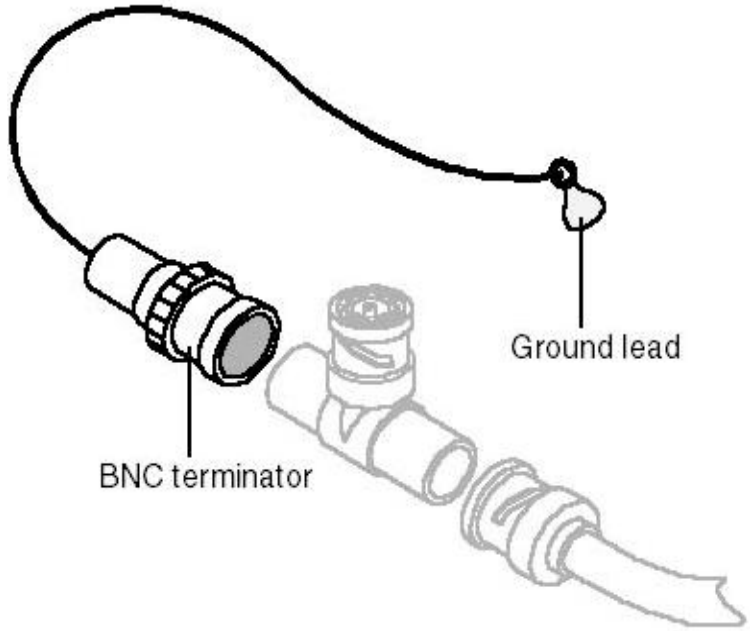
1. **Thinnet(10Base2):-** is a flexible coaxial cable about **0.64** centimeters (0.25 inches) thick.
   - Because this type of coaxial cable is flexible and easy to work with, it can be used in almost any type of network installation.
2. **Thicknet(10Base5):-** is a relatively rigid coaxial cable about **1.27** centimeters (0.5 inches) in diameter.
   - Thicknet cable is sometimes referred to as **Standard Ethernet** because it was the first type of cable used with the popular network architecture Ethernet.
   - Thicknet cable's copper core is thicker than a thinnet cable core.
   - The thicker the copper core, the farther the cable can carry signals.
   - This means that thicknet can carry signals farther than thinnet cable. Thicknet cable can carry a signal for 500 meters (about 1640 feet).
   - Therefore, because of thicknet's ability to support data transfer over longer distances, it is sometimes used as a backbone to connect several smaller thinnet-based networks

Connector


BNC cable connector

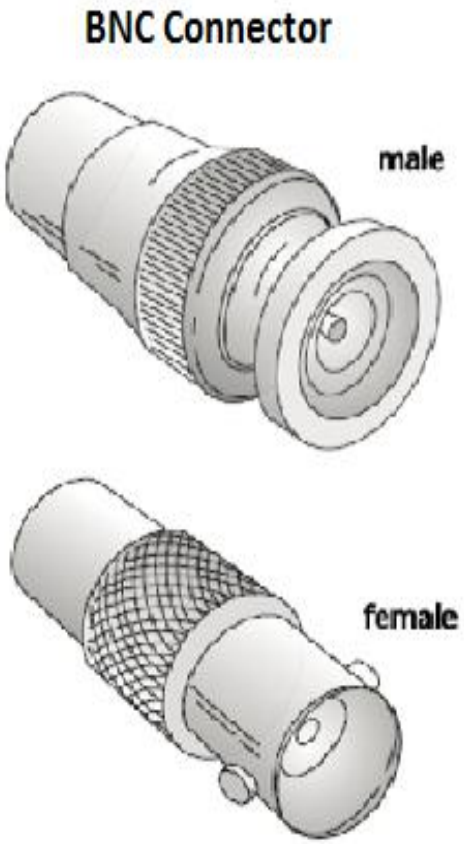

BNC T connector


BNC barrel connector


Ground lead
BNC terminator

Contd.

- The BNC connector is used to connect the end of the cable to a device, such as a TV set.
- The BNCT connector is used in Ethernet networks to branch out to a connection to a computer or other device.
- The BNC terminator is used at the end of the cable to prevent the reflection of the signal
- BNC barrel connector is used to join two lengths of thinnet cable to make one longer length.



Categories of coaxial cables

Category	Impedance	Use
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

Coaxial Cable Applications

- Most versatile medium
- Television distribution
  - Ariel to TV
  - Cable TV
- Long distance telephone transmission
  - Can carry 10,000 voice calls simultaneously
  - Being replaced by fiber optic
- Short distance computer systems links
- Local area networks

Fiber-Optic Cable

- A fiber-optic cable is made of **glass** or **plastic** and transmits signals in the form **of light**.
- Fiber-optic cabling consists of a signal-carrying glass core of **5 to 100 microns** in diameter (a sheet of paper is about 25 microns thick and a human hair about 75 microns thick), surrounded by a layer of pure silica called **cladding**, which prevents light from escaping.
- Surrounding the cladding are **protective layers** of acrylic plastic coating, **Kevlar fibers** for additional strength, and a PVC (polyvinyl chloride) jacket (usually colored a distinctive orange).

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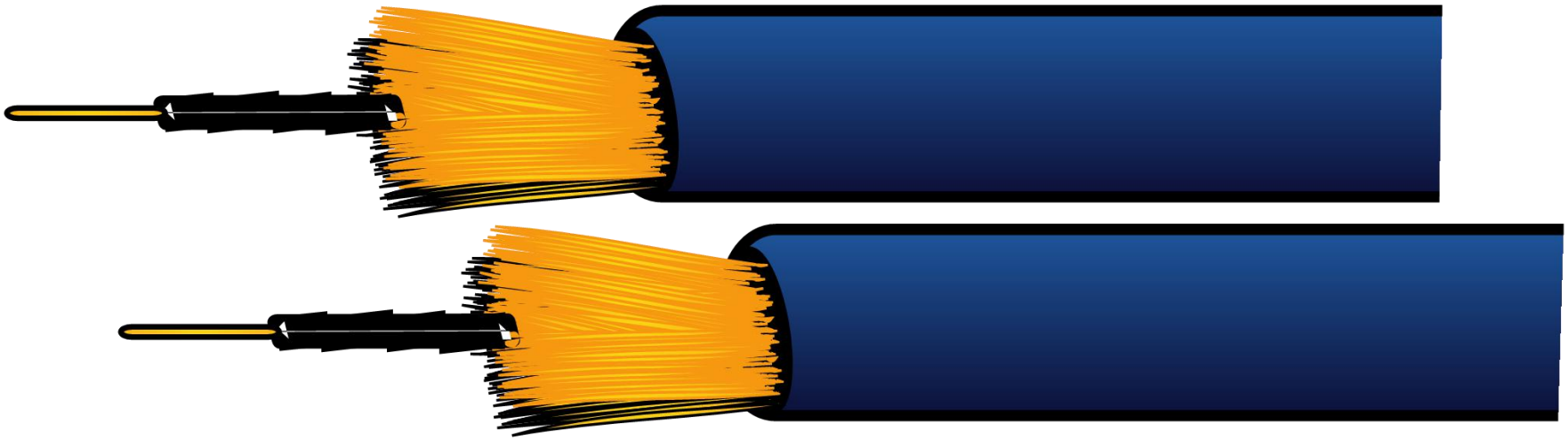
- Network components use **LED or laser diodes** to convert electrical signals into light pulses for transmission on fiber-optic cables.
- An **optical detector** is used to convert the light pulses back into electrical signals.



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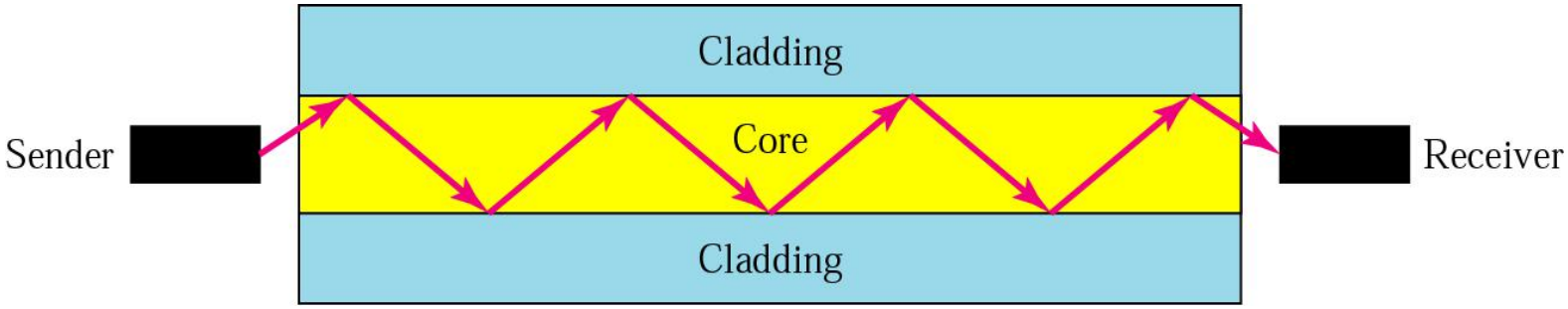
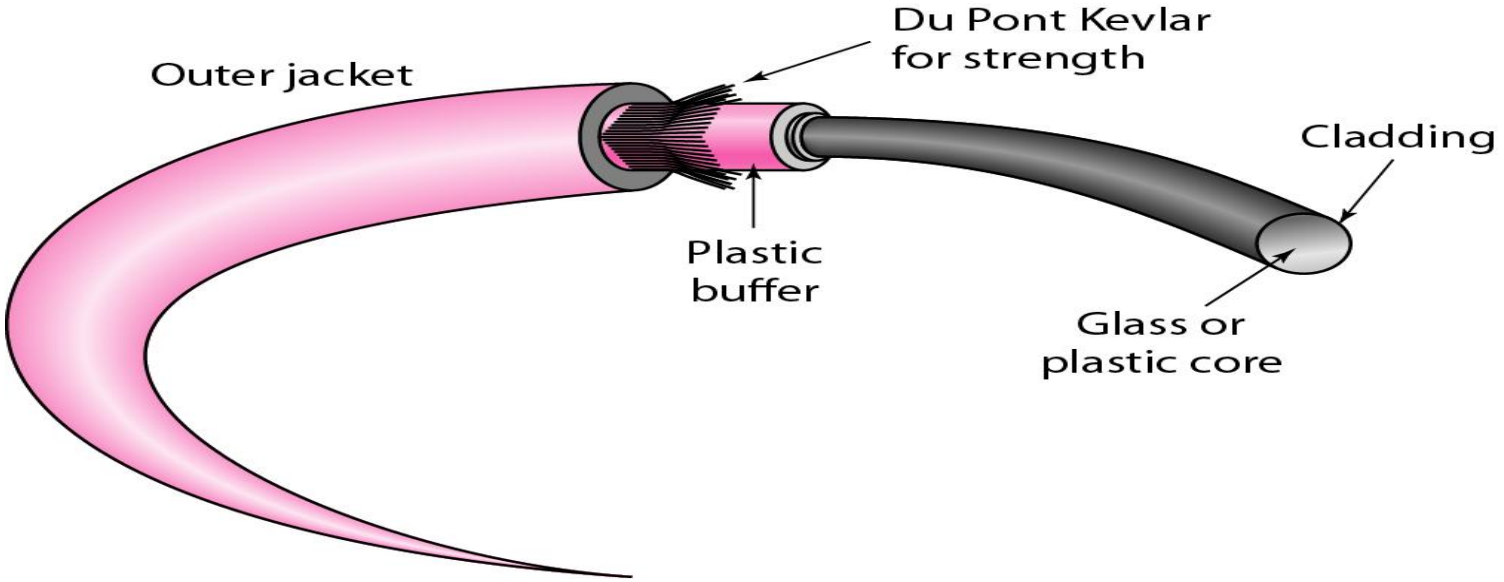
- Optical fibers use **reflection** to guide light through a channel.
- A glass or plastic core is surrounded by a cladding of less dense glass or plastic.
- The difference in density of the two materials must be such that a beam of light moving through the core is reflected off the cladding instead of being refracted into it (cladding)



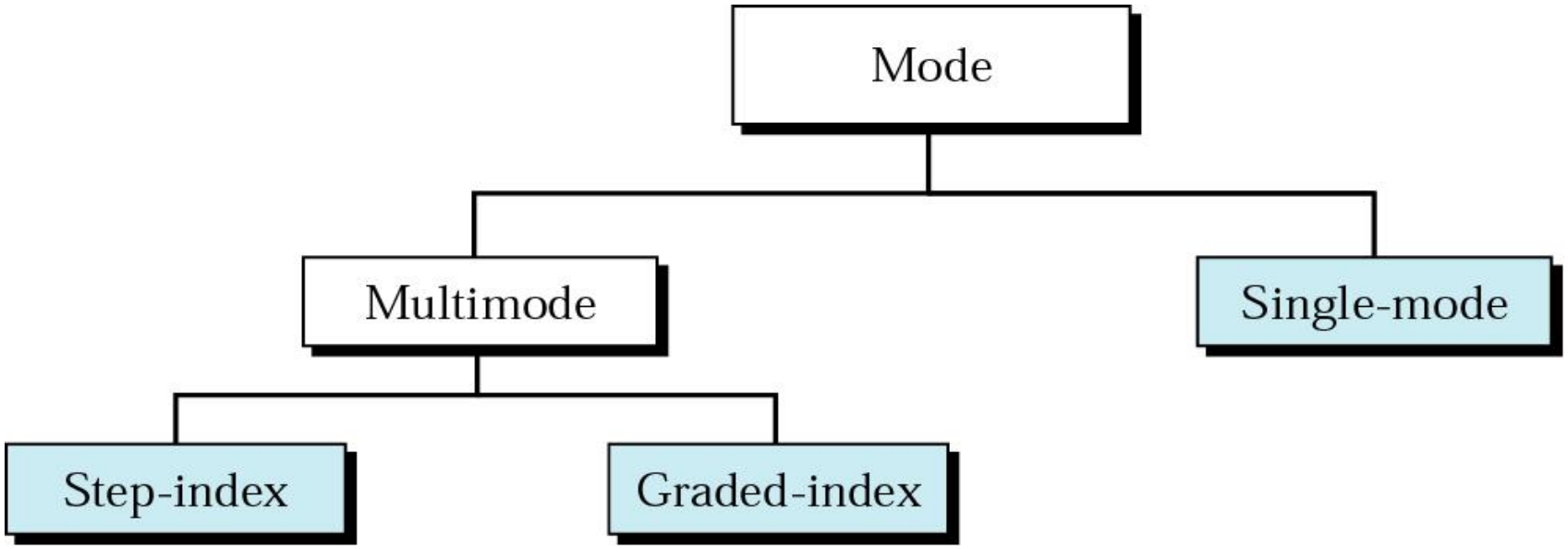
Cable Composition

- The outer jacket is made of either **PVC (polymer of vinyl chloride) or Teflon**.
- Inside the jacket are **Kevlar strands** to strengthen the cable.
- **Kevlar** is a strong material used in the fabrication of bulletproof vests.
- Below the Kevlar is another **plastic coating** to cushion the fiber.
- The fiber is at the center of the cable, and it consists of **cladding** and **core**.



Propagation Modes

- Current technology supports two modes (**multimode** and **single mode**) for propagating light along optical channels, each requiring fiber with different physical characteristics.
- Multimode can be implemented in two forms: **step-index** or **graded-index**



Single-mode fiber-optic cabling

- Has a **narrow core** (5 or 10 microns in diameter) and allows only one signal to be sent or received at a time over very long distances [**about 50 kms**](up to 50 times farther than multimode fiber-optic cabling).
- Single-mode fiber-optic cabling uses **laser-emitting diodes** to introduce signals into the fiber and can transmit only one signal (light beam) at a time.
- Signal transmission is clear for approximately 30 miles (50 kilometers) before dispersion will distort signals, which means that single-mode fiber is ideal for long cable runs.
- Is suitable for l**ong-distance telephony** and **multichannel television broadcast systems**

Multimode fiber-optic cabling:

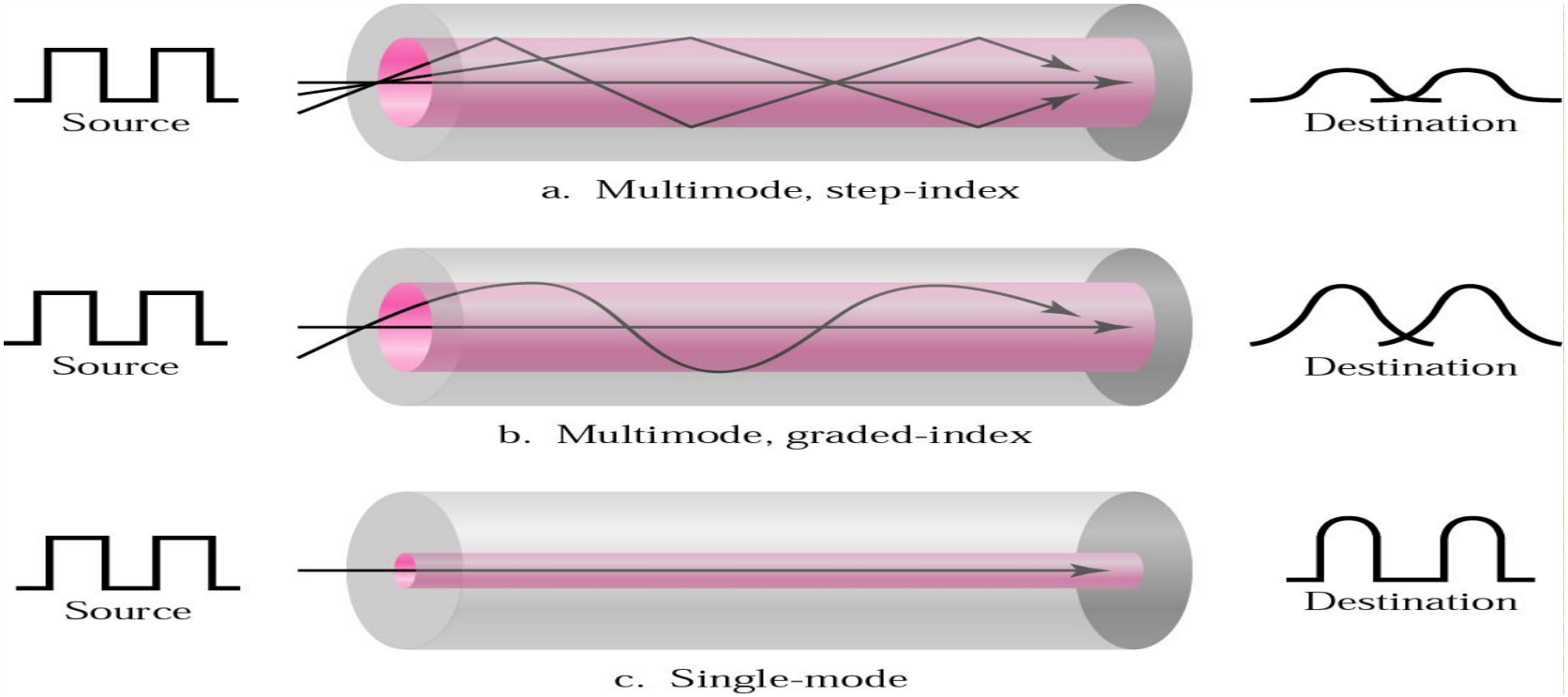
- Has a **thicker core** (50, 62.5, or 100 microns in diameter) and has sufficient bandwidth to allow multiple signals to be simultaneously transmitted or received;
- Each signal follows a different path or mode through the fiber.
- Signal transmission is clear for approximately 3000 feet (**almost 1km**), but longer cable runs can distort signals through modal dispersion.
- There are two types of multimode fiber:
  1. **Step-index multimode fiber**
  2. **Graded-index multimode fiber**
- is suited for use in **LAN systems** and **video surveillance**.

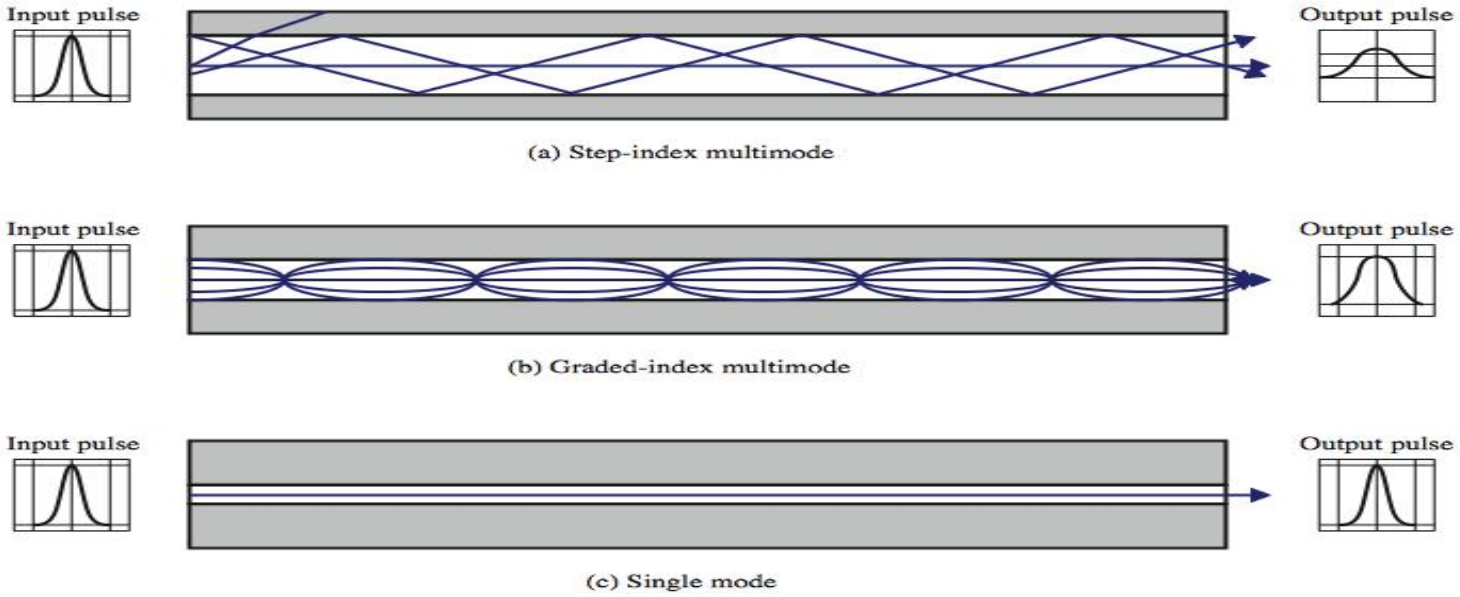
A. Step-index multimode fiber

- Less costly variety of multimode fiber, uses a **wide core with a constant density** from the center to the edges, causing the light beams to reflect **in mirror fashion** off the inside surface of the core by the process of total internal reflection
- At the interface there is an abrupt change to a lower density that alters the angle of the beam's motion.
- Because light can take many different paths down the cable and each path takes a different amount of time, signal distortion can result when step-index fiber is used for long cable runs.
- Used only for short cable runs.

B. Graded-index multimode fiber

- The **more expensive** type of multimode fiber.
- A graded-index fiber is one with **varying densities**.
- Density is highest at the center of the core and decreases gradually to its lowest at the edge.
- Therefore, light beams follow curved paths and all rays reach the end of the fiber simultaneously
- This reduces the signal distortion that occurs in step-index fiber when long cable runs are used.

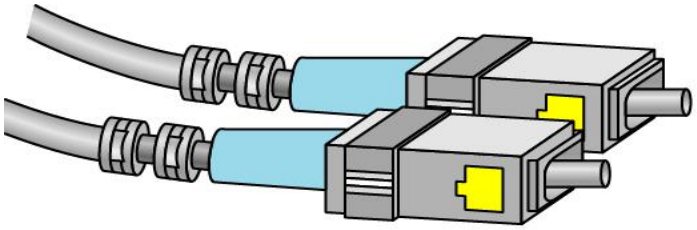

Source
Destination
a. Multimode, step-index
Source
Destination
b. Multimode, graded-index
Source
Destination
c. Single-mode


Input pulse
Output pulse
(a) Step-index multimode
Input pulse
Output pulse
(b) Graded-index multimode
Input pulse
Output pulse
(c) Single mode

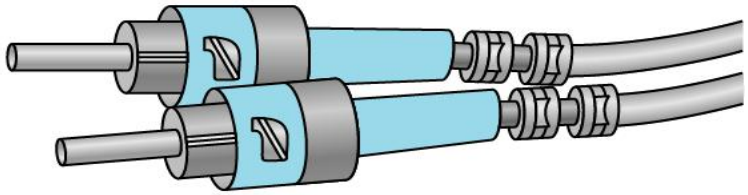
Fiber-Optic Cable Connectors

There are three types of connectors for fiber-optic cables.

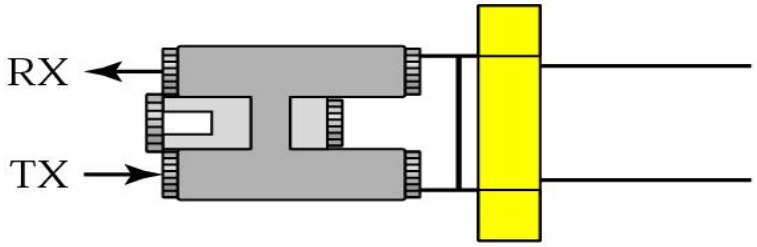
1. **Subscriber channel (SC) connector:-** is used for cable TV. It uses a push/pull locking system.
2. **Straight-tip (ST) connector:-** is used for connecting cable to networking devices. It uses a bayonet locking system and is more reliable than SC.
3. **MT-RJ is a connector:-** that is the same size as RJ45.



SC connector



ST connector



MT-RJ connector

Optical Fiber – Applications

- Long-haul trunks
- Metropolitan trunks
- Rural exchange trunks
- Subscriber loops
- LANs

Advantages of Optical Fiber

- The major advantages offered by fiber-optic cable over twisted-pair and coaxial cable are **noise resistance**, **less signal attenuation**, and **higher bandwidth**.

1. **Noise Resistance**: Because fiber-optic transmission uses light rather than electricity, noise is not a factor. External light, the only possible interference, is blocked from the channel by the outer jacket.
2. **Less signal attenuation:-** Fiber-optic transmission distance is significantly greater than that of other guided media. A signal can run for miles without requiring regeneration.
3. **Higher bandwidth:-** Currently, data rates and bandwidth utilization over fiber-optic cable are limited not by the medium but by the signal generation and reception technology available.

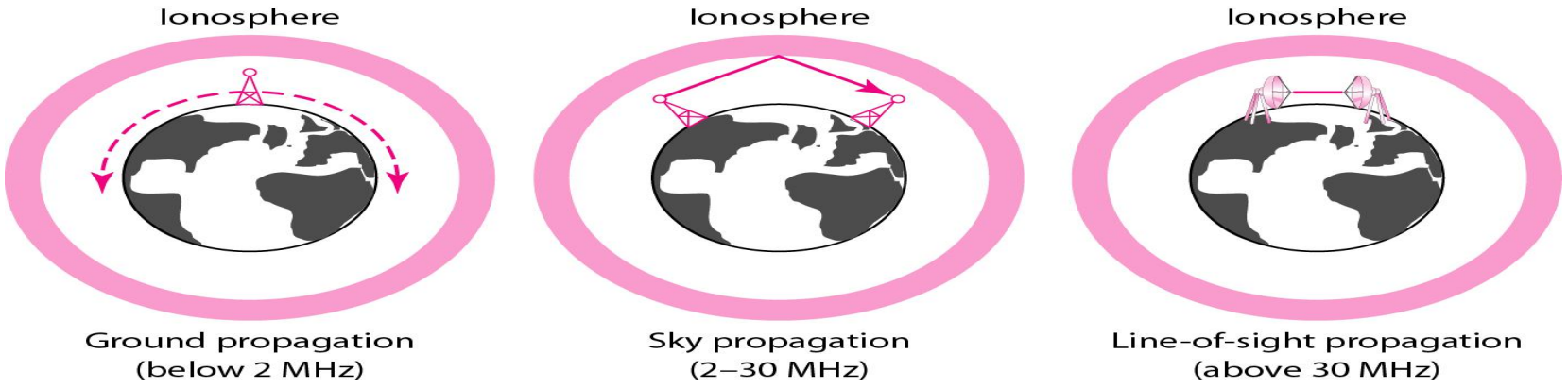
Disadvantages of Optical Fiber

- The main disadvantages of fiber optics are **cost, installation/maintenance, and fragility**.

1. **Cost:-** Fiber-optic cable is expensive. Also, a laser light source can cost thousands of dollars, compared to hundreds of dollars for electrical signal generators.
2. **Installation/maintenance**
3. **Fragility:-** Glass fiber is more easily broken than wire, making it less useful for applications where hardware portability is required.

Unguided (Wireless) Media

- Unguided media transport electromagnetic waves without using any **physical conductor**.
- This type of communication is often referred to as **wireless communication**.
- Signals are normally broadcast through **free space** and thus are available to **anyone** who has a device capable of receiving them.
- Unguided signals can travel from the source to destination in several ways: **ground propagation**, **sky propagation**, and **line-of-sight propagation**.



Ground propagation (below 2 MHz)

Sky propagation (2–30 MHz)

Line-of-sight propagation (above 30 MHz)

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1. 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 planet.
   - Distance depends on the amount of power in the signal: The greater the power, the greater the distance.
2. In sky propagation, higher-frequency radio waves radiate upward into the ionosphere (the layer of atmosphere where particles exist as ions) where they are reflected back to earth.
   - This type of transmission allows for greater distances with lower output power.

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3. 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.
   - Line-of-sight propagation is tricky because radio transmissions cannot be completely focused.

- The section of the electromagnetic spectrum defined as radio waves and microwaves is divided into eight ranges, called *bands, each regulated by government authorities.*
- These bands are rated from *very low frequency (VLF) to extremely high frequency (EHF).*

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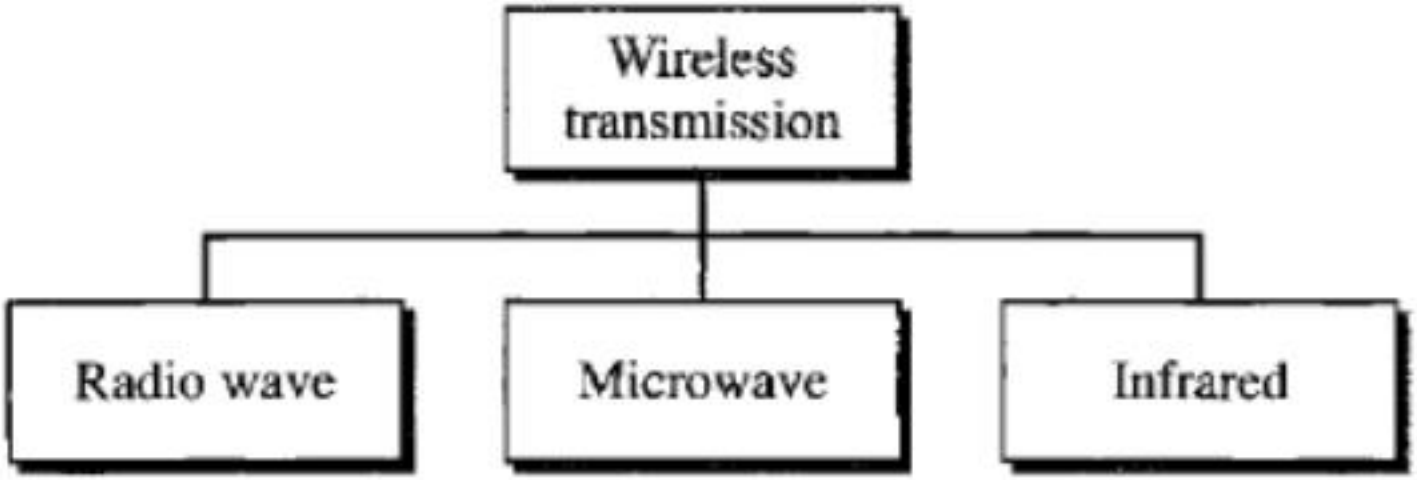
Band	*Range*	*Propagation*	*Application*
VLF (very low frequency)	3-30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30-300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz-3 MHz	Sky	AM radio
HF (high frequency)	3-30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30-300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz-3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3-30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30-300 GHz	Line-of-sight	Radar, satellite

Wireless Transmission Types

- We can divide wireless transmission into three broad groups: radio waves, microwaves, and infrared waves.



Radio Waves

- Although there is no clear-cut demarcation between radio waves and microwaves, electromagnetic waves ranging in frequencies between 3 kHz and 1 GHz are normally called radio waves; waves ranging in frequencies between 1 and 300 GHz are called microwaves.
- However, **the behavior of the waves, rather than the frequencies**, is a better criterion for classification.
- Radio waves, for the most part, are Omni-directional that is, when an antenna transmits radio waves, they are propagated in all directions.
- This means that the sending and receiving antennas do not have to be aligned. A sending antenna sends waves that can be received by any receiving antenna.

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- Radio waves, particularly those waves that propagate in the sky mode, can travel **long distances**.
- This makes radio waves a good candidate for long-distance broadcasting such as AM radio.
- Radio waves, particularly those of **low and medium frequencies**, can penetrate walls.
- This characteristic can be both an advantage and a disadvantage.
- It is an **advantage** because, for example, an AM radio can receive signals inside a building.
- It is a **disadvantage** because we cannot isolate a communication to just inside or outside a building.

Contd.

- The radio wave band is relatively narrow, just under 1 GHz, compared to the microwave band. When this band is divided into sub bands, the sub bands are also narrow, leading to a low data rate for digital communications.
- Almost the entire band is regulated by authorities (e.g., the FCC in the United States). Using any part of the band requires permission from the authorities.

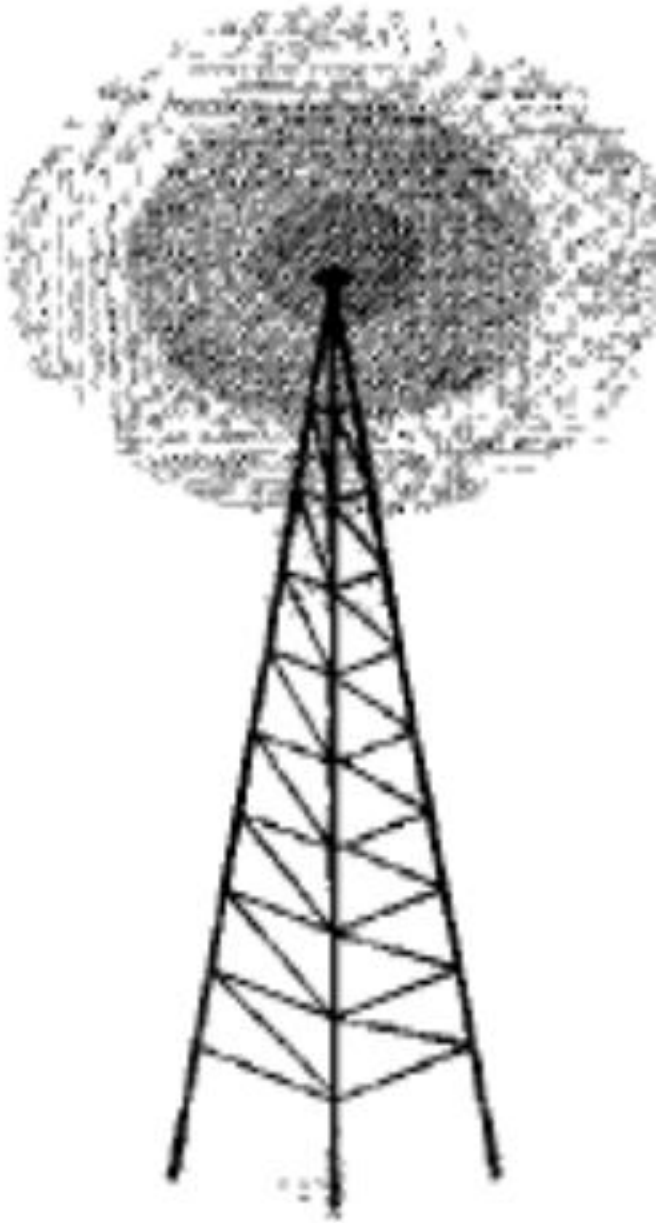
Omni directional Antenna

- Radio waves use omnidirectional antennas that send out signals in all directions.
- Based on the wavelength, strength, and the purpose of transmission, we can have several types of antennas.

Contd.

Applications

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



Microwaves

- Electromagnetic waves having 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 (see each other). The unidirectional property has an obvious advantage. A pair of antennas can be aligned without interfering with another pair of aligned antennas.
- The following describes some characteristics of microwave propagation:
  - Microwave propagation is line-of-sight. Since the towers with the mounted antennas need to be in direct sight of each other, towers that are far apart need to be very tall.

Contd.

- The curvature of the earth as well as other blocking obstacles do not allow two short towers to communicate by using microwaves.
- Repeaters are often needed for long distance communication.
- Very high-frequency microwaves cannot penetrate walls.
  - This characteristic can be a disadvantage if receivers are inside buildings.
- The microwave band is **relatively wide**, almost 299 GHz.
  - Therefore wider subbands can be assigned, and a high data rate is possible
- Use of certain portions of the band requires permission from authorities.

Unidirectional Antenna

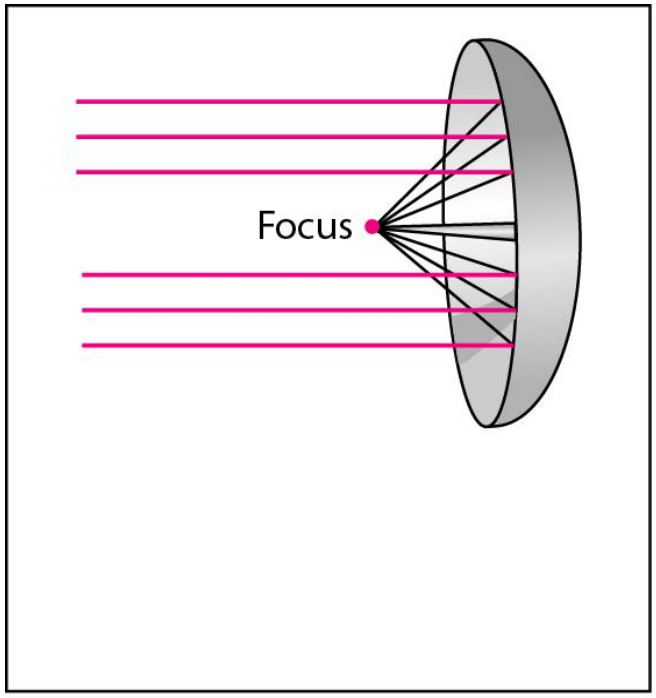
- Microwaves need unidirectional antennas that send out signals in one direction.
- Two types of antennas are used for microwave communications: the **parabolic dish** and the **horn**.

1. **A parabolic dish antenna** is based on the geometry of a parabola:
   - Every line parallel to the line of symmetry (line of sight) reflects off the curve at angles such that all the lines intersect in a common point called **the focus**.
   - The parabolic dish works as a funnel, catching a wide range of waves and directing them to a common point.
   - In this way, more of the signal is recovered than would be possible with a single-point receiver.
   - Outgoing transmissions are broadcast through a horn aimed at the dish. The microwaves hit the dish and are deflected outward in a reversal of the receipt path.

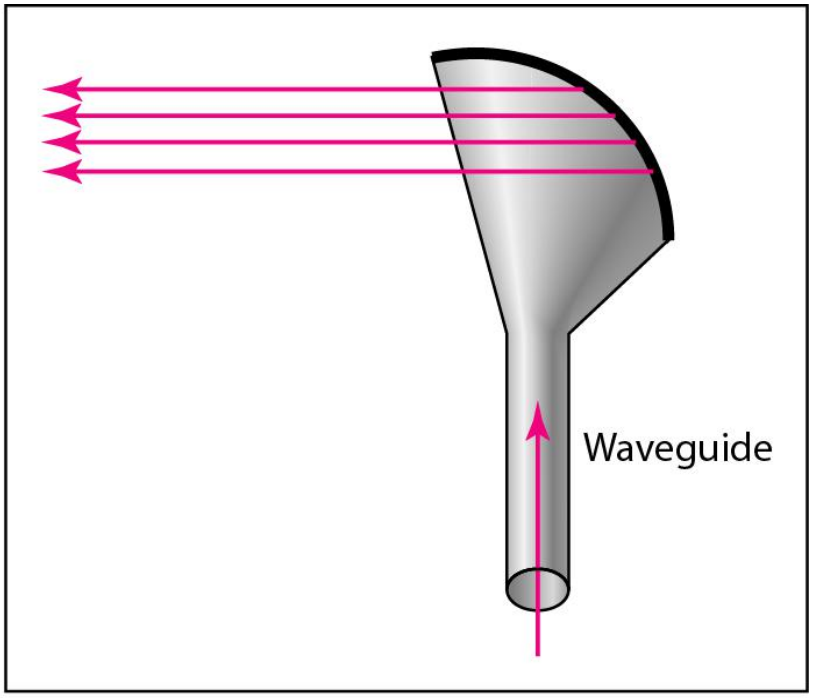
Contd.

2. **A horn antenna** looks like a gigantic scoop.

- Outgoing transmissions are broadcast up a stem (resembling a handle) 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.



a. Dish antenna



b. Horn antenna

Applications

- Microwaves, due to their unidirectional properties, are very useful when **unicast (one-to-one) communication** is needed between the sender and the receiver.
- They are used in **cellular phones**, **satellite networks** , and **wireless LANs.**

Infrared

- Infrared waves, with frequencies from 300 GHz to 400 THz (wavelengths from 1 mm to 770 nm), can be used for short-range communication.
- Infrared waves, having high frequencies, cannot penetrate walls.
- This advantageous characteristic prevents interference between one system and another; a short-range communication system in one room cannot be affected by another system in the next room.
- When we use our infrared remote control, we do not interfere with the use of the remote by our neighbors!!!
- However, this same characteristic makes infrared signals useless for long-range communication.
- In addition, we cannot use infrared waves outside a building because the sun's rays contain infrared waves that can interfere with the communication.

Applications

- 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 standards for using these signals for communication between devices such as keyboards, mice, PCs, and printers.
  - For example, some manufacturers provide a special port called the IrDA port that allows a **wireless keyboard** to communicate with a **PC**.
- The standard originally defined a data rate of 75 kbps for a distance up to 8 m. The recent standard defines a data rate of 4 Mbps.
- Infrared signals defined by IrDA transmit through line of sight; the IrDA port on the keyboard needs to point to the PC for transmission to occur.
- Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation!!!

Wireless Channels

- Are subject to a lot more errors than guided media channels.
- Interference is one cause for errors, can be circumvented with high **Signal -to noise-ratio(SNR)**.
- The higher the SNR the less capacity is available for transmission due to the broadcast nature of the channel.
- Channel also subject to fading and no coverage holes.

Q?