Physical Layer

The Theoretical Basis for Data Communication

- The physical layer deals with transporting bits between two machines.
- Information can be transmitted on wires by varying some physical property such as voltage or current.

Maximum Data Rate

- A very important consideration in communications is how fast we can send data, in bits per second. over a channel.
- Data rate depends on three factors:
    1. The bandwidth available
    2. The level of the signals we use
    3. The quality of the channel (the level of noise)
- Two theoretical formulas were developed to calculate the data rate: one by **Nyquist for a noiseless channel**. another by **Shannon for a noisy channel**.

Noiseless Channel: Nyquist Theorem

- In 1924 Henry **Nyquist** derived an equation expressing the maximum data rate for a finite bandwidth **noiseless** channel.
- For a noiseless channel, the Nyquist bit rate formula defines the theoretical maximum bit rate

$$\textbf{BitRate} = 2 \times \textbf{bandwidth} \times \log_2 L$$

- In this formula, bandwidth is the bandwidth of the channel, L is the number of signal levels used to represent data, and Bit Rate is the bit rate in bits per second.
- Increasing the levels of a signal may reduce the reliability of the system.

Noisy Channel: Shannon Capacity

- In reality, we can not have a noiseless channel
- **Shannon's theorem** gives the maximum data rate for channels having noise (e.g., all real channels).
- Shannon's theorem states that the maximum data rate of a noisy channel of bandwidth B, signal-to-noise ratio of S/N is given by:

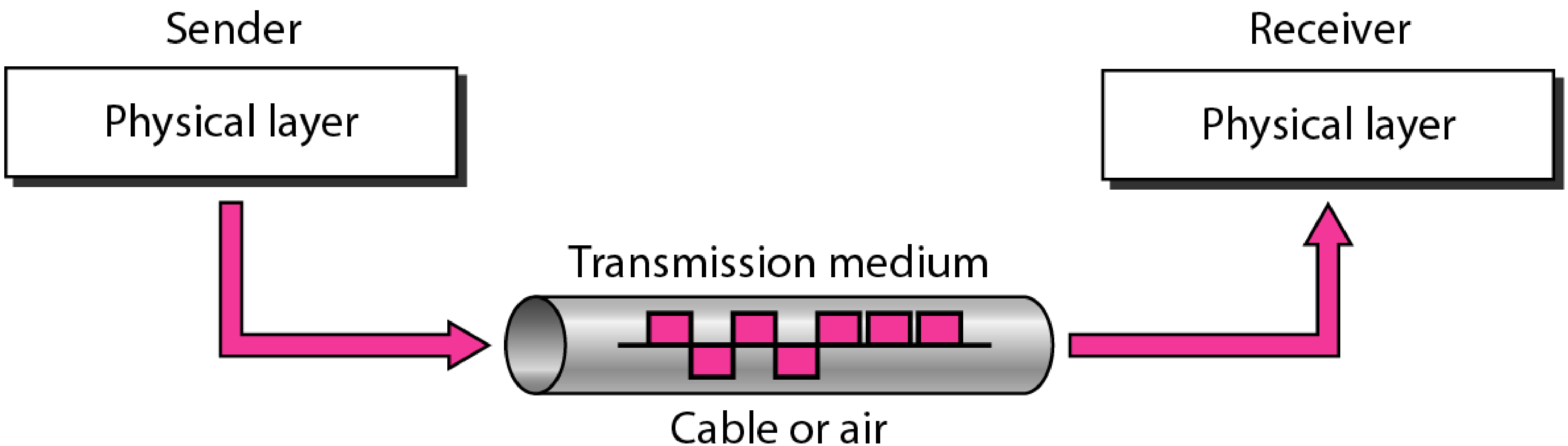
$$\text{max data rate} = B \log_2 (1 + S/N)$$

- Note: the signal to noise ratio S/N used in Shannon's theorem refers to the ratio of signal power to noise power.

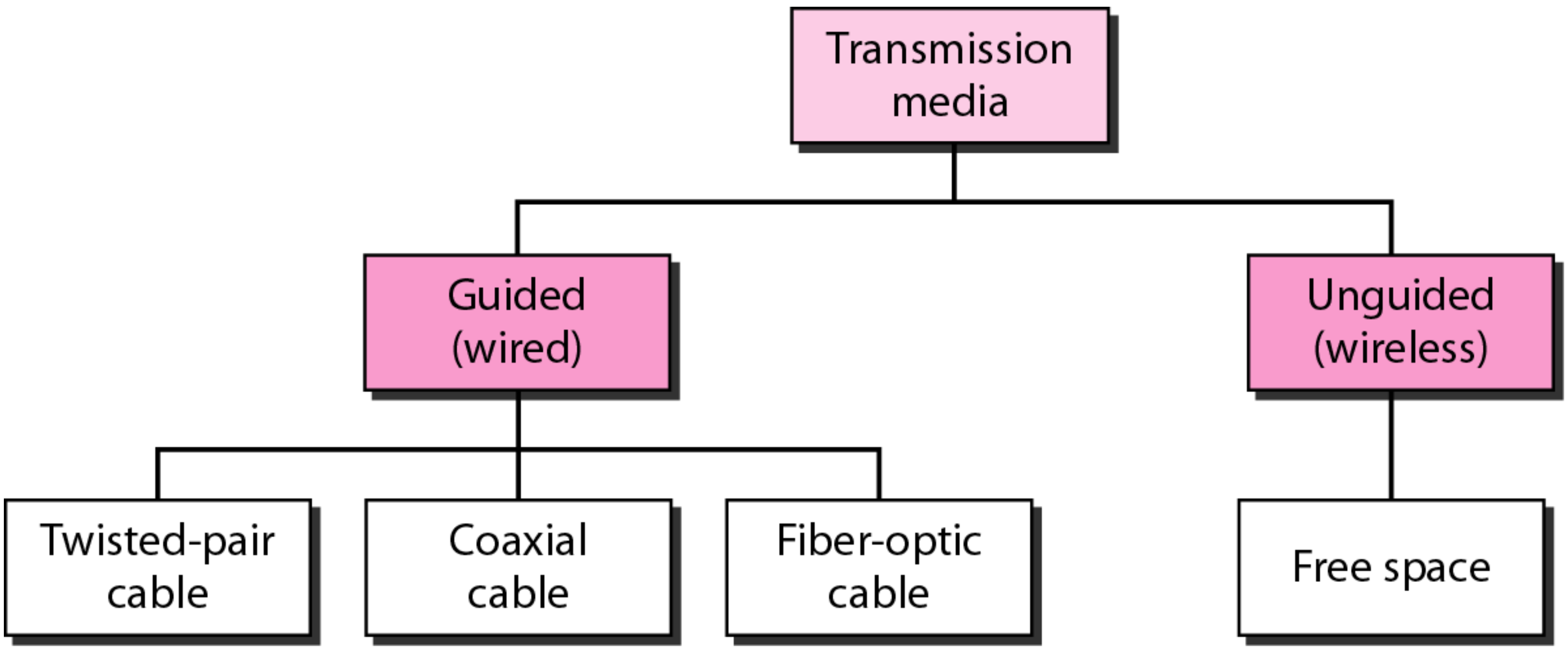
Transmission Media

- Transmission media is a pathway that carries information from sender to receiver.
- We use different types of cables or waves to transmit data.
- Data is transmitted normally through electrical or electromagnetic signals.
- Transmission media are located below the physical layer

Transmission medium and physical layer



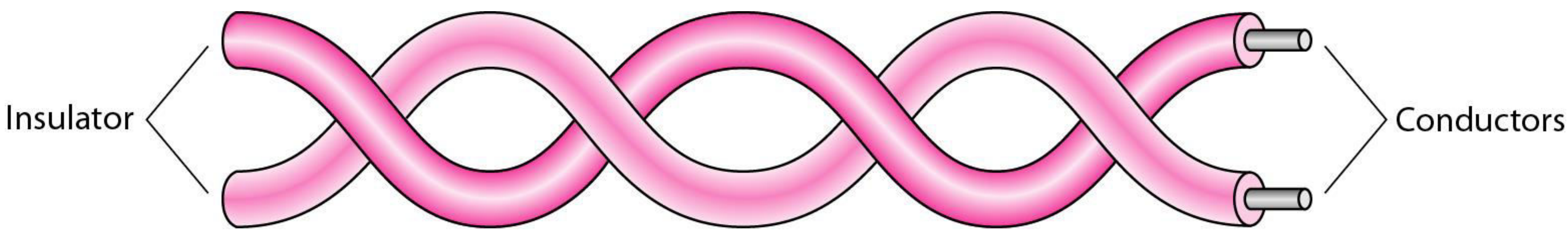
Classes of transmission media



GUIDED MEDIA: Twisted Pair Cable

- Twisted-pair cable use metallic (copper) conductors that accept and transport signals in the form of electric current.
- A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together.
- One of the wires is used to carry signals to the receiver, and the other is used only as a ground reference.

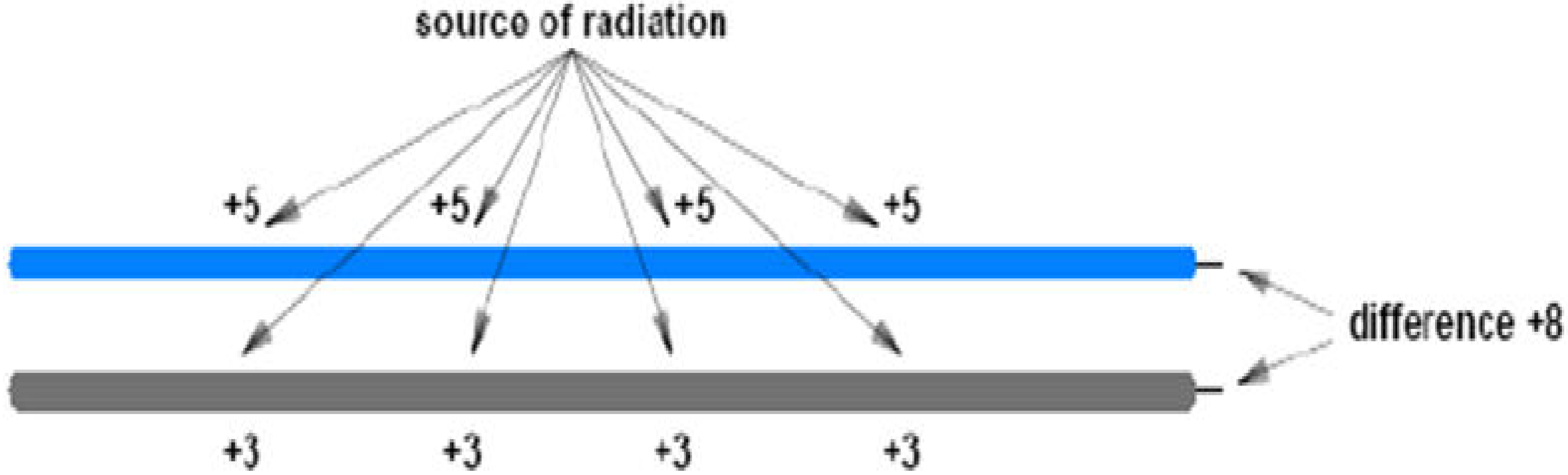
Twisted-pair cable



How Twisted Pair Cable Reduces Noise?

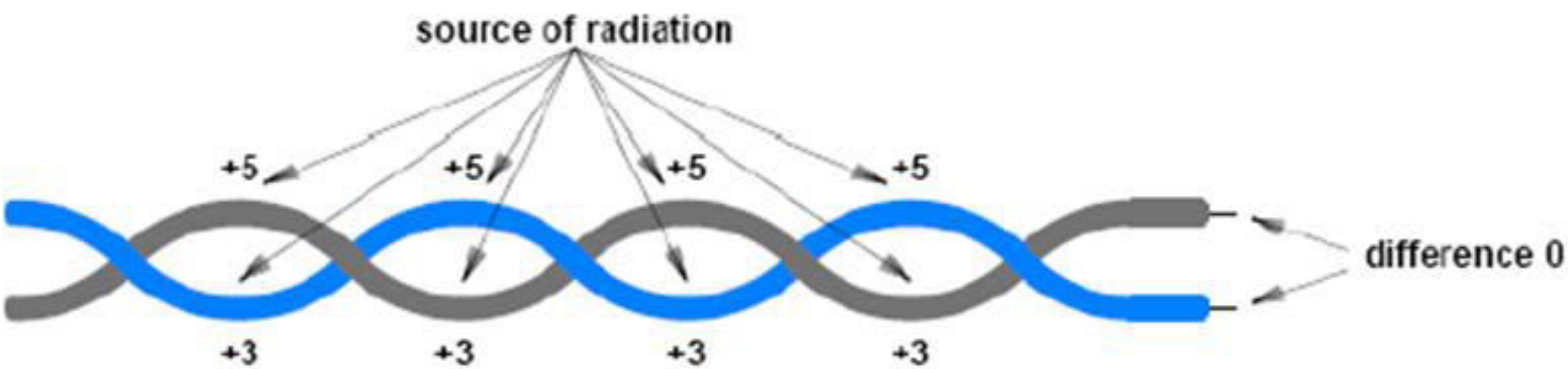
➢ Signal sent by the sender on one of the wires, interference (noise) and crosstalk may affect both wires and create unwanted signals.

➢ 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 (e,g., one is closer and the other is farther).



Reduces Noise?.....

- By twisting the pairs, a balance is maintained.
- 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).



Unshielded Versus Shielded Twisted-Pair Cable

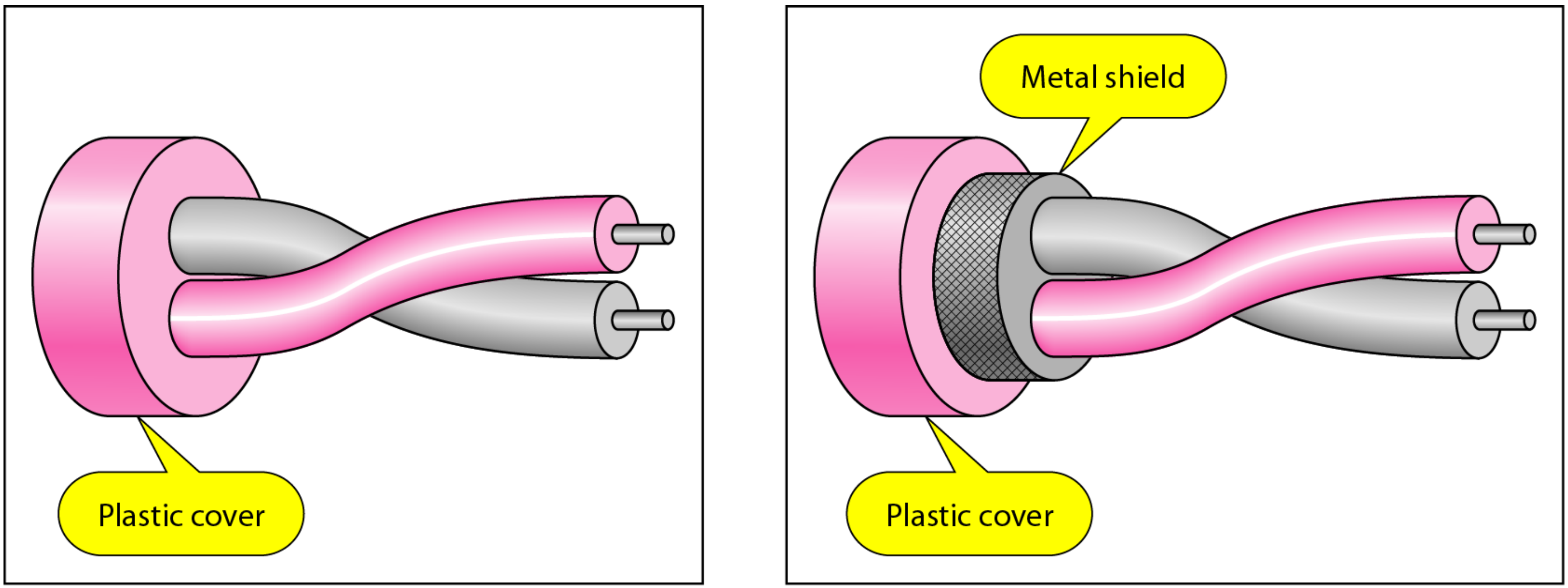
- There are two types of twisted pair cable
  - Unshielded Twisted Pair (UTP)
  - Shielded Twisted Pair (STP)

- STP cable has a metal foil or braided-mesh covering that enclose each pair of insulated conductors.

- Metal casing improves the quality of cable by preventing the penetration of noise or crosstalk.

- It is bulkier and more expensive.

UTP and STP cables



a. UTP

b. STP

Twisted-Pair Cable: 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.

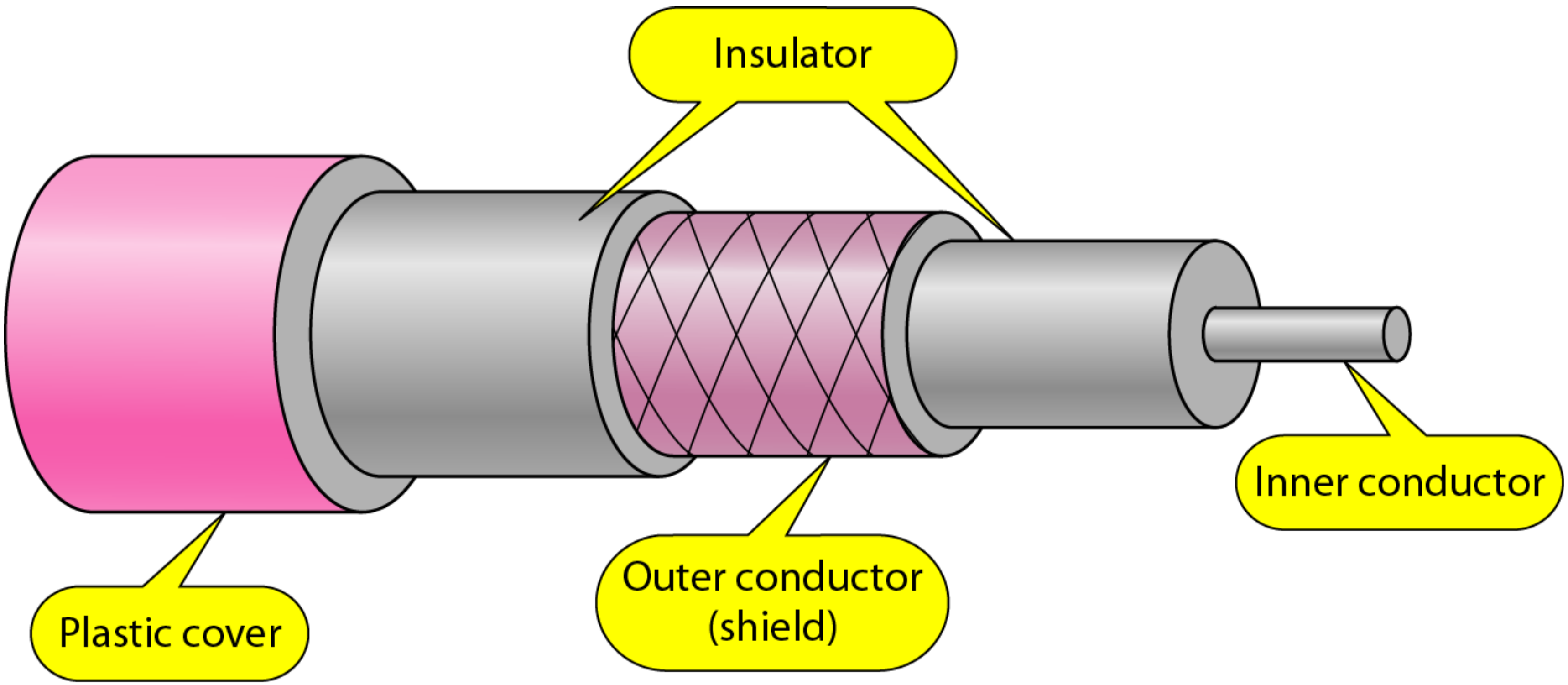
Twisted-Pair Cable: Applications

- Twisted-pair cables are used in telephone 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.

GUIDED MEDIA: Coaxial Cable

- Coaxial cable (or coax) carries signals of higher frequency ranges than those in twisted pair cable.
- 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.

Coaxial cable



Coaxial Cable: Standard

- Coaxial cables are categorized by their Radio Government (RG) ratings.

- Each RG number denotes a unique set of physical specifications, including the wire gauge of the inner conductor, the thickness and type of the inner insulator, the construction of the shield, and the size and type of the outer casing.

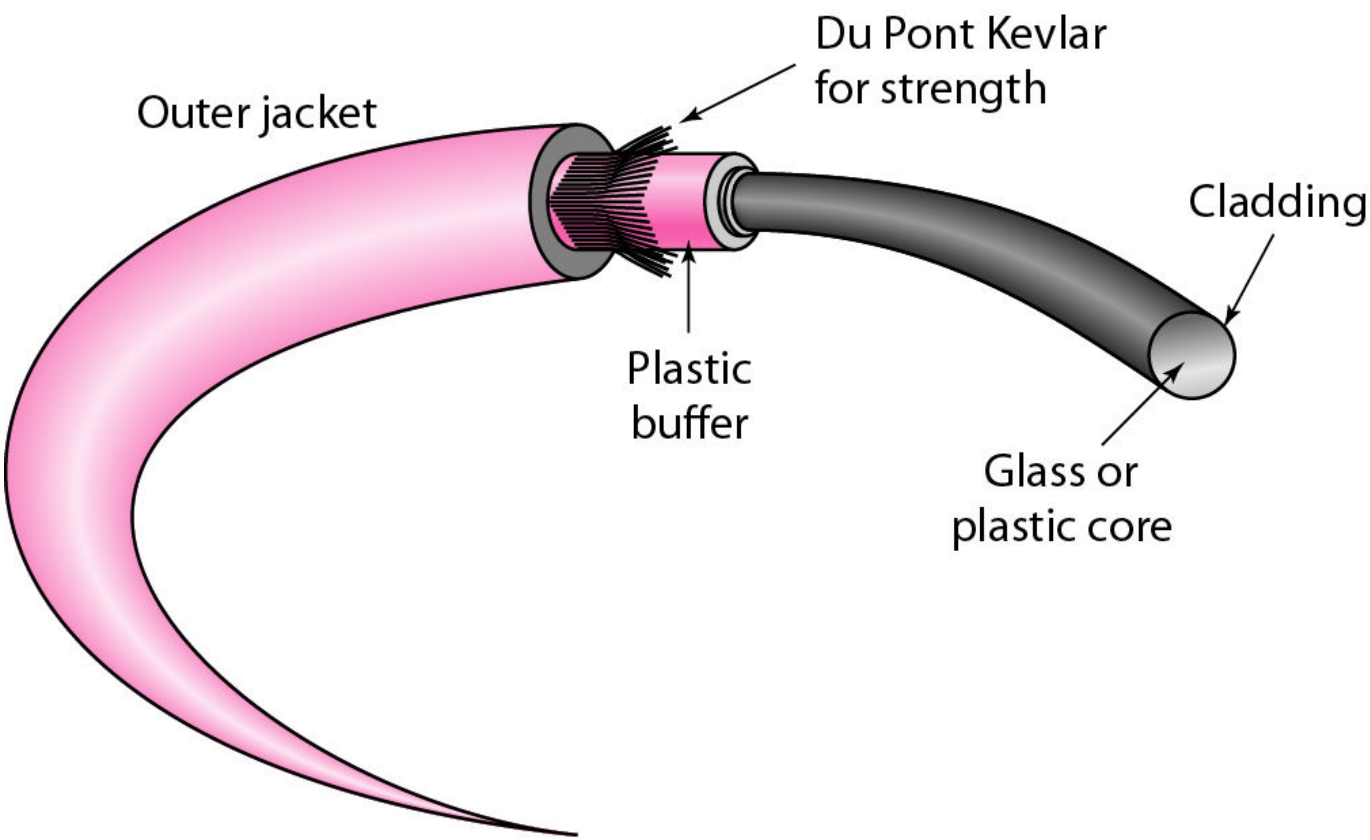
Coaxial Cable: Applications

- Coaxial cable was widely used in analog telephone networks where a single coaxial network could carry 10,000 voice signals.
- Later it was used in digital telephone networks where a single coaxial cable could carry digital data up to 600 Mbps.
- Cable TV networks also use coaxial cables.

GUIDED MEDIA: Fiber-Optic Cable

- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.
- The outer jacket is made of either PVC 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.

Fiber construction



Fiber Optic: Advantage & Disadvantage

Advantage:

1. Higher bandwidth.
2. Less signal attenuation.
3. Electromagnetic noise cannot affect fiber-optic cables.
4. Small size and low weight.

Disadvantage:

1. Installation and maintenance is complex.
2. Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.
3. The cable and the interfaces are relatively more expensive than those of other guided media.

Fiber Optic: Applications

- Fiber-optic cable is often found in backbone networks because its wide bandwidth is cost-effective. Today, we can transfer data at a rate of 1600 Gbps.
- Some cable TV companies use a combination of optical fiber and coaxial cable, thus creating a hybrid network. Optical fiber provides the backbone structure while coaxial cable provides the connection to the user premises.

UNGUIDED MEDIA: WIRELESS

- Unguided media transport electromagnetic waves without using a 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.

Propagation method

1. Ground Propagation: < 2MHz

2. Sky Propagation: 2MHz to 30MHz

3. Line-of-Sight (LOS) Propagation: > 30MHz

Propagation methods

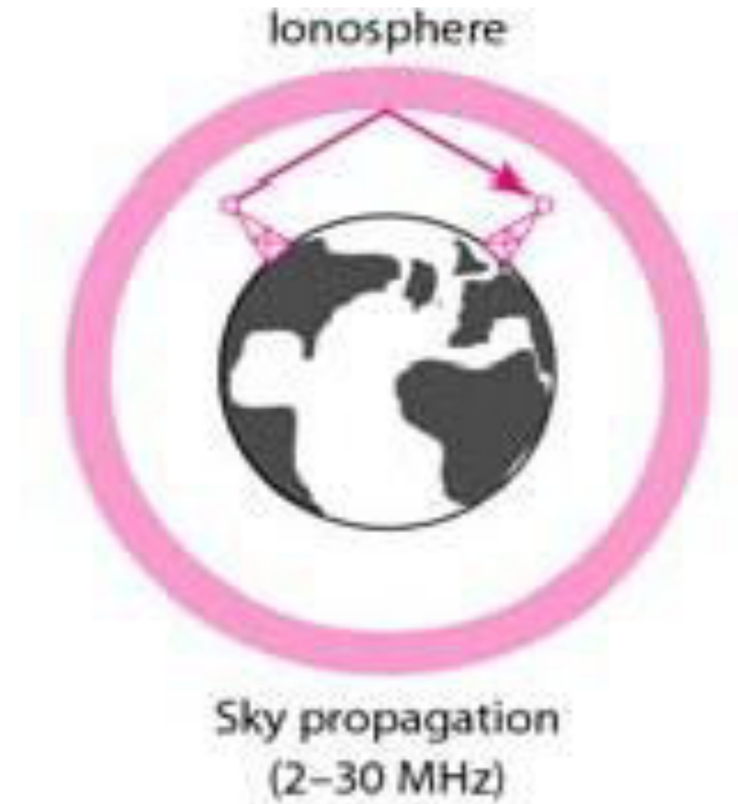
Ground propagation

- Radio waves travel through the lowest portion of the atmosphere, hugging the earths.
- Low frequency signal emanate in all directions from the transmitting antenna and follow the curvature of the planet.

Propagation methods

Sky propagation

- Higher frequency radio waves radiate upward into the ionosphere where they are reflected back to earth. Allows for greater distances with low output power.

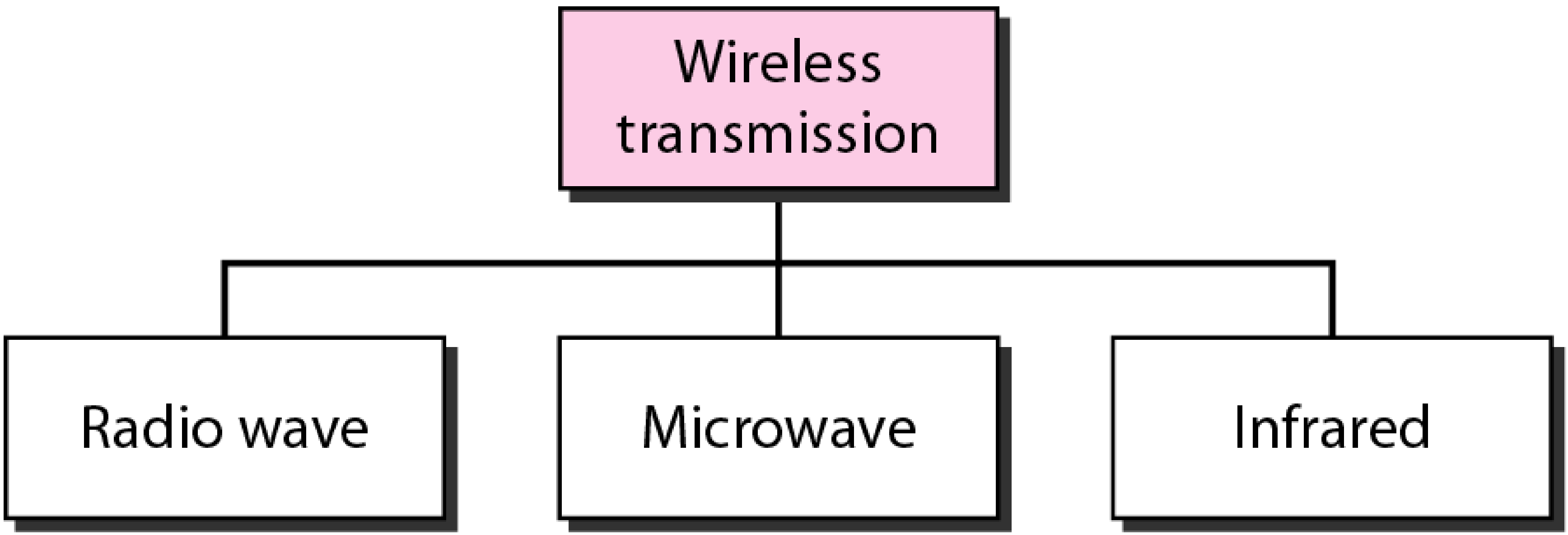


Propagation methods

Line-of-sight propagation

- Very high frequency signals that transmitted in straight line directly from antenna to antenna
- Antenna must be directionally, facing each other and either tall enough or close enough (to be not affected by the curvature of earth)

Wireless transmission waves



Wireless Transmission: Radio Waves

- Electromagnetic waves ranging in frequencies between **3 kHz and 1 GHz** are normally called radio waves. The entire band is regulated by authorities.
- Radio waves are omnidirectional. When an antenna transmits radio waves, they are propagated in all directions.
- Can travel long distances.
- Radio waves, particularly those of low and medium frequencies, can penetrate walls.
- Radio waves are used for multicast communications, such as radio and television, and paging systems.

Wireless Transmission: Microwaves

- Electromagnetic waves having frequencies between **1 and 300 GHz** are called microwaves. Use of certain portions of the band requires permission from authorities.
- Microwaves are unidirectional. When an antenna transmits microwave waves, they can be narrowly focused.
- Very high-frequency microwaves cannot penetrate walls.
- Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs.

Wireless Transmission: Infrared

- Infrared waves, with frequencies from **300 GHz to 400 THz**.
- Infrared signals are used for short-range communication in a closed area.