Introduction to Telecommunication Systems
Lecture 5

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Network Performance

- Characteristics that measure network performance:
  - Bandwidth
  - Throughput
  - Latency (Delay)

Network Performance

- Bandwidth:
- In networking, we use the term bandwidth in two contexts.
  - Bandwidth in hertz, refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.
  - Bandwidth in bits per second, refers to the speed of bit transmission in a channel or link.
- Basically, an increase in bandwidth in hertz means an increase in bandwidth in bits per second.
- The relationship depends on whether we have baseband transmission or transmission with modulation.

Network Performance

- Throughput:
- The throughput is a measure of how fast we can actually send data through a network.
- The bandwidth is a potential measurement of a link; the throughput is an actual measurement of how fast we can send data.
- For example, we may have a link with a bandwidth of 1 Mbps, but the devices connected to the end of the link may handle only 200 kbps. This means that we cannot send more than 200 kbps through this link.

Network Performance

- Latency (Delay):
- The latency or delay defines how long it takes for an entire message to completely arrive at the destination from the time the first bit is sent out from the source.
- We can say that latency is made of four components:
  - propagation time,
  - transmission time,
  - queuing time and
  - processing delay.
- Latency = propagation time + transmission time + queuing time + processing delay

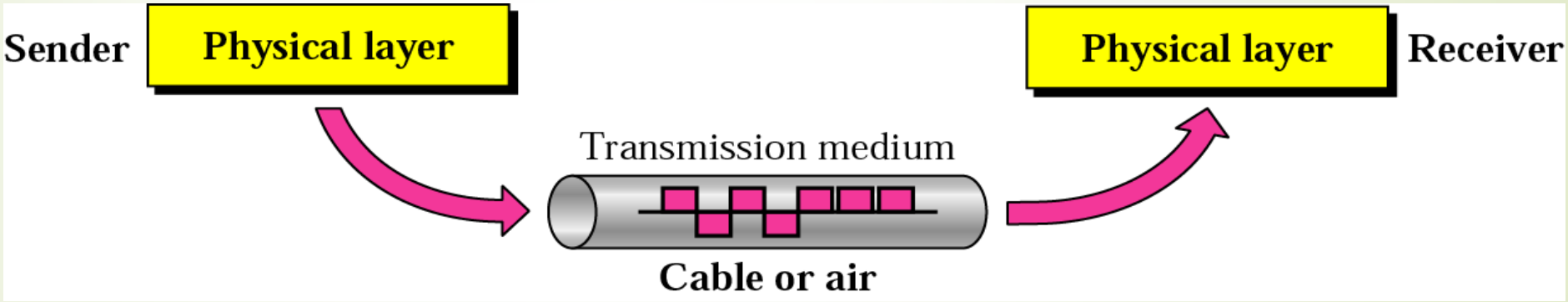
Network Performance

- Jitter:
- Another performance issue that is related to delay is jitter.
- We can roughly say that jitter is a problem if different packets of data encounter different delays and the application using the data at the receiver site is time-sensitive (audio and video data, for example).
- If the delay for the first packet is 20 ms, for the second is 45 ms, and for the third is 40 ms, then the real-time application that uses the packets endures jitter.

Transmission Media

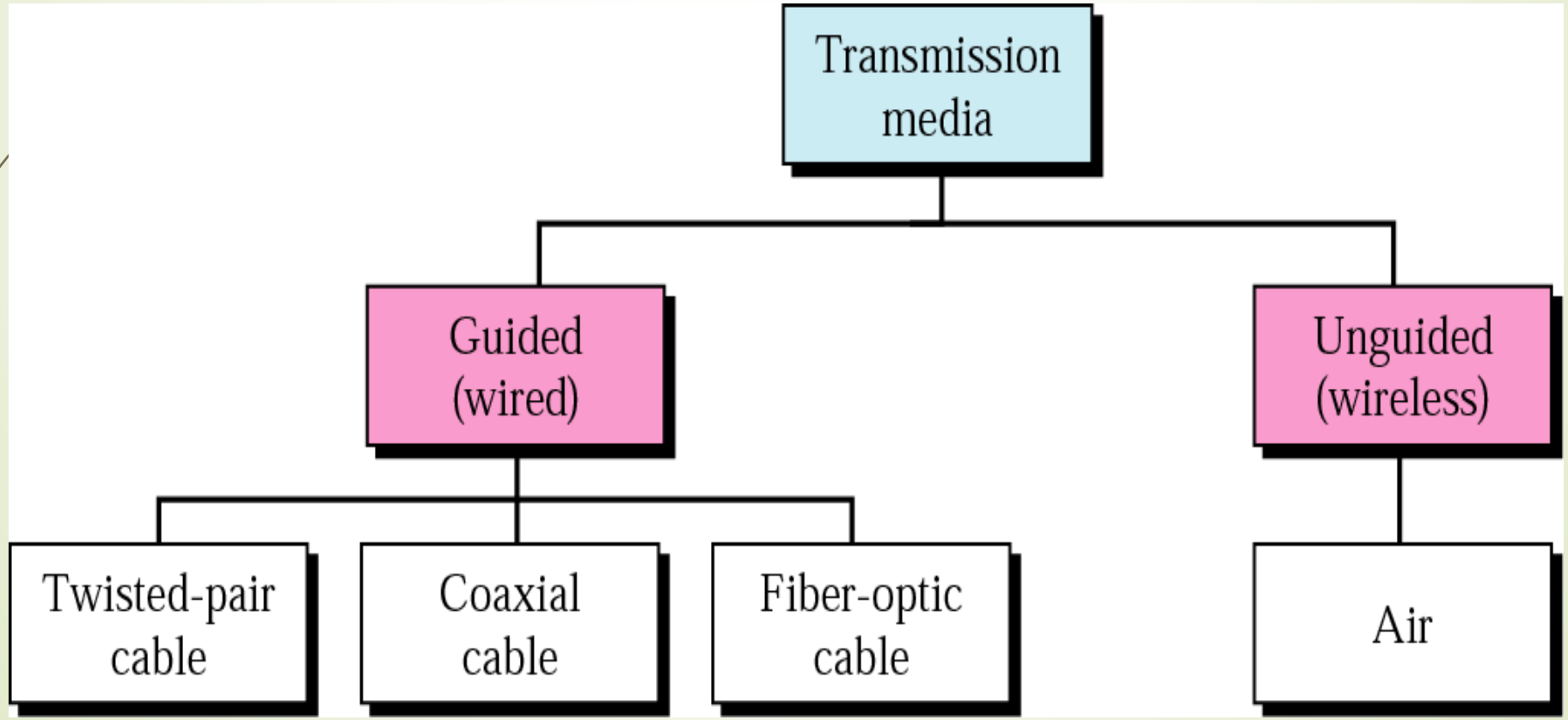
- A transmission medium can be broadly defined as anything that can carry information from a source to a destination.
- Guided Media
  - Twisted-Pair Cable: Shielded, unshielded
  - Coaxial Cable
  - Fiber-Optic
- Unguided Media: Wireless
  - Radio Waves
  - Microwaves
  - Infrared

Transmission Media



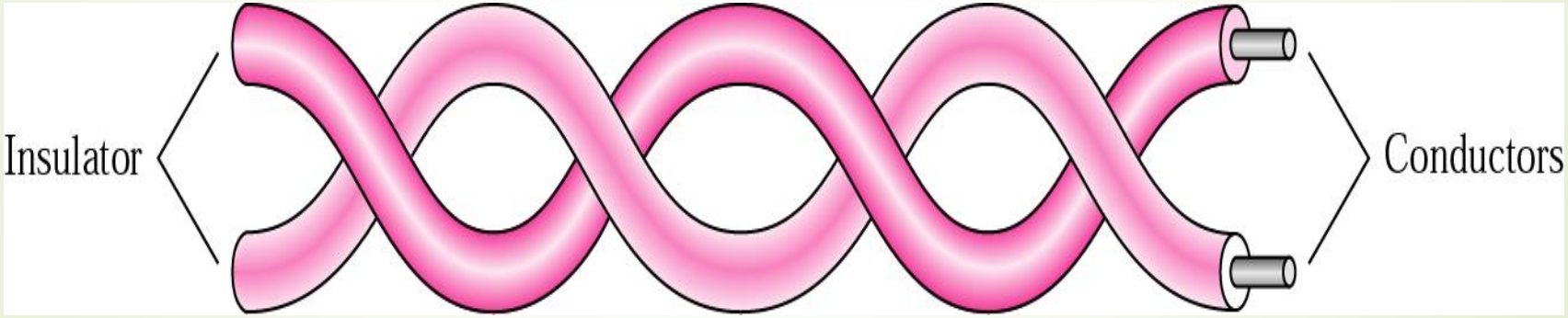
Transmission Media

- Types of transmission Media:



Guided Media – UTP, STP

- Twisted-Pair Cable
- A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in Figure:



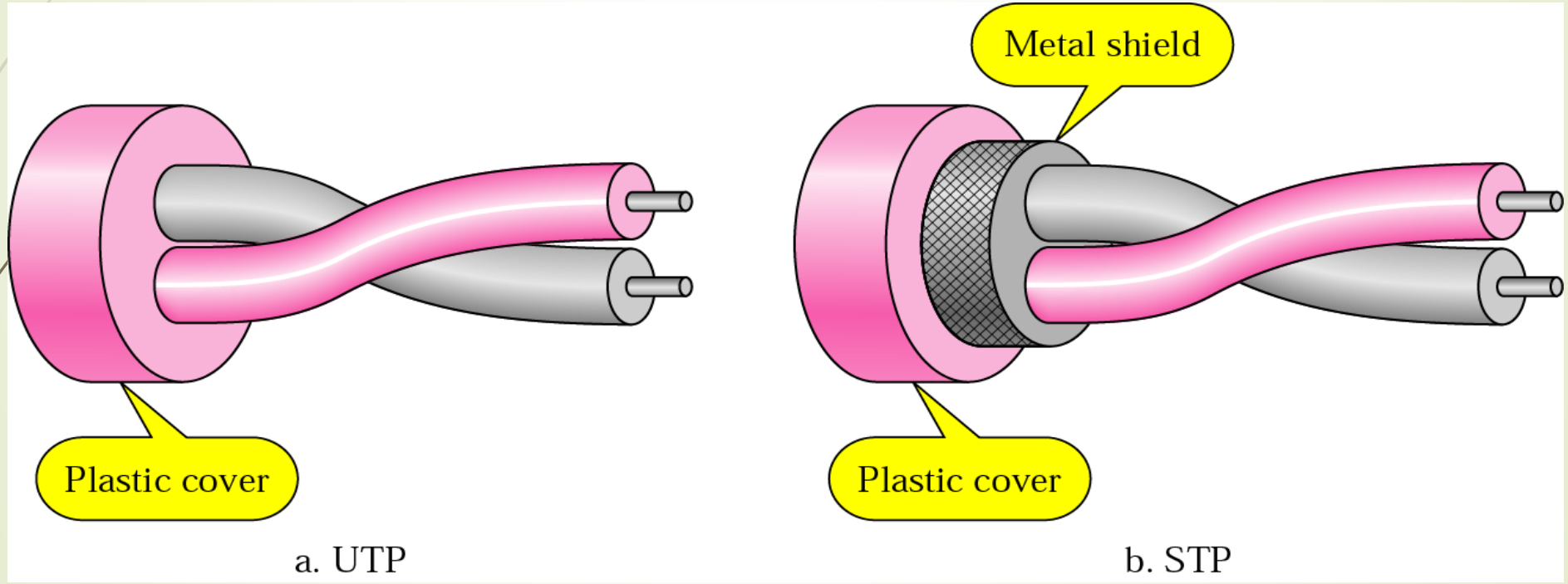
Unshielded Versus Shielded Twisted-Pair Cable

- 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.

Unshielded Versus Shielded Twisted-Pair Cable

- Unshielded Twisted Pair (UTP)
  - Ordinary telephone wire
  - Cheapest
  - Easiest to install
  - Suffers from external EM interference
- Shielded Twisted Pair (STP)
  - Metal braid or sheathing that reduces interference
  - More expensive
  - Harder to handle (thick, heavy)

Unshielded Versus Shielded Twisted-Pair Cable



a. UTP

b. STP

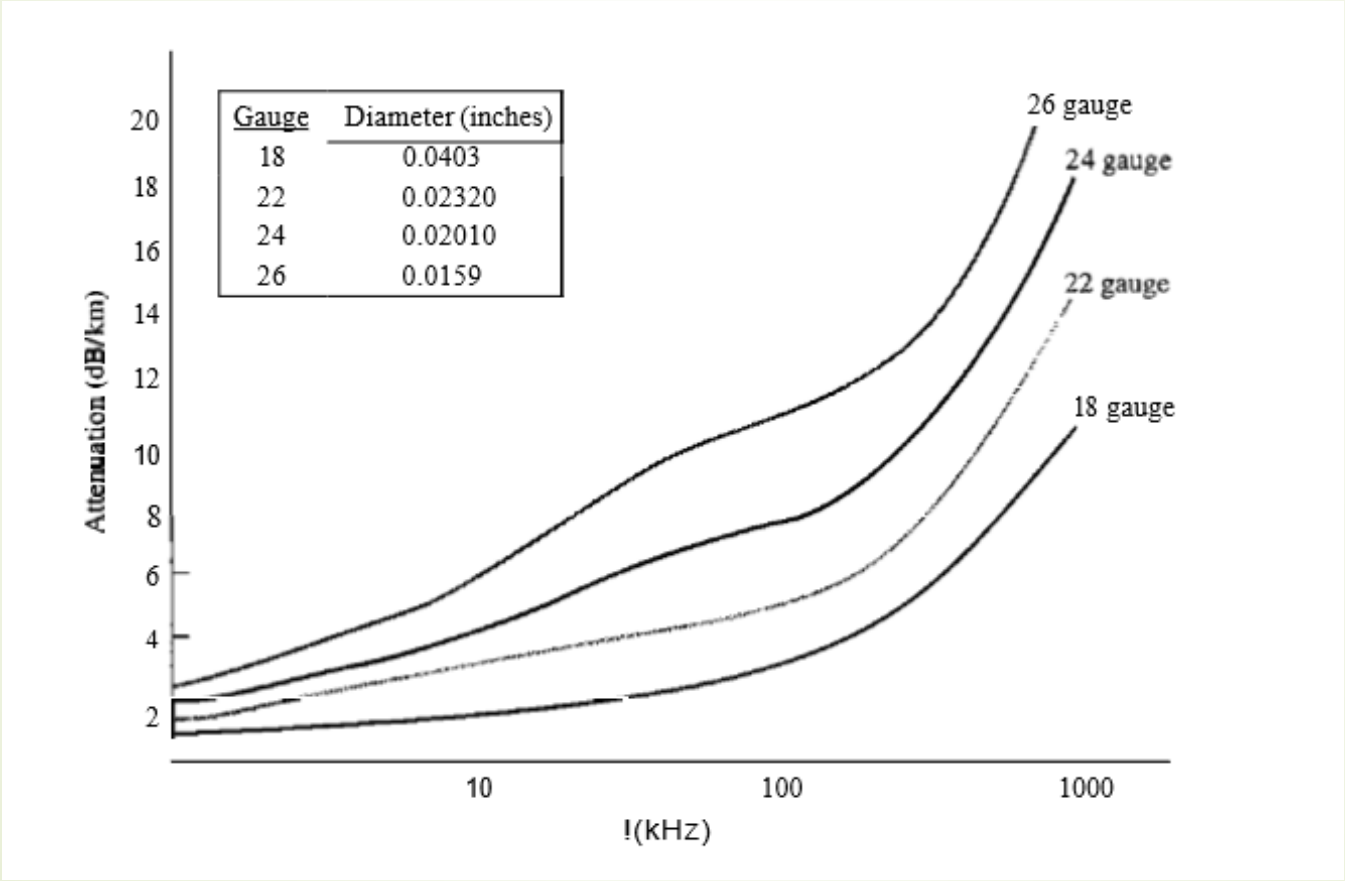
Twisted Pair - Applications

- Most common medium
- Telephone network
  - Between house and local exchange (subscriber loop)
- Within buildings
- For local area networks (LAN)
  - 10Mbps or 100Mbps

Twisted Pair - Pros and Cons

- Cheap
- Easy to work with
- Low data rate
- Short range

UTP performance



Guided Media – UTP, STP

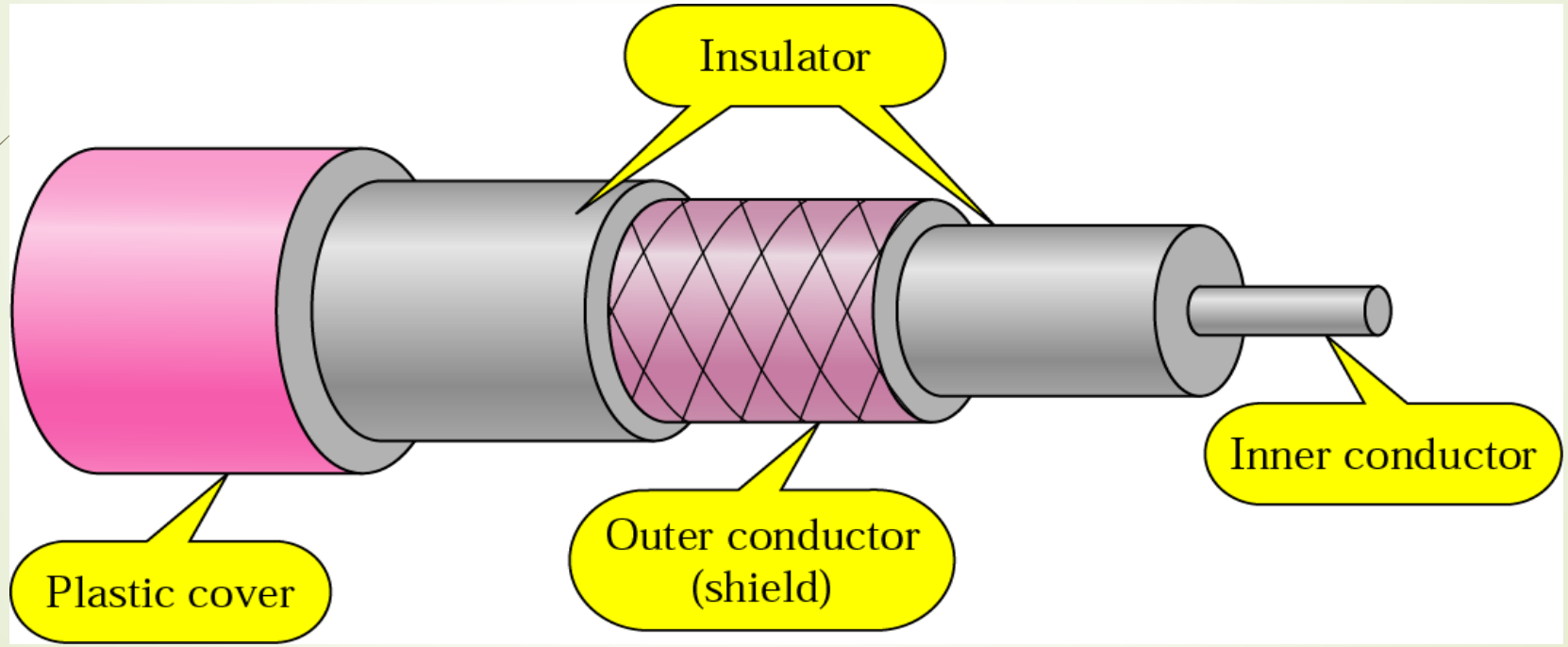
- Categories of unshielded twisted-pair cables:

Category	Bandwidth	Data Rate	Digital/Analog	Use
1	very low	< 100 kbps	Analog	Telephone
2	< 2 MHz	2 Mbps	Analog/digital	T-1 lines
3	16 MHz	10 Mbps	Digital	LANs
4	20 MHz	20 Mbps	Digital	LANs
5	100 MHz	100 Mbps	Digital	LANs
6 (draft)	200 MHz	200 Mbps	Digital	LANs
7 (draft)	600 MHz	600 Mbps	Digital	LANs

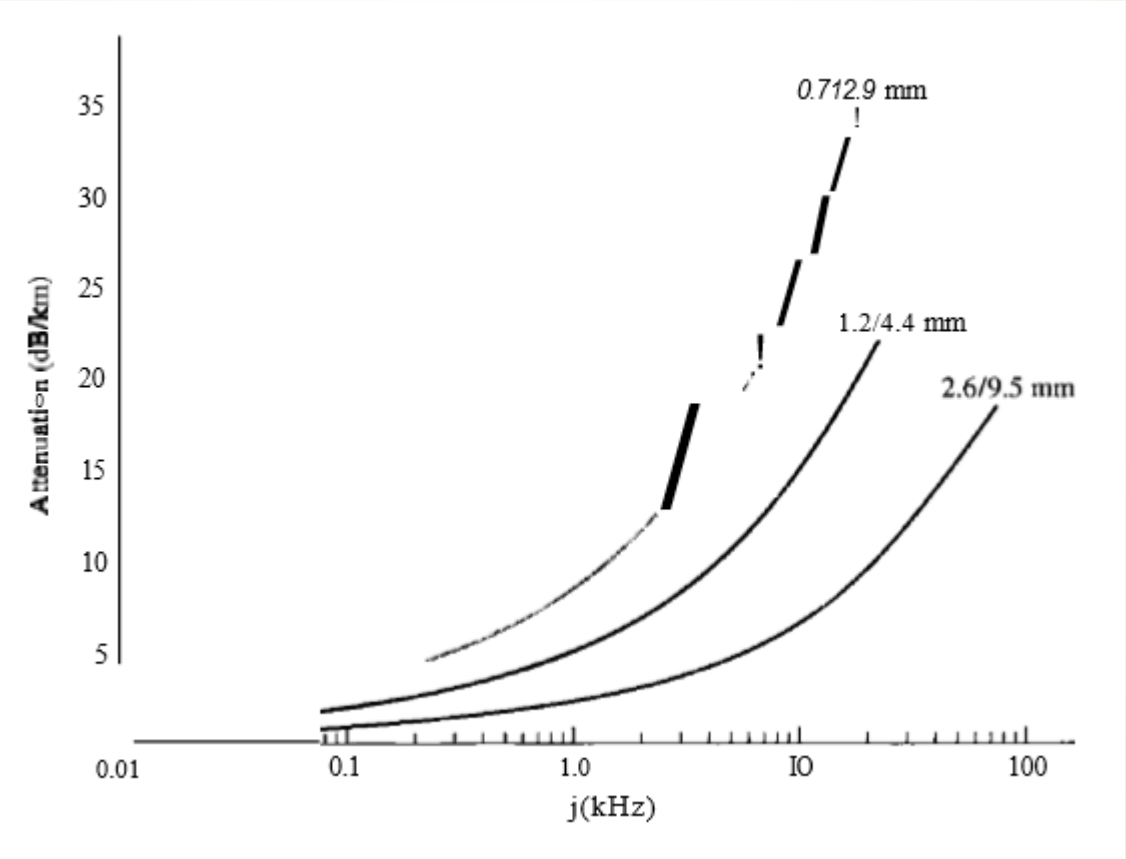
Guided Media – Coaxial Cable

- Coaxial cable carries signals of higher frequency ranges than those in twisted pair cable, in part because the two media are constructed quite differently.
- Coaxial cable 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 conductor is also enclosed in an insulating sheath, and the whole cable is protected by a plastic cover.

Guided Media – Coaxial Cable



Coaxial Cable Performance



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

Guided Media – Coax Cable

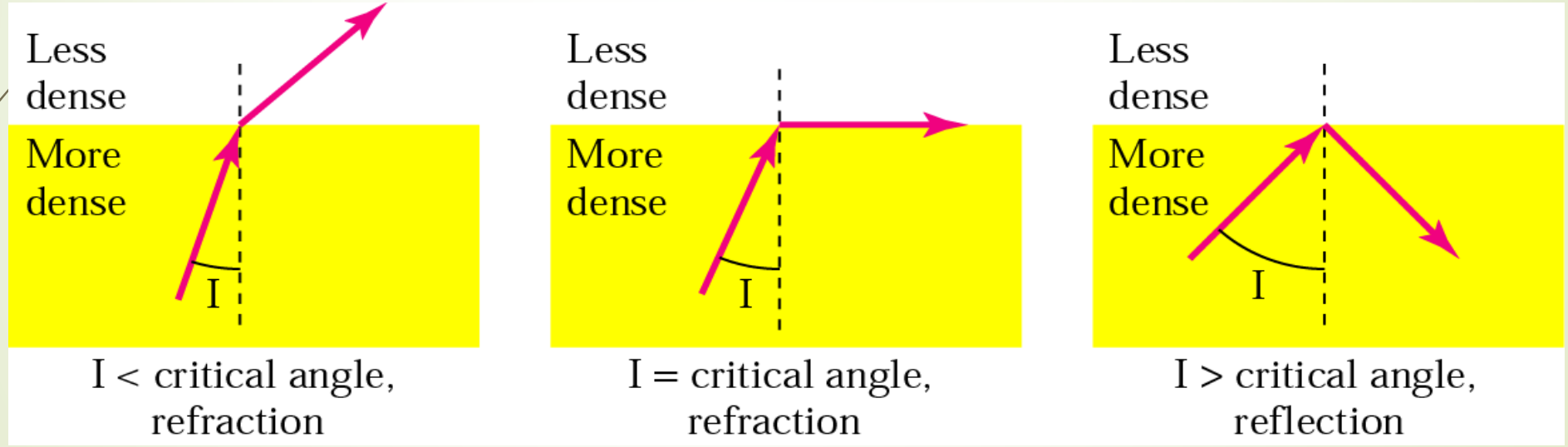
- Categories of Coaxial Cable:

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

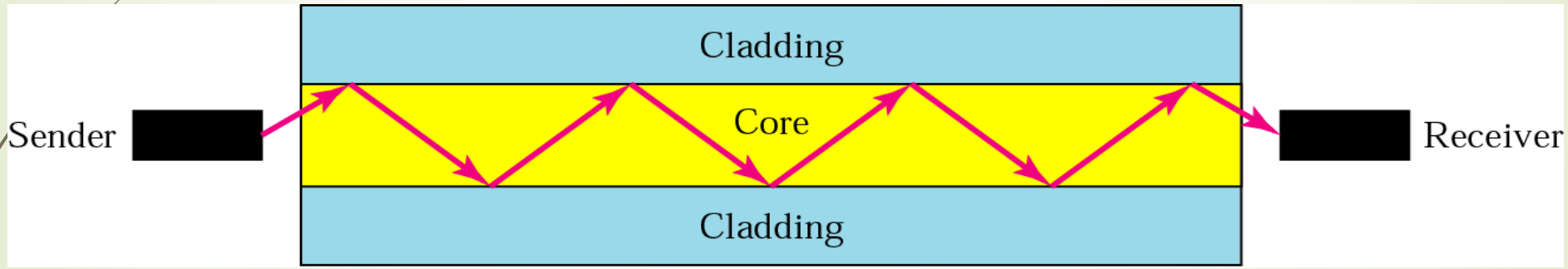
Guided Media – Fiber-Optic

- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.
- To understand optical fiber, we first need to explore several aspects of the nature of light.
- If a ray of light traveling through one substance suddenly enters another substance (of a different density), the ray changes direction.
- Figure shows how a ray of light changes direction when going from a more dense to a less dense substance.

Guided Media – Fiber-Optic

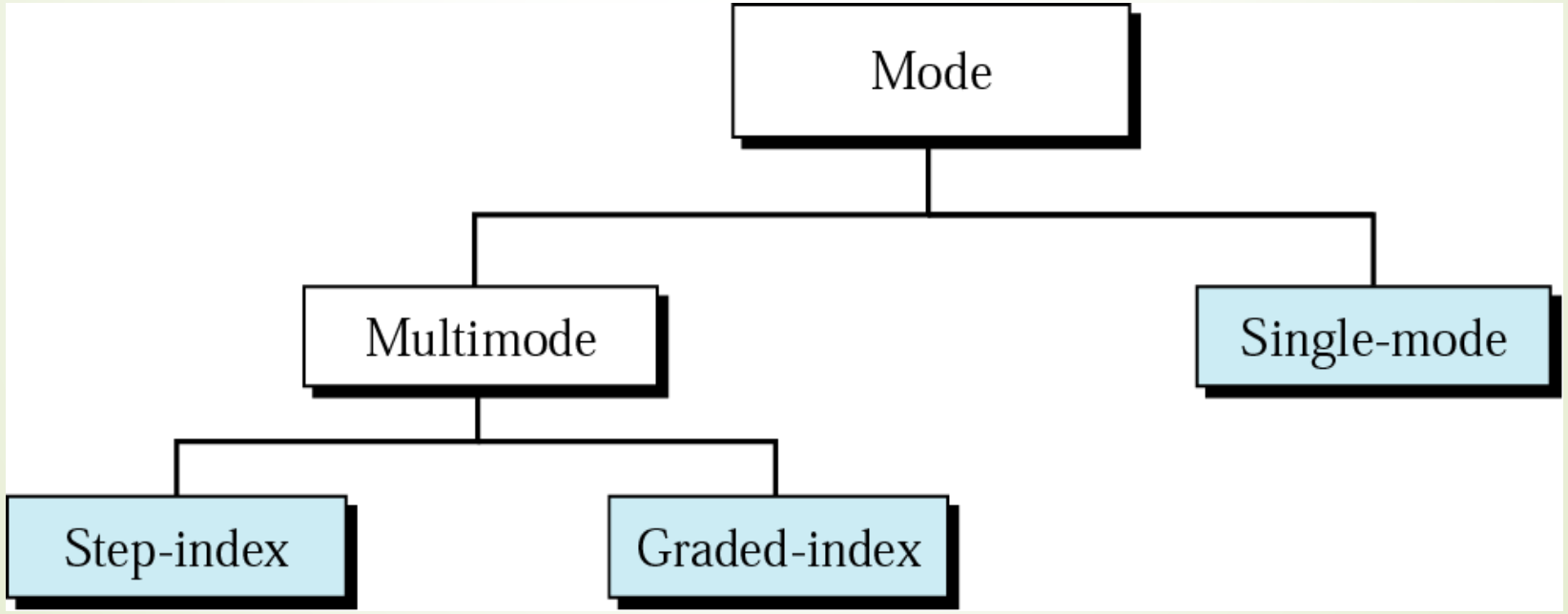


Guided Media – Fiber-Optic



Guided Media – Fiber-Optic

- Optical Fiber propagation modes:

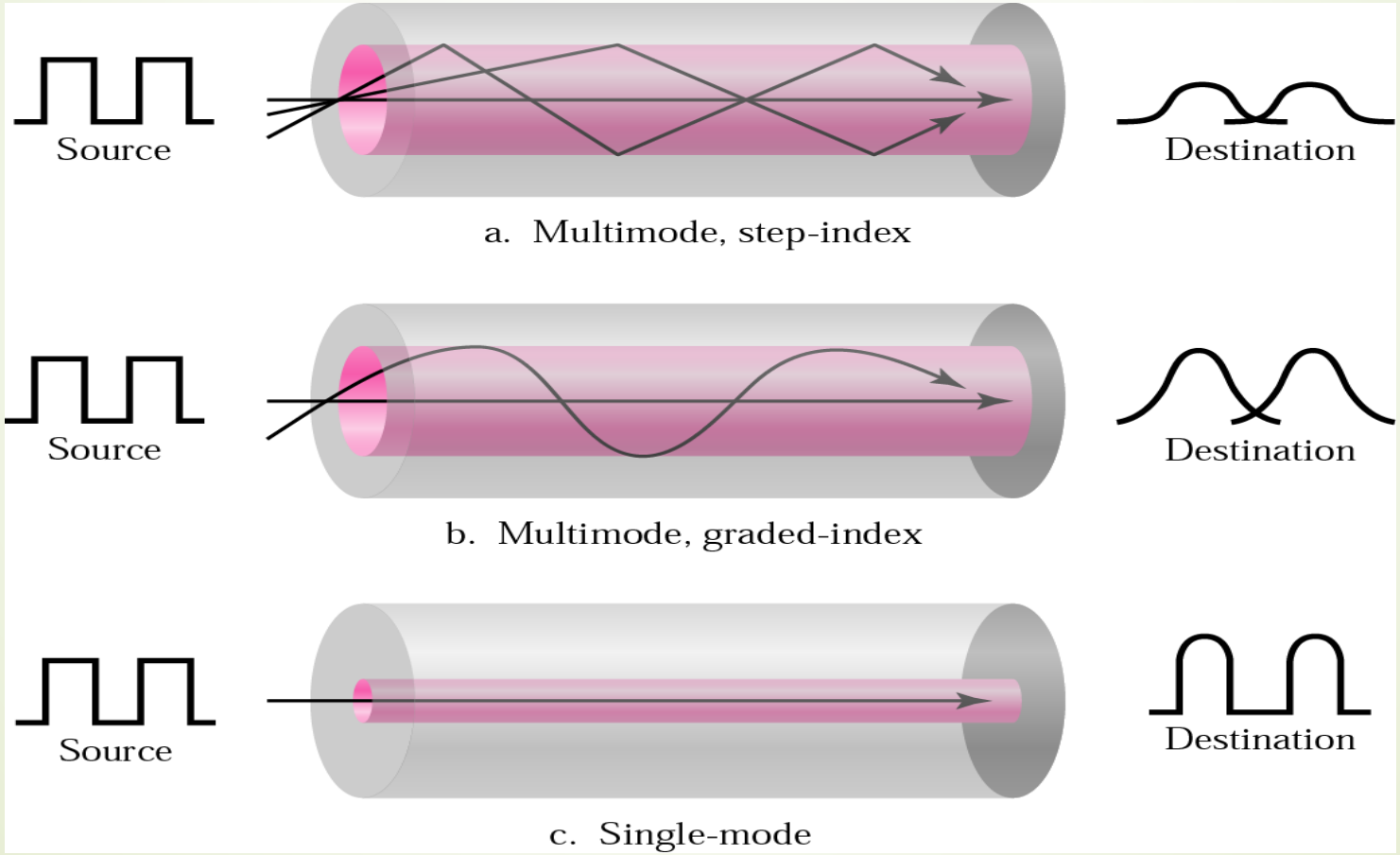


Optical Fiber propagation modes

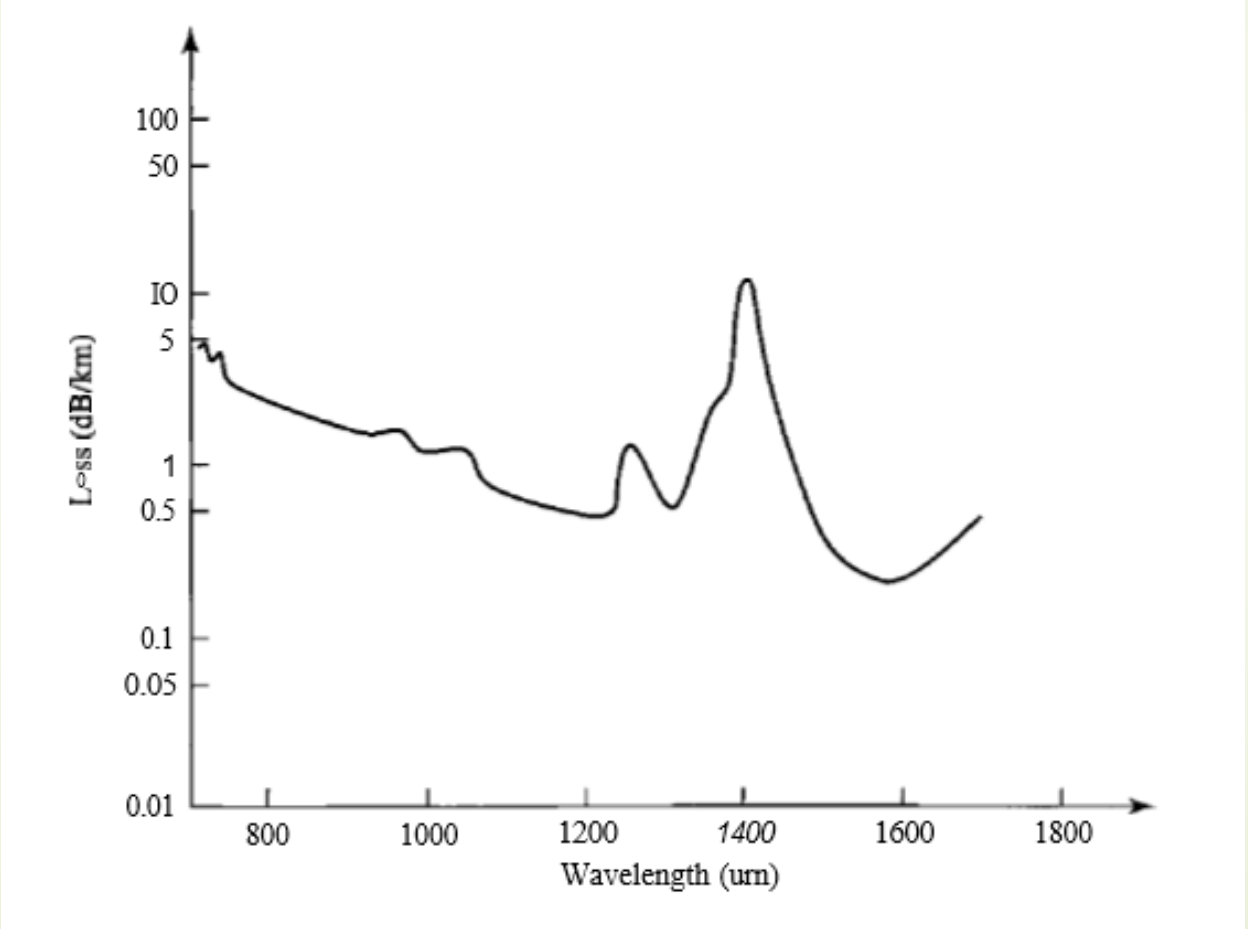
- Multimode: Multimode is so named because multiple beams from a light source move through the core in different paths.
- How these beams move within the cable depends on the structure of the core.
  - Multi mode Step index fiber
  - Multi mode Graded index fiber
- Single-Mode: Single-mode uses step-index fiber and a highly focused source of light that limits beams to a small range of angles, all close to the horizontal.

Optical Fiber propagation modes

- Modes:



Optical fiber Performance



Advantages of Fiber Optic Cables

- Higher bandwidth:
  - Fiber-optic cable can support dramatically higher bandwidths (and hence data rates) than either twisted-pair or coaxial cable.
- Less signal attenuation:
  - Fiber-optic transmission distance is significantly greater than that of other guided media.
  - A signal can run for 50 km without requiring regeneration. We need repeaters every 5 km for coaxial or twisted-pair cable.

Advantages of Fiber Optic Cables

- Immunity to electromagnetic interference:
  - Electromagnetic noise cannot affect fiber-optic cables.
- Resistance to corrosive materials:
  - Glass is more resistant to corrosive materials than copper.
- Light weight:
  - Fiber-optic cables are much lighter than copper cables.
- Greater immunity to tapping:
  - Fiber-optic cables are more immune to tapping than copper cables. Copper cables create antenna effects that can easily be tapped.

Disadvantages of Fiber Optic Cables

- There are some disadvantages in the use of optical fiber.
  - Installation and maintenance: Fiber-optic cable is a relatively new technology. Its installation and maintenance require expertise that is not yet available everywhere.
  - Unidirectional light propagation: Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.
  - Cost: The cable and the interfaces are relatively more expensive than those of other guided media. If the demand for bandwidth is not high, often the use of optical fiber cannot be justified.

End of Slides