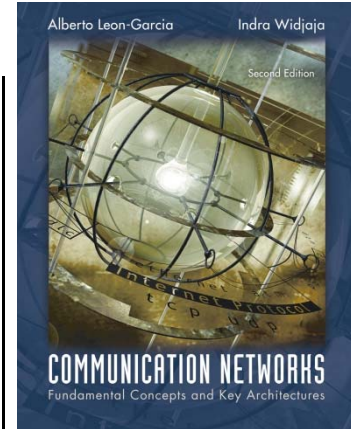


Chapter 3

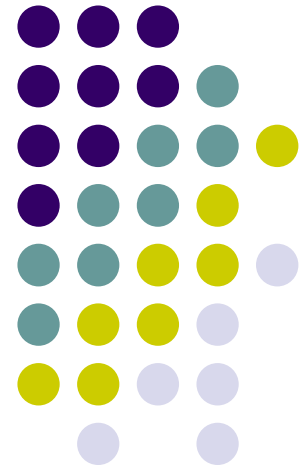
Digital Transmission Fundamentals



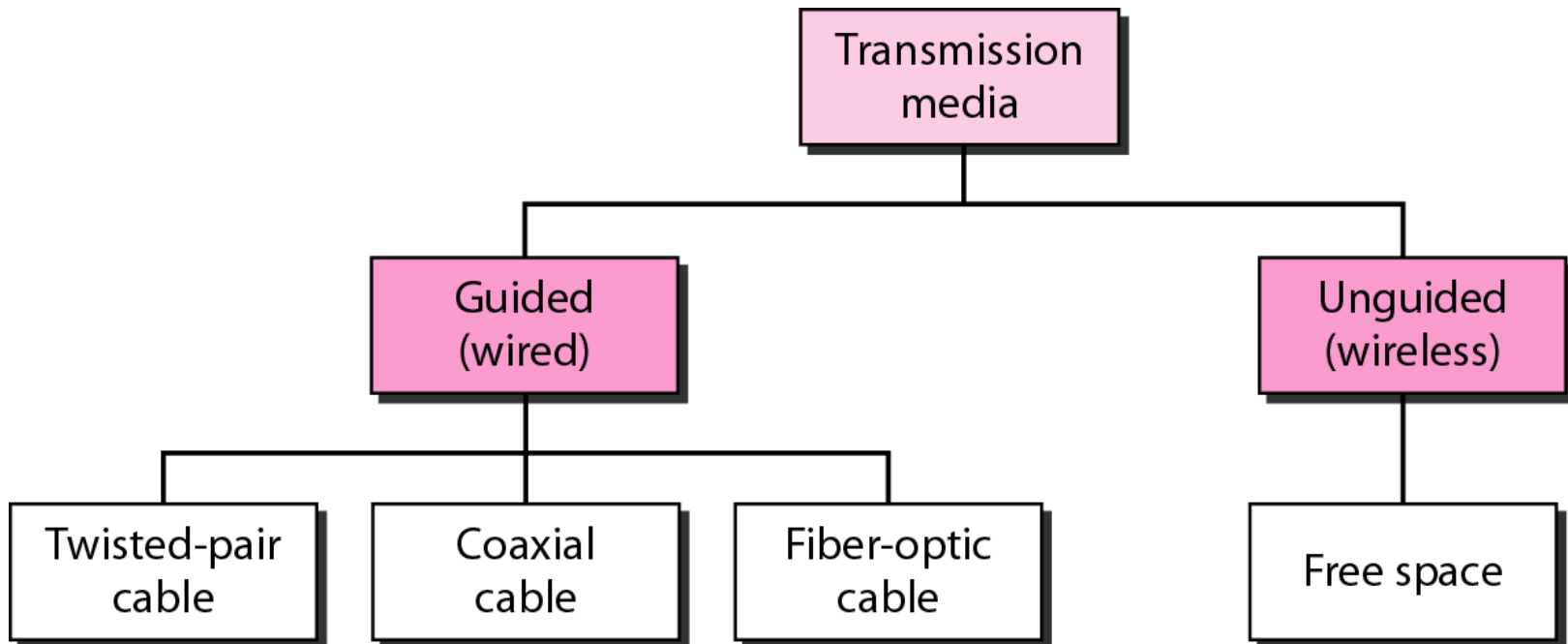
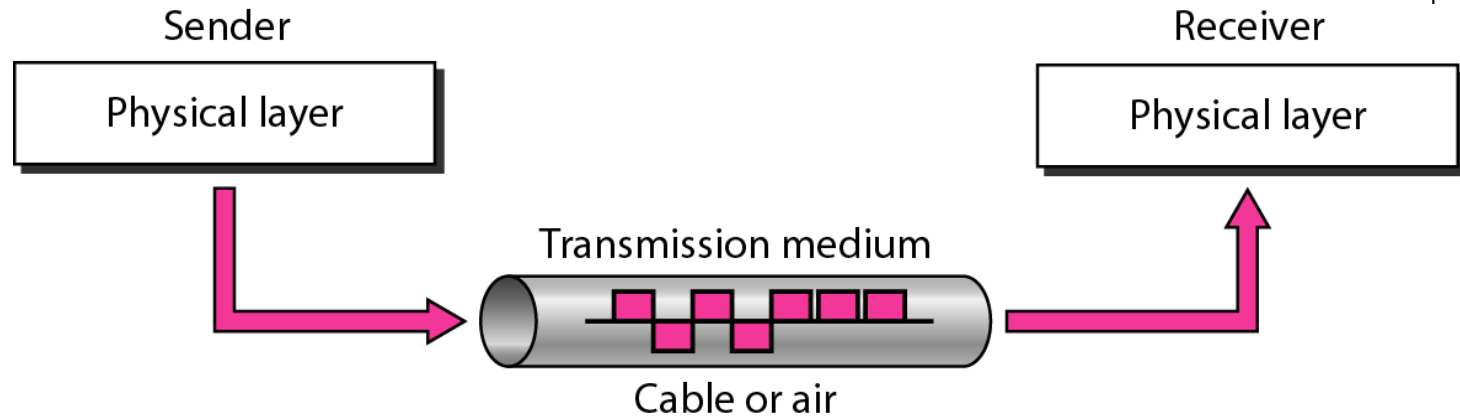
***Properties of Media and Digital
Transmission Systems***

CSE 3213, Winter 2010

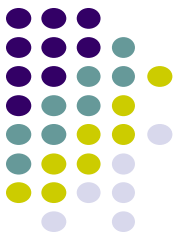
Instructor: Foroohar Foroozan



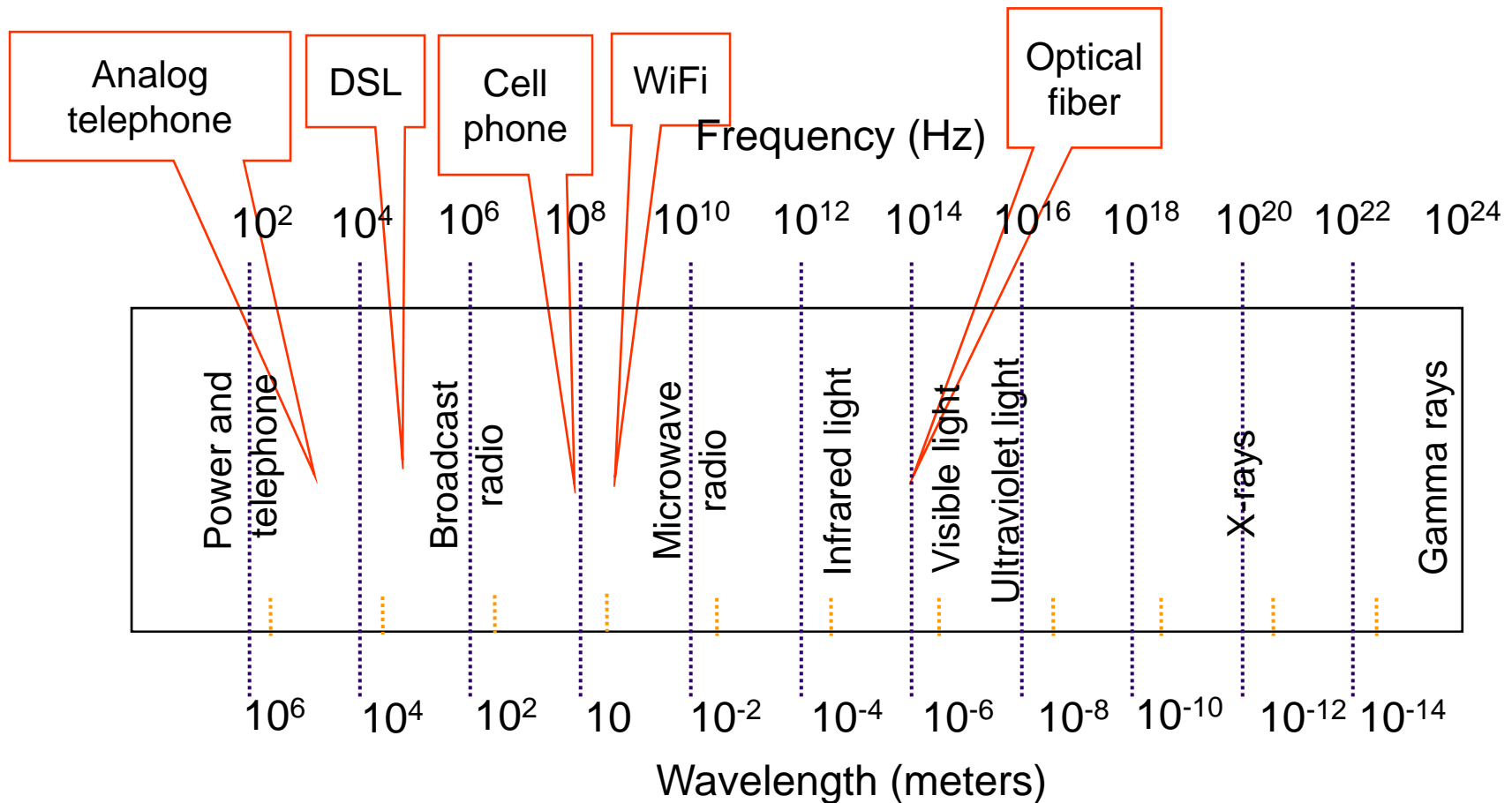
Classes in Transmission Media



Communications systems & Electromagnetic Spectrum



- Frequency of communications signals



Wireless & Wired Media



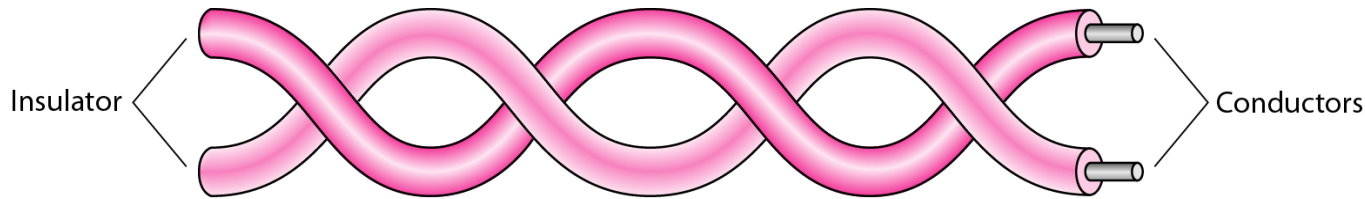
Wireless Media

- Signal energy propagates in space, limited directionality
- Interference possible, so spectrum regulated
- Limited bandwidth
- Simple infrastructure: antennas & transmitters
- No physical connection between network & user
- Users can move

Wired Media

- Signal energy contained & guided within medium
- Spectrum can be re-used in separate media (wires or cables), more scalable
- Extremely high bandwidth
- Complex infrastructure: ducts, conduits, poles, right-of-way

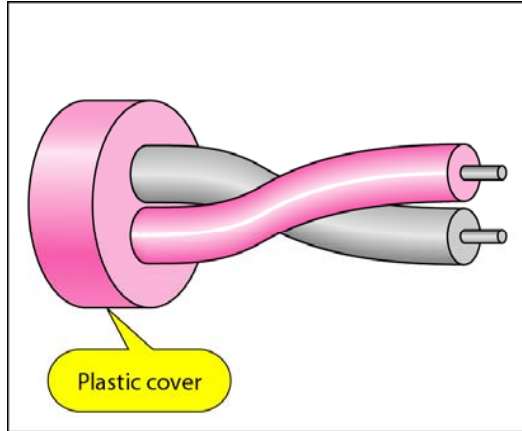
Twisted Pair



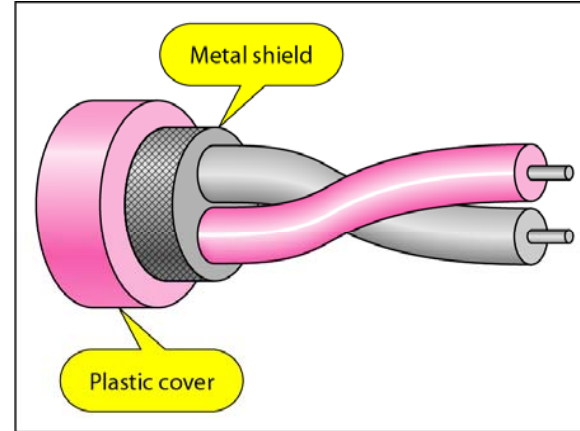
Twisted pair

- Two insulated copper wires arranged in a regular spiral pattern to minimize interference
- Various thicknesses, e.g. 0.016 inch (24 gauge)
- Low cost
- Telephone subscriber loop from customer to CO
- Intra-building telephone from wiring closet to desktop

Twisted Pair

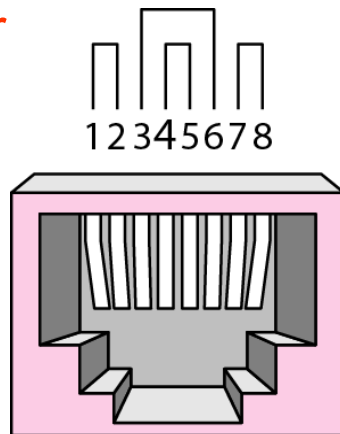


a. UTP

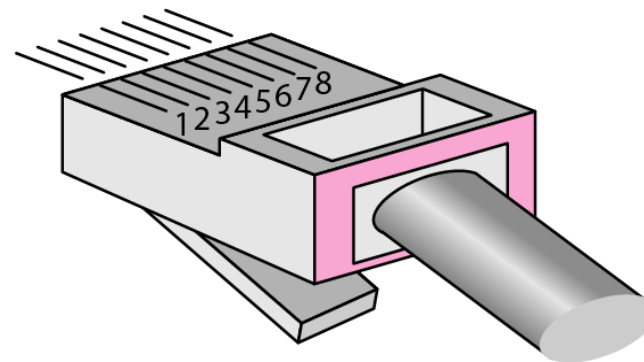


b. STP

UTP connector



RJ-45 Female



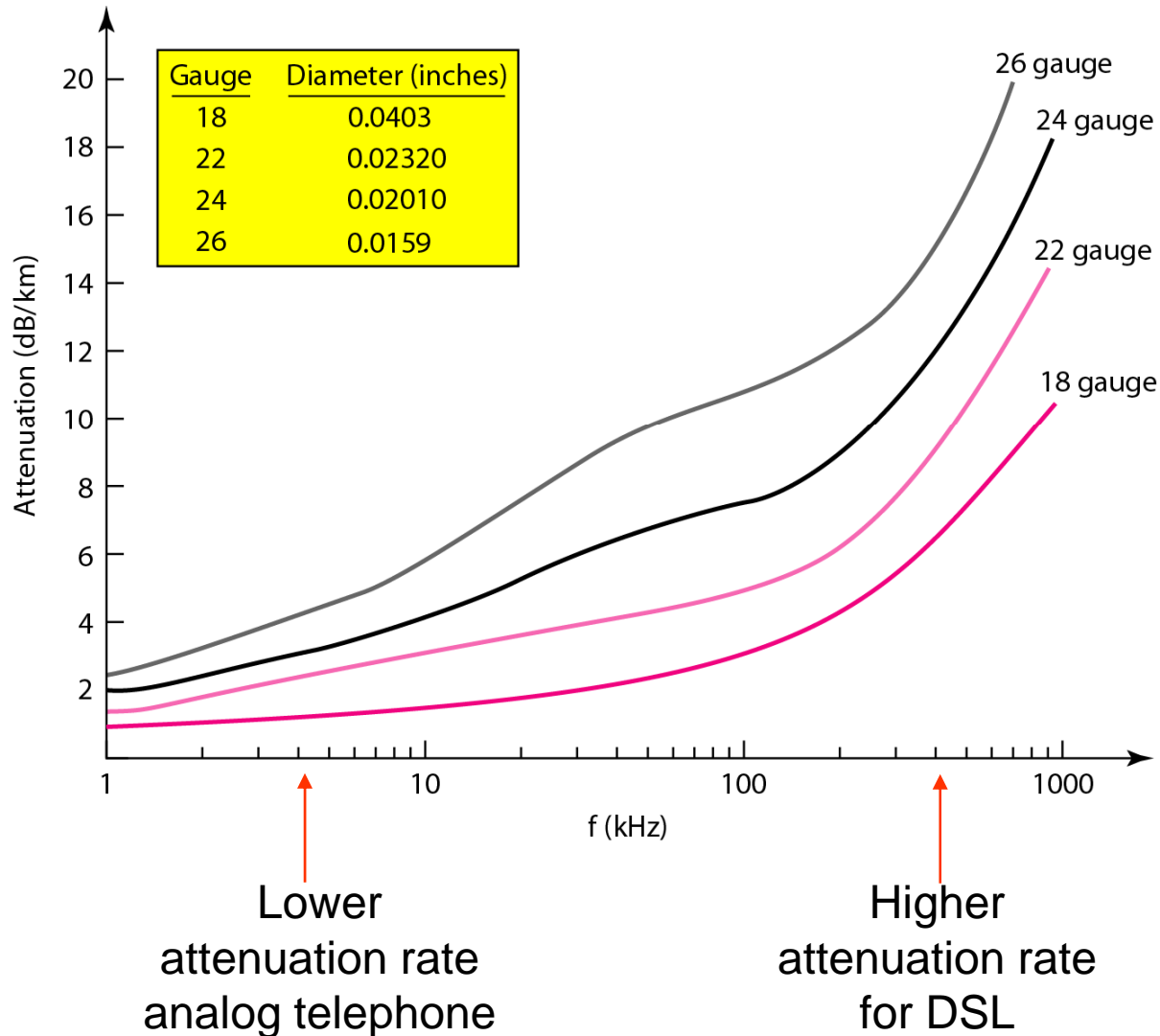
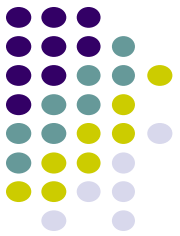
RJ-45 Male

Twisted Pair Bit Rates

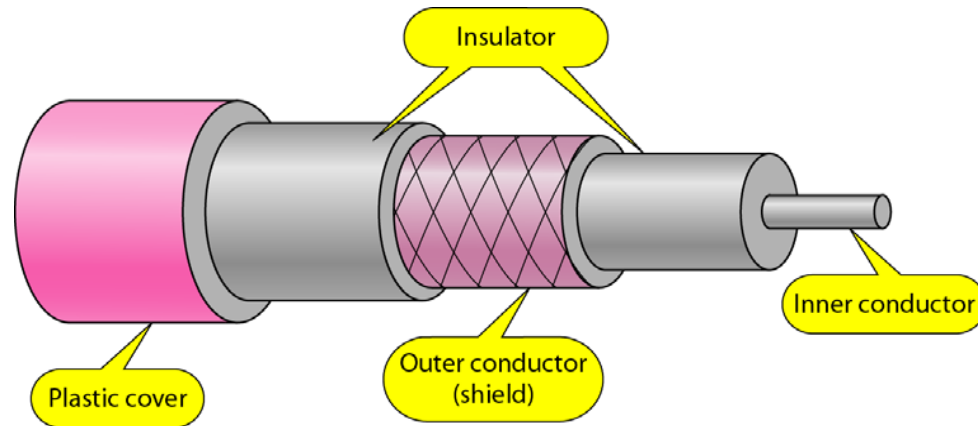
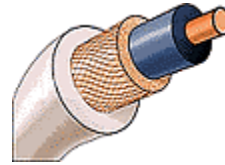


<i>Category</i>	<i>Specification</i>	<i>Data Rate (Mbps)</i>	<i>Use</i>
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
5E	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

UTP Performance



Coaxial Cable



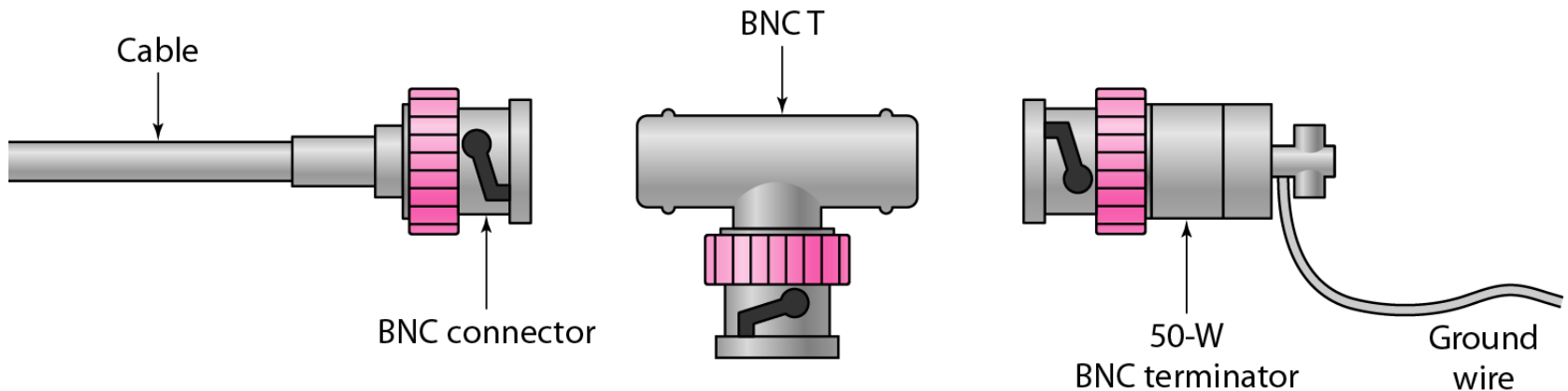
- Cylindrical braided outer conductor surrounds insulated inner wire conductor
- High interference immunity
- Higher bandwidth than twisted pair
- Hundreds of MHz
- Cable TV distribution
- Long distance telephone transmission
- Original Ethernet LAN medium



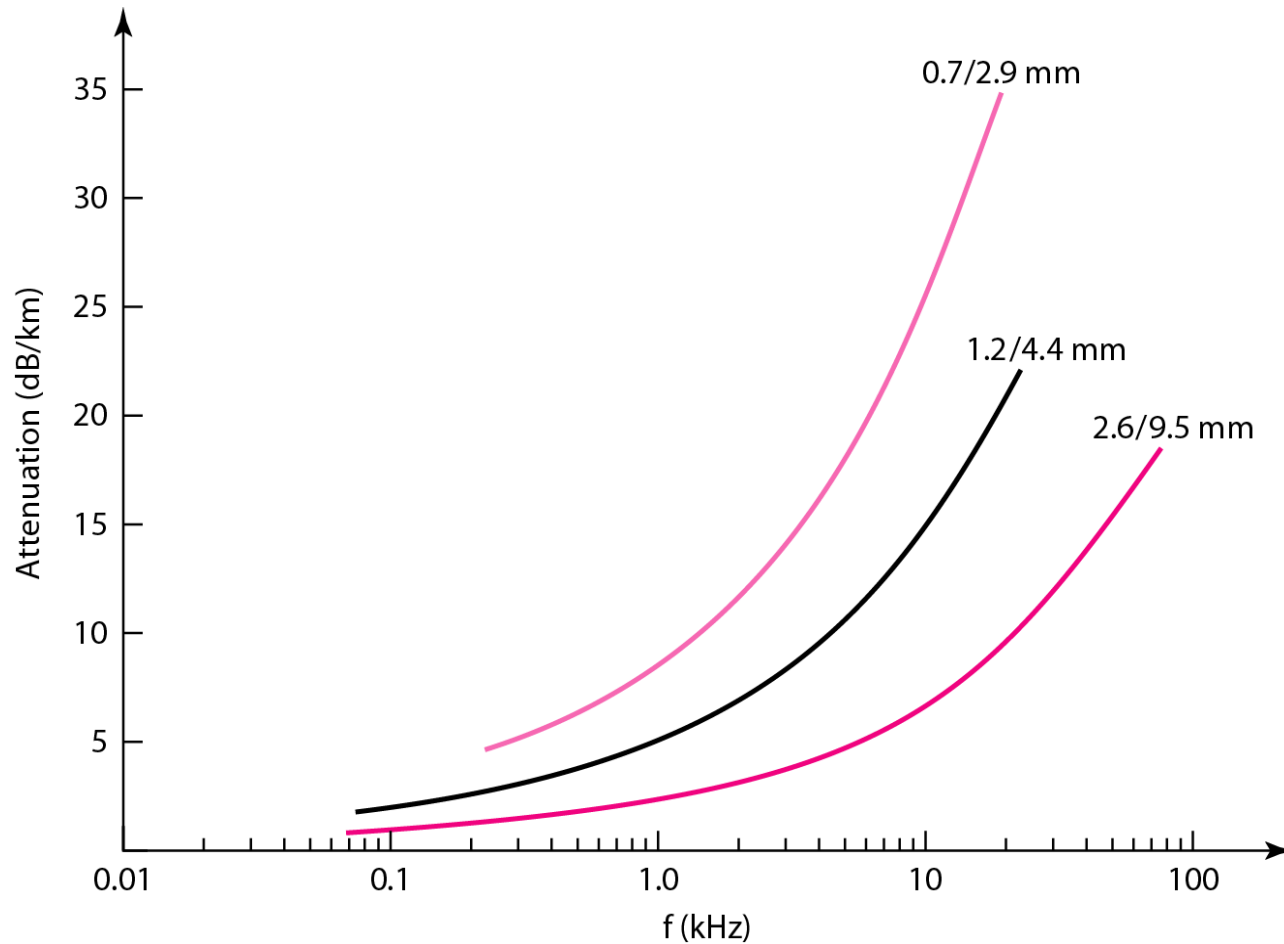
Coaxial Cable

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

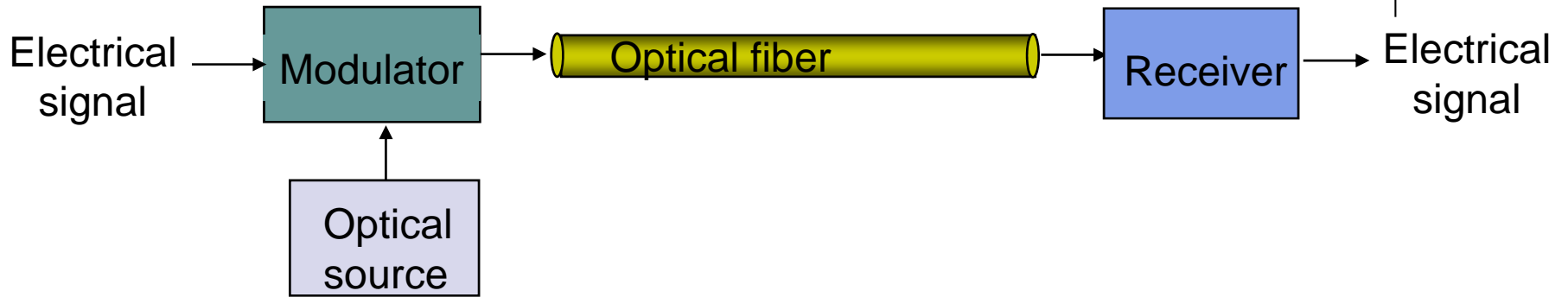
BNC Connector



Coaxial Cable (Performance)

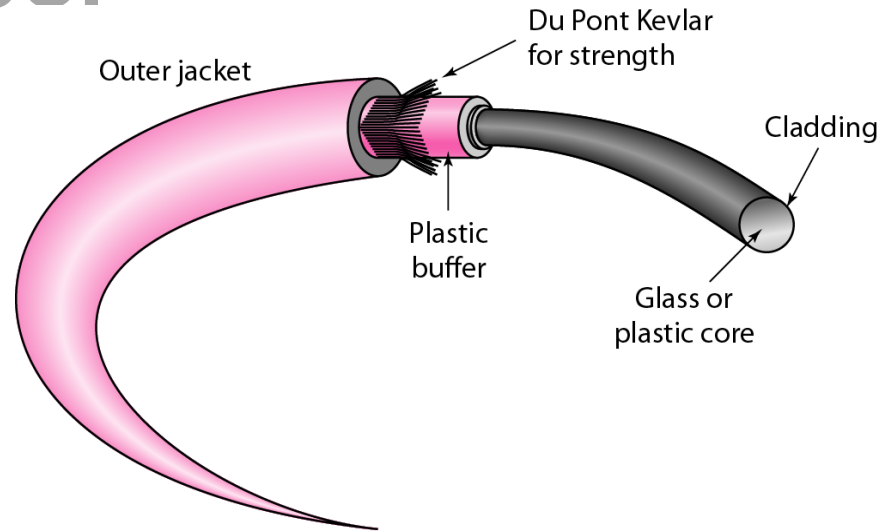


Optical Fiber

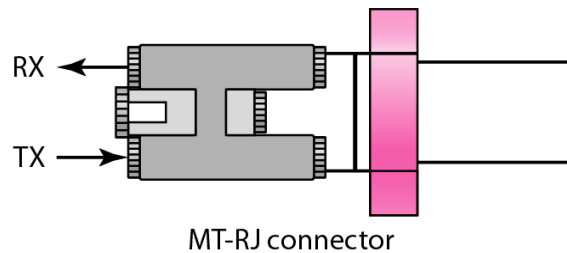
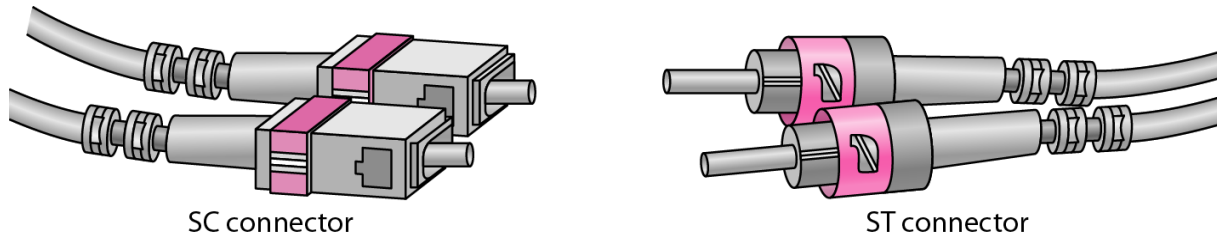


- Light sources (lasers, LEDs) generate pulses of light that are transmitted on optical fiber
 - Very long distances (>1000 km)
 - Very high speeds (>40 Gbps/wavelength)
 - Nearly error-free (BER of 10^{-15})
- Profound influence on network architecture
 - Dominates long distance transmission
 - Plentiful bandwidth for new services

Optical Fiber



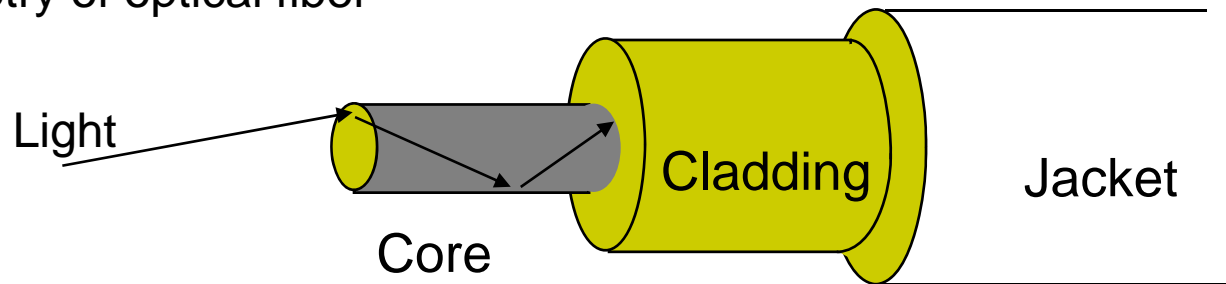
Optical Fiber Cable Connector



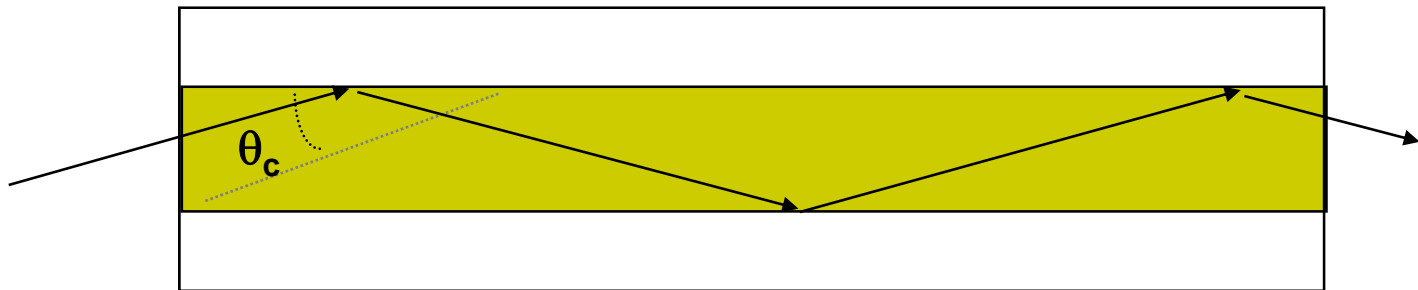
Transmission in Optical Fiber



Geometry of optical fiber



Total Internal Reflection in optical fiber

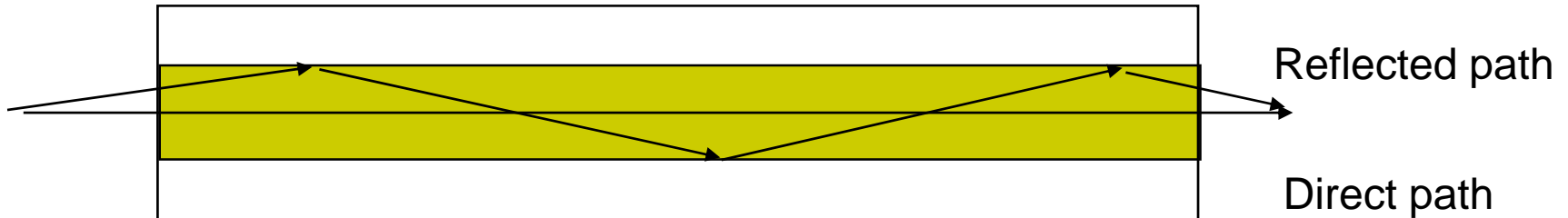


- Very fine glass cylindrical core surrounded by concentric layer of glass (cladding)
- Core has higher index of refraction than cladding
- Light rays incident at less than critical angle θ_c is completely reflected back into the core

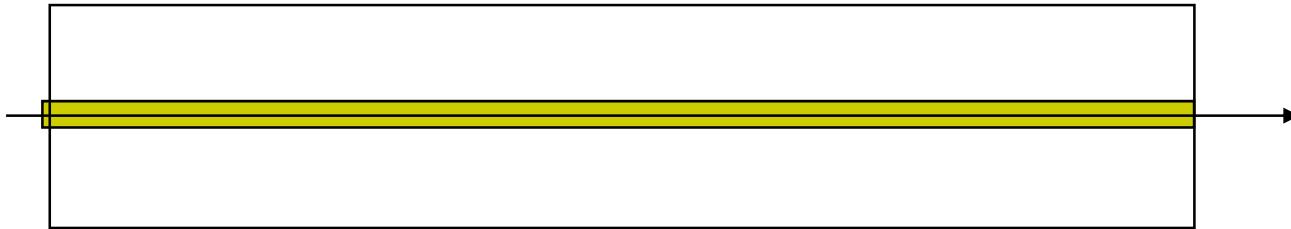
Multimode & Single-mode Fiber



Multimode fiber: multiple rays follow different paths



Single-mode fiber: only direct path propagates in fiber



- Multimode: Thicker core, shorter reach
 - Rays on different paths interfere causing dispersion & limiting bit rate
- Single mode: Very thin core supports only one mode (path)
 - More expensive lasers, but achieves very high speeds

Optical Fiber Properties



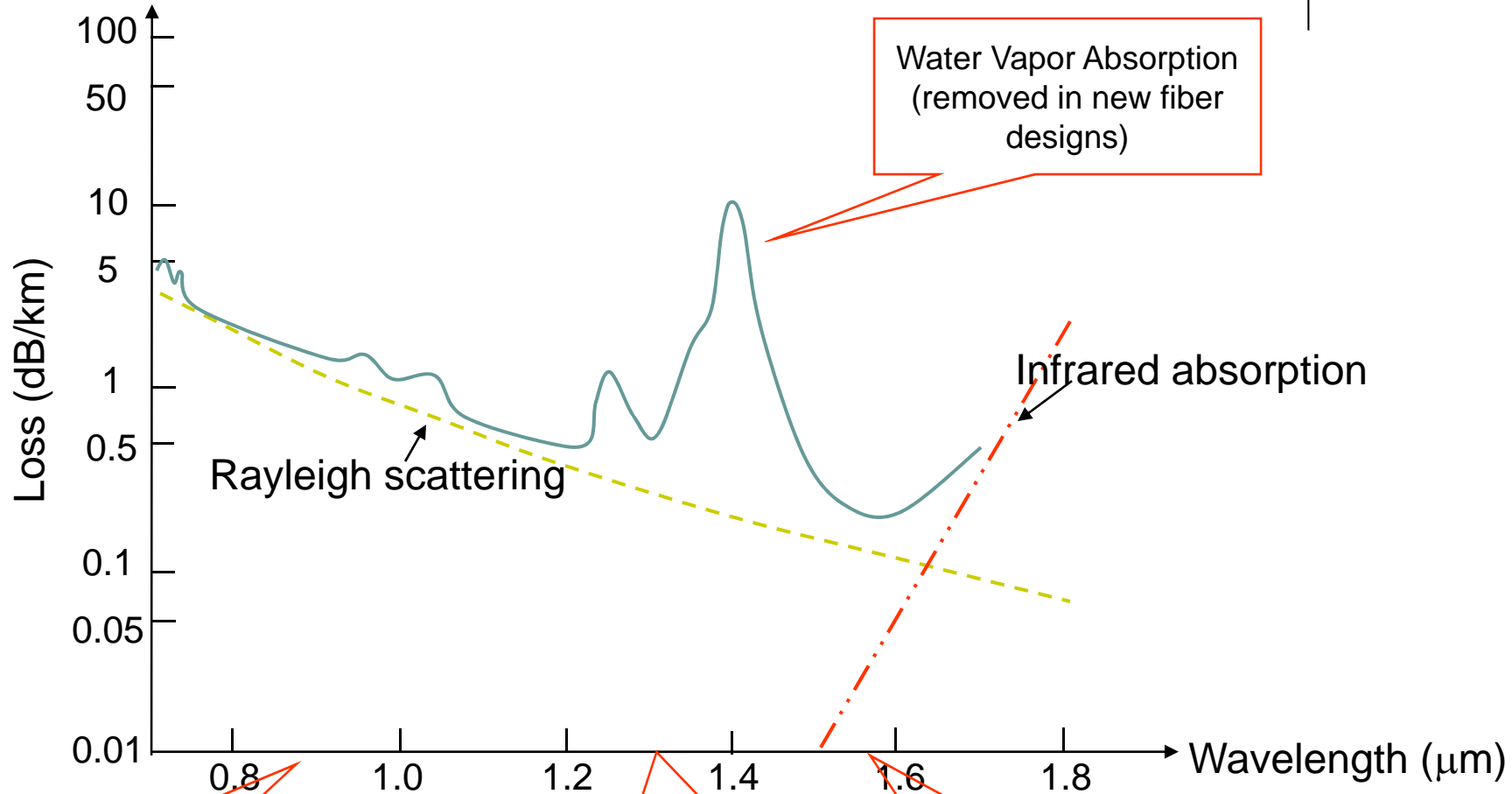
Advantages

- ***Very low attenuation***
- ***Noise immunity***
- ***Extremely high bandwidth***
- Security: Very difficult to tap without breaking
- No corrosion
- More compact & lighter than copper wire

Disadvantages

- New types of optical signal impairments & dispersion
 - Polarization dependence
 - Wavelength dependence
- Limited bend radius
 - If physical arc of cable too high, light lost or won't reflect
 - Will break
- Mechanical vibration becomes signal noise

Very Low Attenuation



Rayleigh scattering

Water Vapor Absorption
(removed in new fiber designs)

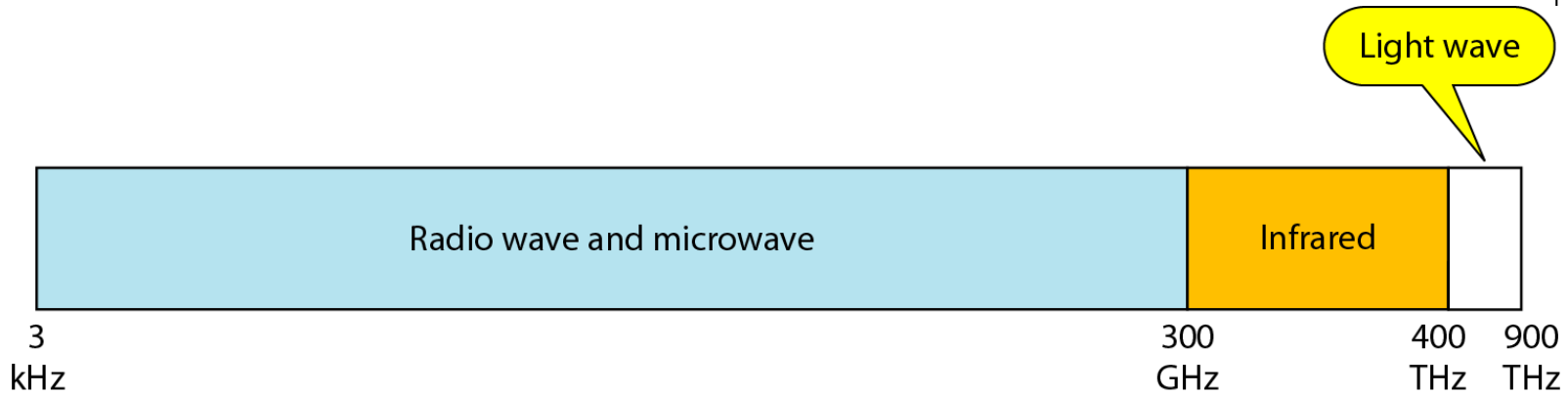
Infrared absorption

850 nm
Low-cost LEDs
LANs

1300 nm
Metropolitan Area
Networks
"Short Haul"

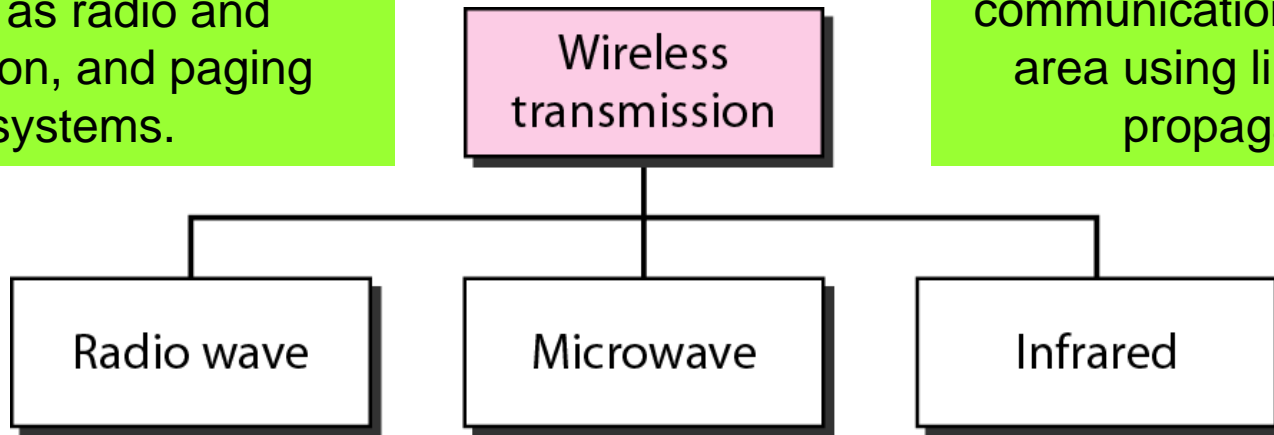
1550 nm
Long Distance Networks
"Long Haul"

Radio Transmission



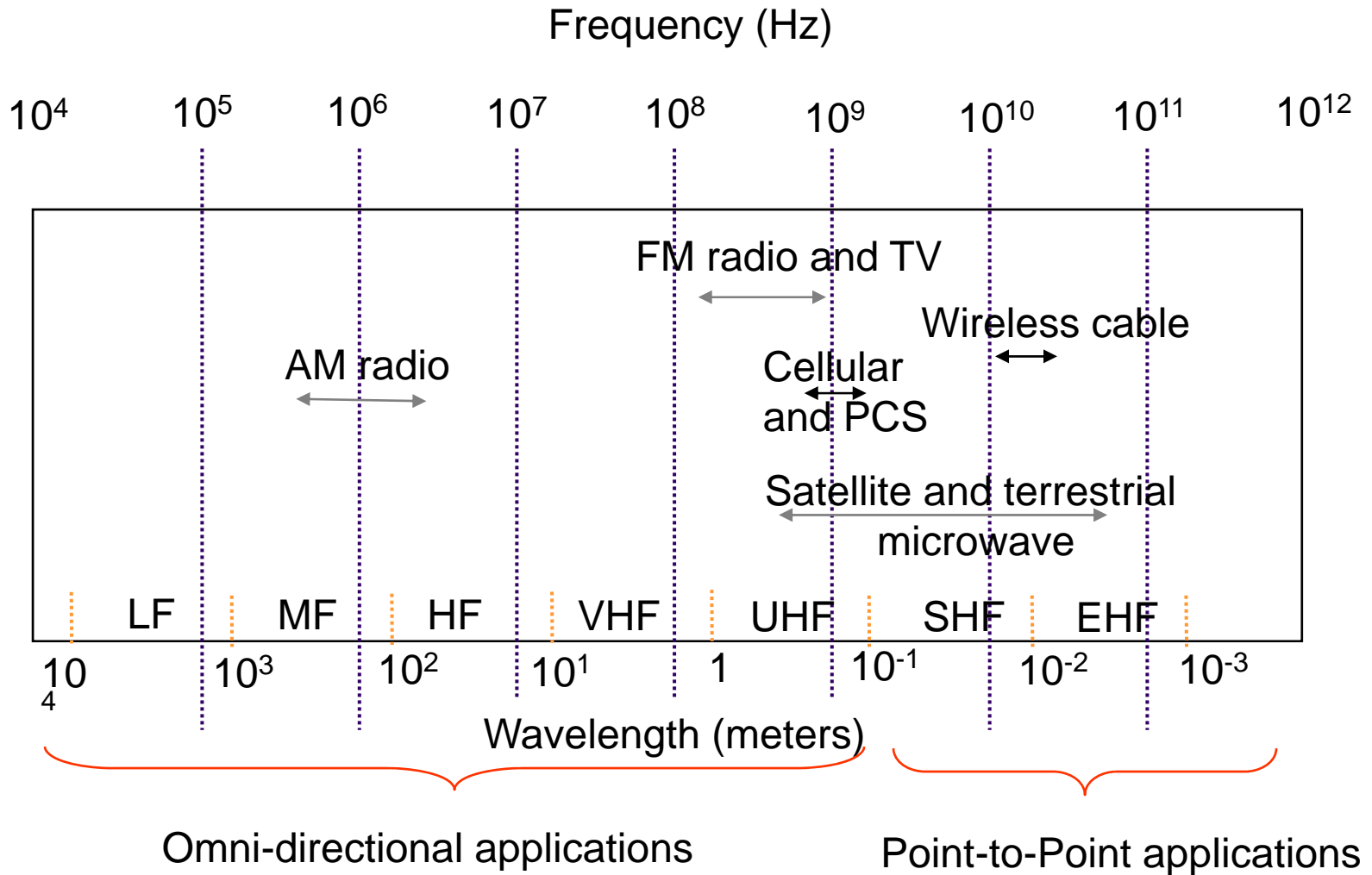
Radio waves are used for multicast communications, such as radio and television, and paging systems.

Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.



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

Radio Spectrum



Examples



Cellular Phone

- Allocated spectrum
- First generation:
 - 800, 900 MHz
 - Initially analog voice
- Second generation:
 - 1800-1900 MHz
 - Digital voice, messaging

Wireless LAN

- Unlicensed ISM spectrum
 - Industrial, Scientific, Medical
 - 902-928 MHz, 2.400-2.4835 GHz, 5.725-5.850 GHz
- IEEE 802.11 LAN standard
 - 11-54 Mbps

Point-to-Multipoint Systems

- Directional antennas at microwave frequencies
- High-speed digital communications between sites
- High-speed Internet Access Radio backbone links for rural areas

Satellite Communications

- Geostationary satellite @ 36000 km above equator
- Relays microwave signals from uplink frequency to downlink frequency
- Long distance telephone
- Satellite TV broadcast