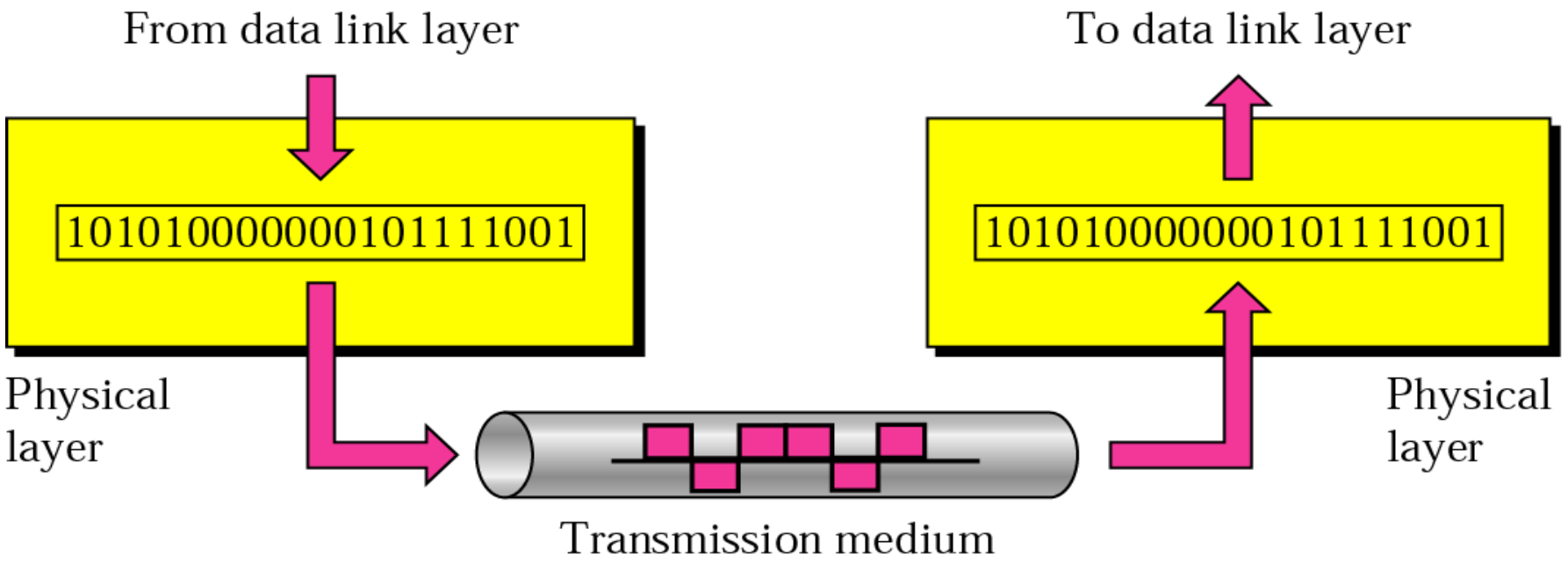
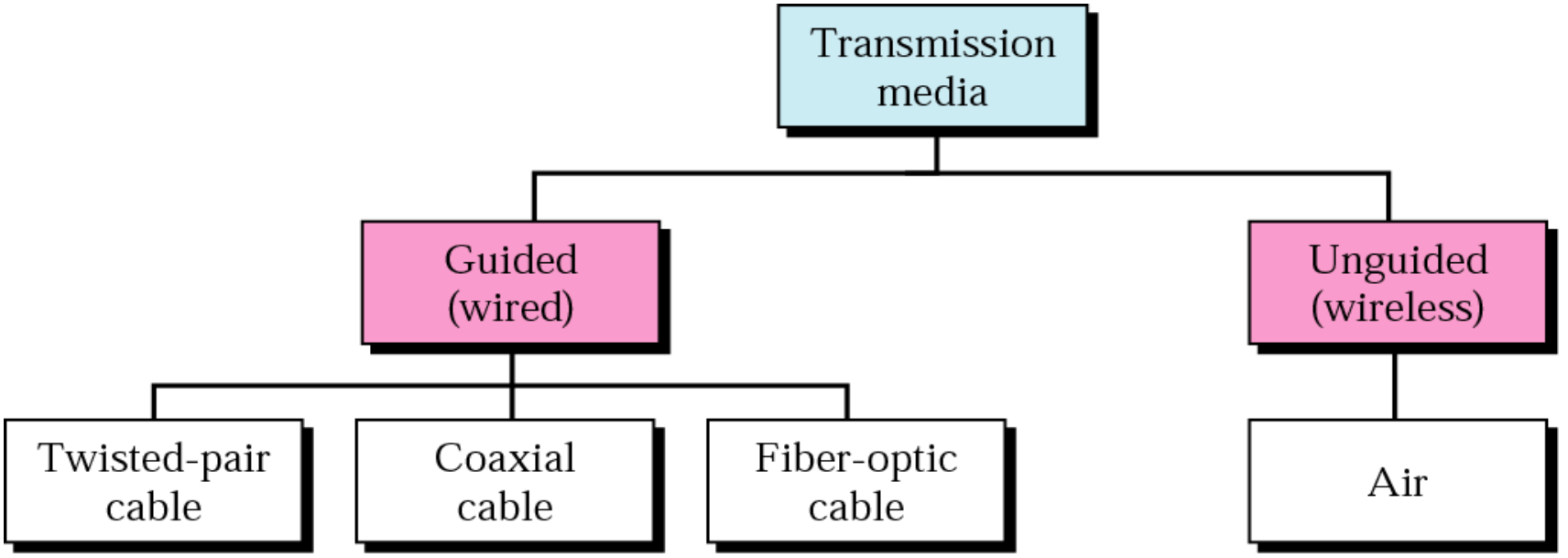
Computer Network

Chapter 3: Physical Layer

OSI Layers : Physical Layer



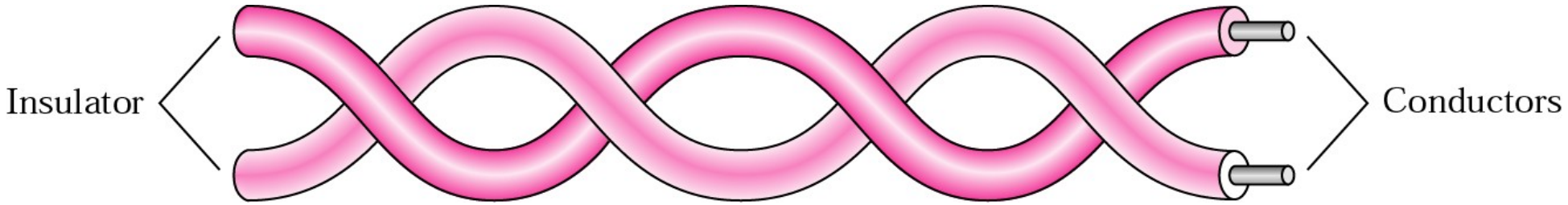
Transmission Media : Classes ??



Copper Cables

- Twisted-pair (unshielded and shielded) cable
- Coaxial cable

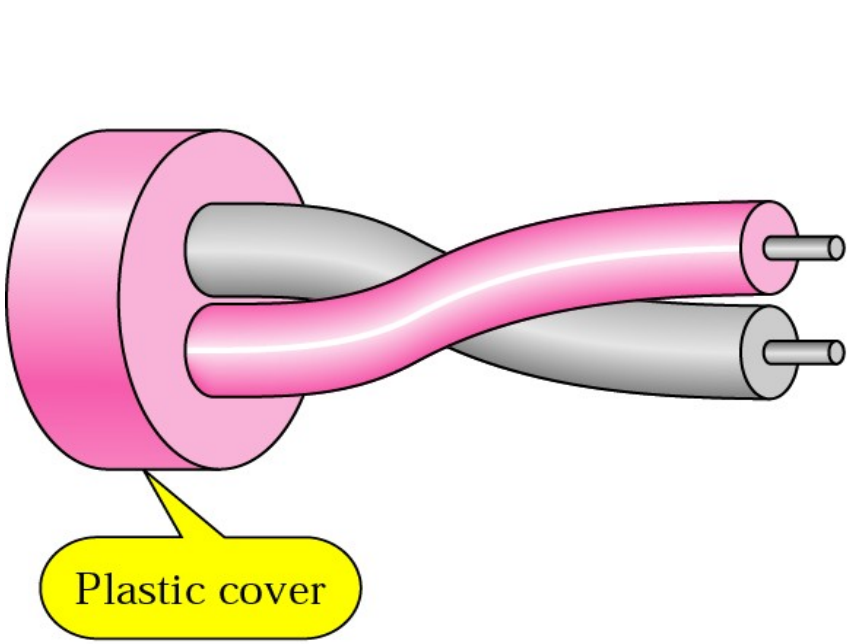
Transmission Media : Twisted Pair Cable



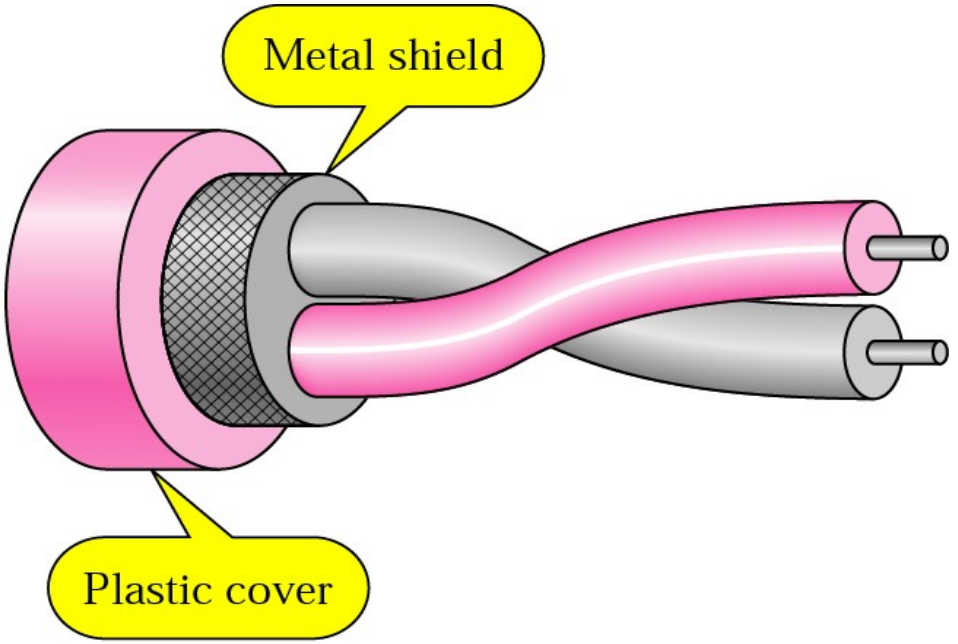
Twisted Pair Cable Cont'd..

- The Twisting cancels out electrical noise from adjacent pairs
    - From other sources such as motors, relays, and Transformers.

Twisted Pair Cable : STP and UTP



a. UTP



b. STP

STP

- STP uses a woven copper-braid jacket
- more protective and of a higher quality than the jacket used by UTP.
- Woven copper-braid jacket gives STP excellent shielding to protect the transmitted data from outside interference, which in turn allows it to support higher transmission rates over longer distances than UTP.
- Although STP prevents interference better than UTP, it is more expensive and difficult to install. In addition, the metallic shielding must be grounded at both ends. If it is improperly grounded, the shield acts like an antenna and picks up unwanted signals.

UTP

- UTP, using the 10BaseT specification
- The maximum cable length segment is 100 meters, about 328 feet
- UTP is particularly susceptible to crosstalk, but the greater the number of twists per foot of cable, the more effective the protection against crosstalk.

Twisted Pair : Applications ??

- Most Common Medium.
- For Local Area Networks (LAN).
- Telephone Networks
  - Between House and Local Exchange (Subscriber Loop).
- Within Buildings
  - To Private Branch Exchange (PBX).
- Cable Connectors => RJ45 and RJ11.

Twisted Pair : UTP Categories

Category	Bandwidth	Data Rate	Digital/Analog	Use
1	Very Low	<100 Kbps	Analog	Telephone
2	< 2MHz	2Mbps	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	200 MHz	1000 Mbps	Digital	LANs

Commonly Used UTP Cablings

Category 1—Used for telephone communications. Not suitable for transmitting data.

Category 2—Capable of transmitting data at speeds up to 2-4 megabits per second (Mbps).

Category 3—Used in 10BASE-T networks. Can transmit data at speeds up to 10 Mbps.

Category 4—Used in Token Ring networks. Can transmit data at speeds up to 16 Mbps.

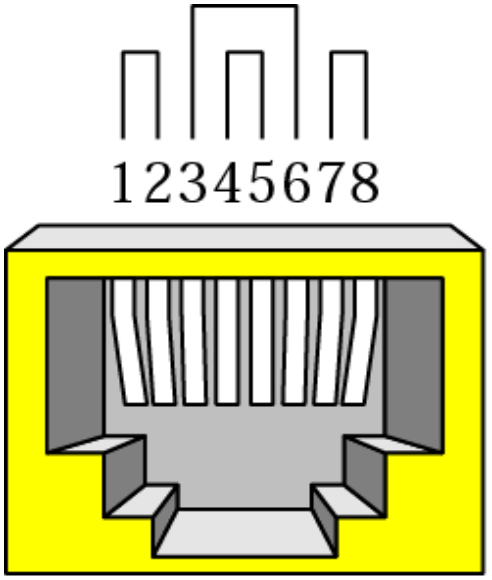
Category 5—Can transmit data at speeds up to 100 Mbps.

UTP Cabling

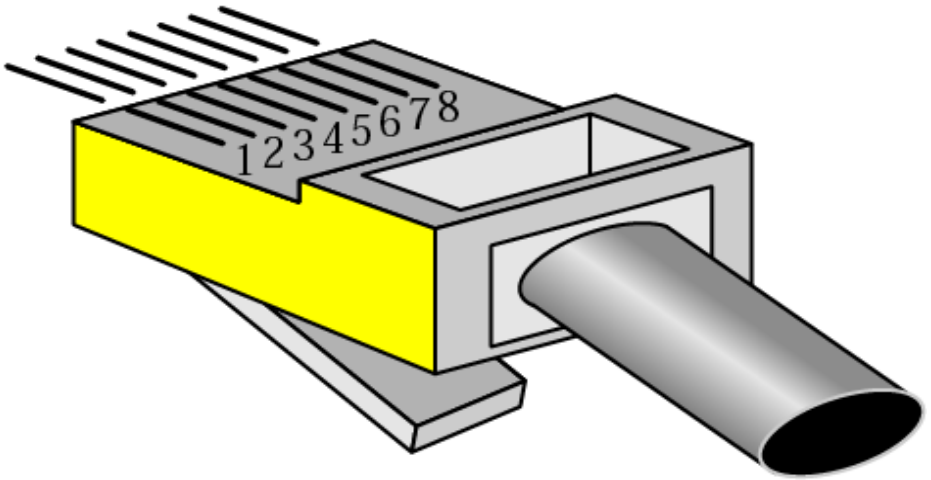
Category 5e —Used in networks running at speeds up to 1000 Mbps (1 gigabit per second [Gbps]).

Category 6—Typically, Category 6 cable consists of four pairs of 24 American Wire Gauge (AWG) copper wires. Category 6 cable is currently the fastest standard for UTP.

Twisted Pair : UTP Connector



RJ-45 Female



RJ-45 Male

Twisted-Pair Cabling Considerations

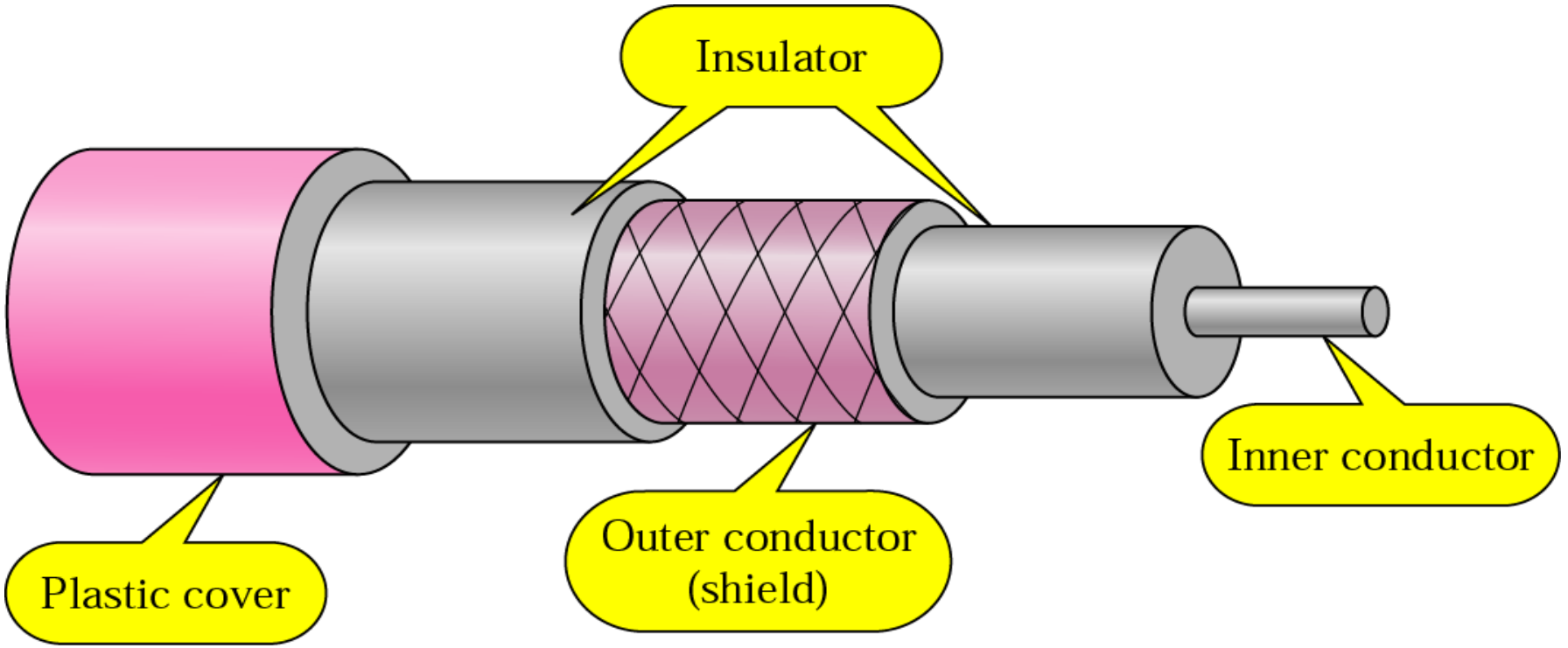
Use twisted-pair cable if:

- Your LAN is under budget constraints.
- You want a relatively easy installation in which computer connections are simple.

Do not use twisted-pair cable if:

- Your LAN requires a high level of security and you must be absolutely sure of data integrity.
- You must transmit data over long distances at high speeds.

Coaxial Cable : Structure ?



Types:

- Based on Size
  - Thicknet
    - Outside Diameter 1 CM
  - Thinnet
    - Outside Diameter 0.35 CM
- Based on Data Transmission
  - Baseband Cable (50 Ohm Cable)
  - Broadband Cable (75 Ohm cable)

Coaxial Cable: Thicknet

- Supports 10 to 100 Mbps
- Relatively inexpensive,
- Costly than UTP on a per-unit length
- cabled over longer distances than twisted-pair cable
- vampire tap was used to connect network devices to Thicknet(Thick Coaxial Cable)
- vampire taps connected to the computers via a more flexible cable called the attachment unit interface (AUI).

Coaxial Cable: Thinnet

- Outside Diameter 0.35 CM
- Primarily Used in Ethernet Network
- Also called Cheapernet
  - Low cost and Easy to Install
- Common Connecter used with Thinnet are BNC
  - Britist Naval Connectors (Male Type Mounted)

Coaxial Cable : Applications ??

- Cable Television Distribution.
- Long Distance Telephone Transmission.
  - Can Carry 10,000 Voice Calls Simultaneously.
- Traditional LAN => Diskless Workstation in Novell Netware.
- Being Replaced by Optical Fibers.
- Baseband Cable and Broadband Cable

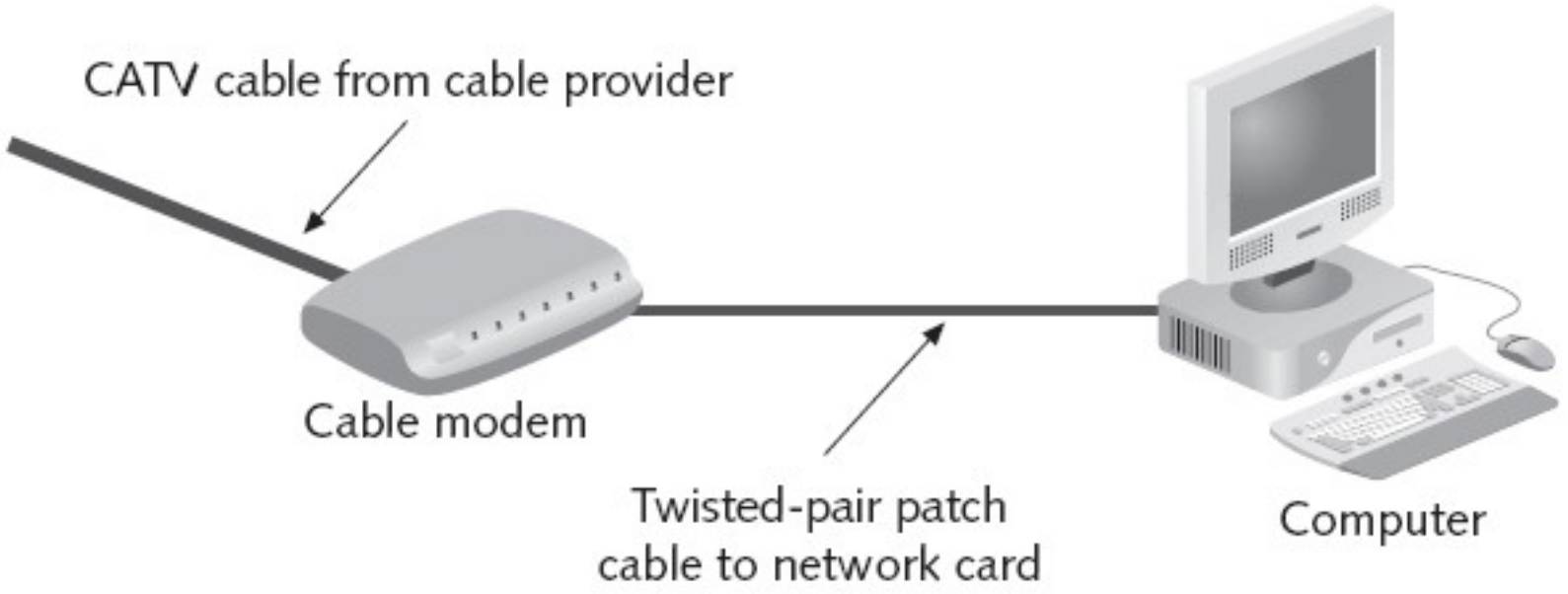
Coaxial Cable : Baseband Cable

- Carries Single Signal at a Fixed Frequency.
- It is used for Digital Transmission.
- Uses Digital Signaling Technique.
- It is used for Small Area.
- 10 Base 5 Cable => Distance up to 500m.
- Repeaters Can be used to deal with attenuation.

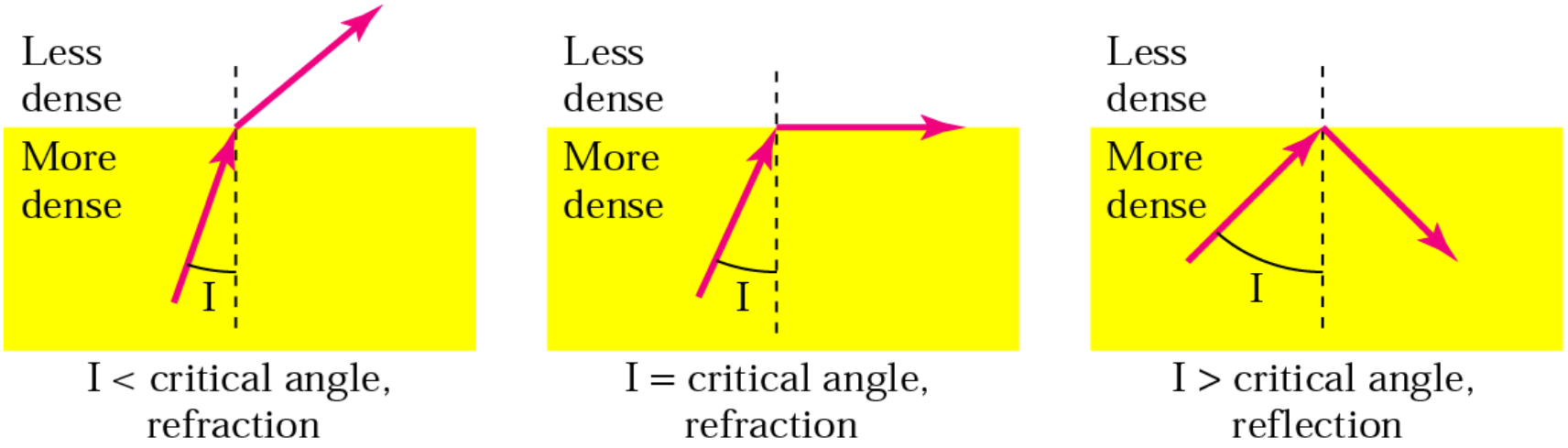
Coaxial Cable : Broadband Cable

- Carries Multiple Signals => Multiplexing.
- It is used for Analog Transmission.
- Uses Analog Signaling Technique.
- It is used for Large Area => Cable Television
- Amplifiers Can be used to deal with attenuation.

Coaxial Cable : Applications



Optical Fiber : Bending of Light Ray



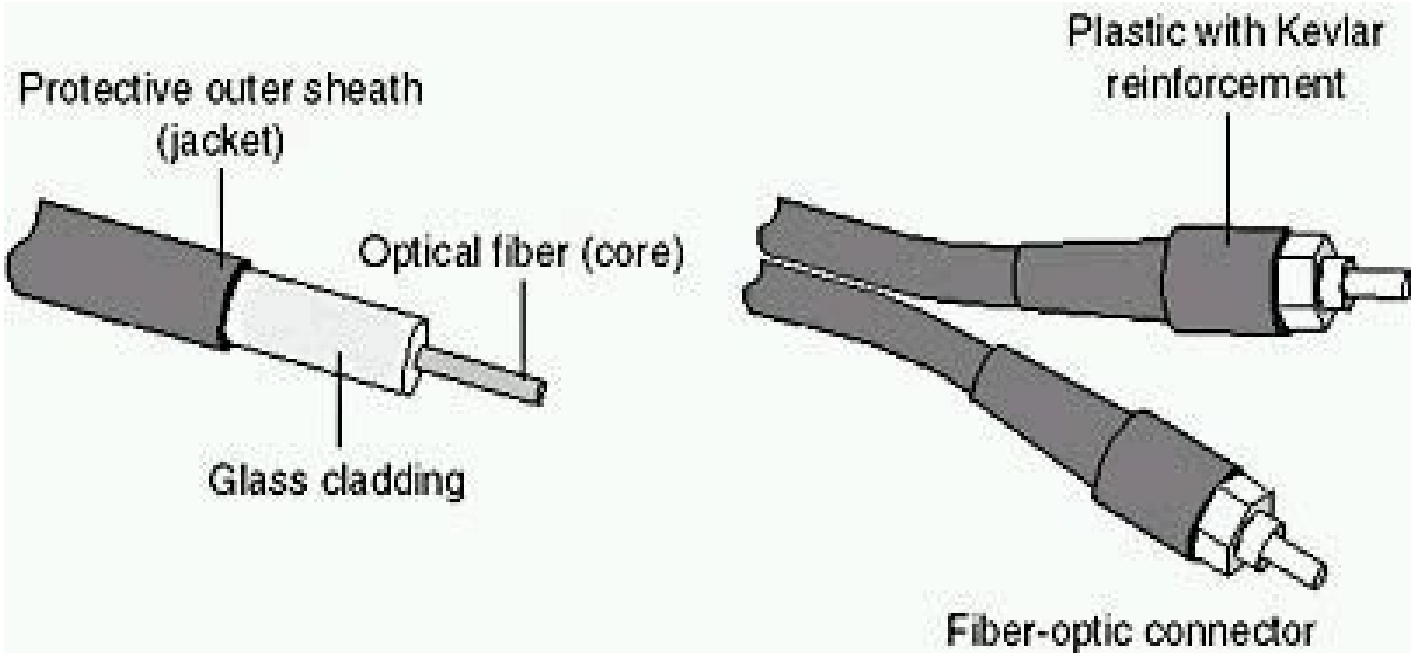
Optical Fiber

- Carry Digital Signals in the Form of Modulated pulses of Light
- High speed
- High-capacity data transmission

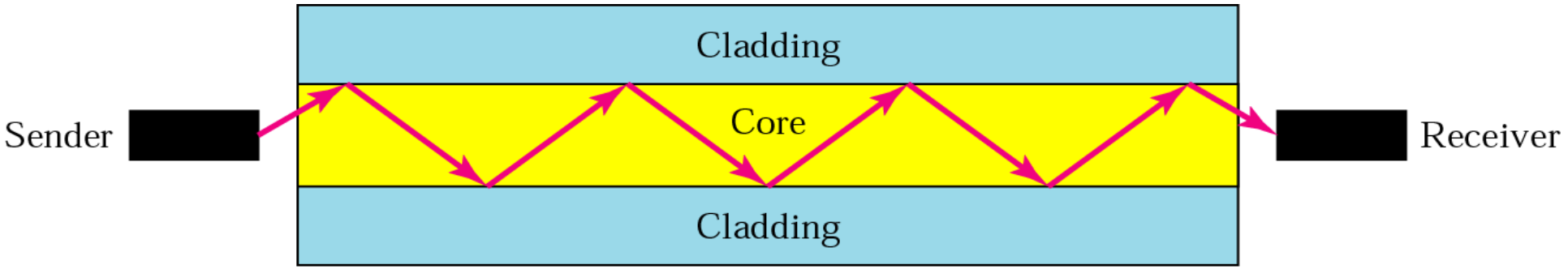
Composition

- Consist extemely thin cylinder glass called Core
- Surronded by a concentric layer known as cladding

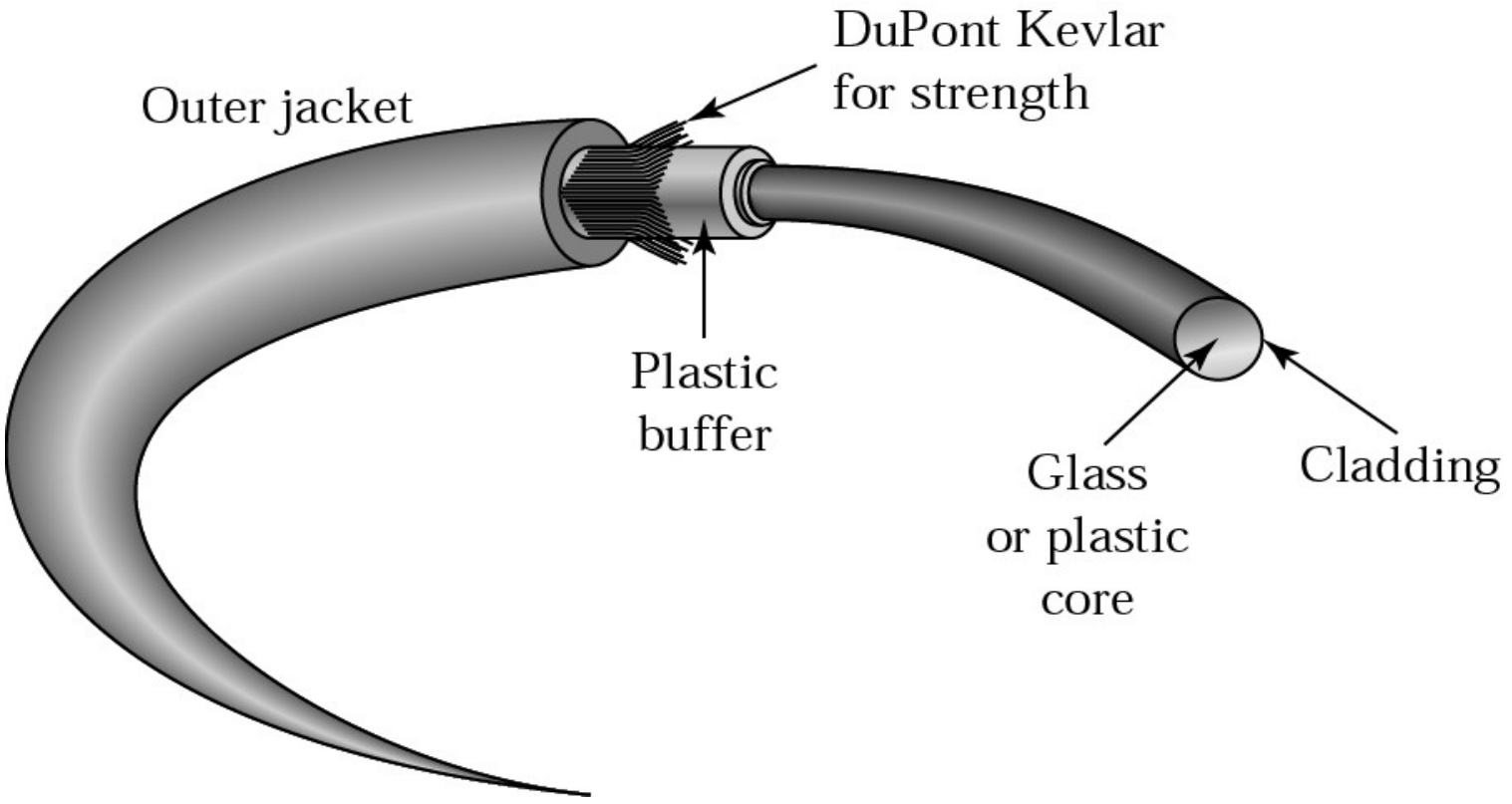
- Each glass strand passes signals in only one direction, a cable includes two strands in separate jackets.


Protective outer sheath
(jacket)
Optical fiber (core)
Glass cladding
Plastic with Kevlar
reinforcement
Fiber-optic connector

Optical Fiber : Structure ?

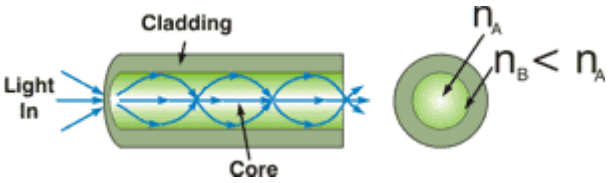


Fiber Construction : Structure ?



Optical Fiber: Types

Types

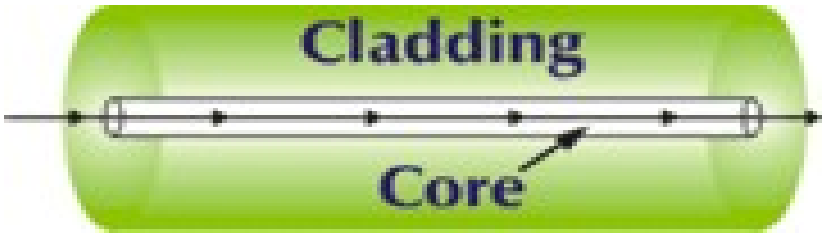


1.Multimode (MM)

- Larger Core Diameter
- propagate more than one mode of light
- Suited for Short distance Transmission

2.Single Mode (SM)

- Only One mode of Light will propagate
- Suited for Long distance transmission



Optical Fiber : Benefits ??

- Supports Higher Data Rate => Up to Tera Bits Per Second (Tbps)
- Smaller Size and Weight.
- Lower Attenuation
- Electromagnetic Isolation
- Greater Repeater Spacing

Fiber-Optic Cabling Considerations

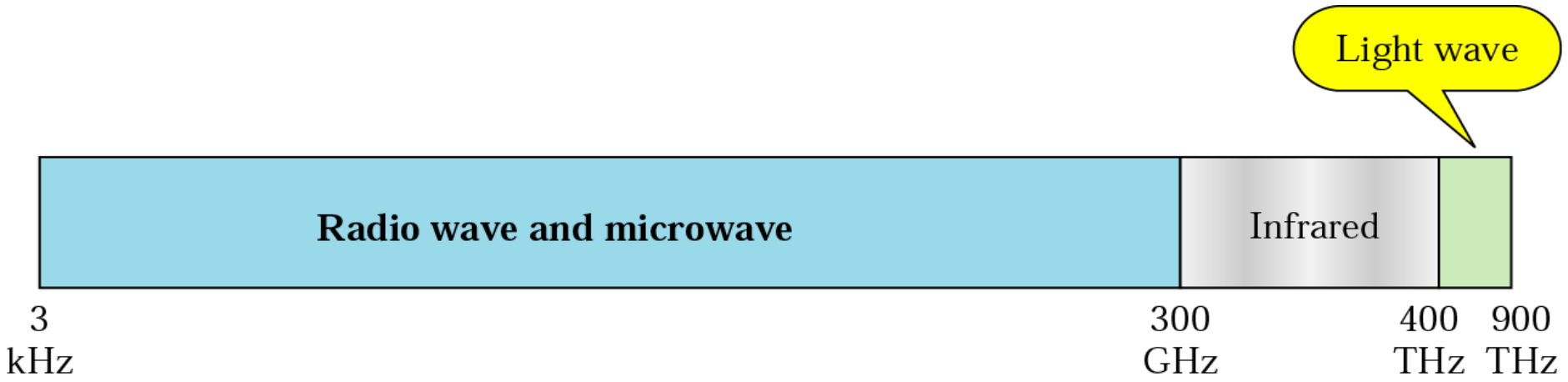
Use fiber-optic cable if you:

- Need to transmit data at very high speeds over long distances in very secure media.

Do not use fiber-optic cable if you:

- Are under a tight budget.
- Do not have the expertise available to properly install it and connect devices to it.

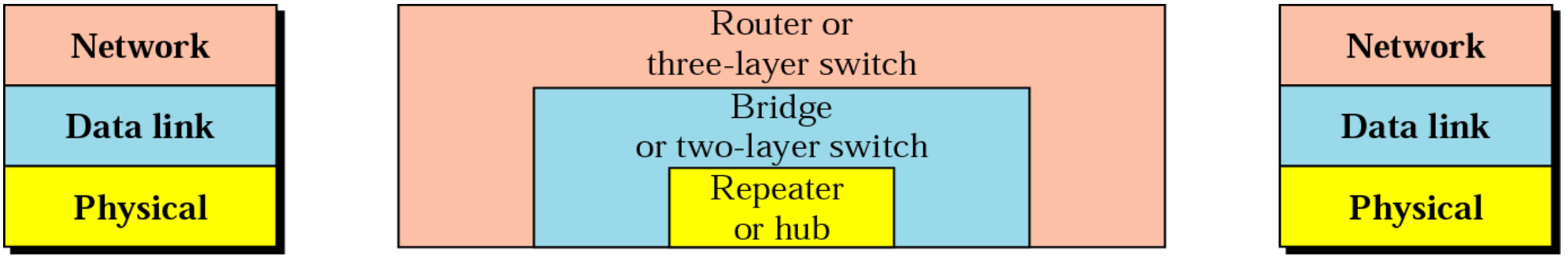
Electromagnetic Spectrum: Wireless Communication



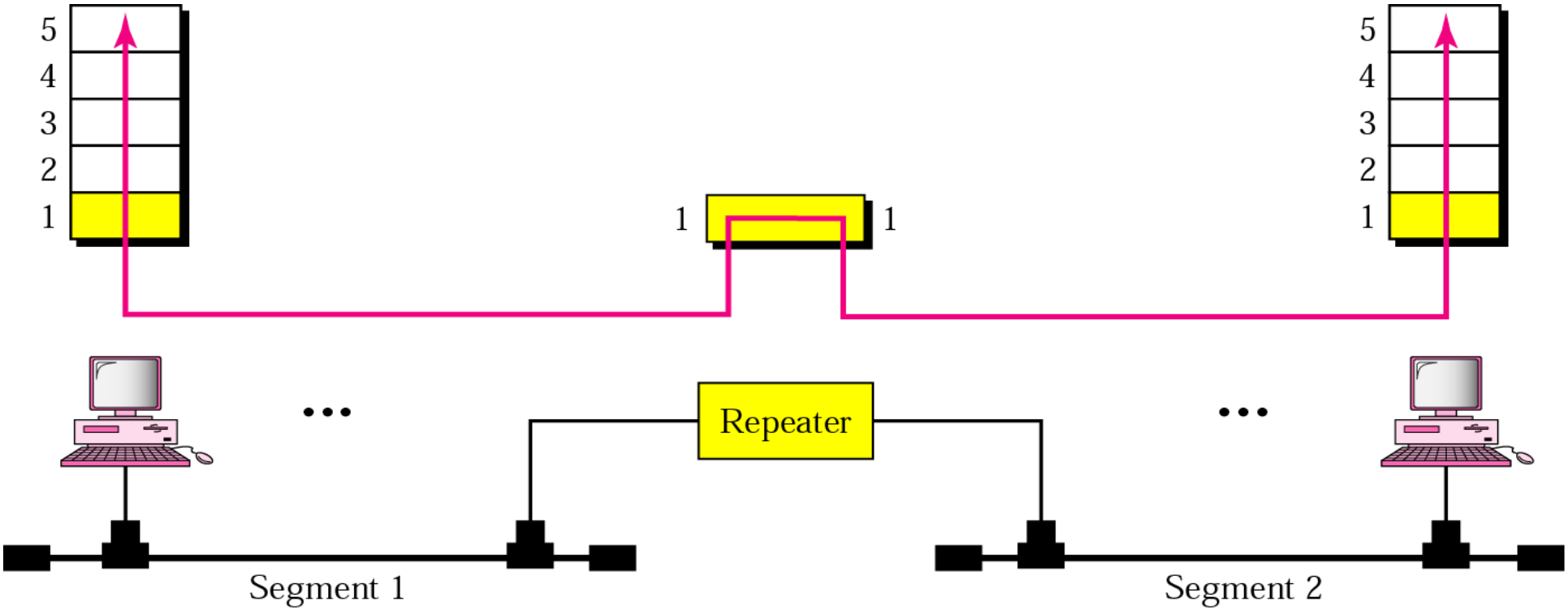
Unguided Media

- BlueTooth
- Wi-Fi /WLAN (Wireless LAN)
- Satellite Communication
  - Microwaves
  - Radio Waves

Physical Layer Devices : Hub and Repeaters

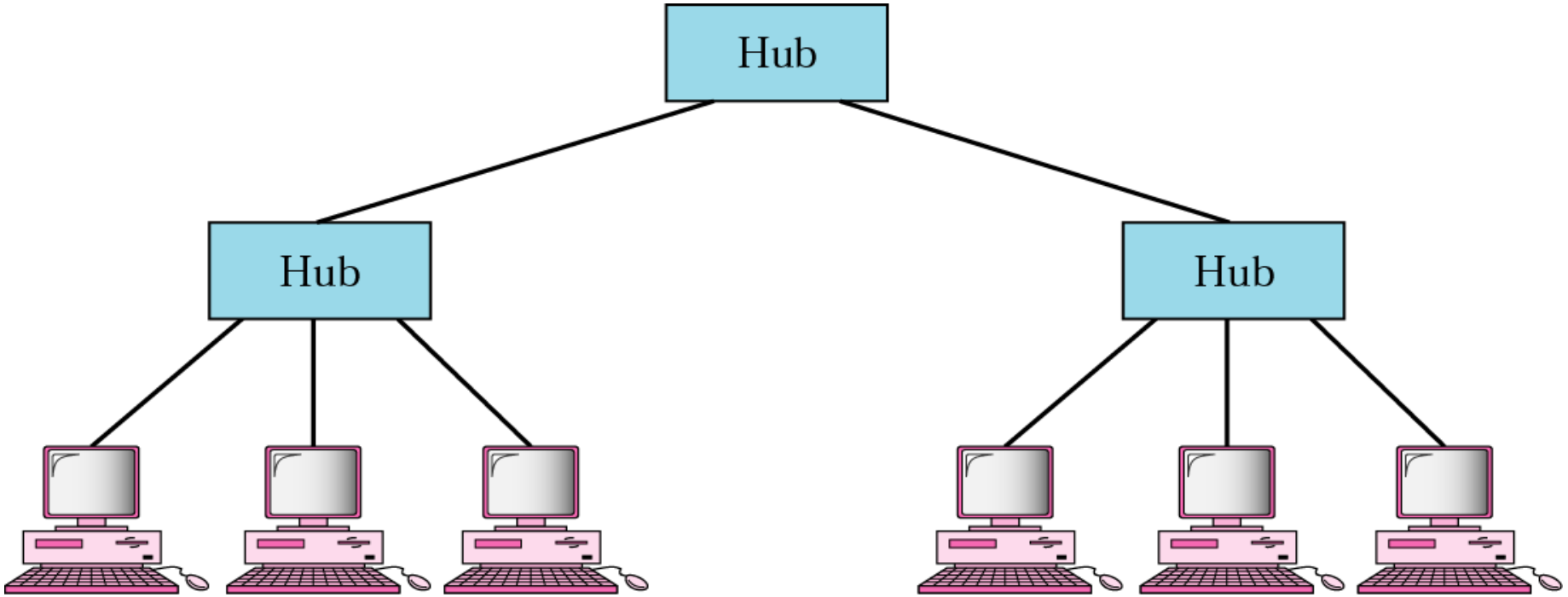


Physical Layer Devices : Repeaters



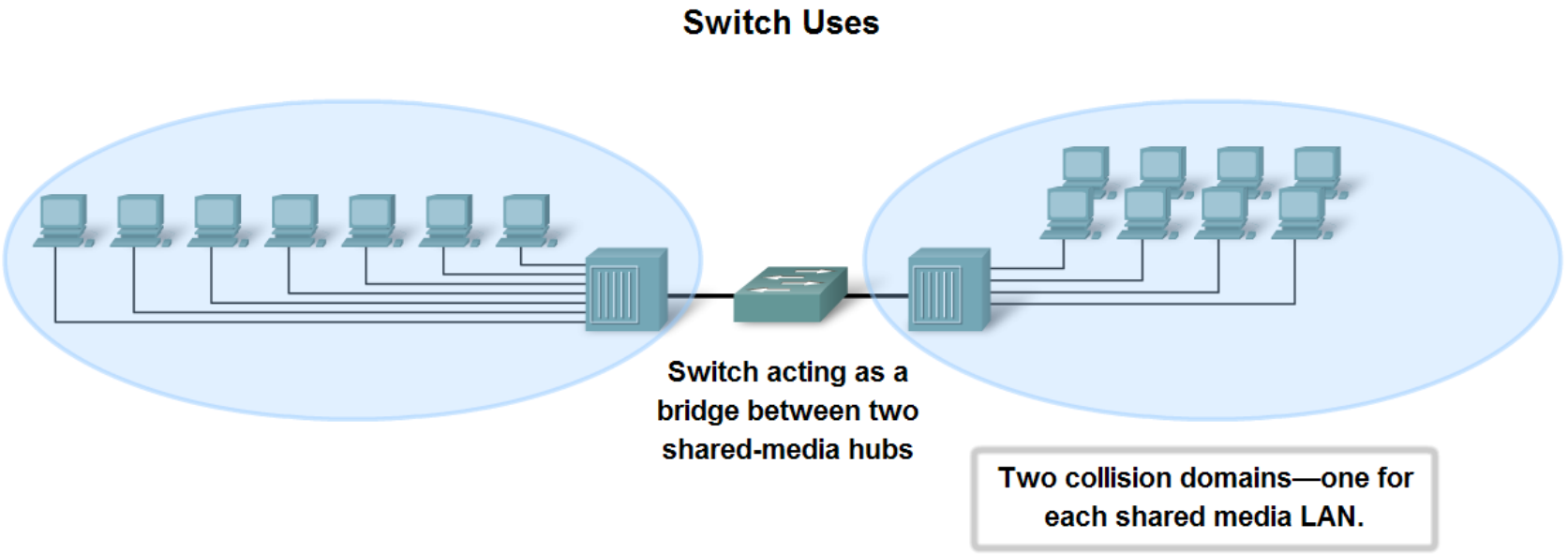
- Repeater Forwards Each Frame.
- It has No Filtering Capability
- Repeater is a Regenerator NOT an Amplifier.

Physical Layer Devices : Hubs



- Physical Topology => Star
- Logical Topology => Bus
- Extends Collision Domain.

Link Layer Devices : Switch



Bluetooth

- Developed by SIG (Special Interest Group)
- Bluetooth is defined by the IEEE 802.15 Standard.
- It defines Wireless PAN operable in an area of room or a hall.
- wireless technology standard for exchanging data over short distances
- Works at ISM band from 2.4 to 2.485 GHz
- The ISM band is spit into 79 channels each 1MHz wide
- Used Technology Called FHSS
  - Frequency Hopping Spread Spectrum
  - full-duplex signal at a nominal rate of 1600 hops/sec
- Use Packet Switching Protocol
- When two Bluetooth devices notice each other they create a network – called a Piconet

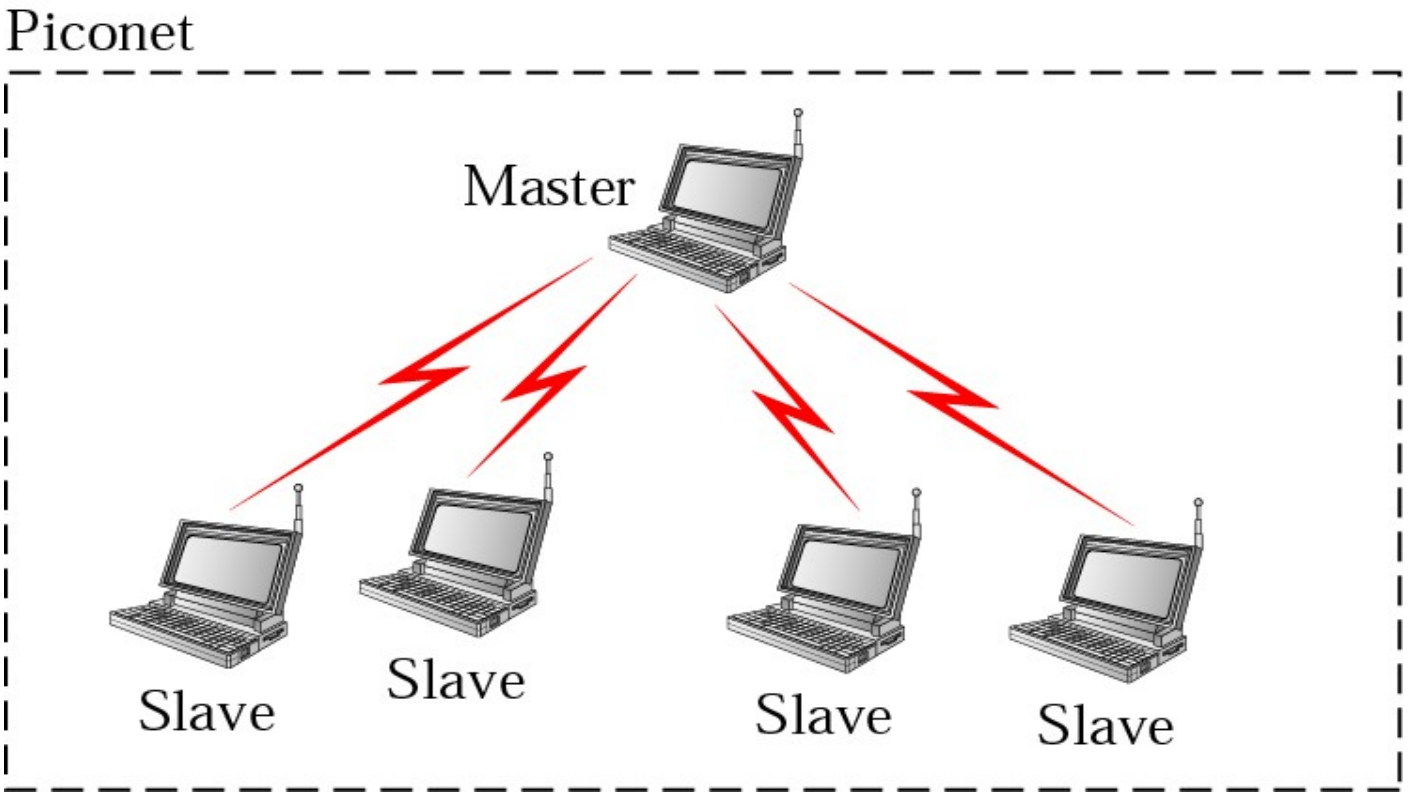
Bluetooth Architecture

- Piconet
- Scatternet

Bluetooth Architecture: Piconet

- Network Created using wireless Bluetooth Connection
- All Devices share the Common Channel
- one master device to interconnect with up to seven active slave device
- 255 further slave devices can be inactive, or parked, which the master device can bring into active status at any time.
- Piconets have a 3-bit address space,

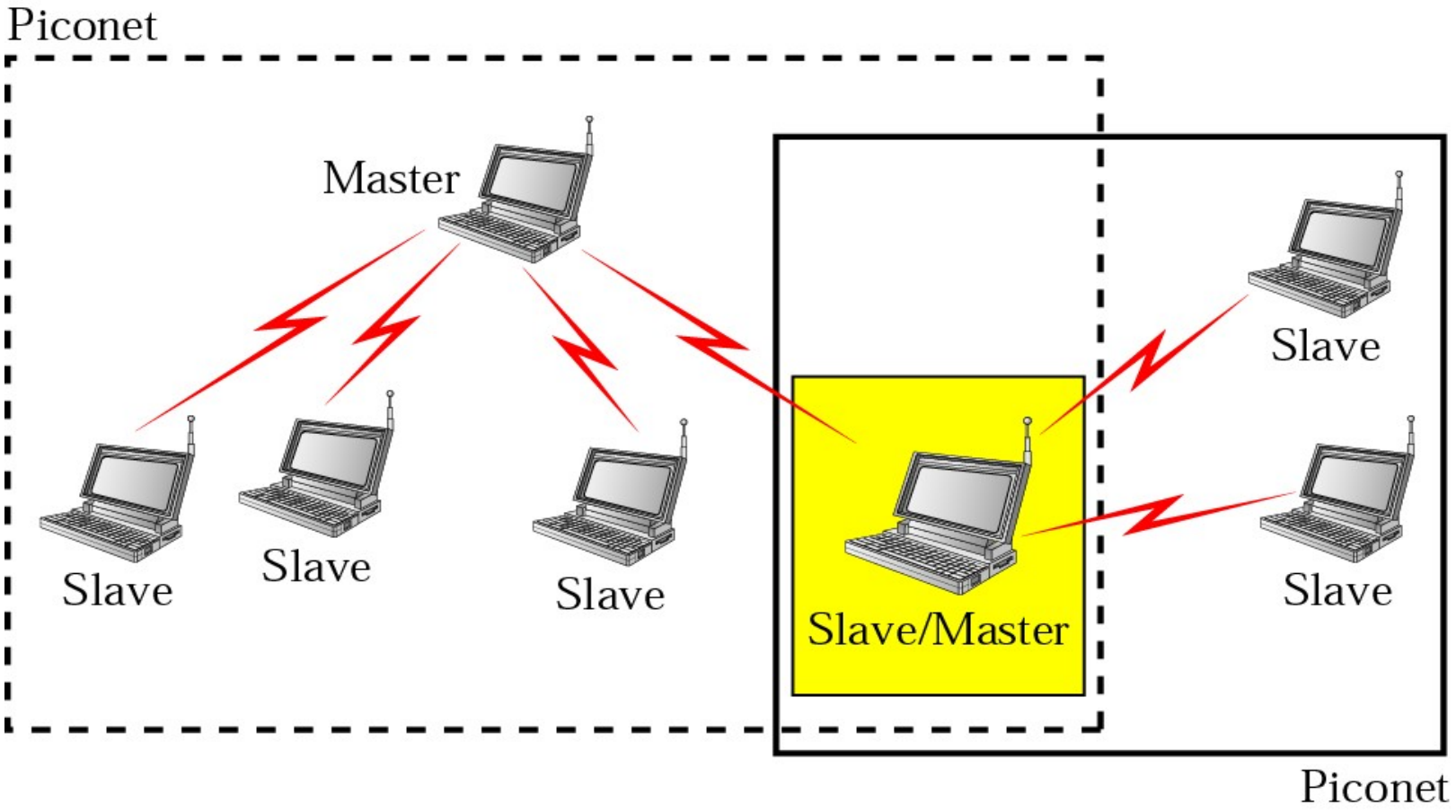
Bluetooth: Piconet



Bluetooth Architecture: Scatternet

- Bluetooth Consisting two or more piconets
- supports communication between more than 8 devices

Bluetooth: Scatternet



Wireless LAN: WiFi

- popular wireless networking technology
  - Use radio waves to provide wireless high-speed Internet

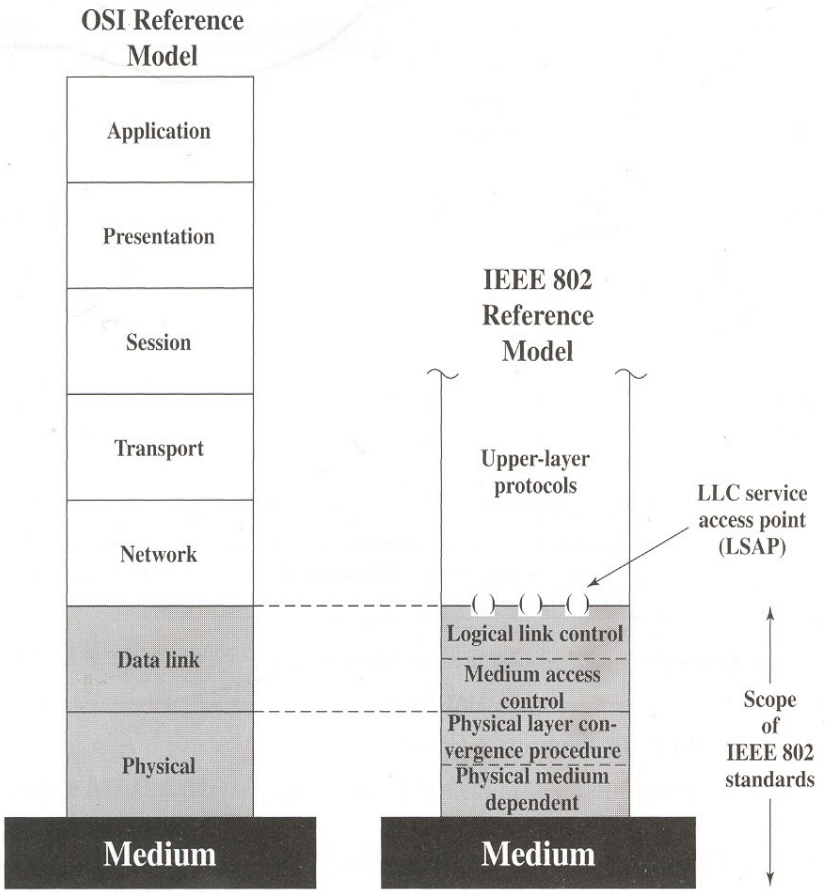
Defined by IEEE 802.11 Standards

- 802.11a
- 802.11b
- 802.11g
- 802.11n

- WiFi-Alliance Owns the registered trademark of WiFi
- Use 2.4 GHz UHF and 5 GHz SHF radio waves

802.11 Standard

- 802.11 is primarily concerned with the lower layers of the OSI model.
- Data Link Layer
  - Logical Link Control (LLC).
  - Medium Access Control (MAC).
- Physical Layer
  - Physical Layer Convergence Procedure (PLCP)
    - Defined Data rate
    - packet length
  - Physical Medium Dependent (PMD).
    - Define bit timing
    - Transmit and receive bits



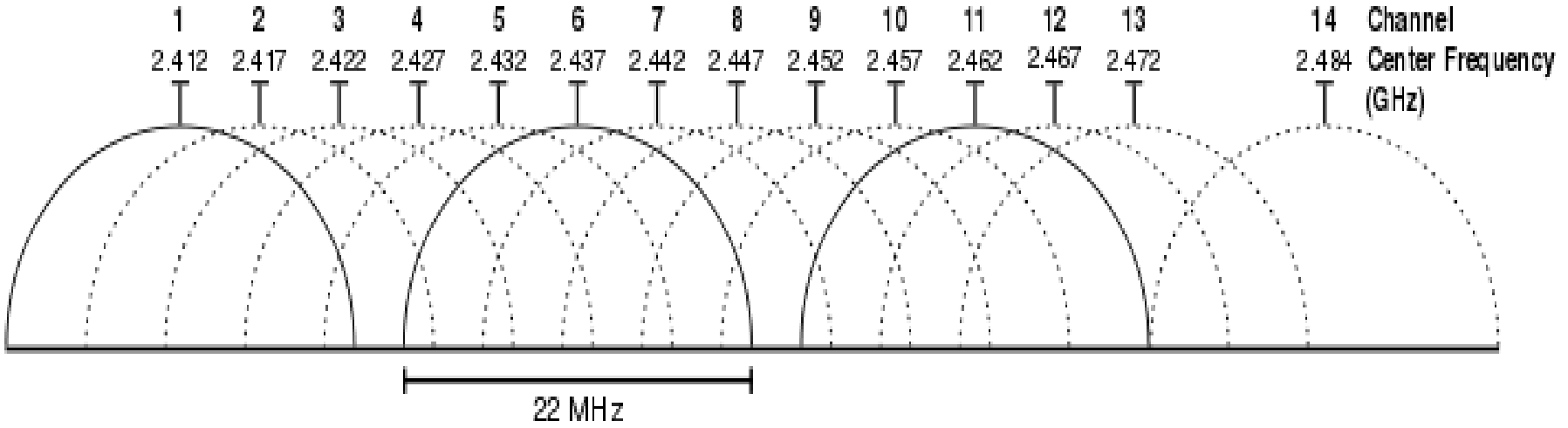
IEEE 802 Protocol Layers Compared to OSI Model

802.11b Standard

- Operate at 2.4 GHz range
- Throughput up to 11 Mbit/s using the same 2.4GHz band. Theoretically
- CSMA/CA media access method to avoid collision
- Use DSSS Modulation Techniques
- 802.11b devices suffer interference from other products operating in the 2.4 GHz band
  - microwave ovens, Bluetooth, cordless phone

802.11b cont'd..

- Maximum 14 channels
- 11 channels (1-11) are allowed to use
- 3 non overlapping channels 1, 6, 11



802.11g

- Extension of 802.11b
- Extended throughput to up to 54 Mbit/s
- Using the same 2.4 GHz band as 802.11b.
- 802.11g hardware is fully backwards compatible with 802.11b hardware
- modulation scheme used in 802.11g is OFDM

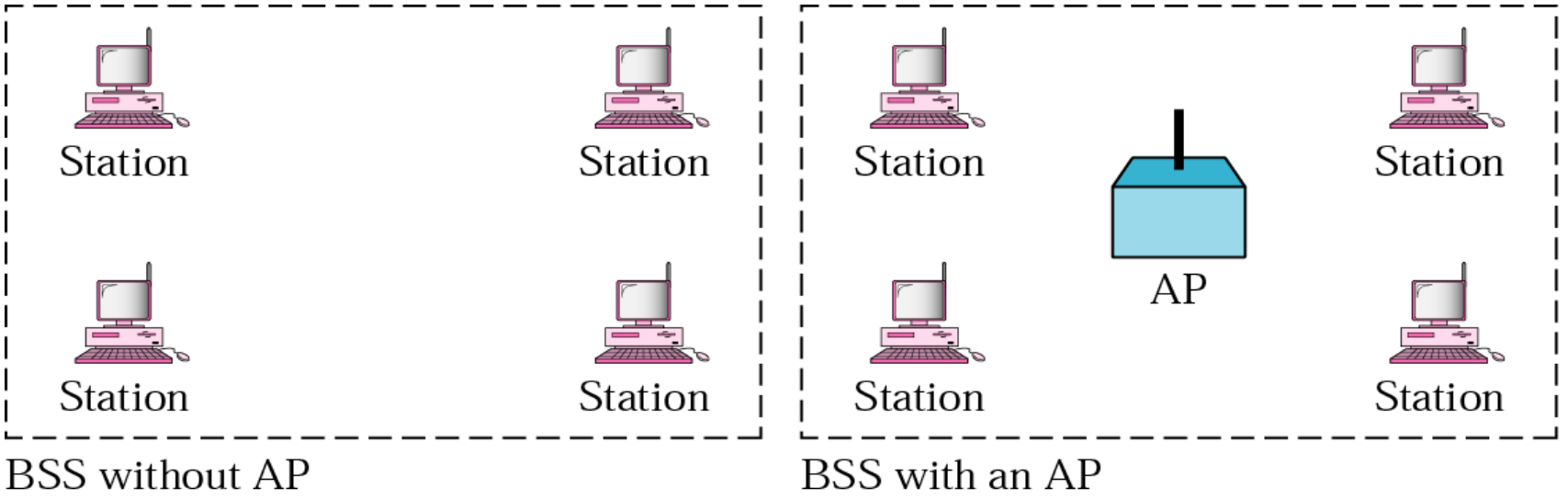
802.11a Standard

- Completely different from 11b and 11g.
- Flexible because multiple channels can be combined for faster throughput and more access points can be co-located.
- Shorter range than 11b and 11g.
- Runs in the 5 GHz range, so less interference from other devices.
- Has 12 channels, 8 non-overlapping, and supports rates from 6 to 54 Mbps, but realistically about 27 Mbps max
- Uses frequency division multiplexing

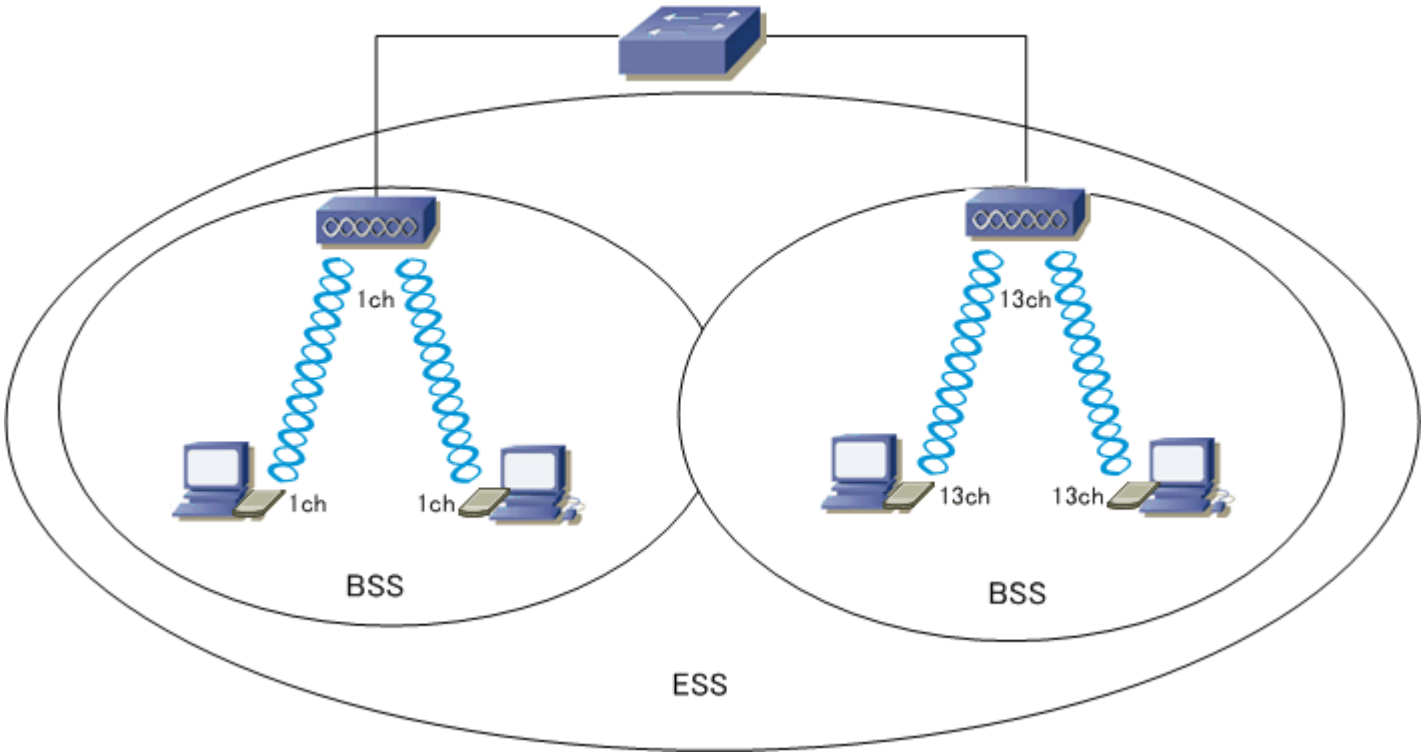
802.11n

- Wireless networking standard
  - uses multiple antennas to increase data rates
- Maximum net data rate from 54 Mbit/s to 600 Mbit/s
- Use OFDM and MIMO technologies
- RF Band (GHz) 2.4 or 5

Wireless LANs Architecture: Basic Service Set



Wireless LANs: Extended Service Set



Advantages

Freedom – You can work from any location that you can get a signal.

Setup Cost – No cabling required.

Flexibility – Quick and easy to setup in temp or permanent space.

Scalable– Can be expanded with growth.

Mobile Access – Can access the network on the move.

Disadvantages

Speed – Slower than cable.

- Range – Affected by various medium.
- Travels best through open space.
- Reduced by walls, glass, water, etc

Security – Greater exposure to risks

- Unauthorized access.
- Compromising data.
- Denial of service.

Satellite Communication Basic

- Microwaves
- Radio Waves

Basics: How do Satellites Work

- Two Stations on Earth want to communicate through radio broadcast but are too far away to use conventional means.
- The two stations can use a satellite as a relay station for their communication
- One Earth Station sends a transmission to the satellite. This is called a Uplink.
- The satellite Transponder converts the signal and sends it down to the second earth station. This is called a Downlink.

Basics: Advantages of Satellites

- The advantages of satellite communication over terrestrial communication are:
  - The coverage area of a satellite greatly exceeds that of a terrestrial system.
  - Transmission cost of a satellite is independent of the distance from the center of the coverage area.
  - Satellite to Satellite communication is very precise.
  - Higher Bandwidths are available for use.

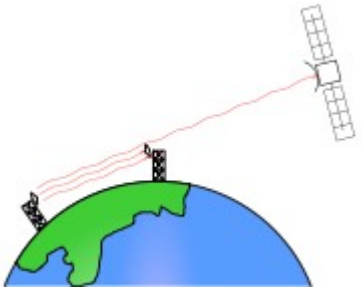
Basics: Disadvantages of Satellites

- The disadvantages of satellite communication:
  - Launching satellites into orbit is costly.
  - Satellite bandwidth is gradually becoming used up.
  - There is a larger propagation delay in satellite communication than in terrestrial communication.

Microwaves

- Technology for transmitting information or energy by using
  - electromagnetic waves whose wavelengths are conveniently measured in small numbers of centimetre; these are called microwaves.
- Line of Sight Radio Communication
- Radio spectrum ranges across frequencies of roughly 1.0 gigahertz (GHz) to 30 GHz
- widely used for point-to-point communications

  Example: Earth Ground Station to Satellite Communication



Uses of microwave links

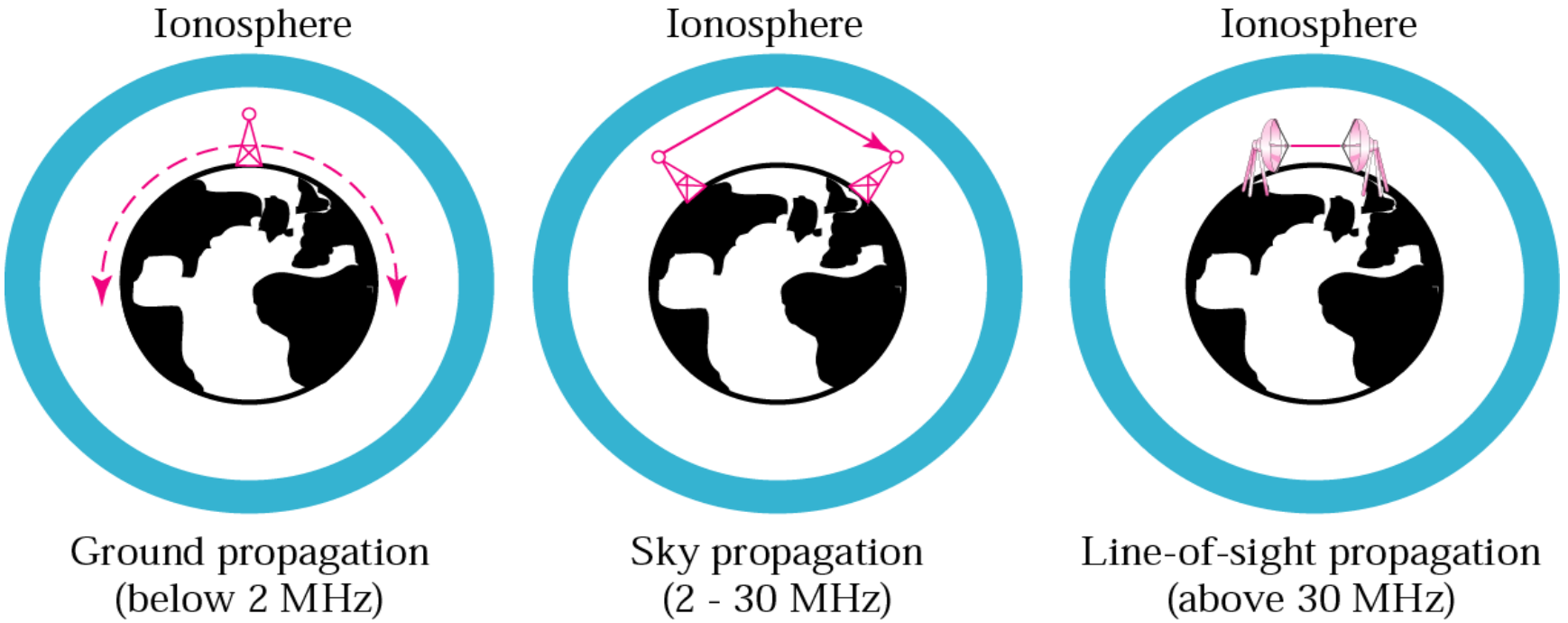
- In communications between satellites and base stations
- As backbone carriers for cellular systems
  - (1800 MHZ, 1900MHZ)
- In short range indoor communications
- Telecommunications, in linking remote and regional telephone exchanges to larger (main) exchanges without the need for copper/optical fibre lines.

Radio Waves

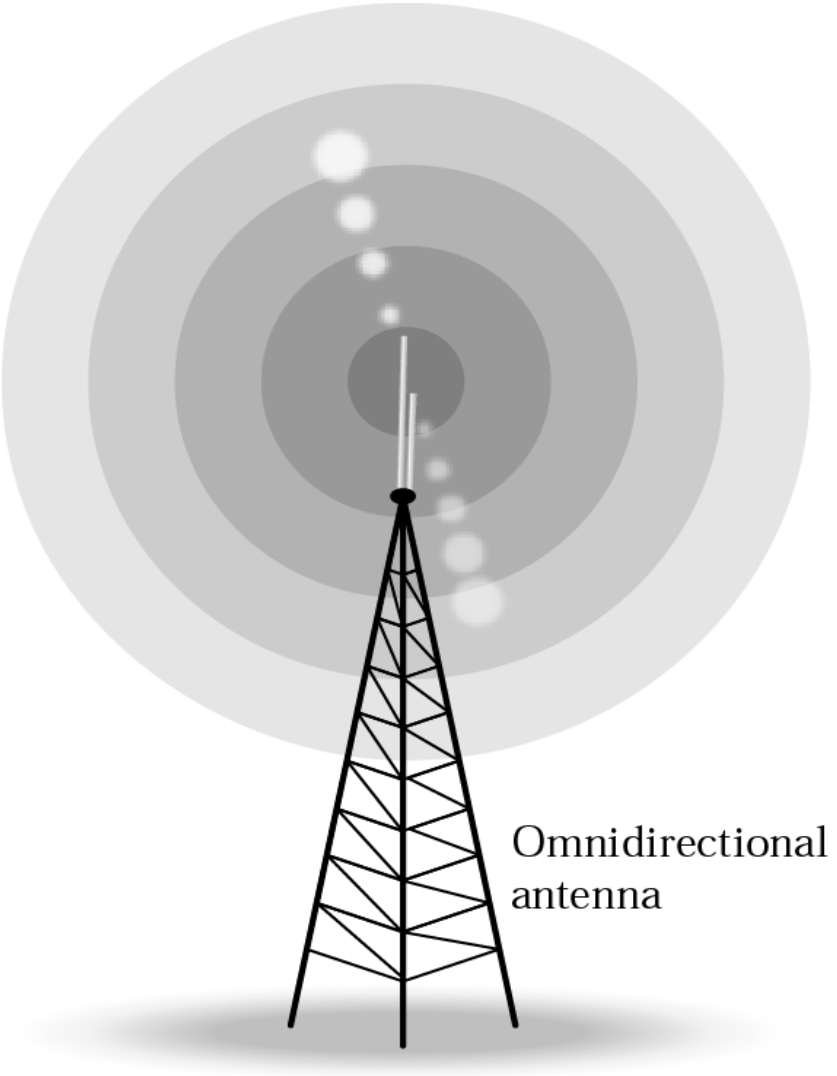
- Radio waves are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light
- Radio waves have frequencies from 300 GHz to as low as 3 kHz

- Radio waves are divided into:-
  - Long wave: wavelength from 1~2 km
    - Atlantic 252 Radio station
  - Medium Wave: wavelength 100 Meter
    - BBC radio
  - VHF: wavelenght around 2Meter
  - UHF: 300MHZ-3GHZ
    - Used by police radio

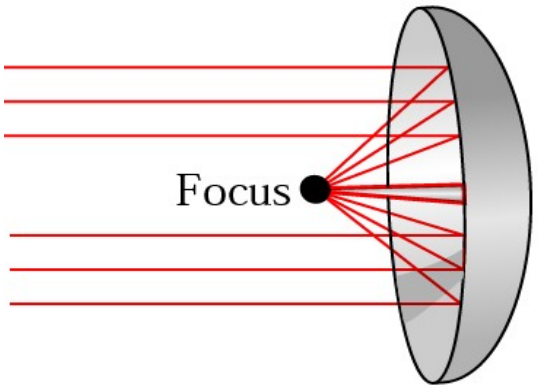
Wave Propagation Methods ??



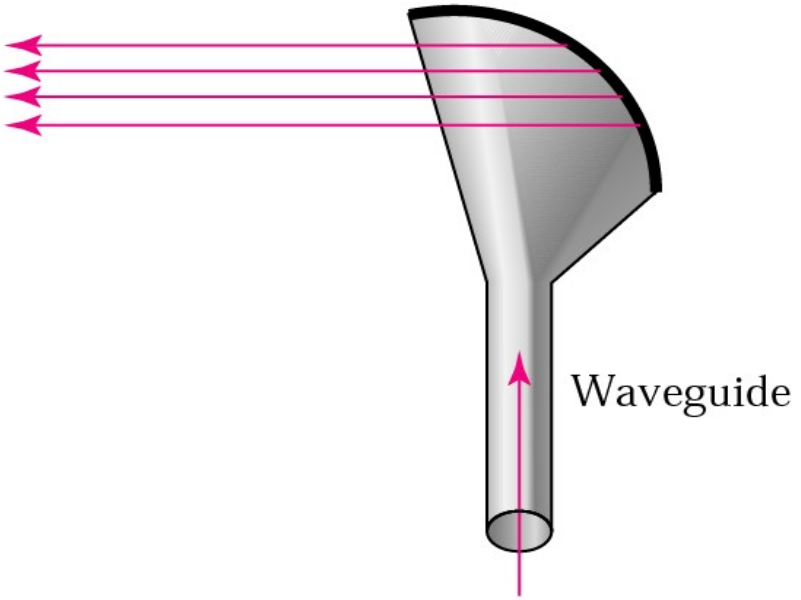
Antennas : Omnidirectional



Antennas : Unidirectional

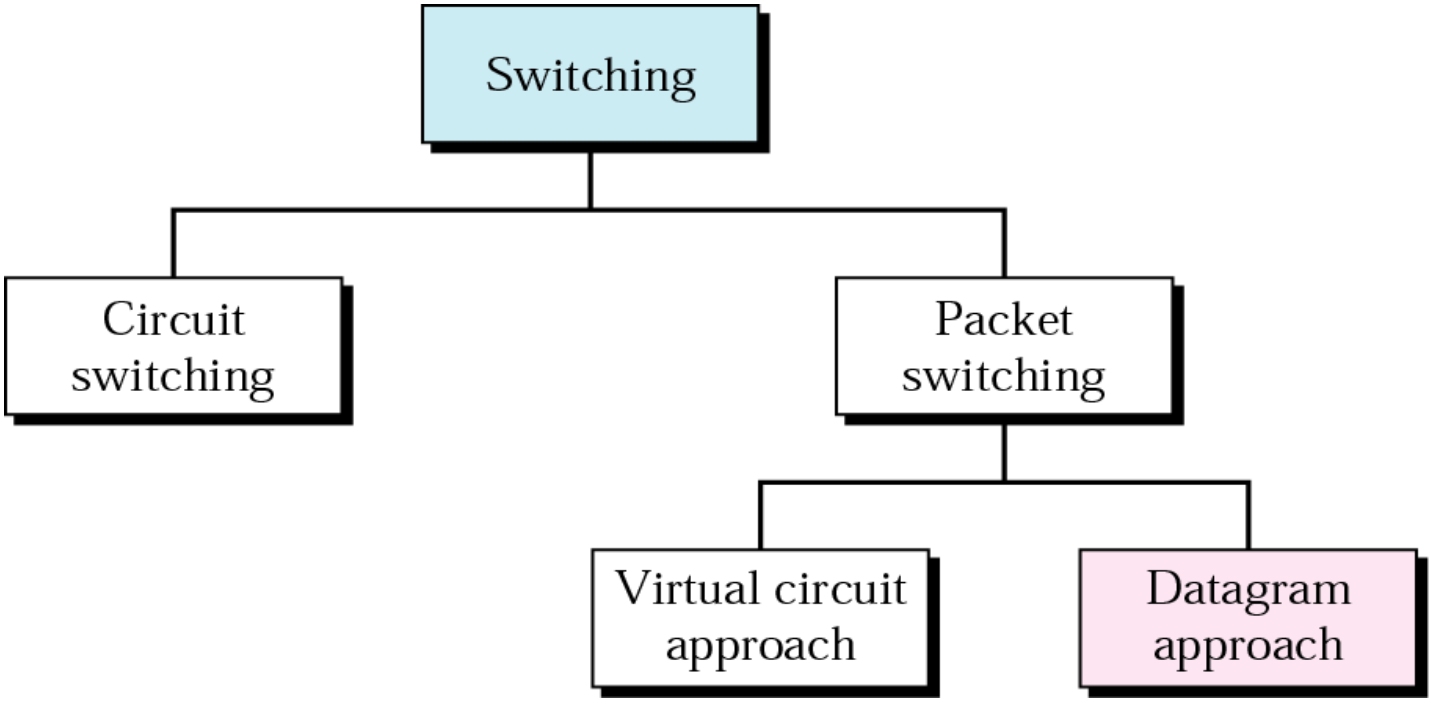


a. Dish antenna



b. Horn antenna

Switching Techniques



Circuit Switching

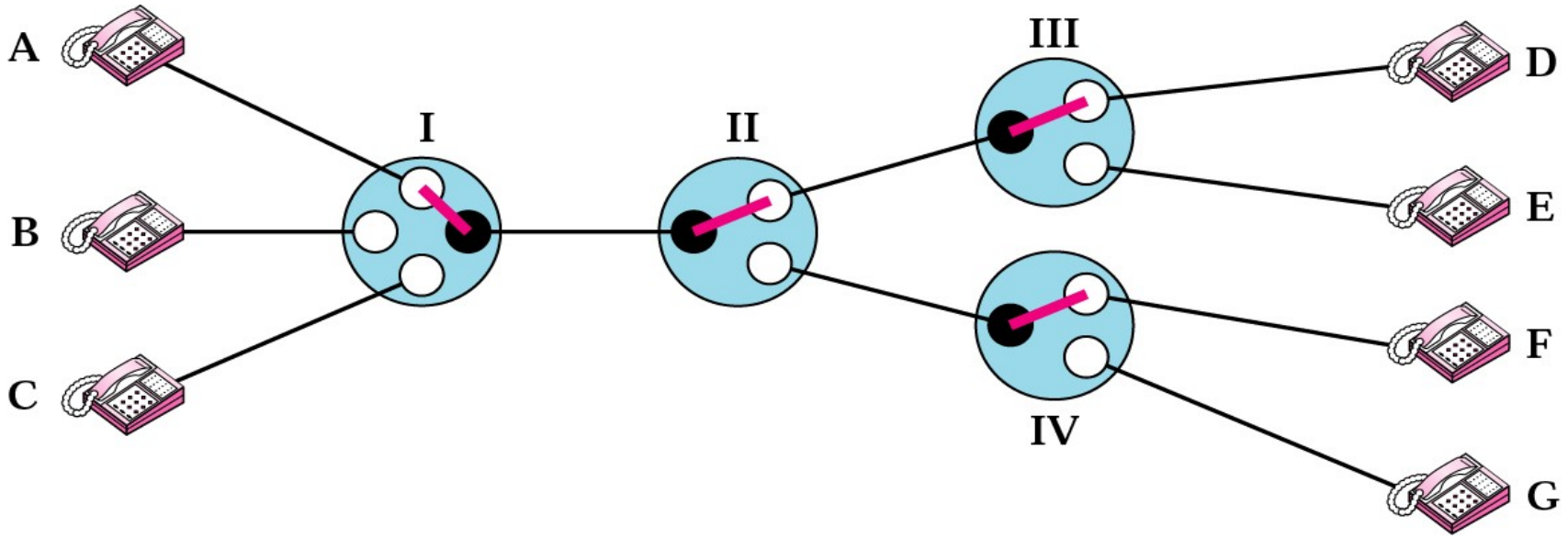
- A complete circuit between source and destination nodes is established before the data can be transmitted.
- Dedicated communication between two stations.
- Communication Link => Telephone line, Coaxial cable, Satellite link, Microwave link etc.
- The following three steps are required to establish the connection
  - Connection Setup
  - Data Interchange
  - Connection Termination

Circuit Switching: Problems ??

- Inefficient
  - Channel dedicated for the duration of connection.
  - If no data => Capacity is wasted

- Setup Connection Takes Time
- Once Connected, Transfer is Transparent
- Developed for Voice Traffic
- Circuit switching usually uses a fixed data rate (E.g. 64 Kbps) and is difficult to support variable data rate.

Circuit Switching: Public Circuit Switched Network



Packet Switching

- Data Transmitted in Small Packets.
- Each Packet Contains User data plus Control Information.
- Control Information => Routing Information.
- Two Types of Packet Switching
  - Datagram Packet Switching
  - Virtual Circuit Packet Switching.

Packet Switching: Datagram Packet Switching

- No need to establish the connection between the source and destination.
- Route chosen on packet by packet basis.
- Packets may be stored until delivered => (Store and Forward)
- Different packets may follow different routes.
- Packets may arrive out of order at the destination.

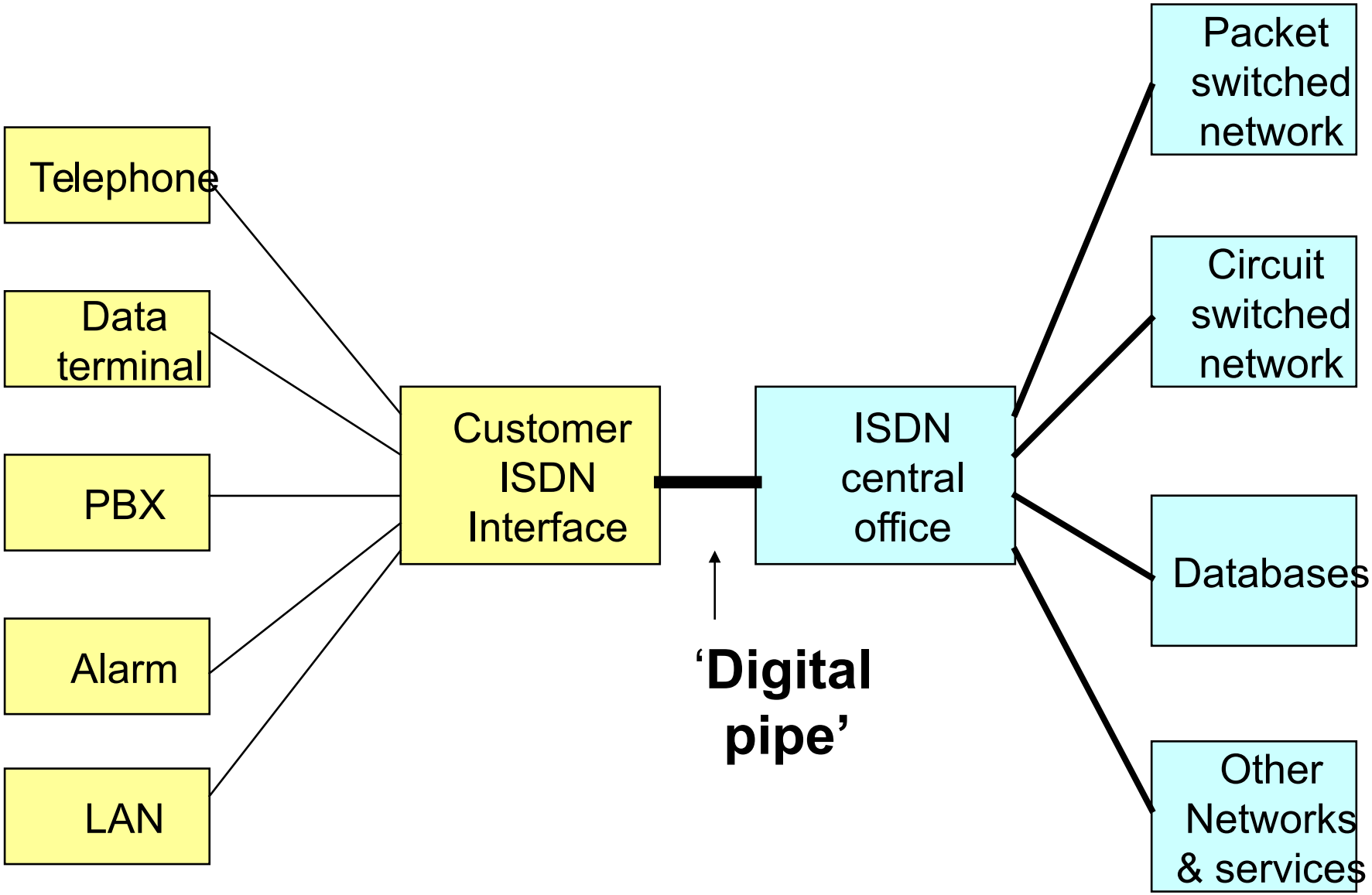
Packet Switching: Virtual Circuit Switching

- Route is chosen at the start of session and it is only a logical connection.
- All Packets associated with a session follow the same path.
- Packets are labeled with a VC# designated the route.
- The VC number must be unique on a given link.
- Packets are forwarded more quickly. (No Routing Decisions)
- Example : Asynchronous Transfer Mode

ISDN: Integrated Service Digital Network

- ITU Standard For global Digital Communication.
- It was Developed in 1984 to replace Analog Telephone System.
- Allow the Complete Integration of both Voice, Video and Data Within a Single System.

Integrated Services Digital Network

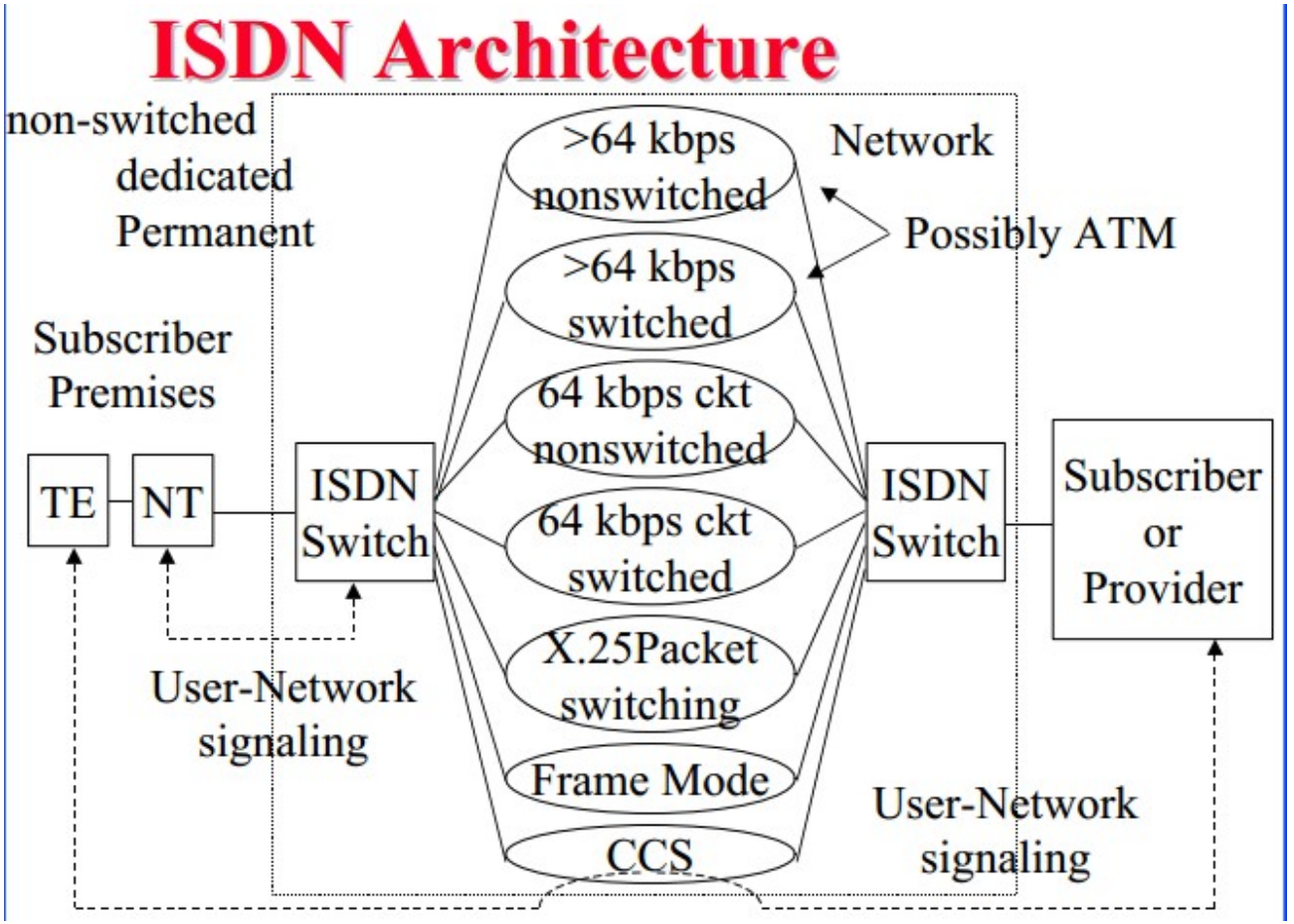


ISDN Channels

- Types of channels
  - Bearer channel (B-channel=64 kb/s) clear pipe for data
  - Delta channel (D-channel, 16 kb/s or 64 kb/s) call signaling information:
    - who is calling
    - type of call
    - calling what number

ISDN Services Types

- Also called ISDN Interface
  - Basic Rate Interface 2B channels + 1 D channel
  - Primary Rate Interface
    - T1 connection: 23B+D
    - American Standards
      - Data rate 23*64Kbps + 64Kbs + 8bits header
        Information = 1544kbs = 1.544Mbps
    - E1 Connection: 30B+D
    - European Standards
      - 30*64Kbps + 64Kbps +64Kbps
      - 2048Kbps=2.048Mbps
      - Last D channel for Framing and Synchronization in E1 Connections


ISDN Architecture
non-switched
dedicated
Permanent
Subscriber
Premises
TE
NT
ISDN
Switch
>64 kbps
nonswitched
>64 kbps
switched
64 kbps ckt
nonswitched
64 kbps ckt
switched
X.25Packet
switching
Frame Mode
CCS
Network
Possibly ATM
ISDN
Switch
Subscriber
or
Provider
User-Network
signaling
User-Network
signaling

Network Performance

- Bandwidth
- Throughput
- Latency
- Bandwidth Delay product
- Jitter

Bandwidth:

- In Computer Networking Bandwidth is also referred as
  - Network bandwidth, Data bandwidth, or Digital bandwidth
- The maximum amount of data that can be carried from one point to another in a given time period (usually a second) is referred as BANDWIDTH
- For Digital Devices
  - Channel Capacity
  - Bandwidth is expressed in bits per second (bps)
- For Analog Devices
  - Refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.
  - Bandwidth is Expressed in cycle per sec OR Hz

Throughput:

- The rate of successful message delivery over a communication channel.
- Throughput is usually measured in bits per second
- **system throughput or aggregate throughput**
  - sum of the data rates that are delivered to all terminals in a network
- Maximum Throughput ??

A network with bandwidth of 10 Mbps can pass only an average of 12,000 frames per minute with each frame carrying an average of 10,000 bits. What is the throughput of this network?

Solution

We can calculate the throughput as

$$\text{Throughput} = \frac{12{,}000 \times 10{,}000}{60} = 2 \text{ Mbps}$$

The throughput is almost one-fifth of the bandwidth in this case.

Propagation & Transmission delay

- Propagation speed - speed at which a bit travels though the medium from source to destination.
  - Depends on the Transmission medium Properties
- Transmission speed:
  - The amount of time from the beginning until the end of a message transmission
  - Difference in arrival time of first and last bit

Propagation and Transmission Delay

- Propagation Delay
  - Time taken for the first bit to travel from the sender to the receiver
  - Distance (Link Length)/Propagation speed
  - D/S = Distance/Speed
  - Time required

- Transmission Delay = Message size/bandwidth bps
  - Also called Store and Forward Delay
  - Amount of time required to push all of the packet's bits into the wire
  - Function of Packet Length
  - Nothing to do with distance between the nodes

- Latency = Propagation delay + Transmission delay + Queuing time + Processing time

What are the propagation time and the transmission time for a 2.5-kbyte message (an e-mail) if the bandwidth of the network is 1 Gbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at 2.4 × 10^8 m/s.

Solution

We can calculate the propagation and transmission time as shown on the next slide:

Propagation time = Distance / Speed

Transmission time = Packet Size / bandwidth of link

Latency

- several kinds of delays that happens in data communication over a network
- Low Latency
  - Network which experiences Low Delay
- High Latency
  - Network which experience High Delay
- Latency = Propagation delay + Transmission delay + Queuing time + Processing time

Bandwidth Delay Product

- Product of a data link's capacity (in bits per second) and its round-trip delay time (in seconds)
- Maximum amount of data on the network circuit at any given time i.e data that has been transmitted but not yet acknowledged

- A network with a large bandwidth-delay product > 10^5 bits is commonly known as a long fat network
- **Generally:The bandwidth-delay product defines the number of bits that can fill the link**

Jitter

- Jitter is the variation in the time between packets arriving, caused by network congestion, timing drift, or route changes.
- causes of jitter are electromagnetic interference (EMI) and crosstalk with other signals
- Video-on-demand application: If jitter is known, application can decide how much buffering is needed

Thank You