Computer Network (MCA-103) UNIT - I

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Overview

- Learning Objective:
  1. Understand basics, topologies and working mechanism of wired and wireless computer networks.
  2. Analyze the features and operations of protocols of OSI reference model & TCP/IP protocol suite.
  3. Design, calculate, and apply routing mechanisms for IPv4 & IPv6.
  4. Identify the networking requirements for an organization and select & propose appropriate architecture and technologies.
  5. Work on Network addressing, design and implementation.

Overview

UNIT-1

- Introductory Concepts:
  - Goals and Applications of Computer Networks,
  - OSI reference model,
  - TCP/lP protocol suite,
  - networks topology & design.
  - Networking Devices (Hub, Bridge, Switch & router).
  - Physical Layer
  - Communication Satellites
  - Digital Signal Encoding Formats, Digital to analog Modulation
  - Digitization - Sampling Theorem, PCM, DM, Analog to digital Modulation
  - The Mobile Telephone System
  - Multiplexing

Overview (cont..)

UNIT-2

- The Data Link Layer
  - Data Link Layer introduction
  - Error Detection and Correction,
  - Flow Control and Error Control protocols
- Medium access sub-layer
  - Channel allocation problem
  - ALOHA Protocols,
  - Carrier Sense Multiple Access Protocols,
  - CSMA with Collision Detection,
  - Collision free protocols,
  - Ethernet, wireless LANs, Blue Tooth, Wi-Fi

Overview (cont..)

UNIT-3

- Network Layer
  - Functions of network layer
  - lPv4: Classful & classless addressing,
  - Routing algorithms, lP packet format
  - lPvS: addressing, neighbor discovery, address auto configuration
- Mobile lP
  - Mobility in networks,
  - lP Multicasting (Source based tree & Group shared tree)

Overview (cont..)

UNIT-4

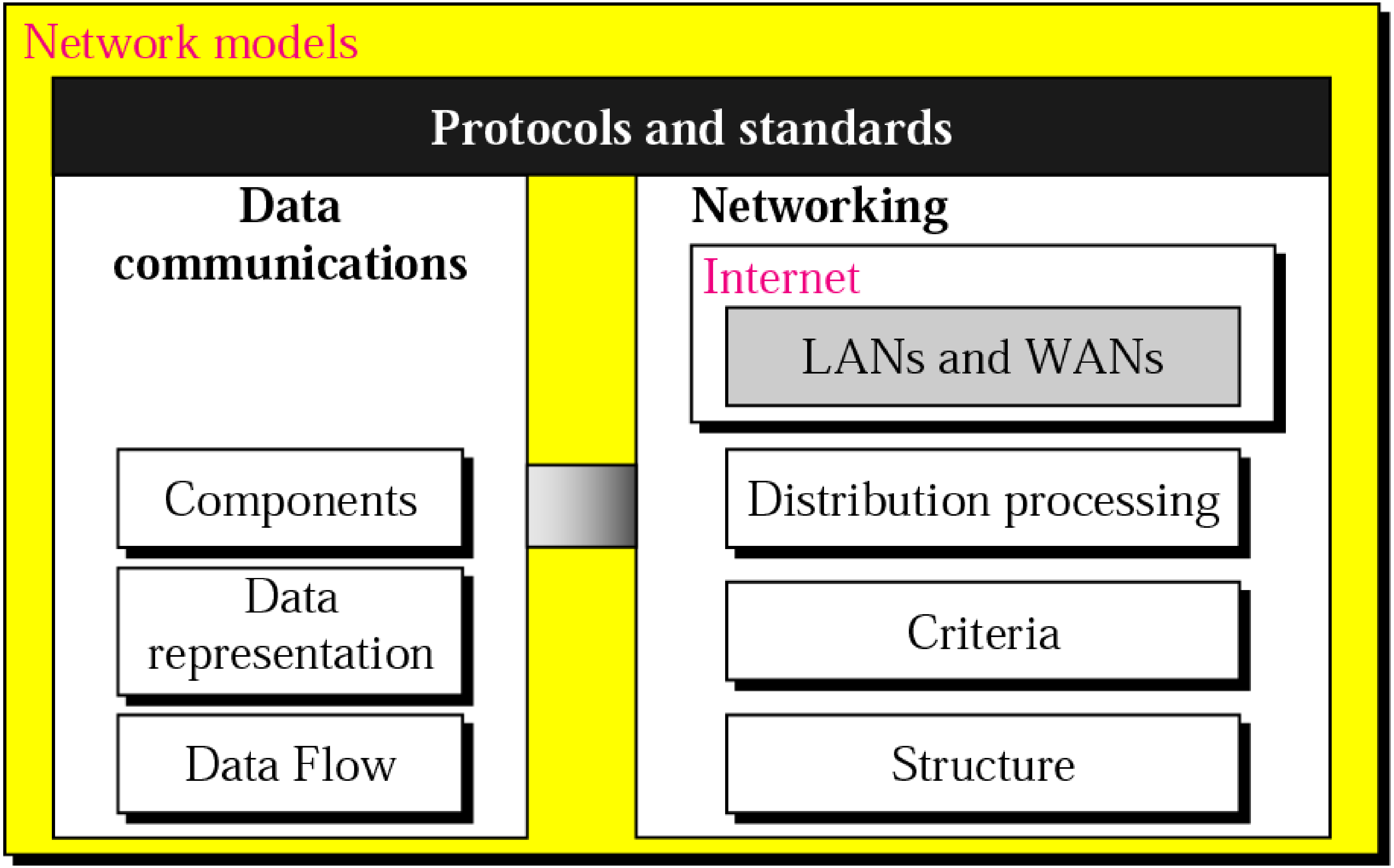
- Transport Layer:
  - Transport layer functions
  - Transport layer protocols:UDP, TCP
  - Connection management, flow control, error control and congestion control.
- Application Layer
  - DNS, Electronic Mail, www, firewalls
  - Concept of public & private keys.

Unit 1

In this Unit we will discuss :

- Introduction and The Physical Layer: Uses of Computer Networks, Network Hardware,
- Network Software, Reference Model (OSI, TCP/IP Overview), The Physical Layer,
- Theoretical Basis for Data Communication, Guided Transmission Media, Wireless
- Transmission, Communication Satellites,
- Digital Signal Encoding Formats
- Digital Modulation
- Analog Modulation –The Public Switched Telephone Network, The Mobile Telephone System

Introduction



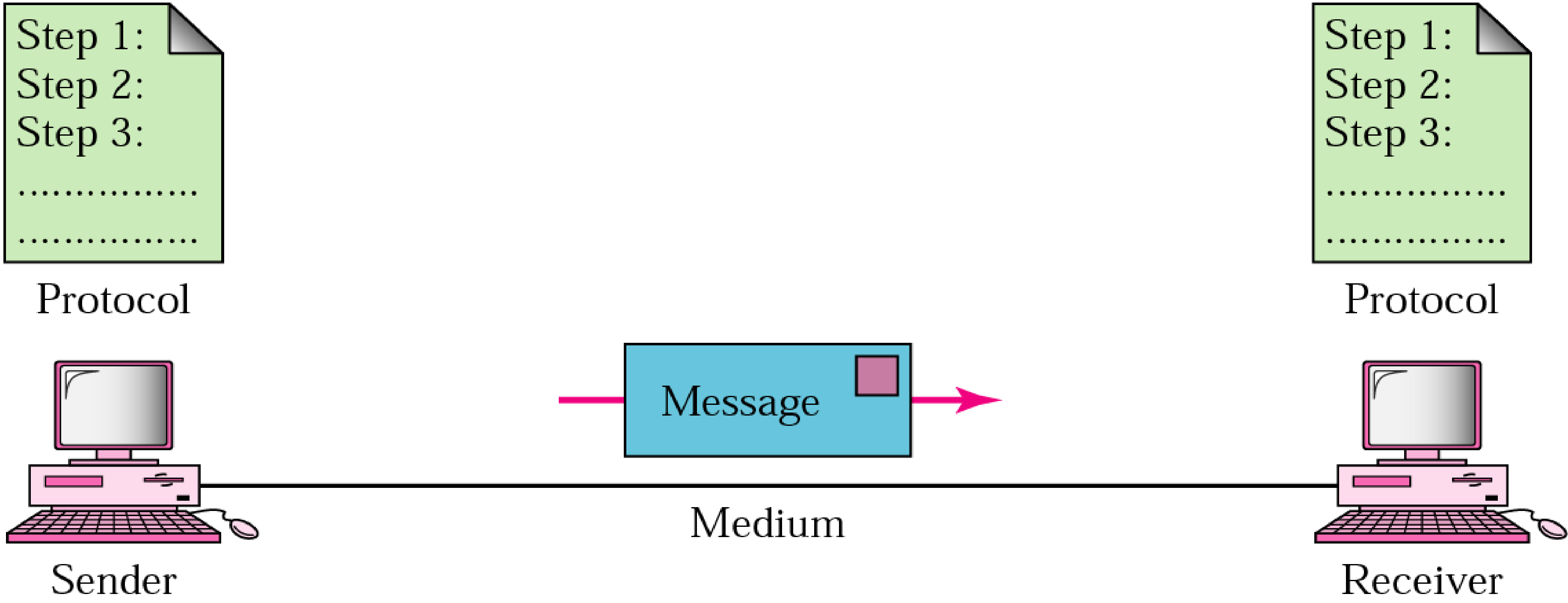
Introduction

BASICS OF DATA COMMUNICATION

- Components
- Data Representation
- Direction of Data Flow

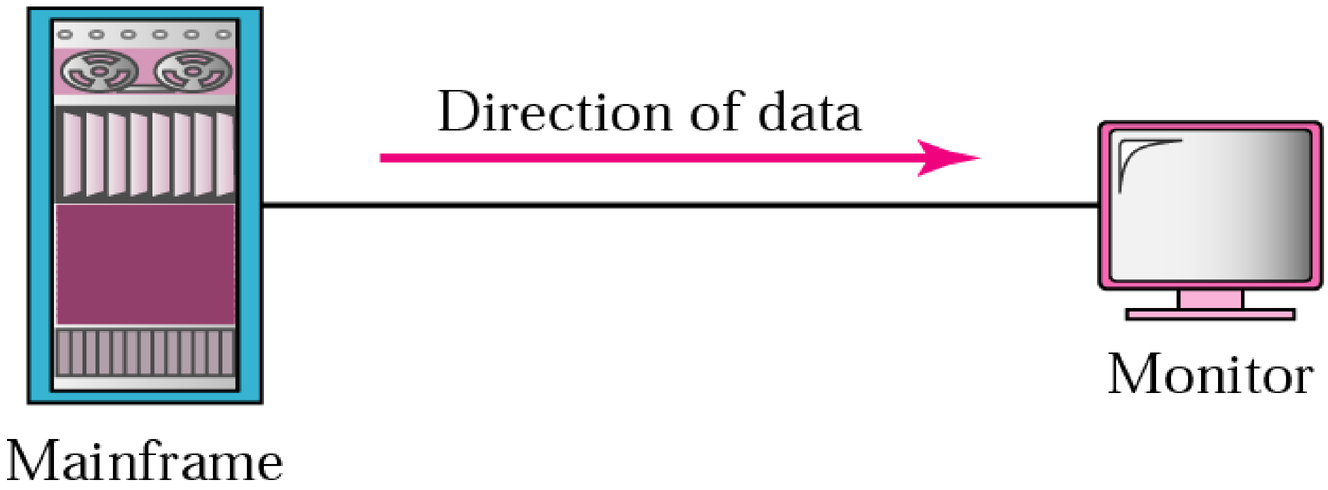
Introduction

Five components of data communication



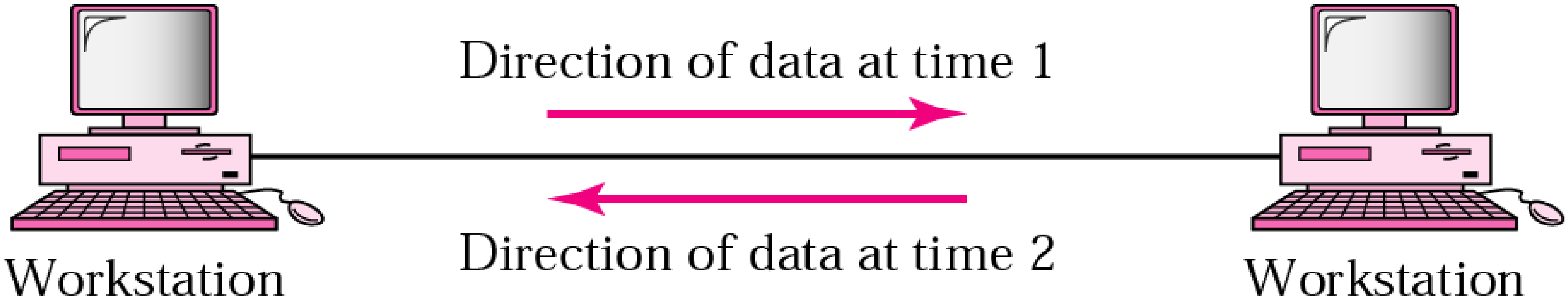
Data Flow

Simplex

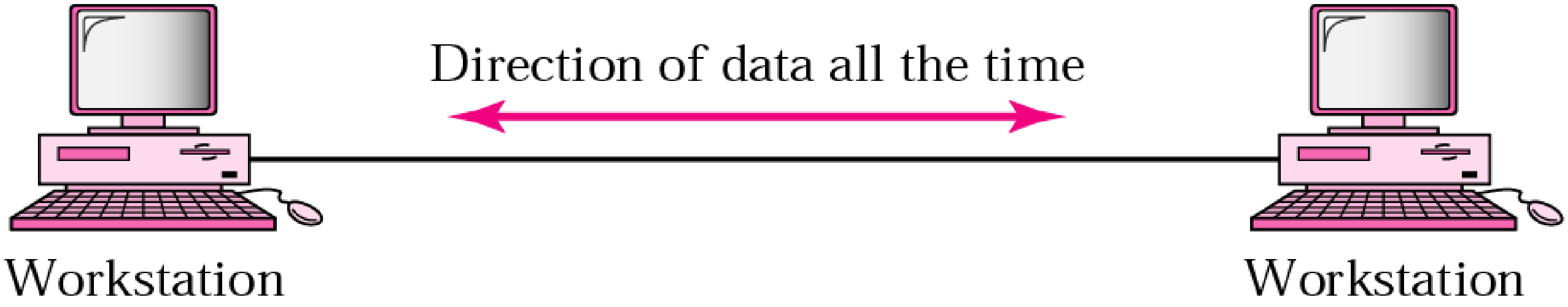


Data Flow

Half-Duplex

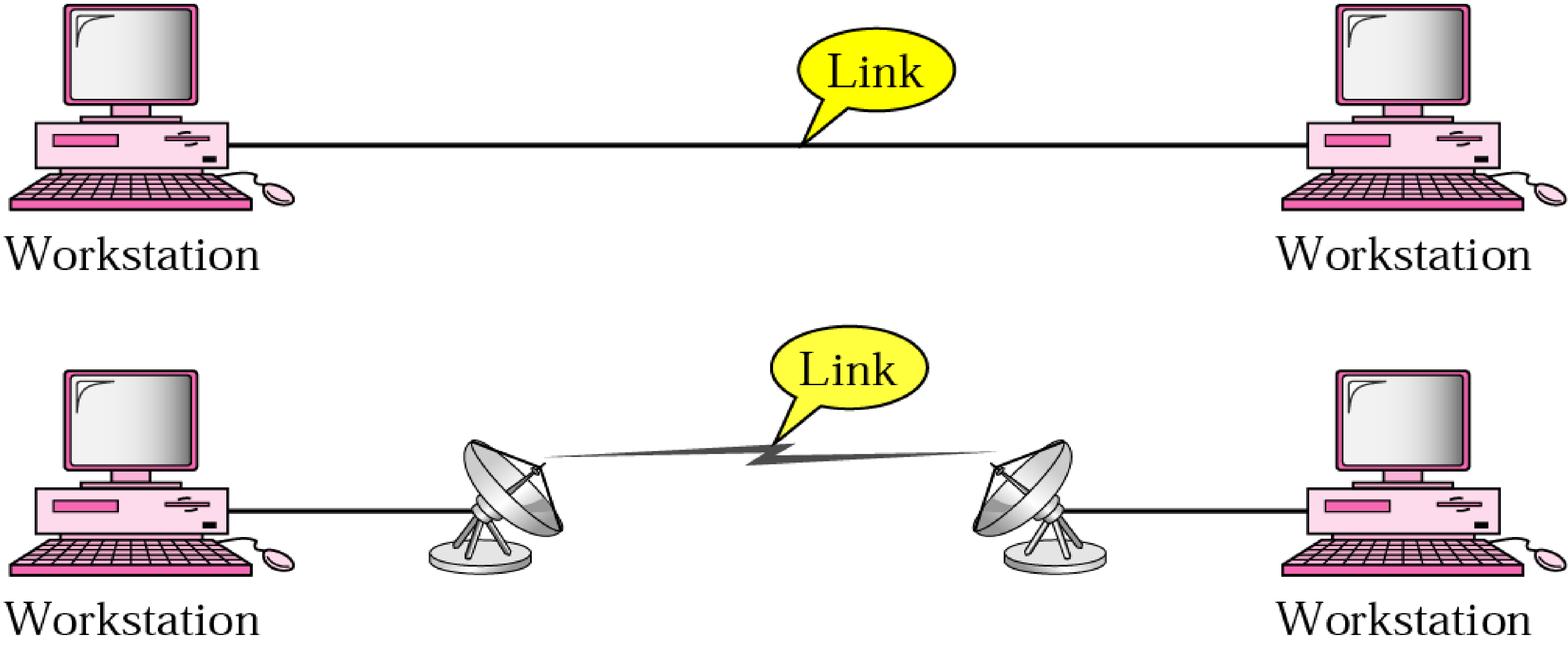


Full-Duplex



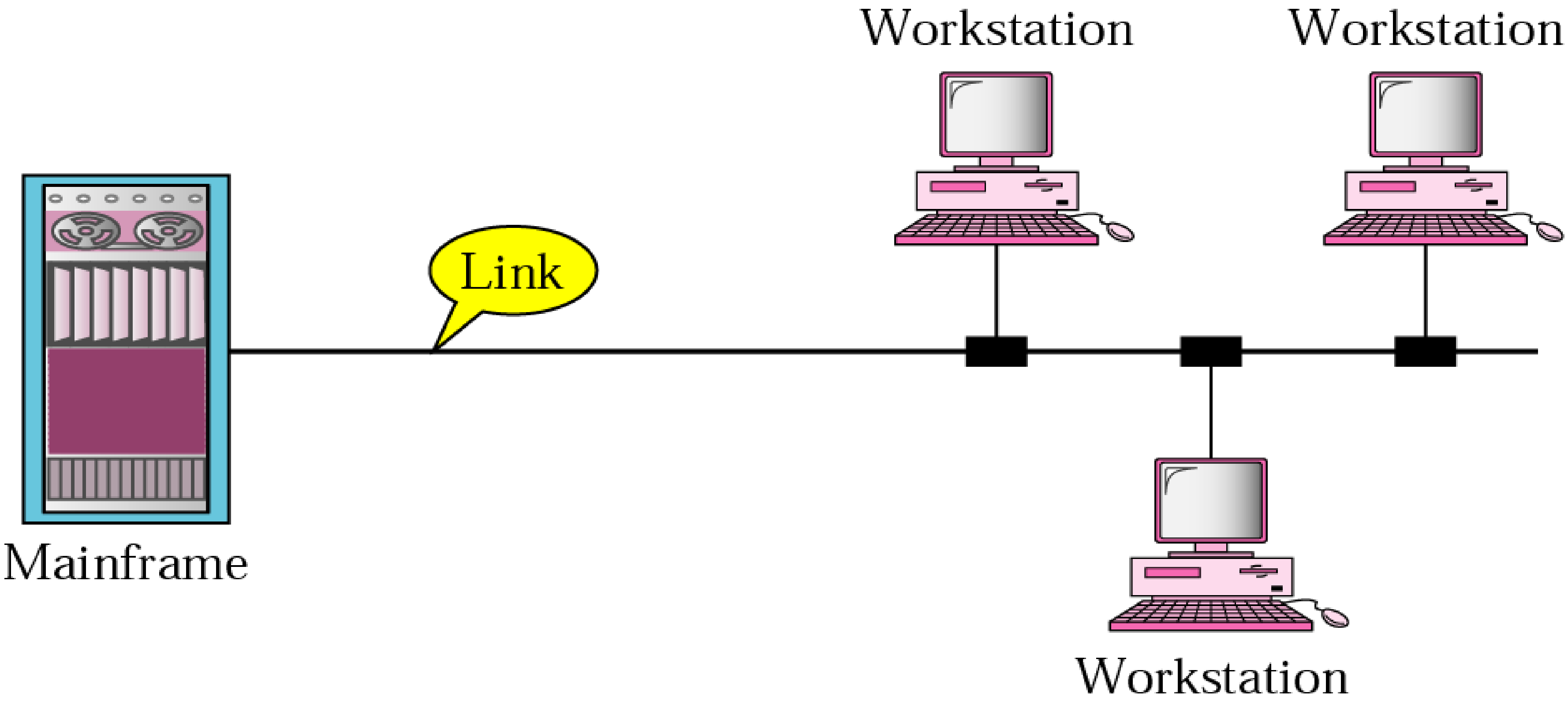
Types of Connection

Point-to-point connection

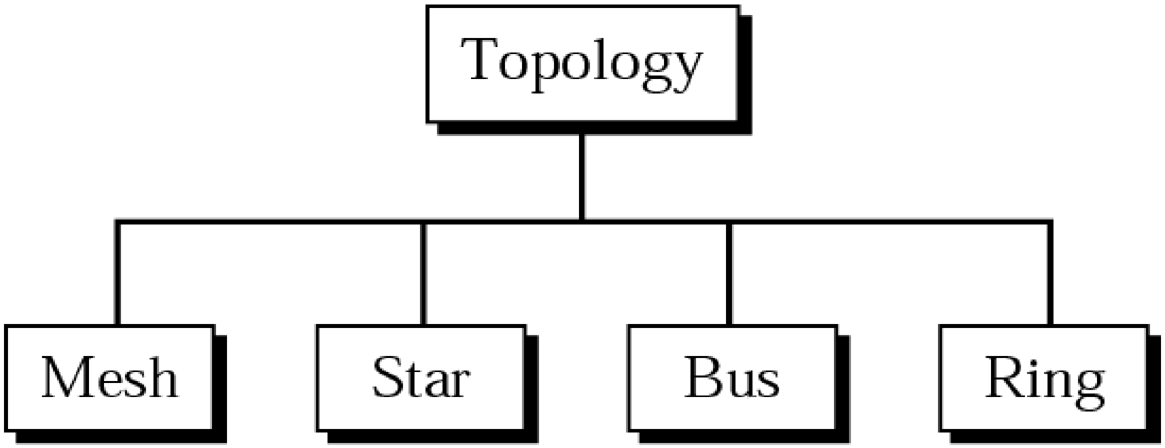


Types of Connection

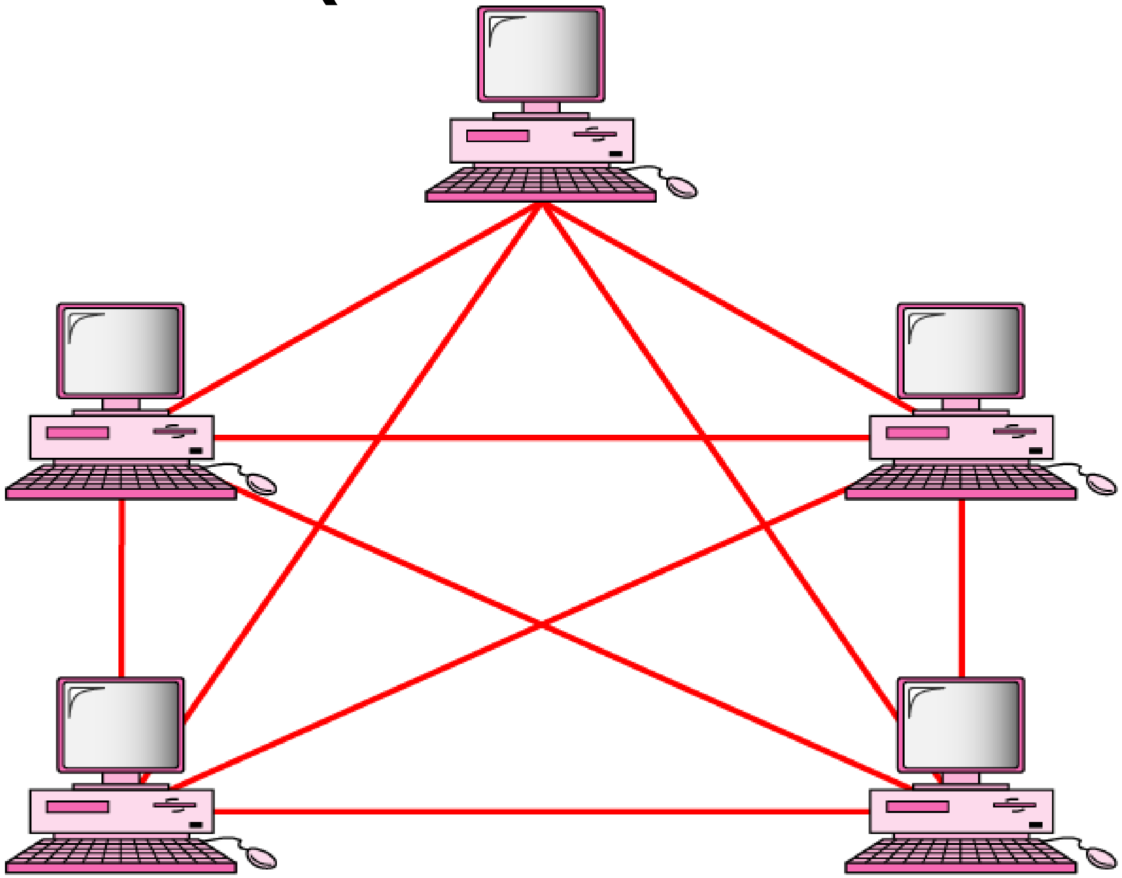
Multi Point Connection



Categories of Topology

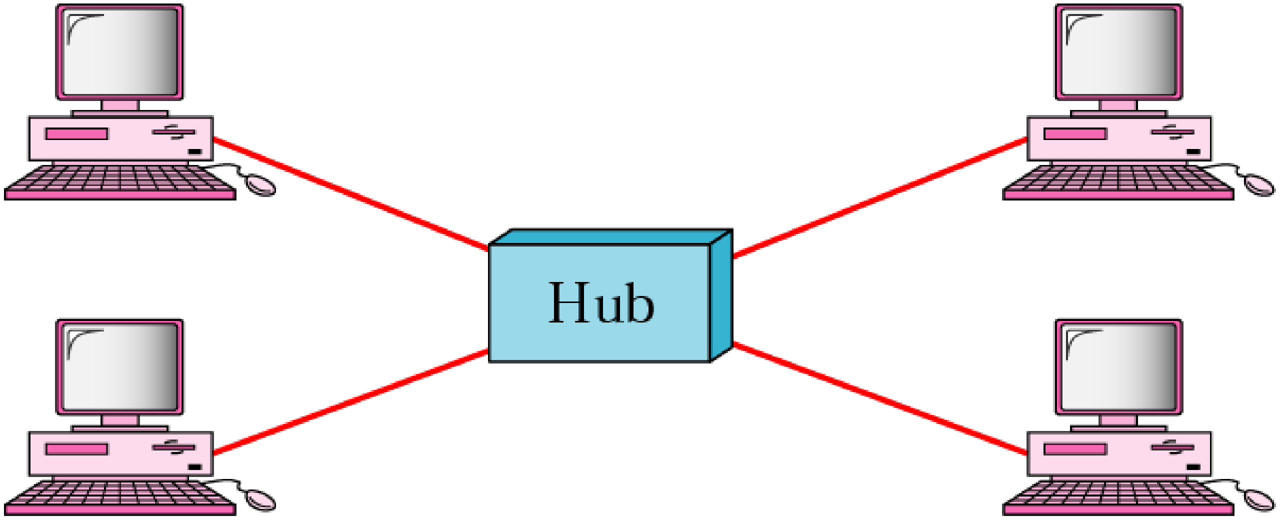


MESH (FULLY CONNECTED)

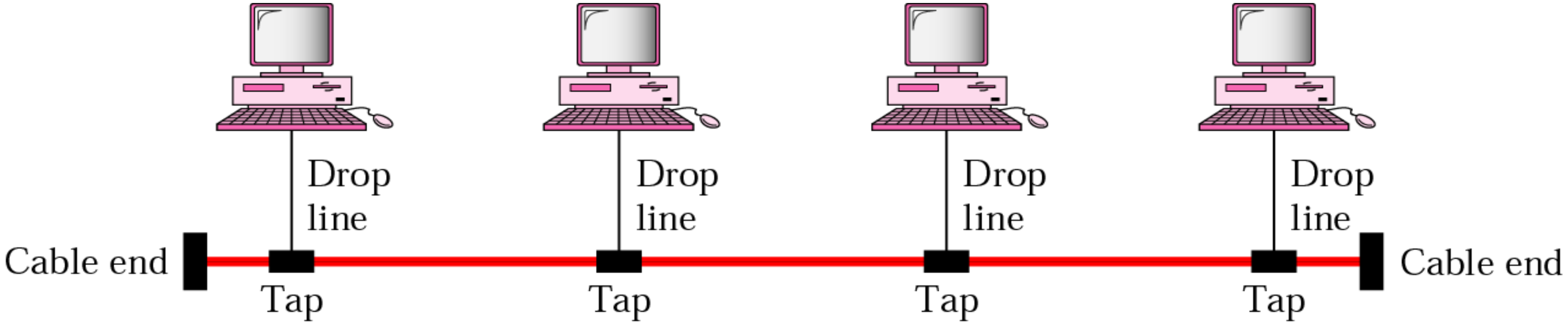


Introduction

STAR

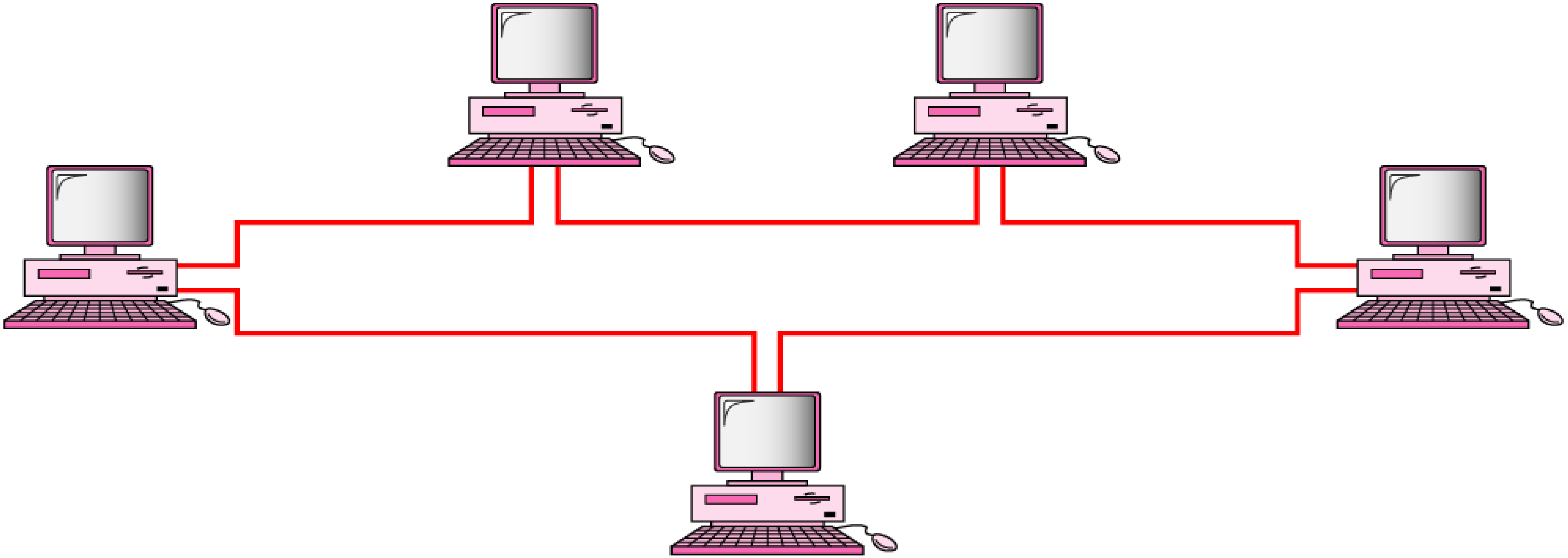


BUS

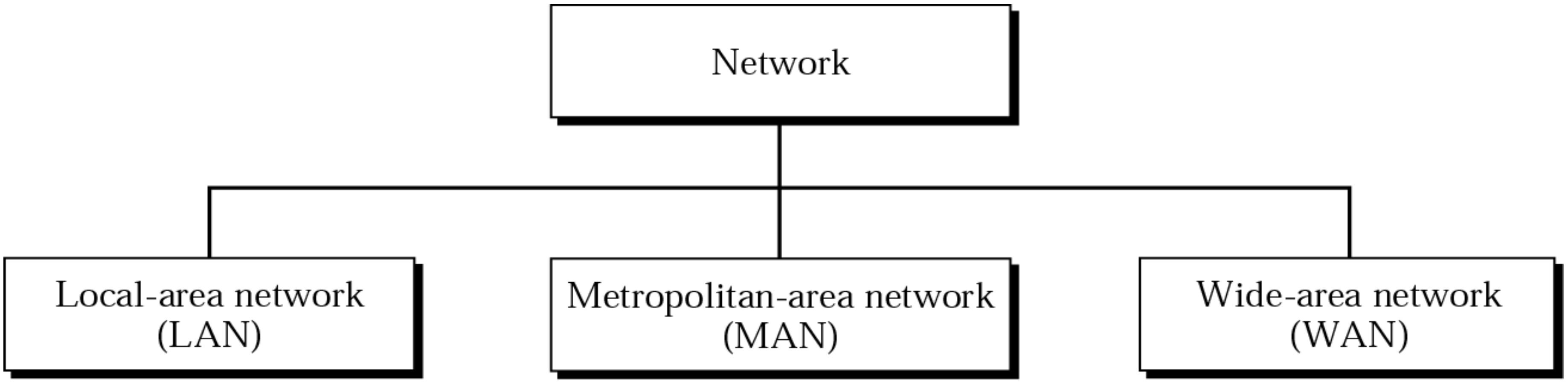

Drop
line
Drop
line
Drop
line
Drop
line
Cable end
Tap
Tap
Tap
Tap
Cable end

Introduction

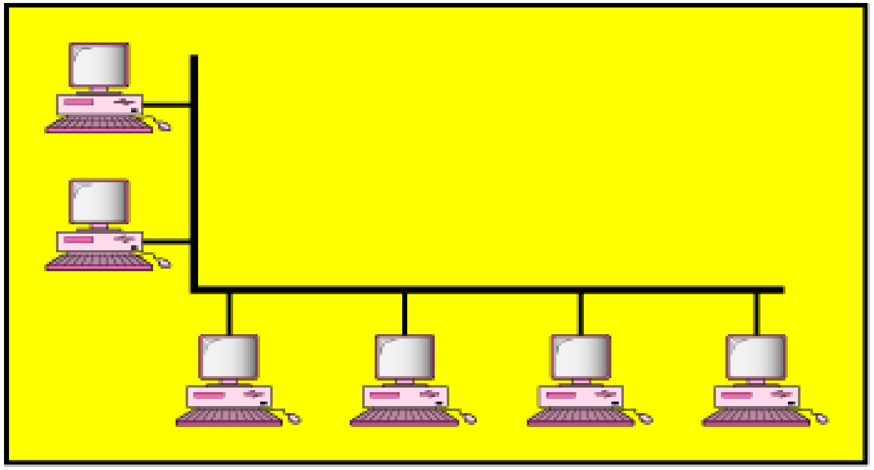
RING



Categories of Networks



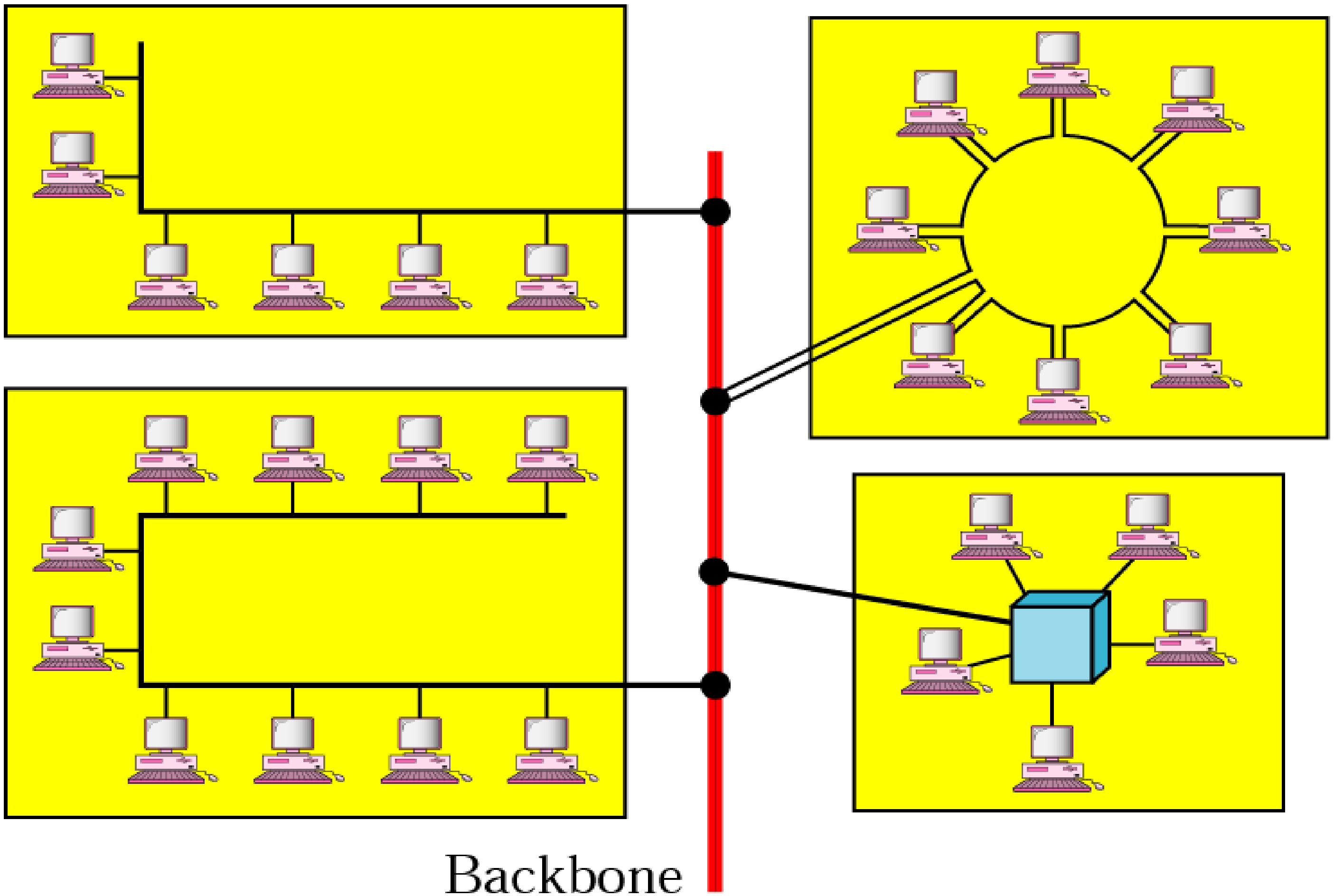
LAN



a. Single-building LAN

Introduction

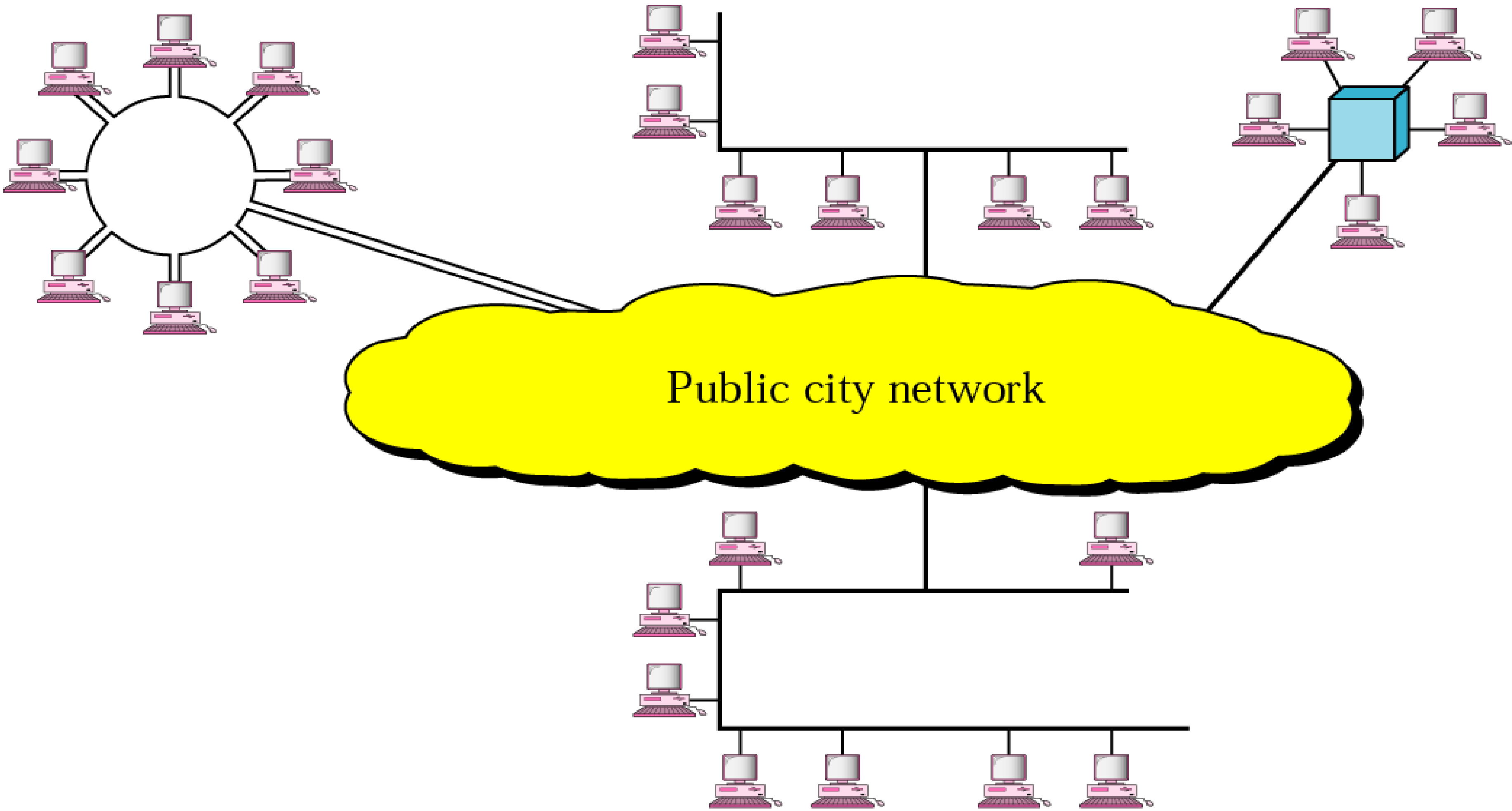
LAN



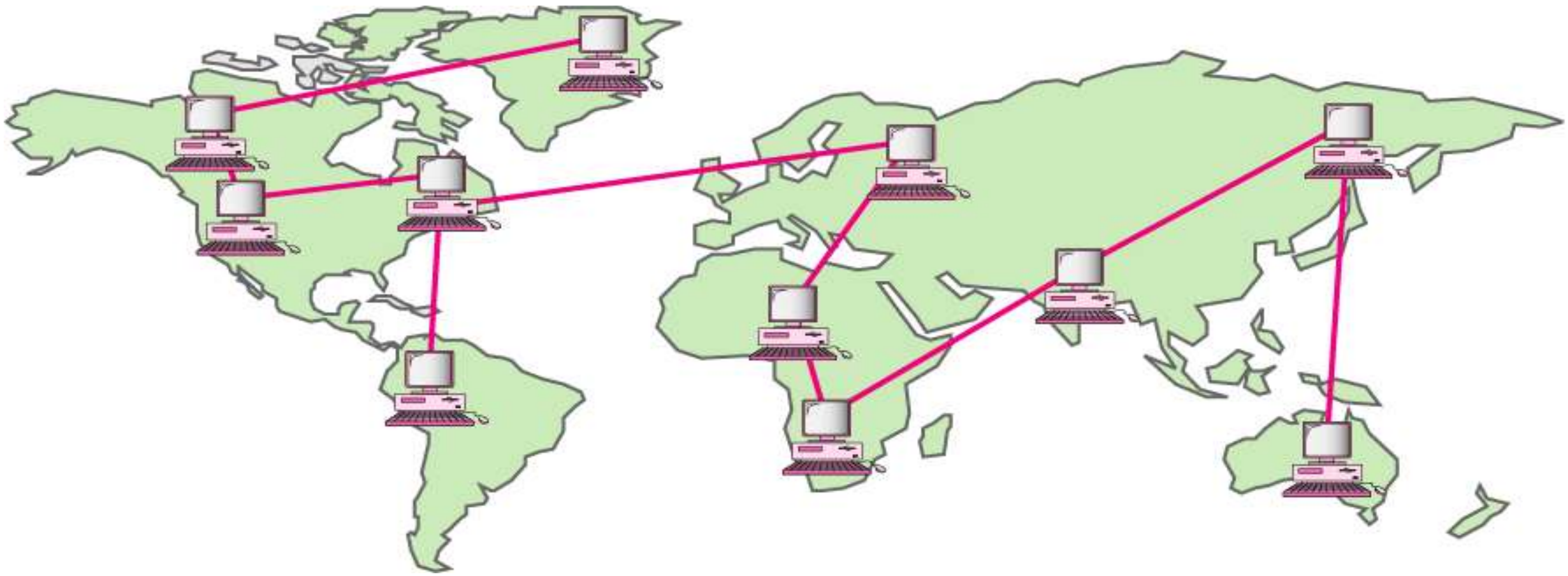
b. Multiple-building LAN

Introduction

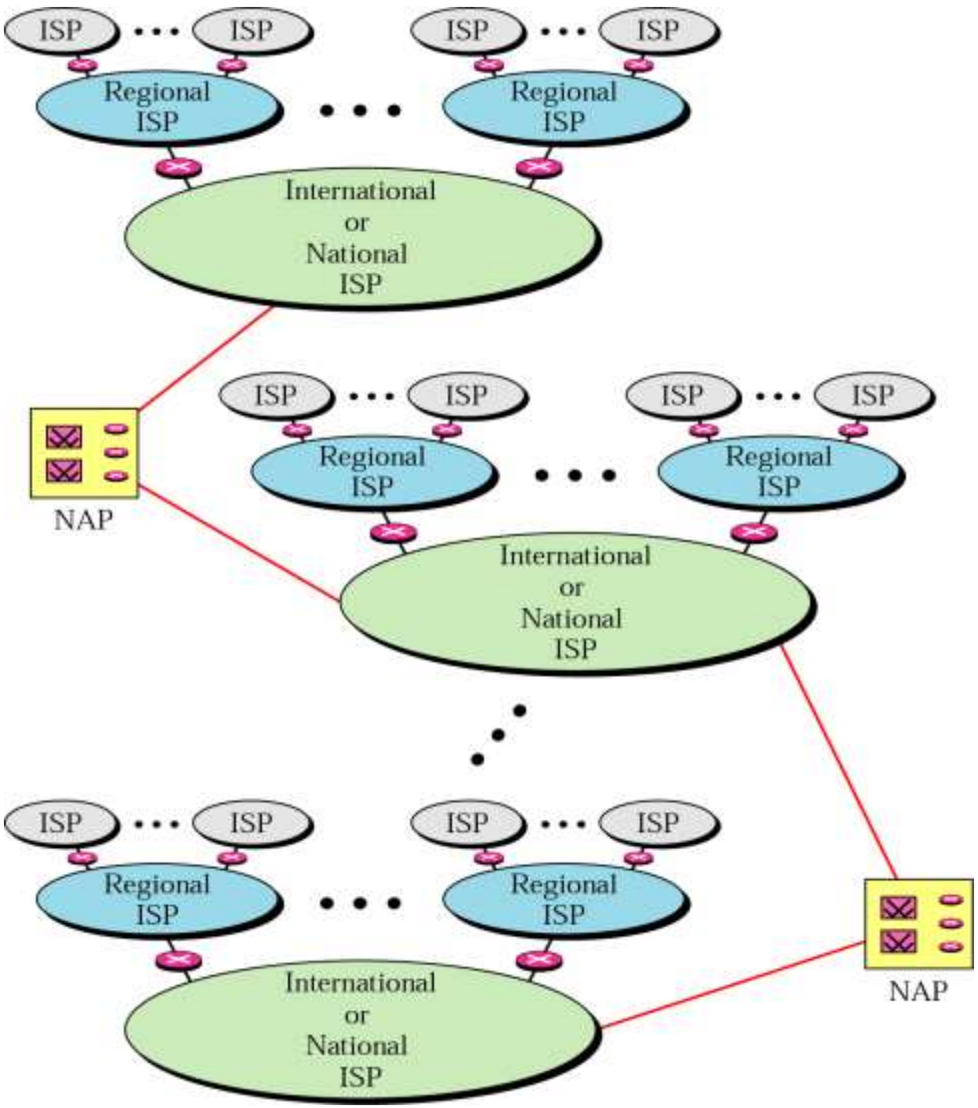
MAN



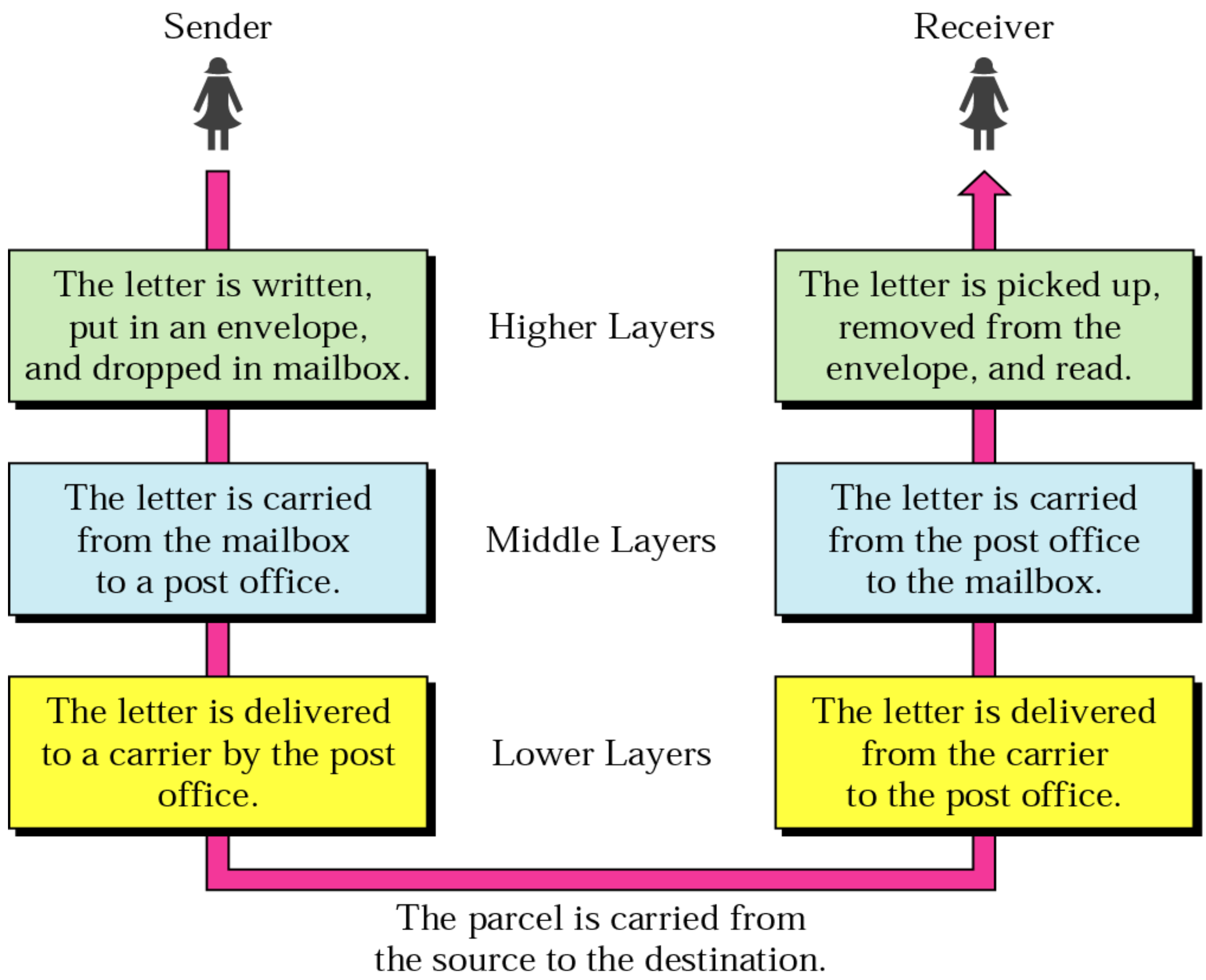
WAN



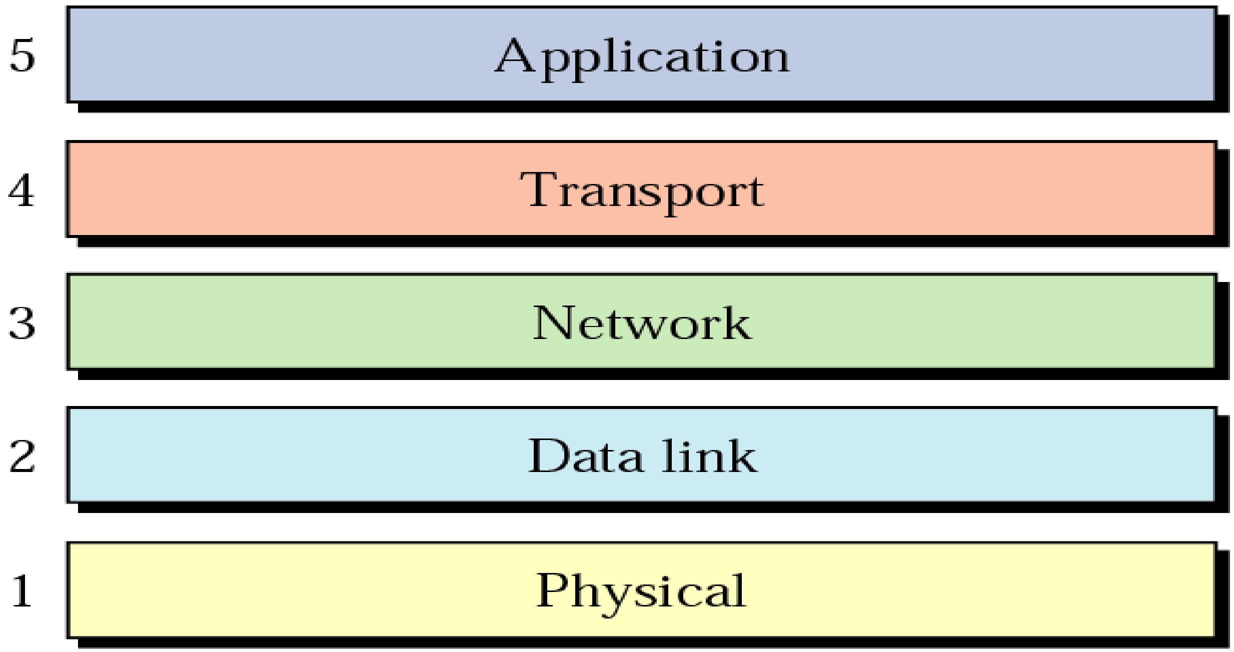
Internet Today



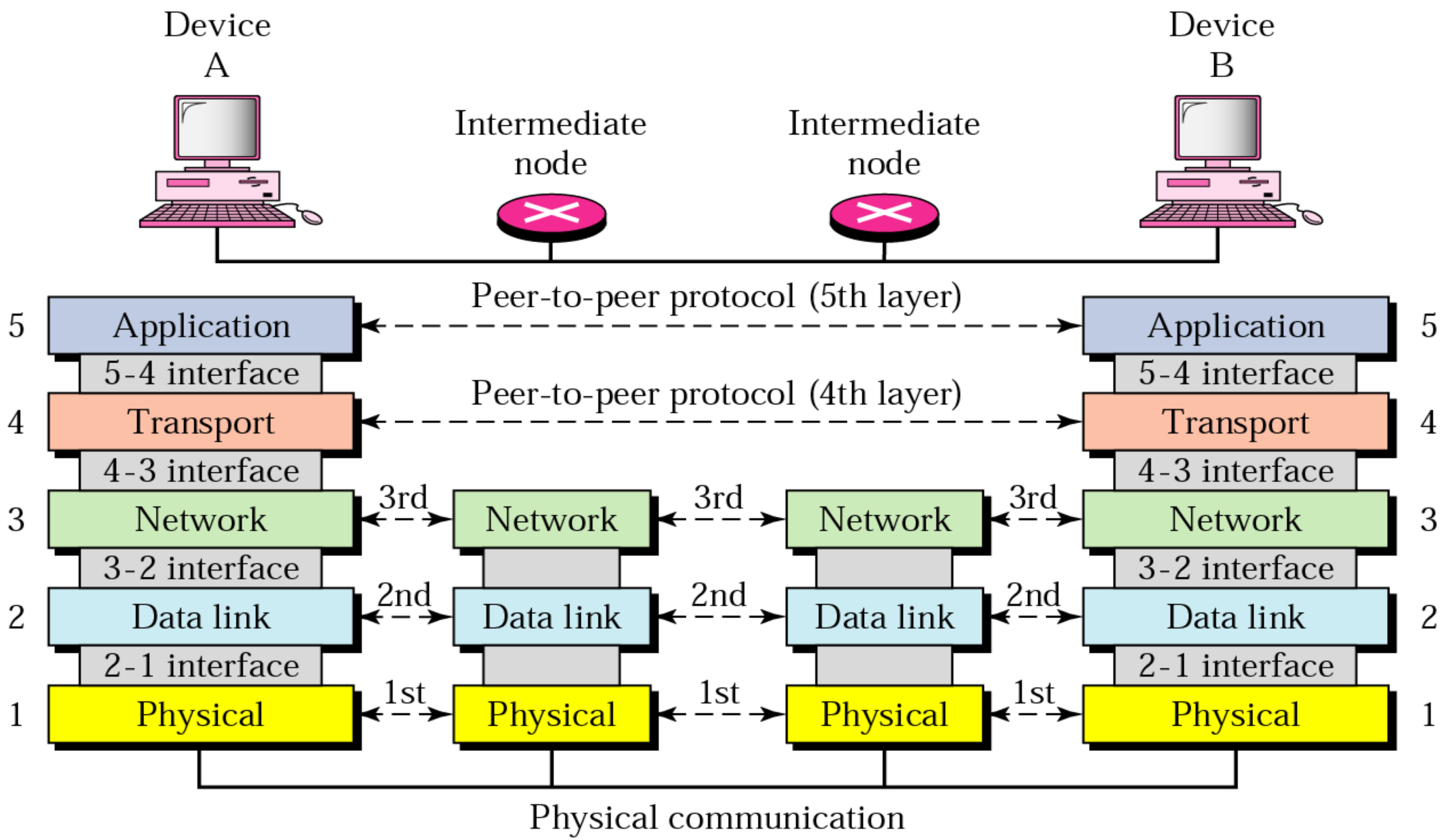
Network Models



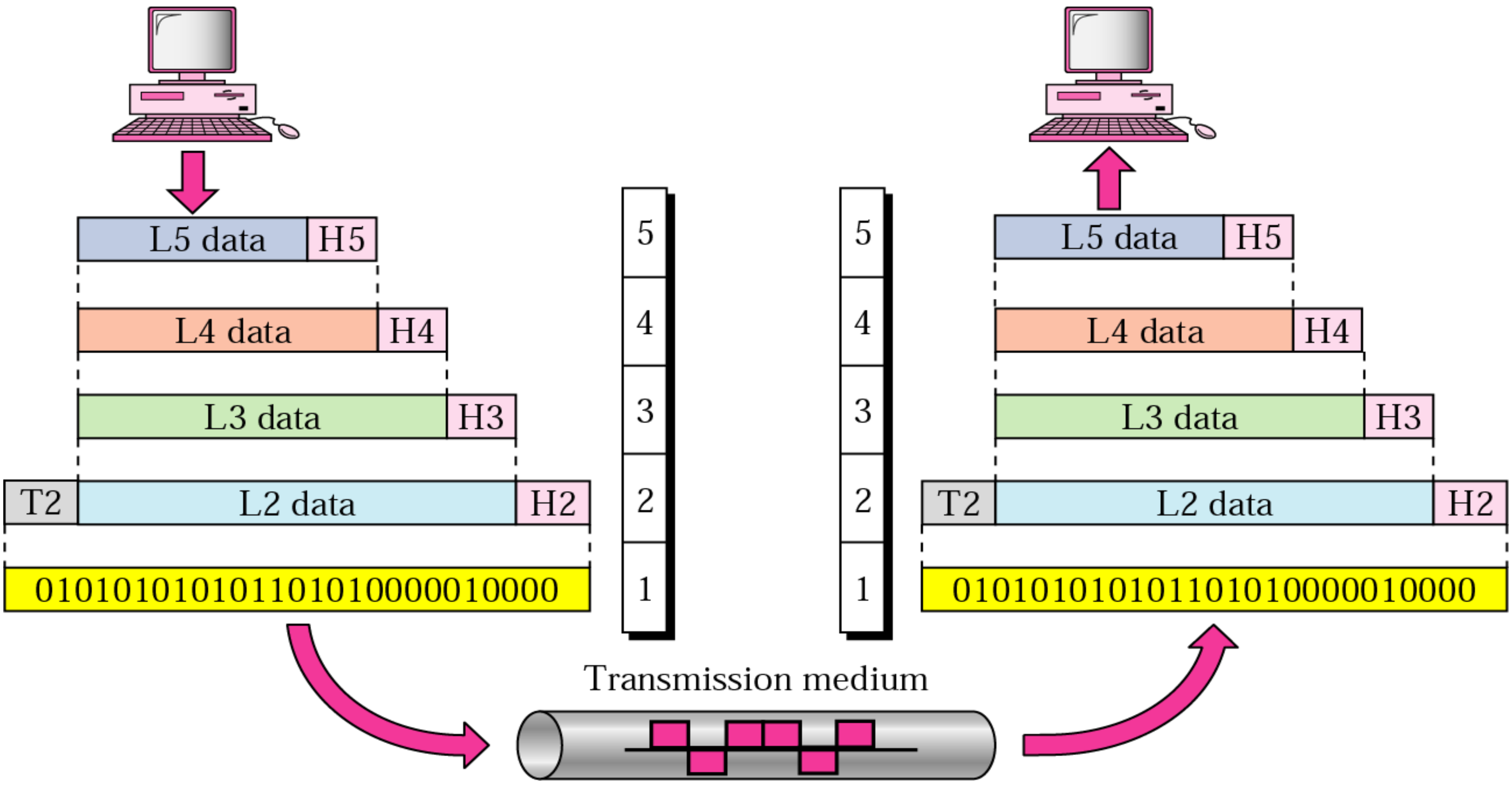
Internet Layers



Internet Layers



Internet Layers

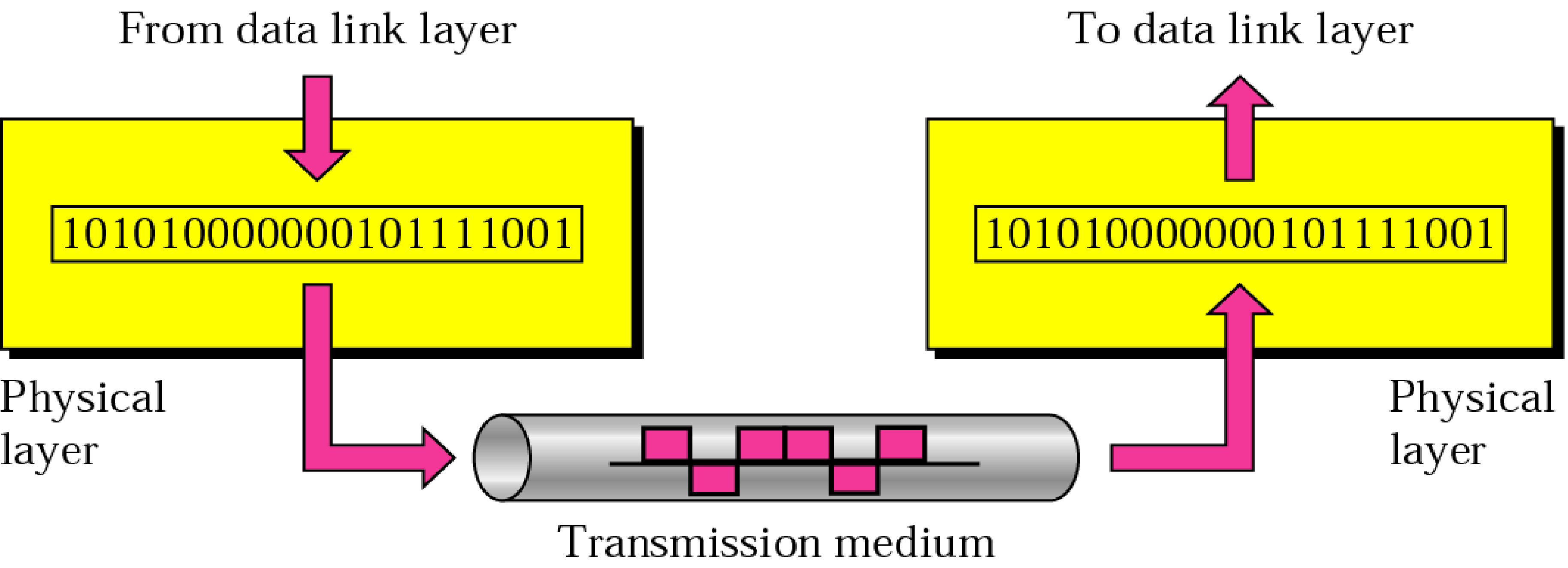


OSI Model

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data link
1	Physical

Physical Layer

The physical layer is responsible for transmitting individual bits from one node to the next.



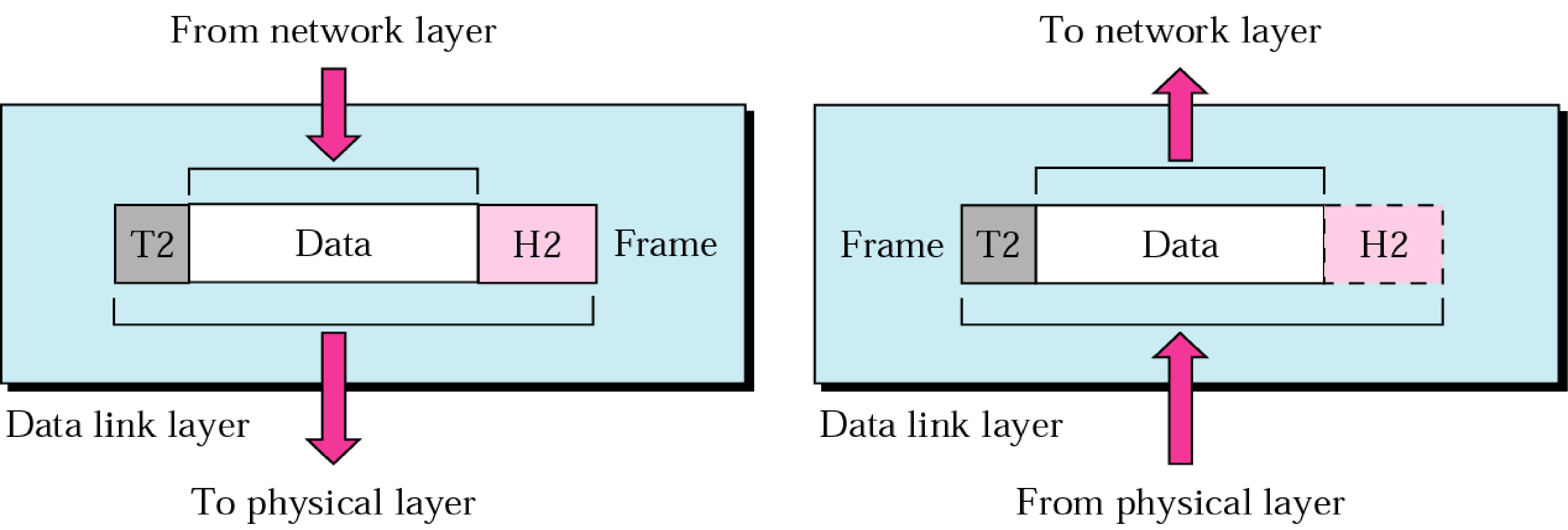
Physical Layer

Responsibilities of Physical Layer :-

- Physical Characteristics of interfaces and medium
- Representation of bits
- Data rate
- Synchronization of bits
- Line configuration
- Physical topology
- Transmission mode

Data Link Layer

The data link layer is responsible for transmitting frames from one node to the next.

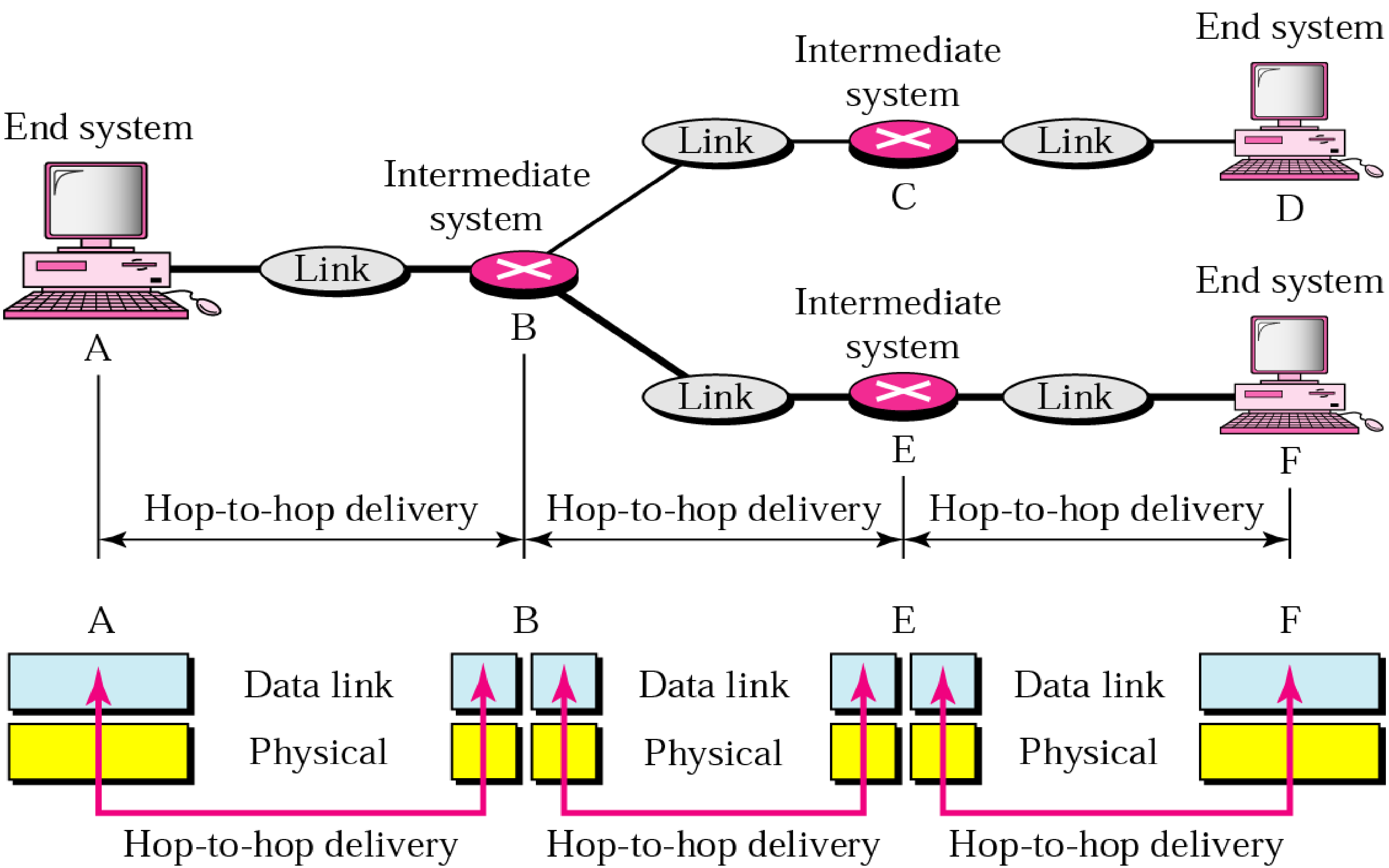


Data Link Layer

Responsibilities of Data Link Layer :-

- Framing
- Physical Addressing
- Flow Control
- Error Control
- Access Control

Node to Node Delivery



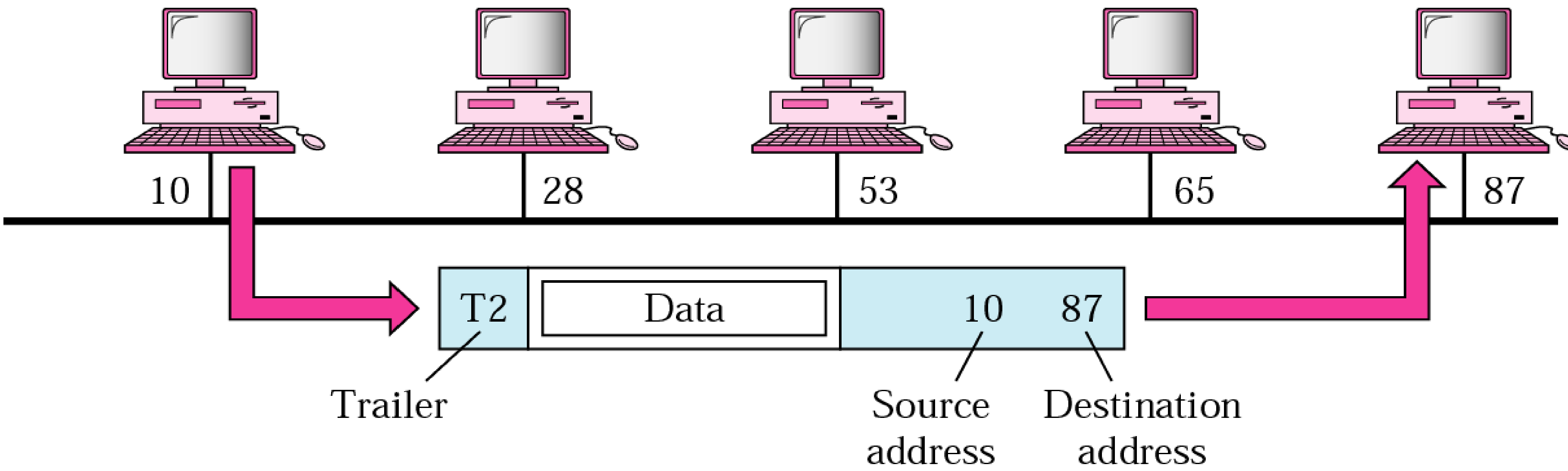
Node to Node Delivery

Example

- In Figure, a node with physical address 10 sends a frame to a node with physical address 87.
- The two nodes are connected by a link. At the data link level this frame contains physical addresses in the header. These are the only addresses needed.
- The rest of the header contains other information needed at this level. The trailer usually contains extra bits needed for error detection

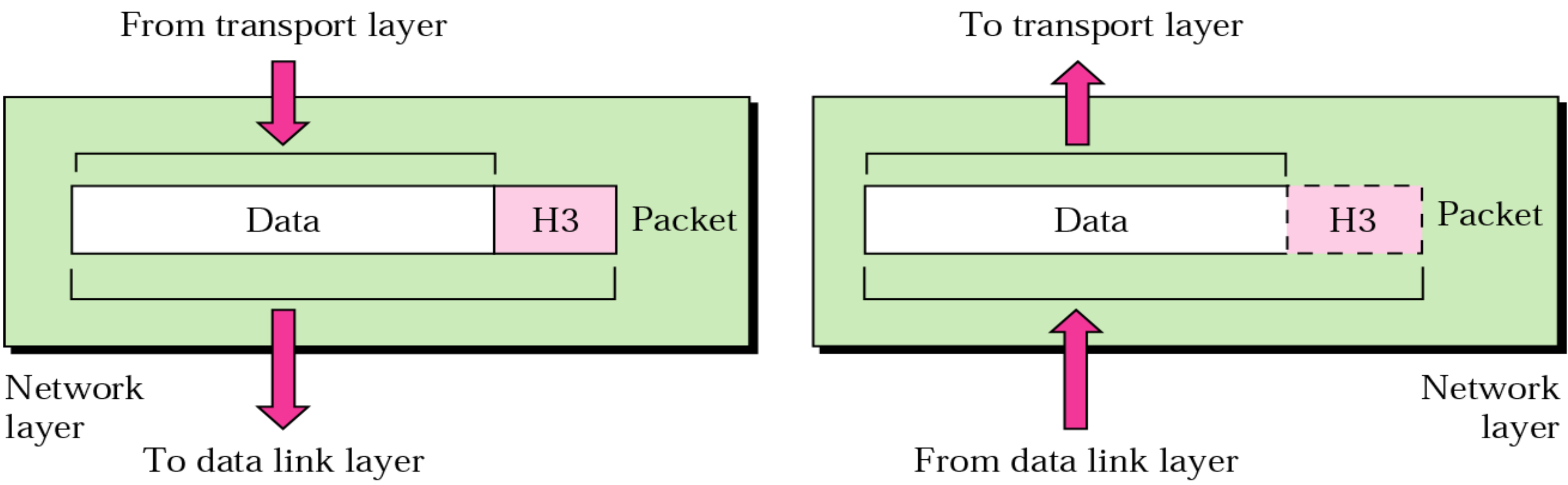
Node to Node Delivery

Example



Network Layer

The network layer is responsible for the delivery of packets from the original source to the final destination.



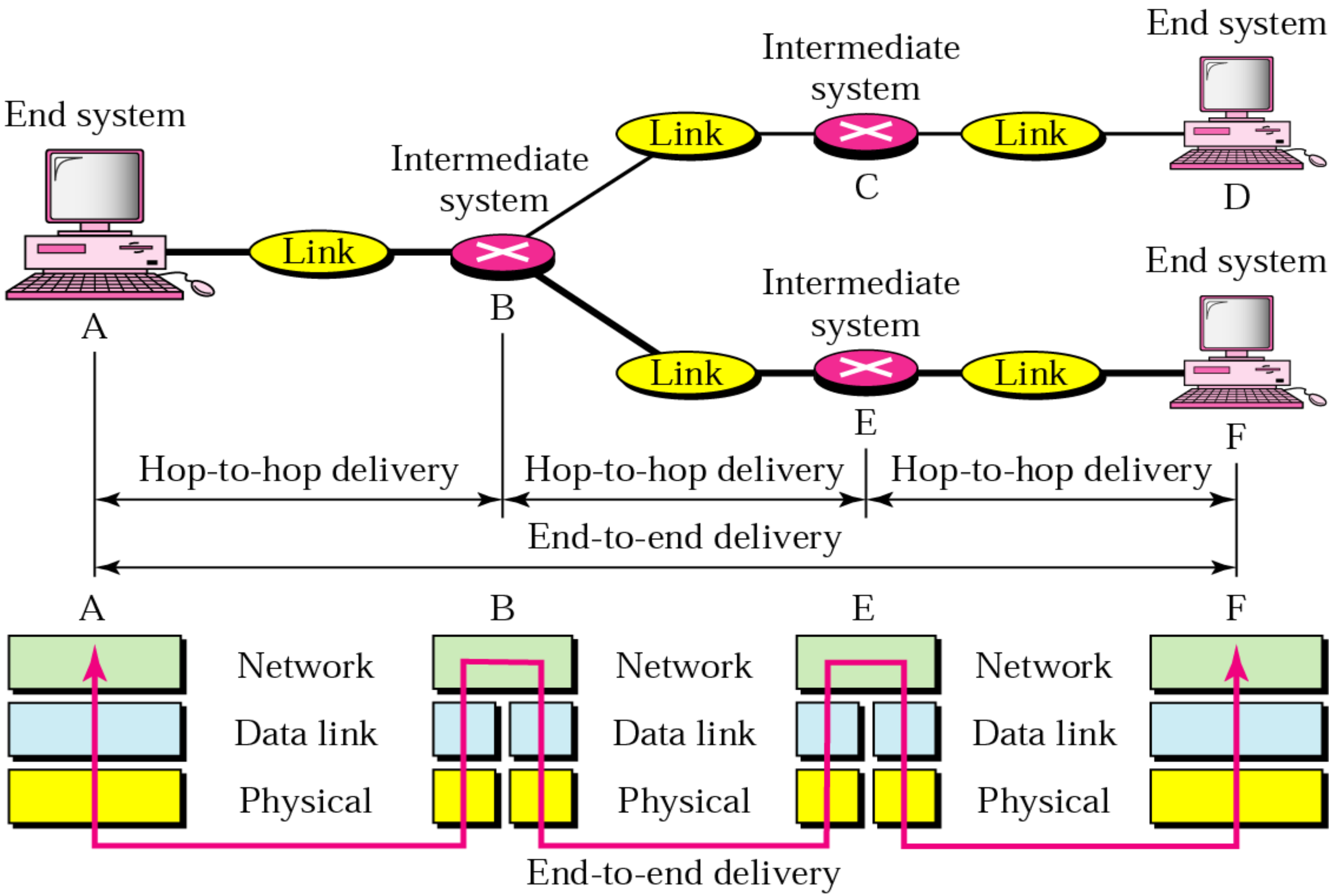
Network Layer

Responsibilities of Network Layer :-

•Logical Addressing

•Routing

Source – to - Destination



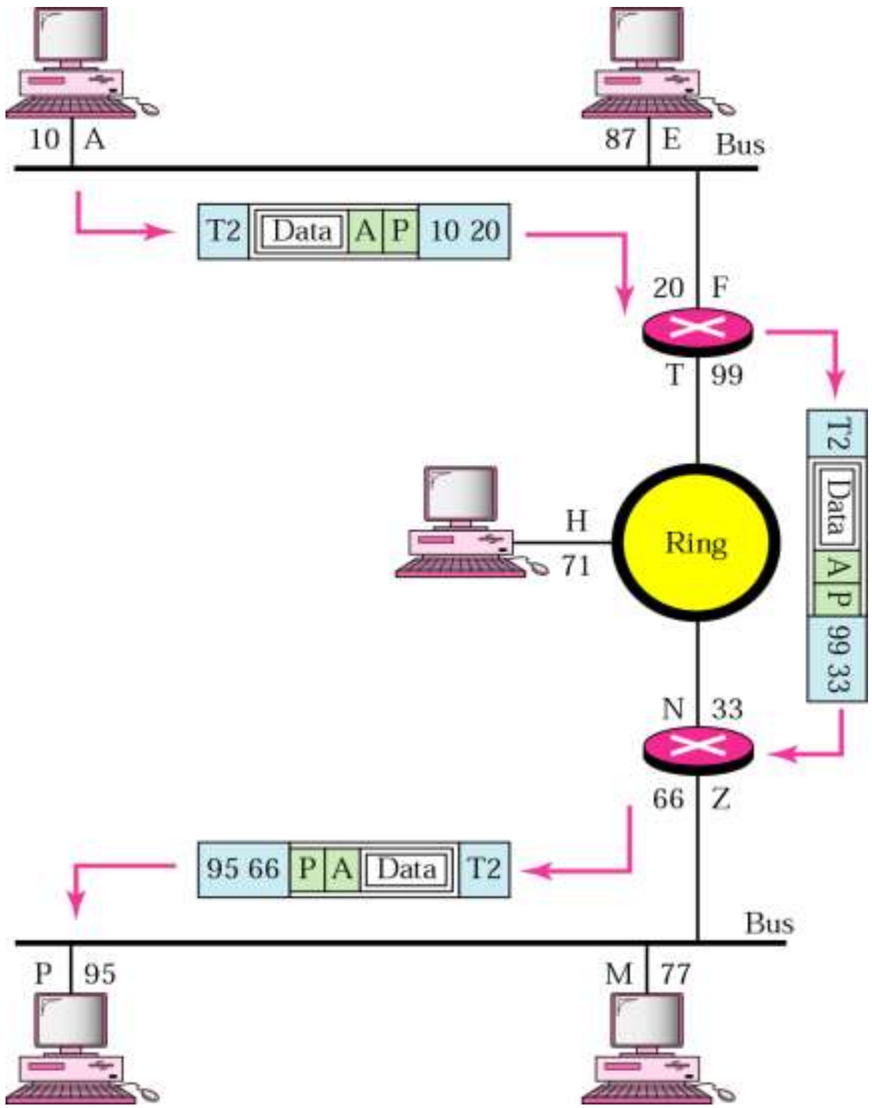
Source – to - Destination

Example

- In Figure, we want to send data from a node with network address A and physical address 10, located on one LAN, to a node with a network address P and physical address 95, located on another LAN.
- Because the two devices are located on different networks, we cannot use physical addresses only; the physical addresses only have local jurisdiction.
- What we need here are universal addresses that can pass through the LAN boundaries. The network (logical) addresses have this characteristic.

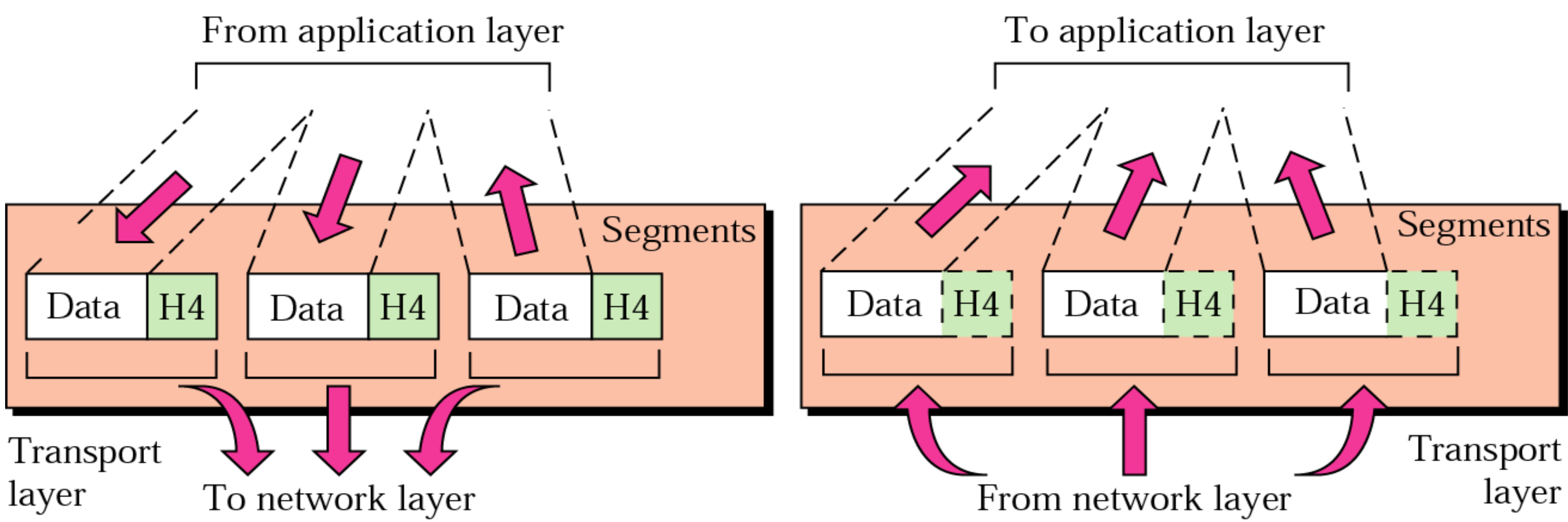
Source – to - Destination

Example



Transport Layer

The transport layer is responsible for delivery of a message from one process to another.



Transport Layer

Responsibilities of Transport Layer :-

•Service-point addressing

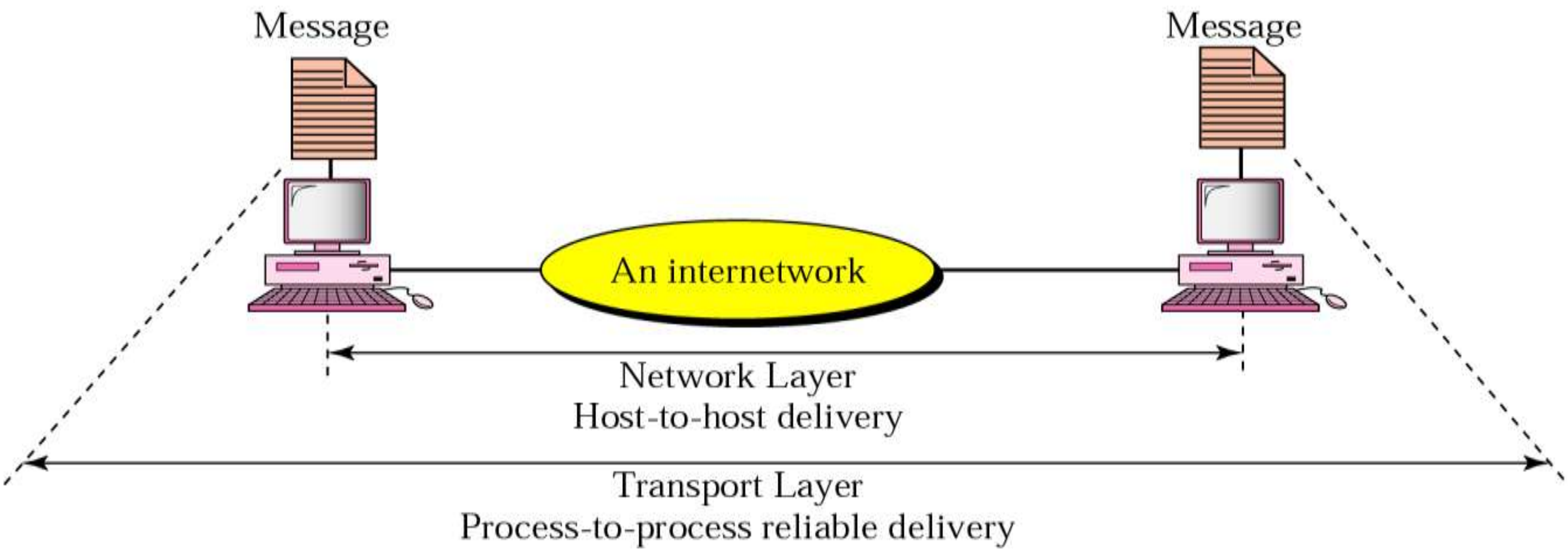
•Segmentation and reassembly

•Connection control

•Flow control

•Error Control

Process to Process



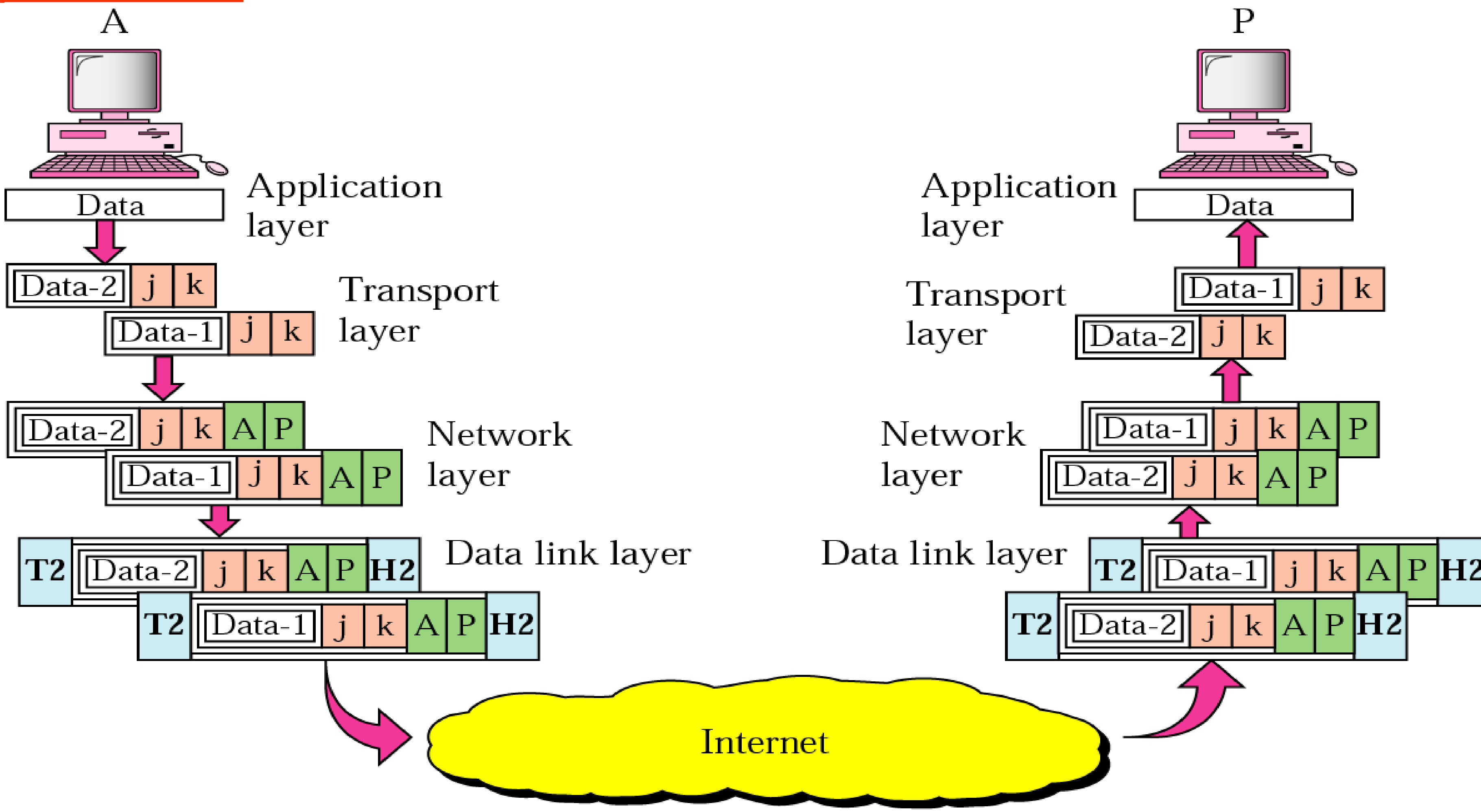
Process to Process

Example

- Figure, shows an example of transport layer communication. Data coming from the upper layers have port addresses j and k (j is the address of the sending process, and k is the address of the receiving process).
- Since the data size is larger than the network layer can handle, the data are split into two packets, each packet retaining the port addresses (j and k). Then in the network layer, network addresses (A and P) are added to each packet.

Process to Process

Example



Session Layer

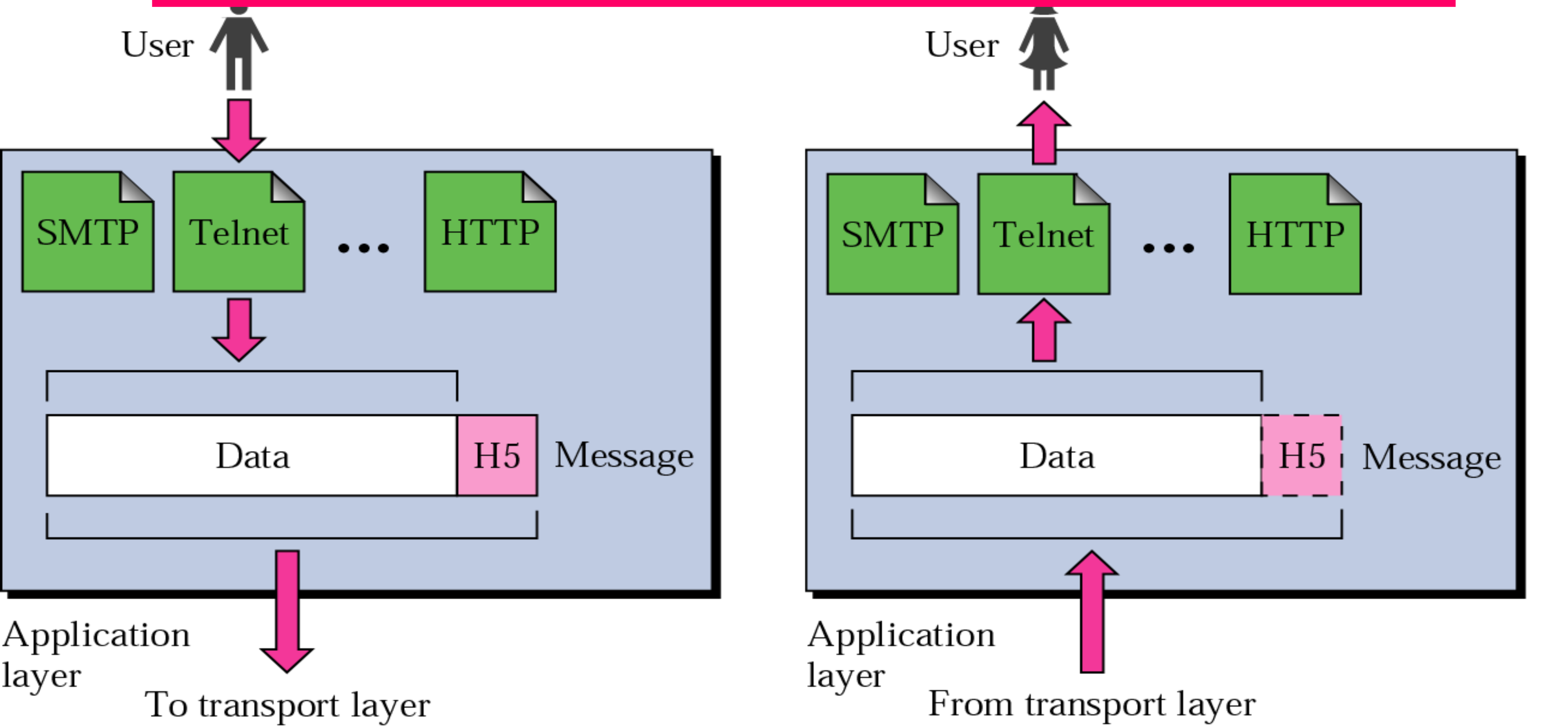
The session layer is responsible for dialog control and synchronization.

Presentation Layer

The presentation layer is responsible for translation, compression, and encryption.

Application Layer

The application layer is responsible for providing services to the user.

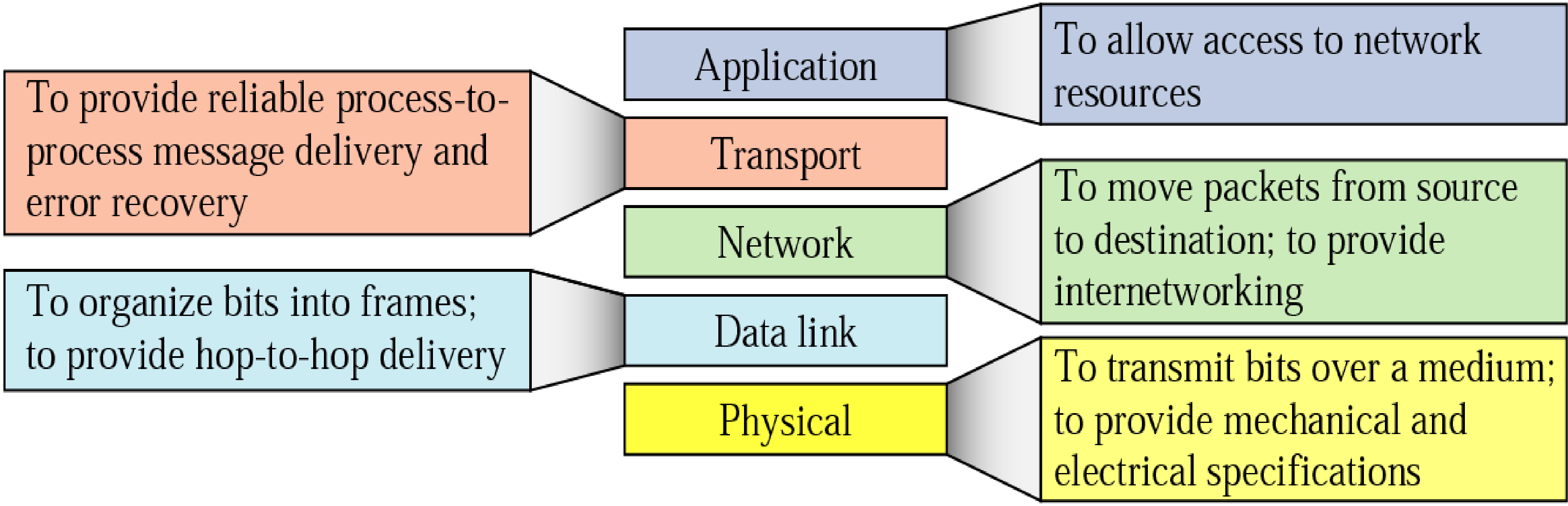


Application Layer

Services provided by the Application Layer :-

- Network virtual terminal
- File transfer, access and management
- Mail services
- Directory services

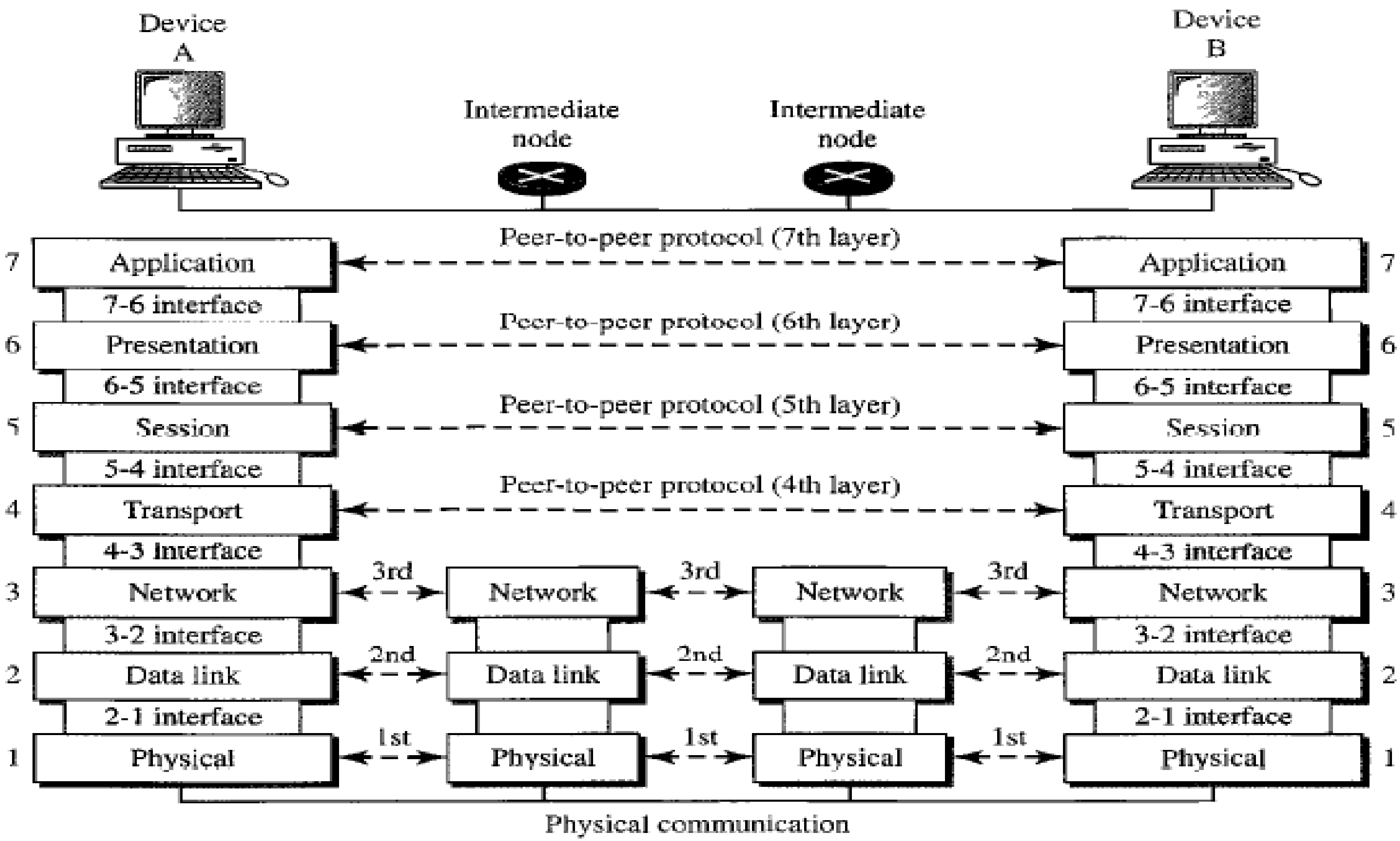
Summary of Layers



OSI Model

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data link
1	Physical

OSI Model



Device A
Device B
Intermediate node
Intermediate node
Peer-to-peer protocol (7th layer)
Peer-to-peer protocol (6th layer)
Peer-to-peer protocol (5th layer)
Peer-to-peer protocol (4th layer)
7 Application
7-6 interface
6 Presentation
6-5 interface
5 Session
5-4 interface
4 Transport
4-3 interface
3 Network
3-2 interface
2 Data link
2-1 interface
1 Physical
3rd
2nd
1st
Network
Data link
Physical
Physical communication

OSI Model

Physical layer	Deals with the mechanical and electrical specification of the interface and transmission media.
Data Link Layer	Transforms the physical layer, to a reliable link and is responsible for node-to-node delivery.
Network Layer	Responsible for the source-to-destination delivery of a packet across multiple links.

OSI Model

Transport Layer	Responsible for the source-to-destination (end-to-end) delivery of the entire message.
Session Layer	It establishes, maintains and synchronizes the interaction between communicating systems.
Presentation Layer	It concerns with the syntax and semantics of the information between two systems.

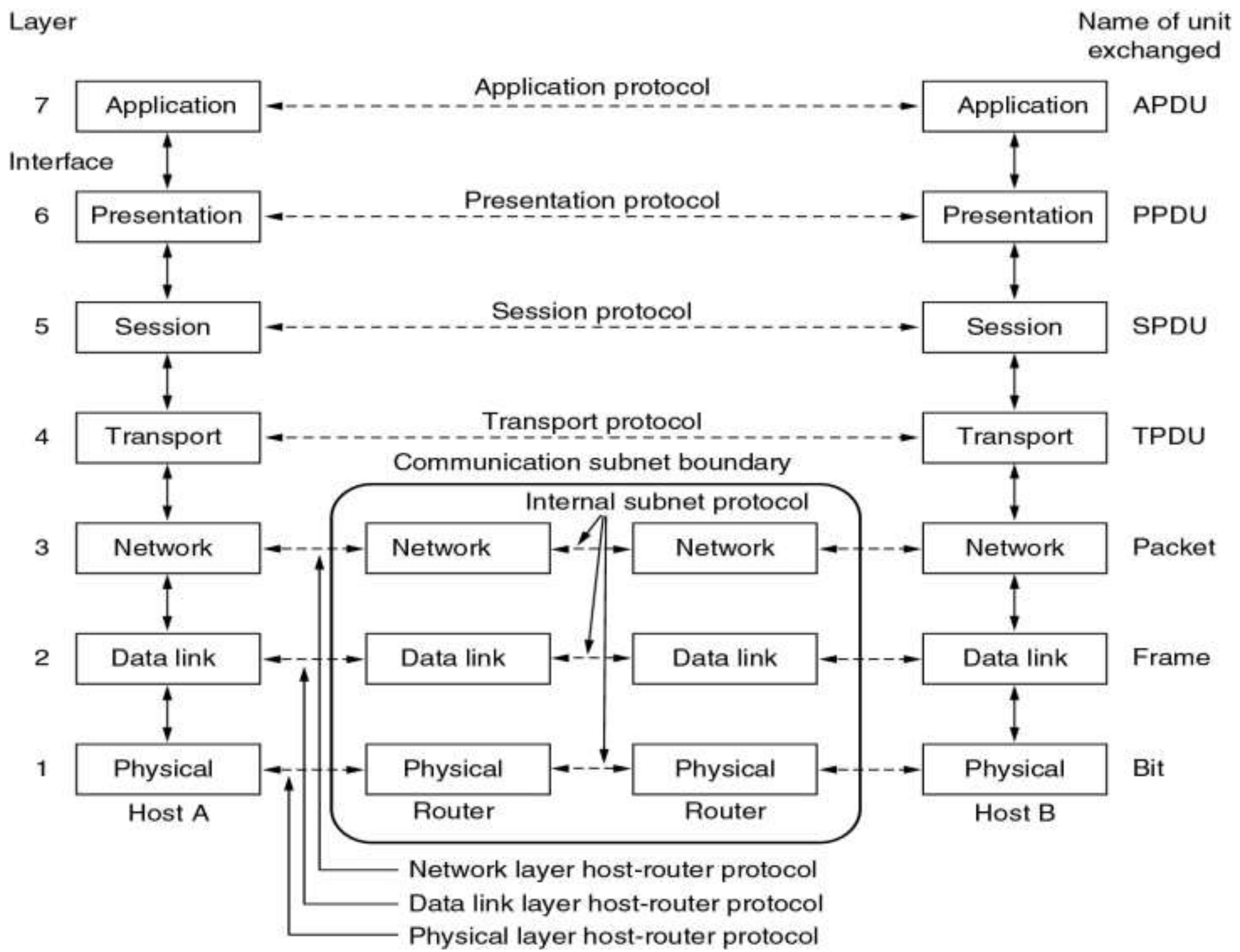
OSI Model

Application Layer	It provides user interfaces and support for services such as E-Mail, Remote Login and other types of Distributed Information Services.

Reference Models

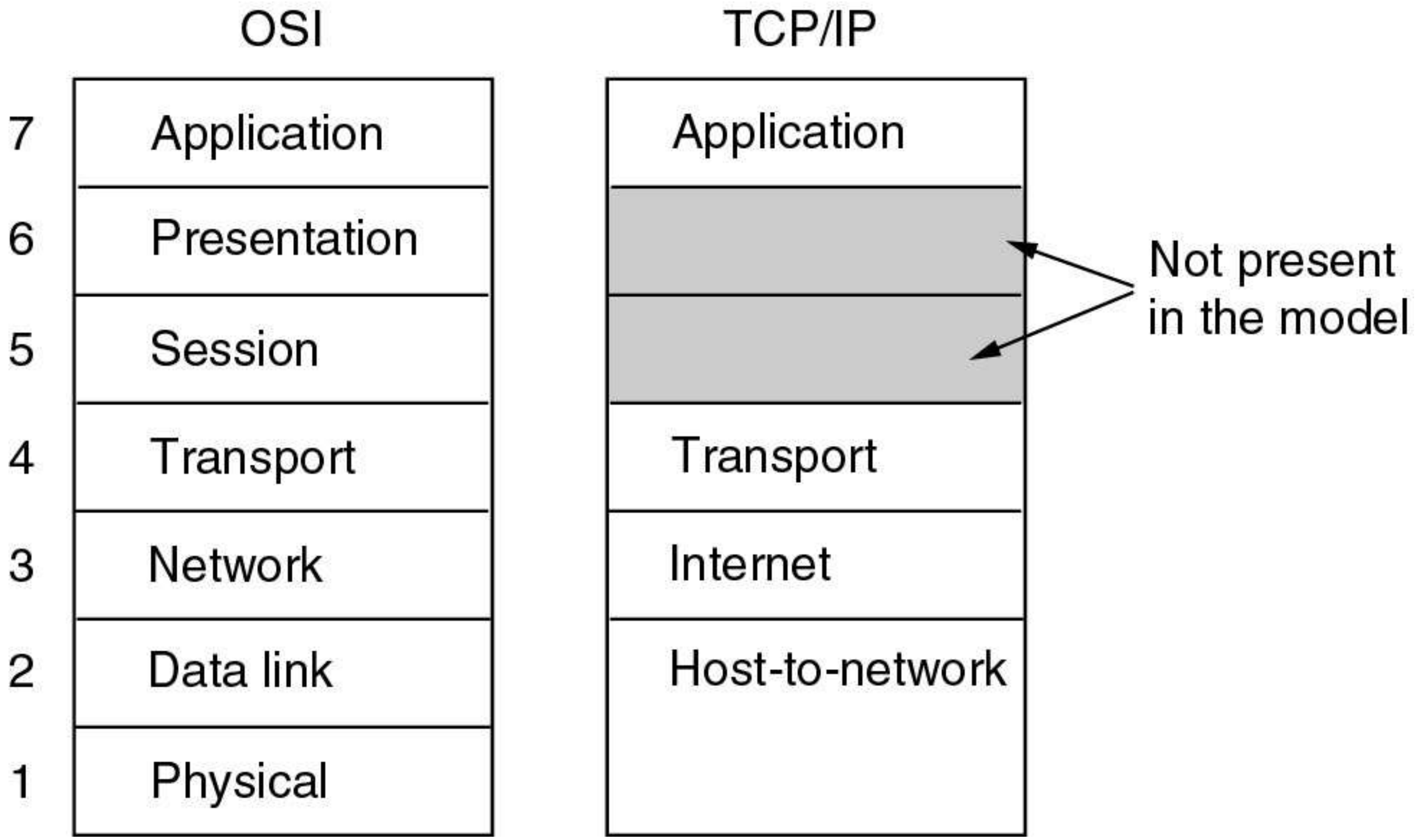
- The OSI Reference Model
- The TCP/IP Reference Model
- A Comparison of OSI and TCP/IP
- A Critique of the OSI Model and Protocols
- A Critique of the TCP/IP Reference Model

The OSI reference model.



Reference Models (2)

The TCP/IP reference model.



Comparing OSI and TCP/IP Models

Concepts central to the OSI model

- Services
- Interfaces
- Protocols

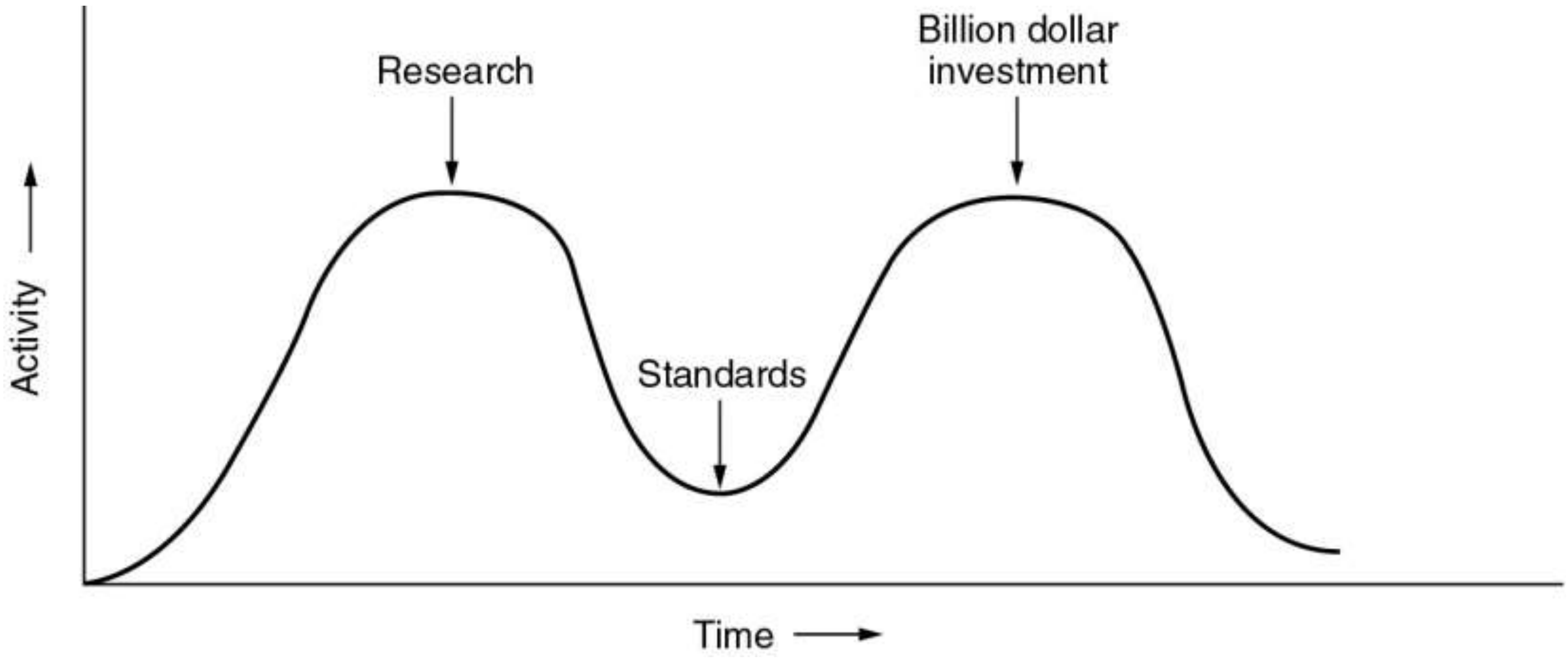
A Critique of the OSI Model and Protocols

Why OSI did not take over the world

- Bad timing
- Bad technology
- Bad implementations
- Bad politics
- **Disadvantages**
- Setting up a model is a challenging task.
- Sometimes, it becomes difficult to fit a new protocol into this model.
- It is only used as a reference model.

Bad Timing

The apocalypse of the two elephants.



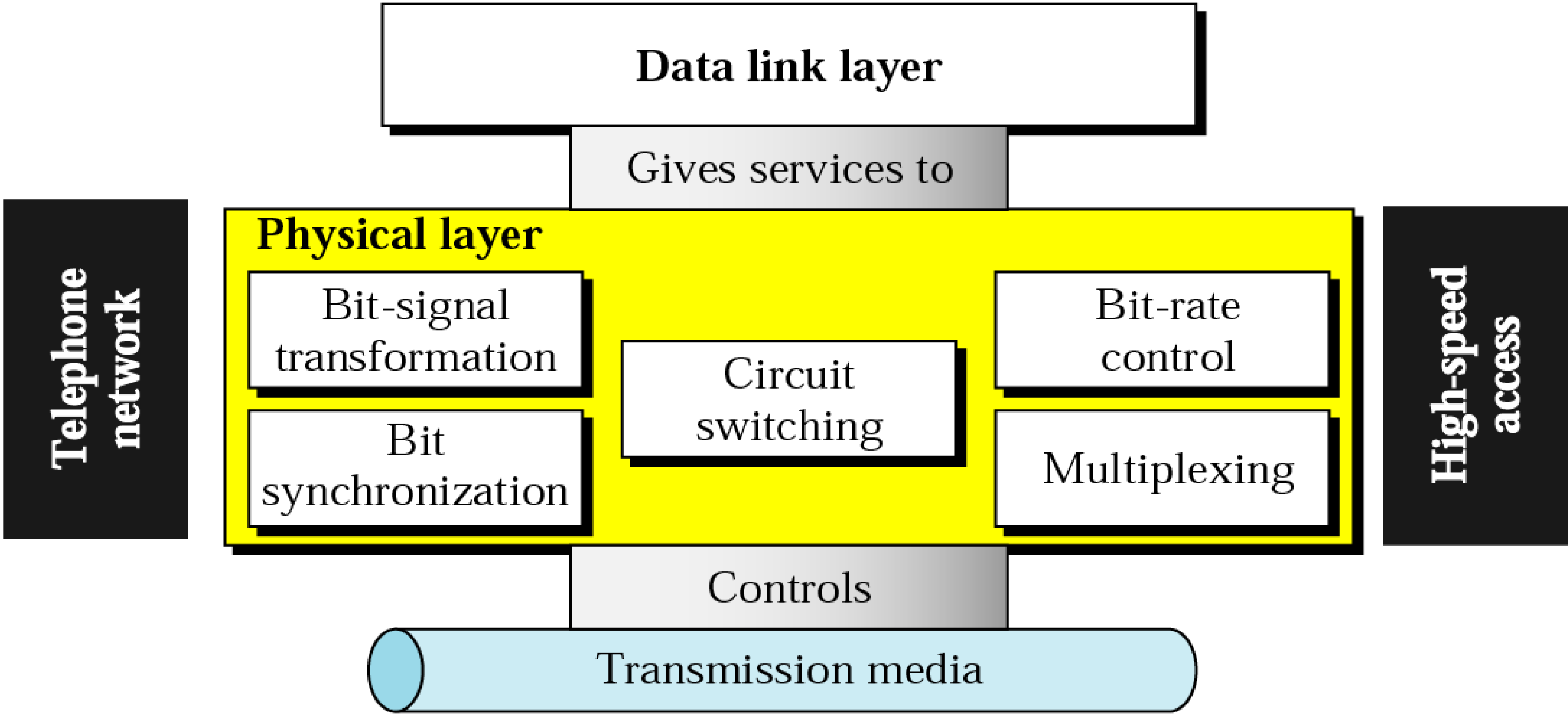
A Critique of the TCP/IP Reference Model

Problems:

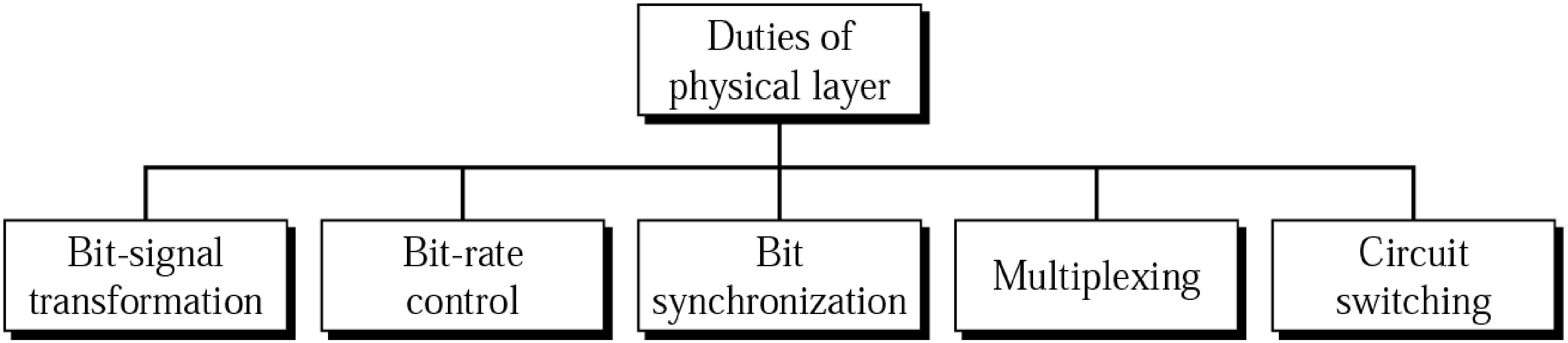
- Service, interface, and protocol not distinguished
- Not a general model
- Host-to-network “layer” not really a layer
- No mention of physical and data link layers
- Minor protocols deeply entrenched, hard to replace

Physical Layer

Position of Physical Layer



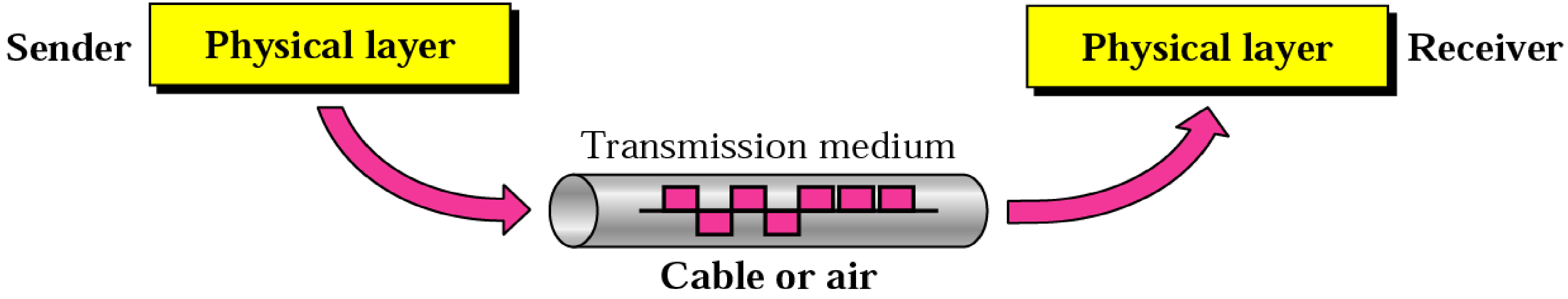
Physical Layer



Transmission Media

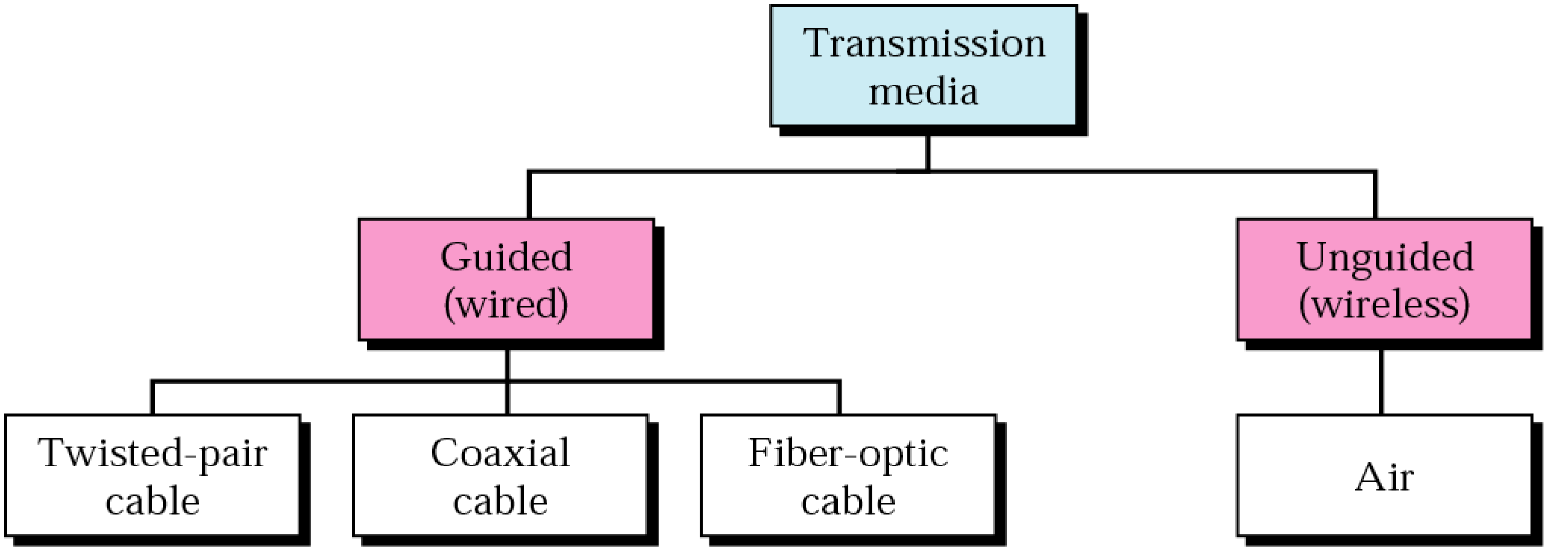
Cont …

Transmission medium and physical layer



Types of network

Based on communication channel



Cont …

Guided: Transmission capacity depends critically on the medium, the length, and whether the medium is point-to-point or multipoint (e.g. LAN). Examples are co-axial cable, twisted pair, and optical fiber.

Unguided: provides a means for transmitting electro-magnetic signals but do not guide them. Example wireless transmission.

Physical Layer

Guided Media

- Twisted-Pair Cable
- Coaxial Cable
- Fiber-Optic Cable

Physical Layer

•A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twister together

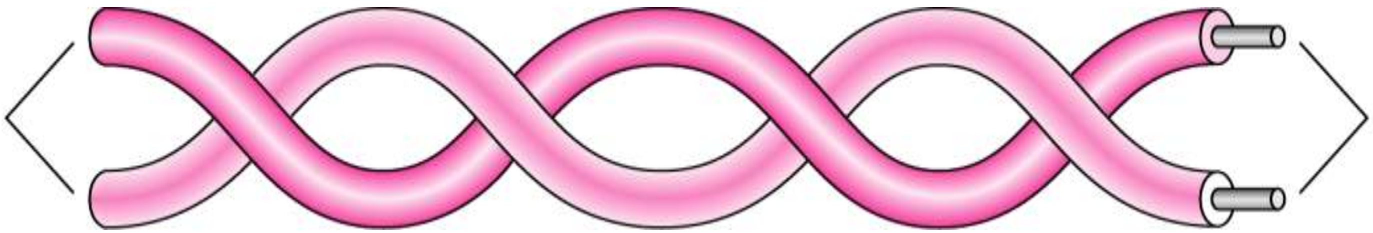
•One of the wires is use to carry signals to the receiver, and the other is used only as a ground reference

•The receiver uses the difference between the two.

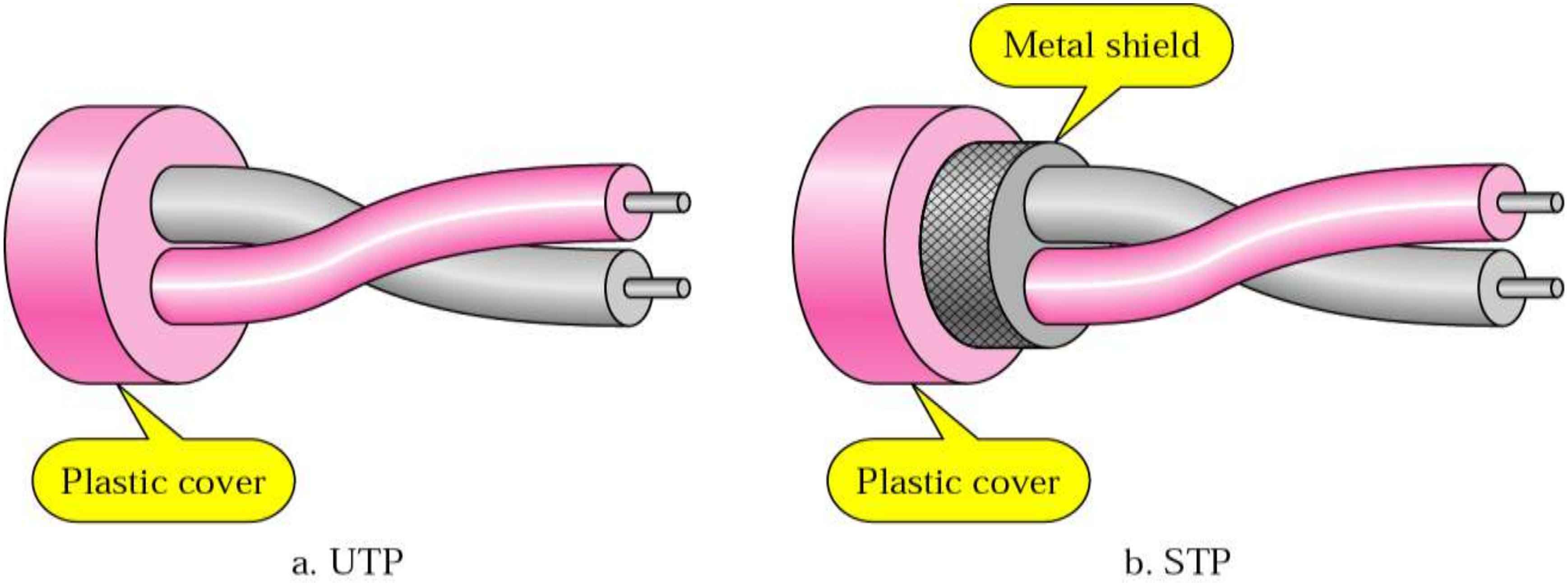
•In addition to the signal sent by the sender on one of the wires, interference (noise) and crosstalk may affect both wires and create unwanted signals.

•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.

Twisted-pair cable



UTP and STP



UTP: Unshielded twisted pair cable

STP: shielded twisted pair cable, cable has a metal foil covering that encases each pair of insulated conductors. Electro magnetic noise penetration is prevented by metal casing. Expensive, allow high transmission rate

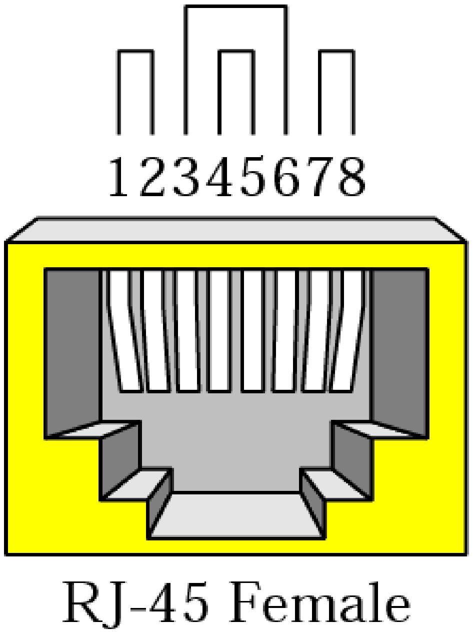
Cont'd…

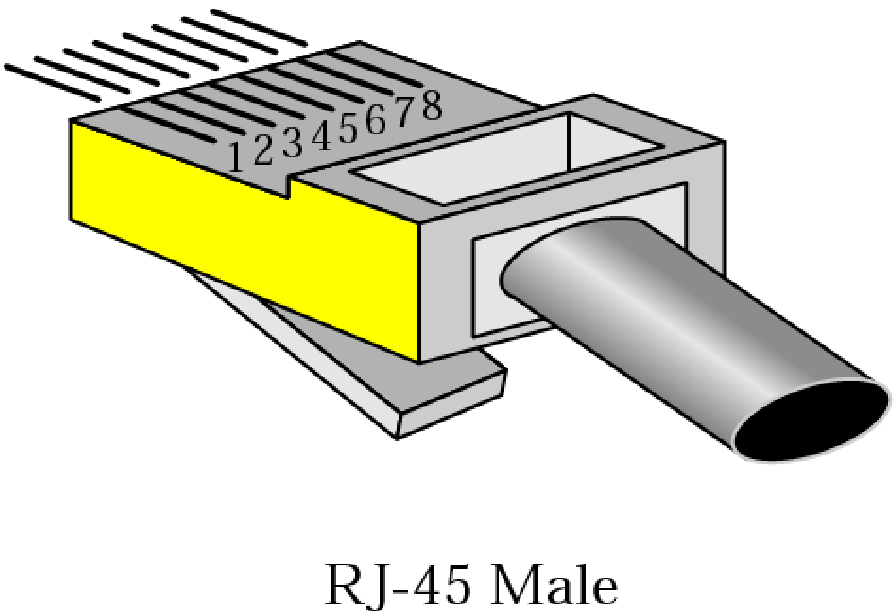
Categories of unshielded twisted-pair cables

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

Cont'd…

UTP connector



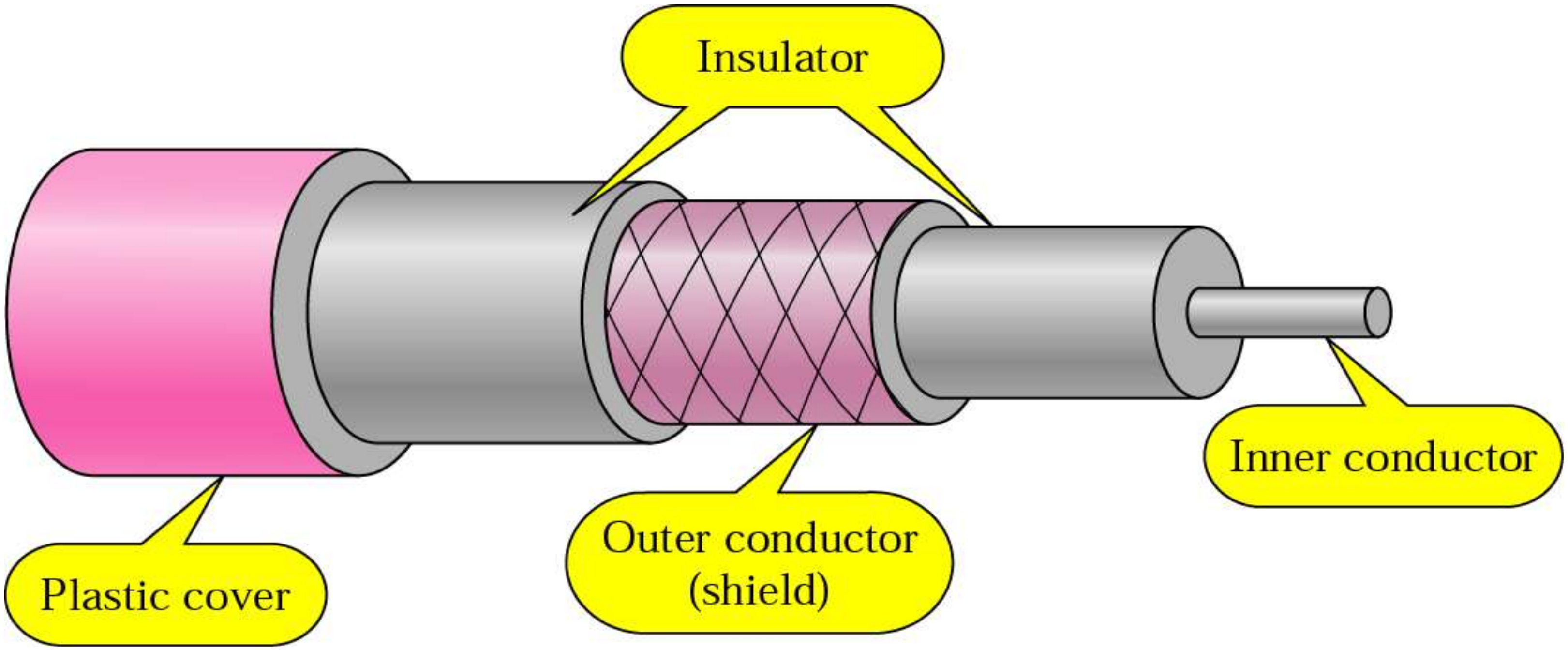


RJ 45 connector is used with Ethernet cable in computer networking

RJ 11 connector is used in connecting telephone units

Cont'd…

Coaxial cable



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•Coaxial cable carries signals of higher frequency ranges than those in twisted pair cable, in part because the two media are constructed 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.

•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.

Cont'd…

Categories of coaxial cables

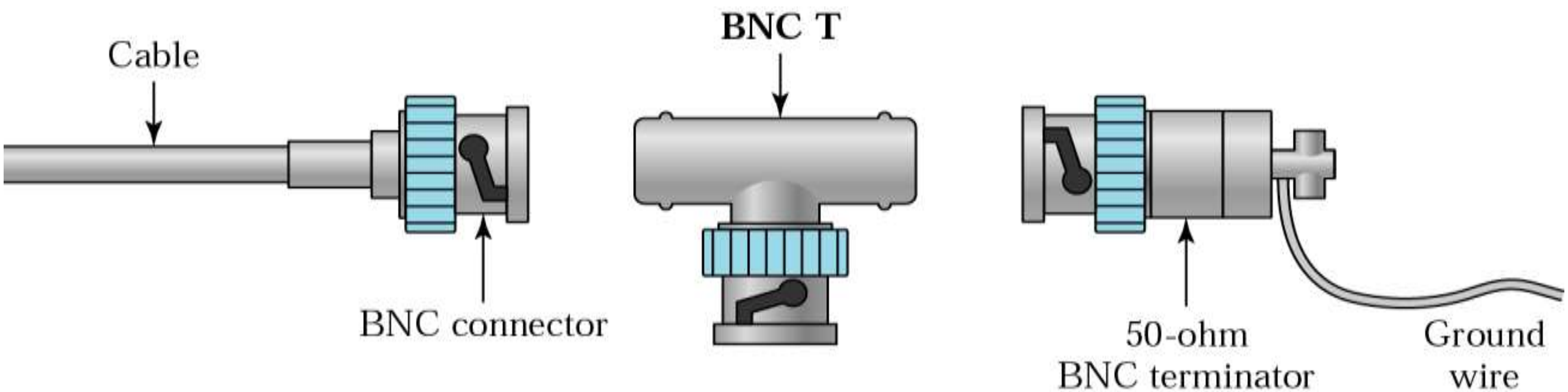
Category	Impedance	Use
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

RG-Radio Government (ratings)

Each RG number denotes a unique set of physical specification

Cont'd…

BNC connectors



BNC – Bayone-Neill-Concelman

Cont'd…

•The BNC connector is used to connect the end of the cable to a device, such as a TV set

•BNC T connector is used in ETHERNET

•BNC terminator is used at the end of the cable to prevent the reflection of the signal.

Cont'd…

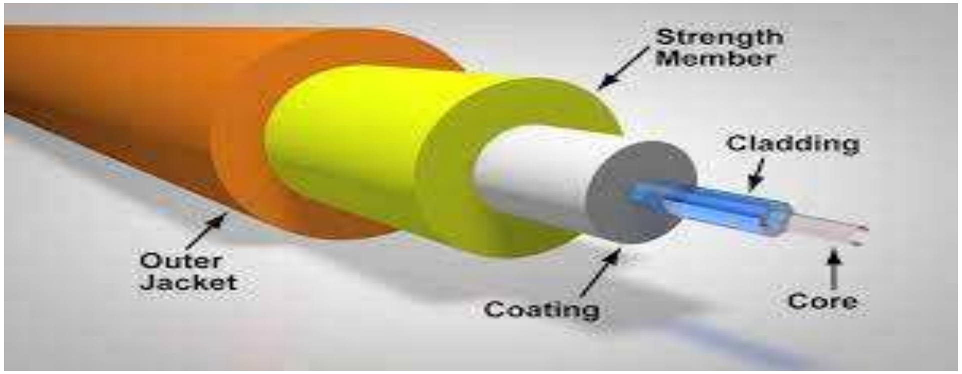
- The attenuation is much higher in coaxial cable that in twister pair.

- In other words, although coaxial cable has a much higher bandwidth, the signal weakens rapidly and requires the frequent use of repeaters.

- It is less affected by external magnetic field.

Optical Fiber

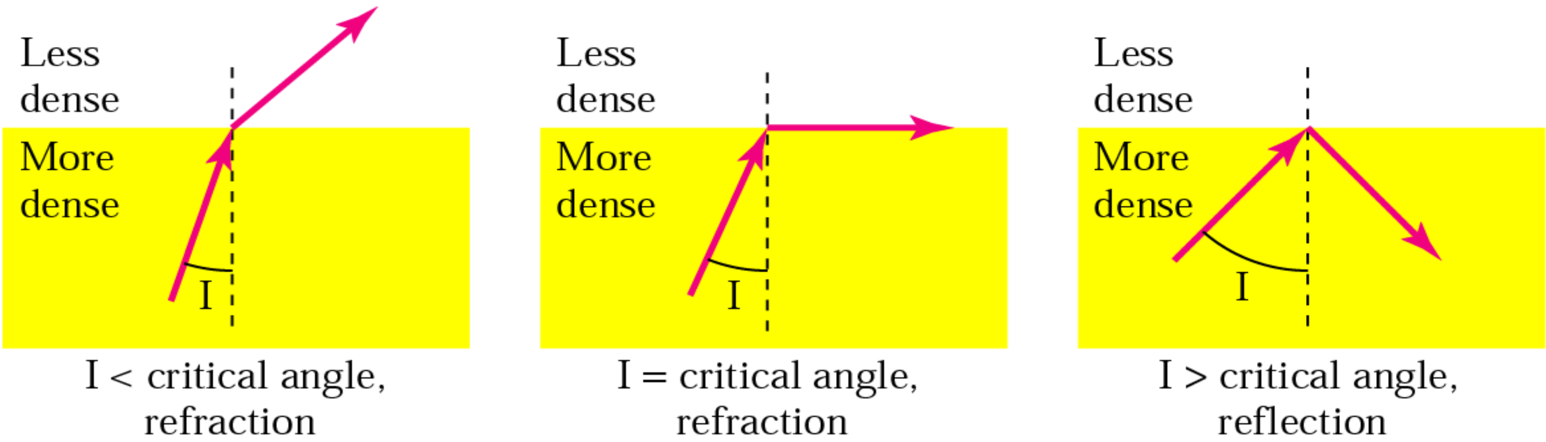
•Optical Fiber is made of glass or plastic and transmit signals in the form of light.



•Light travels in a straight line as long as it is moving through a single medium substance.

•If a ray of light traveling through one instance suddenly enters another substance (of a different density), the ray changes direction.

Bending of light ray



Optical Fiber

- If the angle of incidence I (the angle the ray makes with the line perpendicular to the interface between the two substance) is less that the critical angle, the ray refracts and moves closer to the surface.

- If the angle of incidence is equal to the critical angle, the light bends along the surface.

- If the angle I greater than the critical angle, the ray reflects (makes a turn) and travels again in the denser substance.

- Note that the critical angle is property of the substance, and its value differs from one substance to another.

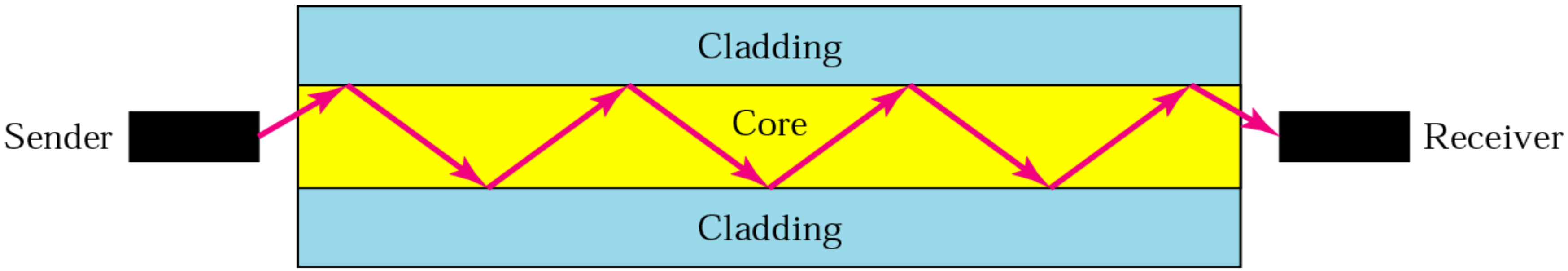
Optical Fiber

- Optical fibers use reflection to guide light through a channel.

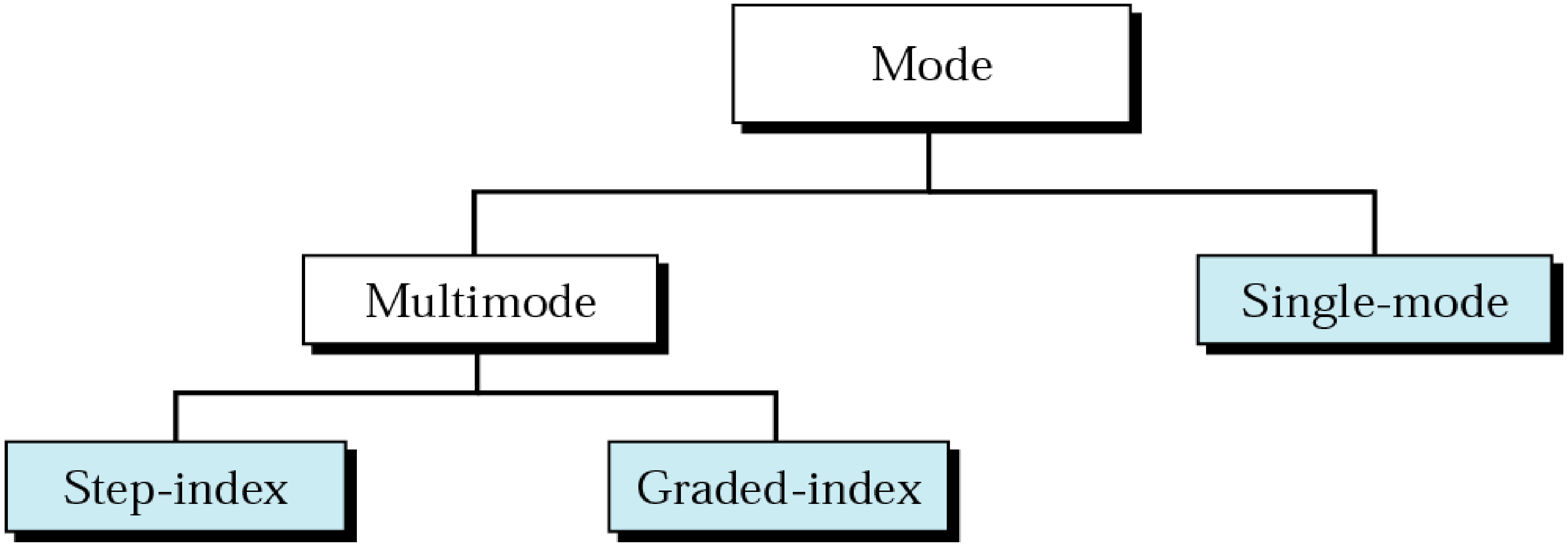
- A glass or plastic is surrounded by a cladding of less dense glass or plastic.

- The difference in density of the two materials must be such that a beam of light moving through the core is reflected of the cladding instead of being refracted into it.

Optical fiber



Propagation modes



Optical Fiber

- **Multimode** is so named because multiple beams from a light source move through the core in different paths.

- In **multimode step-index** fiber, the density of the core remains constant from the center to the edges.

- A beam of light moves through this constant density in a straight line until it reaches the interface of the core and the cladding.

- At the interface, there is an abrupt change due to a lower density, this alters the angle of the beam's motion.

- The term step index refers to the suddenness of this change, which contributes to the **distortion** of the signal as it passes through the fiber.

Optical Fiber

•Multimode step index fibers are similar to the single mode step index fibers except the center core is much larger with multimode configuration.

•With this large core diameter there are many paths through which light can travel.

•This type of fiber has a large light to fiber aperture and allows more light to enter the fiber.

•The light rays that strike the core/cladding interface at an angle greater than the critical angle are propagated down the core in a zigzag fashion.

Optical Fiber

•Light rays that strike the core/cladding interface at an angle less than the critical angle enter the cladding and are lost.

•Light rays take different paths down the fiber, which results in large difference in propagation times.

•Due to this light rays travelling down fiber have a tendency to spread out.

Optical Fiber

- **Multimode graded-index fiber,** decreases this distortion of the signal through the cable.
- The word index here refers to the index of refraction.
- Refraction is related to the density.
- A graded-index fiber, therefore is one with varying densities.
- Density is highest at the center of the core and decreases gradually to its lowest at the edge.

Optical Fiber

- The multimode graded index fiber is an improvement on the multimode step index fiber.
- Multimode graded index fibers have non-uniform refractive index.
- This fiber has maximum density at the center which gradually decreases towards the outer edge.
- Light rays propagate down this type of fiber through refraction rather than reflection.

Optical Fiber

- As the light rays propagate down the fiber, the rays travelling in the outer most area of the fiber travel a greater distance than the rays travelling near the center.

- Because the refractive index decreases with distance from the center, the light rays travelling farthest from the center propagate at a higher velocity.

- Therefore all light rays take approximately the same time to travel the length of the fiber.

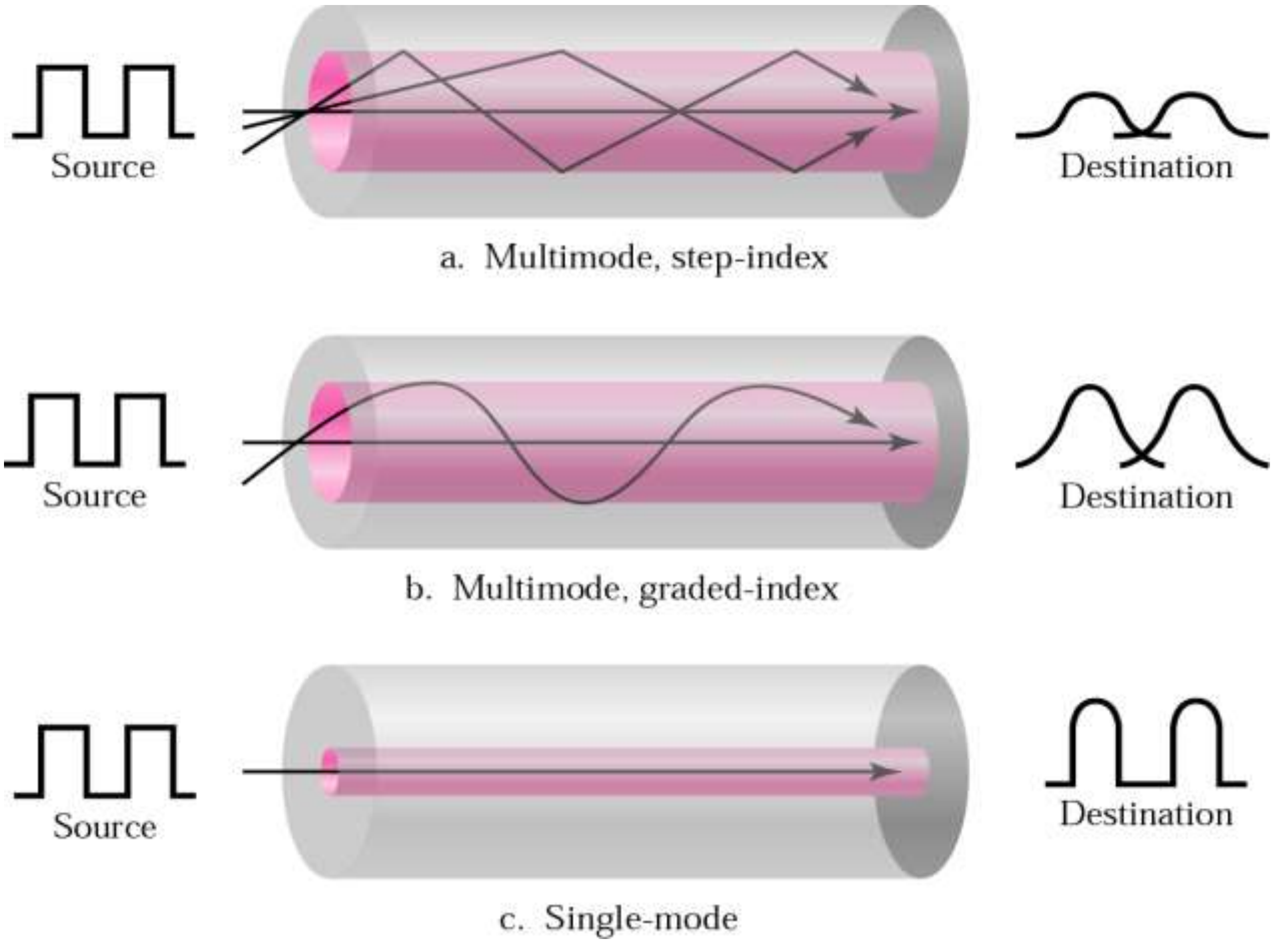
Optical Fiber

•**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 horizontal.

•The single mode fiber itself is manufactures with a much smaller diameter than that of multimode fiber, and with substantially lower density (index of refraction).

Cont'd…

Modes


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

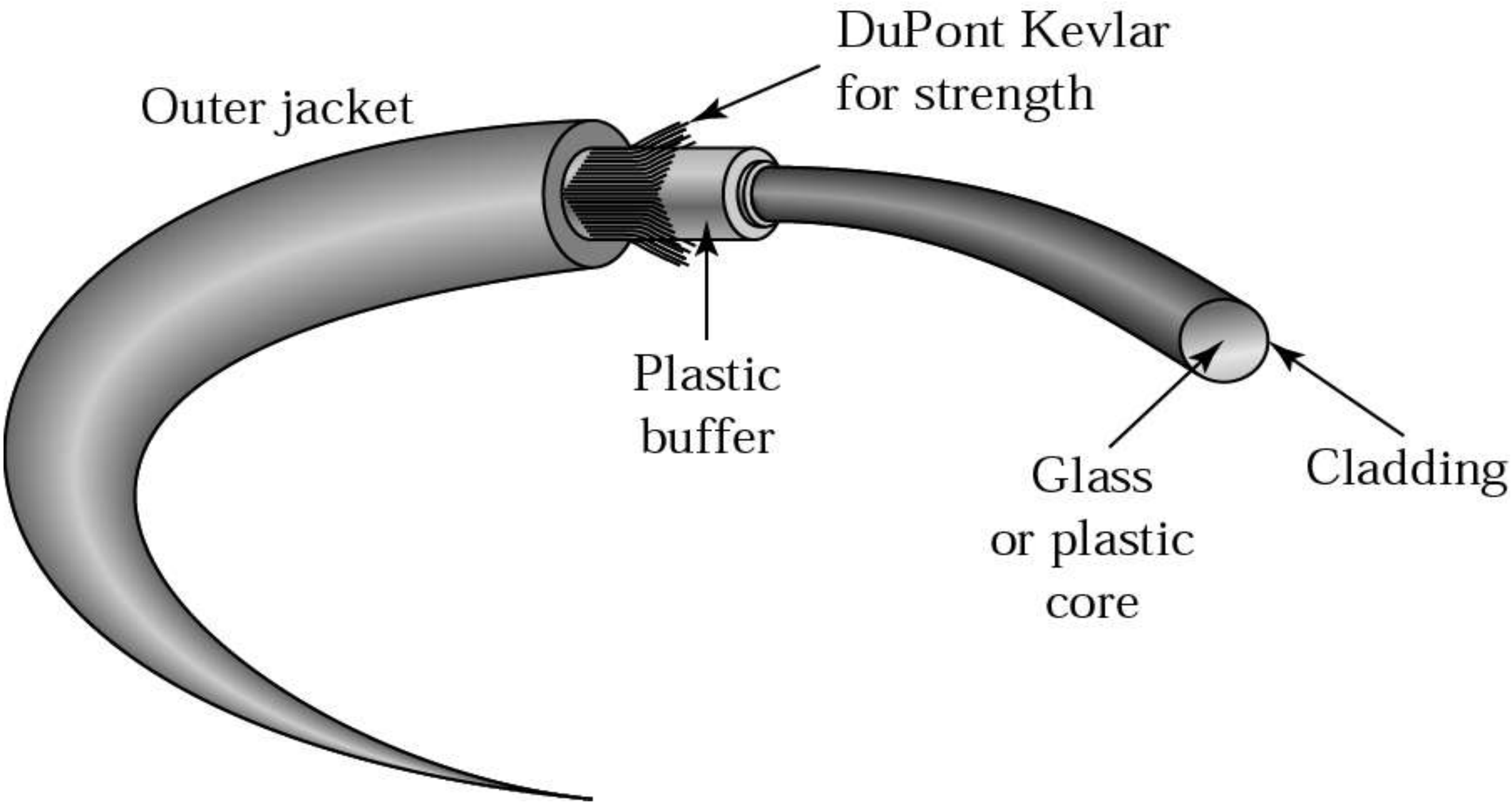
Cont'd…

Fiber types

Type	Core	Cladding	Mode
50/125	50	125	Multimode, graded-index
62.5/125	62.5	125	Multimode, graded-index
100/125	100	125	Multimode, graded-index
7/125	7	125	Single-mode

Cont'd…

Fiber construction

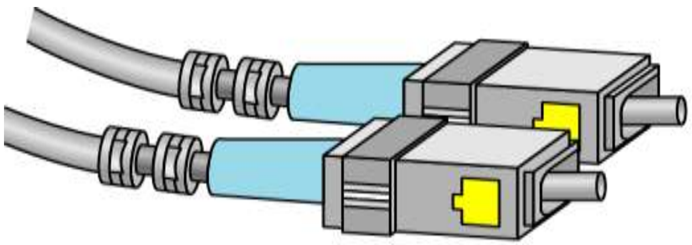


Optical Fiber

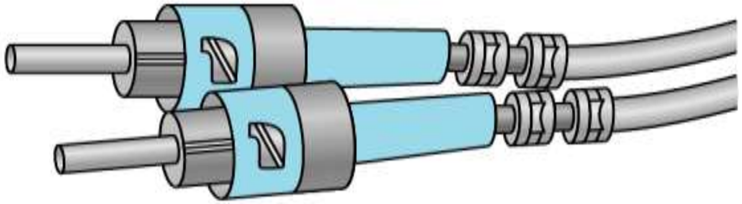
- The outer jacket is made of either PVC or Teflon.
- Inside the jacket are KEVLAR strands to strengthen the cable.
- KEVLAR is a strong material used in the fabrication of bulletproof vests.
- Below the KEVLAR is another plastic coating to cushion the fiber.
- The fiber is at the center of the cable,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

Cont …

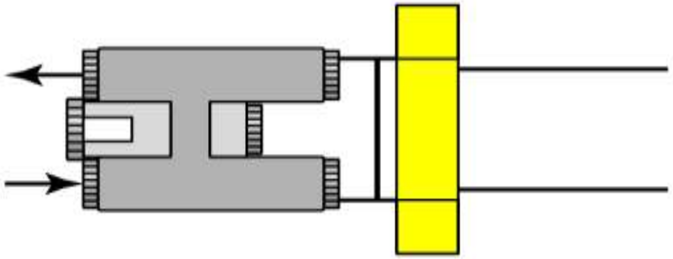
Fiber-optic cable connectors



SC connector



ST connector



MT-RJ connector

Optical Fiber

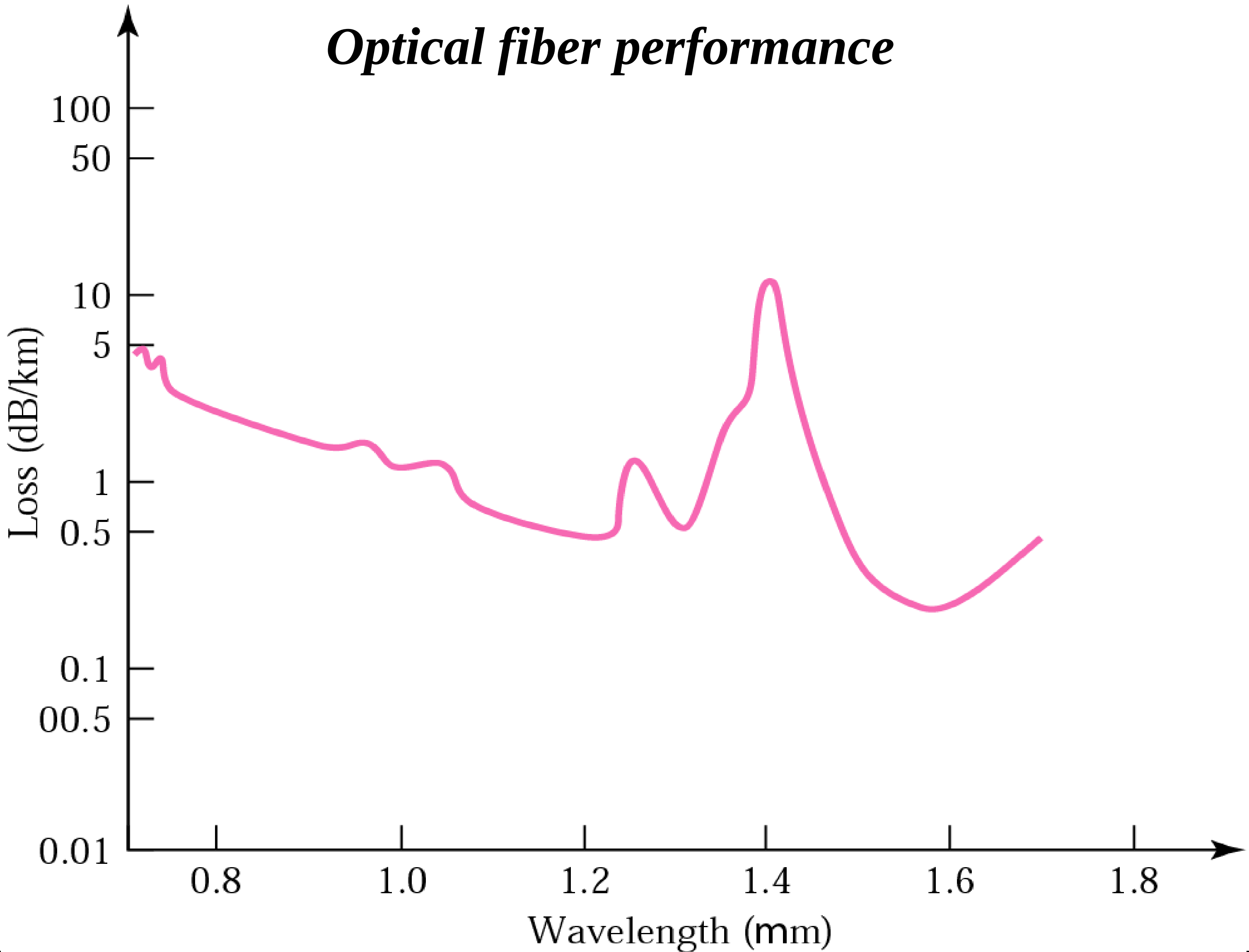
•Subscriber Channel (SC) connector is used for cable TV. It used push/pull locking system.

•Straight Tip (ST) connector is used for connecting cable to networking devices.

•It uses a bayonet locking system and is more reliable than SC.

•MT-RJ is a connector that is the same size as RJ45.

Cont'd…



Optical fiber performance
100
50
10
5
1
0.5
0.1
00.5
0.01
Loss (dB/km)
0.8
1.0
1.2
1.4
1.6
1.8
Wavelength (mm)

Unguided Media: Wireless

Unguided transmission is used when running a physical cable (either fiber or copper) between two end points is not possible.

For example, running wires between buildings is probably not legal if the building is separated by a public street.

Infrared signals typically used for short distances (across the street or within same room),

Microwave signals commonly used for longer distances (10's of km). Sender and receiver use some sort of dish antenna

Cont'd…

Unguided Media: Wireless

Difficulties:

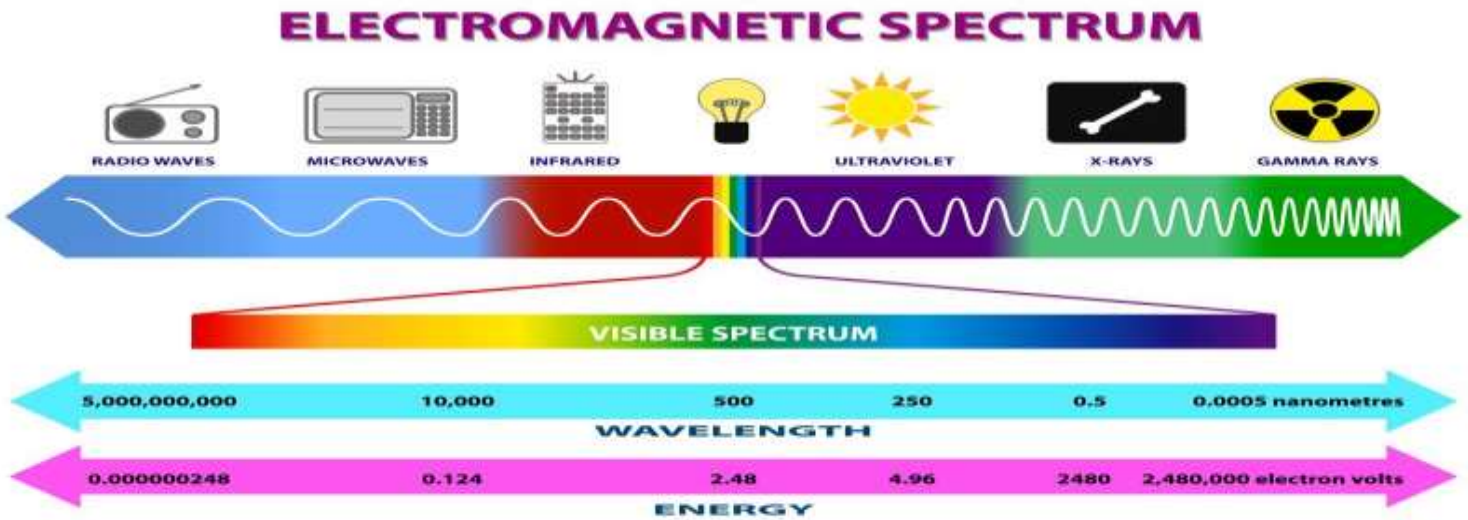
1. Weather interferes with signals. For instance, clouds, rain, lightning, etc. may adversely affect communication.

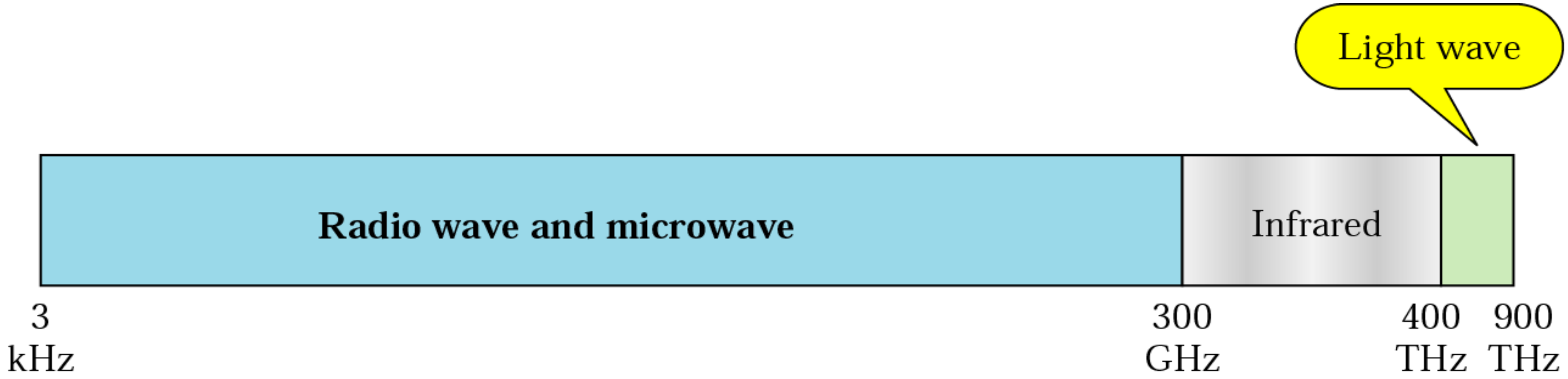
2. Radio transmissions easy to tap. A big concern for companies worried about competitors stealing plans.

3. Signals bouncing off of structures may lead to out-of-phase signals that the receiver must filter out.

Cont …

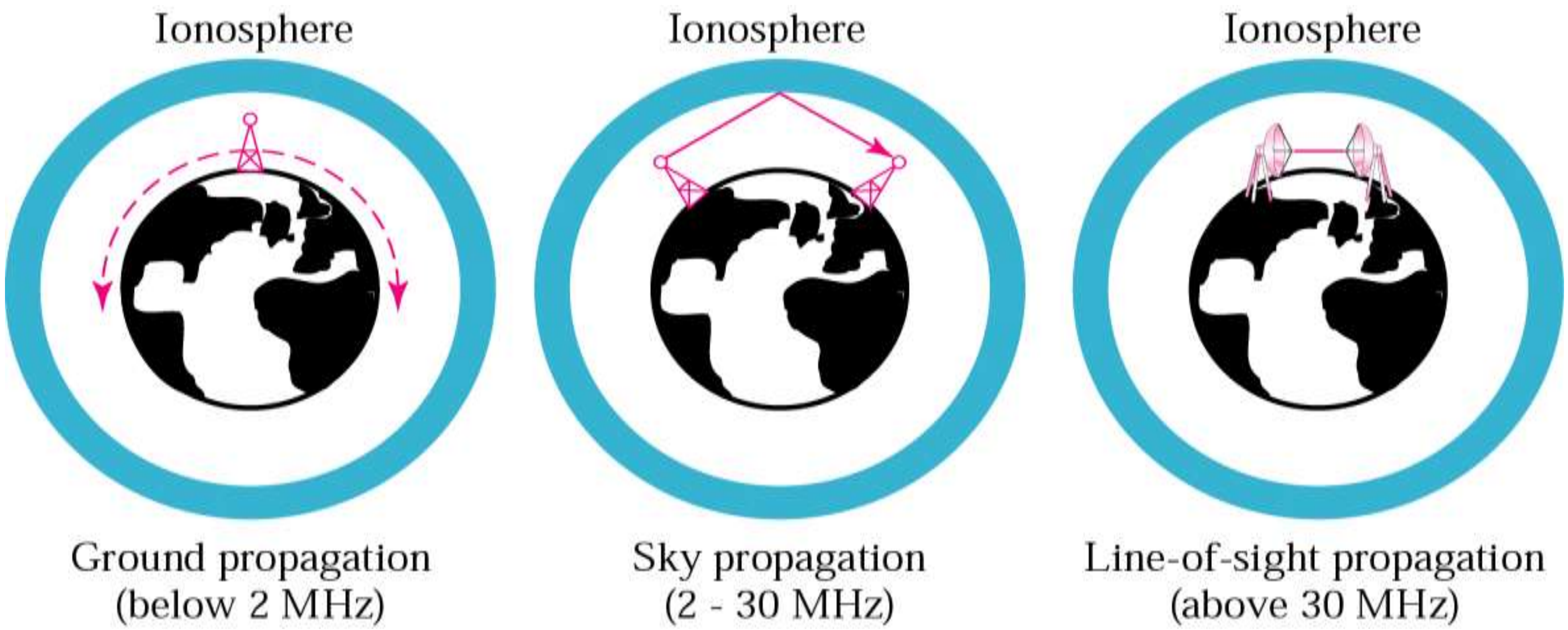
Electromagnetic spectrum for wireless communication





Cont'd…

Propagation methods



WIRELESS

•**Ground propagation** – radio waves travel through the lowest portion of the atmosphere.

•These low-frequency signals emanate in all directions form the transmitting antenna and follow the curvature of the planet.

•Distance depends on the amount of power of the signal : The greater the power, the greater the distance.

WIRELESS

•**Sky propagation-** higher-frequency radio waves radiate upward into the ionosphere (the layer of atmosphere where particles exists as ions) where they are reflected back to the earth.

•This type of transmission allows for greater distances with lower output power.

WIRELESS

•**Line –of-Sight propagation -** very high-frequency signals are transmitted in straight lines directly from antenna to antenna.

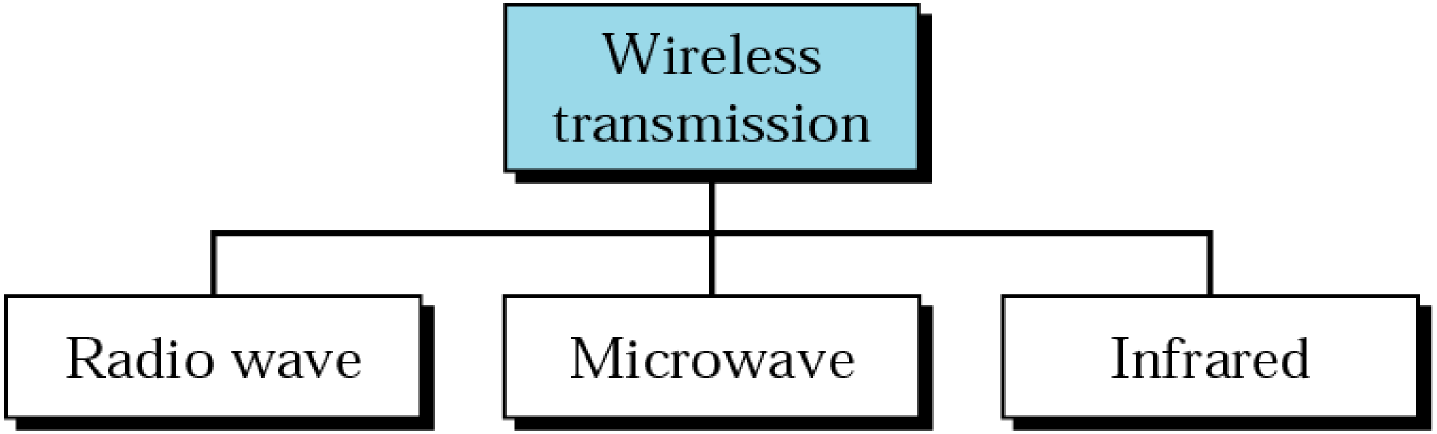
•Antennas must be directions, facing each other, and either tall enough or close enough together not to be affected by the curvature of the earth.

Cont …

Bands

Band	Range	Propagation	Application
VLF	3–30 KHz	Ground	Long-range radio navigation
LF	30–300 KHz	Ground	Radio beacons and navigational locators
MF	300 KHz–3 MHz	Sky	AM radio
HF	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF	3–30 GHz	Line-of-sight	Satellite communication
EHF	30–300 GHz	Line-of-sight	Long-range radio navigation

Wireless transmission waves

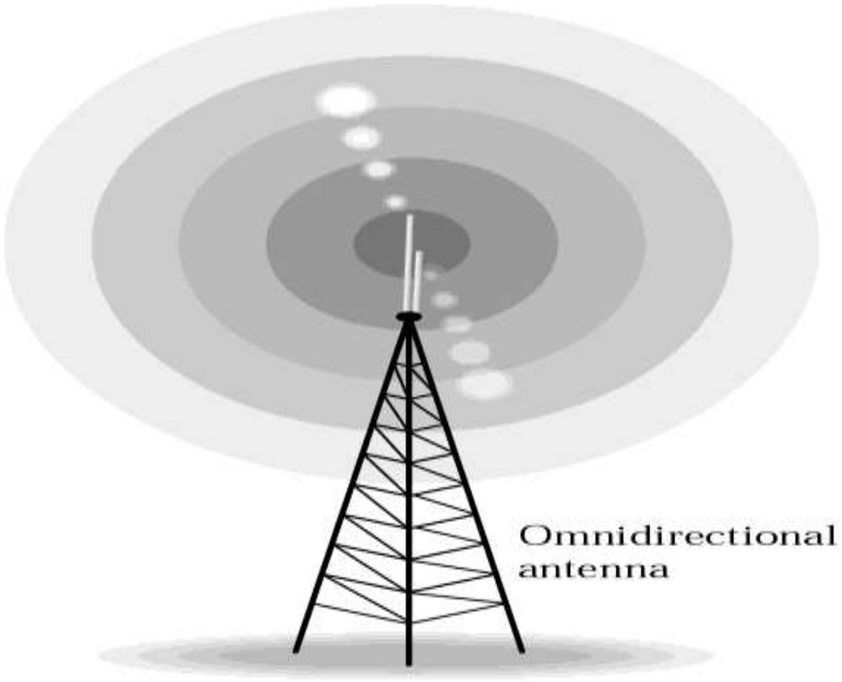


RADIO WAVE

- Ranges in frequencies between 3 Khz and 1 Ghz.
- Radio waves use omnidirectional antenna.
- When an antenna transmits radio waves, they are propagated in all directions.
- This means that the sending and receiving antenna do not have to be aligned.
- A sending antenna send waves that can be received by any receiving antenna.
- It has a disadvantage , that radio waves transmitted by one antennas are susceptible to interference by another antenna that may send signals using the same frequency or band.

RADIO WAVE

•Omnidirectional antenna of radio waves make them useful for multicasting, in which there is one sender but many receivers



Note:

Radio waves are used for multicast communications, such as radio and television, and paging systems. AM, FM, Television, Cordless Phone and paging

Microwave

•Electromagnetic waves having frequencies between 300 Mhz and 300 GHz are called micro-waves.

•It uses uni-directional antenna

•When an antenna transmits microwave waves, they can be narrowly focused.

•This means that the sending and receiving antennas need to be aligned.

•It has an advantage, a pair of antennas can be aligned without interfering with another pair of aligned antennas.

Microwave

•Unidirectional antenna can be **parabolic dish** antenna and **the horn**

•A **parabolic antenna** is based on the geometry of a parabola : Every line parallel to the line of symmetry 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.

Microwave

•Outgoing transmission 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

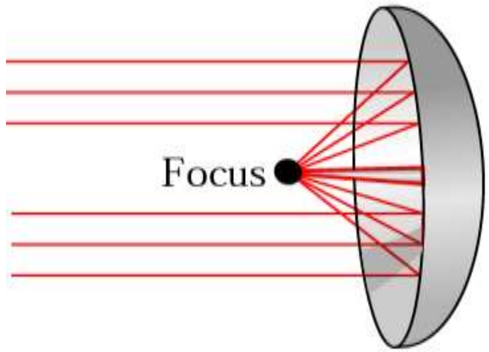
•Outgoing transmission are broadcast up a stem (resembling a handle) and deflected outward in a series of narrow parallel beams of a curved head.

•Received transmissions are collected by the scooped shape of the horn, in a manner similar to the parabolic dish, and deflected down into the stem.

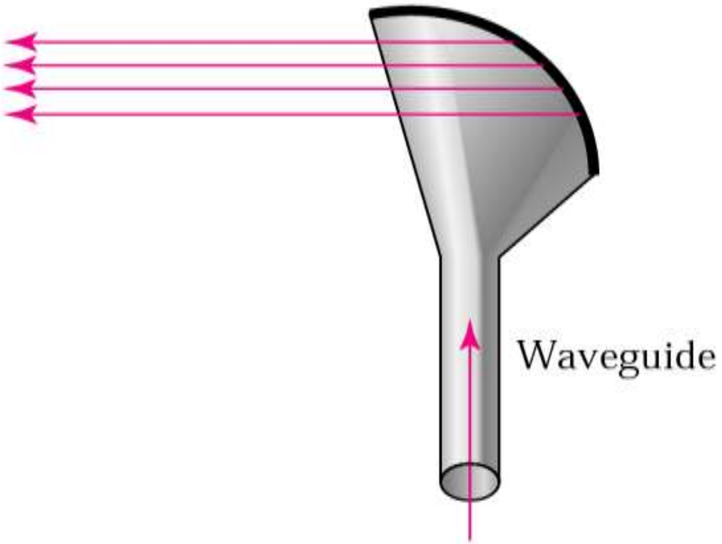
•USED IN CELLULAR PHONES, SATELLITE NETWORKS, WIRELESS LANs

Cont …

Unidirectional antennas



a. Dish antenna



b. Horn antenna

Cont …

Note:

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

Cont …

Note:

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

Satellite Networks

Microwave frequencies, which travel in straight lines, are commonly used for wideband communication.

The curvature of the earth results in obstruction of the signal between two *earth stations* and the signal also gets attenuated with the distance it traverses.

To overcome both the problems, it is necessary to use a *repeater*, which can receive a signal from one earth station, amplify it, and retransmit it to another earth station.

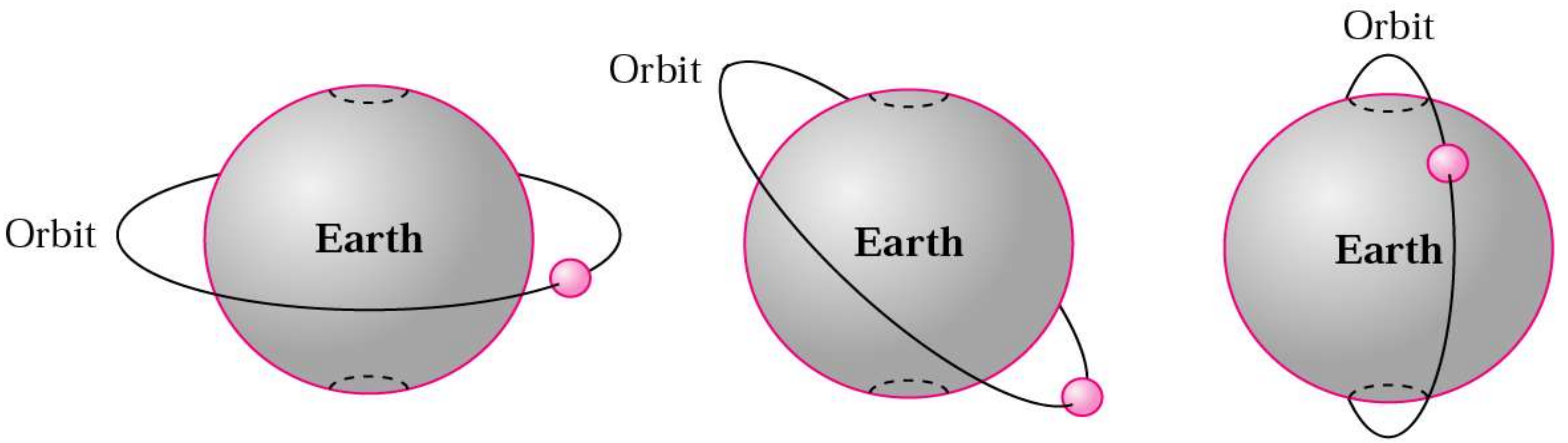
Larger the height of a repeater from the surface of the earth, longer is the distance of line-of-sight communication.

Satellite Networks

Satellite networks were originally developed to provide long-distance telephone service.

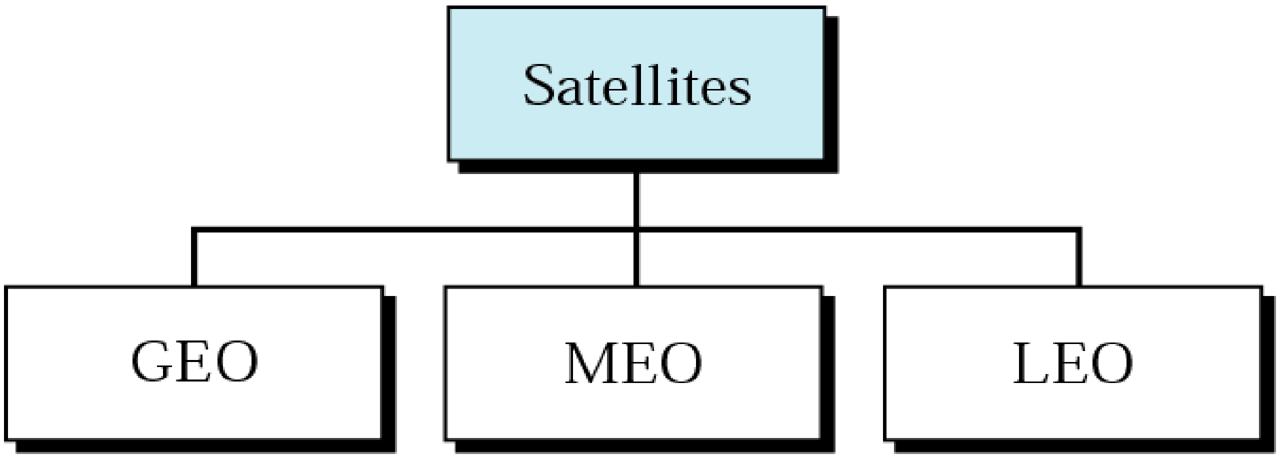
So, for communication over long distances, satellites are a natural choice for use as *repeaters in the sky*.

Satellite Networks



a. Equatorial-orbit satellite b. Inclined-orbit satellite c. Polar-orbit satellite

Satellite Networks



Satellite Networks

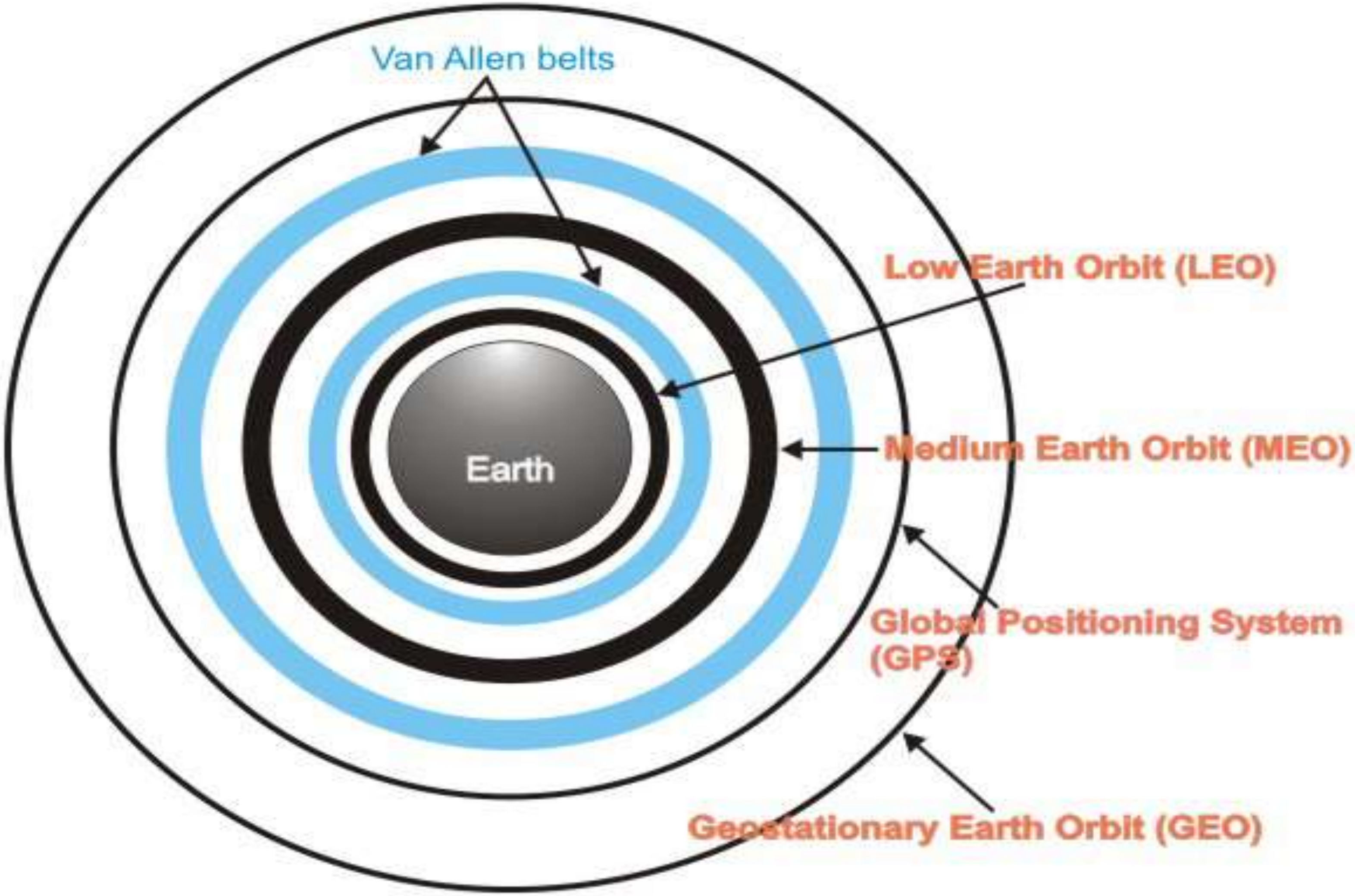
Three different types categories(basis: location of the orbit)

These orbits are chosen such that the satellites are not destroyed by the high-energy charged particles present in the two *Van Allen belts*,

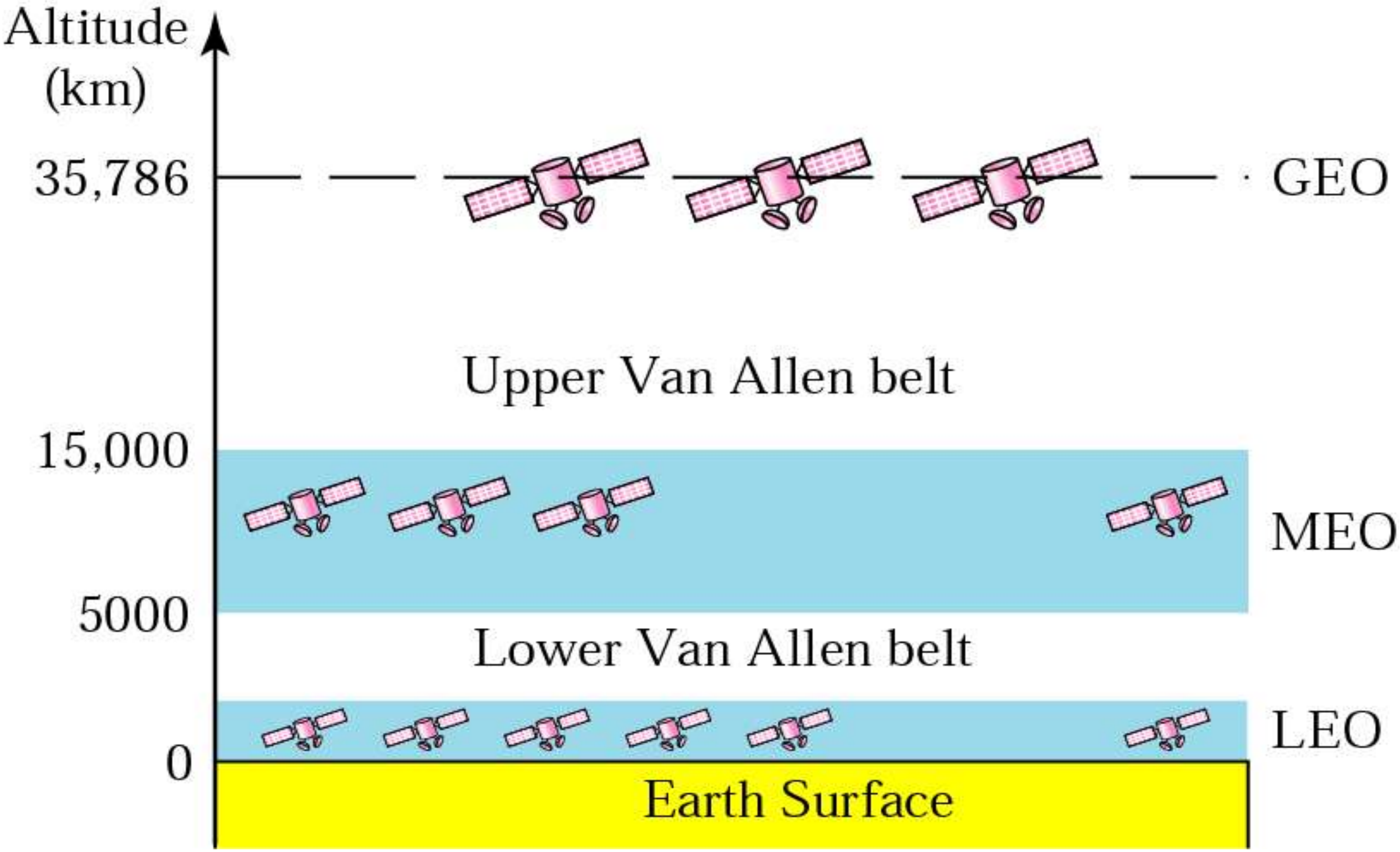
- The Low Earth Orbit (LEO) is below the lower Van Allen belt in the altitude of 500 to 2000 Km. T
- he Medium Earth Orbit (MEO) is in between the lower Van Allen belt and upper Van Allen belt in the altitude of 5000 to 15000 Km.
- Above the upper Van Allen belt is the Geostationary Earth Orbit (GEO) at the altitude of about 36,000 Km.

Below the Geostationary Earth Orbit and above the upper Van Allen belt is Global Positioning System (GPS) satellites at the altitude of 20,000 Km.

Satellite Networks



Satellite Networks



Satellite Networks

Frequency Bands

Two frequencies are necessary for communication between a ground station and a satellite; one for communication from the ground station on the earth to the satellite called *uplink frequency* and another frequency for communication from the satellite to a station on the earth, called *downlink frequency*.

These frequencies, reserved for satellite communication, are divided in several bands such as L, S, Ku, etc are in the gigahertz (microwave) frequency range as shown in Table . Higher the frequency, higher is the available bandwidth.

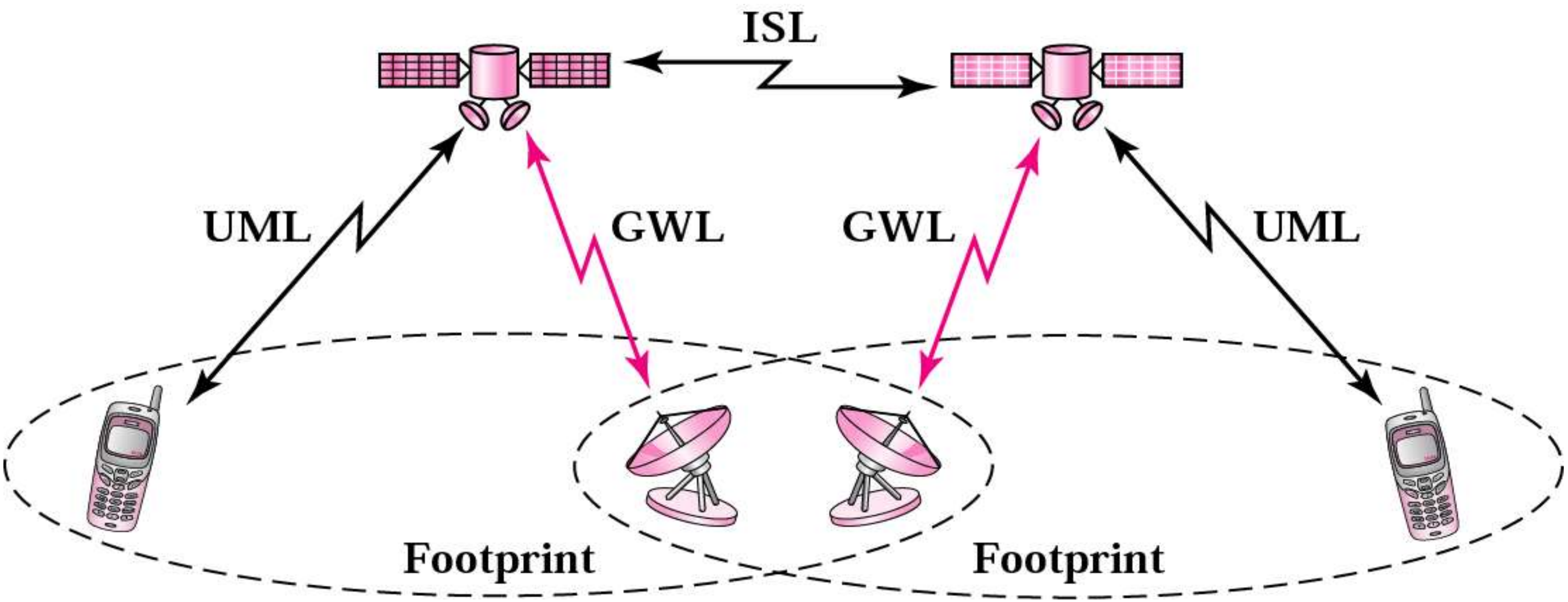
Satellite Networks

Satellite frequency band

Band	Downlink, GHz	Uplink, GHz	Bandwidth, MHz
L	1.5	1.6	15
S	1.9	2.2	70
C	4	6	500
Ku	11	14	500
Ka	20	30	3500

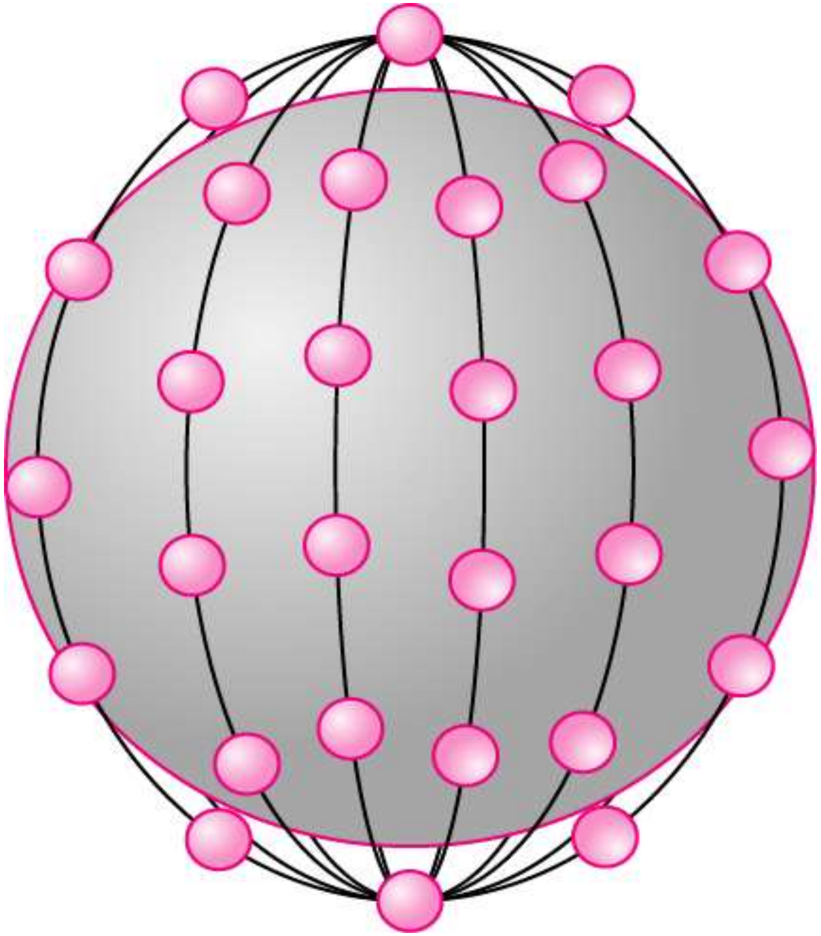
Satellite Networks

LEO satellite system



Satellite Networks

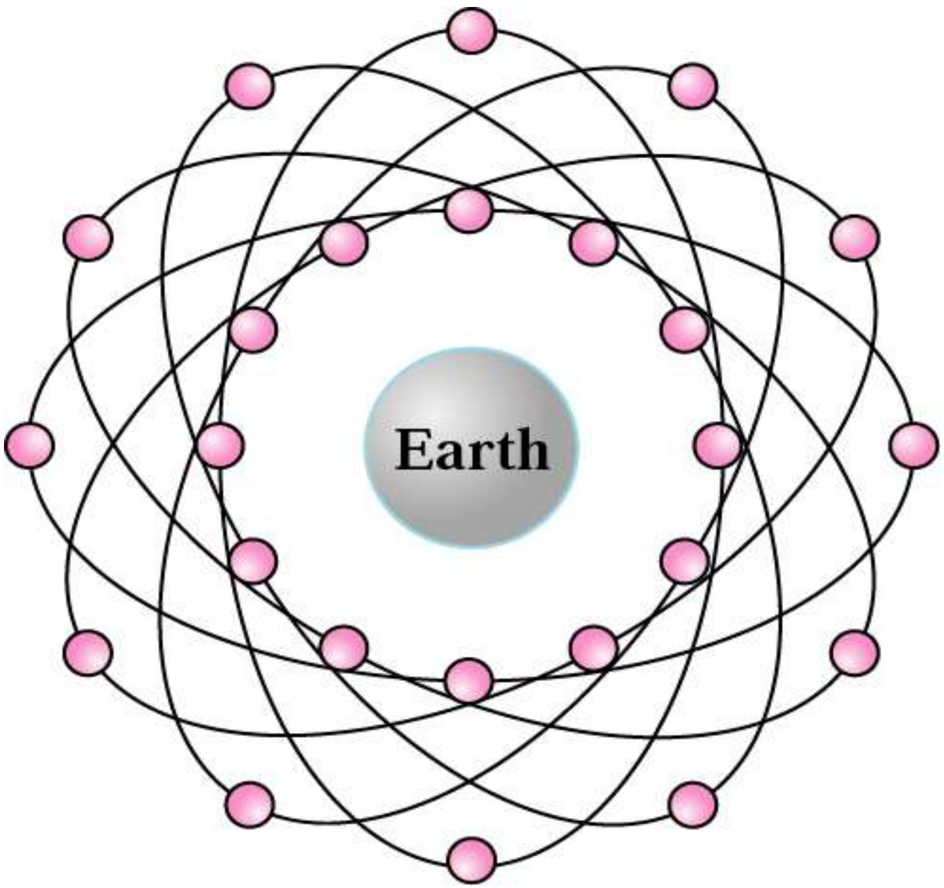
Iridium constellation



The Iridium system has 66 satellites in six LEO orbits, each at an altitude of 750 km.

Medium Earth Orbit

GPS



Satellite Networks

GPS

- The Global Positioning System (GPS) is a satellite-based navigation system. It comprises a network of 24 satellites at an altitude of 20,000 Km (Period 12 Hrs) and an inclination of 55° as shown in Fig.
- Originally intended for military applications and deployed by the Department of Defence, the system is available for civilian use since 1980.
- Allows land, sea and airborne users to measure their position, velocity and time.
- Works in any weather conditions, 24 hrs a day.
- Positioning is accurate to within 15 meters.

Signals

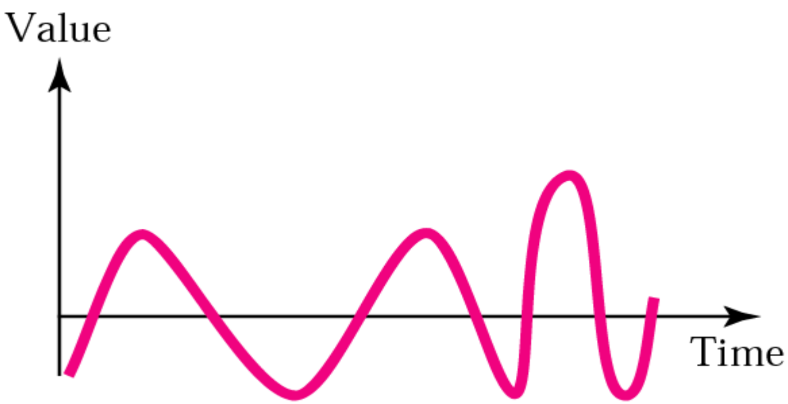
Physical Layer

To be transmitted, data must be transformed to electromagnetic signals.

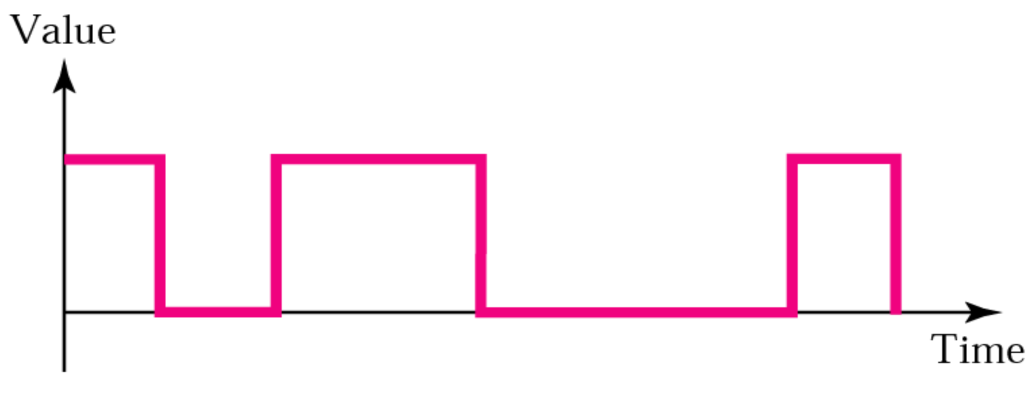
Physical Layer

Signals can be analog or digital. Analog signals can have an infinite number of values in a range; digital signals can have only a limited number of values.

Comparison of analog and digital signals



a. Analog signal

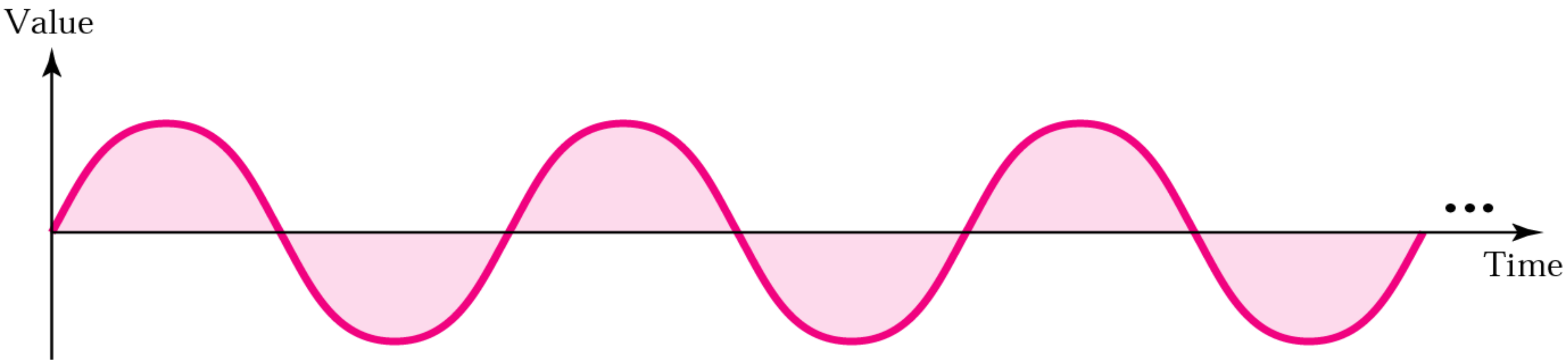


b. Digital signal

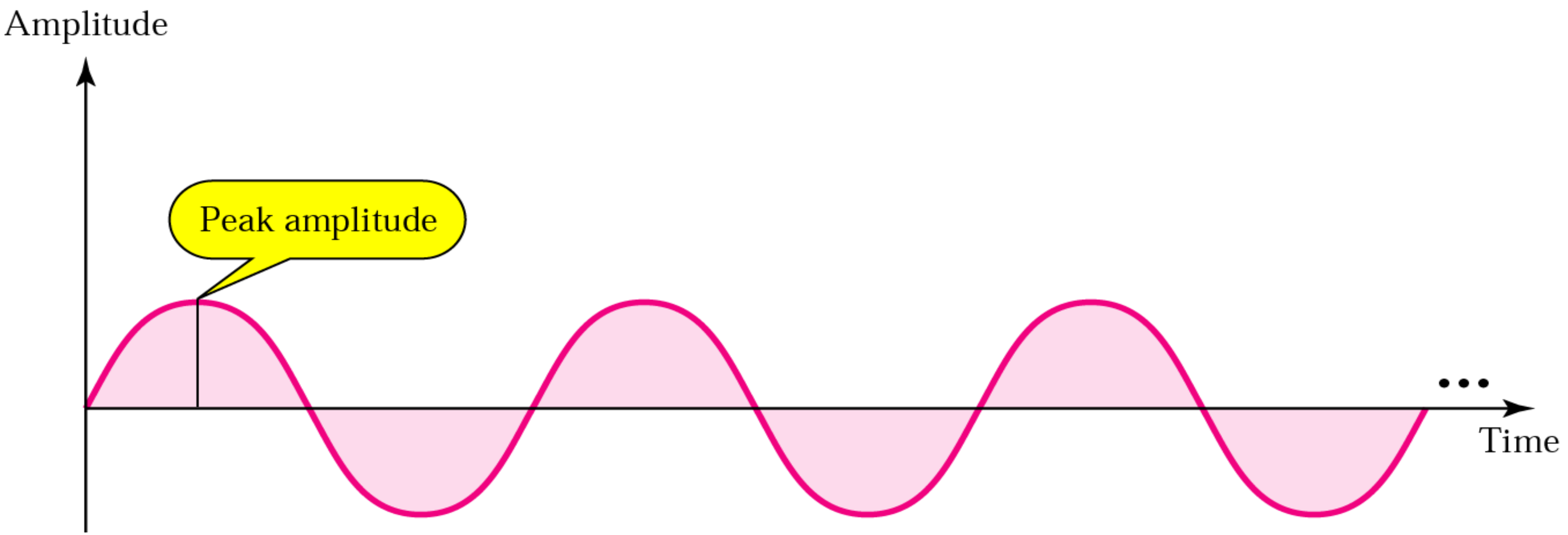
Analog Signals

- *Sine Wave*
- *Phase*
- *Examples of Sine Waves*
- *Time and Frequency Domains*
- *Composite Signals*
- *Bandwidth*

Sine Wave



Amplitude



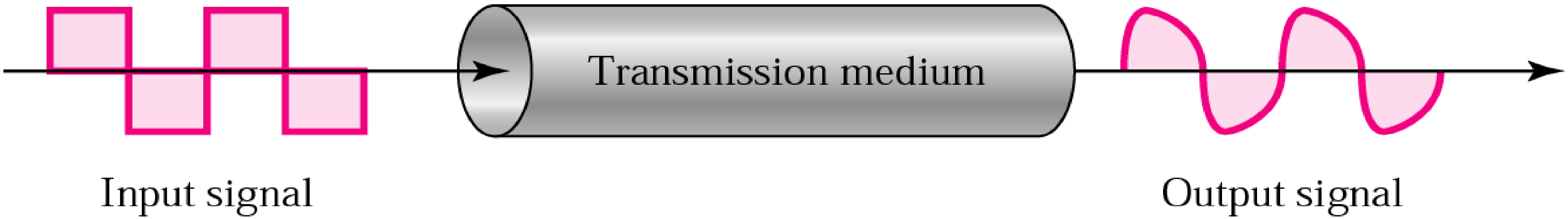
Signals

Frequency is the rate of change with respect to time. Change in a short span of time means high frequency. Change over a long span of time means low frequency.

Signals

If a signal does not change at all, its frequency is zero. If a signal changes instantaneously, its frequency is infinite.

Signals



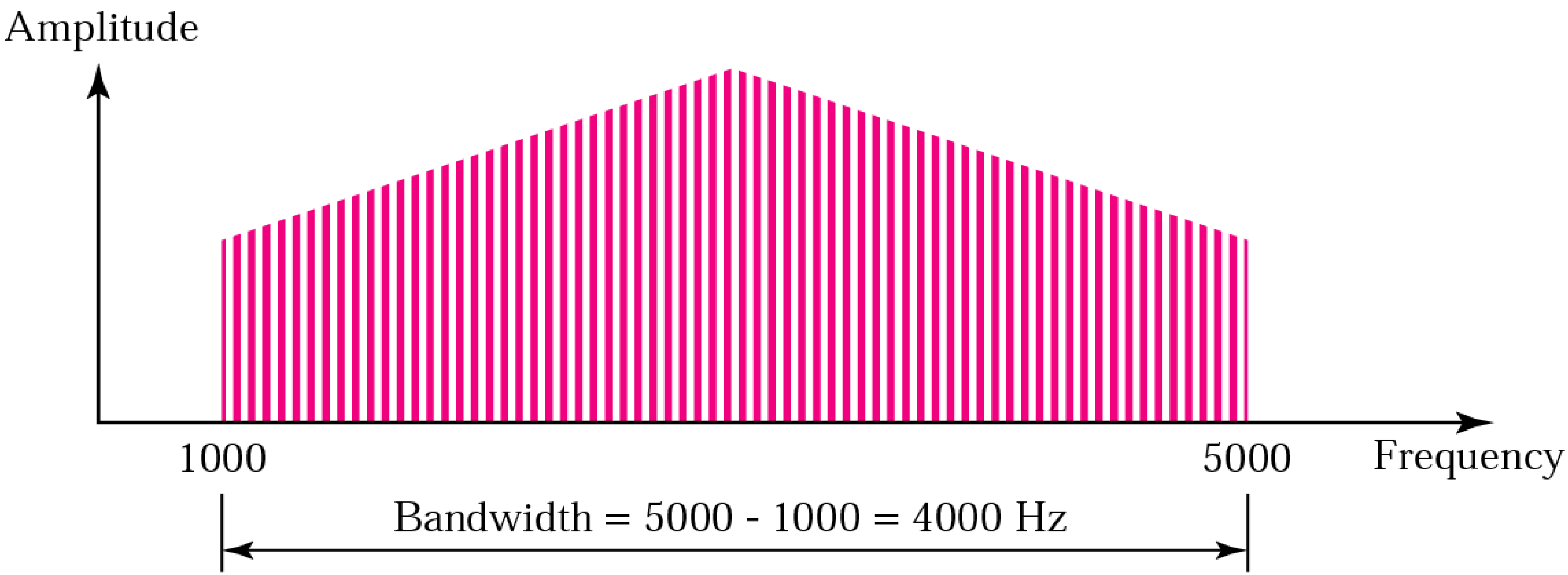
Signals

The bandwidth is a property of a medium: It is the difference between the highest and the lowest frequencies that the medium can satisfactorily pass.

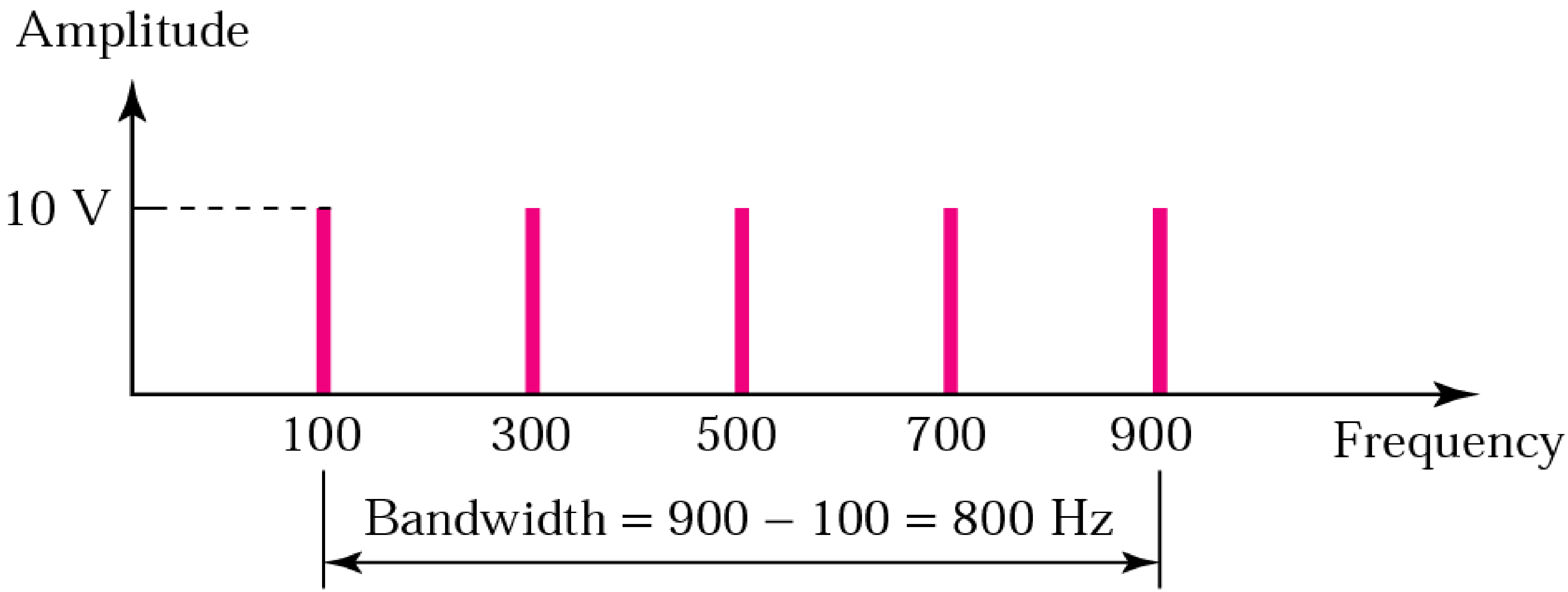
Signals

Here, we use the term bandwidth to refer to the property of a medium or the width of a single spectrum.

Bandwidth

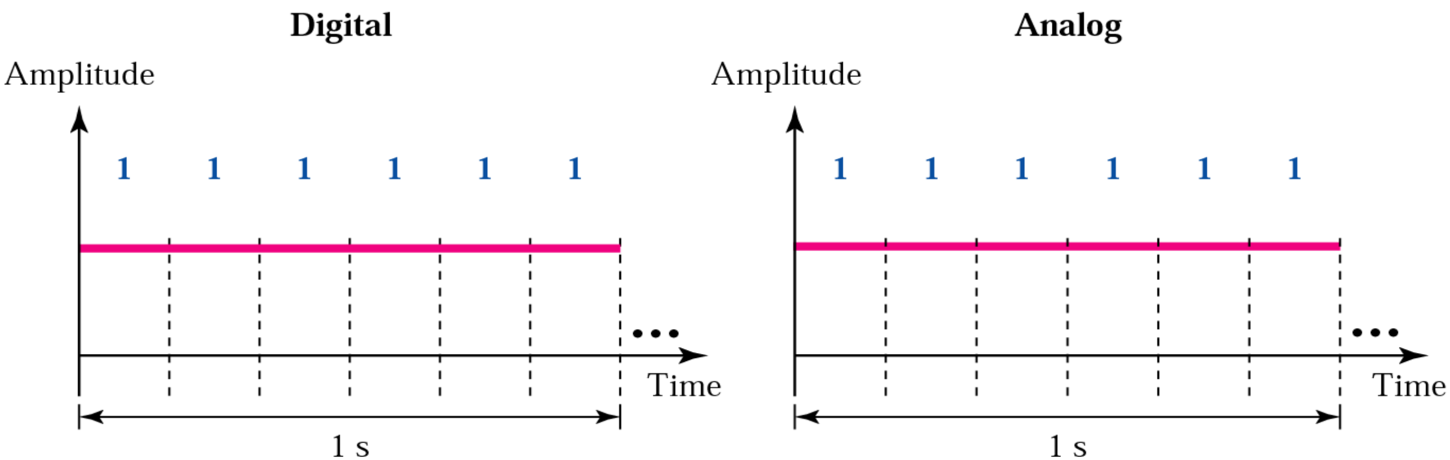


Example

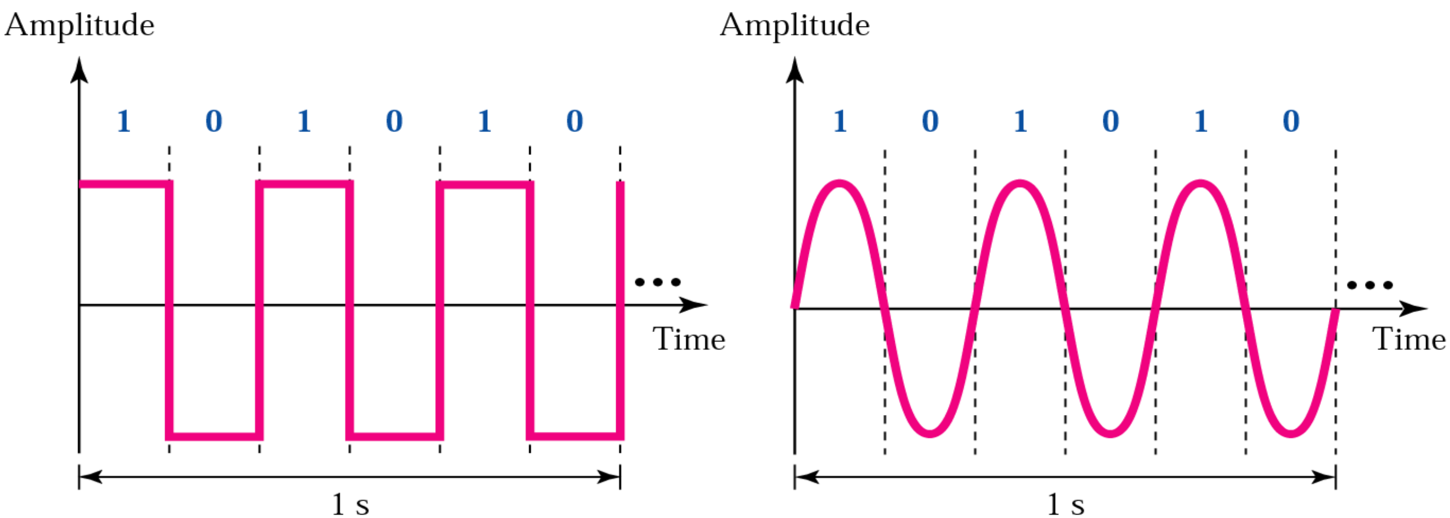


Amplitude
10 V
100
300
500
700
900
Frequency
Bandwidth = 900 − 100 = 800 Hz

Digital Versus Analog



a. Best case, bit rate = 6, $f = 0$



b. Worst case, bit rate = 6, $f = 3$

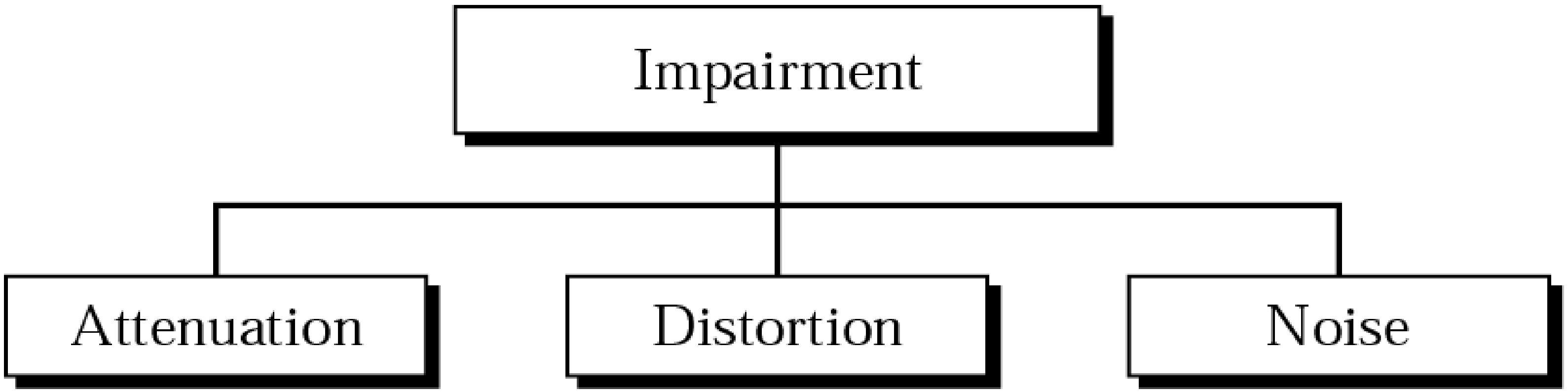
Transmission Impairment

A transmission impairment is a property of a transmission medium which causes the signal to be degraded, reduced in amplitude, distorted or contaminated.

Impairment can introduce errors into digital signals.

Examples of transmission impairments are attenuation, delay distortion, and several sources of noise including, thermal noise, impulse noise, and inter-modulation noise.

Transmission Impairment



Transmission Impairment

•It is important to understand transmission impairments for several reasons.

•Understanding the source of a transmission impairment like attenuation or dispersion will enable the user to partially correct for (equalize the signal) these effects.

•Understanding the source of transmission impairments (dispersion, attenuation, impulse noise, thermal noise) can also help the user understand some of the constraints placed on the transmission of data as a result of these effects.

Transmission Impairment

- Such constraints include the maximum length of network links, the choice of physical transmission media, the choice of encoding methods, and the data rate supported by the medium.

Transmission Impairment

•Attenuation is a property of the transmission medium.

•It measures how much energy is absorbed and/or radiated from the traveling signal due to it's interaction with the transmission medium.

•Attenuation is measured as a function of the distance traveled through the transmission medium.

Transmission Impairment

•The transmission medium absorbs energy because the signal is influenced by small impurities within it.

•Such impurities have different sizes and distributions depending on the type of medium. Impurities of different sizes effect different frequencies in the signal.

•The effect of attenuation is, therefore, a function of frequency.

Transmission Impairment

•The frequency variation of attenuation can be partially corrected, or equalized, by applying corrections based on a physical model.

•When a signal is attenuated it's amplitude is reduced.

•The interpretation of a received signal depends on being able to tell the difference between different signal levels.

•If the amplitude is reduced too much by attenuation it becomes impossible to accurately tell the difference between the different signal levels, and the information in the signal is lost.

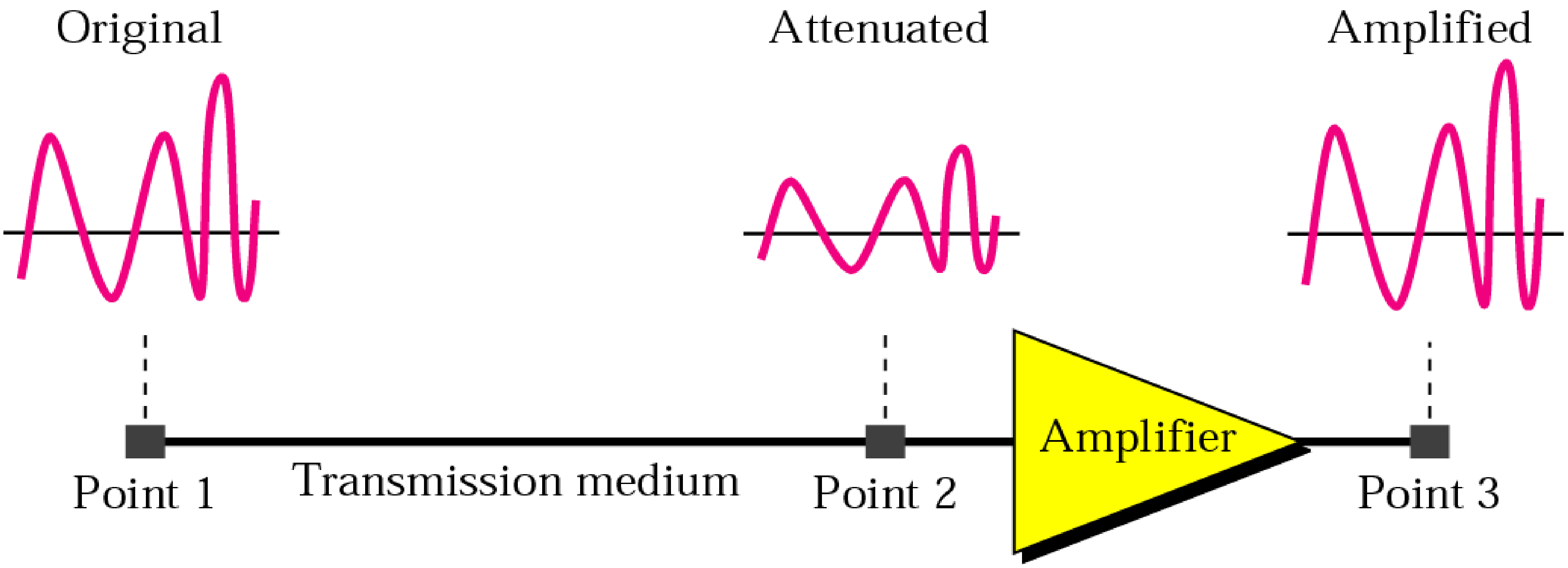
Transmission Impairment

•To prevent this from happening repeaters (digital) or amplifiers (analog) are used.

•These devices increase the amplitude of the signal by decoding and retransmitting the signal or increasing the received amplitudes respectively.

•By inserting amplifiers or repeaters in the transmission media, the maximum signal propagation distance (a property of the attenuation of the medium) is increased.

Attenuation



Example

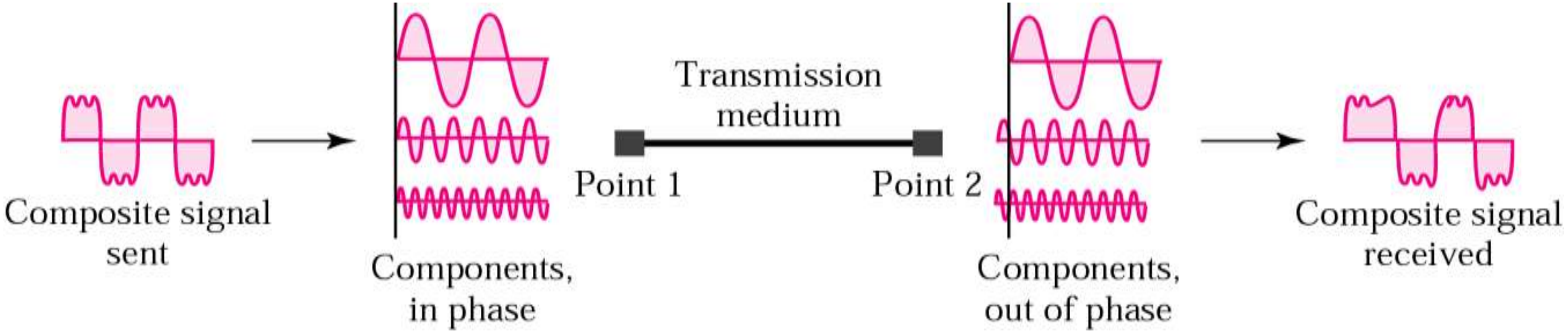
Imagine a signal travels through a transmission medium and its power is reduced to half. This means that P2 = 1/2 P1. In this case, the attenuation (loss of power) can be calculated as

Solution

$$10 \log_{10} (P2/P1) = 10 \log_{10} (0.5P1/P1) = 10 \log_{10} (0.5)$$

$$= 10(-0.3) = -3 \text{ dB}$$

Distortion



Transmission medium
Point 1
Point 2
Composite signal sent
Components, in phase
Components, out of phase
Composite signal received

Distortion

•**Dispersion** is also a property of the transmission medium.

•Signals with different frequencies will travel through a transmission medium with slightly different velocities.

•

•Therefore, the signal will be smeared or distorted when it reaches the destination.

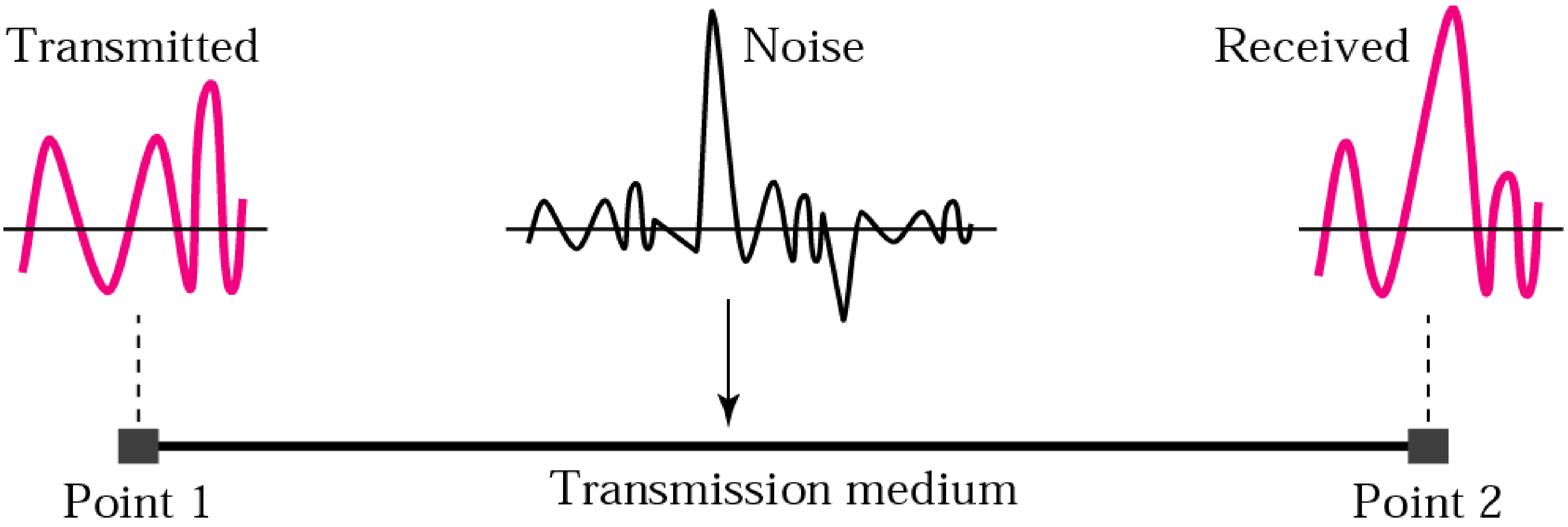
•The longer the transmission medium the larger the time difference in the arrival times of the parts of the signal with different frequencies and the more severe the smearing or distortion of the signal.

Distortion

- Like attenuation, the physical properties of dispersion can be modeled.

- Thus it is also possible to develop an equalization model to partially compensate for dispersion.

Noise


Transmitted
Noise
Received
Point 1
Transmission medium
Point 2

Noise

•Noise of different types will affect a transmitting signal.

•Thermal noise, low amplitude random noise at predictable low amplitude (amplitude related to the temperature of the transmission medium), is caused by the thermal vibration of the molecules within the transmission medium.

•The difference between signal levels in a transmitted signal will generally be much larger than the amplitude of the thermal noise.

Noise

•Thermal noise sets a limit of how close different signal levels can be at the receiver (larger than the 2X amplitude of the thermal noise).

•Thermal noise will not usually be of high enough amplitude to cause the introduction of bit errors in an encoded signal (unless attenuation has been excessive).

• However, impulse noise picked up from the environment can have high amplitude for significant lengths of time

Noise

•Such impulse noise can be caused by interference from other signals in the environment including other transmitted signals, or electrical fields natural (lightning, aurora) or manmade (signals emitted by other electrical equipment).

•The amplitude of impulse noise may reach or exceed the magnitude of the signal.

Noise

•The duration of a pulse of impulse noise may be several time the duration of a single signal.

•Because of the large amplitude of the impulse noise pulse it is possible that, when added to the real signal, the resultant received signal may appear to have been transmitted at a different level that it actually was.

Noise

For example,

•for a signal with three levels (1 , 0, -1) and impulse noise has an amplitude of 1 added to a signal, the resulting received signal will have a level of (0, 1, 2).

•During the noise pulse a signal transmitted at level 0 will arrive at the receiver with an amplitude of 1,.

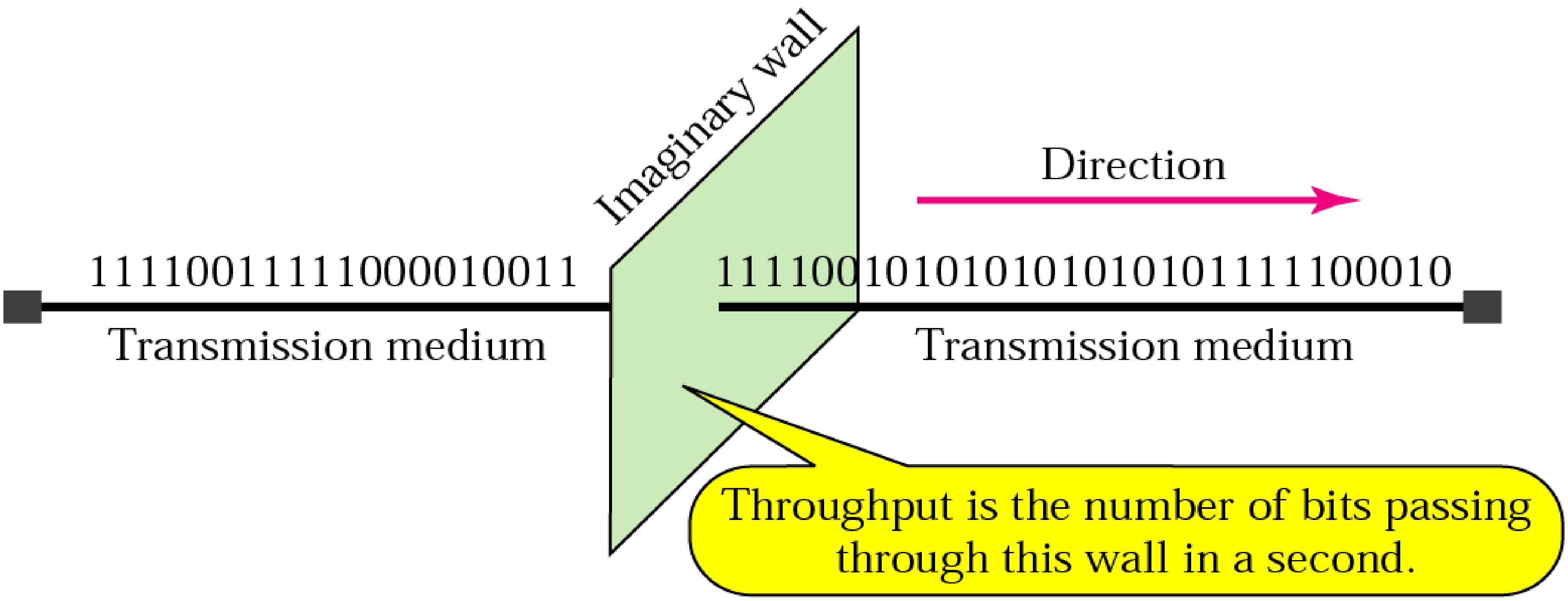
•Similarly a signal transmitted at level -1 will arrive at the receiver with an amplitude of 0. In both cases the level of the received signal will be different from the signal that was sent.

•When the signal is decoded the resulting value of the data bit will have changed in transmission. A bit error has been introduced into the received signal.

Signals

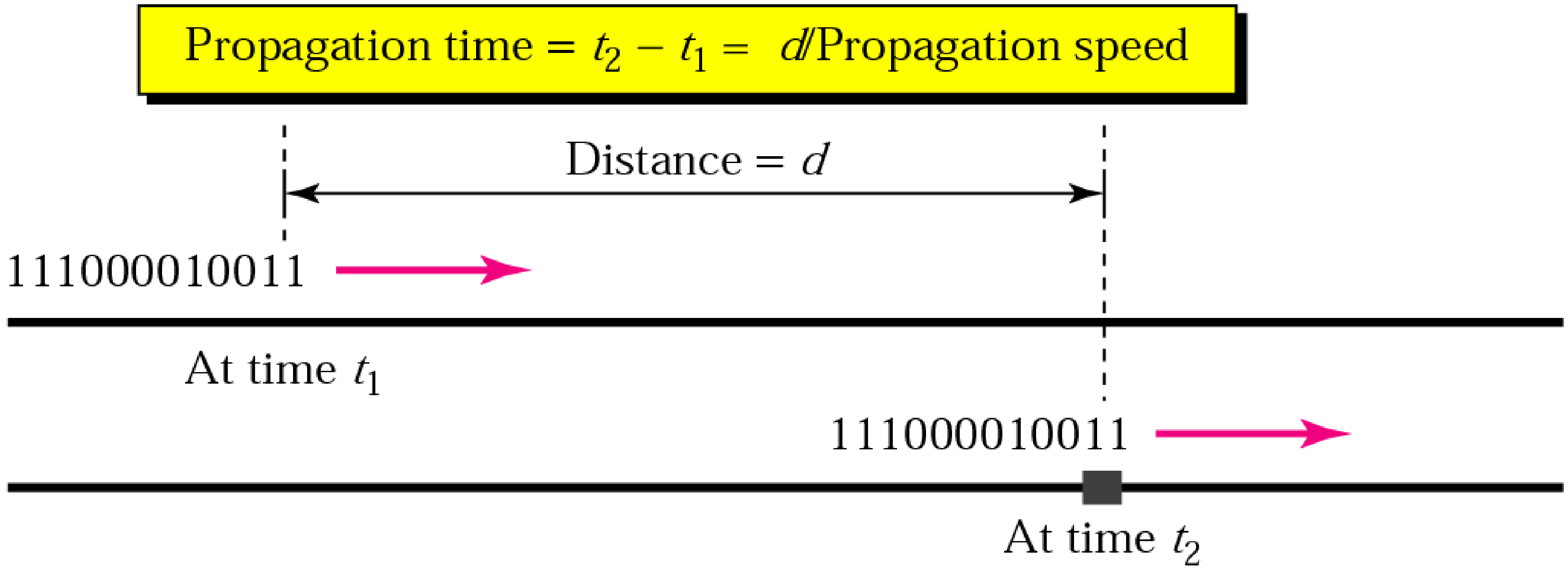
- ***Throughput***
- ***Propagation Speed***
- ***Propagation Time***
- ***Wavelength***

Throughput

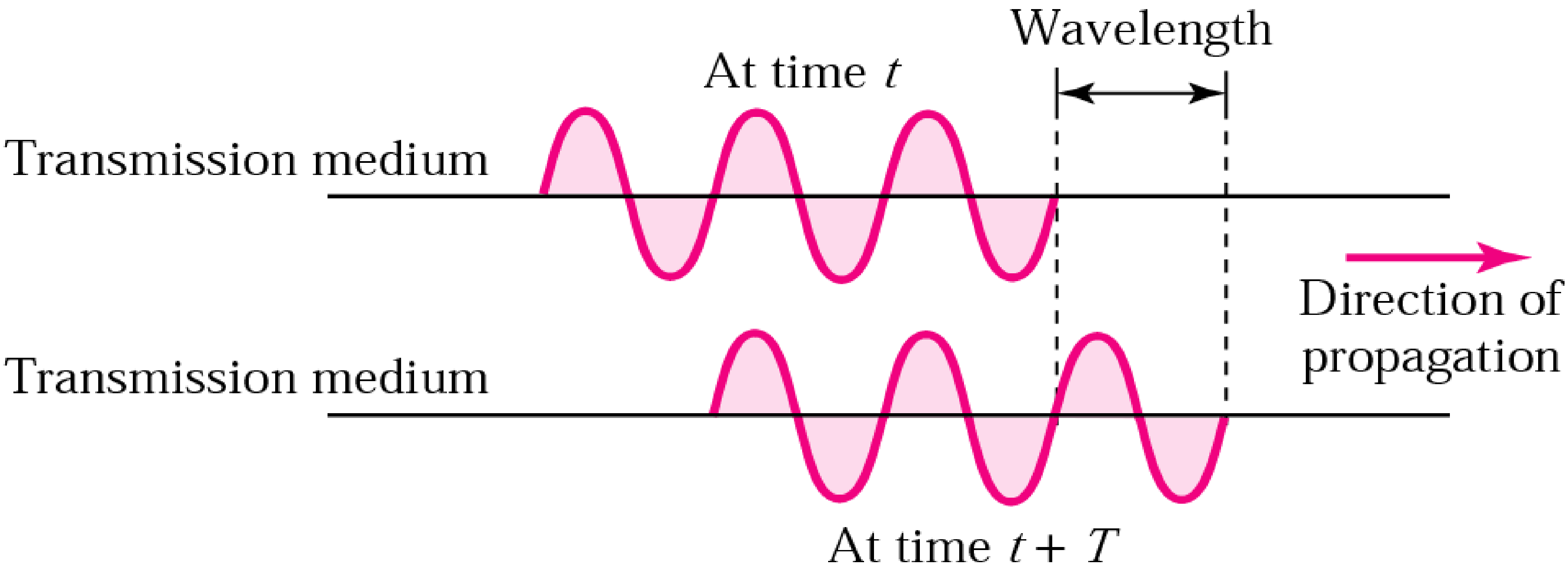


Imaginary wall
Direction
11110011111000010011
111100101010101010101111100010
Transmission medium
Transmission medium
Throughput is the number of bits passing through this wall in a second.

Propagation Time



Wave Length


Wavelength
At time t
Transmission medium
Direction of propagation
Transmission medium
At time t + T

Digital Transmission

Characterstics

Some Characteristics

Line Coding Schemes

Some Other Schemes

Characterstics

•The basis of analog signaling is a constant frequency signal known as a ***carrier signal***, which is chosen to be compatible with the transmission media being used, so that it can traverse a long distance with minimum of attenuation and distortion.

•Data can be transmitted using these carrier signals by a process called ***modulation***, where one or more fundamental parameters of the carrier wave, i.e. amplitude, frequency and phase are being modulated by the source data.

•The resulting signal, called ***modulated signal*** traverses the media, which is ***demodulated*** at the receiving end and the original signal is extracted.

Characterstics

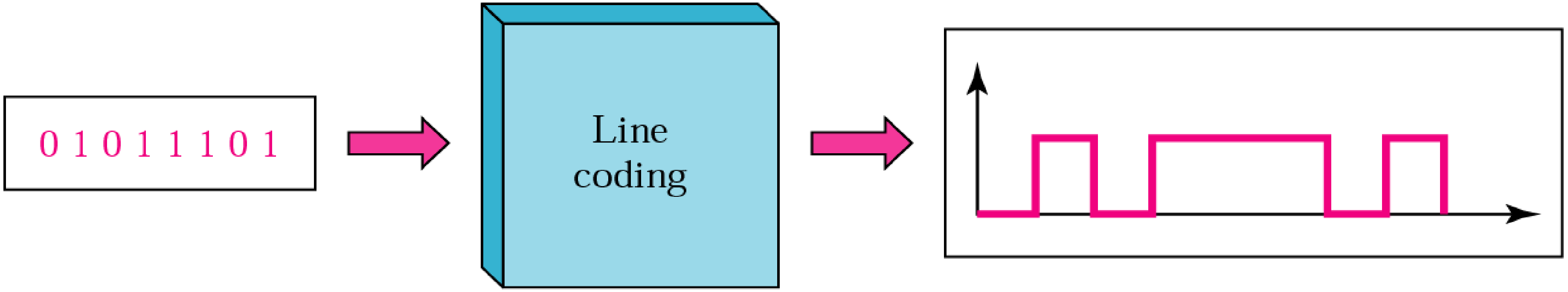
•**No of signal levels**: This refers to the number values allowed in a signal, known as s**ignal levels**, to represent data.

•**Bit rate versus Baud rate**:

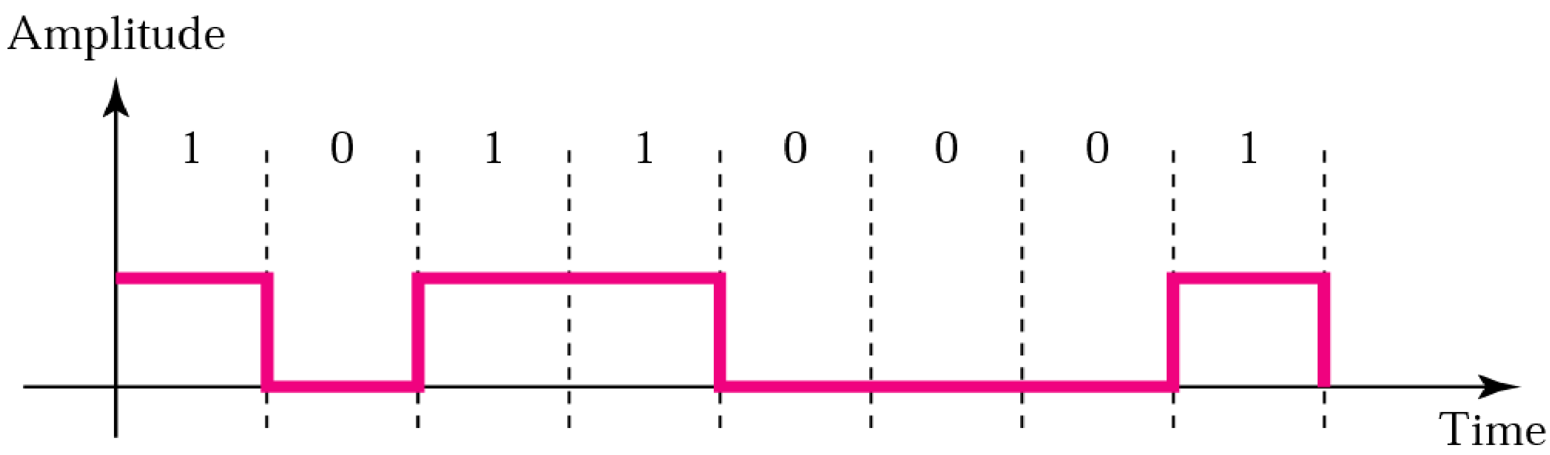
•The **bit rate** represents the number of bits sent per second, whereas the **baud rate** defines the number of signal elements per second in the signal.

•Depending on the encoding technique used, baud rate may be more than or less than the data rate.

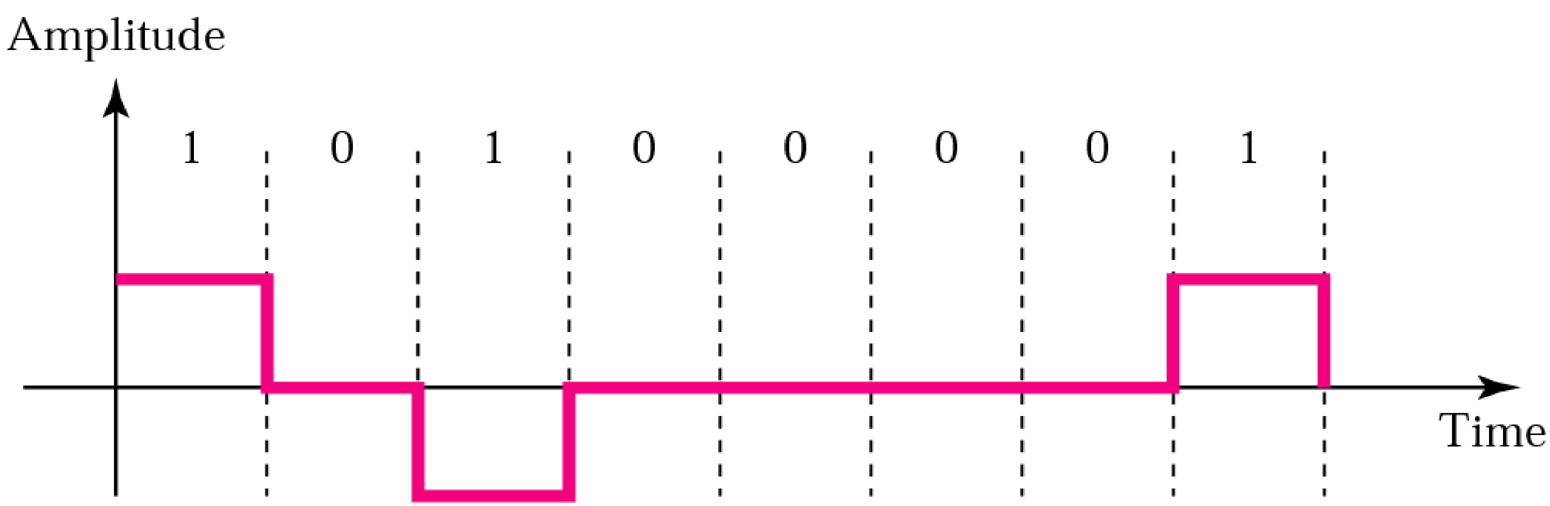
Line Coding



Signal Levels Vs Data level

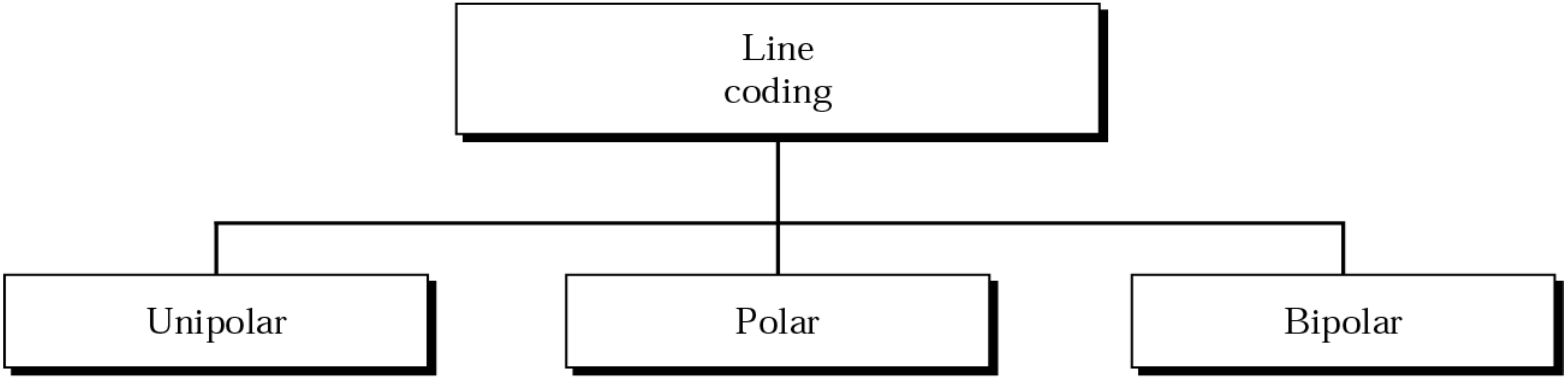


a. Two signal levels, two data levels



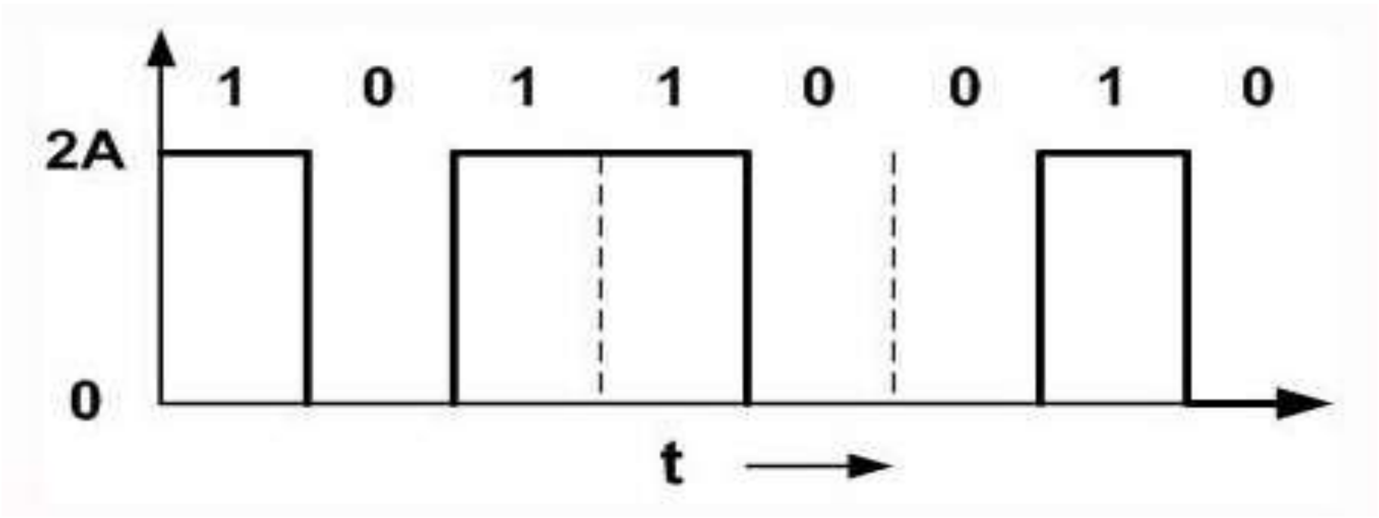
b. Three signal levels, three data levels

Digital Signal Encoding Formats



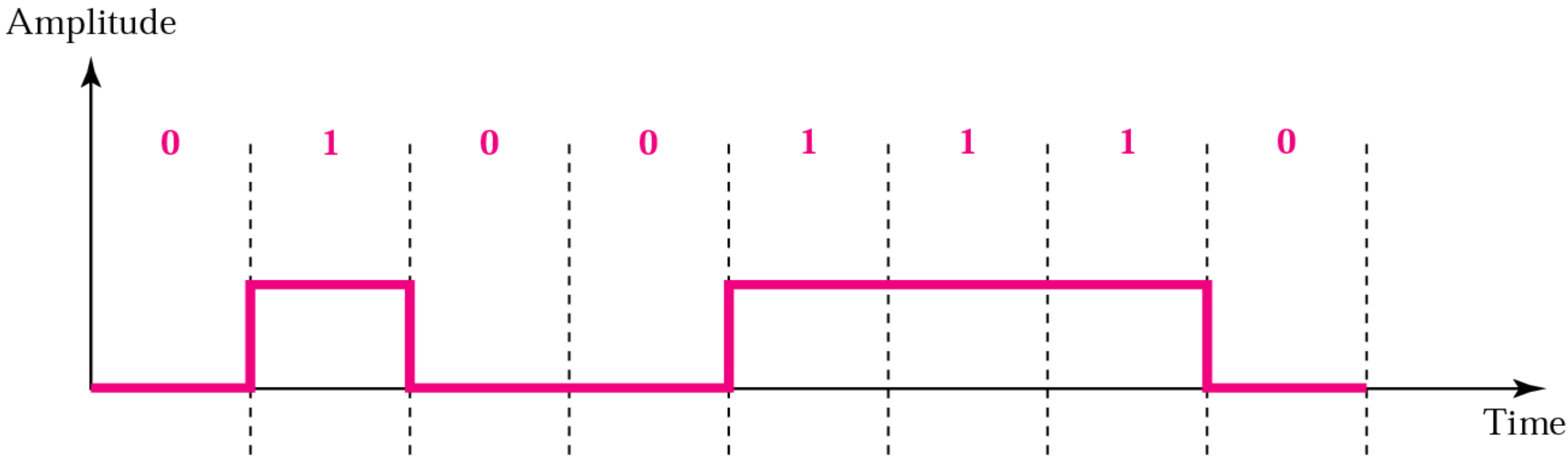
Unipolar Encoding

- In unipolar encoding technique, only one voltage levels are used.
- It uses only one polarity of voltage level
- Unfortunately, DC component present in the encoded signal and there is loss of synchronization for long sequences of 0's and 1's.
- It is simple but obsolete.



Unipolar Encoding

Unipolar encoding uses only one voltage level.

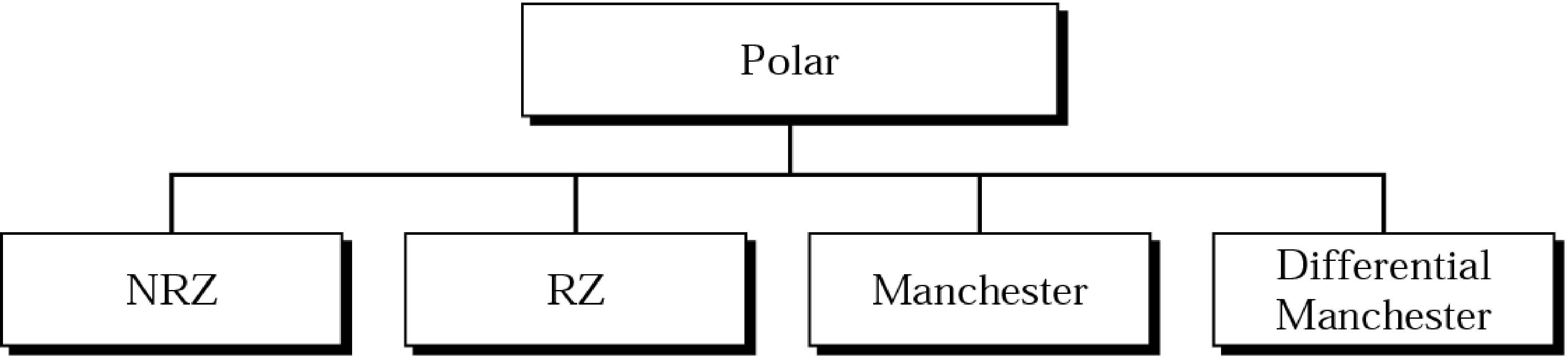


•This scheme is very costly.

•Unipolar scheme is normally not used in data communications today.

Polar Encoding

Polar encoding uses two voltage levels (positive and negative).



NRZ Encoding

Non Return to zero (NRZ):

•The most common and easiest way to transmit digital signals is to use two different voltage levels for the two binary digits.

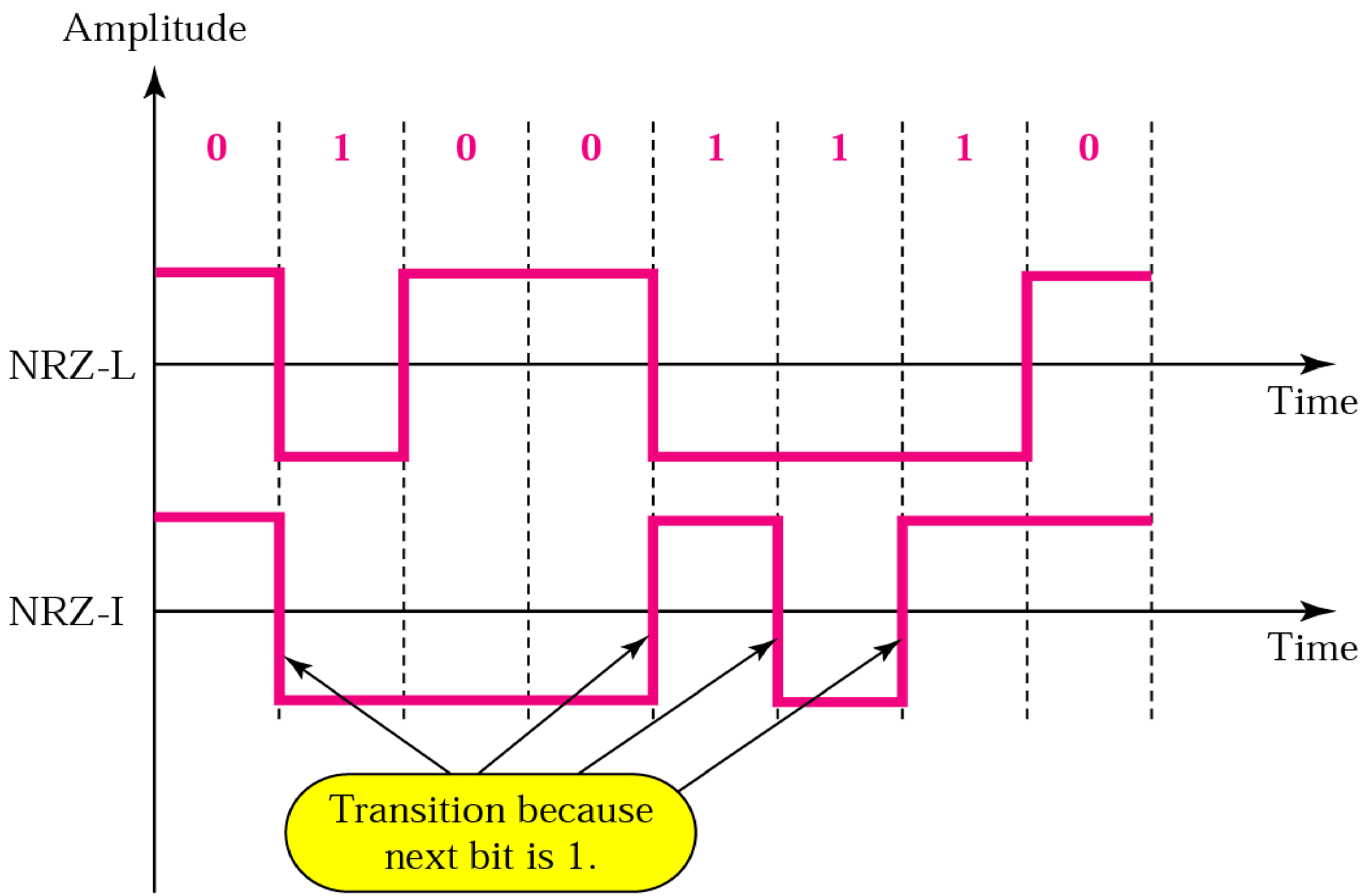
•Usually a negative voltage is used to represent one binary value and a positive voltage to represent the other.

•The data is encoded as the presence or absence of a signal transition at the beginning of the bit time.

•As shown in the figure below, in NRZ encoding, the signal level remains same throughout the bit-period.

•There are two encoding schemes in NRZ: NRZ-L and NRZ-I, as shown in Fig.

NRZ Encoding



NRZ Encoding

In NRZ-L the level of the signal is dependent upon the state of the bit.

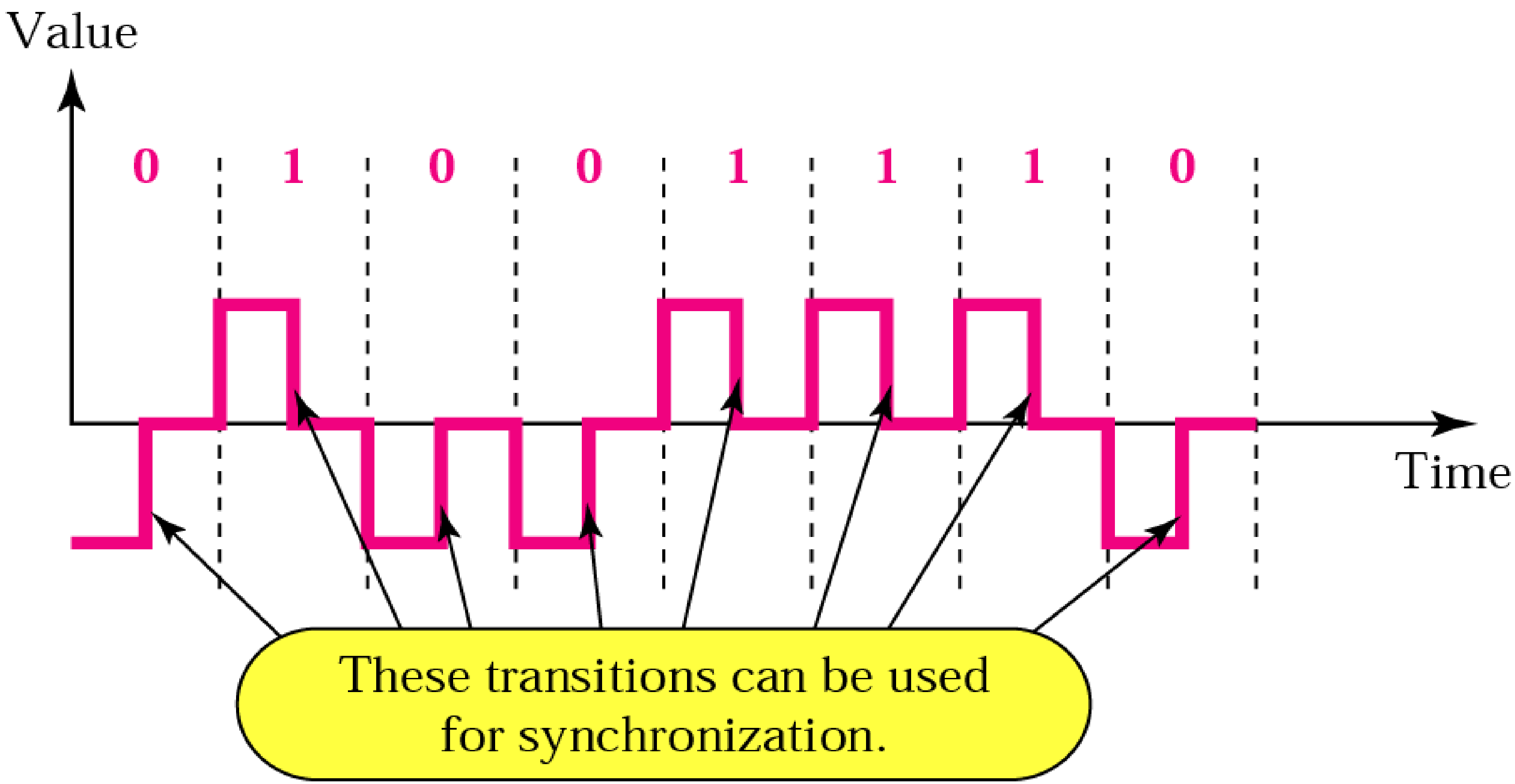
In NRZ-I the signal is inverted if a 1 is encountered.

Digital Transmission

•The main problem with NRZ encoding occurs when the sender and receiver clocks are not synchronized. The receiver does not know when one bit has ended and the next bit is starting.

•One solution is the RZ (return-to-zero) scheme, which uses three voltage levels.

RZ Encoding


Value
0
1
0
0
1
1
1
0
Time
These transitions can be used for synchronization.

RZ Encoding

Return to Zero RZ: Key characteristics of the RZ coding are:

- Three levels
- Good synchronization
- Main limitation is the increase in bandwidth

The main disadvantage of RZ encoding is that it requires two signal changes to encode a bit and therefore occupies greater bandwidth.

Manchaster

Biphase:

•To overcome the limitations of NRZ encoding, biphase encoding techniques can be adopted.

•*Manchester* and *differential Manchester Coding* are the two common Biphase techniques

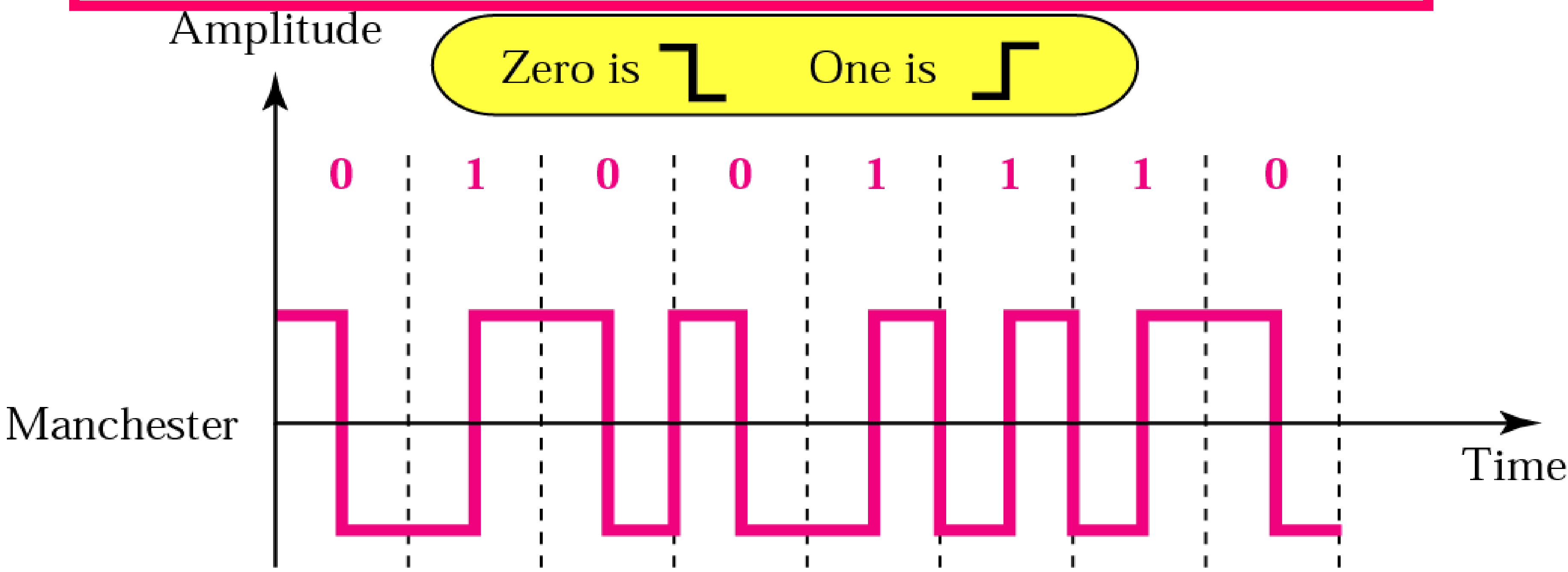
•In Manchester coding the mid-bit transition serves as a clocking mechanism and also as data.

•In the standard Manchester coding there is a transition at the middle of each bit period.

•A binary 1 corresponds to a *low-to-high transition* and a binary 0 to a *high-to-low transition* in the middle.

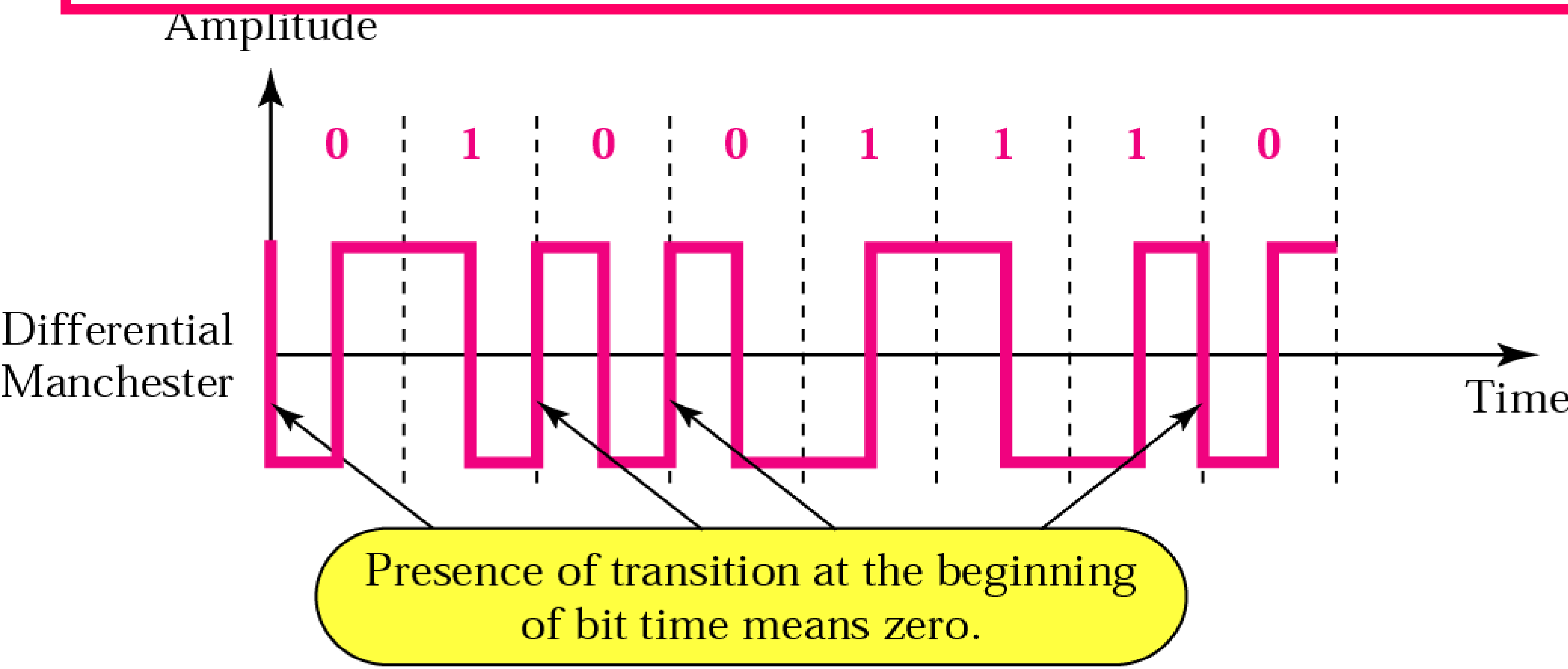
Manchester

In Manchester encoding, the transition at the middle of the bit is used for both synchronization and bit representation.



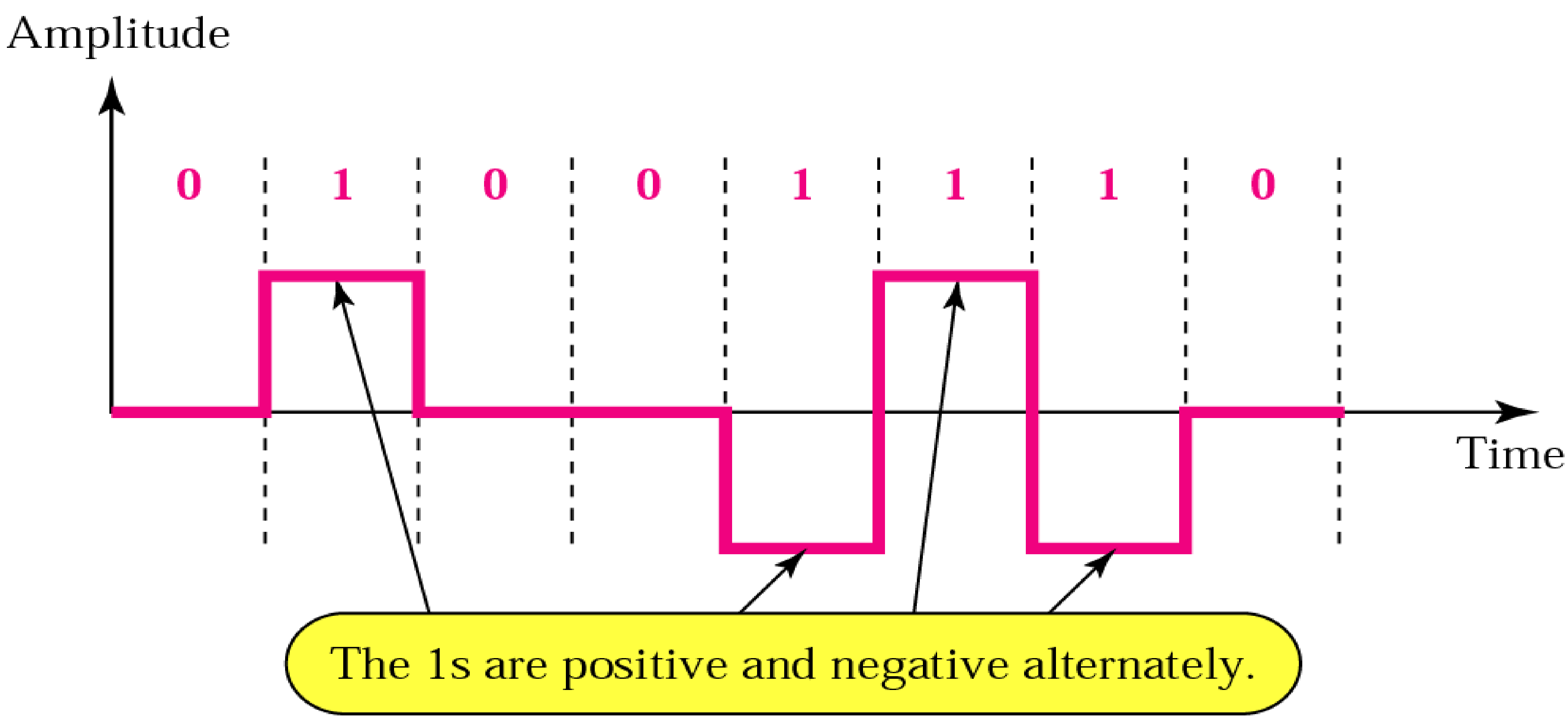
Differential Manchester

In differential Manchester encoding, the transition at the middle of the bit is used only for synchronization. The bit representation is defined by the inversion or noninversion at the beginning of the bit.



Bipolar Encoding

In bipolar encoding, we use three levels: positive, zero, and negative.



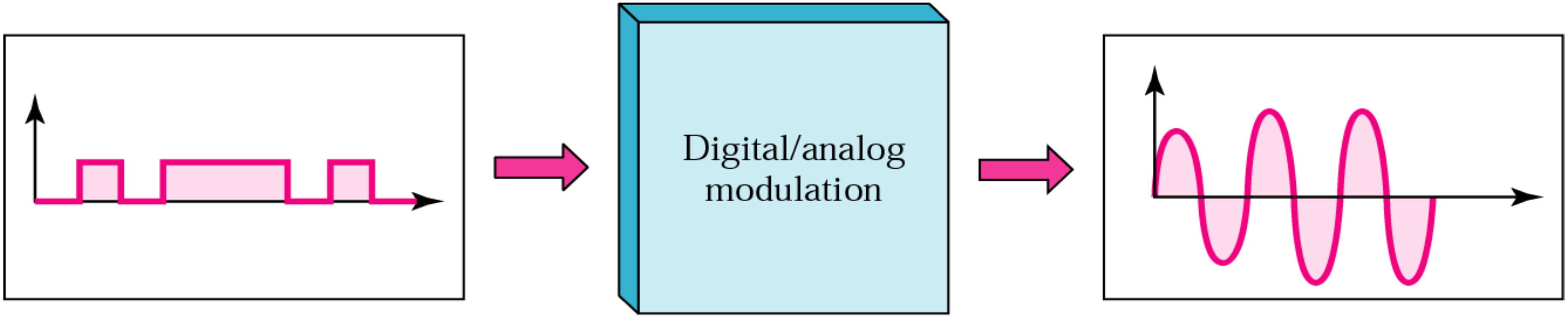
Sampling

- ***Pulse Amplitude Modulation***
- ***Pulse Code Modulation***
- ***Sampling Rate: Nyquist Theorem***
- ***How Many Bits per Sample?***
- ***Bit Rate***

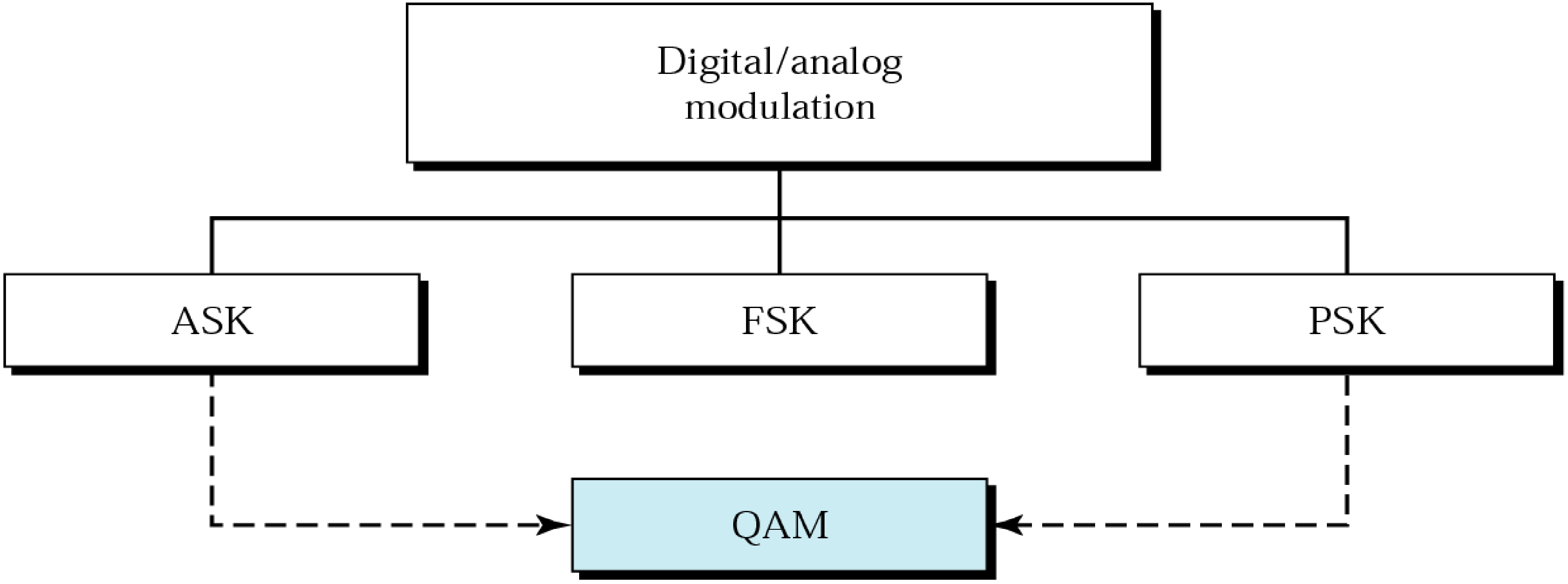
Modulation of Digital Data

- ***Digital-to-Analog Conversion***
- ***Amplitude Shift Keying (ASK)***
- ***Frequency Shift Keying (FSK)***
- ***Phase Shift Keying (PSK)***
- ***Quadrature Amplitude Modulation***

Digital to Analog



Digital to Analog



Digital to Analog

Bit rate is the number of bits per second. Baud rate is the number of signal units per second. Baud rate is less than or equal to the bit rate.

Digital to Analog

An analog signal carries 4 bits in each signal unit. If 1000 signal units are sent per second, find the baud rate and the bit rate

Solution

Baud rate = 1000 bauds per second (baud/s)
Bit rate = 1000 x 4 = 4000 bps

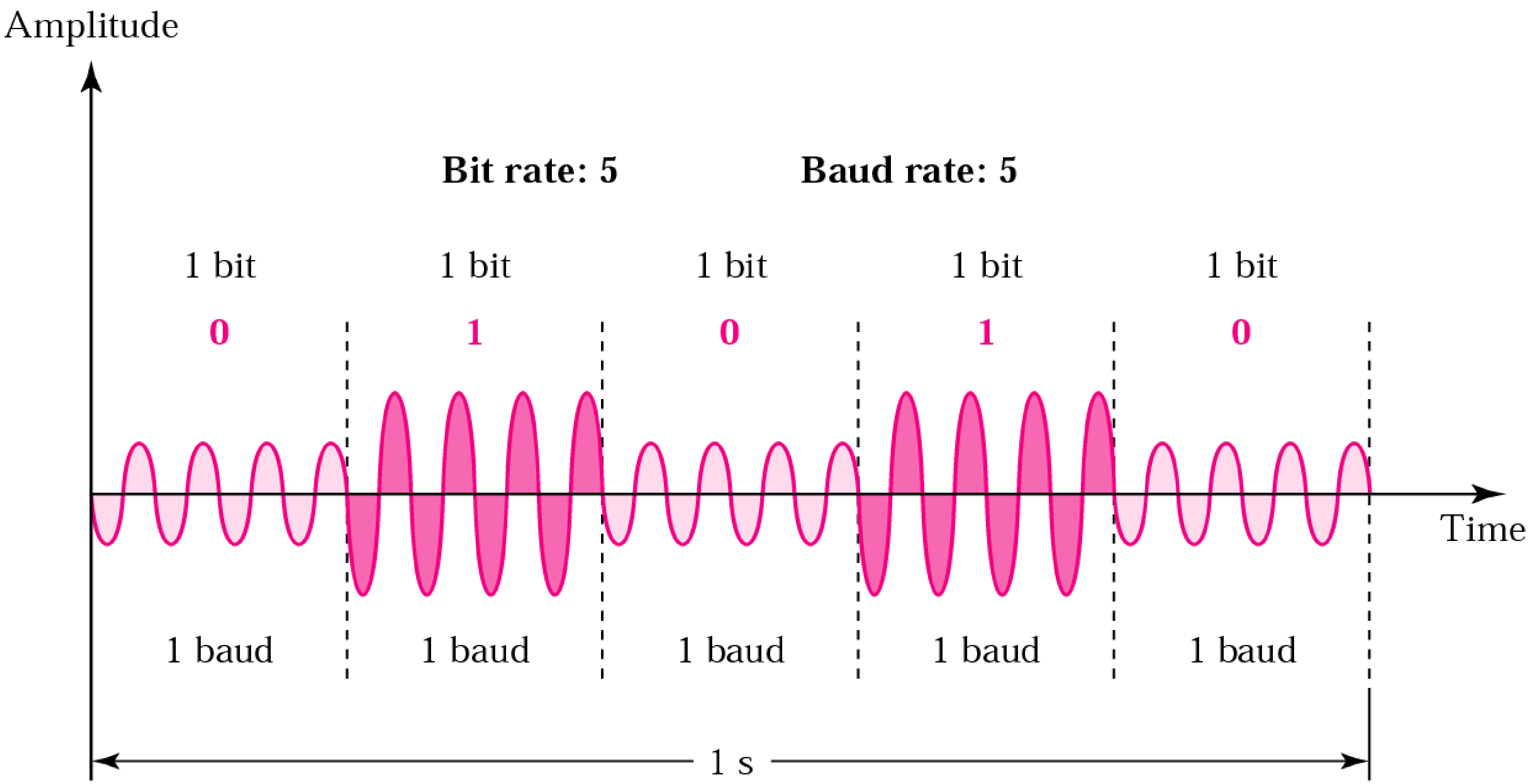
Digital to Analog

The bit rate of a signal is 3000. If each signal unit carries 6 bits, what is the baud rate?

Solution

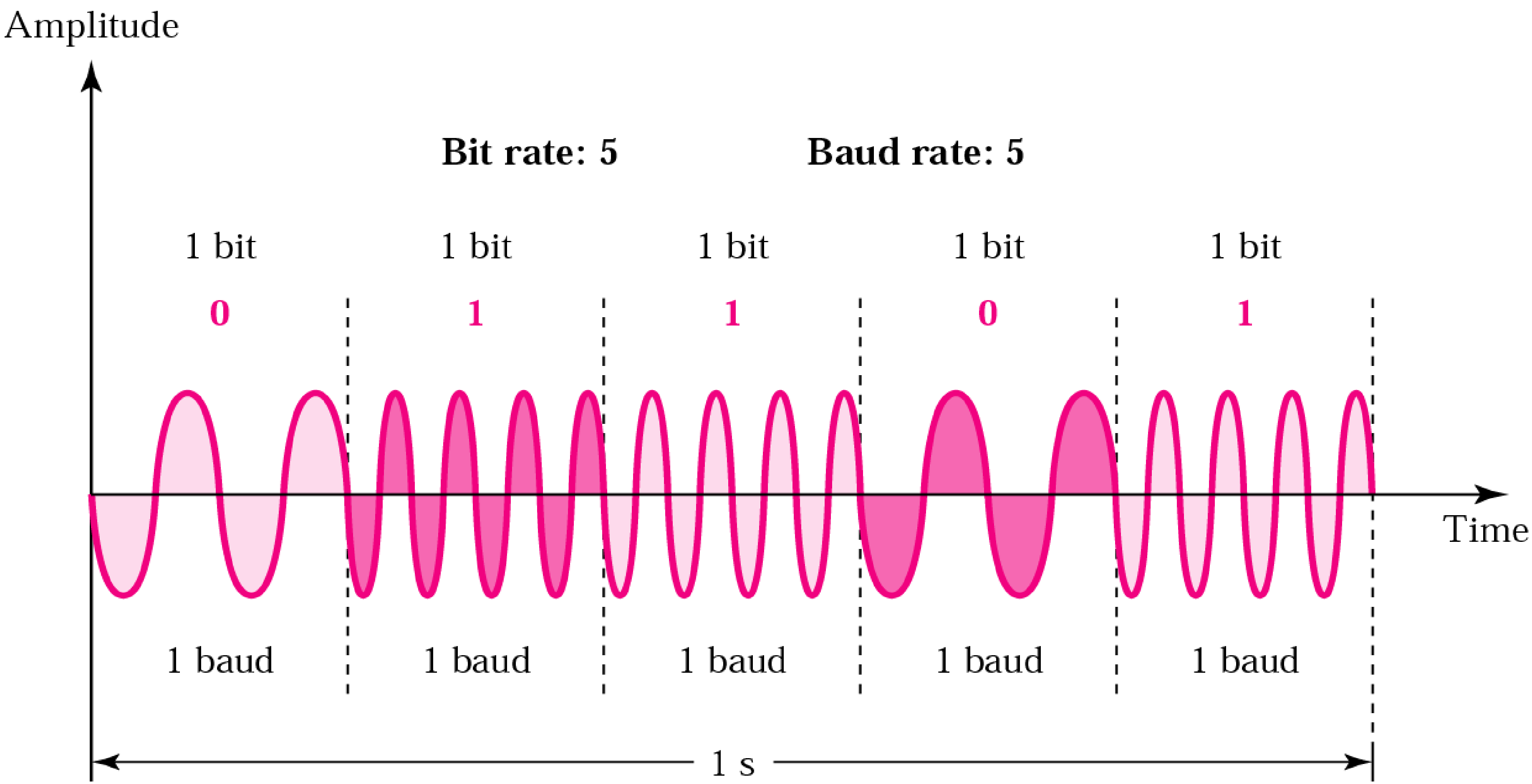
Baud rate = 3000 / 6 = 500 baud/s

ASK



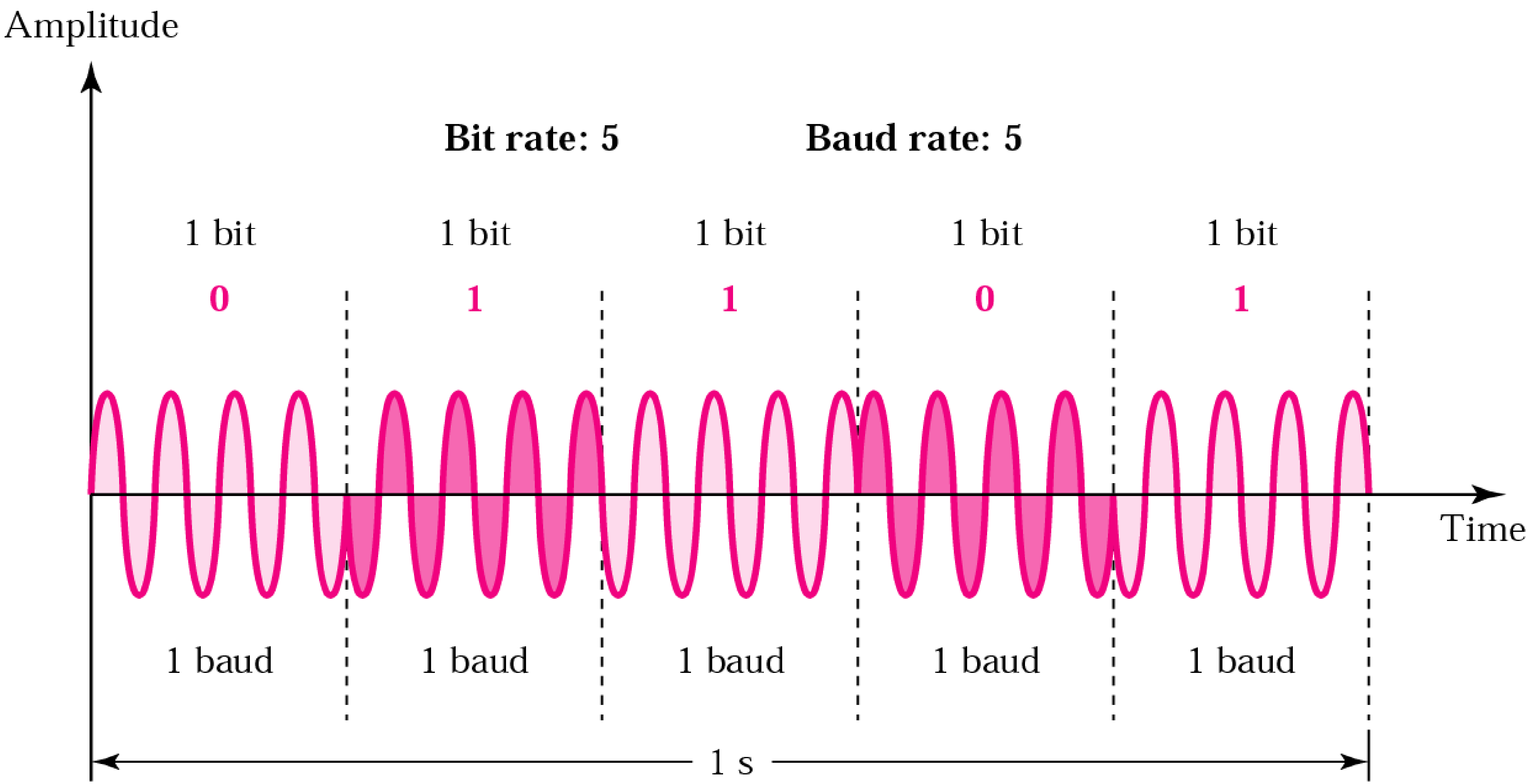
Amplitude
Bit rate: 5
Baud rate: 5
1 bit
1 bit
1 bit
1 bit
1 bit
0
1
0
1
0
Time
1 baud
1 baud
1 baud
1 baud
1 baud
1 s

FSK



Amplitude
Bit rate: 5
Baud rate: 5
1 bit
1 bit
1 bit
1 bit
1 bit
0
1
1
0
1
Time
1 baud
1 baud
1 baud
1 baud
1 baud
1 s

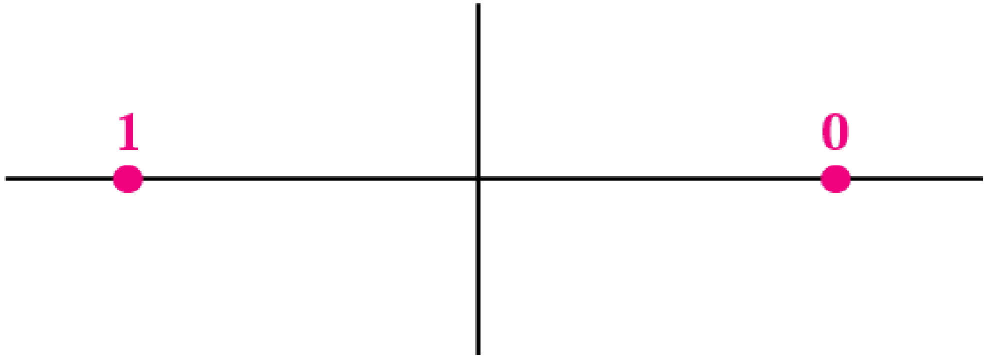
PSK


Amplitude
Bit rate: 5
Baud rate: 5
1 bit
1 bit
1 bit
1 bit
1 bit
0
1
1
0
1
Time
1 baud
1 baud
1 baud
1 baud
1 baud
1 s

PSK Constellation

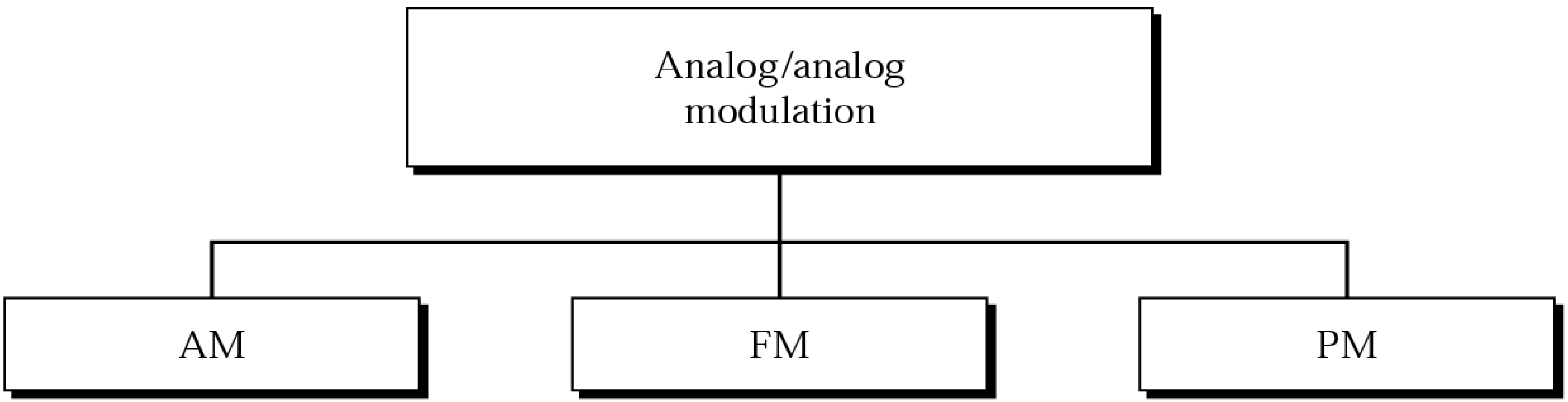
Bit	Phase
0	0
1	180

Bits

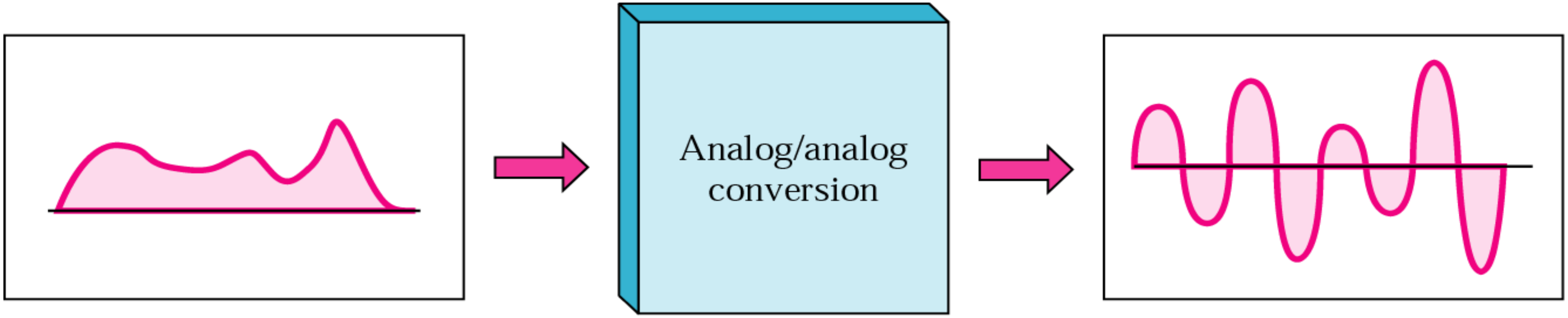


Constellation diagram

Analog Modulation



Analog Modulation

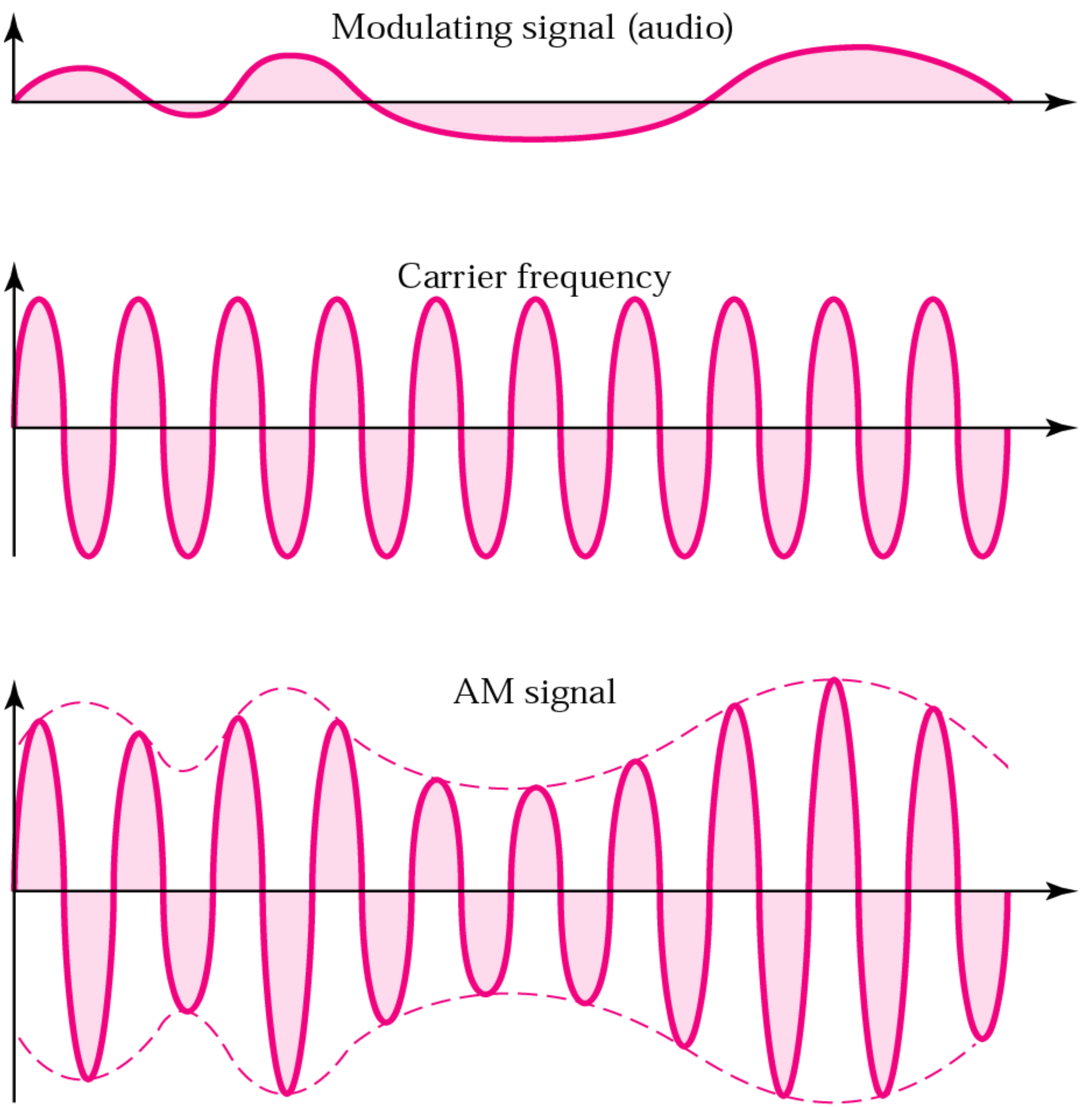


AM

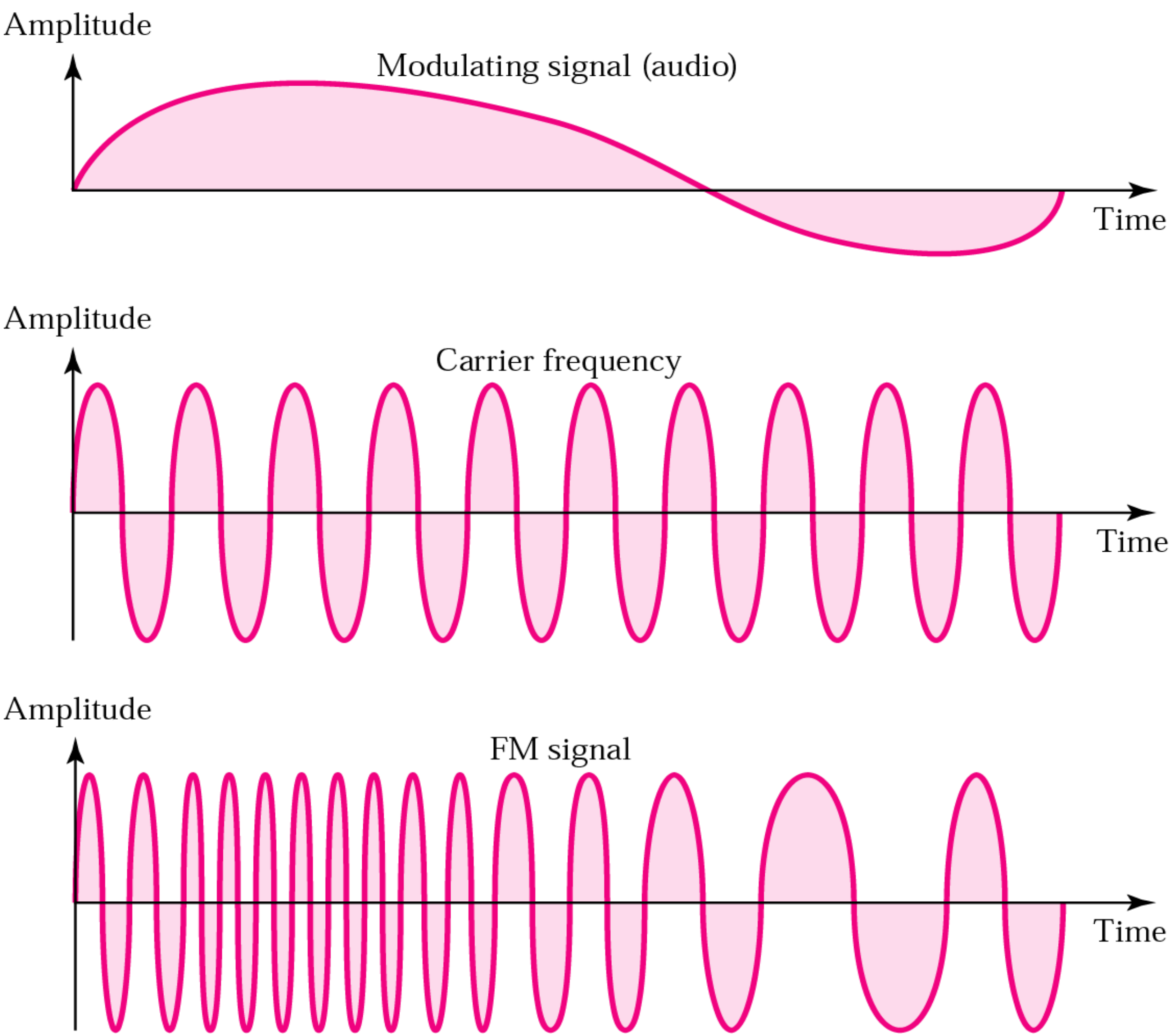
The total bandwidth required for AM can be determined from the bandwidth of the audio signal:

BWt = 2 x BWm.

AM



Frequency Modulation



Sampling

Analog data such as voice, video and music can be converted into digital signal communication through transmission media. This allows the use of modern digital transmission and switching equipment's. The device used for conversion of analog data to digital signal and vice versa is called a *coder* (coder-decoder). There are two basic approaches:

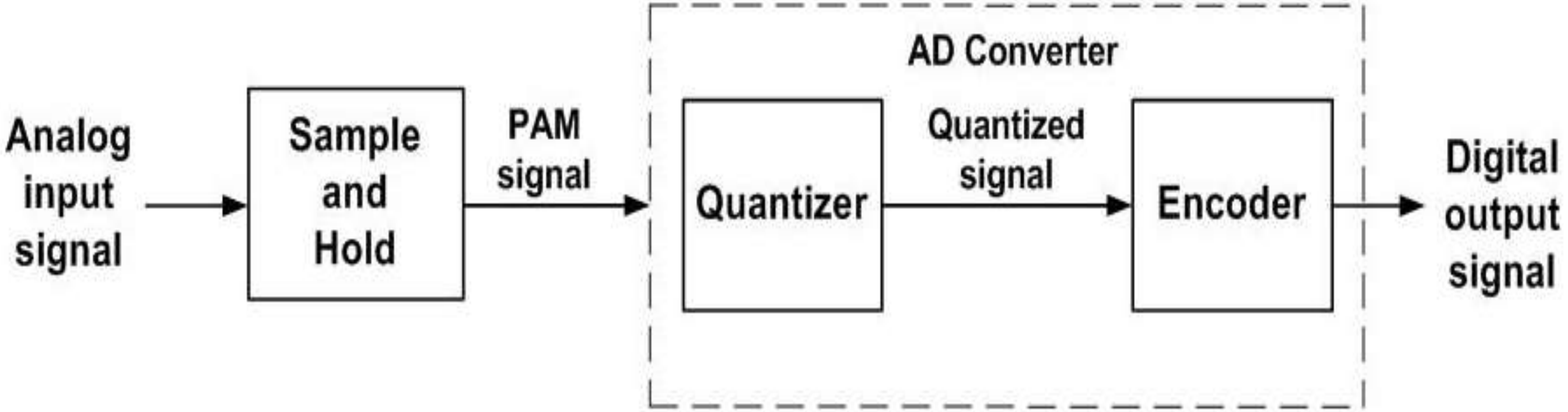
Pulse Code Modulation (PCM)
Delta Modulation (DM)

Sampling

Pulse Code Modulation involves the following three basic steps as shown in Fig. :

- Sampling – PAM
- Quantization
- Line coding

Sampling

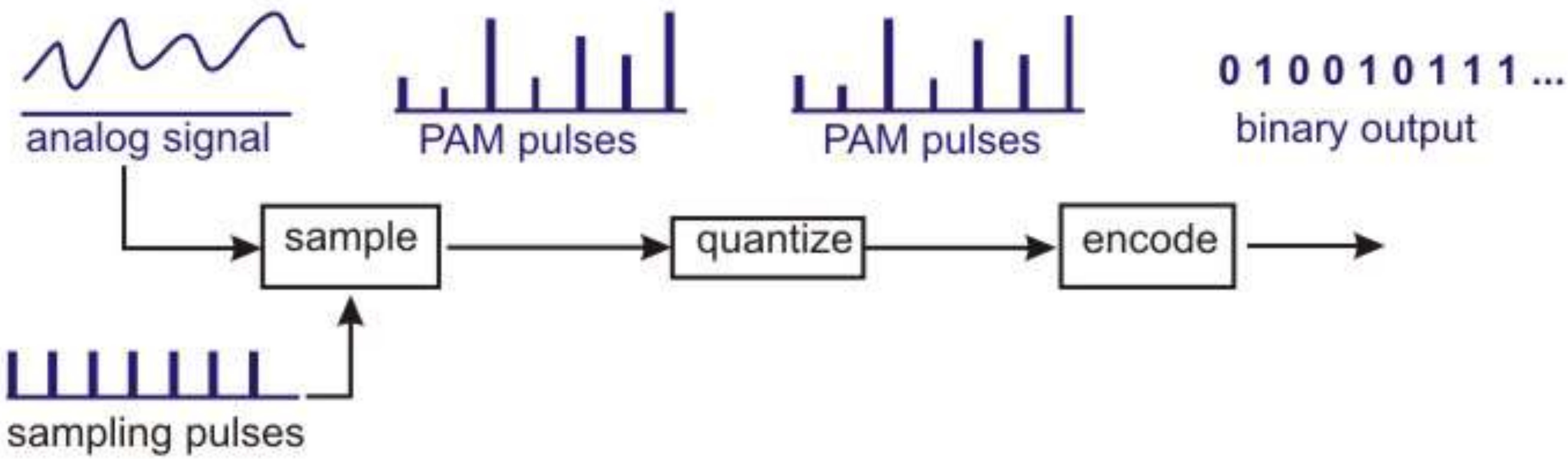


Analog input signal
Sample and Hold
PAM signal
AD Converter
Quantizer
Quantized signal
Encoder
Digital output signal

Sampling

Sampling: This process is based on Shannon's sampling theorem. Numbers of samples of the signal are taken at regular intervals, at a rate higher than twice the highest significant signal frequency. This basic step is known as Pulse Amplitude Modulation (PAM) as shown in Fig. . For example, during the sampling of voice data, in the frequency range 300 to 4000 Hz, 8000 samples per second are sufficient for the coding

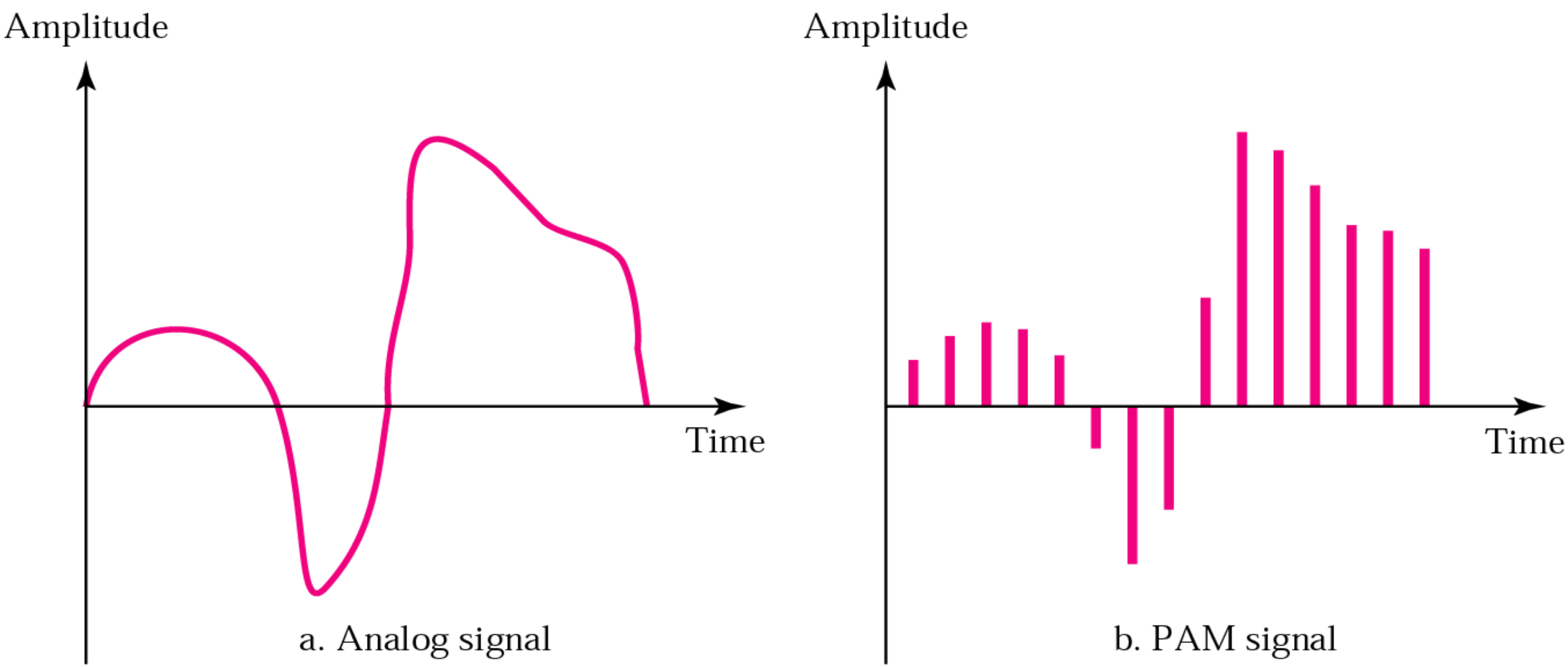
Sampling


analog signal
PAM pulses
PAM pulses
0 1 0 0 1 0 1 1 1 ...
binary output
sample
quantize
encode
sampling pulses

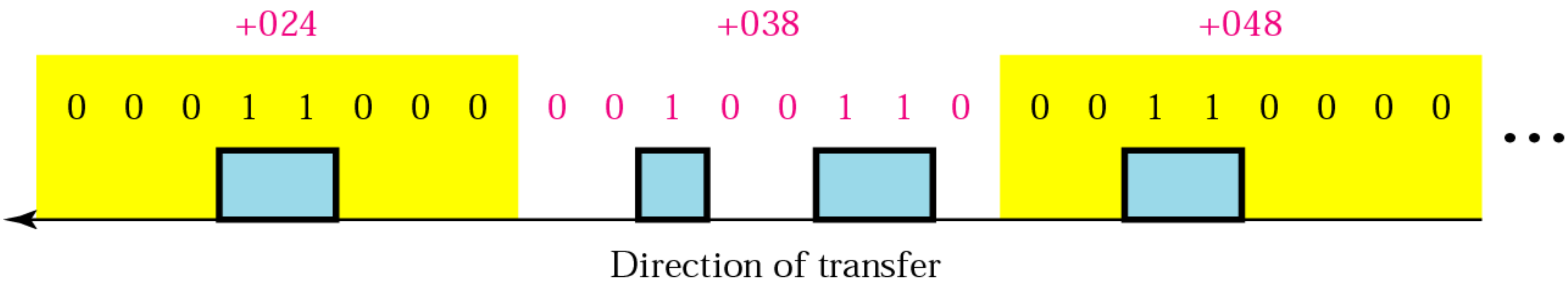
PAM

Pulse amplitude modulation has some applications, but it is not used by itself in data communication. However, it is the first step in another very popular conversion method called pulse code modulation.

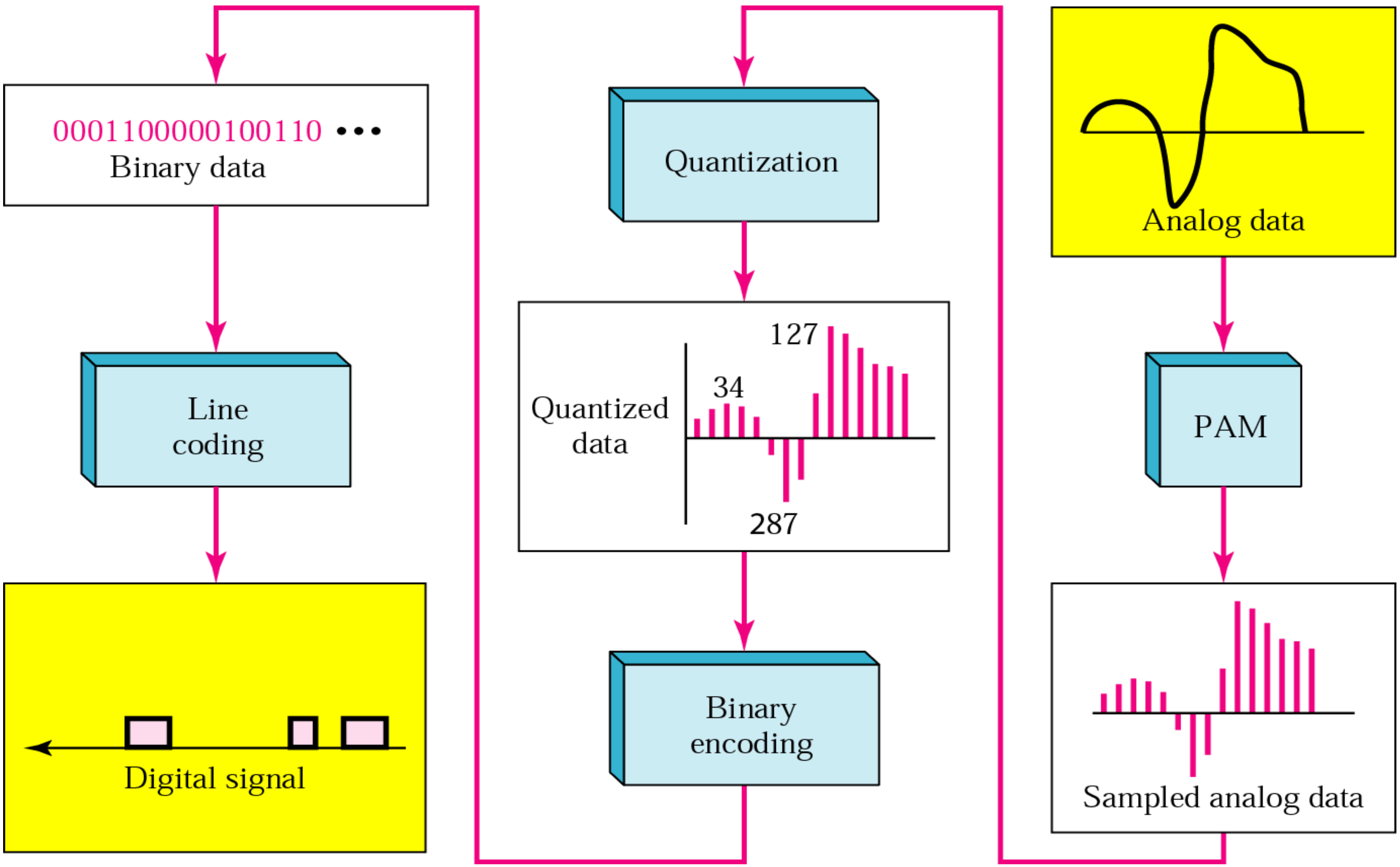
PAM



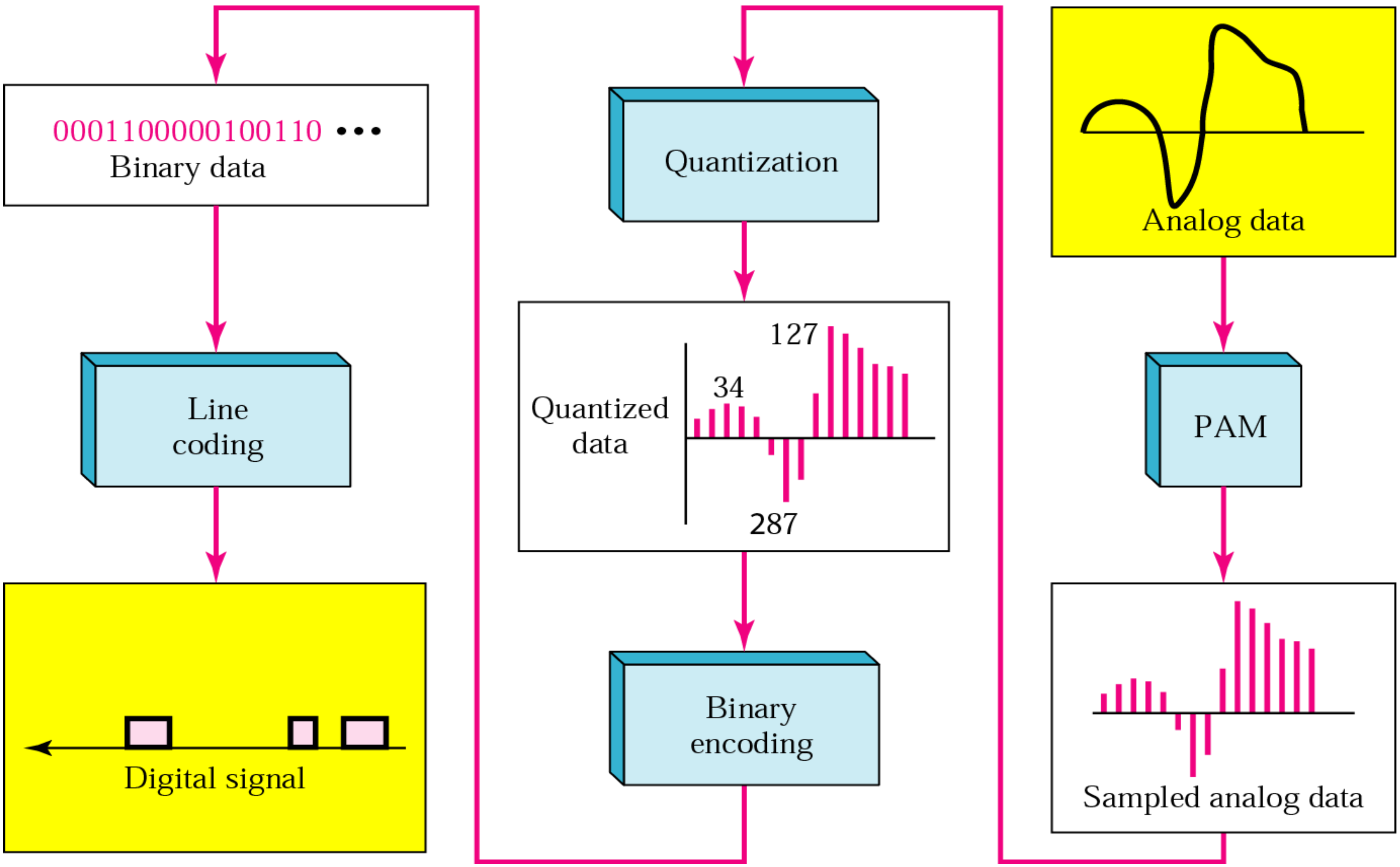
PCM


+024
+038
+048
0 0 0 1 1 0 0 0
0 0 1 0 0 1 1 0
0 0 1 1 0 0 0 0
Direction of transfer

Analog to PCM Digital code



Analog to PCM Digital code



Sampling

According to the Nyquist theorem, the sampling rate must be at least 2 times the highest frequency.

Example

What sampling rate is needed for a signal with a bandwidth of 10,000 Hz (1000 to 11,000 Hz)?

Solution

The sampling rate must be twice the highest frequency in the signal:

Sampling rate = 2 x (11,000) = 22,000 samples/s

Example

We want to digitize the human voice. What is the bit rate, assuming 8 bits per sample?

Solution

The human voice normally contains frequencies from 0 to 4000 Hz.
Sampling rate = 4000 x 2 = 8000 samples/s

Bit rate = sampling rate x number of bits per sample
= 8000 x 8 = 64,000 bps = 64 Kbps

Example

We want to digitize the human voice. What is the bit rate, assuming 8 bits per sample?

Solution

The human voice normally contains frequencies from 0 to 4000 Hz.

Sampling rate = 4000 x 2 = 8000 samples/s

Bit rate = sampling rate x number of bits per sample

= 8000 x 8 = 64,000 bps = 64 Kbps

Delta Modulation (DM)

•Delta Modulation is a very popular alternative of PCM with much reduced complexity.

•Here the analog input is approximated by a staircase function, which moves up or down by one quantization level (a constant amount) at each sampling interval.

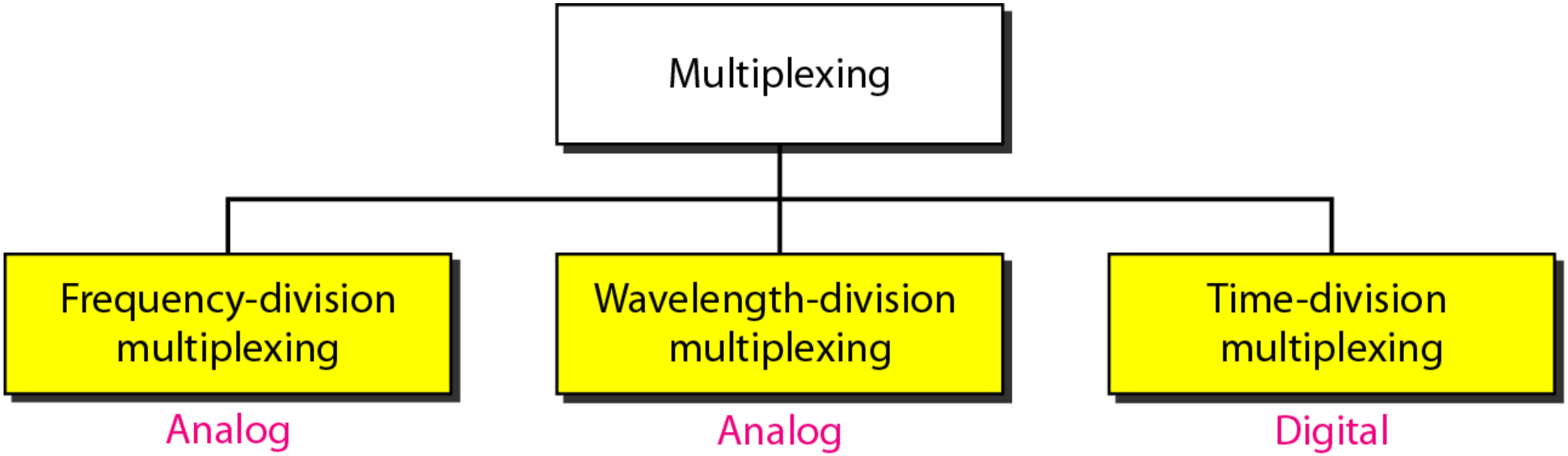
•Each sample delta modulation process can be represented by a single binary digit, which makes it more efficient than the PCM technique.

Sampling

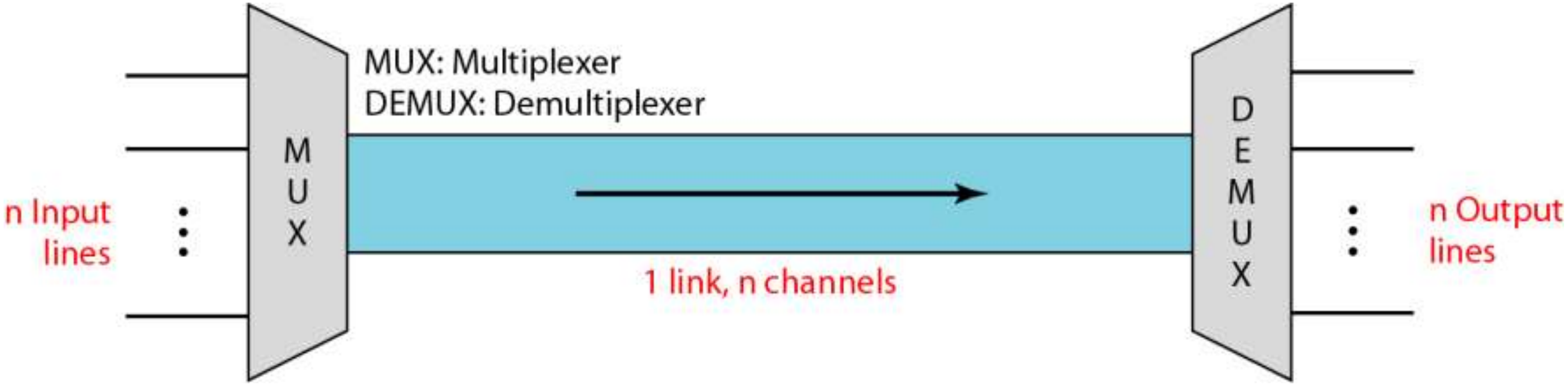
In this modulation technique, instead of sending the entire encoding of each and every sample, we just send the change from previous sample.

If the difference between analog input and the feedback signal is positive, then encoded output is 1, otherwise it is 0. So, only one bit is to be sent per sample.

Multiplexing



Dividing a link into channels

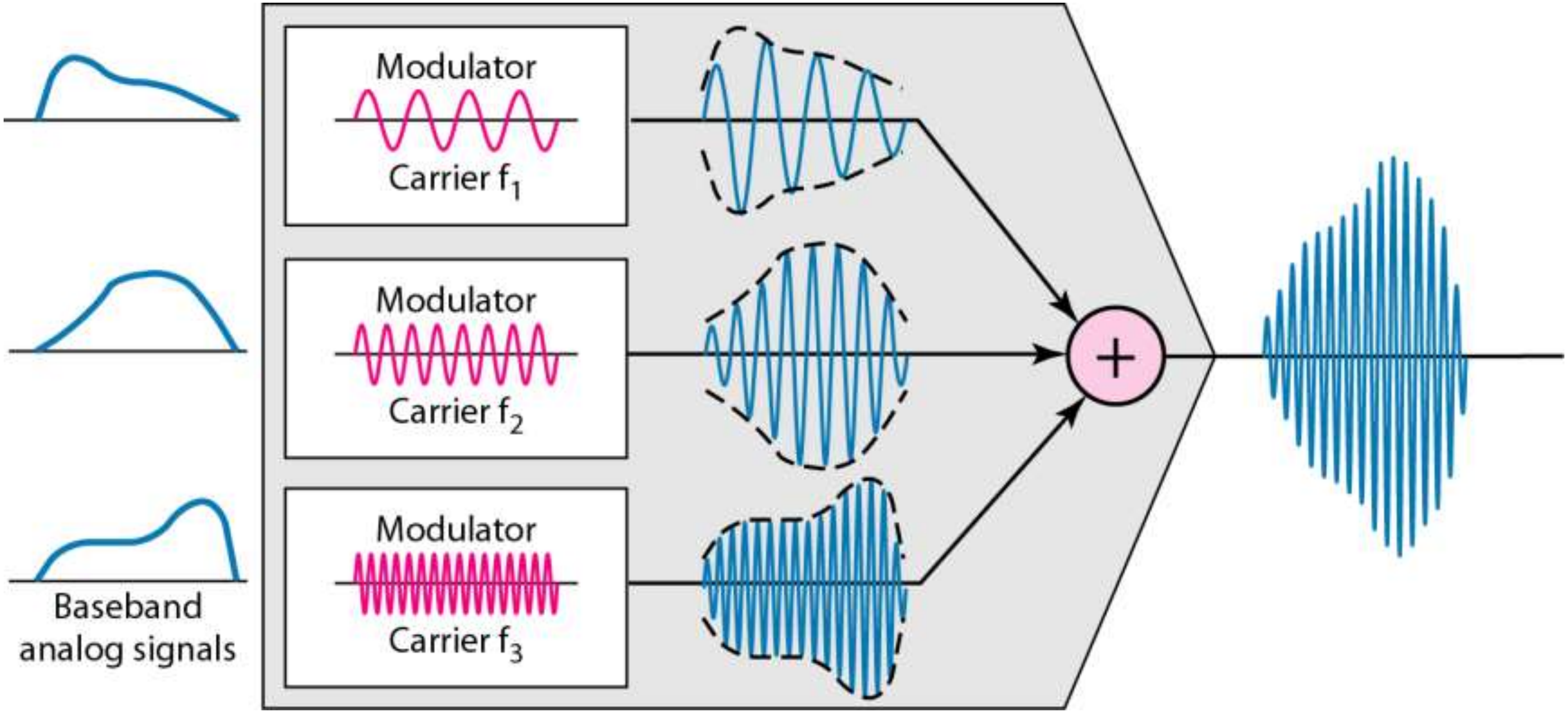


Frequency-division multiplexing

Note

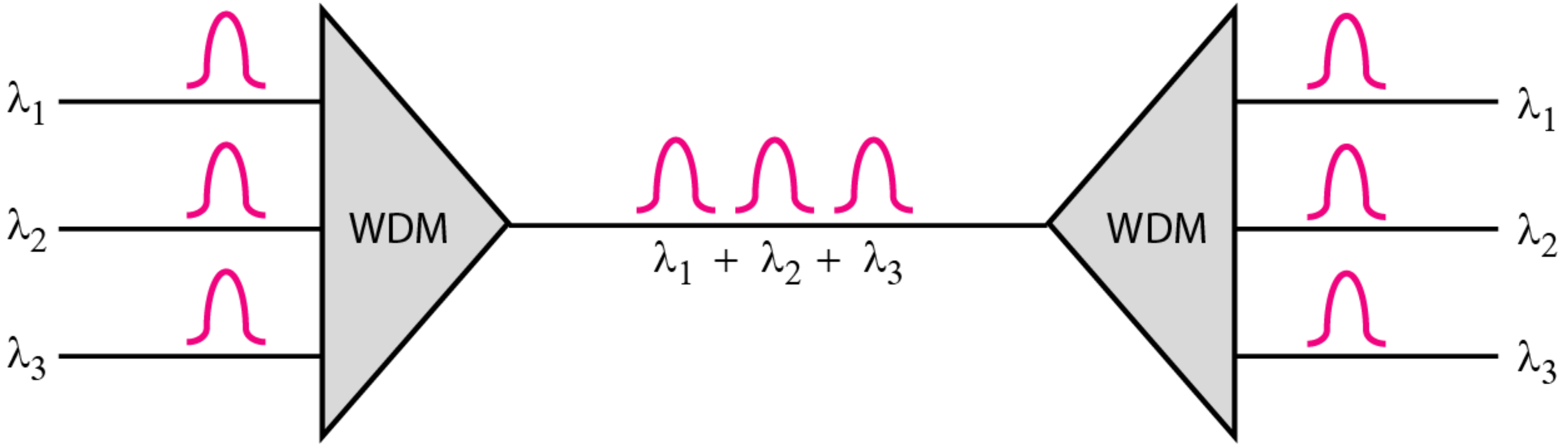
FDM is an analog multiplexing technique that combines analog signals.

FDM process

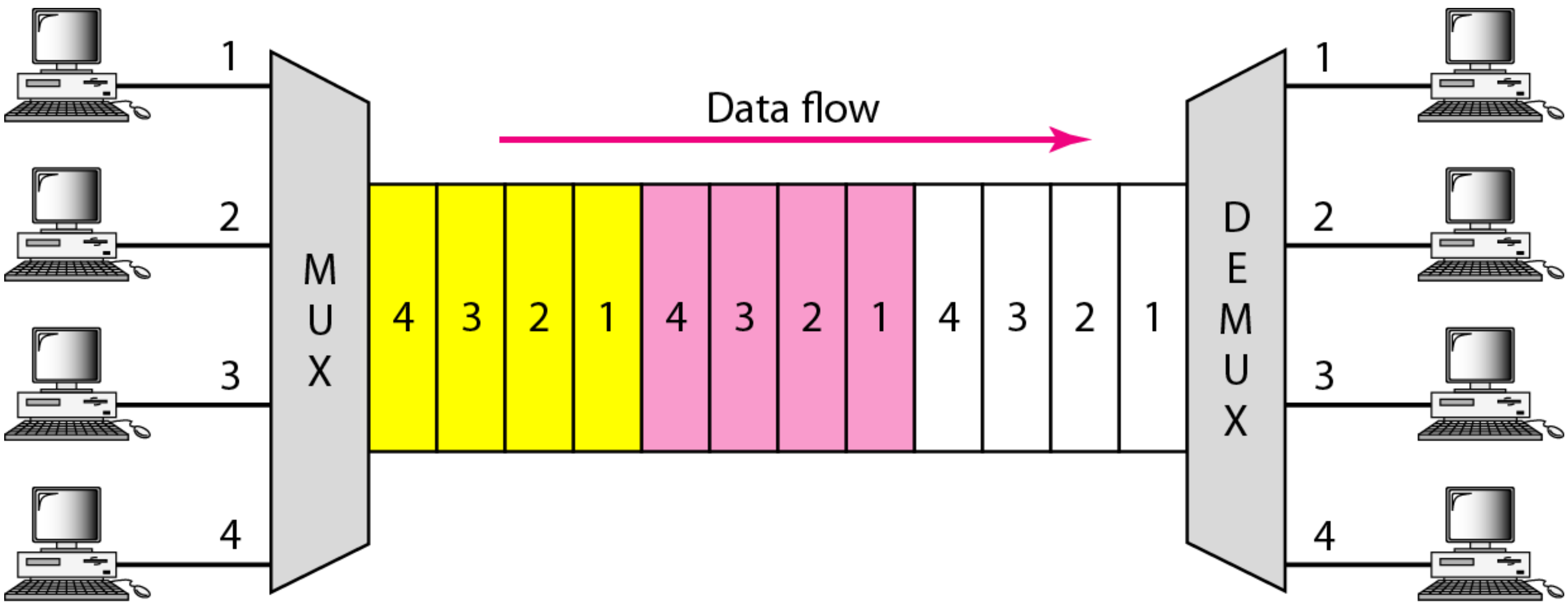


Modulator
Carrier f_1
Modulator
Carrier f_2
Modulator
Carrier f_3
Baseband analog signals
+

Wavelength-division multiplexing



TDM

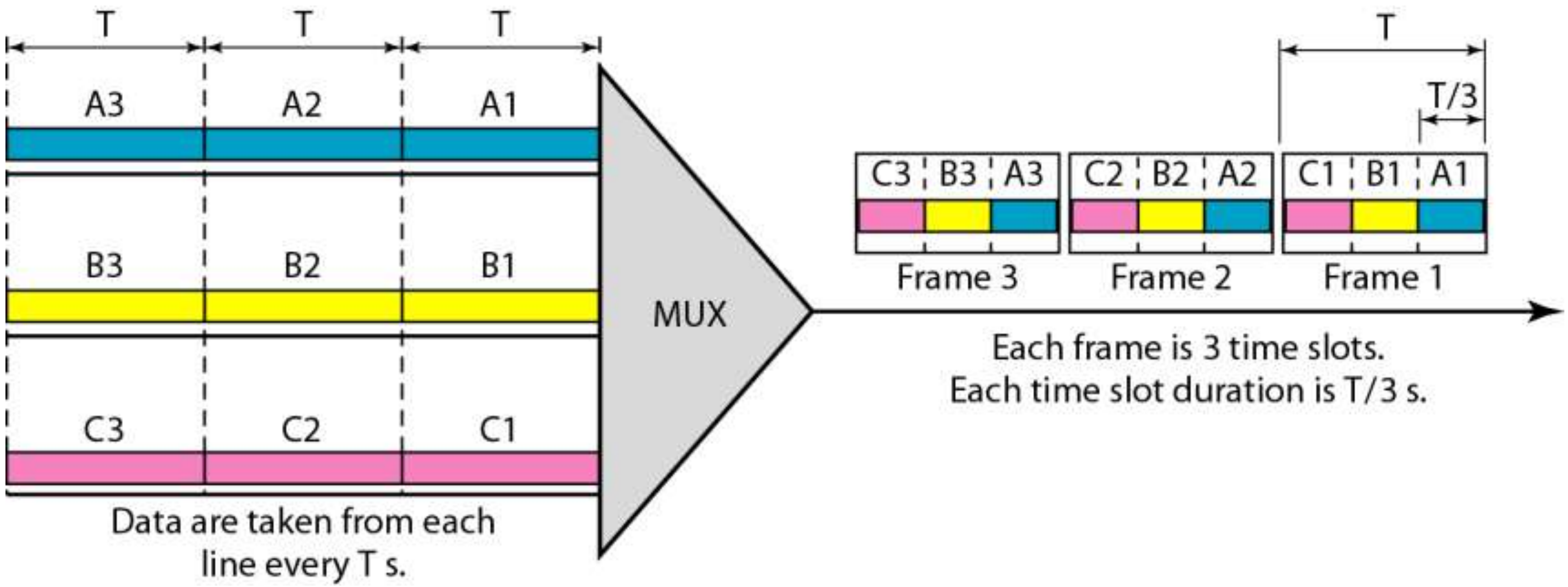


Cont …

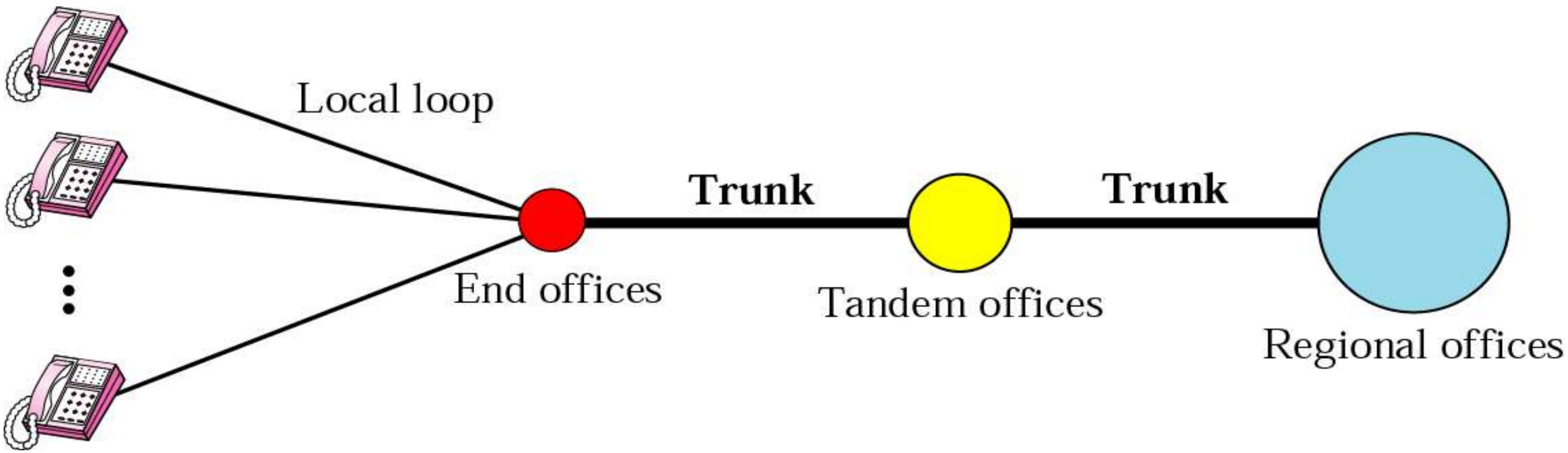
Note

TDM is a digital multiplexing technique for combining several low-rate channels into one high-rate one.

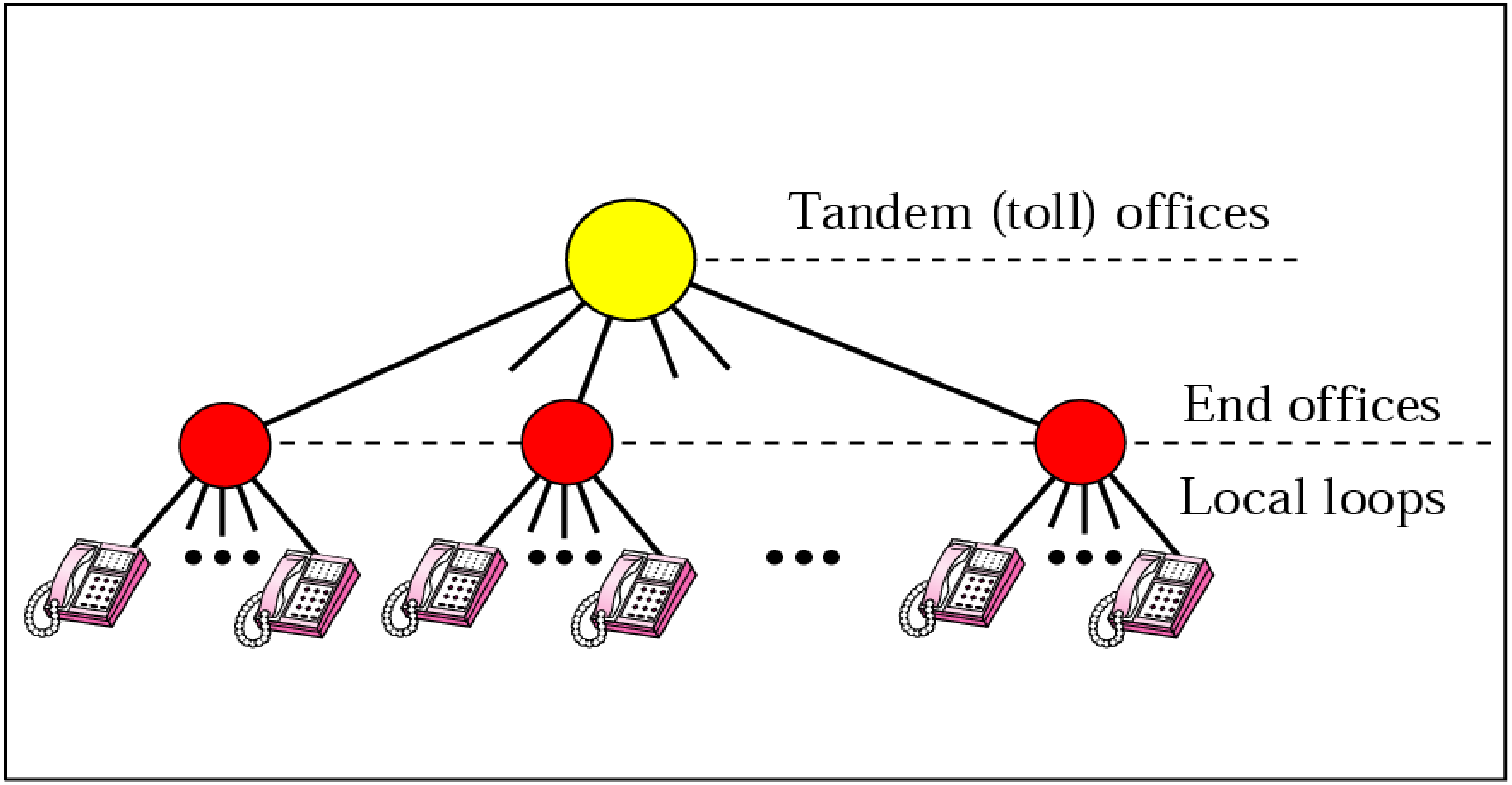
Synchronous Time-Division Multiplexing



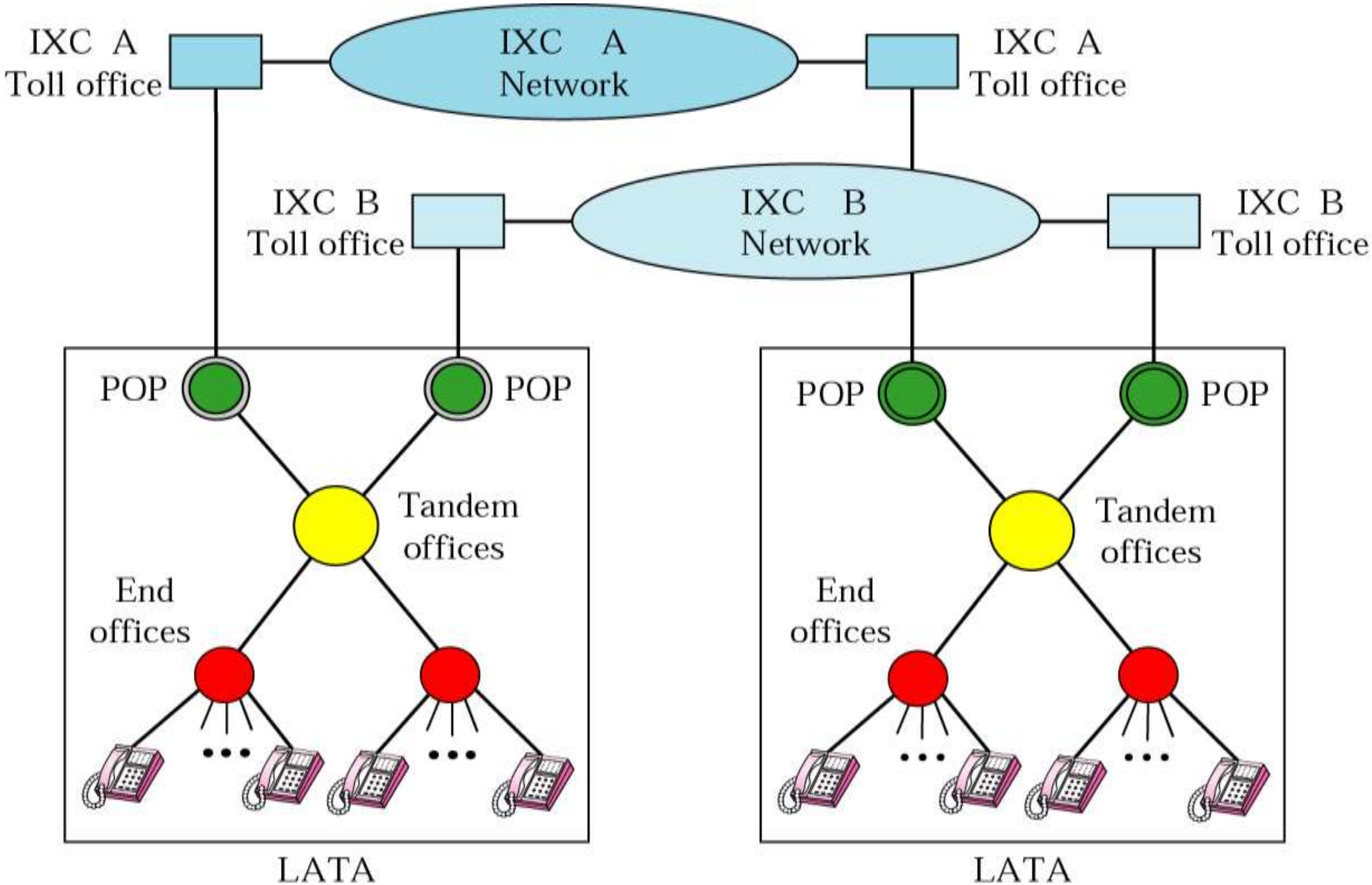
Telephone System



Telephone System



Telephone System



Review Questions (Short)

1. What is computer networking? Discuss the various types of it.
2. Give the names of various layers in OSI model. State the role of network layer in it.
3. What do you mean by wireless transmission? Briefly describe the various media that support wireless transmission.
4. Distinguish between FSK, PSK and ASK? Discuss Pulse code modulation.

Review Questions (Long)

1. An analog signal has a bandwidth of 40 KHz. If we sample this signal and send it through a 50Kbps channel. What is the SNR?
2. Which of the four digital-to-analog conversion techniques (ASK, FSK, PSK or QAM) is the most susceptible to noise? Defend your answer.
3. Explain Mobile Telephone System.
4. Difference between guided and unguided media with the help of an example.
5. Explain Pulse Code Modulation.
6. What does the Shannon capacity and Nyquist theorem have to do with communication?

Recommended Reading

1. Behrouz Forouzun, “Data Communication and Networking”:TMH
2. Tanenbaum , “A computer Networks”: Prentice Hall
3. Stallings , “High speed Networks” :Prentice Hall
4. Comer D. “Computer Networks”: Prentice hall
5. Kurose, J and Ross , “Computer Networking : Addison Wesley