



## Chapter 17

# Data Communications and Computer Networks

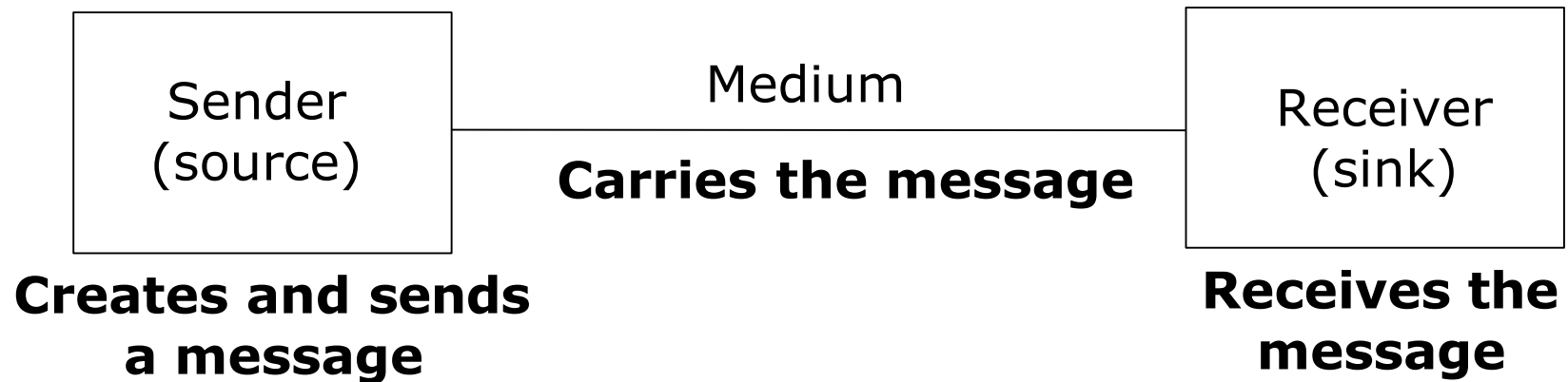
Computer Fundamentals - Pradeep K. Sinha & Priti Sinha

# Learning Objectives

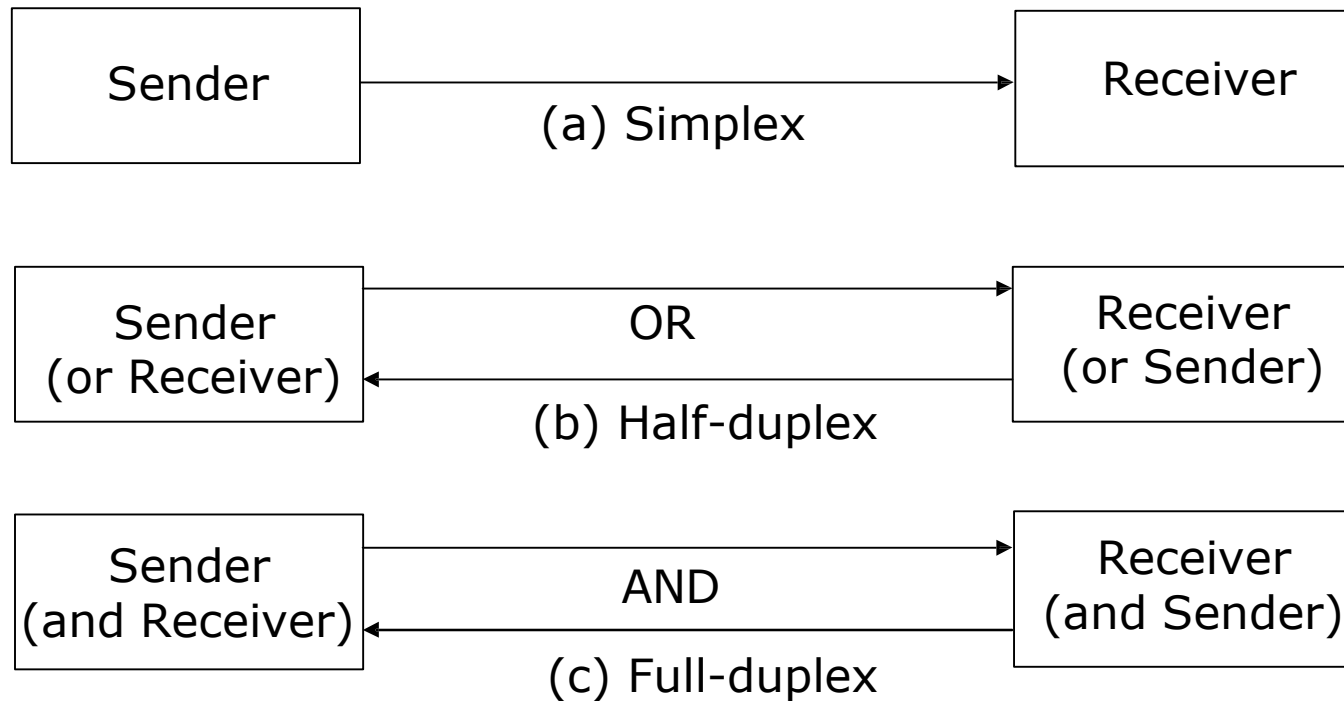
## **In this chapter you will learn about:**

- Basic elements of a communication system
- Techniques, channels, and devices used to transmit data between distant locations
- Types of computer networks
- Communication protocols and their use in computer networks
- Internetworking tools and their use in building large computer networks
- Characteristics and advantages of distributed data processing

# Basic Elements of a Communication System



# Data Transmission Modes



# Data Transmission Speed

- **Bandwidth:** Range of frequencies available for data transmission. It refers to data transmission rate. Higher the bandwidth, the more data it can transmit
- **Baud:** Unit of measurement of data transfer rate. Measured in bits per second (bps)



# Data Transmission Speed Category

- **Narrowband:** Sub-voice grade channels in range from 45 to 300 baud. Mainly used for telegraph lines and low-speed terminals
- **Voiceband:** Voice grade channels with speed up to 9600 baud. Mainly used for ordinary telephone voice communication and slow I/O devices
- **Broadband:** High speed channels with speed up to 1 million baud or more. Mainly used for high-speed computer-to-computer communication or for simultaneous transmission of data

# Data Transmission Media

The most commonly used ones are:

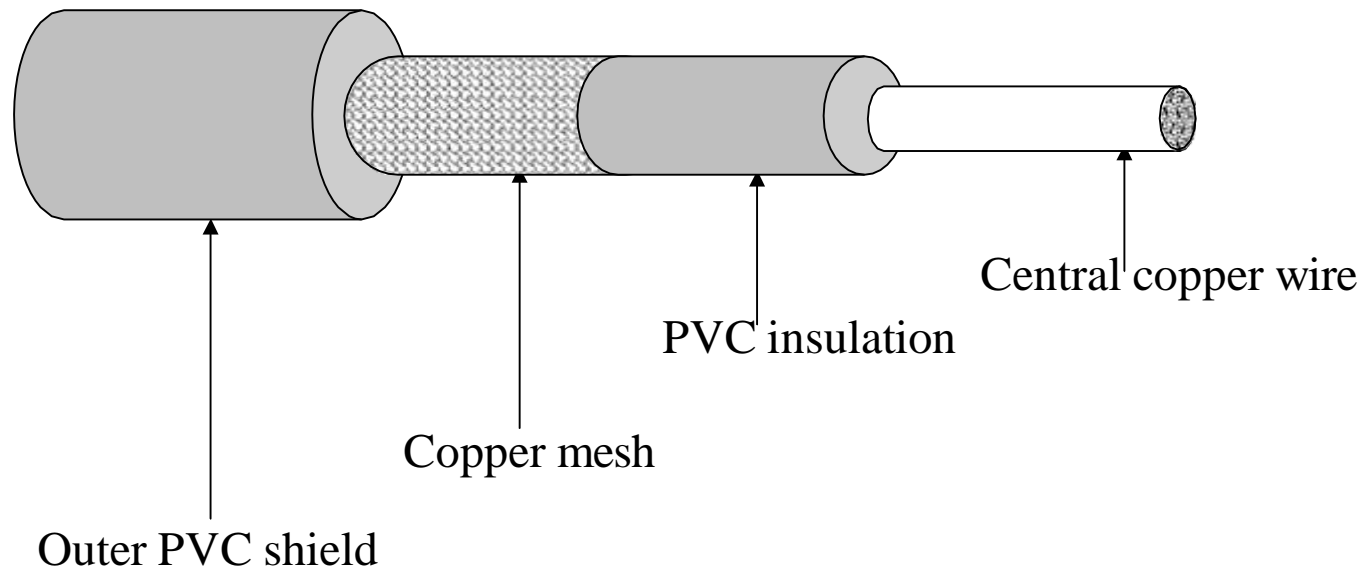
- Twisted-pair wire (UTP cable)
- Coaxial cable
- Microwave system
- Communications satellite
- Optical fibers

# Unshielded Twisted-Pair (UTP) Cable

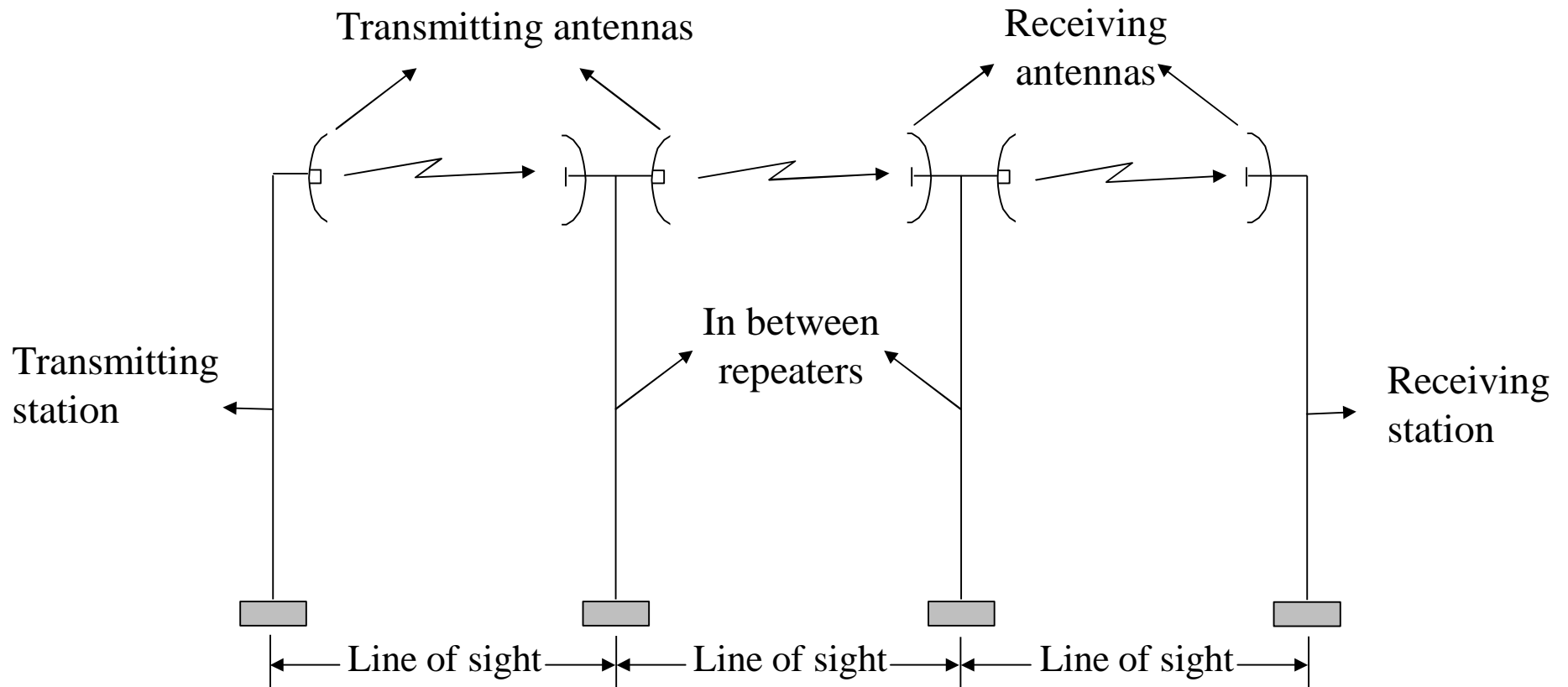




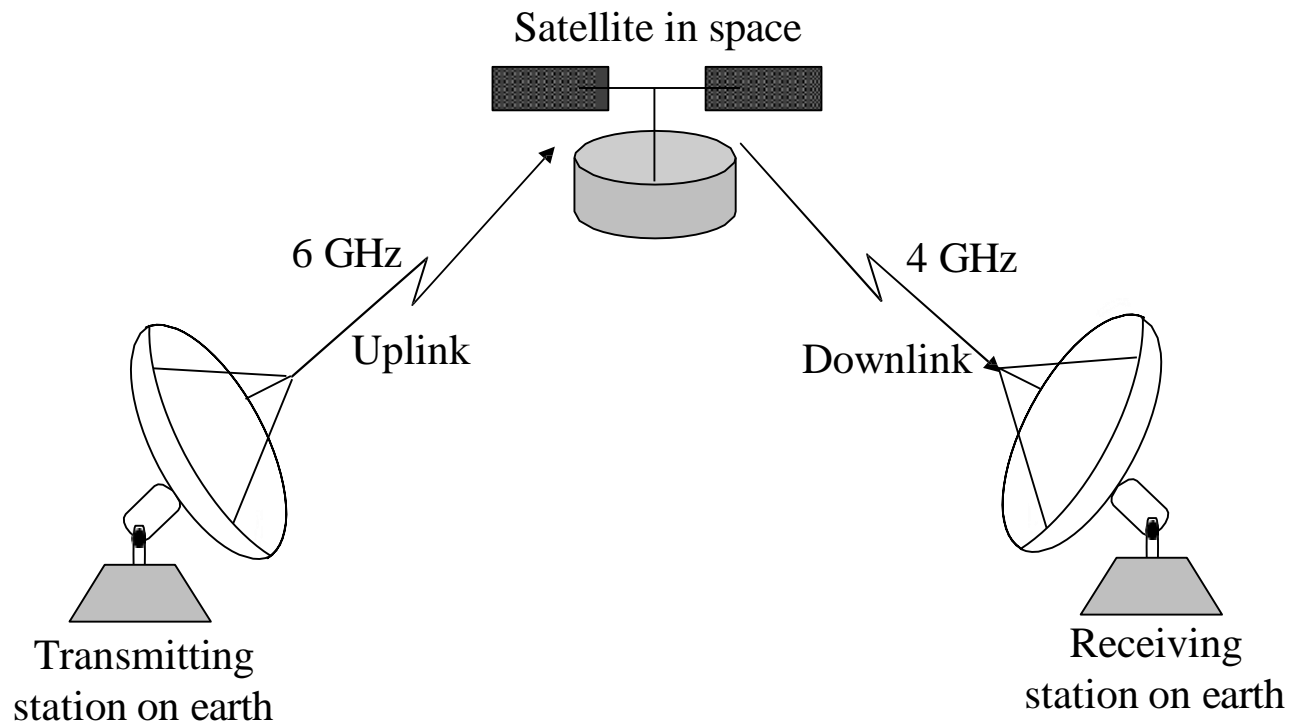
# Coaxial Cable



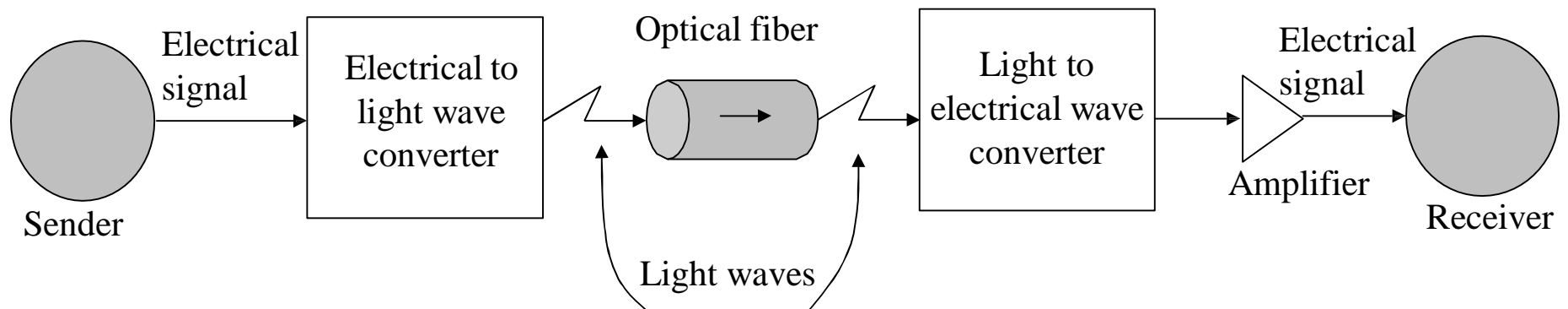
# Microwave Communication System



# Satellite Communication System



# Optical Fiber Communication System



# Digital and Analog Data Transmission

- *Analog signal*: Transmitted power varies over a continuous range. Example: sound, light, and radio waves
- *Digital signal*: Sequence of voltage pulses represented in binary form
- Computer generated data signal is digital, whereas telephone lines carry analog signals

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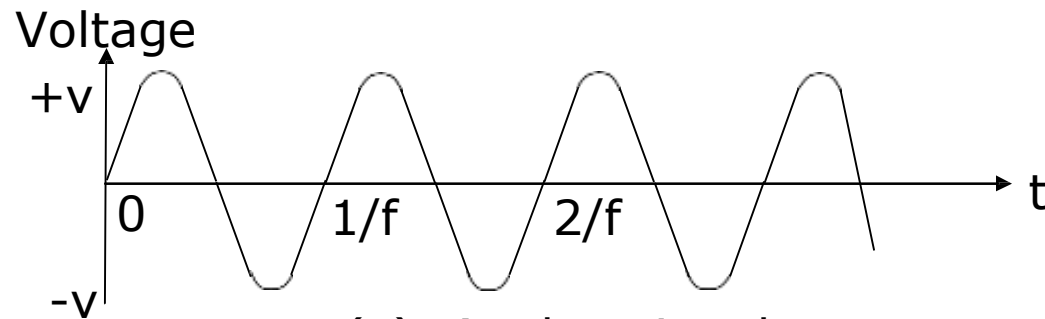
# Digital and Analog Data Transmission

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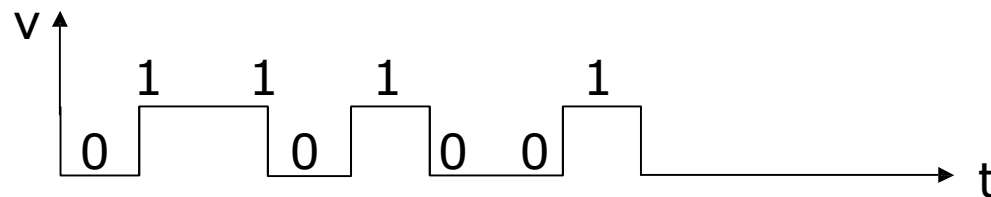
- When digital data is to be sent over an analog facility, digital signals must be converted to analog form
- Conversion of digital signal to analog form is known as modulation
- Conversion of analog signal to digital form is known as demodulation
- Digital transmission of data is preferred over analog transmission of data due to lower cost, higher transmission speeds, and lower error rate



# Analog and Digital Signals



(a) Analog signal



(b) Digital signal

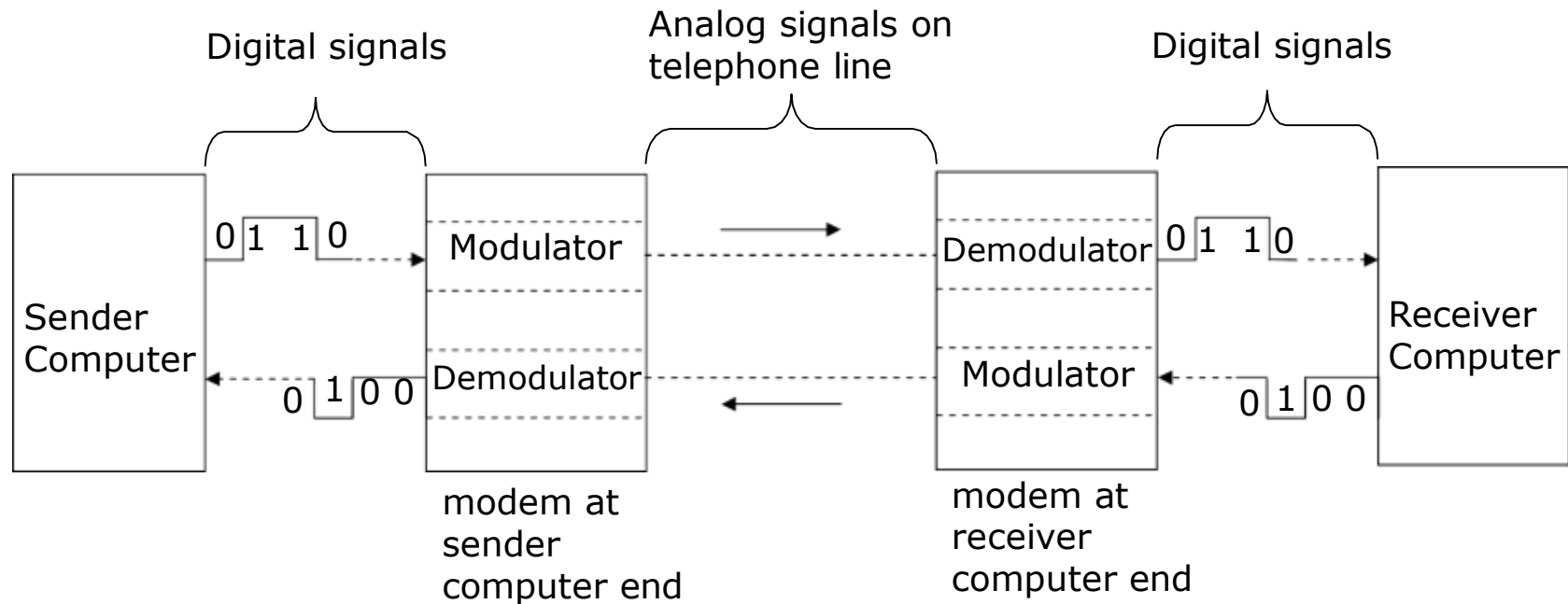
# Modulation Techniques

- **Amplitude Modulation (AM):** Two binary values (0 and 1) of digital data are represented by two different amplitudes of the carrier signal, keeping frequency and phase constant
- **Frequency Modulation (FM):** Two binary values of digital data are represented by two different frequencies, while amplitude and phase are kept constant
- **Phase Modulation (PM):** Two binary values of digital data are represented by shift in phase of carrier signal

# Modems

- Modem is short for **MO**dulator/**DE**Modulator
- Special device used for conversion of digital data to analog form (modulation) and vice-versa (demodulation)
- Essential piece of hardware where two digital devices (say two computers) want to communicate over an analog transmission channel (say a telephone line)

# Use of Modems in Data Communications



# Factors for Modem Selection

- Transmission speed
- Internal versus external
- Facsimile facility

# Data Transmission Services

- Data transmission service providers are popularly known as *common carriers*
- Various types of services offered by common carriers are:
  - **Dial-up line:** Operates in a manner similar to a telephone line
  - **Leased line:** Special conditioned telephone line that directly and permanently connects two computers
  - **Integrated Services Digital Network (ISDN):** Telephone system that provides digital (not analog) telephone and data services

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# Data Transmission Services

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- **Value Added Network (VAN):** Provides value-added data transmission service. Value added over and above the standard services of common carriers may include e-mail, data encryption/decryption, access to commercial databases, and code conversion for communication between computers

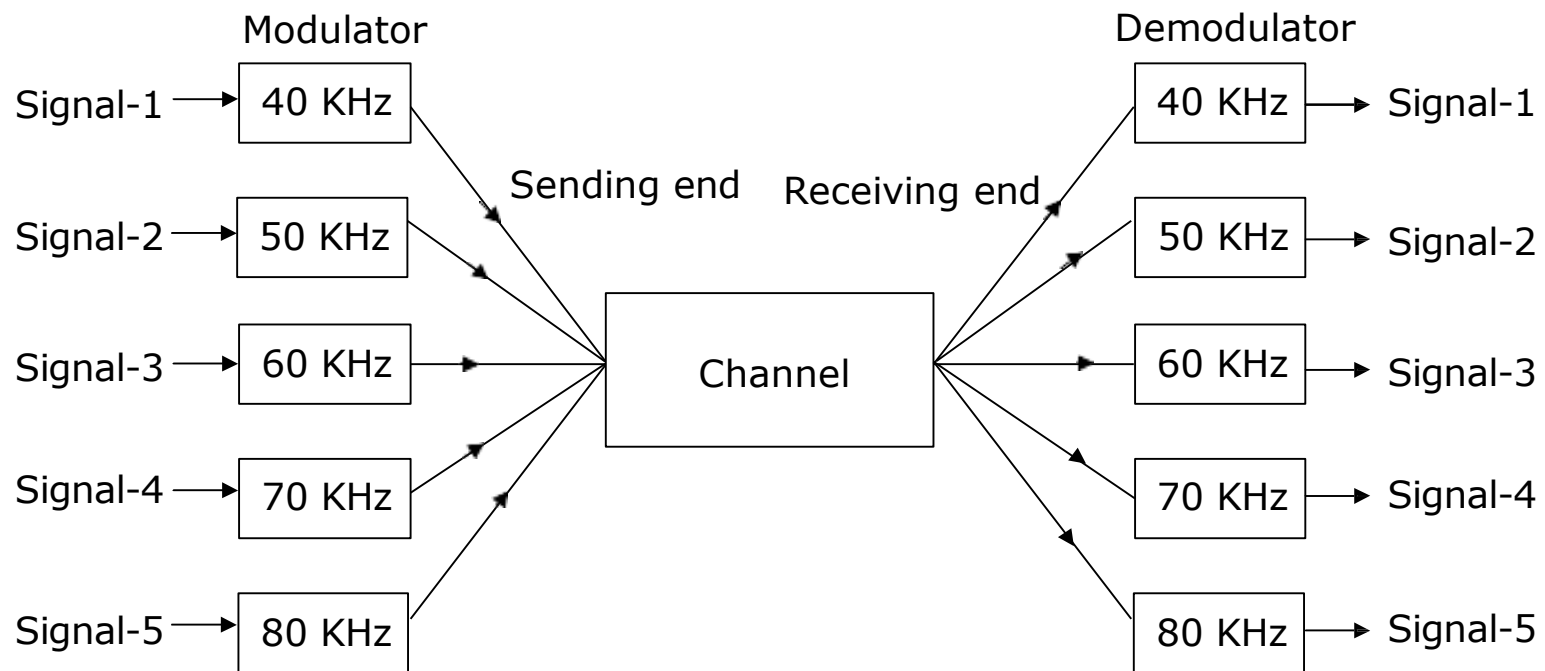
# Multiplexing

- Method of dividing physical channel into many logical channels so that a number of independent signals may be simultaneously transmitted
- Electronic device that performs multiplexing is known as a *multiplexer*
- Multiplexing enables a single transmission medium to concurrently transmit data between several transmitters and receivers

## Two Basic Methods of Multiplexing

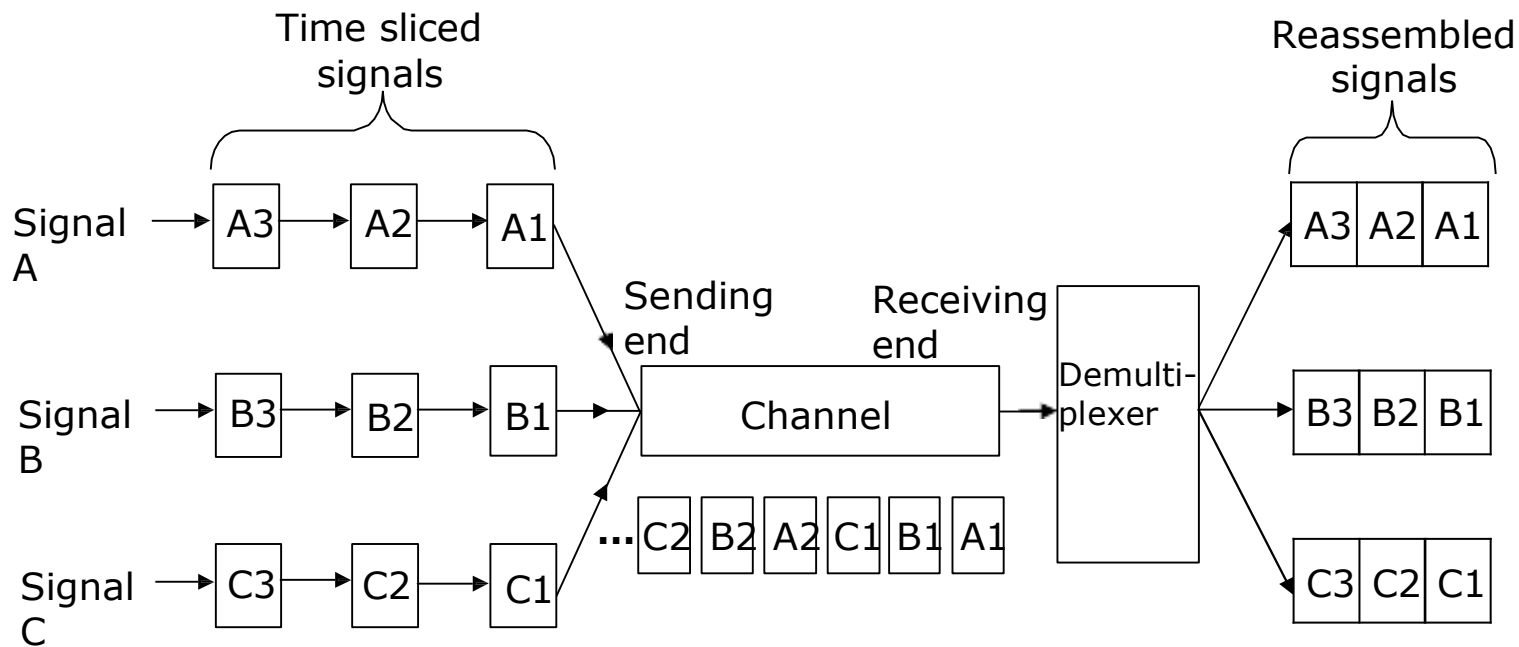
- **Frequency-Division Multiplexing (FDM):** Available bandwidth of a physical medium is divided into several smaller, disjoint logical bandwidths. Each component bandwidth is used as a separate communication line
- **Time-Division Multiplexing (TDM):** Total time available in a channel is divided among several users, and each user of the channel is allotted a time slice during which he/she may transmit a message

# Frequency-Division Multiplexing



Frequency-Division Multiplexing

# Time-Division Multiplexing



# Asynchronous and Synchronous Transmission

- Two modes of data transmission on a communication line are asynchronous and synchronous
- Asynchronous transmission
  - Sender can send data at any convenient time and the receiver will accept it
  - Data is transmitted character by character at irregular intervals
  - Well suited to many keyboard type terminals

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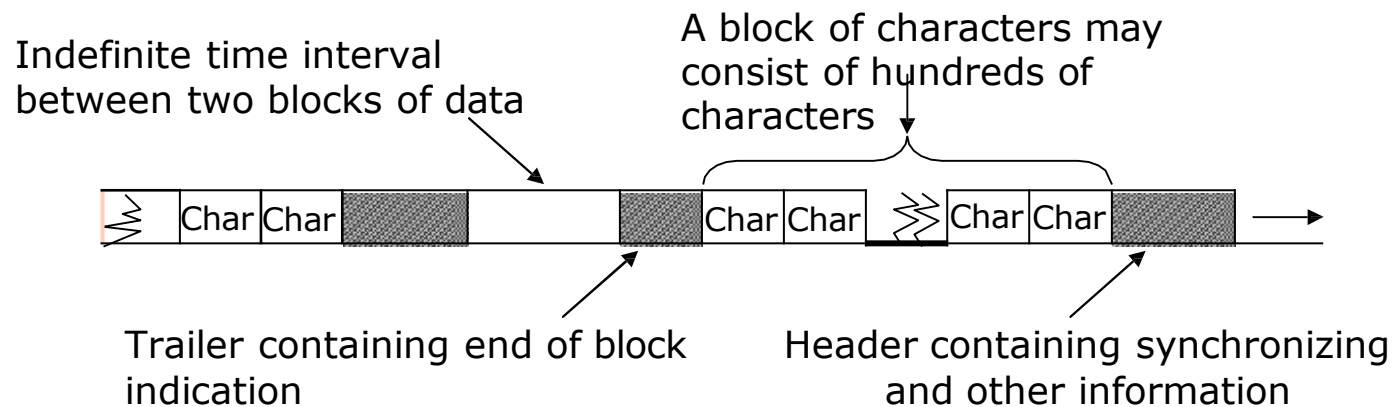
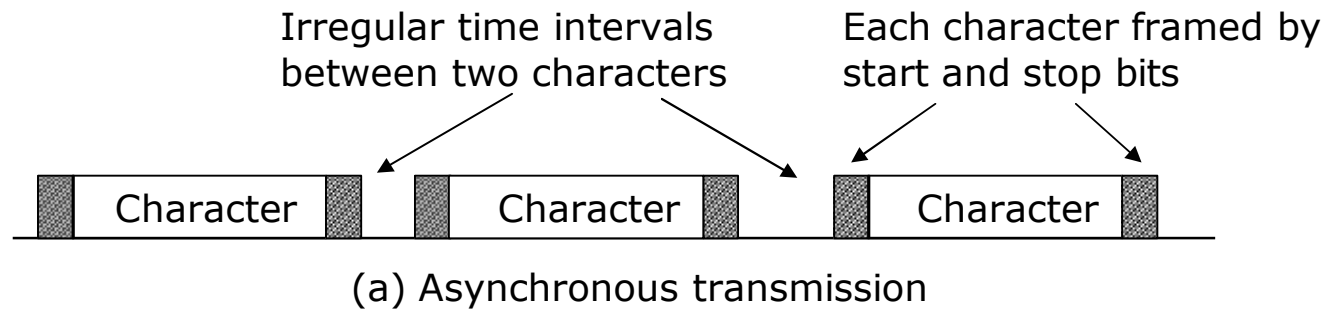


# Asynchronous and Synchronous Transmission

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- Synchronous transmission
  - Sender and receiver must synchronize with each other to get ready for data transmission before it takes place
  - Entire blocks of characters are framed and transmitted together
  - Well suited to remote communication between a computer and such devices as buffered terminals and printers

# Data Transmission



# Switching Techniques

- Data is often transmitted from source to destination through a network of intermediate nodes
- Switching techniques deal with the methods of establishing communication links between the sender and receiver in a communication network
- Three commonly used switching techniques are:
  - **Circuit switching:** Dedicated physical path is established between sending and receiving stations through nodes of the network for the duration of communication

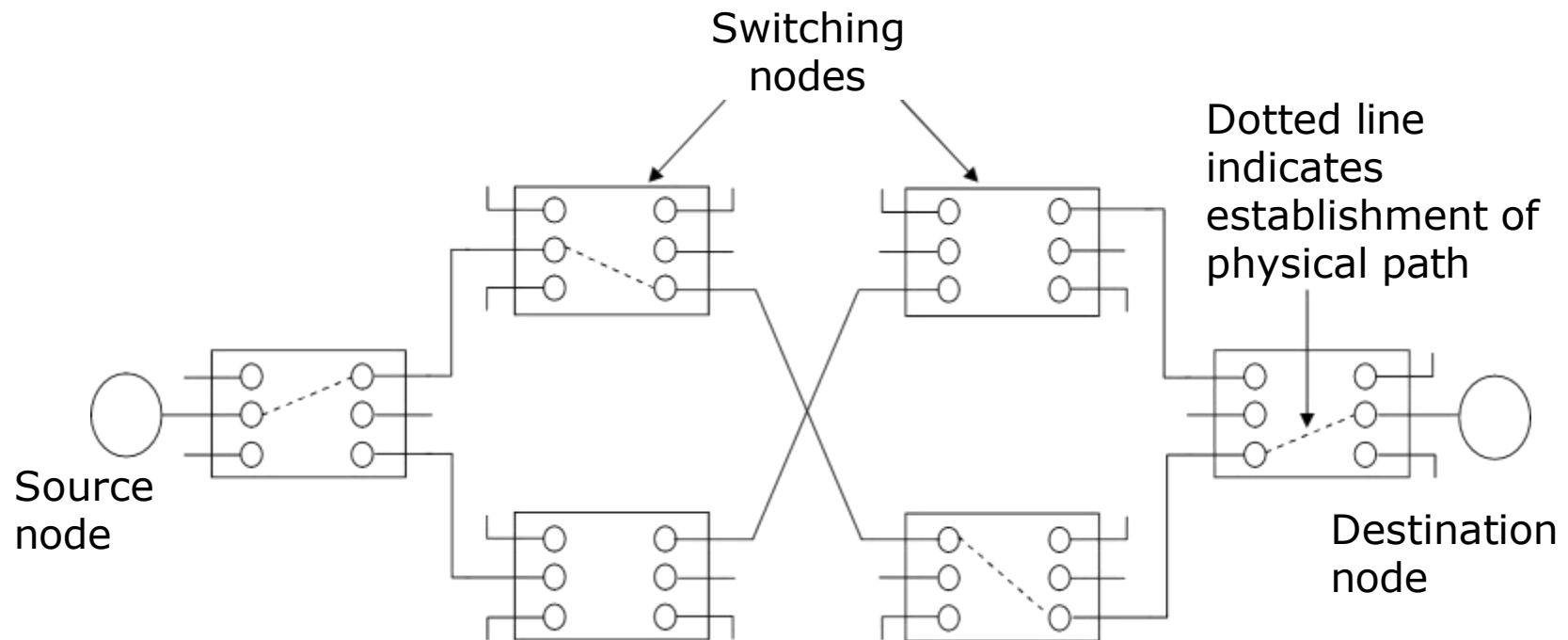
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# Switching Techniques

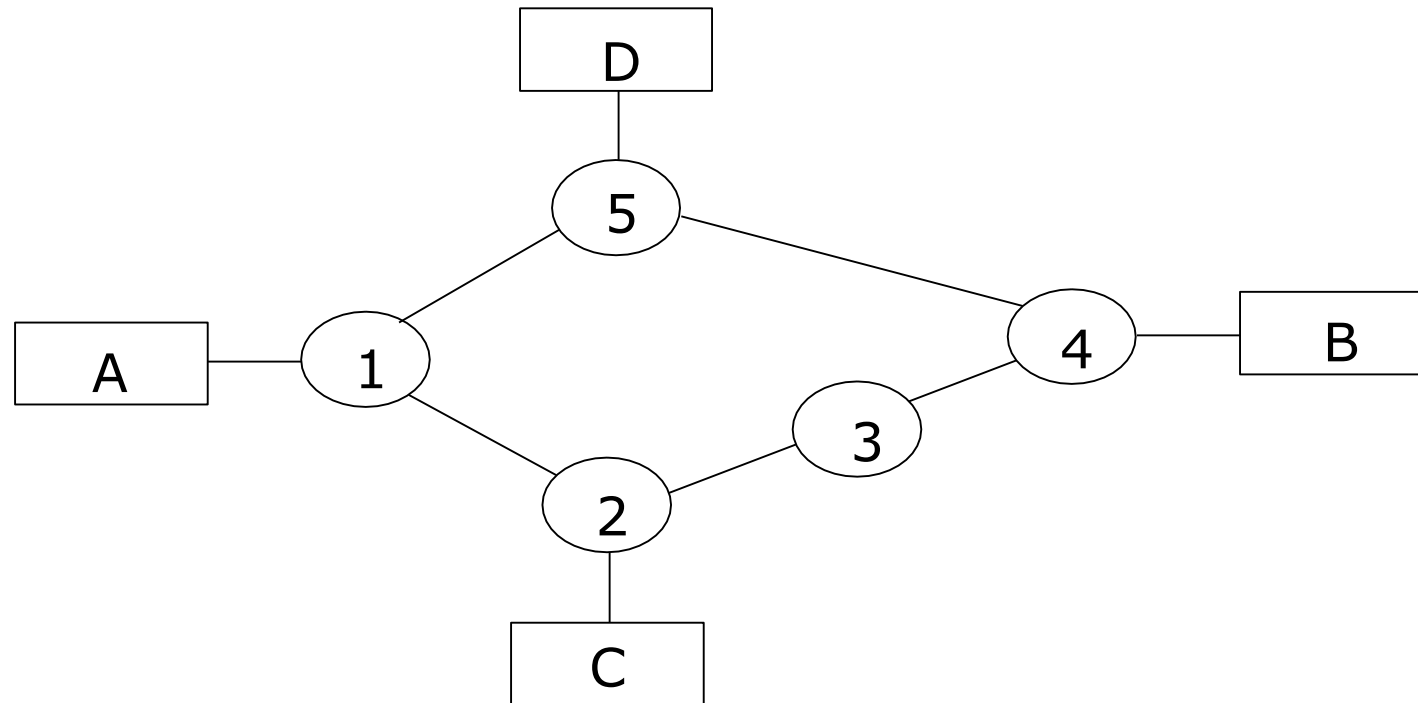
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- **Message switching:** Sender appends receiver's destination address to the message and it is transmitted from source to destination either by store-and-forward method or broadcast method
- **Packet switching:** Message is split up into fixed size packets and each packet is transmitted independently from source to destination node. Either store-and-forward or broadcast method is used for transmitting the packets. All the packets of a message are re-assembled into original message at the destination node

# Circuit Switching Method



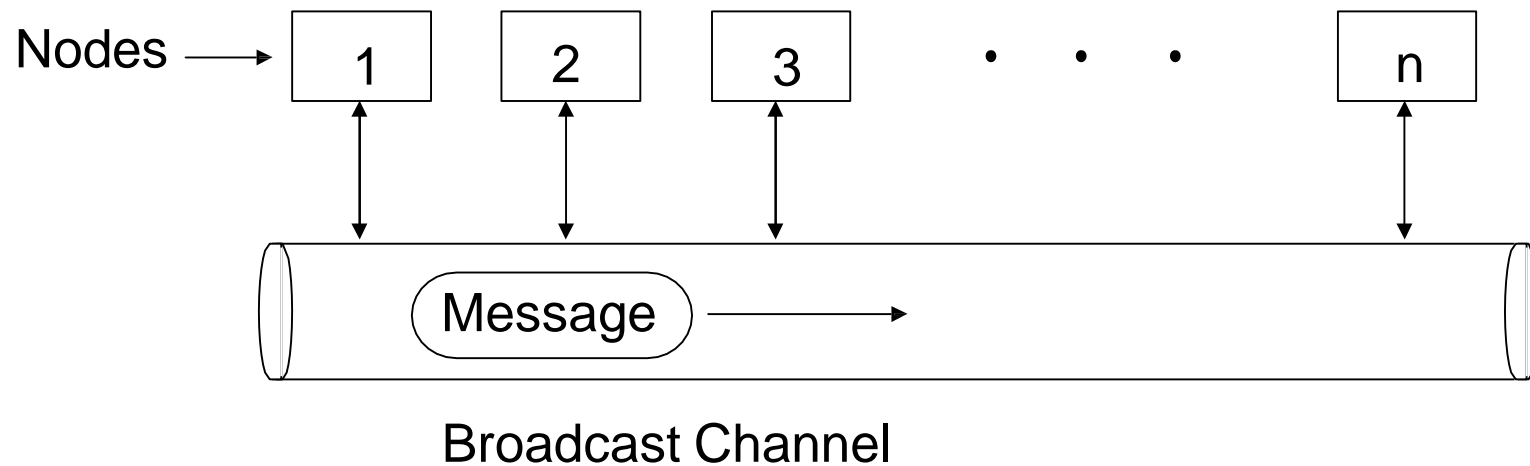
# Store-and-Forward Method of Message Switching



Either path 1-2-3-4 or 1-5-4 may be used to transmit a message from A to B.



# Broadcast Method of Message Switching



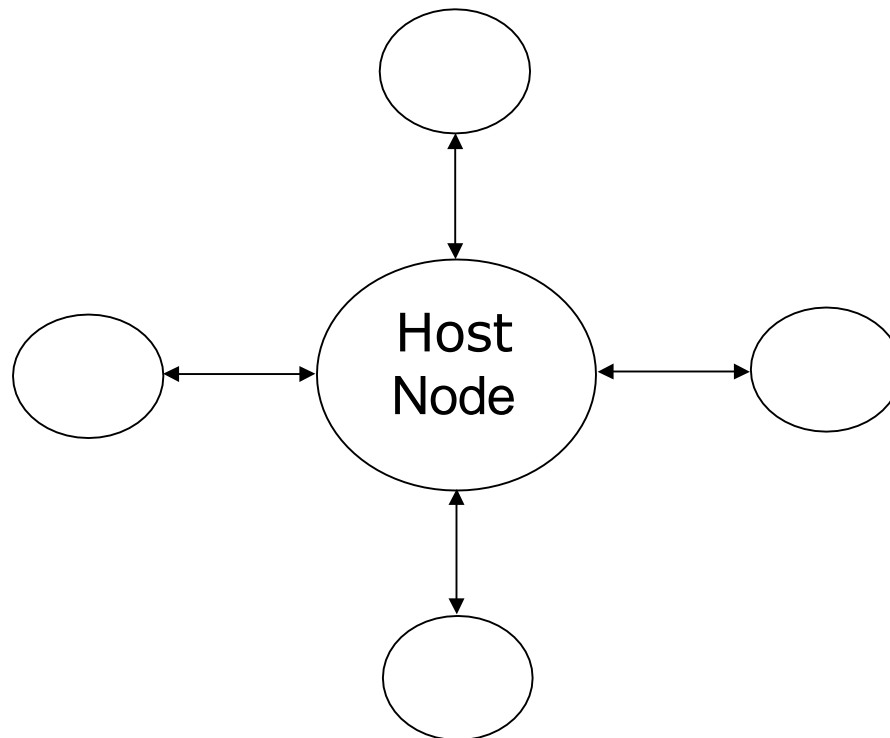
# Routing Techniques

- In a WAN, when multiple paths exist between the source and destination nodes of a packet, any one of the paths may be used to transfer the packet
- Selection of path to be used for transmitting a packet is determined by the routing technique used
- Two popularly used routing algorithms are:
  - **Source routing:** Source node selects the entire path before sending the packet
  - **Hop-by-hop routing:** Each node along the path decides only the next node for the path

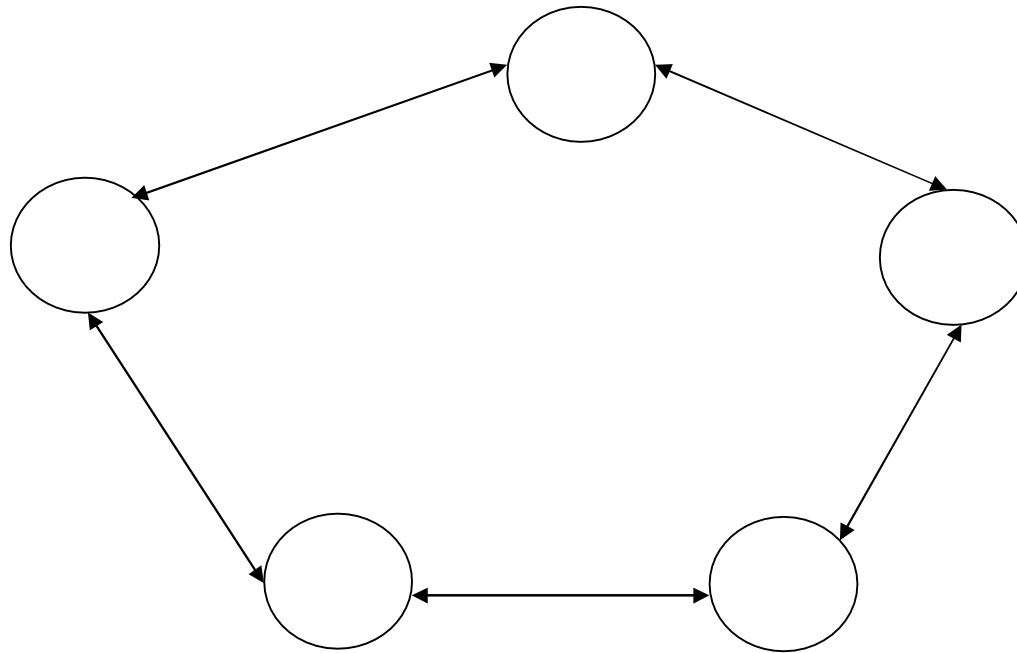
# Network Topologies

- Term *network topology* refers to the way in which the nodes of a network are linked together
- Although number network topologies are possible, four major ones are:
  - Star network
  - Ring network
  - Completely connected network
  - Multi-access bus network

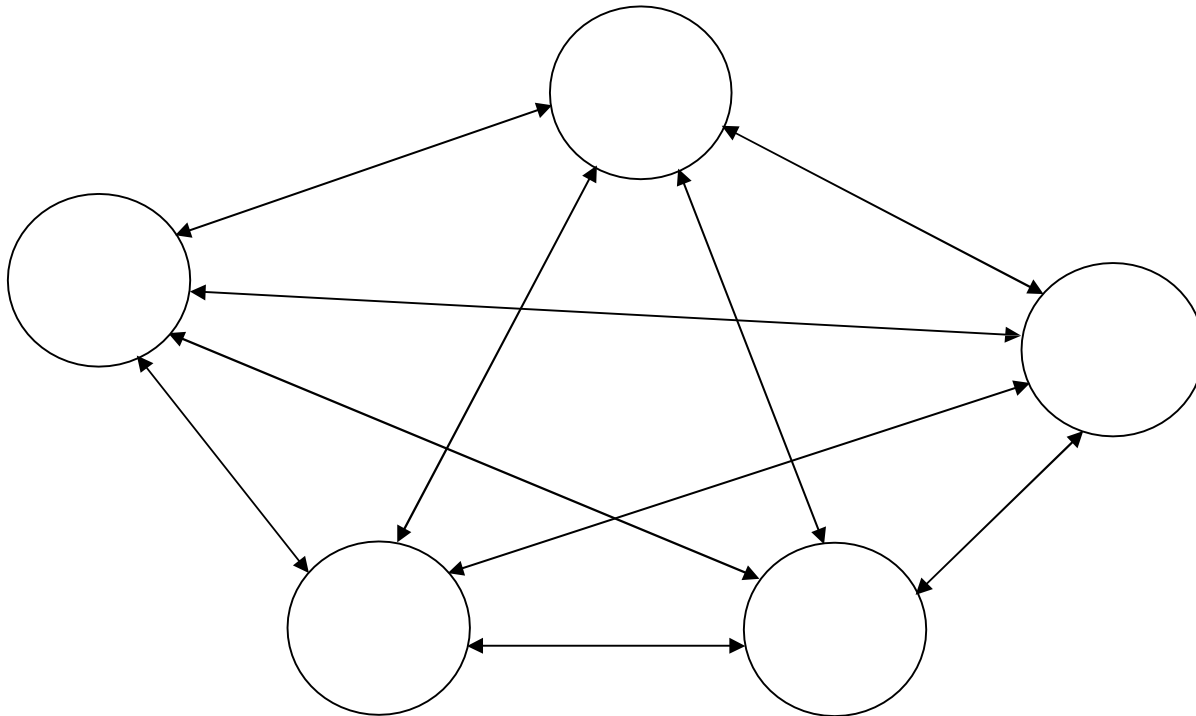
# Star Network



# Ring Network

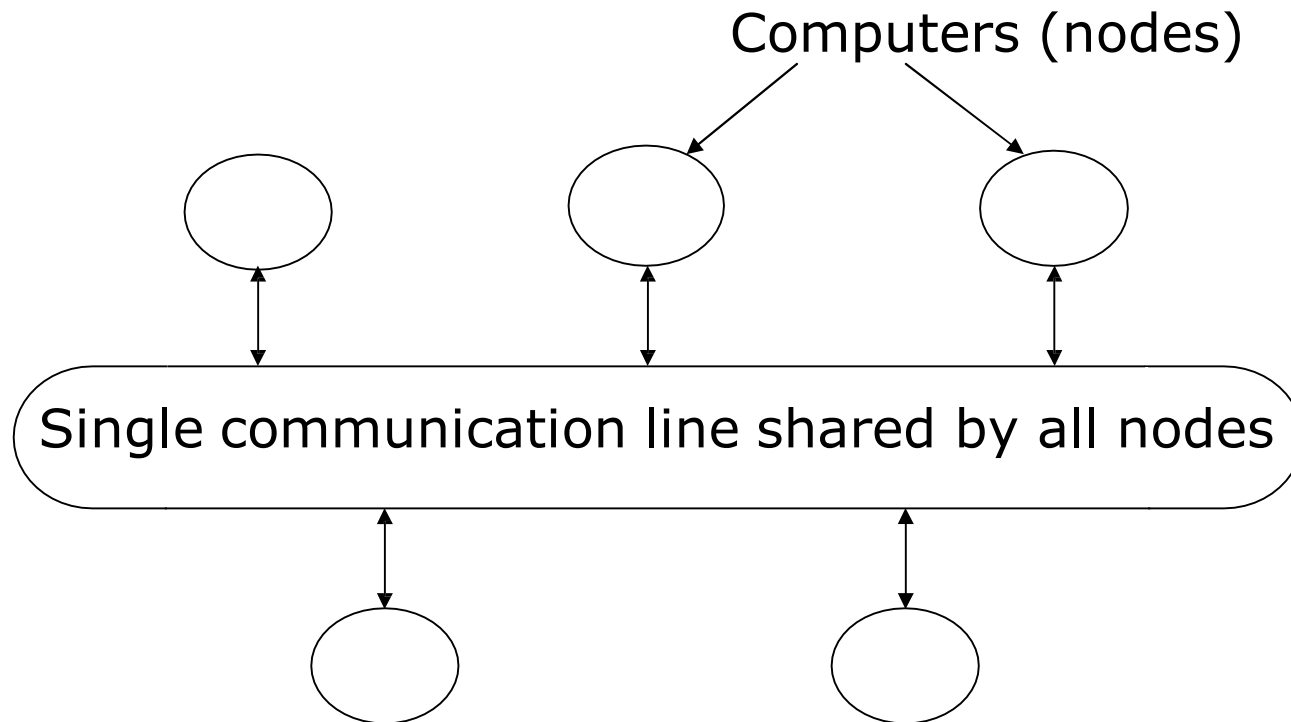


# Completely Connected Network

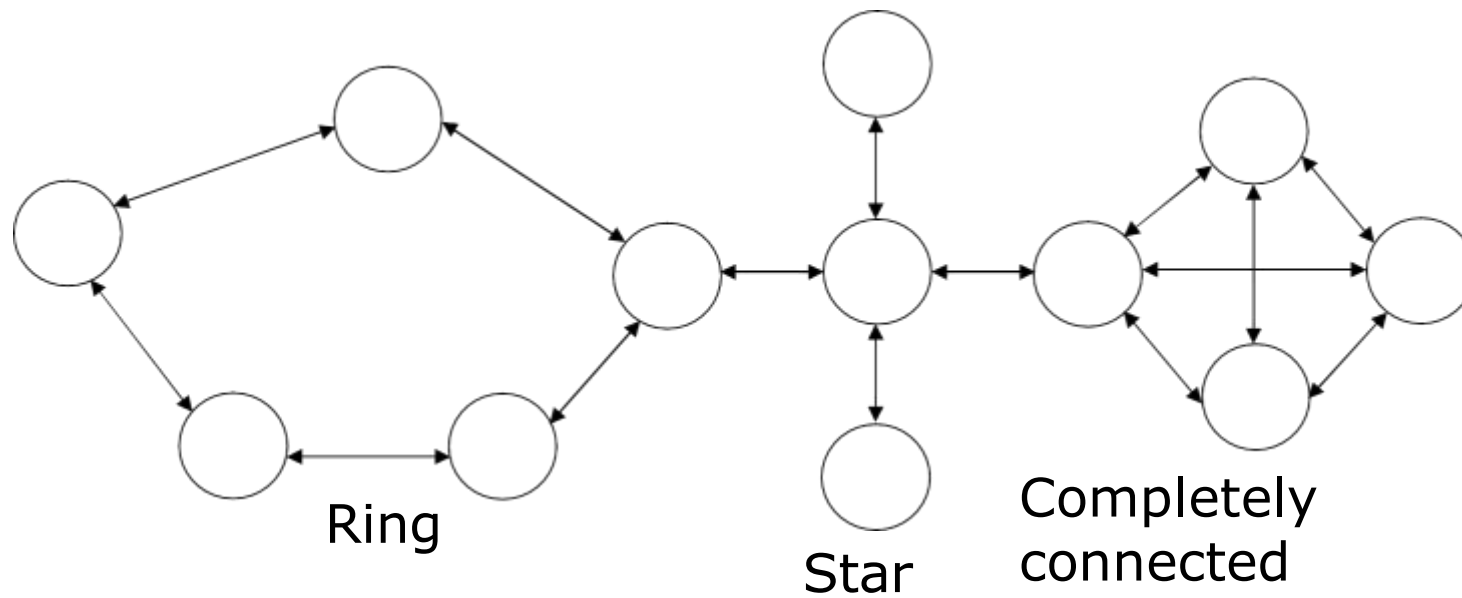




# Multi-Access Bus Network



# Hybrid Network



# Network Types

- Networks are broadly classified into two types: Local Area Network (LAN) and Wide Area Network (WAN)
- Local Area Network (LAN) as compared to WAN:
  - Limited to a small geographic coverage
  - Has much higher data transmission rate
  - Experiences fewer data transmission errors
  - Has lower data communication cost
  - Typically owned by a single organization
- Networks that share some of the characteristics of both LANs and WANs are referred to as Metropolitan Area Network (MAN)

# Communication Protocols

- Protocol is a set of formal operating rules, procedures, or conventions that govern a given process
- Communication protocol describes rules that govern transmission of data over communication networks
- Roles of communication protocol:
  - Data sequencing
  - Data routing
  - Data formatting
  - Flow control
  - Error control

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# Communication Protocols

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- Precedence and order of transmission
- Connection establishment and termination
- Data security
- Log information.
- Communication protocols are normally split up into a series of modules logically composed of a succession of layers.
- Terms *protocol suite*, *protocol family*, or *protocol stack* are used to refer to the collection of protocols (of all layers) of a network system

# Network Interface Card (NIC)

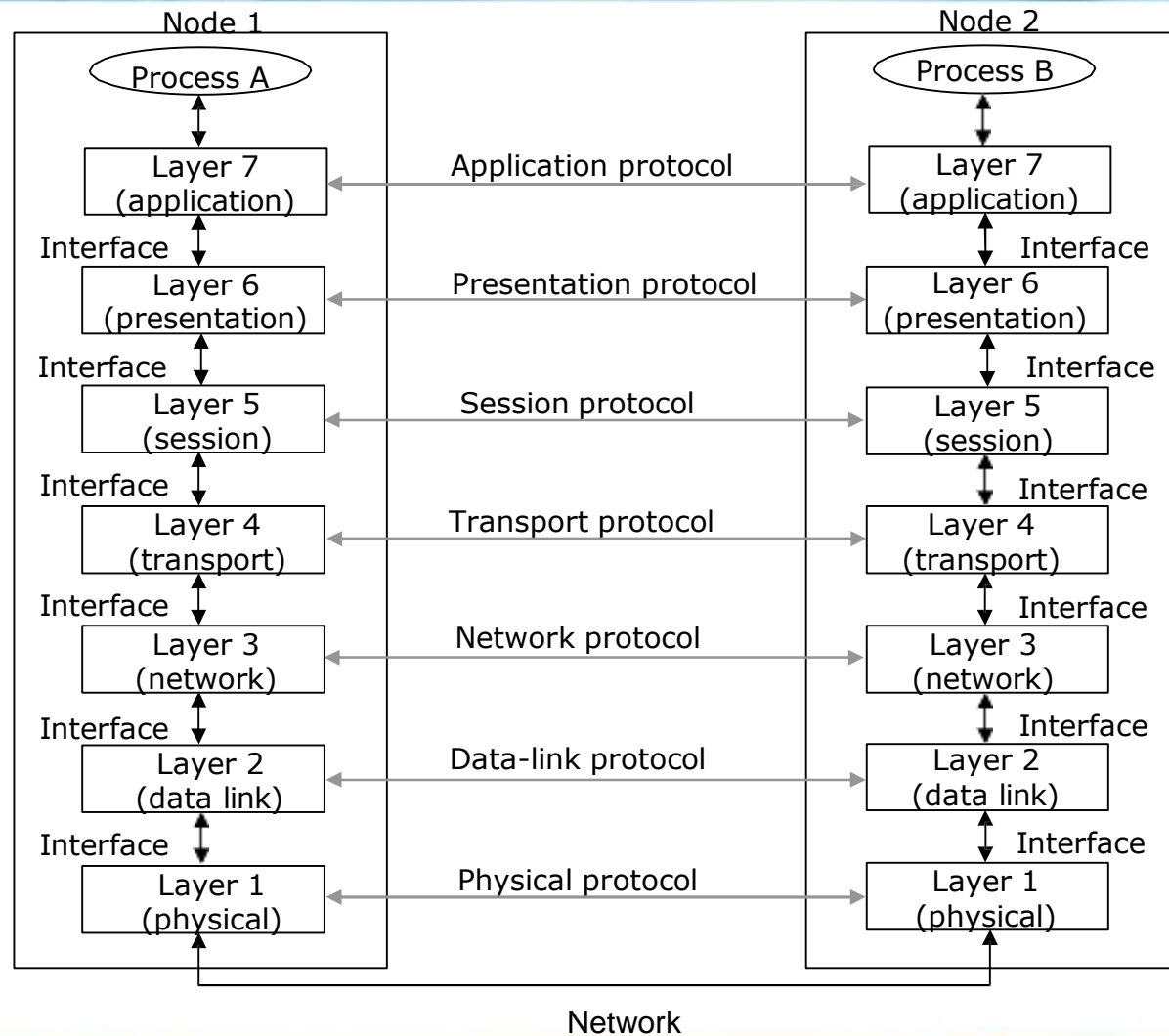
- Hardware device that allows a computer to be connected to a network, both functionally and physically
- Printed circuit board installed on to one of the expansion slots of computer
- Provides a port on the back to which network cable is attached



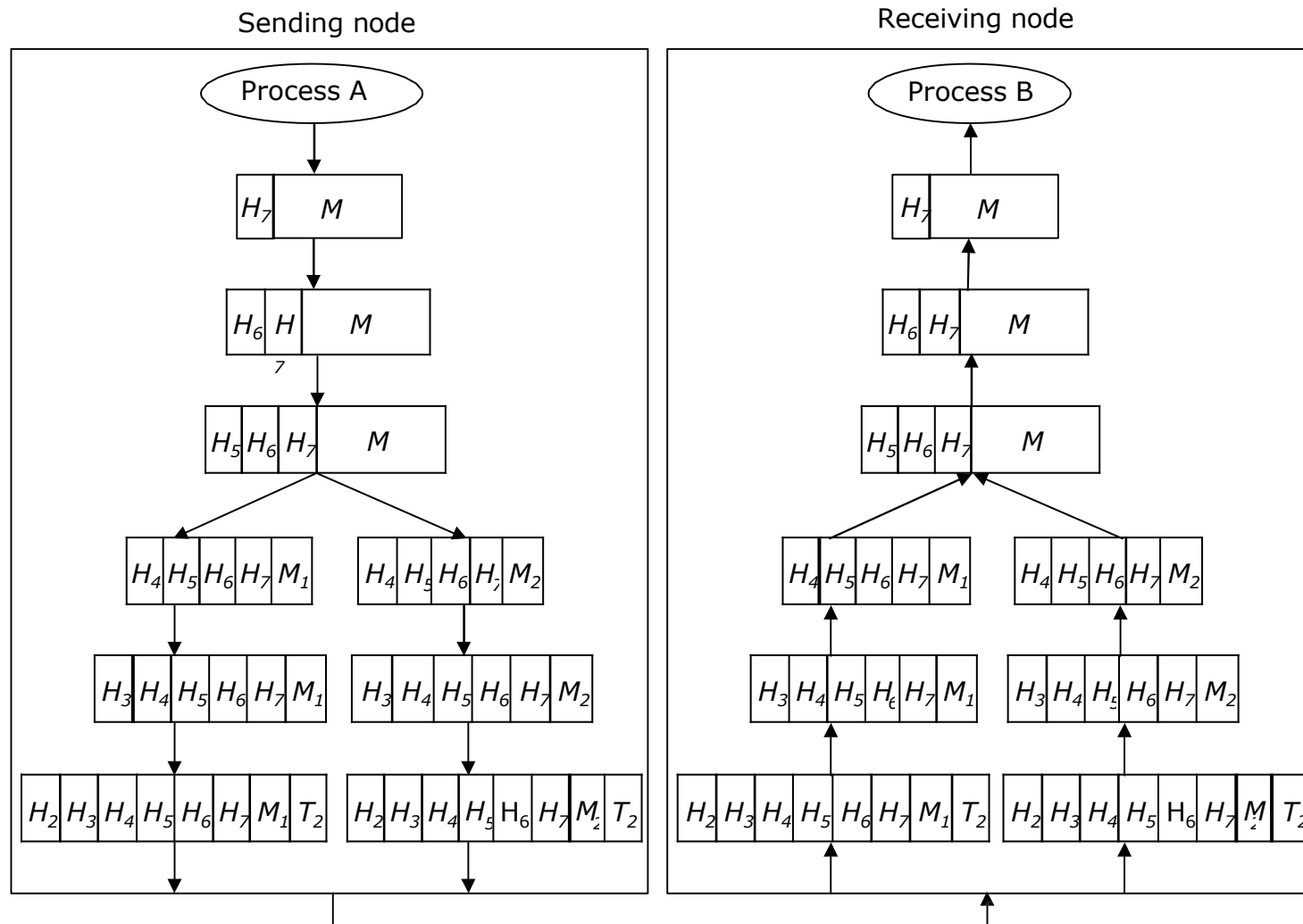
# The OSI Model

- The Open System Interconnection (OSI) model is framework for defining standards for linking heterogeneous computers in a packet switched network
- Standardized OSI protocol makes it possible for any two heterogeneous computer systems, located anywhere in the world, to easily communicate with each other
- Separate set of protocols is defined for each layer in its seven-layer architecture. Each layer has an independent function

# Layers, Interfaces, and Protocols in the OSI Model



An example illustrating transfer of message  $M$  from sending node to the receiving node in the OSI model:  $H_n$ , header added by layer  $n$ ;  $T_n$ , trailer added by layer  $n$ .



# Internetworking

- Interconnecting two or more networks to form a single network is called *internetworking*, and the resulting network is called an *internetwork*
- Goal of internetworking is to hide details of different physical networks, so that resulting internetwork functions as a single coordinated unit
- Tools such as bridges, routers, brouters, and gateways are used for internetworking
- The Internet is the best example of an internetwork

# Bridges

- Operate at bottom two layers of the OSI model
- Connect networks that use the same communication protocols above data-link layer but may use different protocols at physical and data-link layers

# Routers

- Operates at network layer of the OSI model
- Used to interconnect those networks that use the same high-level protocols above network layer
- Smarter than bridges as they not only copy data from one network segment to another, but also choose the best route for the data by using routing table



# Gateways

- Operates at the top three layers of the OSI model (session, presentation and application)
- Used for interconnecting dissimilar networks that use different communication protocols
- Since gateways interconnect dissimilar networks, protocol conversion is the major job performed by them

# Wireless Computing Systems

- Wireless computing system uses wireless communication technologies for interconnecting computer systems
- Enhances functionality of computing equipment by freeing communication from location constraints of wired computing systems
- Wireless computing systems are of two types:
  - **Fixed wireless systems:** Support little or no mobility of the computing equipment associated with the wireless network
  - **Mobile wireless systems:** Support mobility of the computing equipment to access resources associated with the wireless network

# Wireless Technologies

- 2G and 3G
- Wireless LAN
- WiMAX
- Wireless Local Loop (WLL)
- Radio-router
- Multihop Wireless Network
- Wireless Application Protocol (WAP)

# Distributed Computing Systems

- Configuration where many independent computer systems are connected, and messages, processing task, programs, data, and other resources are transmitted between cooperating computer systems
- Such an arrangement enables sharing of many hardware and software resources as well as information among several users who may be sitting far away from each other

# Main Advantages of Distributed Computing Systems

- Inherently distributed applications
- Information sharing among distributed users
- Resource sharing
- Shorter response times and higher throughput
- Higher reliability
- Extensibility and incremental growth
- Better flexibility in meeting users' needs

# Keywords/Phrases

- Amplifier
- Amplitude Modulation (AM)
- Application layer
- ARPANET
- Asynchronous transmission
- Bandwidth
- Baud
- Bridge
- Broadband
- Broadcast
- C-band transmission
- Circuit switching
- Coaxial cable
- Common Carriers
- Communication protocol
- Communications satellite
- Completely connected network
- Computer network
- Concentrators
- Data-link layer
- Demodulation
- Dial-up line
- Distributed Computing System
- Ethernet
- Fax modem
- File Transfer Protocol (FTP)
- Font-End Processors (FEP)
- Frequency Modulation (FM)
- Frequency-Division Multiplexing (FDM)
- Full duplex
- Gateway
- Half duplex
- Hop-by-hop routing
- Hybrid network
- Internet Protocol (IP)
- Internetworking
- ISDN (Integrated Services Digital Network)
- Ku-band transmission
- Leased line
- Local Area Network (LAN)
- Message switching

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# Keywords/Phrases

- Metropolitan Area Network (MAN)
- Microwave system
- Mobile computing
- Modem
- Modulation
- Multi-access Bus network
- Multiplexer
- Narrowband
- Network Interface Card (NIC)
- Network layer
- Network topology
- Nomadic computing
- Optical fibers
- OSI Model
- Packet switching
- Phase Modulation (PM)
- Physical layer
- POTS (Plain Old Telephone Service)
- Presentation layer
- Protocol family
- Protocol stack
- Protocol suite (Continued from previous slide)
- Repeater
- Ring network
- Router
- Session layer
- Simplex
- Source routing
- Star network
- Store-and-forward
- Synchronous transmission
- Time-Division Multiplexing (TDM)
- Transport Control Protocol (TCP)
- Transport layer
- Twisted-pair
- Unshielded twisted-pair (UTP)
- User Datagram Protocol (UDP)
- Value Added Network (VAN)
- Voiceband
- VSAT (Very Small Aperture Terminals)
- Wide Area Network (WAN)
- Wireless network