

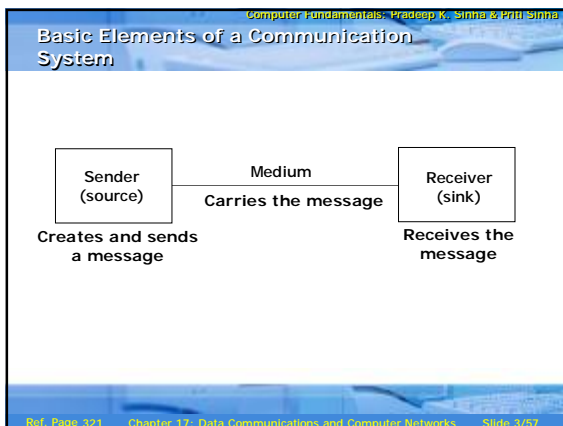
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Learning Objectives

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

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Data Transmission Modes

```

graph LR
    subgraph (a) Simplex
        S1[Sender] --> R1[Receiver]
    end
    subgraph (b) Half-duplex
        S2[Sender (or Receiver)] <--> R2[Receiver (or Sender)]
    end
    subgraph (c) Full-duplex
        S3[Sender (and Receiver)] <--> R3[Receiver (and Sender)]
    end
  
```

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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)

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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

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Data Transmission Media


The most commonly used ones are:

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

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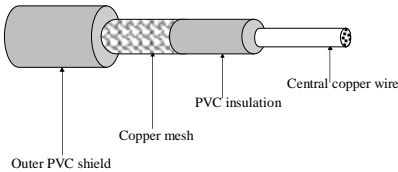
Unshielded Twisted-Pair (UTP) Cable



Ref. Page 323 Chapter 17: Data Communications and Computer Networks Slide 8/57

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Coaxial Cable



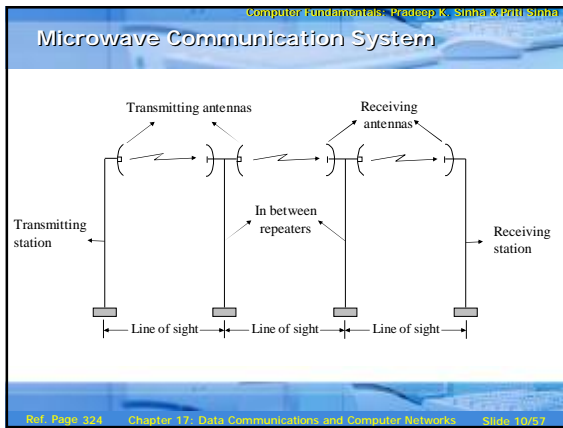
Outer PVC shield

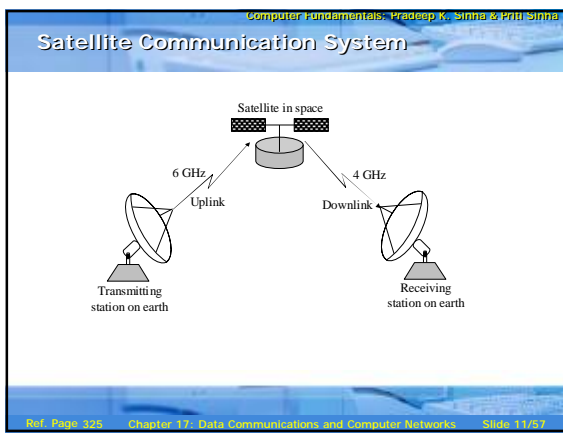
Copper mesh

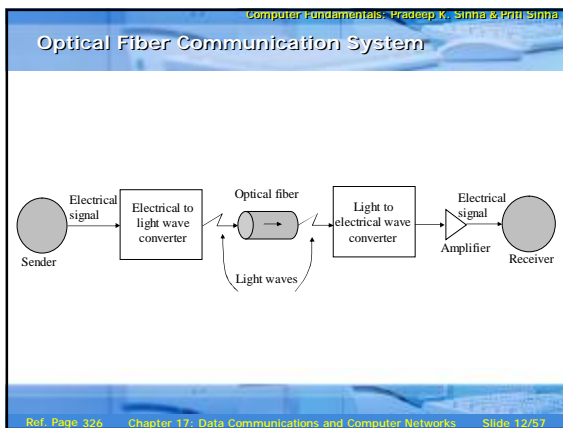
PVC insulation

Central copper wire

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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

(Continued from previous slide)

- § 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

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Analog and Digital Signals

(a) Analog signal

(b) Digital signal

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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

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Modems

- § Modem is short for **MOD**ulator/**DEM**odulator
- § 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)

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Use of Modems in Data Communications

The diagram illustrates the process of data communication using modems. On the left, a 'Sender Computer' sends 'Digital signals' (represented as 0, 1, 0, 0) to a 'modem at sender computer end'. This modem contains a 'Modulator' and a 'Demodulator'. The 'Modulator' converts the digital signals into 'Analog signals on telephone line', which are sent to a 'modem at receiver computer end'. This second modem also contains a 'Modulator' and a 'Demodulator'. The 'Demodulator' receives the analog signals and converts them back into 'Digital signals' (represented as 0, 1, 1, 0, 0), which are then sent to the 'Receiver Computer'.

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Factors for Modem Selection

- § Transmission speed
- § Internal versus external
- § Facsimile facility

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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

(Continued from previous slide)

- § **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

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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

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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

Ref. Page 332 Chapter 17: Data Communications and Computer Networks Slide 23/57

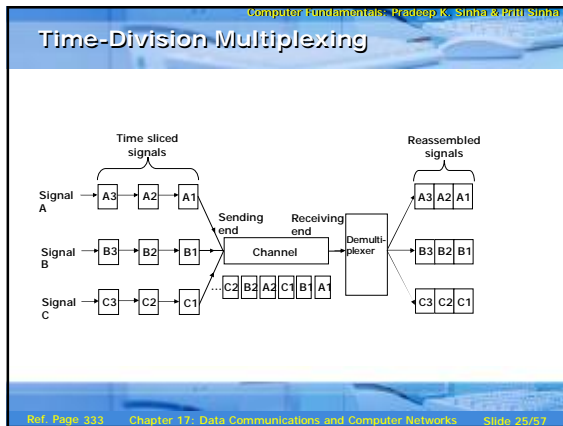
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Frequency-Division Multiplexing

```
graph LR
    subgraph Sending_end [Sending end]
        S1[Signal-1 40 KHz] --> M[Modulator]
        S2[Signal-2 50 KHz] --> M
        S3[Signal-3 60 KHz] --> M
        S4[Signal-4 70 KHz] --> M
        S5[Signal-5 80 KHz] --> M
    end
    M --> CH[Channel]
    CH --> D[Demodulator]
    subgraph Receiving_end [Receiving end]
        D --> R1[Signal-1 40 KHz]
        D --> R2[Signal-2 50 KHz]
        D --> R3[Signal-3 60 KHz]
        D --> R4[Signal-4 70 KHz]
        D --> R5[Signal-5 80 KHz]
    end
```

Frequency-Division Multiplexing

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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

(Continued from previous slide)

- § 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

Ref. Page 333 Chapter 17: Data Communications and Computer Networks Slide 27/57

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Data Transmission

The diagram illustrates two data transmission methods:

- (a) Asynchronous transmission:** Shows three individual characters being transmitted. Each character is framed by start and stop bits. There are irregular time intervals between the characters.
- (b) Synchronous transmission:** Shows a continuous block of data. A header at the beginning contains synchronizing and other information. A trailer at the end contains the end of block indication. The time interval between two blocks of data is indefinite. A note states: 'A block of characters may consist of hundreds of characters'.

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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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Ref. Page 334 Chapter 17: Data Communications and Computer Networks Slide 29/57

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Switching Techniques

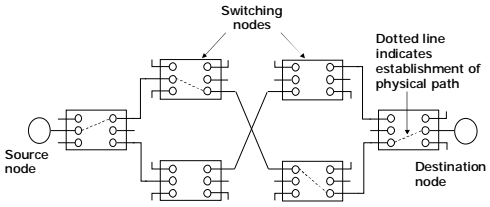
(Continued from previous slide)

- § **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

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Circuit Switching Method

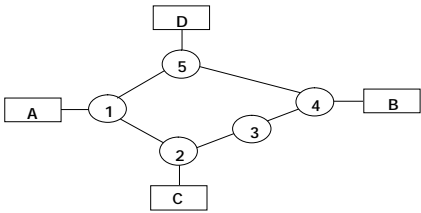


The diagram illustrates the circuit switching method. It shows a 'Source node' on the left and a 'Destination node' on the right. Between them are two 'Switching nodes'. Dotted lines represent the establishment of a physical path from the source node through the switching nodes to the destination node. Labels include 'Source node', 'Switching nodes', 'Dotted line indicates establishment of physical path', and 'Destination node'.

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Store-and-Forward Method of Message Switching

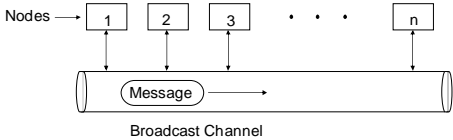


The diagram shows a network topology for store-and-forward message switching. It consists of nodes A, B, C, and D connected to numbered nodes 1, 2, 3, 4, and 5. Node A is connected to node 1. Node 1 is connected to nodes 2 and 5. Node 2 is connected to node 3. Node 3 is connected to node 4. Node 4 is connected to node B. Node 5 is connected to node D. Node C is connected to node 2. Below the diagram, it states: 'Either path 1-2-3-4 or 1-5-4 may be used to transmit a message from A to B.'

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Broadcast Method of Message Switching



The diagram illustrates the broadcast method of message switching. It shows a 'Broadcast Channel' represented by a horizontal cylinder. Above the channel, there are 'Nodes' labeled 1, 2, 3, ..., n. Arrows point from each node to the broadcast channel. Inside the channel, a 'Message' is shown with an arrow pointing to the right, indicating it is being broadcast to all nodes.

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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

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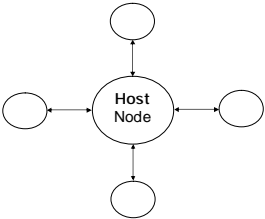
Network Topologies

- § 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

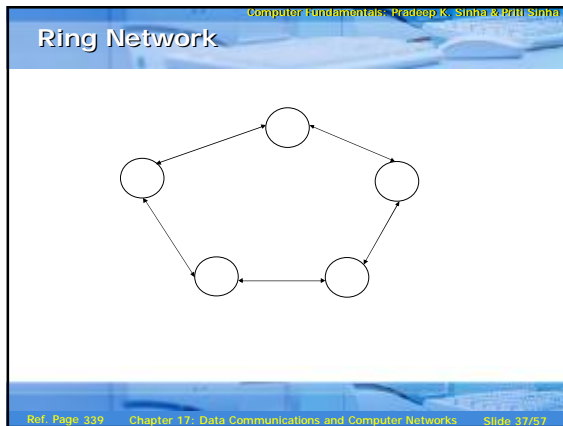
Ref. Page 338 Chapter 17: Data Communications and Computer Networks Slide 35/57

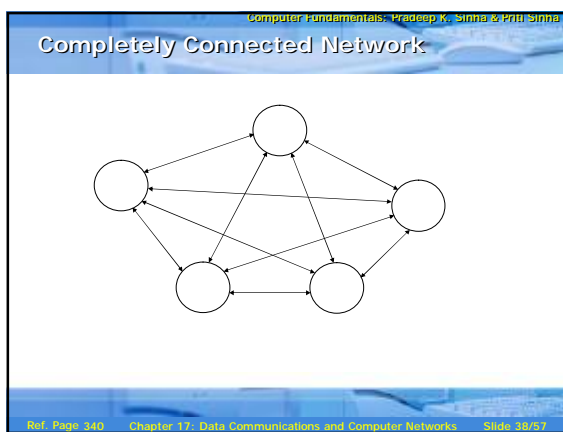
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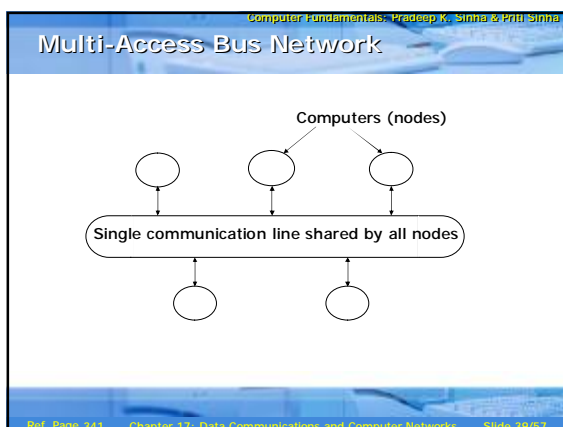
Star Network



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Hybrid Network

The diagram illustrates a hybrid network topology. It consists of three main components connected in a sequence: a Ring topology (a closed loop of nodes), a Star topology (a central node connected to multiple peripheral nodes), and a Completely connected topology (every node connected to every other node). Arrows indicate the flow of data between these components.

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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)

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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

(Continued on next slide)

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Communication Protocols

(Continued from previous slide)

- § 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

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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

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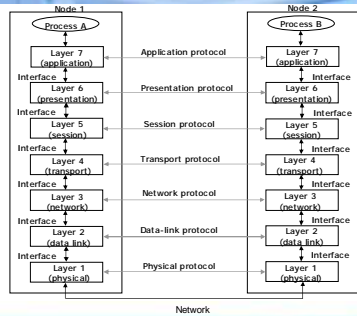
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The OSI Model

- § 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

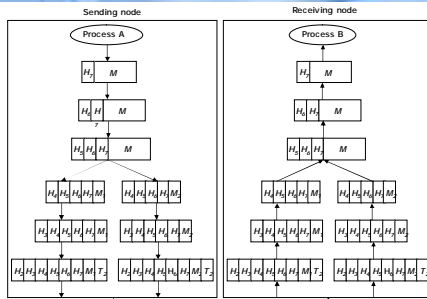
Ref. Page 344 Chapter 17: Data Communications and Computer Networks Slide 45/57

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- § 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

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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

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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

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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

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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

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Wireless Technologies

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

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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

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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

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Keywords/Phrases

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

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Keywords/Phrases

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

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