Chapter 17

Data Communications and Computer Networks

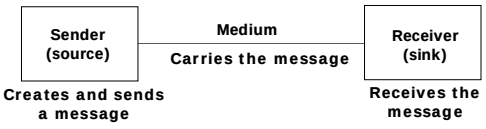
Computer Fundamentals - Pradeep K. Sinha & Priti Sinha

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

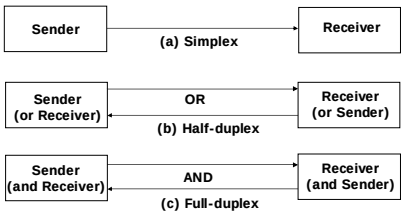
Basic Elements of a Communication System



Creates and sends a message

Receives the message

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

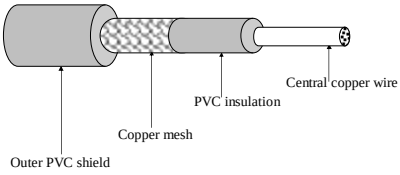
Data Transmission Media

The most commonly used ones are:

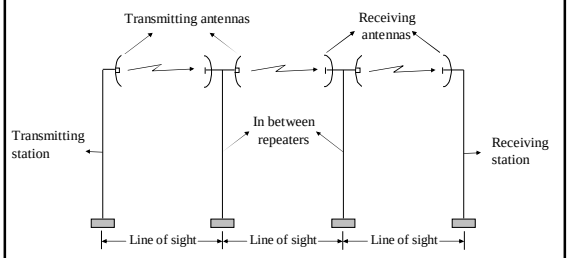
- Twisted-pair wire (UTP cable)
- Coaxial cable
- Microwave system
- Communications satellite
- Optical fibers

Unshielded Twisted-Pair (UTP) Cable

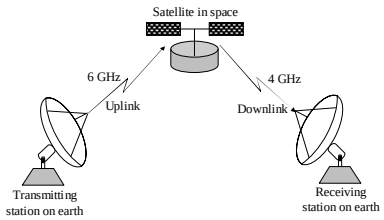
Coaxial Cable



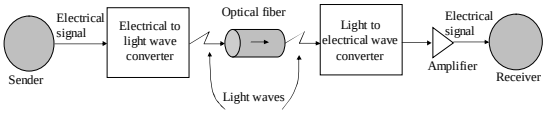
Microwave Communication System



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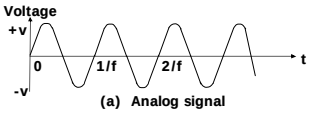
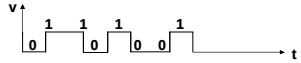
- When digital data is to be sent over an analog facility, digital signals must be converted to analog form
- Conversion of digital signal to analog form is known as modulation
- Conversion of analog signal to digital form is known as demodulation
- Digital transmission of data is preferred over analog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

Analog and Digital Signals



(a) Analog signal



(b) Digital signal

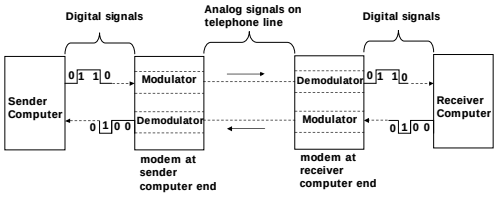
Modulation Techniques

- **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 MOdulator/DEModulator
- 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

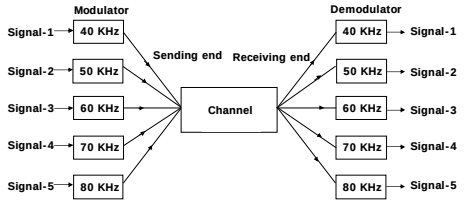
Multiplexing

- 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

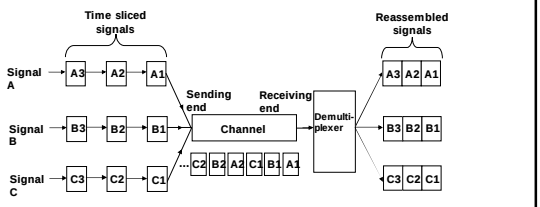
- **Frequency-Division Multiplexing (FDM):** Available bandwidth of a physical medium is divided into several smaller, disjoint logical bandwidths. Each component bandwidth is used as a separate communication line
- **Time-Division Multiplexing (TDM):** Total time available in a channel is divided among 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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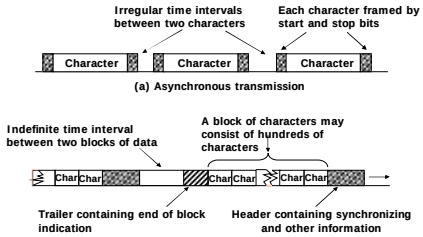
- Synchronous transmission
  - Sender and receiver must synchronize with each other to get ready for data transmission before it takes place
  - Entire blocks of characters are framed and transmitted together
  - Well suited to remote communication between a computer and such devices as buffered terminals 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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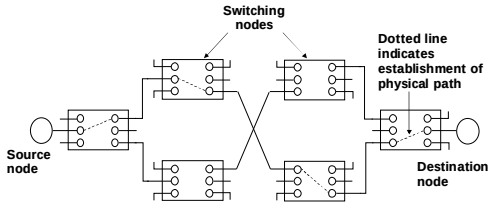
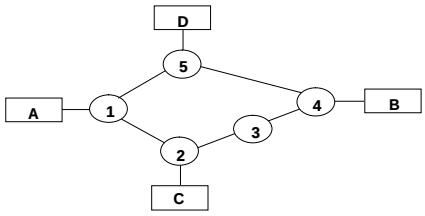
- Message switching: Sender appends receiver's destination address to the message and it is transmitted from source to destination either by store-and-forward method or broadcast method
- Packet switching: Message is split up into fixed size packets and each packet is transmitted independently from source 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

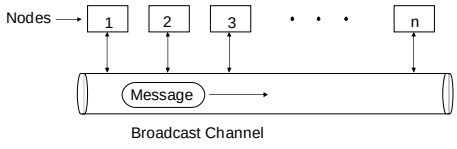


Store-and-Forward Method of Message Switching



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



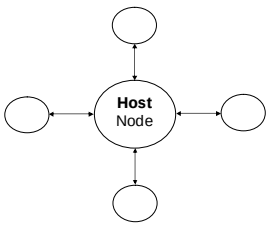
Routing Techniques

- 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

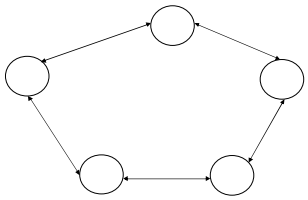
Network Topologies

- 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

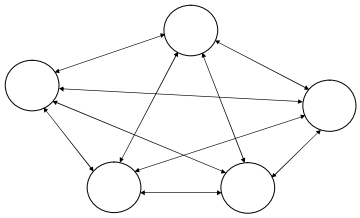
Star Network



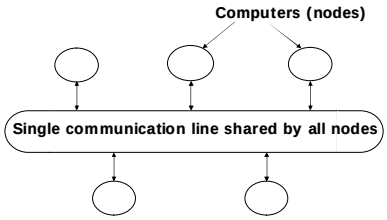
Ring Network



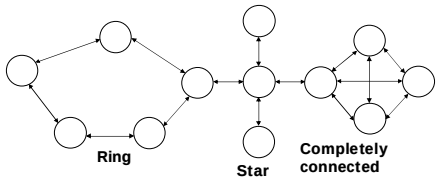
Completely Connected Network



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

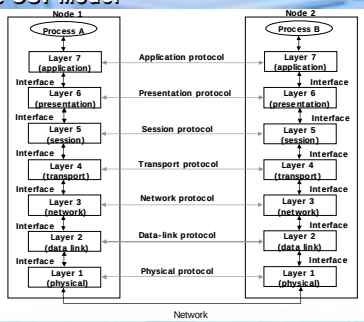
Network Interface Card (NIC)

- 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

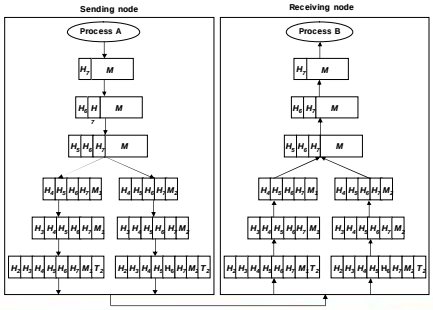
The OSI Model

- 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

(Continued from previous slide)

- 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
- 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