16th Edition
Understanding Computers
Today and Tomorrow
Comprehensive

Chapter 7
Networks and Communication Devices

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What Is a Network?

- A network is a connected system of objects or people

- **A computer network** is a collection of computers and other hardware devices connected together so users can share hardware, software, and data, and electronically communicate
  - Converging with telephone and other communications networks
  - Range from small private networks to the Internet
  - Essential in most businesses

USES FOR COMPUTER NETWORKS

Sharing an Internet connection among several users.

Sharing application software, printers, and other resources.

Facilitating Voice over IP (VoIP), e-mail, videoconferencing, messaging, and other communications applications.

Working collaboratively; for example, sharing a company database or using collaboration tools to create or review documents.

Exchanging files among network users and over the Internet.

Connecting the computers and the entertainment devices (such as TVs, gaming consoles, and stereo systems) located within a home.

FIGURE 7-1

Common uses for computer networks.

Intranets, Extranets, and Virtual Private Networks (VPNs)

- **Internet** is largest network (essentially public)
- An **intranet** is a private network designed to be used by an organizations' employees
  - Set up like the Internet
- An **extranet** is a company network accessible by authorized outsiders
- A **virtual private network (VPN)** provides a private, secure path over the Internet
  - Provides authorized secure access to a private network via the Internet
  - Uses tunneling and special encryption technology (public key encryption)
  - Without a VPN, passwords, credit card numbers, etc. sent via a hotspot can be intercepted (*not entirely true => HTTPS)
    - VPN encrypts all traffic between computer/VPN Server
    - HTTPS encrypts end to end between browser/HTTPS server

Network Size and Coverage Area

- **Personal area networks (PANs)** connect an individual's personal devices
  - Devices must be physically located close together
- **Local area networks (LANs)** connect devices located in a small geographic area
- **Metropolitan area networks (MANs)** cover a metropolitan area such as a city or county
- **Wide area networks (WANs)** cover a large geographic area
  - The Internet

Data Transmission Characteristics: Bandwidth and Signal Representation

- Bandwidth is the amount of data that can be transferred in a given period of time
  - Measured in bits per second (bps), Kbps (thousands), Mbps (millions), or Gbps (billions)

- **Analog signals** vs. **digital signals**
  - Analog: Data is represented by continuous waves
    - Conventional telephones
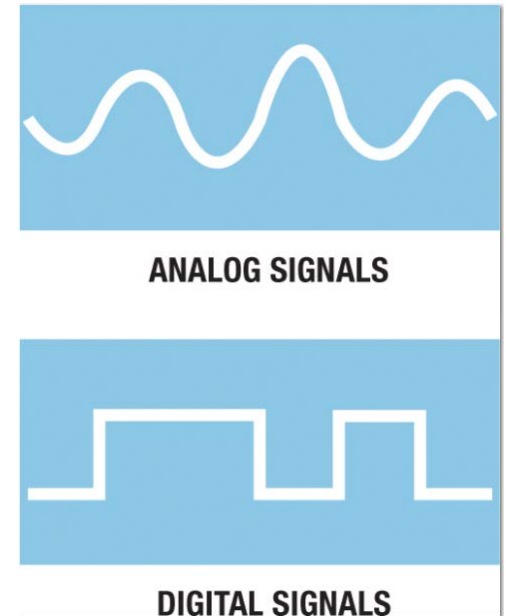 - Digital: Data is represented by two discrete states (0s and 1s)

ANALOG SIGNALS

DIGITAL SIGNALS

FIGURE 7-14
Analog vs. digital signals.

Manchester Encoding
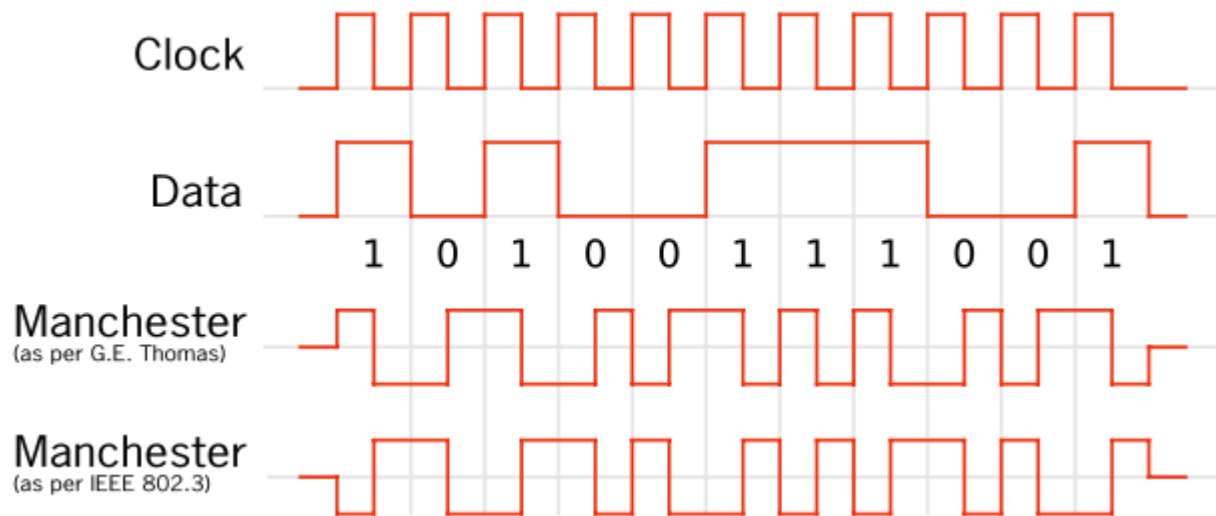
Transmission Type and Timing

- **Serial transmission:** Data is sent one bit at a time, one after another, along a single path
  - Typically used with networking media (recall b/s)

- **Parallel transmission:** Data is sent in a group of bits with each bit taking a different path
  - Most often used within computer components

FIGURE 7-15
Serial vs. parallel transmissions.
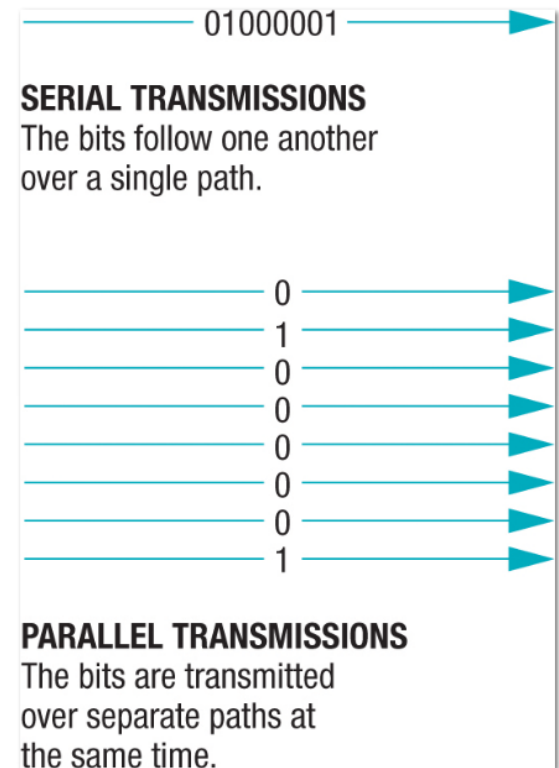
Transmitted Data Direction

- Simplex transmission
  - Data travels in a single direction only
  - Relatively uncommon

- Half-duplex transmission
  - Data travels in either direction but only one way at a time
  - Used with some network transmissions

- Full-duplex transmission
  - Data travels in both directions at the same time
  - Most often used with network transmissions

Communications Protocols and Networking Standards

- Protocol
  - A set of rules for a particular situation
  - Communications protocol
    - A set of rules that determine how devices on a network communicate
- Standard
  - A set of criteria or requirements approved by a recognized standards organization (e.g. ISO, IEEE)
  - Address how networked computers connect/communicate
  - Needed to ensure products can work with other products

Ways of Timing Serial Transmissions

- Synchronous transmission
 - Blocks of data are transferred at regular, specified intervals
  - Most data transmissions within a computer and over a network are synchronous

- Asynchronous transmission
  - Data is sent when ready without being synchronized
  - Start bits and stop bits used to identify the bits that belong in each byte

- Isochronous transmission
  - Data is sent in time to be delivered at the time it is needed

Delivery Methods

- Circuit switching
 - Dedicated path over a network is established between sender and receiver; all data follows that path

- Packet switching
  - Messages are separated into small units called packets and travel along the network separately; packets are reassembled once destination is reached

- Broadcasting
  - Data is sent out to all other nodes on the network and retrieved only by the intended recipient; primarily used with LANs

Examples of Data Delivery Methods

Dedicated circuit   **Recipient**
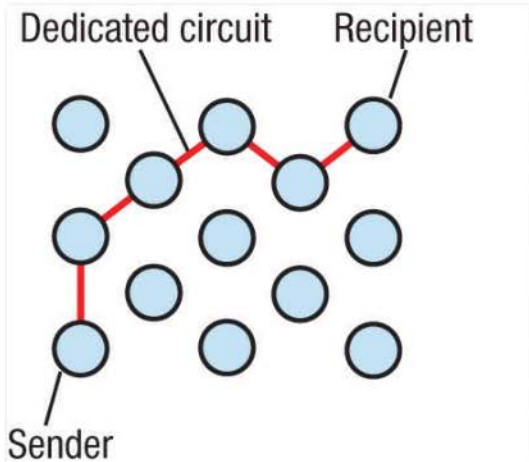
Sender

CIRCUIT-SWITCHED NETWORKS
Data uses a dedicated path from the sender to the recipient.

Packet A   **Recipient**

Packet B

Packet C

Sender
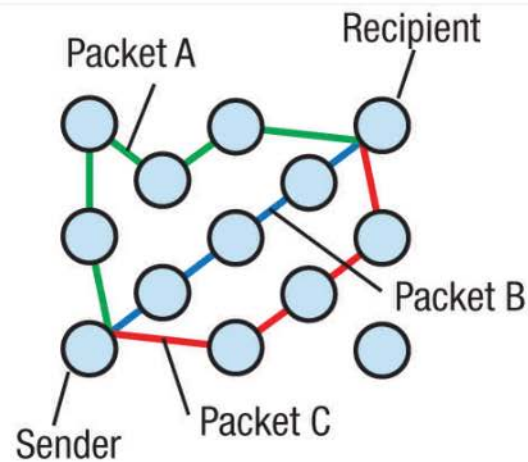
PACKET-SWITCHED NETWORKS
Data is sent as individual packets, which are assembled at the recipient's destination.

Recipient

Sender
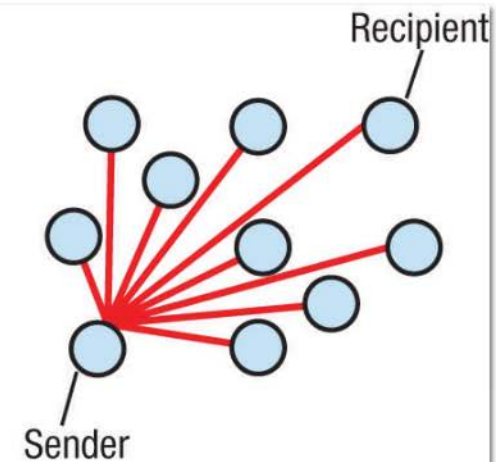
BROADCAST NETWORKS
Data is broadcast to all nodes within range; the designated recipient retrieves the data.

Assess - Fault Tolerance, QoS, Security, Scalability

TCP/IP

- **TCP/IP** is the most widely used communications protocol
  - Consists of two protocols
    - Transmission Control Protocol (TCP)
      - Responsible for delivery of data
    - Internet Protocol (IP)
      - Provides addresses and routing information
  - Uses packet switching to transmit data
  - TCP/IP support is built into almost all operating systems
    - IP addresses are used to identify computers and devices on networks

TCP/IP Protocol Stack

TCP/IP model	Protocols and services
Application	HTTP, FTTP, Telnet, NTP, DHCP, PING
Transport	TCP, UDP
Network	IP, ARP, ICMP, IGMP
Network Interface	Ethernet
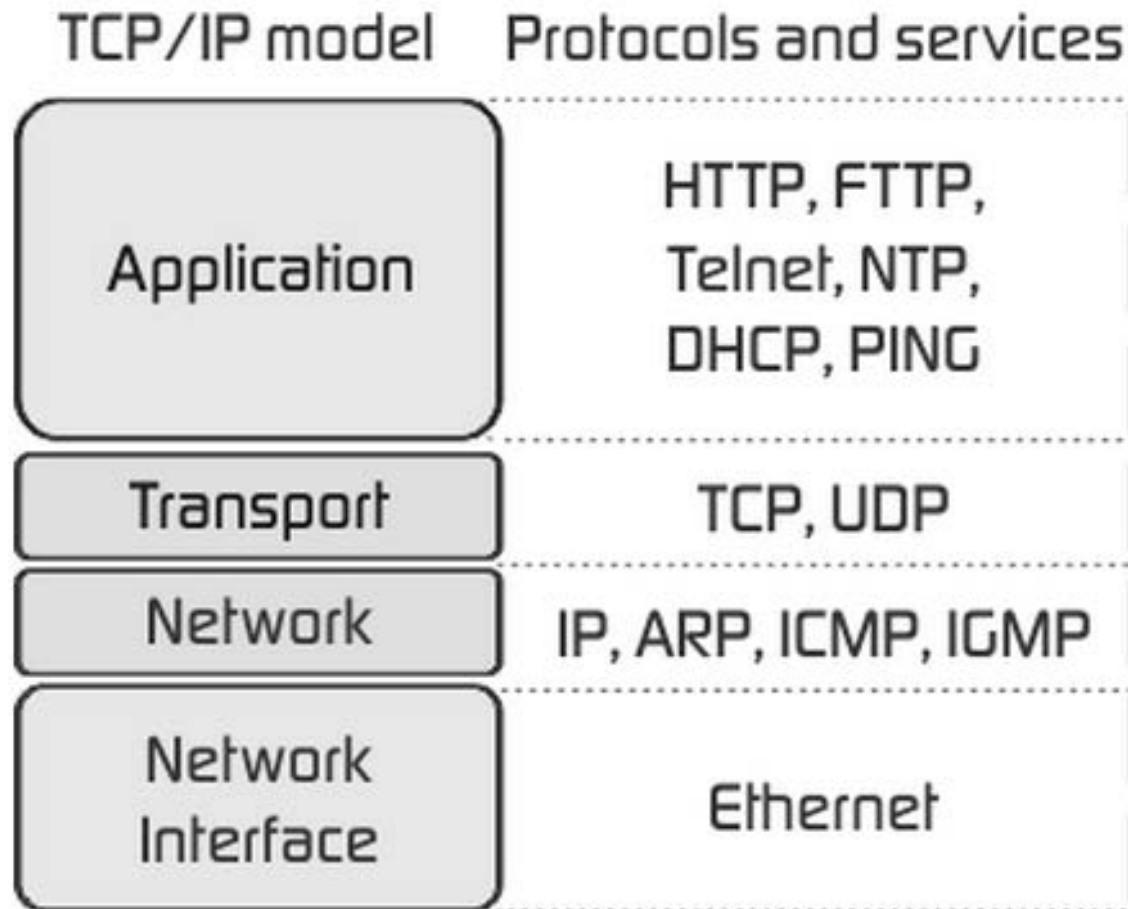
Example of How TCP/IP Works
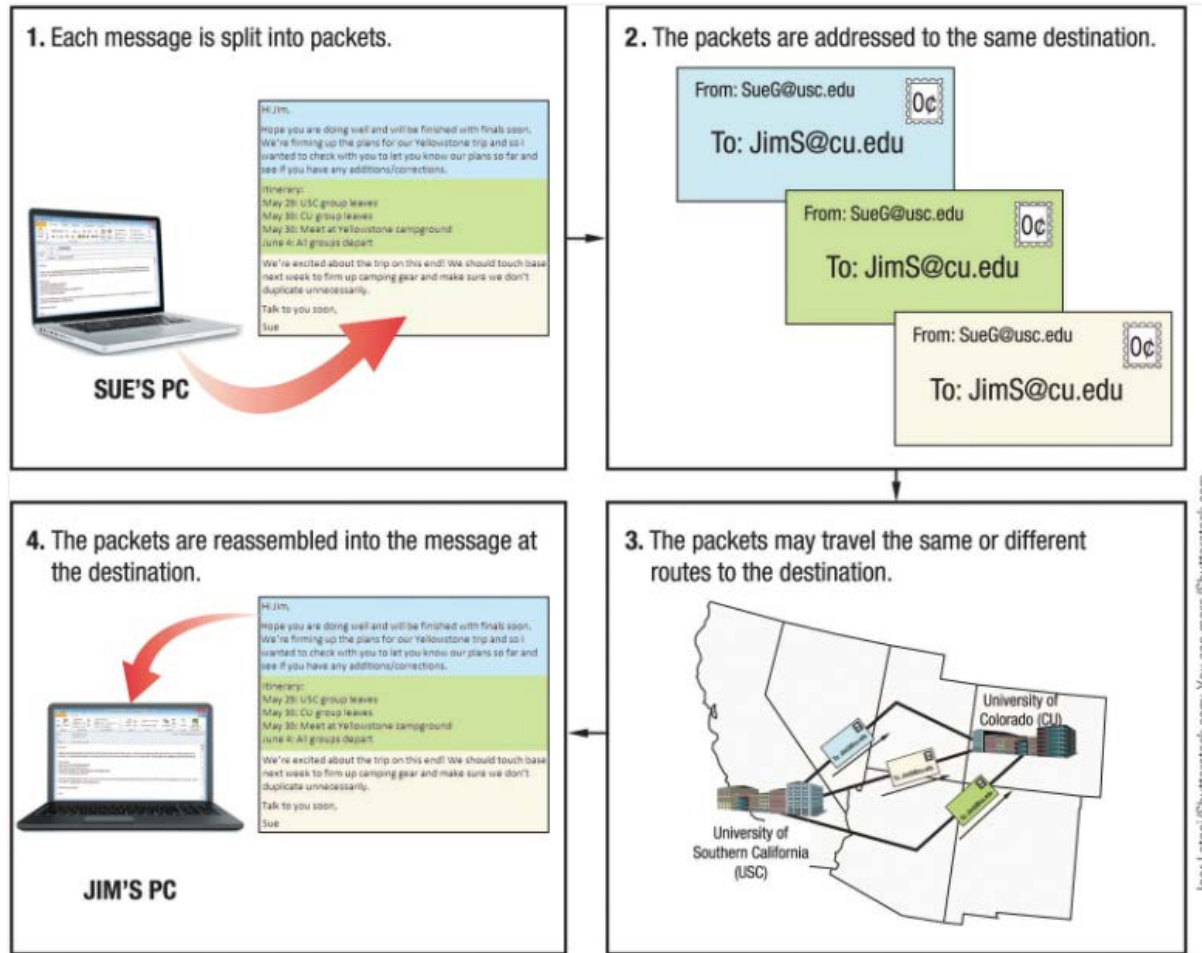
FIGURE 7-22
How TCP/IP works. TCP/IP networks (like the Internet) use packet switching.

Other Internet Communications Protocols

- HTTP (Hypertext Transfer Protocol) and HTTPS (Secure Hypertext Transfer Protocol)

  – Used to display Web pages

- FTP (File Transfer Protocol) and SFTP (Secure File Transfer Protocol)

  – Used to transfer files over the Internet

- SMTP (Simple Mail Transfer Protocol and POP3 (Post Office Protocol)

  – Used to deliver e-mail over the Internet

Networking Hardware

- A **network adapter** is used to connect a computer to a network

  – Also called **network interface card (NIC)** when in the form of an expansion card

- A **modem** is a device that enables a computer to communicate over analog networking media

  – Term is often used interchangeably with network adapter

- Most computers and mobile devices today come with a built-in network adapter and/or modem

Examples of Network Adapters and Modems

FIGURE 7-35
Network adapters and modems.

Port for twisted-pair Ethernet cable

PCI EXPRESS GIGABIT ETHERNET ADAPTERS

Source: D-Link Systems, Inc.

Connects to USB port

MICRO USB WI-FI ADAPTERS (802.11N)

Source: NETGEAR

Connects to USB port

TRADITIONAL USB WI-FI ADAPTERS (802.11AC)

Source: Novatel Wireless, Inc.

Connects to USB port

USB 4G MODEMS (4G LTE)

Source: Ubee Interactive

Incoming coaxial cable from cable provider and an Ethernet cable coming from the computer or router connect to the back of the modem.

ETHERNET CABLE MODEMS

Source: Ubee Interactive

Switches and Routers

- A **switch** is a central device that connects devices in a wired network but only sends data to the intended recipient
  - Contains ports to which devices are connected
    - => Uses physical/MAC addresses
  - Hub is similar but sends data to all recipients
- A **router** connects multiple networks: Two LANs, two WANS, LAN and the Internet, etc.
  - Passes data to intended recipient only
    - => Uses logical IP addresses
  - Can plan the most efficient path (dynamic)
  - Are used to route traffic over the Internet

Wireless Access Points, Wireless Routers, and Bridges

- A **wireless access point** allows devices to connect to a network

- A **wireless router** is a router with a built-in wireless access point and, typically, a switch
  - If so, it can connect both wireless and wired devices to a network and connect that network to the Internet
  - Travel and mobile broadband routers are available

- A **bridge** is used to connect two LANs together
  - In a home network, often used to wirelessly connect a group of wired devices (TV, Blu-ray player, etc.) to a home network

Other Networking Hardware

- **Repeaters** amplify signals along a network
- **Range extenders** are repeaters for a wireless network
- **Antennas** are devices used for receiving or sending radio signals
  - Some network adapters and routers can use an external antenna
  - Can be directional or omnidirectional
  - Strength measured in decibels (dB)
- Multiplexers combine transmissions from several different devices to send them as one message
  - Frequently used with fiber-optic cables and other high-capacity media to increase data throughput

Network Topologies

- The physical topology of a network indicates how the devices in the network are arranged (*Some networks use a combination of topologies)*
  - **Star network**: All network devices connect to a central device
    - If the central device fails, the network cannot work
  - **Bus network**: All network devices connect to a central cable
    - Data is transmitted down the bus line from one device to another
    - If bus line fails, the network cannot function
  - **Mesh network**: Network devices are interconnected so that messages can take any of several possible paths
    - A network in which there are multiple connections between the devices on the network so that data can take any of several paths
    - Full Mesh and Partial Mesh topologies
  - **Ring network**: not in text

Basic Network Topologies

FIGURE 7-9
Basic network topologies.

STAR NETWORKS
Use a central device to connect each device directly to the network.

BUS NETWORKS
Use a central cable to connect each device in a linear fashion.

MESH NETWORKS
Each computer or device is connected to multiple (sometimes all of the other) devices on the network.

Assess - Fault Tolerance, QoS, Security, Scalability

Mediums: Wired vs. Wireless Networks

- A **wired network** is a network in which computers and other devices are physically connected to the network with cables
  - Found in schools, businesses, and government facilities
- A **wireless network** is a network in which computers and other devices are connected to the network without physical cables
  - Data is typically sent via radio waves
  - Found in homes, schools, and businesses
  - A public wireless **hotspot** is a location that provides wireless Internet access to the public

Assess - Fault Tolerance, QoS, Security, Scalability

Wired Networking Media

- **Twisted-pair cable**
  - Pairs of insulated wires twisted together
  - Used for telephone and network connections (LANs)
- **Coaxial cable**
  - Thick center wire surrounded by insulation
  - Used for computer networks and cable television delivery
- **Fiber-optic cable**
  - Utilizes hundreds of thin transparent clear glass or plastic fibers over which lasers transmit data as light
  - Used for high-speed communications

Assess - Fault Tolerance, QoS, Security, Scalability

Examples of Wired Network Transmission Media

FIGURE 7-18

Wired network transmission media.

TWISTED-PAIR CABLES

The entire cable is covered by a plastic covering.

Pairs of copper wires are insulated with a plastic coating and twisted together; most cables contain at least two pairs.

Twisted-pair cable connector.

COAXIAL CABLES

The entire cable is covered by a plastic covering.

Outer conductor is made out of woven or braided metal.

White insulating material surrounds the copper wire.

The innermost part of the cable is a single copper wire.

Coaxial cable connector.

FIBER-OPTIC CABLES

The entire cable is surrounded by strengthening material and covered by a plastic covering.

The core of each fiber is a single glass or plastic tube, which is surrounded by a reflective cladding.

A protective plastic coating protects each fiber; a cable contains multiple fibers.

Fiber-optic cable connector.

Source: Black Box Corporation; Belkin International, Inc.

Networking Applications: The Internet and Telephone Service

- The Internet – the largest computer network in the world

  => Chapter 8 although this chapter covers many Internet applications and technologies.

Telephone

- **Telephone service**
  - Plain Old Telephone Service (POTS)
    - POTS Network was one of the first networks
    - Still provides telephone service to landline phones
    - Still used for ISDN overseas
      - => Bundled for Broadband

Ethernet (802.3)

- **Ethernet (802.3)** is the most widely used standard for wired networks (see ciss100.com => LM7 submenu)
  - Typically used with LANs
    - LANs evolved from bus to star topology
  - Works with twisted-pair, coaxial, and fiber-optic cabling
  - Continually evolving
  - Most common today are Fast Ethernet, Gigabit Ethernet, and 10 Gigabit Ethernet
  - 40 Gigabit Ethernet and 100 Gigabit Ethernet standards ratified in 2010
  - 400 Gigabit and Terabit Ethernet standards are currently being explored

Power over Ethernet (PoE)

- PoE allows electrical power to be sent along the cables on an Ethernet network along with data
  - Devices are not plugged into an electrical outlet as long as they are connected to Ethernet ports that support PoE
    - PoE injector can be used to send power to the device if needed
  - Most often used in business networks with remote devices (outdoor networking hardware, cameras, etc.)
  - Can also be used to place networked devices near ceilings or other locations where a nearby power outlet may not be available

Powerline and G.hn

- Powerline
  - Allows networking via ordinary electrical outlets
  - Broadband over Powerline (BPL): Can deliver Internet via existing outdoor power lines but is not widely used
  - HomePlug Powerline: Networks computers over existing powerlines
    - HomePlug AV2 can also network home entertainment devices
- G.hn
  - A unified world-wide standard for creating home networks over any existing home wiring—phone lines, power lines, and coaxial cable

Wireless Networking Media

- With wireless networking media, data is sent through the airwaves using radio signals
  - The electromagnetic spectrum is the range of common electromagnetic radiation (energy)
    - Radio frequencies are assigned by the FCC and are measured in hertz (Hz)
    - Different parts of the spectrum have different properties, which make certain frequencies more appropriate for certain applications
    - Wireless spectrum is the RF band (up to 300 GHz)
      - Unlicensed frequencies can be used for any application
      - Wireless networks often use frequencies in the 2.4GHz and 5 GHz bands
    - Microwave typically defined as 300 MHz – 300 GHz
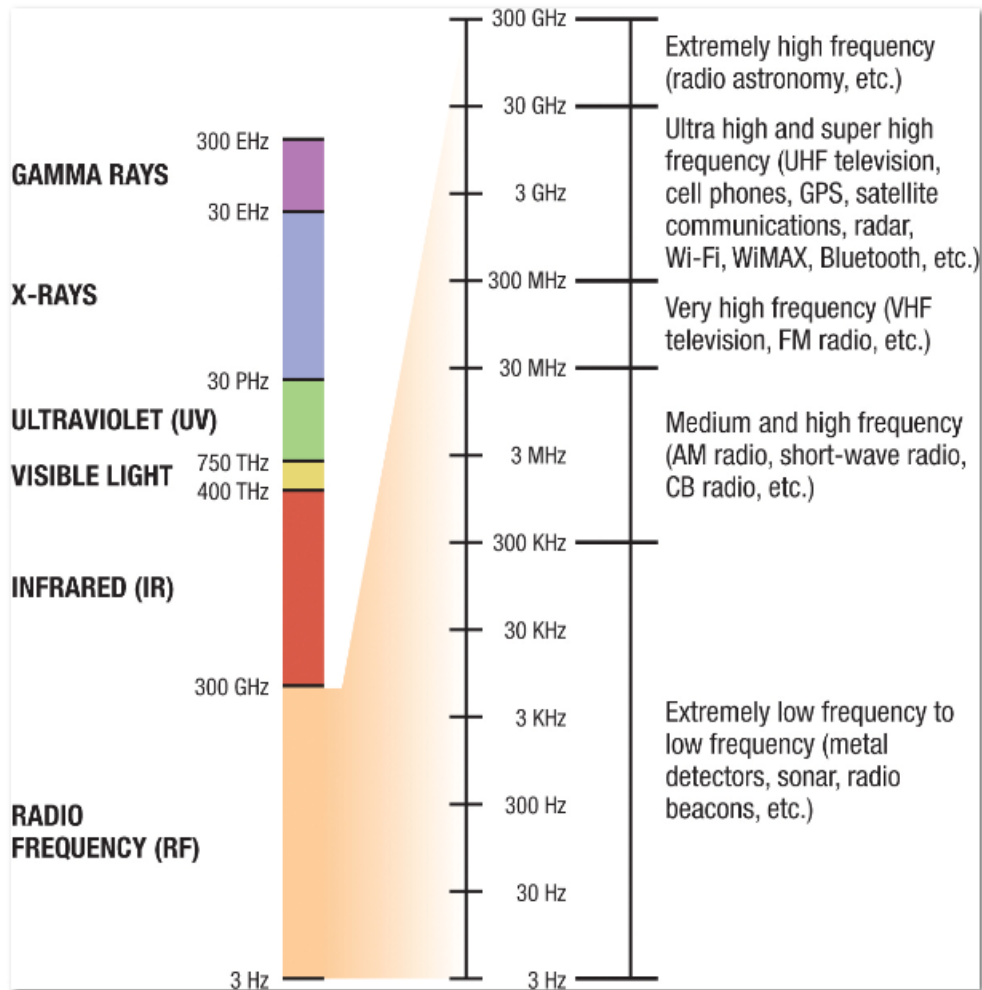
The Electromagnetic Spectrum

FIGURE 7-19
The electromagnetic spectrum. Each type of communication is assigned specific frequencies within which to operate.

Wi-Fi (802.11)

- **Wi-Fi (802.11)** is a family of wireless networking standards using IEEE standard 802.11
    - Current standard for wireless networks in homes and offices
    - Built into many everyday objects today
    - Designed for medium-range transmission; speed and distance depends on Wi-Fi standard, solid objects in the way, interference, etc.

FIGURE 7-26
Smart appliances.
This coffeemaker
is controlled by a
smartphone via the
home's Wi-Fi network.

Source: Belkin International, Inc.

Wi-Fi Standards

- The most widely used standards are 802.11n and 802.11ac
- Wi-Fi products are backward compatible

WI-FI STANDARD	DESCRIPTION
802.11b	An early Wi-Fi standard; supports data transfer rates of 11 Mbps.
802.11g	An older Wi-Fi standard; supports data transfer rates of 54 Mbps and uses the same 2.4 GHz frequency as 802.11b, so their products are compatible.
802.11a	An older Wi-Fi standard; supports data transfer rates of 54 Mbps, but uses a different radio frequency (5 GHz) than 802.11b/g (2.4 GHz), making the standards incompatible.
802.11n	A current Wi-Fi standard; supports speeds up to about 450 Mbps and has twice the range of 802.11g. It can use either the 2.4 GHz or 5 GHz frequency.
802.11ac	The newest Wi-Fi standard; supports speed up to about three times faster than 802.11n and uses the 5 GHz frequency (though most 802.11ac routers are *dual band* to also support 2.4 GHz devices for backward compatibility).
802.11ax*	A proposed Wi-Fi standard; expected to support speeds of more than 2 Gbps.

* Expected by 2018

FIGURE 7-27
Wi-Fi standards.

WiMAX (802.16)

- **WiMAX (802.16)** is a set of standards for longer range wireless networking connections, typically MANs
  - Fixed WiMAX
    - Designed to provide Internet access fixed locations (hotzones)
    - Typical hotzone radius is between 2 and 6 miles
    - Possible to provide coverage to an entire city by using multiple WiMAX towers
  - Mobile WiMAX (802.16e)
    - Mobile version of the standard
    - Being replaced with cellular standards

Wi-Fi Direct, WiGig, and Wireless HD

- **Wi-Fi Direct** is a standard for connecting Wi-Fi devices directly, without using a router or an access point

- **WiGig (802.11ad)** and **WirelessHD (WiHD)** are used to wirelessly connect computers and home entertainment devices together
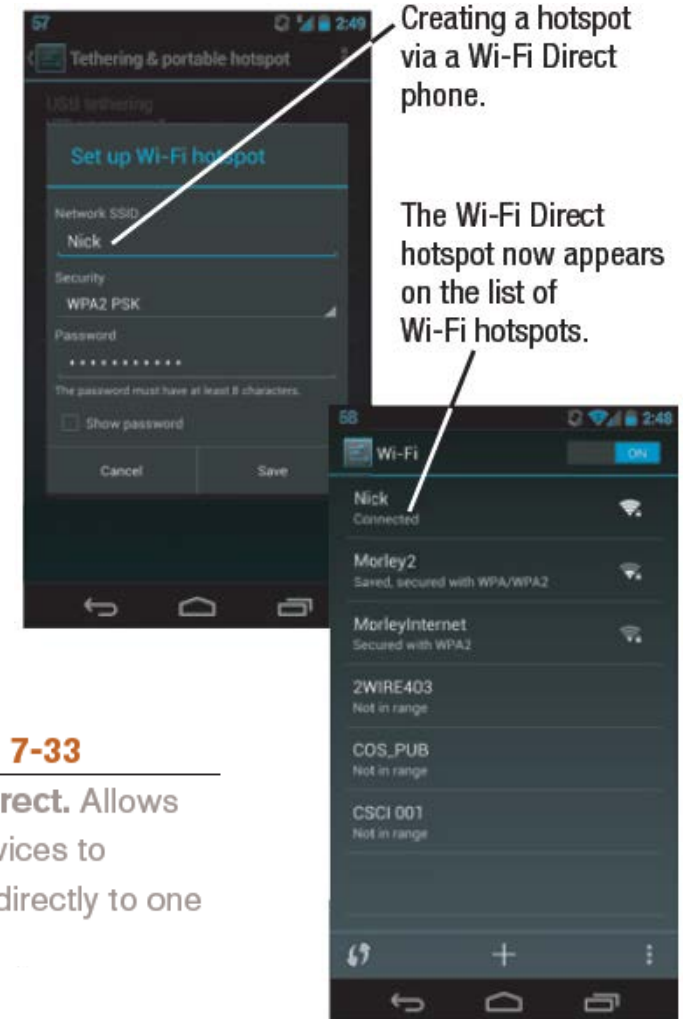

Creating a hotspot via a Wi-Fi Direct phone.

The Wi-Fi Direct hotspot now appears on the list of Wi-Fi hotspots.

FIGURE 7-33

Wi-Fi Direct. Allows Wi-Fi devices to connect directly to one another.

Bluetooth

- **Bluetooth** is a networking standard for very short-range wireless connections
  - Typical range is about 10 meters (33 feet)
    - Bluetooth 4.0 => 100 ft
  - Designed to connect devices wirelessly
    - Keyboard/mouse to a PC, send print jobs to a printer, connect a wireless speaker to a smartphone, send photos from a smartphone to another smartphone or a PC, etc.
  - Can transmit through clothing or other objects
  - Devices form piconets when connected (8 devices max)
  - Bluetooth 4 (Bluetooth Smart) is energy efficient

Cellular Radio Transmissions

- Cellular radio transmissions use cellular towers within overlapping honeycomb-shaped zones called cells
  - Calls are transferred from cell tower to cell tower as the individual moves
  - Cell tower forwards call to the MTSO
    - MTSO = mobile telephone switching office
  - MTSO routes call to the recipient's phone
  - Data sent via cell phones works in similar manner
- The speed of cellular radio transmissions depends on the type of cellular standard being used

Mobile Phones

Use wireless networks for communications

- **Cellular (cell) phones** must be within range of cell tower to function

- **Dual-mode phones** allow users to make telephone calls using more than one communications network
  - Cellular/Wi-Fi dual-mode phones

- **Satellite phones** communicate via satellite technology
  - Most often used by individuals such as soldiers, journalists, wilderness guides, and researchers

- Research Cell-Site Simulators (Govt/police/org crime)

Communication Satellites

- **Communication satellites** are launched into orbit to send and receive microwave signals from earth
  - Traditional satellites use geosynchronous orbit 22,300 miles above the earth
  - A delay of less than one half-second is common when signals travel from earth to satellite and back
  - Low earth orbit (LEO) satellites have less delay and are used with satellite telephones
  - Medium earth orbit (MEO) satellites are most often used for GPS systems

GPS Applications

- The **global positioning system (GPS)** uses 24 GPS satellites for location and navigational purposes
  - GPS receivers use the GPS system to determine their exact geographic location
  - GPS III is under development and will be more powerful and accurate than the current system

Broadcasting

- Television and radio broadcasting
  - Over the air networks still used to deliver TV and radio content to the public
  - Also includes cable TV networks, satellite TV networks, and private closed-circuit television (CCTV) systems

Infrared (IR) Transmissions

- **Infrared (IR) transmissions** send data as infrared light rays
  - Like an infrared television remote, requires line of sight
  - Because of this limitation, many formerly IR devices (wireless mice, keyboards) now use RF technology
- IR is sometimes used to beam data between some mobile devices, game consoles, and handheld gaming devices

Client-Server Networks

- **Client-server networks**
  - Client: A computer or other device on the network that requests and utilizes network resources
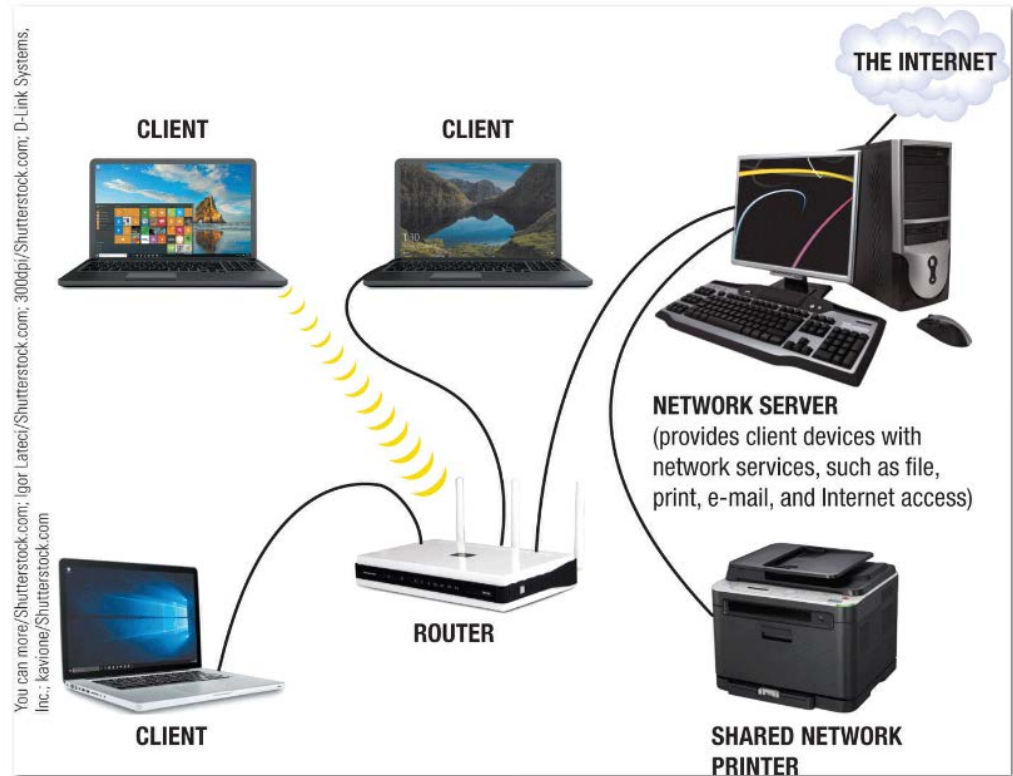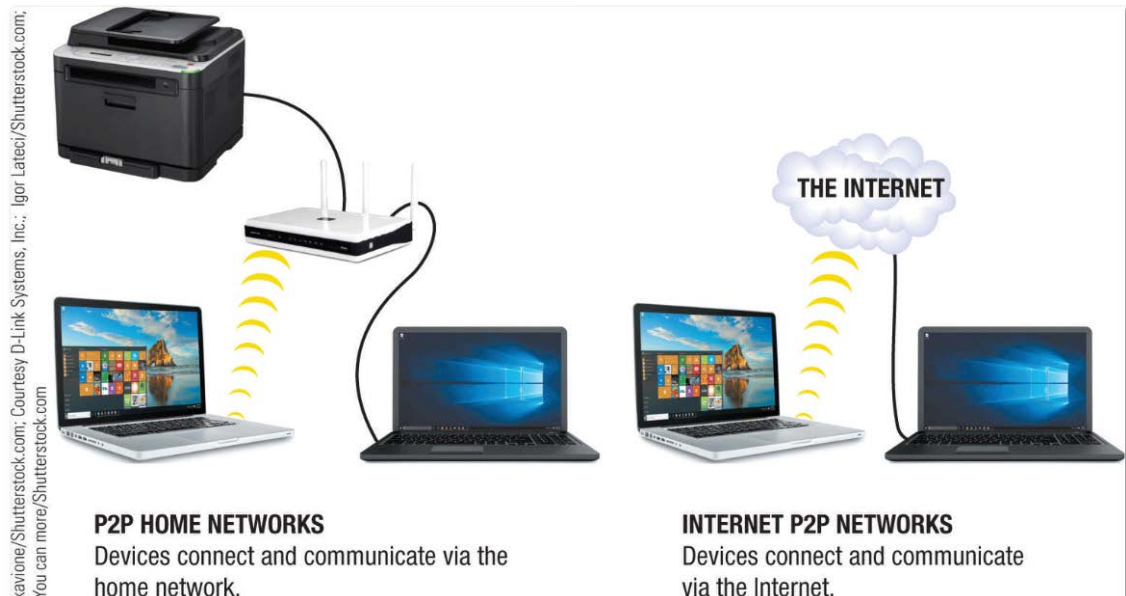 - Server: The computer dedicated to processing client requests

FIGURE 7-10
Client-server networks.
Client computers communicate through one or more servers.

Peer-to-Peer (P2P) Networks

- P2P networks
  - All computers work at the same functional level

    => No server

  - Users have direct access to the computers and devices attached to the network

  - Internet P2P networks
    - Content is exchanged over the Internet directly between users

FIGURE 7-11

Peer-to-peer networks. Computers communicate directly with one another.

P2P HOME NETWORKS
Devices connect and communicate via the home network.

INTERNET P2P NETWORKS
Devices connect and communicate via the Internet.

Trend

Smart Homes

- Home automation
  - Use Z-Wave, Bluetooth, or Wi- to control lights, door locks, thermostats, etc.
- Smart door locks can be unlocked via proximity sensors and Bluetooth 4.0
  - Can send temporary keys to others
  - Can check on status of locks and keys online

Using your smartphone as your door key.

Monitoring Systems

- Monitoring systems use networking technology to determine the current location or status of an object
  - RFID-based systems
    - Monitor the status of objects
  - GPS-based monitoring systems
    - Monitor the physical location of objects
    - Vehicle and child monitoring systems
  - Electronic medical monitors
    - Home healthcare
  - Sensor systems
    - Shipping, home automation (smart thermostats), etc.

Multimedia Networking

- Multimedia networking involves distributing digital multimedia content, typically via a home network
  – Smart TVs, streaming media players, etc.

- Placeshifting - Allows individuals to view multimedia content at a more convenient location (i.e., Slingbox)

FIGURE 7-6

Placeshifting. Used to transfer multimedia content to the user's current location.

1. Slingbox device is connected to the user's home cable or satellite set-top box, as well as to the home Wi-Fi network.

2. SlingPlayer software allows the user to watch and control his or her home TV system from anywhere with an Internet connection.

Source: Sling Media, Inc.

Videoconferencing, Collaborative Computing, and Telecommuting

- **Videoconferencing** uses computers, video cameras, microphones, and networking technologies to conduct face-to-face meetings over a network
  - Telepresence videoconferencing more closely mimics a real-time meeting environment
- Collaborative computing (workgroup computing) enables individuals to work together on documents and projects
  - Markup tools, collaboration software, shared documents, etc.
- With **telecommuting**, individuals work from a remote location (usually home) and communicate with their places of business and clients using networking technologies
  - Allows for employee flexibility
  - Greener computing

Telemedicine

- **Telemedicine** uses networking technology to provide medical information and services
  - Remote monitoring and consultations
  - Remote diagnosis
  - Provides individuals in rural locations access to medical care
  - Necessary for long-term space exploration
  - **Telesurgery** involves robot-assisted surgery where doctor's physical location is different from that of the patient and robot

Summary

- What Is a Network?
- Networking Applications
- Network Characteristics
- Data Transmission Characteristics
- Networking Media
- Communications Protocols and Networking Standards
- Networking Hardware