Connecting with Computer Science

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chapter

networks

Objectives

- Learn how computers are connected
- Become familiar with different types of transmission media
- Learn the differences between guided and unguided media
- Learn how protocols enable networking

Objectives (continued)

- Learn about the ISO/OSI reference model
- Understand the differences between network types
- Learn about local area networks (LANs)
- Learn about wide area networks (WANs)
- Learn about wireless local area networks (WLANs)

Objectives (continued)

- Learn about network communication devices
- Learn how WANs use switched networks to communicate
- Learn how devices can share a communication medium
- Learn about DSL, cable modems, and satellite communications

Why You Need to Know About... Networks

- Networks connect computers and peripheral devices
  - Effectively an extension of the system bus
  - TCP/IP protocols at the core
- Networks are central to all forms of computing
  - E-commerce, research, communication
- Computer scientists and networking
  - Fundamental knowledge

Connecting Computers

- Linking computers via system bus impractical
  - PCI bus has 98 wires
  - Remote connection virtually impossible
- Connection problem solved with networks
  - Medium, such as wire, carries electric signal
  - Communications protocol (TCP/IP) manages process

Transmission Medium

- Transmission medium: material that conducts electrical and/or electromagnetic signals
- Transmission media rated in four different ways:
  - Bandwidth: medium speed measured in bits/second
  - Signal-to-noise ratio: = 10 $\log_{10}$ (signal/noise)
  - Bit error rate: percentage of incorrect bits to total number of bits in unit time
  - Attenuation: signal weakening over distance

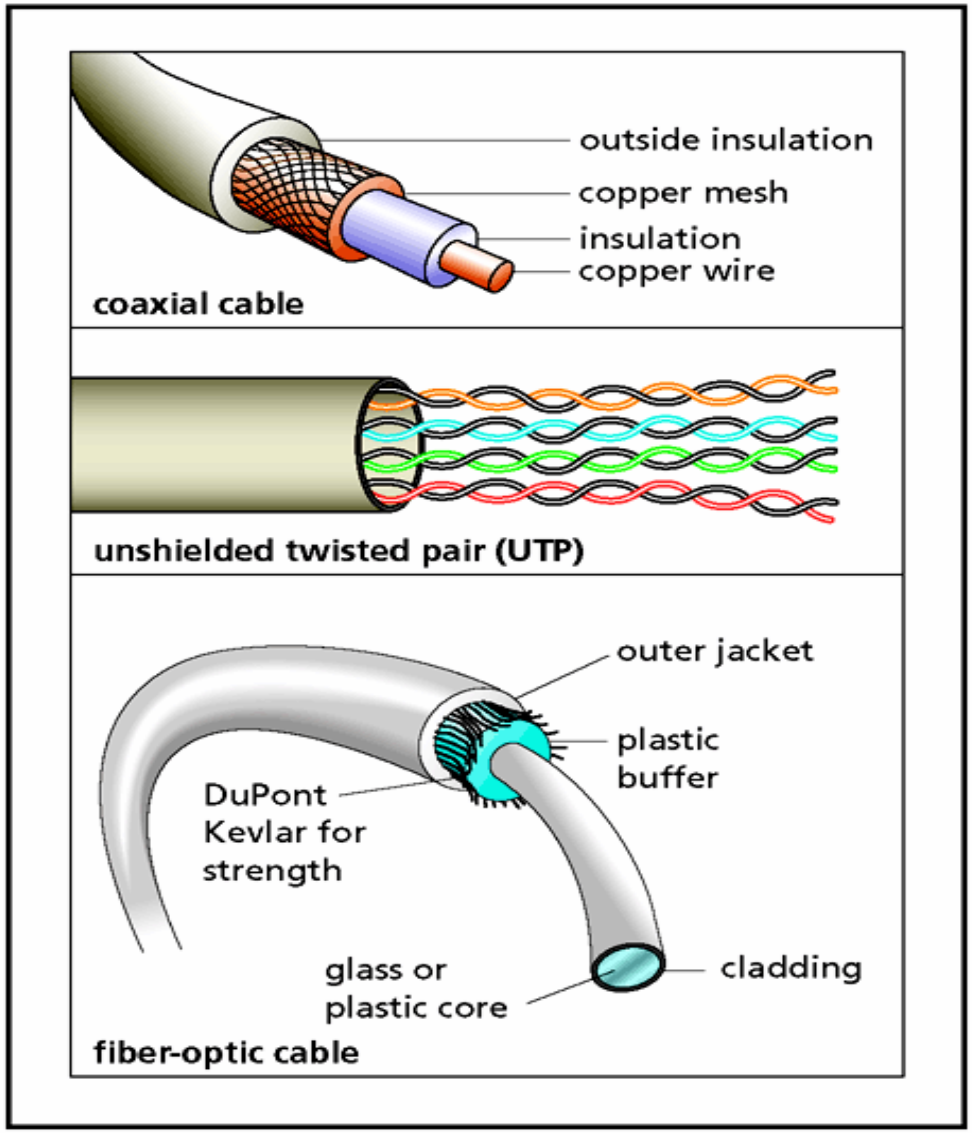
Transmission Medium (continued)

- Two general transmission medium types
  - Guided: physical media such as copper wire
  - Unguided: air and space that carry electromagnetic signals

Guided Media

- Two broad categories
  - Copper wire
    - Shielded and unshielded twisted pair
    - Coaxial cable (coax)
  - Fiber-optic cable
    - Uses glass and light to transmit signals

Figure 6-1, Coax, twisted pair, and fiber-optic cable are guided media



Guided Media (continued)

- Copper Wire: Coax and Twisted Pair
  - Coaxial cable (coax)
    - Copper surrounded by metal shield to reduce noise
    - Support bandwidths up to 600 MHz
    - Examples: 10Base2 and 10Base5
  - Twisted Pair
    - Dampens effects of inductance
    - Two types: shielded and unshielded (UTP)
    - UTP more popular than shielded twisted pair or coax

Table 6-1, EIA/TIA twisted pair cable categories

category	maximum frequency
1	4–9 KHz
2	1 Mbps or less
3	10 MHz
4	20 MHz
5	100 MHz
6	250 MHz
7	600 MHz

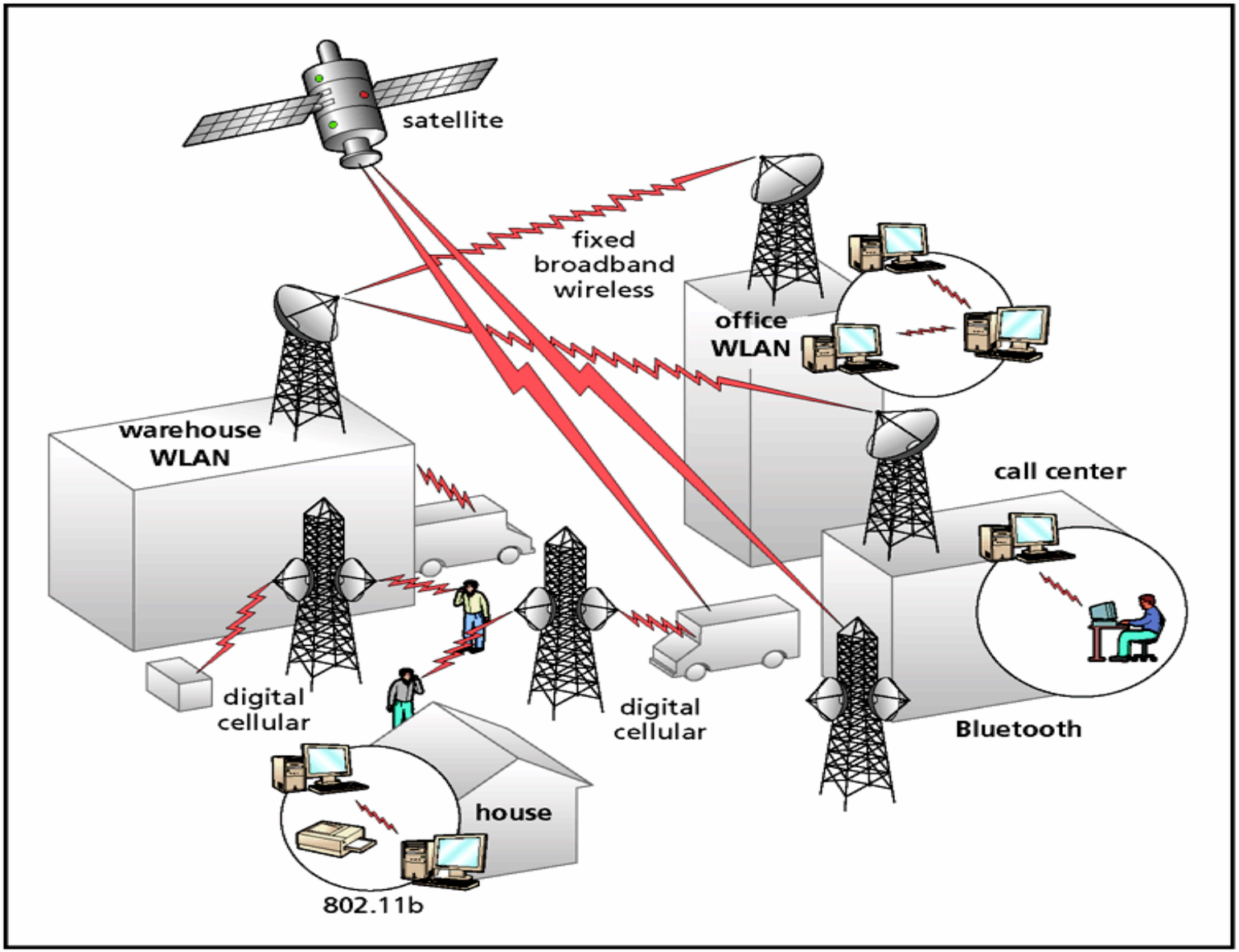
Guided Media (continued)

- Impedance: attenuates signals in copper wires
- Fiber-optic cables
  - Glass fibers guide light pulses
  - Less susceptible to attenuation than copper wires
  - Principle of inductance does not apply
  - Bandwidth hundreds of times faster than copper wire
  - Economies of scale are lowering manufacturing cost

Unguided Media: Wireless Technologies

- Benefits of wireless technology
  - Eliminate cabling costs
  - Device mobility or portability
- Basis of wireless technology: radio waves
  - Radios, cell phones, walkie-talkies, garage door openers, and microwave ovens share same basis

Figure 6-2, Wireless technologies



Unguided Media: Wireless Technologies (continued)

- Radio wave manipulation
  - Electronic signal amplified
  - Signal then transmitted as electromagnetic wave
  - Receiving antenna converts back to electronic signal
  - Transmission occurs at many different frequencies
- Industry standards (based on 2.4 GHz range)
  - IEEE 80211 series: most common
  - Bluetooth: short range: 3" to 328 ' (mice, keyboards, printers, other I/O devices)

Unguided Media: Wireless Technologies (continued)

- Light transmission
  - Infrared light also used over short distances
  - Capable of speeds up to 4 Mbps
  - Requires clear line of sight between sender/receiver
  - Used in mice, keyboards, PDAs, cell phones, notebook computers, other portable devices

Table 6-2 Wireless technologies

wireless technology	transmission distance	speed
Bluetooth	33 feet (10 meters)	1 Mbps
WLAN 802.11b	375 feet (112 meters)	11 Mbps
WLAN 802.11a	300 feet (90 meters)	54 Mbps
WLAN 802.11g	375 feet (112 meters)	54 Mbps
Satellite	Worldwide	1 Mbps
Fixed broadband	35 miles (56 kilometers)	1 Gbps
WAP (cell phones)	Nationwide	384 Kbps

Protocols

- Protocols: set of rules facilitating communication
  - Example: classroom questioning
  - Timing diagrams organize interchange
- Many machine protocols
  - Provide for orderly flow of information transfer
  - Example: TCP (Transmission Control Protocol)
    - Responsible for faithful message reproduction
    - Error checking and retransmission performed

Table 6-3, Protocol timing diagram

time period	professor	student
1	Lecturing	
2		Raises hand to show desire to ask question
3	Notices student's hand and finishes thought	
4	Tells student to proceed	
5		Lowers hand to acknowledge professor's recognition
6		Asks question
7		Stops talking to indicate question is complete
8	Answers question	
9	Continues lecturing	

Table 6-4, Timing diagram for a communication protocol

time period	computer 1	computer 2
1	Listening	Listening
2	Are you ready?	
3		Yes I am
4	Here comes part 1	
5		I received part 1
6	Here comes part 2	
7		I received part 2
8	I'm finished	
9		Terminate

ISO/OSI Reference Model

- Conceptual model with seven discrete layers

1. Physical: defines specifications for physical link
2. Data Link: provides for data transit, physical addressing and notification, ordered frames delivery, and flow control
3. Network: provides connectivity and path selection. Also responsible for assigning addresses to messages

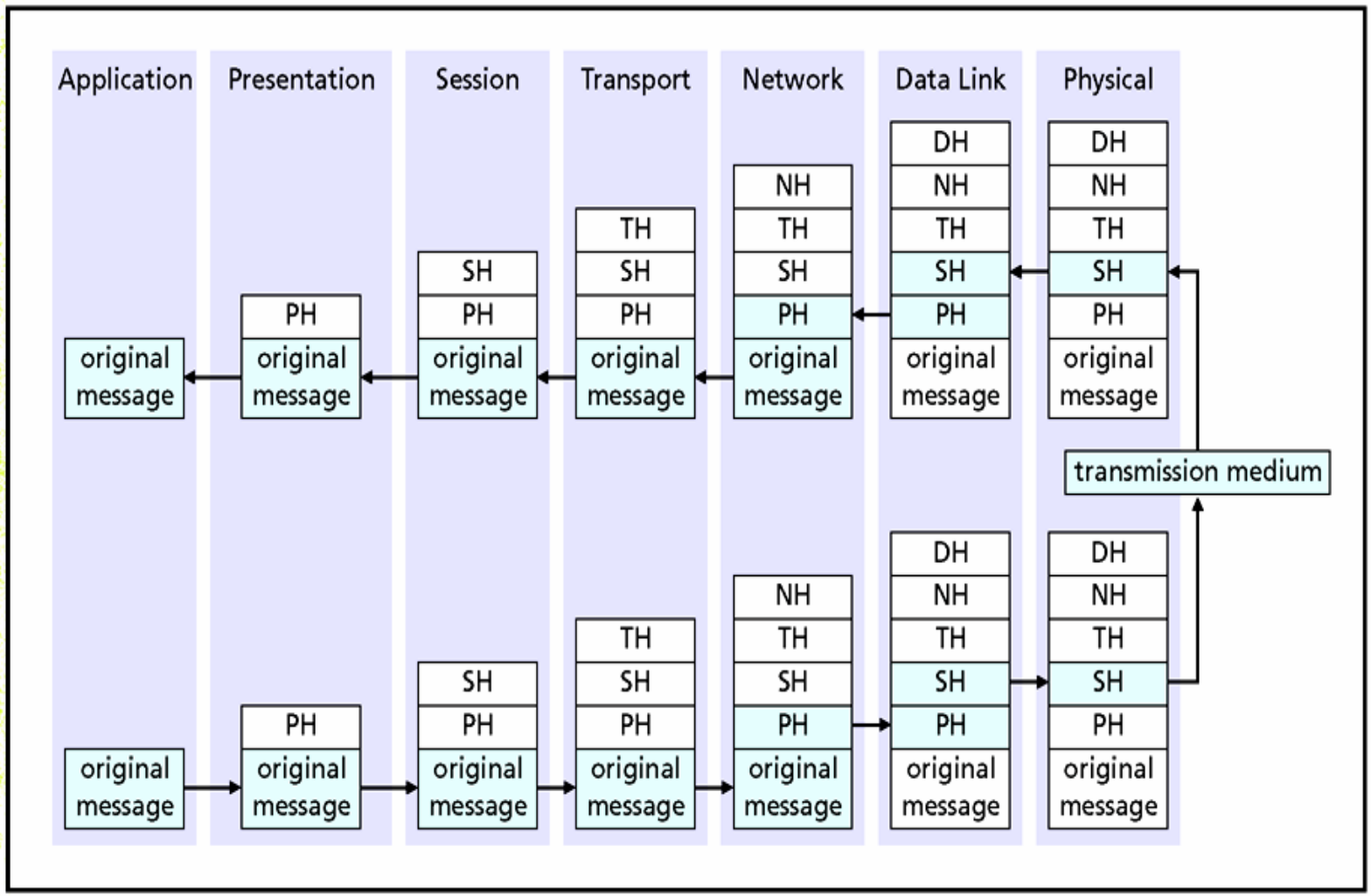
ISO/OSI Reference Model (continued)

4. Transport: guarantees delivery of datagrams. Also responsible for fault detection, error recovery, and flow control
5. Session: establishes, maintains, terminates sessions
6. Presentation: has format responsibilities such as translation, formatting, and syntax selection
7. Application: provides network access

ISO/OSI Reference Model (continued)

- Layers defined by two components
  - Protocol Data Unit (PDU)
  - Header: layer and message information
- Message transfer
  - Originates in application
  - Enhanced by each layer as passed up stack Physical layer places on transmission medium
  - Receiving node dismantles in reverse mode
- Modularity: simplifies redesign and modification

Figure 6-3, How the OSI model processes data



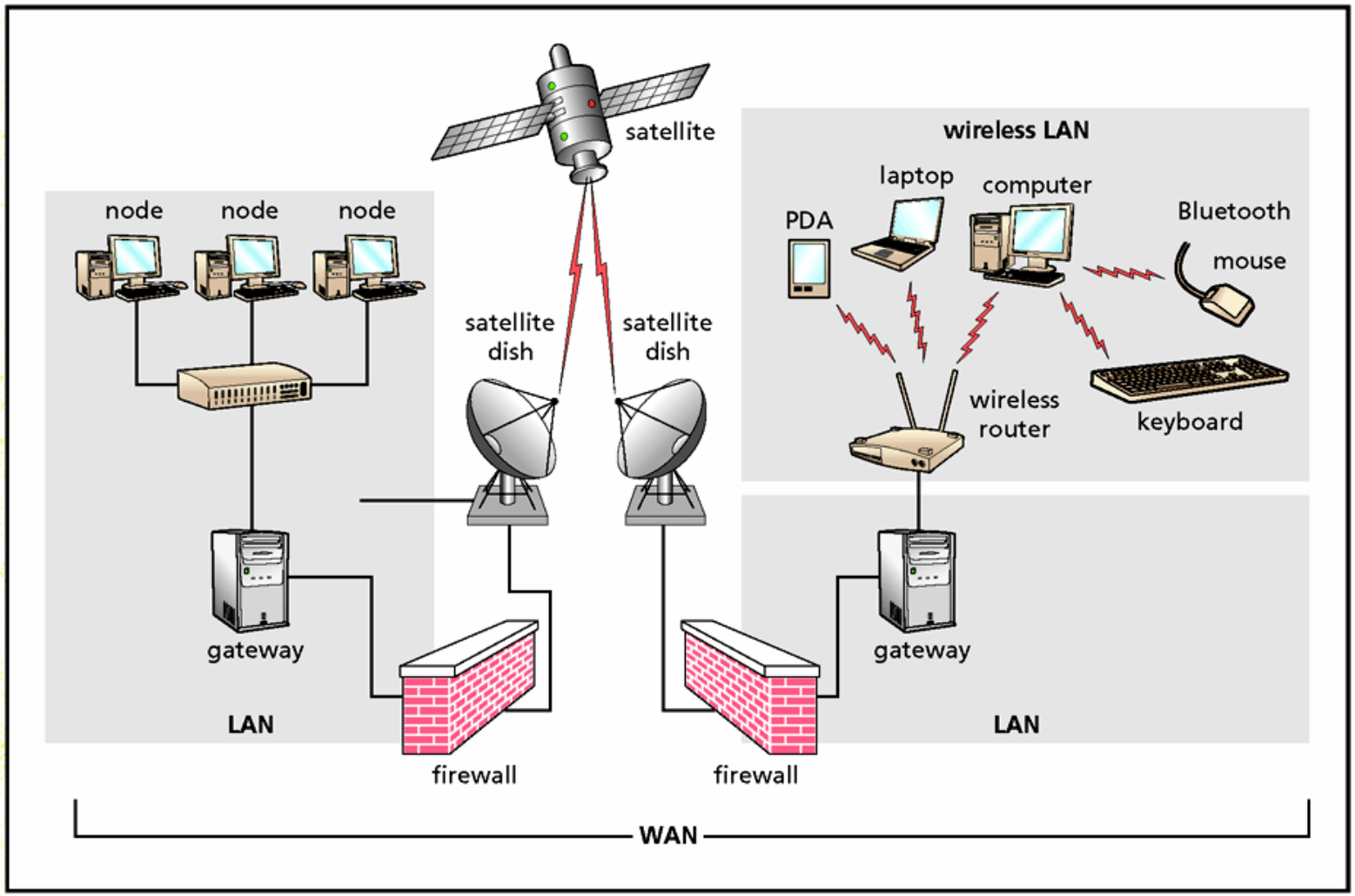
Network Types

- Classify according to size and proximity
- LAN (local area network)
  - Small number of computers in close proximity
  - Usually confined to building or complex
  - Typically connected with copper wiring
  - WLAN (wireless local area network)
- WAN (wide area network)
  - Connect LANs and WLANs (wider geography)

Network Types (continued)

- MAN (metropolitan area network)
  - Spans city or metropolitan area
- Distinctions between types
  - Not hard and fast
  - Internet sometimes classified as WAN

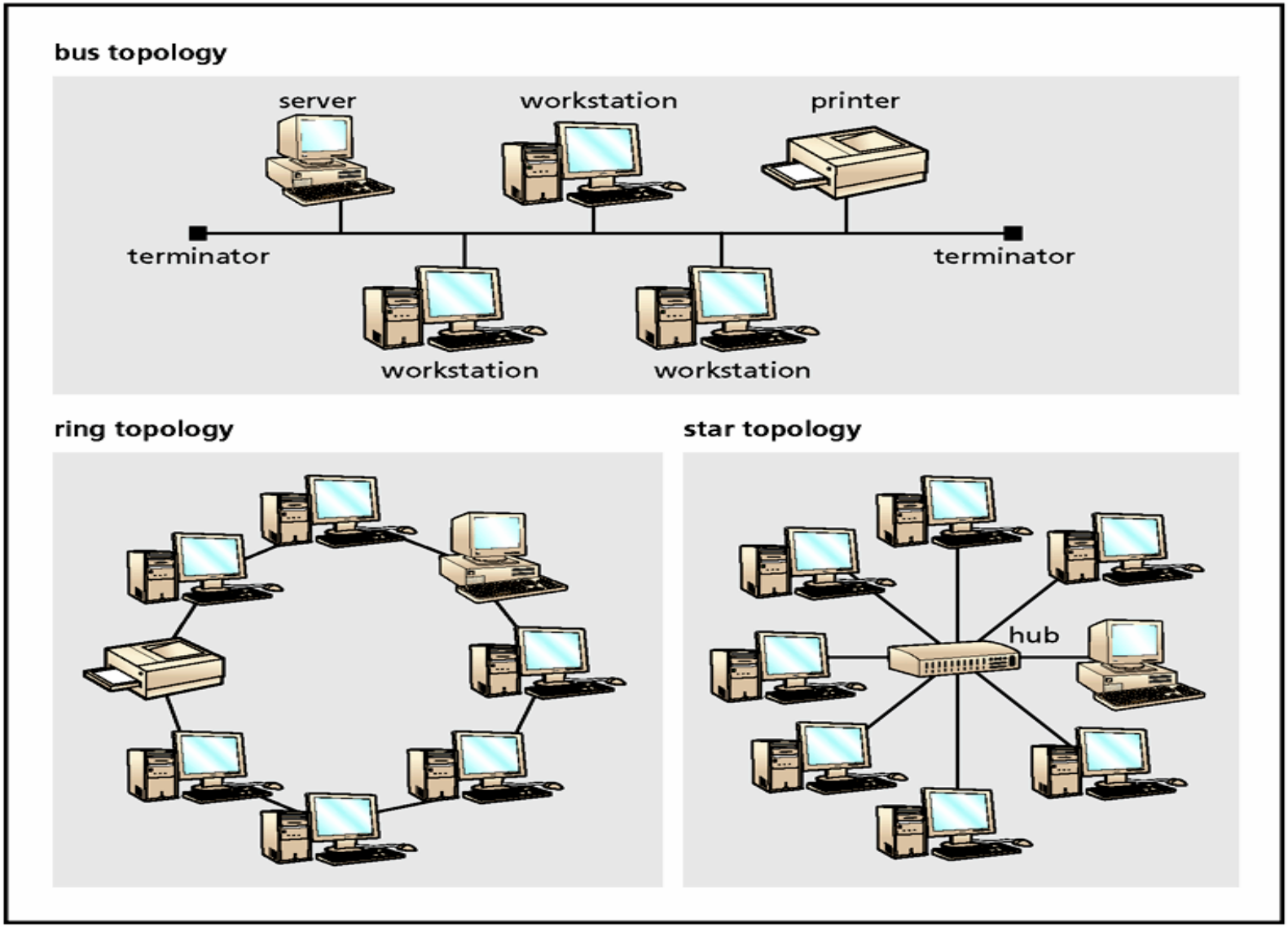
Figure 6-4, Example WAN configuration



LAN Topologies

- Network configurations often called network topologies
- Node: Computer attached to network
  - Each node has a unique network address
- Three basic LAN topologies
  - Ring: connects computers in a loop with cable
  - Star: computers connected to hub (central point)
  - Bus: configured like a system bus on a computer (most popular)

Figure 6-5, LAN topologies



LAN Communication Technologies

- Ethernet
  - Widely used technology that has become industry standard
  - Based on a bus topology
  - Can be wired in a star pattern (star/bus) topology
  - Original Ethernet transferred data at 10 Mbps
  - Fast Ethernet, transfers data at 100 Mbps
  - Gigabit Ethernet transfers data from 1 to 10 Gbps

LAN Communication Technologies (continued)

- Token ring
  - Second most popular LAN technology
  - Uses a ring topology
  - Controls access to the network by passing token
  - Capable of data transfer of 4 or 16 Mbps
- FDDI and ATM: fastest and most expensive LAN technologies

Table 6-5, Bandwidth of LAN technologies

LAN technology	bandwidth
Ethernet	10 Mbps (megabits per second)
Fast Ethernet	100 Mbps
Gigabit Ethernet	1 Gbps (gigabits per second)
10 Gigabit Ethernet	10 Gbps
Token ring	4 Mbps, 16 Mbps
Fast token ring	100 Mbps, 128 Mbps
FDDI	100 Mbps
ATM	Up to 2.488 Gbps

Network Communication Devices

- LANs and WLANs are joined to form WANs
- WANs are joined to form more complex WANs
- Present devices used to created connectivity
  - Network interface cards, repeaters, hubs, switches, bridges, gateways, routers, and firewalls

NIC (network interface card)

- NIC
  - Physical link between computer and network
  - Located in expansion slot on mother board or card slot in notebook
  - Includes external port
  - Each NIC has 48-bit address (physical or MAC address)

Repeater

- Repeater
  - Solves attenuation problem
  - Amplifies signal along cable between nodes
  - Does not change signal

Hub

- Hub
  - Special repeater with multiple input and output ports
  - Allows multiple nodes to share same repeater

Switch

- Switch
  - Similar to a hub
  - Unlike hub, inputs and outputs not connected
  - Assumes Data Link duties (OSI Layer 2)
  - Examines header, makes point-to-point connection to output addressed by packet

Bridge

- Bridge
  - A switch with intelligence
  - Divides networks into segments to reduce global traffic

Gateway

- Gateway
  - Similar to a bridge
  - Can interpret and translate different network protocols
  - Can connect networks of different types

Router

- Router
  - Like bridges and gateways
  - Function at higher OSI layer 3
  - Route traffic based on IP address assigned at Network Layer

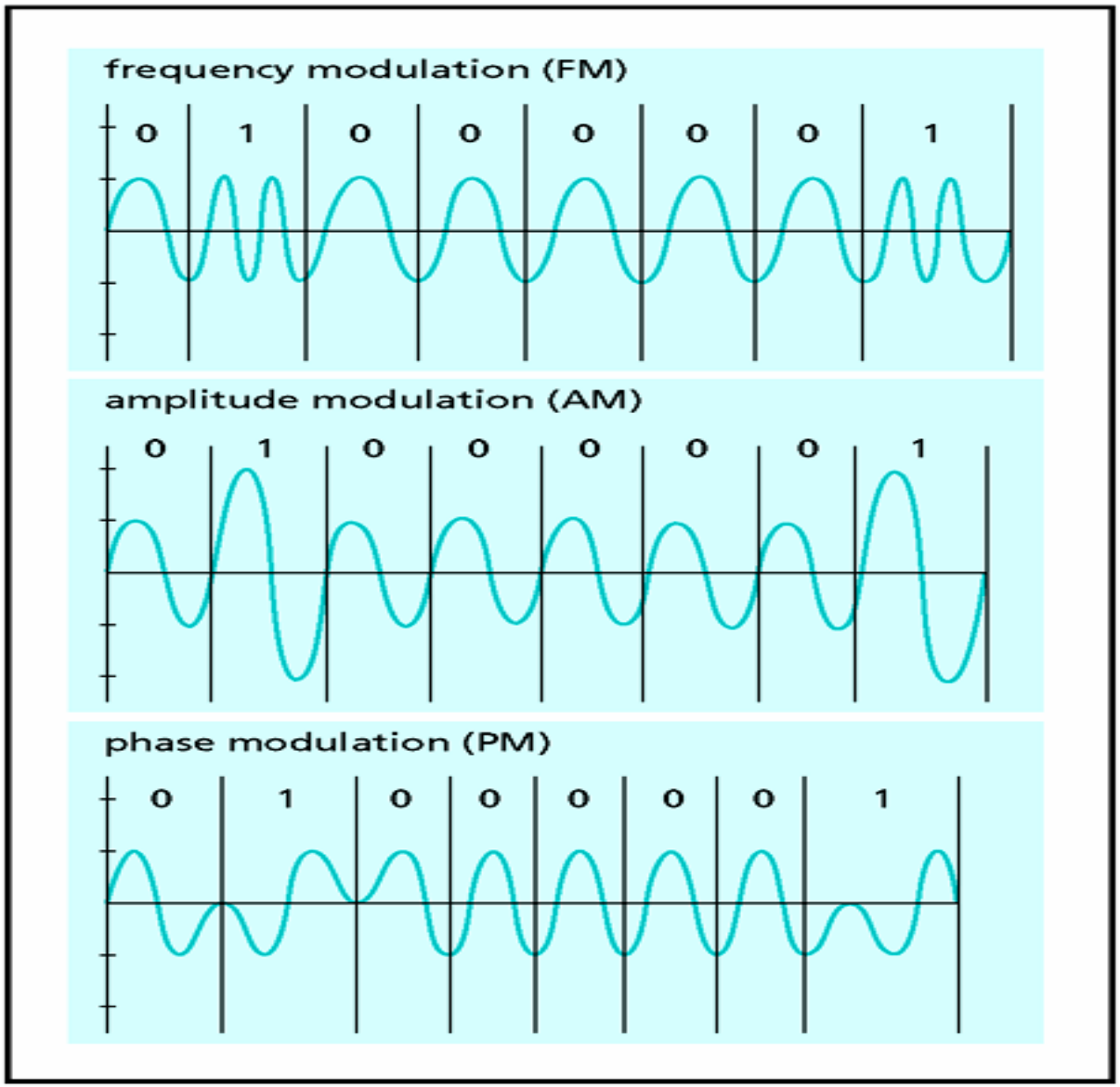
Firewall

- Firewall
  - Protect internal network or node
  - May be router based
  - Examines/restricts inbound and outbound traffic
  - May be implemented in hardware or software

Switched Networks

- Telephone network adapted to carry digital data
- Modems (modulator/demodulator): modify analog signals to represent binary data
- Small bandwidth designed for range 300 to 3300 Hz
  - Frequency modulation (FM), amplitude modulation (AM), phase modulation (PM) boost speed to 3Kbps
  - Combine compression techniques and rearranged transitions to reach 56Kbps limit

Figure 6-6, Frequency modulation, amplitude modulation, and phase modulation



High-Speed Wide Area Networks

- Demand for higher access speeds
  - Extend system bus
- Copper capable of speeds up to 1.5 Mbps
  - Need to lease wire bandwidth (24 channels)
  - Very expensive
  - Dedicated line called T1
  - T3 line consists of 28 T1 lines
- Fiber-optic cables: OC lines faster than T3

Table 6-6, High-speed WAN connections

connection	speed	equivalent
T1	1.544 Mbps (megabits per second)	24 voice lines
T3	43.232 Mbps	28 T1 lines
OC3	155 Mbps	84 T1 lines
OC12	622 Mbps	four OC3 lines
OC48	2.5 Gbps (gigabits per second)	four OC12 lines
OC192	9.6 Gbps	four OC48 lines

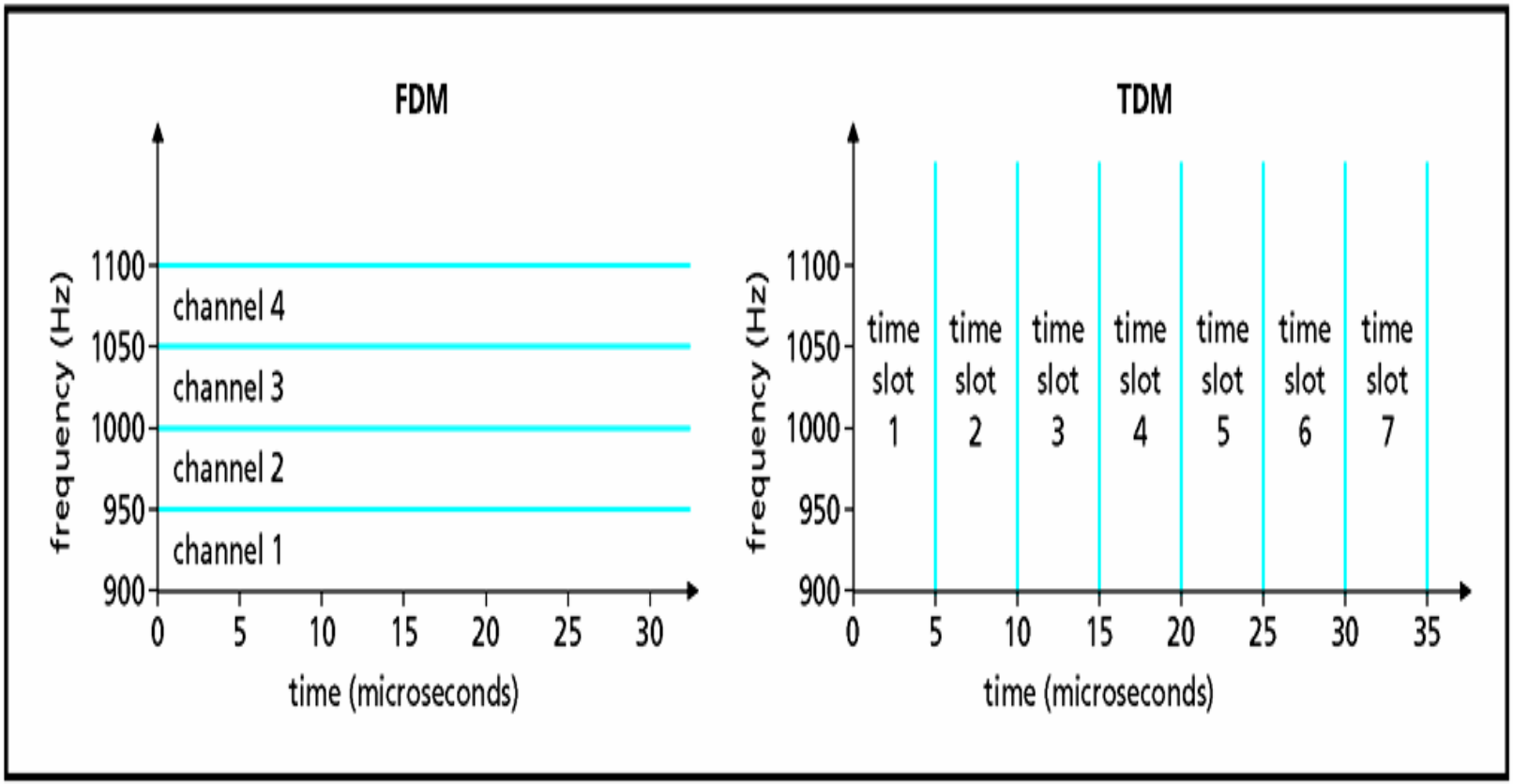
Multiple Access

- FDM (frequency division multiplexing)
  - Divide bandwidth among subscribers
  - Channel sustained for duration of session
  - Wasteful use of resources
- TDM (time division multiplexing)
  - Divide bandwidth based on time
  - Achieve effect speeds greater than FDM

DSL

- DSL (Digital Subscriber Line)
  - Combines FDM and TDM
  - Divide bandwidth into 247 channels
  - Allocate 4 KHz for voice, remainder for data
  - Speeds range from 256 Kbps to 1.5 Mbps
  - Download speeds differ from upload speeds
  - Subscriber located less than 18,000 feet from station

Figure 6-7, FDM and TDM



Cable Modems

- CATV Coax cable carries hundreds of channels
- Channels allocated 6 MHz bandwidth
- Transmit speeds up to 42 MHz
- Connect Ethernet cable to modem
- Use TDM technology to vary upload and download speeds

Satellites

- Satellites
  - Long distance wireless technology
  - Provide high speed access to users in remote locale
  - Dish used to receive television signals adapted for data transmission
  - Becoming an affordable alternative

One Last Thought

- Networks are integral to computers and computing
- Computer scientists extensively interact with networks
- Chapter 6 concepts are foundational

Summary

- Networks link computers around the world
- Networks are extensions of system bus
- Transmission media, set of protocols, and network devices create connectivity
- Metrics for rating media: bandwidth, signal-to-noise ratio, bit error rate, and attenuation
- Transmission media may be guided or unguided

Summary (continued)

- Guided media: copper wire (coax and twisted pair) and fiber-optic cables
- Unguided media: air or space (wireless)
- Protocols: set of rules for communication
- Standards: TCP/IP and seven layered OSI model
- Network Types: LANs, WLANs, WANs, MANs

Summary (continued)

- LAN topologies: ring, star, bus
- LAN technologies: Ethernet, token ring, FDDI, ATM
- Network devices: NIC, repeater, hub, switch, bridge, gateway, router, firewall
- Switched Networks: convert analog to digital using FM, AM, PM, compression, rearranged transitions

Summary (continued)

- DSL: combines FDM and TDM to boost copper wire signals to 1.5 Mbps
- Cable Modems: coax cables transmit at 1.5 to 42 Mbps
- Satellite technologies: long distance wireless