Technology Briefing

Networking
Learning Objectives

1. Describe the evolution of and types of computer networks.
2. Understand networking fundamentals, including network services and transmission media.
3. Describe network software and hardware, including media access control, network topologies, and protocols, as well as connectivity hardware for both local area and wide area networks.
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Evolution of Computer Networking

- Computer networking
  - Sharing of information or services
  - Comparable to human communication
Messages, Senders, and Receivers

• Components of communication:
  o **Senders and receivers** with something to share
  o A **transmission medium** to send the message
  o **Protocols** (rules) dictating communication
Coding, Sending, Decoding

1. Coding Your Message
2. Sending Your Message
3. Decoding and Receiving Message

Is this English? I speak only French.
Computer Networks

• Computer communication
  o Bits are sent
  o Any type of information can be transmitted
    • Documents, art, music, film, information

• Digitizing
  o Conversion of analog into digital information
Bandwidth Requirements

- **Voice**
  - Telephone: 64 KBps
  - Compact Disc: 1.41 MBps

- **Data**
  - Single screen of text: 14.4 KB
  - Publication-quality photograph: 230.4 MB

- **Video**
  - Video telephony: 9.3 MBps
  - HDTV: 1.33 GBps
Centralized Computing

• 1940s – 1970s (mainframe era)

• Central computer (mainframe)
  o Processing and storage of data

• Terminal
  o Local input/output device

• Not a true network – no information sharing
Distributed Computing

- **1980s**
- **Driver:** Introduction of PCs
- **Separate** computers work on subsets of tasks
- **Results are pooled** via network
Collaborative Computing

- 1990s
- Synergistic form of distributed computing
- Two or more computers working on a common processing task
  - Computers collaborate to keep employee records current

Diagram:
1. Computer Requests Record to Change
2. Returns Requested Record
3. Modifies Record
4. Returns Changed Record
5. Stores Changed Record in Database
Collaborative Computing

- Collaborative functionality in IM platforms
- Collaborative components in office automation applications
Computing Networks Today

• All types are still present
  • (centralized, distributed, collaborative)
• Usually combined into a network
  • Networks classified by size, distance covered and structure:
    • Private branch exchange
    • Local area network
    • Wide area network
    • Metropolitan area network
    • Personal area network
Private Branch Exchange

• Telephone system serving a particular location
  o Connects phones and computers
  o Connects PBX to outside network

• Limited bandwidth
Local Area Network

• Spans relatively small area – tens of kilometers
• Computers share:
  o Information
  o Peripheral devices
• Usually one type of cable used
• Wireless Local Area Network (WLAN)
Wide Area Network

• Spans relatively large area
  o Usually connects multiple LANs
  o Different hardware and transmission media used
• Used by multinational companies
• Information transmitted across cities and countries
• 4 specific types of WAN
Global and Enterprise Networks

- **Global networks**
  - Span multiple countries
  - E.g., The Internet

- **Enterprise networks**
  - Connect disparate networks of a single organization
Value-Added and Metropolitan Area Networks

• Value-added networks
  o Medium speed WANs
  o Third party managed
  o Shared by multiple organizations
  o Added value:
    • network management, e-mail, EDI, security

• Metropolitan area networks
  o Limited geographic scope – citywide area
  o Combine LAN and fiber-optic technologies
Personal Area Networks

- Exchange data between computing devices
- Short range radio communication – 10 meters
  - E.g., networking of PCs, peripheral devices, mobile phones, portable stereos, etc.
- Enabling Technology: Bluetooth
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Networking Fundamentals

• Three different roles:
  ○ Servers
  ○ Clients
  ○ Peers
Servers

- Only provide services
- Usually have:
  - More advanced microprocessors
  - More memory
  - Larger cache
- Many users share services
Clients

- Request services
- Workstations or PCs
- Software applications
- Usually one user per client
Peers

- May request and provide services
- Peer-to-peer networks
  - Equivalent capabilities and responsibilities
- Usually found in small offices and homes
- Popular for file sharing
  - E.g., BitTorrent, KaZaA
- Used as distribution channel
  - Warner Brothers
**Network Services**

- **File services**
  - Store, retrieve and move data files

- **Print services**
  - Control and manage access to printers
Network Services (II)

• Message services
  o Store, access and deliver data
  o Communication between users and applications

• Application Services
  o Run software for network clients
  o Enable computers to share processing power
  o Client/server computing
Network Operating System (NOS)

• System software controlling the network
• Enables computers to communicate
• Two parts:
  o Network server
    • Coordinates: user accounts, information access, security, resource sharing
  o Workstation
    • Runs on top of the local OS
    • Sometimes integrated into the OS
• Example: Novell NetWare, Microsoft Windows Server
Transmission Media

- Physical pathways for sending data
- Message sending:
  - Computers send electromagnetic waves
  - Waves altered by semiconductors to become 0s or 1s – known as bits
  - Bits are transmitted
- Two types:
  - Cable media
  - Wireless media
Bandwidth

• Transmission capacity of a computer or a communications channel
• Measured in megabits per second (Mbps)
• Example:
  o IS Today textbook: 2 million characters (16 million bits)
    • 1.6 seconds at 10 Mbps
    • 0.16 seconds at 100 Mbps
    • Nearly 5 minutes using 56 Kbps modem
Attenuation

- Power of an electric signal weakens with distance
- How far can a signal travel with the same properties and meaning?

- Electromagnetic interference (EMI)
  - Interference by fluorescent light, weather or other electronic signals
Cable Media: Twisted Pair Cable

- Two or more insulated pairs of cable
  - Unshielded (UTP)
    - Telephone wire
    - Rated according to quality: Cat 5, Cat 6
    - Cheap and easy to install
    - Up to 1 Gbps at distance up to 100 meters
    - Rapid attenuation – sensitive to EMI and eavesdropping
    - Used in network installations
  - Shielded (STP)
    - Less prone to EMI and eavesdropping
    - More expensive and harder to install
    - 500 Mbps up to 100 meters
    - Used to support networks running at 16 Mbps
Twisted Pair Cable

(a) Several twisted pairs  
(b) Sample network installation
Coaxial Cable

• Components
  o Solid inner copper conductor
  o Plastic insulation
  o Outer braided copper or foil shield

• Variety of thicknesses
  o Thinnet – less costly than TP but not commonly used
  o Thicknet – more costly than TP
    • Used for cable television and networks operating at 10-100 Mbps
Fiber-Optic Cable

• Components:
  o Light-conducting glass or plastic
  o Cladding (glass)
  o Tough outer sheath

• Transmission:
  o Pulses of light
  o Immune to EMI and eavesdropping
  o Low attenuation
  o 100 Mbps to more than 2 Gbps
  o 2 to 25 kilometers
  o Used for high-speed backbones
## Key Benefits and Drawbacks of Different Cable Media

<table>
<thead>
<tr>
<th>Medium</th>
<th>Key Benefit(s)</th>
<th>Drawback(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twisted pair</td>
<td>Inexpensive; easy to install and reconfigure</td>
<td>Highly susceptible to EMI, eavesdropping, and attenuation; unsuitable for high speeds</td>
</tr>
<tr>
<td>Coaxial</td>
<td>Higher bandwidth than twisted pair; lower susceptibility to EMI, eavesdropping, and attenuation than twisted pair</td>
<td>More expensive than twisted pair; more difficult to install, reconfigure, and manage attenuation than twisted pair; bulky</td>
</tr>
<tr>
<td>Fiber optic</td>
<td>Very high bandwidth; low attenuation and immune to EMI and eavesdropping</td>
<td>Expensive cable and hardware; complex installation and maintenance</td>
</tr>
</tbody>
</table>
Wireless Media: Infrared Line of Sight

- High frequency light waves
- Distance of up to 24.4 meters
- Attenuation, EMI and eavesdropping problems
- Relatively inexpensive
- Two types:
  - Point-to-point
    - Strict line of sight
    - Up to 16 Mbps at 1 meter
    - E.g., TV remote
  - Broadcast
    - Devices don’t need to be directly in front of each other
    - Less than 1 Mbps
Wireless Media: High Frequency Radio

- Ideal for mobile transmission
- Expensive due to cost of antenna towers
- Complex installation
- Susceptible to EMI and eavesdropping
- Attenuation not a problem
- Distance between nodes 12.2 – 40 kilometers
- Rate up to several hundred Mbps
- E.g., cellular phones and wireless networks
Cellular Network

- Coverage area divided into cells
  - Low-powered radio antenna/receiver
  - Cells controlled by a central computer

- Unique frequency assigned for duration of phone call

- Mostly digital today
  - Less static
  - Data transmission capability
  - Wider reception range
WLANs or Wi-Fi

- 802.11 family of standards
- Transmission speed up to 540 Mbps (802.11n)
- Easy installation
- Connection of computers within a building/home

Boeing wireless classroom at Washington State University
Wireless Media: Microwave

- High frequency radio
  - Terrestrial microwave
    - Line-of-sight
    - Transmission up to 274 Mbps
    - EMI and eavesdropping problems
    - Cross inaccessible terrain
    - Cost depends on distance
    - Alternative when cabling too expensive
Microwave (II): Satellite Microwave

• Relay station transfers signals between antennae on earth and satellites in the orbit
  o Propagation delay
  o Satellites orbit 400-22,300 miles above earth
  o Typically 1-10 Mbps, up to 90 Mbps
  o Prone to attenuation
  o Susceptible to EMI and eavesdropping
Microwave (III): Satellite Microwave

- GPS (Global Positioning System)
  - 24 satellites
  - Receivers pick up signals from at least 4 satellites
  - GPS receivers triangulate position using time stamps
  - Accuracy: 10 square centimeters
## Wireless Media

### Key Benefits and Drawbacks of Different Wireless Media

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<tr>
<td>Infrared line of sight</td>
<td>Easy to install and configure; inexpensive</td>
<td>Very limited bandwidth; line of sight required; environmental factors influence signal quality</td>
</tr>
<tr>
<td>High-frequency radio</td>
<td>Mobile stations; low attenuation</td>
<td>Frequency licensing; complex installation</td>
</tr>
<tr>
<td>Terrestrial microwave</td>
<td>Can access remote locations or congested areas; high bandwidth; low attenuation</td>
<td>Frequency licensing; complex installation; environmental factors influence signal quality</td>
</tr>
<tr>
<td>Satellite microwave</td>
<td>Can access remote locations; high bandwidth; earth stations can be fixed or mobile</td>
<td>Frequency licensing; complex installation; environmental factors influence signal quality; propagation delays</td>
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Network Software and Hardware

- Standards ensure interpretability and compatibility of network devices
- Established by IEEE
- Three major standards for LANs

<table>
<thead>
<tr>
<th>Network Standards</th>
<th>Access Control</th>
<th>Topology</th>
<th>Typical Media</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethernet</td>
<td>CSMA/CD</td>
<td>Bus</td>
<td>Coax or twisted pair</td>
<td>10 Mbps–1 Gbps</td>
</tr>
<tr>
<td>Token ring</td>
<td>Token passing</td>
<td>Ring</td>
<td>Twisted pair</td>
<td>4–100 Mbps</td>
</tr>
<tr>
<td>ARCnet</td>
<td>Token passing</td>
<td>Star or bus</td>
<td>Coax or twisted pair</td>
<td>2.5–20 Mbps</td>
</tr>
</tbody>
</table>

- Software blended with hardware to implement protocols
Media Access Control

• Problem: Collision occurs when 2 workstations transmit data simultaneously

• Media Access Control: Set of rules that govern access

• Types of Media Access Control:
  - Distributed
    - 1 workstation at a time with access
    - Authorization transferred sequentially
  - Random access
    - Any workstation can transmit if medium is available
    - No permission required
Distributed Access Control

- Token passing most common
  - Uses electronic token – small packet of data
  - Only computers possessing token can send – avoids collisions
Random Access Control

• **CSMA/CD - Carrier Sense Multiple Access/Collision Detect**
  - Most commonly used method of random access
    1. Workstation listens
    2. If network is quiet, workstation transmits
    3. Message sent to all workstations on the network
    4. Destination with proper address opens the message

• Collisions more likely under heavy traffic
Network Topologies: Star

- All workstations connected to a central hub
- Active hubs amplify transmission
- Easy to lay out and modify
- Most costly (cabling)
- Failure of hub can cause network failure
Network Topologies: Ring

- Messages move in one direction around the circle
- Covers large distances
- Relatively little cabling
- Failure of one node can cause network failure
  - Self-healing ring
- Difficult to modify
- Token passing used
Network Topologies: Bus

- Open-ended line
- Easiest to extend
- Simplest wiring layout
- All nodes can receive the same message at the same time
- Difficult to diagnose network faults
- Uses CSMA/CD
Network Topologies: Mesh

- Devices fully or partially connected to each other
  - Full mesh
  - Partial mesh
- Short routes between nodes
- Many possible routes
- Performs well in heavy traffic
- Most WANs use partial mesh
Protocols

• Rules or procedures used to transmit and receive data

• Specify:
  o Connection of computers to the network
  o Error checking
  o Data compression
  o Signal of finished transmission
  o Signal of received message

• There are thousands of protocols:
  o TCP, IP, UDP, IPX, SPX, etc.
The OSI Model

- Open System Interconnection (OSI)
- 7 layers

The OSI Model is a framework for describing how data flows between systems on a network. It consists of seven layers, each responsible for a specific aspect of network communication.

1. Physical Layer:
   - Validates the integrity of the flow of data.
   - Defines the mechanism for communicating with the transmission media and interface hardware.

2. Data Link Layer:
   - Defines the protocols for data routing to ensure that information arrives at the correct destination.

3. Network Layer:
   - Defines the protocols for data routing and addressing.

4. Transport Layer:
   - Defines the protocols for data transmission over a network.

5. Session Layer:
   - Coordinates communications and maintains the session for as long as needed—including security and log-on functions.

6. Presentation Layer:
   - Defines the way that application programs such as electronic mail interact with the network.

7. Application Layer:
   - Defines the way data is formatted, converted, and encoded.
OSI Model: Message Transmission
The Ethernet

- LAN protocol developed by Xerox in 1976
- Bus network topology
- Random access control
- Originally: 10 Mbps
- Later: 100Base-T (Fast Internet) – 100 Mbps
- Latest: Gigabit Ethernet – 1,000 Mbps
TCP/IP

• Defined by Vinton Cerf and Robert Kahn
• Protocol of the Internet
• Interconnected networks can communicate
• Allows different platforms to communicate
Connectivity Hardware

• Connectors
  o Used to terminate a cable
    • T-connectors (coaxial cable)
    • RJ-45 connectors (twisted pair cable)

• Network interface cards
  o PC expansion board
  o Allows computer to be connected to a network
  o Each NIC has a unique identifier
Modems

- Enable transmission over telephone lines
- Digital signal converted to analog
Networking Hardware (I)

- Repeaters – replicate signal
- Hubs – central point of connection
- Bridges – connect two different LANs
- Multiplexers – used when communication line is shared
Networking Hardware (II)

- Routers – connect 2 or more individual networks

- Brouters – capabilities of bridge and router

- Channel service unit – buffer between LAN and public carrier’s WAN

- Gateway – performs protocol conversion