C H A P T E R

6   Telecommunications and Networks
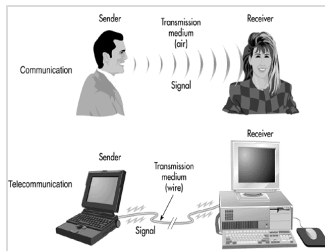

Communications

- The transmission of a signal by way of a medium from a sender to a receiver.

Telecommunications

- The <u>electronic</u> transmission of signals for communications, including such means as:
  - Telephone
  - Radio
  - Television
  - Computer Network

Benefits of Telecommunications

- Better Communication
  - E-mail, voice mail, faxes, teleconferencing
- Greater Efficiency
  - Workflow, concurrent access
- Better Access to Data
  - File transfer, distributed databases

Modes of Data Transfer

- Parallel
  - More than one bit at the same time
  - Printers, Processors, Motherboards
- Serial
  - One bit at a time
  - Slower, but longer distances

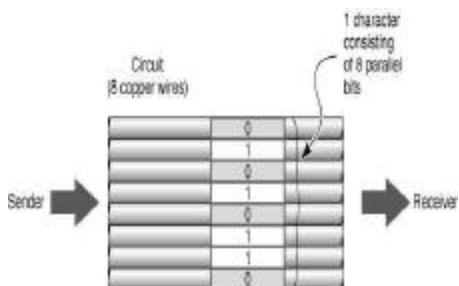# Parallel Transmission

Serial Transmission
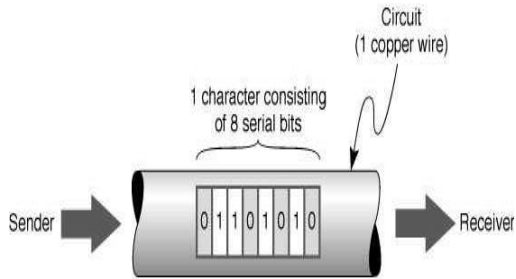
Modes of Data Transfer

- Simplex
  - One-way transmission
- Half-Duplex
  - One-way at a time
- Full-Duplex
  - Two-way transmission

The Concept of Networking

- Computers connected to each other so they can share data
- Before Networking: SneakerNet
  - Copy information to a floppy disk and pass it to anyone who needs it
  - Risks?

Why Network

- File Management
  - Sharing, transferring
- Application Sharing
- Device Sharing
  - Printers, Storage Devices, Modems
- Workgroup Activities
  - Scheduling, e-mail, conferencing

A Computer Network

- Hardware
  - Modems, servers, routers, NICs
- Software
  - Network operating systems
  - Communications software
- Communication Channels
  - Cabling, microwave, etc.

Networking

- Local Area Network (LAN)
  - A group of computers (physically) connected together within a certain area
- Wide Area Network (WAN)
  - A network that extends over a larger area, such as a city block or a country

Categories of Networks

- Peer-to-Peer (workgroups)
  - Typically <10 people
  - No central communication control device
  - Each computer acts as client and server
  - Inexpensive
  - Limited security
  - Uses each PC's resources
  - Windows, Windows NT/2000

Categories of Networks

- Server-based
  - Dedicated servers
    - File, application, mail, fax, communication
  - Centralized, shared resources
  - Security
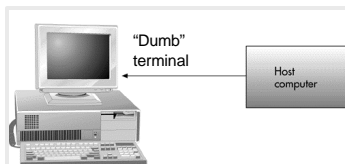 - Backup
  - Thousands of users

Terminal-to-Host

"Dumb" terminal

Host computer

- Applications and databases reside on the host computer (server).
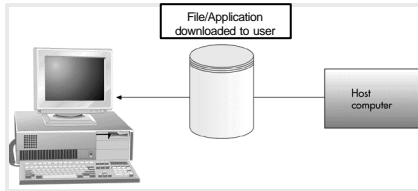- User interacts with the application using a terminal with no processing power.

29

File/Application Server

File/Application downloaded to user

Host computer

- Databases (and applications) reside on the host computer (server).
- File server transfers data (and programs) to PCs on the network, where these "fat" PCs perform most of the processing.

30

Client/Server
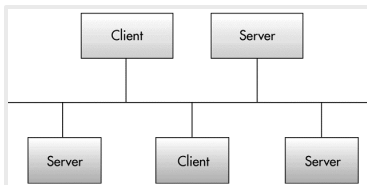

Client   Server

Server   Client   Server

- Applications and databases reside on specialized servers.
- Servers do most or all of the processing and transmit the results to the "thin" clients.

31

Client/Server

- The client makes a request and the server fulfills it…
  - The client application (front-end) requests data
  - The request is sent over the network
  - The server (back-end) processes the request
  - Only the requested information is returned to the client
  - The data is presented to the user
- Improved Performance
  - Minimizes network traffic – only the information needed is transmitted

Network Terminology

- Workstation
  - Each computer attached to the network
- Node
  - Each device attached to the network (each has a unique hexadecimal MAC - Media Access Control – address e.g. 08:00:69:02:01:FC)
- Server
  - A central repository for information
- Topology
  - The overall configuration of the network

Network Topology

- Connecting every node to every other node would require N x (N-1)/2 cables

- Network Topology
  - A logical model that describes how networks are structured or configured.
    - Bus
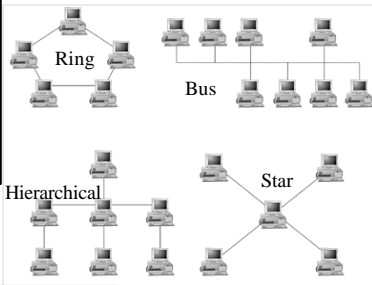   - Star   …or combinations
    - Ring

24

Network Topologies

Ring
A typology that contains computers and computer devices placed in a ring.

Ring

Bus

Hierarchical

Star

Bus
Computers and computer devices are on a single line. Each device can communicate directly to all devices on the bus.

Star
All computers are connected via a central hub.

Hierarchical
A typology arranged in a tree-like structure.

The Role of Network Communications Software

- Sending data from one node to another
  - Recognize the data
  - Divide the data into manageable chunks
  - Add information to each chunk of data to identify the receiver
  - Add timing and error checking information
  - Put the data on the network and send it on its way

The OSI Model
(Open Systems Interconnection)

- Describes how network hardware and software work together in a layered fashion
  - Each layer provides some service or action that prepares the data for delivery over the network
  - Requests are passed from one layer to the next
  - Each layer adds information to the data packet

The OSI Layers

7) Application – Provides application with access to the network

6) Presentation – Determines format used to exchange data among networked computers

5) Session – Allows two applications to establish a connection (name recognition, security)

4) Transport – Ensures data is error free. Repackages long messages.

3) Network – Addresses messages to proper location. Translates logical addresses into physical addresses and determines path.

2) Data Link – Packages and un-packages data packets

1) Physical – Transmits bits over physical devices

Mail Delivery Analogy
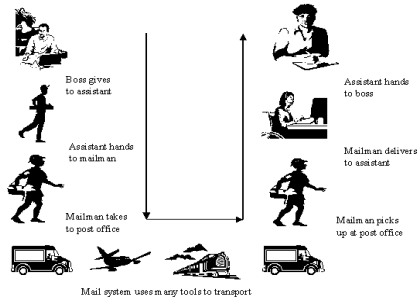
Boss gives to assistant

Assistant hands to boss

Assistant hands to mailman

Mailman delivers to assistant

Mailman takes to post office

Mailman picks up at post office

Mail system uses many tools to transport

Data Packets

- Packets are the basic units of network communications
  - Each packet has three sections:
    - Header:
      - An alert signal
      - Source & destination addresses
      - Clock information
    - Data
    - Trailer – Error checking information

Protocols

- From the Greek *protocollon*, which was a leaf of paper glued to a manuscript volume, describing its contents
- The special set of rules that nodes in a telecommunication connection use when they communicate.
- Protocols exist at several OSI levels in a telecommunication connection.
- Both nodes must recognize and observe a protocol.

Protocols

- Rules & procedures for communicating
  - Sending Computer
    - Breaks the data into packets
    - Adds addressing information
    - Prepares the data for transmission
  - Receiving Computer
    - Takes packets off the cable
    - Strips the packets of addressing information
    - Reassembles the data form the packets

Protocols

- For two computers to communicate, they must be using the same set of protocols (rules)
- Examples of protocols
  - SMTP – Mail transfer protocol
  - FTP – File transfer protocol
  - TCP/IP – Internet protocol
  - IPX/SPX – Novell protocol
  - Ethernet – Physical layer protocol

Traffic Control

- If two computers put data onto the cable at the same time, the packets will collide and be destroyed
- There must be a way to…
  - Access the cable without running into other data
  - Be accessed by the receiving computer with assurance that it is intact

Access Methods

- Carrier-Sense Multiple Access
  - Each node checks the cable for traffic before sending
  - No node can transmit data until the cable is free (no contention)
  - If two computers transmit at the same time, they detect the collision and wait a random time to re-transmit
- Token Passing

Communication Media/Channels

- Cabling
- Microwave/Satellite
- Cellular
- Infrared
- Telephone Lines

Cabling Considerations

- Cost
- Ease of Installation & Maintenance
- Reliability
- Speed
- Distance

Distance Considerations

- Attenuation
  - Loss of signal quality & strength
  - Repeaters can extend the distance
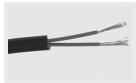- Packet Collisions
- Susceptibility to RF Noise

Types of Cabling

- Twisted Pair Wire Cable
  - Insulated pairs of wires historically used in telephone service
    - Category 1 – Telephones
    - Category 3 – Up to 10Mbps
    - Category 5 – Up to 100Mbps

Twisted Pair Details

- RF Noise
  - Twisting cancels out electrical noise
  - Shielded is less susceptible
- Crosstalk
- 10Base-T
- Maximum segment ~100 meters
- RJ-45 connectors

Types of Cabling

- Coaxial Cable (BNC)
  - Consists of an inner conductor wire surrounded by insulation, called the dielectric. The dielectric is surrounded by a conductive shield, which is surrounded by a non-conductive jacket. Coaxial cable has better data transmission rate than twisted pair

Coax Details

- More resistant to interference and attenuation than TP
- Supports longer distance and faster rates
- BNC or RG6 connectors

Types of Cabling

- Fiber-optic Cable
  - Many extremely thin fibers of glass or plastic coated with a cladding and bound together in a sheathing which transmits signals with light beams.
    - Fast transfer rates
    - Immune to electrical interference (long distances)
    - Hard to tap into
    - Takes less space

Wireless Networks

- Microwave
  - Terrestrial
  - Satellite
- Cellular
- Infrared
  - Line-of-sight

Channels and Media

Medium	Capacity	Vulnerability to electromagnetic interference	Cost	Guided/ Unguided	Availability
Twisted Pair	Lower	High	Lower	Guided	Everywhere
Coaxial Cable	↑	Low	↑	Guided	Low
Microwave	↓	Low	↓	Unguided	High
Optical Fiber	Higher	Nonexistent	Higher	Guided	Most of U.S. and parts of

Data Communications Over Telephone Lines

- Computers generate a digital signal

- Phone circuits were designed to accommodate an analog signal

Analog Signals

- Signals of varying frequency (pitch) and amplitude (loudness)
  - Continuous (infinite number of values)
  - "Analogous" to the original data
    - e.g. phone lines carry electronic signals analogous to the original voices
  - Must be amplified (repeated)
  - Signal picks up (and amplifies) noise
    - Cannot differentiate between signal and noise

Digital Signals

- Signals with only two possible values
  - Discrete (fixed number of values)
  - Repeaters can clean up noise
    - Expects only "0" or "1"
- Telephones
  - Use analog over "local loop" to local phone office
  - Converted to digital for longer distances
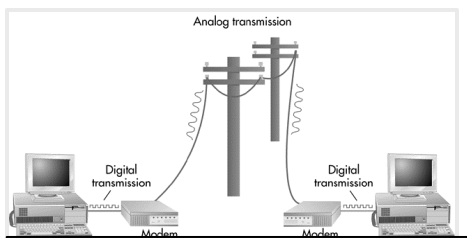   - Analog wave is converted to discrete digital signals

What a Modem Does

Modem
Modulates a digital signal into an analog signal for transmission via analog medium, then demodulates the signal into digital for receiving.

Modulation

- Converts digital signals into analog signals
  - Frequency Modulation – Vary the frequency (pitch) to express a "1" or "0"
  - Amplitude Modulation – Vary the amplitude (volume) to express a "1" or "0"
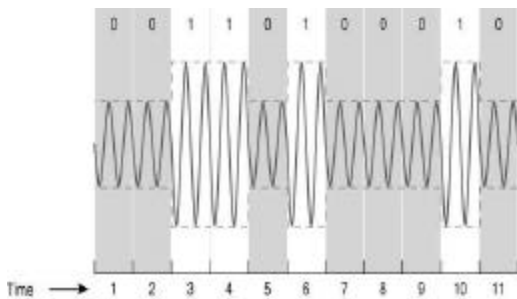- Demodulation converts them back

Amplitude Modulation

Frequency Modulation
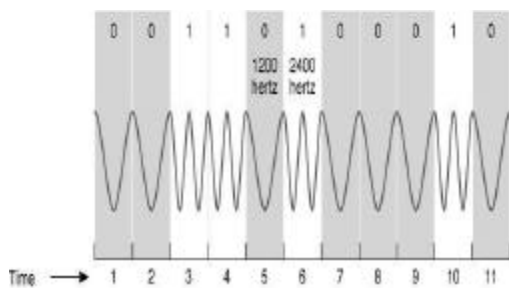
Synchronization

- How do analog noises get divided up into bits?
  - Asynchronous Communications
    - Sends stop bit (1) after 7-8 bits per character
    - Sends start bit (0) to indicate next character
  - Synchronous Communications
    - Splits the channel into two channels
    - Uses the second channel to send a clock

Error Detection

- Redundancy
  - Send everything twice
- Parity
  - 8th bit makes parity even or odd
- Longitudinal Redundancy Check (LRC)
  - Checks parity vertically & horizontally per block
- Checksum
  - Checks the last 7 digits of the sum of a block

Error Correction

- Automatic Repeat Request (ARQ)
  - Sender sends a block
  - Receiver ACKnowledges or…
  - Receiver sends a Negative Acknowledgement (NAK)
- Full Duplex
  - Sender keeps sending numbered blocks while awaiting acknowledgements

Finding a Path

- Circuit Switching
  - A dedicated channel (circuit) is established for the duration of the transmission (e.g. a phone call)
- Packet Switching
  - A message is divided into packets and each may take a different path (e.g. TCP/IP)
- Dedicated Lines

Multiplexing

- Sharing Channels
  - Phone conversation has 4Khz bandwidth
  - Copper wire pair has 3Mhz bandwidth
- Allows multiple TV signals on coax
- Frequency Division Multiplexing
- Time -Division Multiplexing

Multiplexer (mux)
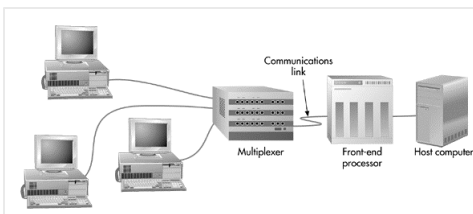

Multiplexer
Allows several telecommunications signals to be transmitted over a single communications medium at the same time.

Carriers and Services

- Plain Old Telephone Service (POTS)
  - 56Kbps
- Integrated Services Digital Network (ISDN)
  - 128Kbps
- Digital Subscriber Line (DSL)
  - 1,544Kbps
- Cable Modem
  - Receive 256K-36Mbps; send at 64K-2Mbps
- T-1
  - 1,544Kbps (or multiples/fractions thereof)

Network Management

- Network Monitors
  - Keep track of network traffic, number of packets, packet size, collisions, re-transmissions, etc.
  - Enables planning
- Network Analyzers
  - Randomly dissects packets, analyzes problems, and determines the source

Networks and Distributed Processing

- Centralized Processing
  - Data processing that occurs in a single location or facility.
- Decentralized Processing
  - Data processing that occurs when devices are placed at various remote locations.
- Distributed Processing
  - Data processing that occurs when computers are placed at remote locations but are connected to each other via telecommunications devices.

23

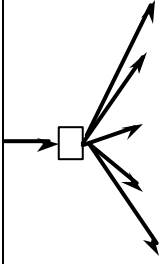## Bridges, Routers, Gateways and Switches

- Repeaters
  - Repeat transmission signals, allowing a cabled network to extend farther than it ordinarily would
- Bridges
  - Connects two or more networks, with the same or different protocols. Can also solve traffic problems by splitting a network into two segments.
- Routers
  - Feature more sophisticated addressing software than bridges. Can determine preferred paths, translating only those packets that need to be routed.
- Gateways
  - Devices that monitors/controls entry to another network
- Switches/Hubs
  - Points of convergence where data arrives from one or more directions and is forwarded out in one or more other directions