Chapter 7: Network Concepts and Communications

Going online to do everything from banking to buying groceries, just a fad or is it here to stay?

7-1

Network Concepts and Communication

- In this lecture:
  - What can be done online?
  - How are computers connected?
  - What are the physical properties of networks?
  - How does a computer communicate with a network?
  - Can all computers talk to each other?
  - How does TCP/IP work?

7-2

Introduction: "Everything is Connected to Everything"

- Going online: Connecting to a collection of interconnected computers on a network.
  - Do banking.
  - Pay bills.
  - Buy groceries.
  - Book vacation travel.
  - Send messages.
  - Participate in discussions.
  - Do research.
  - Play games.
- **Network**: A collection of computers, display terminals, printers, and other devices linked either by physical or wireless means.

7-3

Introduction: "Everything is Connected to Everything"

- Seeds of Networking
  - 1966: ARPA (Advanced Research Projects Agency) State Defense Department's research organization.
    - Focused major development effort on computer networking.
    - ARPA's Goal: To promote research in advanced future technologies by funding university and industry research proposals.
      - Distributed communication system
      - Enable research communication
      - Enable dissimilar computers to share information
      - Reroute information automatically
      - Act as a network of networks; internetworking
  - Result: Thousands of databases became available to the public.

7-4

The Internet: Struggling to Maturity

- ARPA intended to sell off the ARPAnet to an academic or corporate consortium.
  - Before the sale, federal rules required the Defense Department to determine if ARPAnet was needed for national defense.
  - ARPAnet was transferred to the Defense Communications Agency in 1975.
  - Only about 15 universities were given access to the network.
- 1980: National Science Foundation started CSnet
  - Purpose: To provide a resource-sharing network opportunity to computer science research at all universities.
  - Used TCP/IP protocol.

7-5

The Internet: Struggling to Maturity

- CSnet fueled interest in creating a more comprehensive network to link all scientific communities (not just CS)
  - NSF couldn't fund such an expensive project.
    - Backbone: NSF built a very fast connection between 5 supercomputing centers linking them all together.
    - Each region surrounding each center would develop its own community network.
    - NSF allowed the regional community networks exclusive use of the backbone.

7-6

The Internet: Struggling to Maturity

- 1983: ARPAnet split.
  - Converted from Network protocol to TCP/IP protocol.
  - Part remained ARPAnet: universities, research institutes.
  - Part became Milnet: non-classified military information.
  - By 1989, ARPAnet was costing $14 million per year to keep up and running.
- 1989: majority of ARPAnet switched to NSF's backbone.
  - ARPAnet sites were connected to the NSF backbone through the regional community networks.
- NSFnet became what is known as the **Internet**.
- Early 1995: "Information Superhighway."

7-7

Introduction: "Everything is Connected to Everything"

- Computer Networking
  - **Internet**: A world-wide network connecting millions of computer networks for the purpose of exchanging data and communications using special rules of communication.
  - **internet**: (lower case i) Any network connecting two or more computer networks.
- The World Wide Web <> the Internet
  - WWW exists on the Internet
  - Internet includes the basic technology of interconnecting networks, WWW is an application on the Internet
    - Just like telnet, ssh, ftp, etc.

7-8

Communication Basics of Networks

- Types of connections of computers into networks: Physical versus Wireless connections
  - The first type: The Physical Connection.
    - Physically connect computers together.
      - Use of wires or optical cables.
      - The connections are called network links.
    - Three most common physical links:
      - Twisted pair
      - Coaxial cable
      - Fiber-optic cable

7-9

Communication Basics of Networks

- **Twisted pair**
  - Two wires twisted together.
    - Makes them less susceptible to acting like an antenna and picking up radio frequency information or appliance noise.
    - Cat1 to Cat5e
    - Shielded, Unshielded, use RJ-45 connector
      - 10BaseT or 100BaseT network
  - Telephone company uses twisted-pair copper wires to link telephones.

7-10

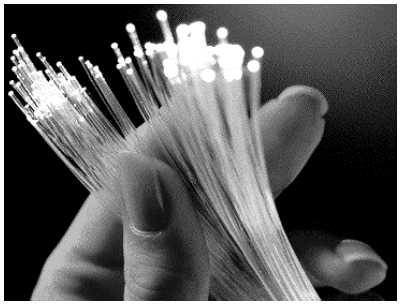
Communication Basics of Networks

- **Coaxial cable**
  - Also two wires:
    - One of the wires is woven of fine strands of copper forming a tube.
    - The wire mesh surrounds a solid copper wire that runs down the center.
    - Space between has a non-conducting material.
    - Makes them more impervious to outside noise.
  - Uses BNC connector, 10Base2 or 10Base5

7-11

Communication Basics of Networks

- **Fiber-optic cable**
  - Light is electromagnetic.
  - Can transmit more information down a single strand.
    - It can send a wider set of frequencies.
  - Each cable can send several thousand phone conversations or computer communications.
  - Single Mode, Multimode, Step Index Multimode



7-12

Communication Basics of Networks

- Second type of connections of computers into networks: Wireless connections
  - The link is made using electromagnetic energy that goes through space instead of along wires or cables.
  - Three types of wireless communications commonly used in networking:
    - Infrared
    - Radio frequency
    - Microwave

7-13

Communication Basics of Networks

- **Infrared**
  - Commonly used in TV and VCR remote controls.
  - Use infrared frequencies of electromagnetic radiation that behave much like visible light.
  - Must be in the line of sight.
  - Often used to connect keyboards, mice, and printers.
  - Relatively slow due to protocol

7-14

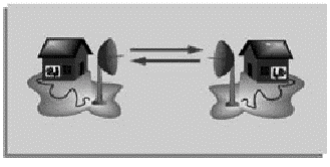
Communication Basics of Networks

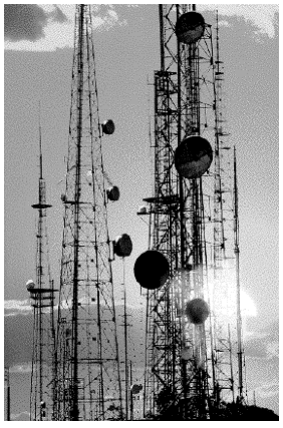
- **Radio frequency**
  - Uses radio frequencies.
    - Function even though line of sight is interrupted.
  - Book says: Not commonly used because of the possible interference from other sources of electromagnetic radiation such as old electric drills and furnace motors.
  - Not anymore! RF becoming very popular
    - Wireless networking is becoming a huge market
    - New standards, 802.11
    - 2.4Ghz unlicensed ISM band
    - Range of typically ~300 feet
    - Security concerns

7-15

Communication Basics of Networks

- **Microwave**
  - Often used to communicate with distant locations.
  - Must be line of sight.
  - Satellite communications use microwaves.
    - ~22,000 mile orbit





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Communication Basics of Networks

- Properties of Transmission

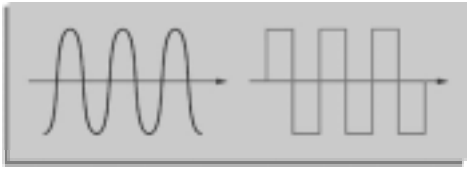
  Five basic properties of both the physical and wireless links:

  1. Type of signal communicated (analog or digital).
  2. The speed at which the signal is transmitted (how fast the data travels).
  3. The type of data movement allowed on the channel (one-way, two-way taking turns, two-way simultaneously).
  4. The method used to transport the data (asynchronous or synchronous transmission).
  5. Single channel (baseband) and multichannel (broadband) transmission.

7-17

Communication Basics of Networks

1. Type of signal communicated (analog or digital).
   - **Analog:** Those signals that vary with smooth continuous changes.
     - A continuously changing signal similar to that found on the speaker wires of a high-fidelity stereo system.
   - **Digital:** Those signals that vary in steps or jumps from value to value. They are usually in the form of pulses of electrical energy (represent 0s or 1s).



7-18

Communication Basics of Networks

2. The speed at which the signal is transmitted (how fast the data travels).
   - In digital systems: Speed is measured in...
     - **Bits per second** (bps).
       - The number of bits (0's and 1's) that travel down the channel per second.
     - **Baud rate**
       - The number of bits that travel down the channel in a given interval.
       - The number is given in signal changes per second, not necessarily bits per second.

7-19

Communication Basics of Networks

- **MODEM** - MOdulator DEModulator
  - Outgoing: Converts binary data from computer (digital) into telephone compatible signals (analog).
  - Incoming: Converts telephone signal (analog) into binary data for the computer (digital).
  - Can be an external or internal device (usually a "card").

7-20

Communication Basics of Networks

- Speed of Signal: Sample bps and baud rate speeds.

300 bps	(=300 baud)	Painfully slow to the college-level reader
1200 bps	(=1200 baud)	Good reader can keep up
2400 bps	(=2400 baud)	A speed reader would get the general idea
9600 bps	(=9600 baud)	Impossible to read
14.4 K bps	(not measured in baud)	14,400 bps - 10 to 20 sec. wait for graphics
28.8 K bps		Minimum desired for WWW (5 to 10 sec. wait for graphics)
56 K bps		Efficient speed for WWW.

These speeds are restricted to the maximum speed of the modem at the other end of the connection.

7-21

Communication Basics of Networks

3. The type of data movement allowed on the channel.
   - **Simplex** transmission - One way transmission.
   - **Half-duplex** transmission - Flows only one way at a time.
   - **Full-duplex** transmission - Two-way transmission at the same time.

7-22

Communication Basics of Networks

4. The method used to transport the data.
   - Two types of data transmission, each requiring a different device to interface with the network.
   - **Asynchronous transmission** -
     - Information is sent byte by byte.
     - Cheaper and more commonly used mdem
   - **Synchronous transmission** -
     - Data is sent in large blocks rather than in small pieces.
     - Preceded by special information, concerning error detection and block size.
     - Network interface card (NIC)

7-23

Communication Basics of Networks

5. Multiplexing - Single channel versus multichannel transmission
   - **Channel** - A path of a signal.
   - **Single channel** - Capable of only sending/receiving one signal at a time.
     - Phone line: Single line = single phone call at a time.
   - **Multichannel** - Capable of more than one channel at a time.
     - Fiber-optic cable, microwaves, Satellite transmissions.
     - Multichannel transmission could typically be used instead as one single channel medium with capacity equal to the sum of the individual channels
       - Need to figure out optimal way to split up the channel

7-24

Communication Basics of Networks

- How is it possible to measure the capacity of communications links?
  - **Bandwidth**: Digital
    - Number of bits per second (bps) that can be sent over a link.
    - The wider the bandwidth, the more diverse kinds of information can be sent.
    - Simplest is voice, most sophisticated is moving videos.
  - **Bandwidth**: Analog
    - The difference between the highest and lowest frequencies that can be sent over an analog link (like phone lines).
    - Measurement is given in cycles per second, or hertz (Hz).
  - For both: The wider the bandwidth, the more information can flow over the channel.

7-25

Communication Basics of Networks

Typical cable bandwidths used in local area networks.

Cable:	Typical Bandwidth:
Twisted Pair	10 to 100 Mbps
Coaxial Cable	10 to 100 Mbps
Fiber-optic cable	100 to 200 Mbps

The bandwidths of different services offered by a telephone company:

Service:	Bandwidth
ISDN	64 Kbps/channel
T1	1.544 Mbps
T3	44.736 Mbps
STS-1	51.840 Mbps
STS-3	155.250 Mbps
STS-12	622.080 Mbps
STS-24	1.244160 Gbps
STS-48	2.488320 Gbps

Mbps = megabytes per sec. (millions) Gbps=Gigabytes per sec. (billions)

7-26

The Physical Organization of Networks

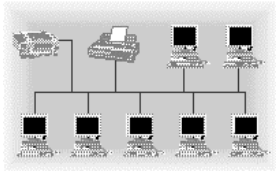
- Node: The generic name given to all devices hooked up to a network.
  - Each node must have a unique address assigned to them by the network.
  - Networks are either direct-connected or those that are not directly linked.
    - **Direct-connected network**: Those whose nodes have direct connections through either physical or wireless links.
      - **Point-to-point**: Simplest version of direct-connected network. Connecting two computing systems.
        - » Example of point to point: Home to ISP.
    - Example of a network that is not directly linked: Internet.

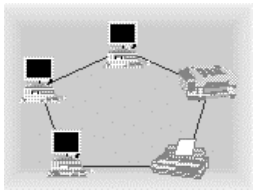
7-27

The Physical Organization of Networks

- The **bus network** -
  - A continuous coaxial cable to which all the devices are attached.
  - All nodes can detect all messages sent along the bus.
- The **ring network** -
  - Nodes linked together to form a circle.
  - A message sent out from one node is passed along to each node in between until the target node receives the message.

Linking nodes:





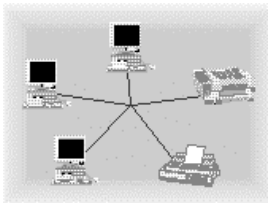
Both of these topologies are uncommon today

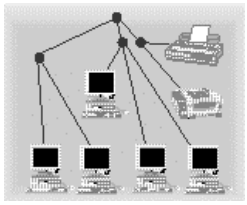
7-28

The Physical Organization of Networks

- The **star network** -
  - Each node is linked to a central node.
  - All messages are routed through the central node, who delivers it to the proper node.
  - Most common today
- The **tree network** - (**hierarchical network**)
  - Looks like an upside-down tree where end nodes are linked to interior nodes that allow linking through to another end node.

Linking nodes:



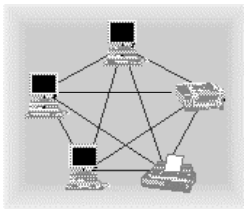


7-29

The Physical Organization of Networks

- The **fully connected network** -
  - All nodes are connected to all other nodes.
  - Typically too expensive to implement, need n(n-1)/2 connections for n nodes
- **Internetworking** -
  - Connecting together any number of direct-connected networks.
  - The largest: Internet.

Linking nodes:



7-30

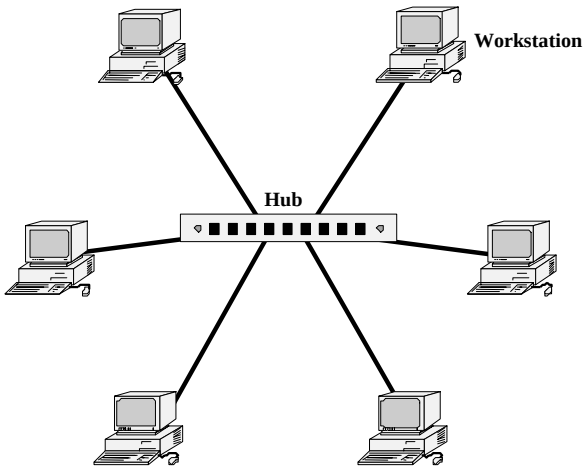
Hardware Architecture of Networks

- Types of hardware used to create networks:

Hub	A device that repeats or broadcasts the network stream of information to individual nodes (usually personal computers)
Switch	A device that receives packets from its input link, and then sorts them and transmits them over the proper link that connects to the node addressed.
Bridge	Transparently links two local networks that have identical rules of communication.
Gateway	A link between two different networks that have different rules of communication.
Router	A node that sends network packets in one of many possible directions to get them to their destination.

7-31

Star Network via Hub



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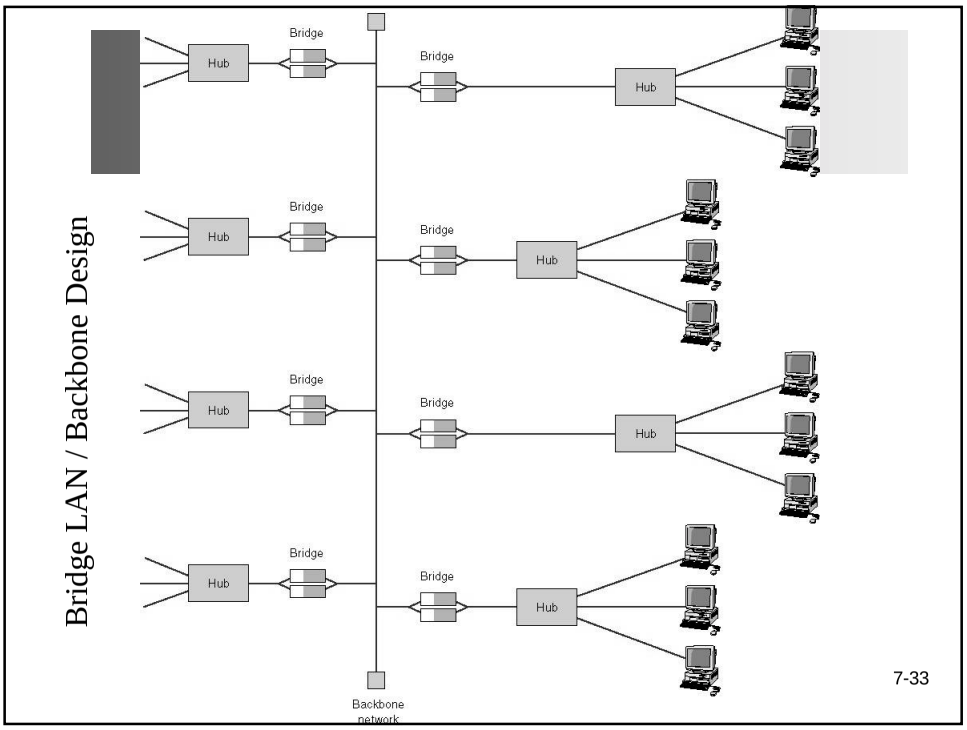
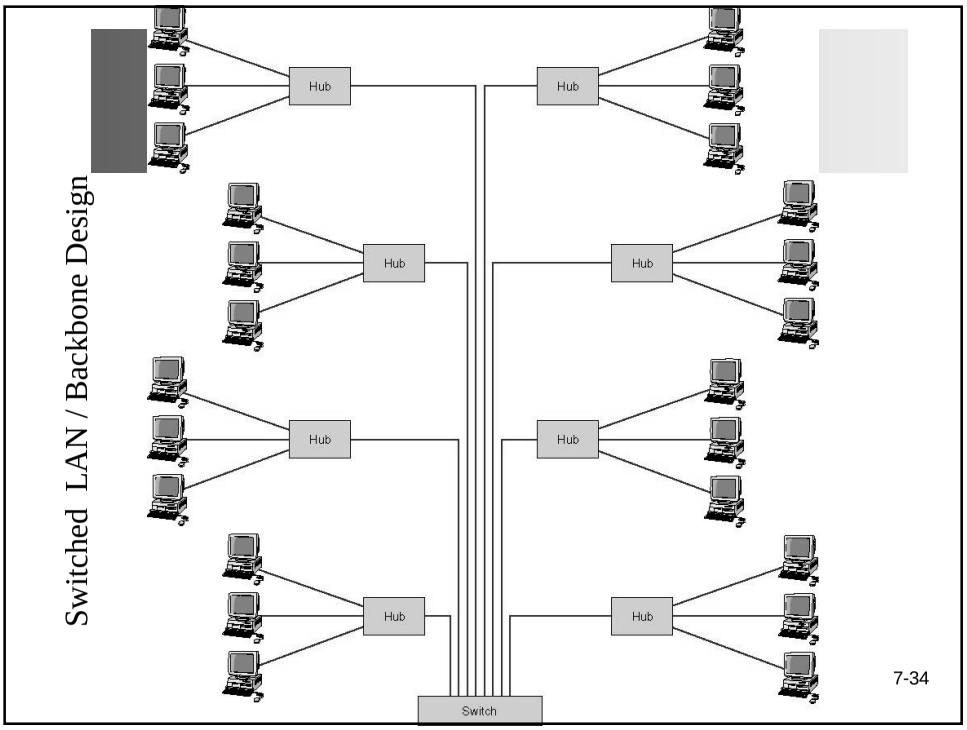
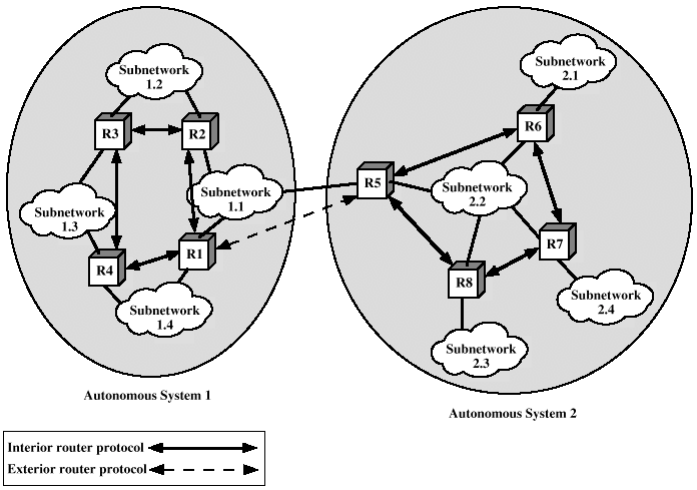

Bridge LAN / Backbone Design
Hub
Bridge
Backbone network
7-33


Switched LAN / Backbone Design
Hub
Switch
7-34

Routers – Connect Networks



7-35

The Physical Organization of Networks

- Categorizing networks according to size:
  - **DAN** (Desk Area Network)
  - **LAN** (Local Area Network)
  - **MAN** (Metropolitan Area Network)
  - **WAN** (Wide Area Network)

7-36

The Physical Organization of Networks

- **DAN** (Desk Area Network)
  - Making all components of a desktop computer available to other computers on the network.
    - CPU - Unused computing power can be used by other computers on the network.
    - Hard Disk - Items stored can be accessed by others or items may be placed on the hard drive from other computers.
    - Video Display - Alert messages can be sent to the computer's display.
    - Other items - Other devices connected to the computer might be needed by others connected to the network.

7-37

The Physical Organization of Networks

- **LAN** (Local Area Network)
  - A collection of nodes within a small area.
  - The nodes are linked in a bus, ring, star, tree, or fully connected topology network configuration.
  - Benefits of LANs:
    - Sharing of hardware resources.
    - Sharing of software and data.
    - Consolidated wiring/cabling.
    - Simultaneous distribution of information.
    - More efficient person-to-person communication.

7-38

The Physical Organization of Networks

- **MAN** (Metropolitan Area Network)
  - Consists of many local area networks linked together.
  - Span the distance of just a few miles.
  - Sometimes called a BN (Backbone Network)
- **WAN** (Wide Area Network)
  - Consists of a number of computer networks including LANs.
  - Connected by many types of links.

7-39

Software Architecture of Networks

- Problem:
  - Connect several different machines running different operating systems (Windows, OS/2, MacOS, UNIX, VMS...)
  - Now, try to: send email, data or files between them.
- Solution:
  - Create a standardized set of rules, or **protocols**, that, when followed, will allow an orderly exchange of information.
  - A collection of these programs is called a **protocol suite**.
    - Must be on all computers or nodes in the network.
    - In order to send data over the network, the necessary programs must be executed.
  - **Network's architecture**: The protocol suite and the general scheme that guides the network's rules.

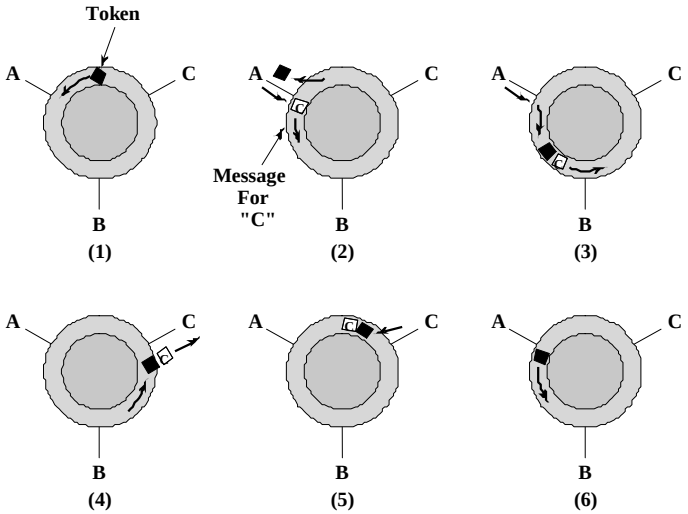
7-40

Software Architecture of Networks

- Problem: Collisions of information are caused by two computers simultaneously attempting to send information to the network.
- Solution: Different networks have different protocol suites:
  - Apple Computer's **LocalTalk** Protocol - Permission must be granted before information can be sent along the network.
  - **Token-Ring** Protocol (IBM and others) - A token is "picked up" by a node signifying that a message is about to be sent, the computer sends the message, then, replaces the token so that others can use the network.
  - **Ethernet** Protocol (Xerox and others) – CSMA/CD
    - "Listen" for quiet line; then send message
    - Collision occurs with simultaneous messages
    - Must wait and resend

7-41

Token Ring Operation



7-42

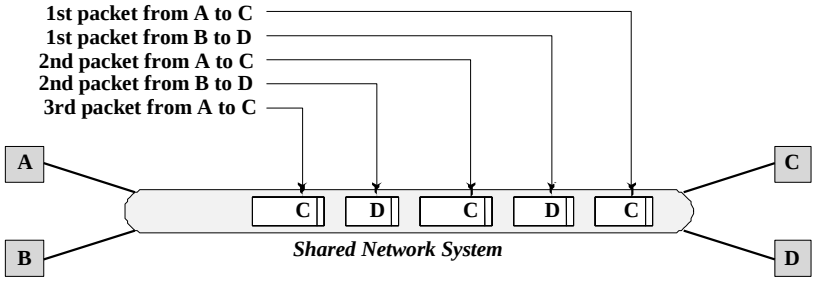
How Does the Internet Work?

- Packet-Switching Technology
- Connecting Independent Networks
- TCP/IP
- Internet Services
- The World Wide Web

Packet-Switching Technology

- Data sent in small standard sized chunks called “packets”
- Packets have headers with addresses of sending and receiving computers
- Users take turns sending packets
- Packets reassembled by the receiver

Packet Switching

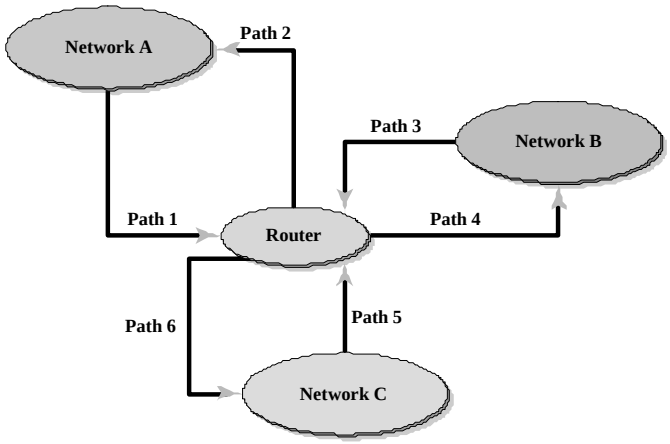


7-45

Connecting Independent Networks

- Router: fundamental building block of the Internet
  - Has a processor, memory, and network interface, its own specialized software
  - Connects LANs to backbone WANs
  - Forwards packets from one network to another
  - Determines best routes for packets to travel

Routers Enable Different Paths between Networks



7-47

TCP/IP

- Transmission Control Protocol
  - Breaks information into data packets
  - Reassembles packets when received
  - Checks for lost packets
- Internet Protocol
  - Each computer given a unique IP address, e.g. 137.224.44.12
  - IP address corresponds to an application level “Name”, e.g. www.yahoo.com
  - Name shows up in URLs, Email…
    - http://www.yahoo.com/somepage/on/yahoo/index.html
    - afkjm@uaa.alaska.edu

Basics of Internet Communication

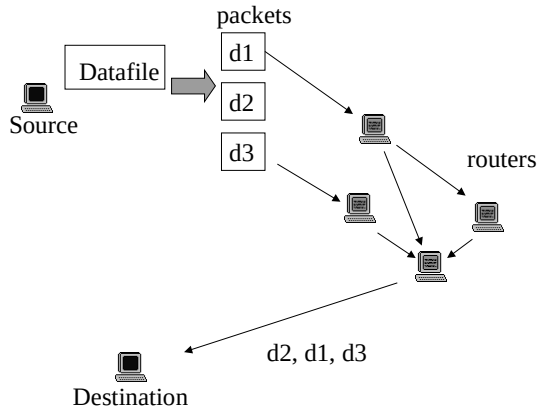
Messages broken into *datagrams*, also known as *packets*:

Sequence Number	34
Source Address	128.120.56.214
Destination Address	199.237.80.7
Data Size	7
(Other fields)	…
Data	hi mom

TCP/IP : Transmission Control Protocol / Internet Protocol

7-49

Packet Routing



Packets may travel different routes to reach their destination
Sequence number used to put data back in the original order

7-50

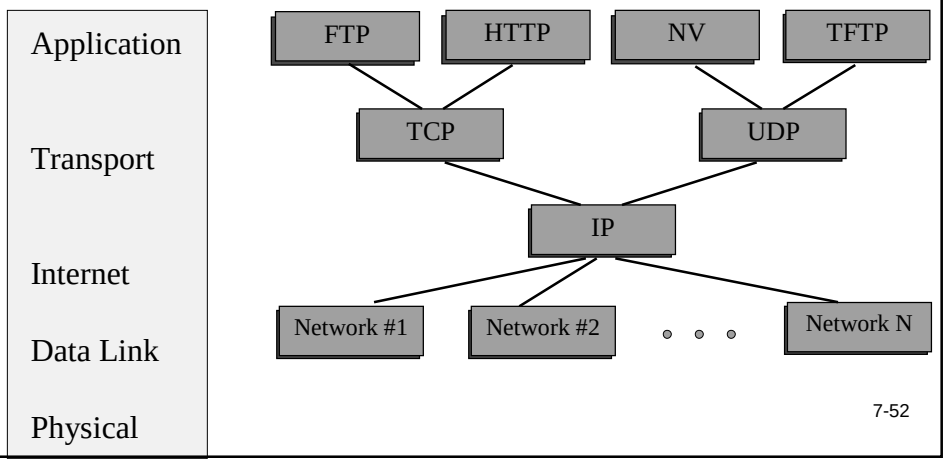
High Level Software Architecture

- Different **Layers** in the "Stack"
  - Application
    - Programs like web browsers, servers,
    - Protocols such as ftp, ssh, httpd, html
  - Transport
    - Keeps track of a session, breaks data into packets, error checking
    - Protocols such as TCP or UDP
  - Internet
    - Routes messages to their destination
    - Protocols such as IP
  - Data Access or Data Link
    - Controls physical hardware
    - Protocols such as Ethernet, PPP
  - Physical
    - Physical medium, twisted pair, fiber, radio, etc.

7-51

Software Architecture of Networks

- The Architecture of the Internet



7-52

Internet Naming Conventions

- Names of computers use the following convention for domains
- hostname.subdomain.domain.type
  - type : Organization status
  - domain : Registered ICANN name
  - Subdomain : optional hostname
  - Hostname : Name of the machine

7-53

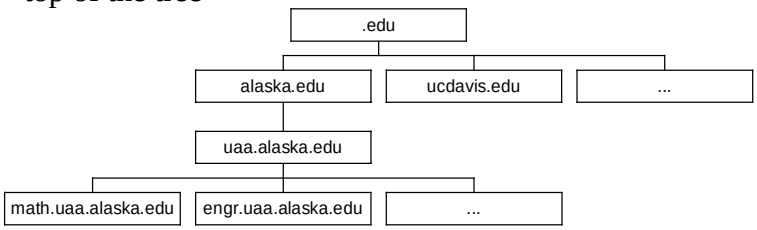
Common Types

- .edu - Educational
- .gov - Government
- .org - Nonprofit organizations
- .net - Internet service providers, backbone
- .country - Two letter country code, e.g. .jp for Japan, .us for United States, .to for Togo
- New names recently approved:
  - .aero, .biz, .museum, .info

7-54

Hierarchy of Names - DNS

- Routers are based on IP address (e.g. 134.114.140.34), not the English-like domain name!
- DNS = Domain Name Server system
  - Way to translate from domain name to IP address
- Tree-based hierarchy, with .org, .com, .edu, and .gov at the top of the tree



7-55

DNS - Finding IP Addresses

- Each computer on the network has an IP address
  - 0.0.0.0 to 255.255.255.255
  - Some of these are reserved; 127.0.0.l, 192.168.x.x
- DNS name servers map names to IP addresses
  - distributed database on the network

7-56

Network Example: Traceroute

- Traceroute: A program that allows the the tracing of packets over the Internet or any network using TCP/IP protocol.
  - Uses a special number - TTL (Time to Live) - contained in a place at the beginning of each packet sent over the network.
    - The number is originally set to 255.
    - Each time it is received by a router, it decrements by 1.
    - If the TTL number becomes 0 before reaching its destination, the router where this happened sends back an error message (time exceeded) with the address of the router.
      - Stops messages from circulating forever.

7-57

Tracing the router hops…

- On mazzy: /usr/sbin/traceroute <dest> On Windows: tracert <dest>

```
Tracing route to www.alaska.net [209.112.131.196] over a maximum of 30 hops:
 1   431 ms   440 ms   421 ms  uaa-du-02.alaska.edu [137.229.98.66]
 2   350 ms   341 ms   300 ms  r98-99-e1.alaska.edu [137.229.98.99]
 3   361 ms   340 ms   381 ms  swf-7507-1 [137.229.254.21]
 4   300 ms   341 ms   300 ms  m40 [137.229.2.1]
 5   290 ms   321 ms   320 ms  uacore1-ge-0-0-0-0.pnw-gigapop.net [198.32.40.129]
 6   411 ms   401 ms   390 ms  westincore1-so-0-1-0-0.pnw-gigapop.net [198.48.91.33]
 7   431 ms   380 ms   441 ms  westinnsp2-GE1-0.pnw-gigapop.net [198.32.170.17]
 8   631 ms   440 ms   461 ms  p1-1-2-2.a07.sttlwa01.us.ra.verio.net [204.203.3.1]
 9   591 ms   640 ms   461 ms  ge-6-2-0.r03.sttlwa01.us.bb.verio.net [129.250.28.1]
10   521 ms   500 ms   421 ms  p4-5-0-0.r06.plalca01.us.bb.verio.net [129.250.3.89]
11   461 ms   450 ms   511 ms  p4-6-0-0.r01.snjsca03.us.bb.verio.net [129.250.2.198]
12   621 ms   681 ms   620 ms  p4-1-0-0.r00.lsanca01.us.bb.verio.net [129.250.2.114]
13   611 ms   661 ms   621 ms  p1.att.r00.lsanca01.us.bb.verio.net [129.250.9.34]
14   601 ms   541 ms   531 ms  gbr3-p50.la2ca.ip.att.net [12.123.28.130]
15   481 ms   421 ms   560 ms  gbr4-p20.sffca.ip.att.net [12.122.2.69]
16   371 ms   420 ms   401 ms  gbr3-p30.st6wa.ip.att.net [12.122.2.198]
17   400 ms   481 ms   481 ms  gbr2-p10.st6wa.ip.att.net [12.122.5.166]
18   421 ms   421 ms   410 ms  gar1-p370.st6wa.ip.att.net [12.123.44.62]
19   521 ms   561 ms   540 ms  12.123.203.1
20   440 ms   441 ms   501 ms  12.124.174.6
21   561 ms   440 ms   461 ms  www.alaska.net [209.112.131.196]
```

21 hops from Anchorage to Anchorage!

7-58

Network Security

- Security of a Network
  - Enterprise and intranet networks: Corporations, government agencies, and other organizations have created their own internal networks.
    - **Firewall**: A set of programs that monitor all communication passing into and out of a corporation's intranet.
      - Helps prevent, but doesn't eliminate, unauthorized access.
- Upgrade and Apply Patches Often!
  - Avoid intrusions via known bugs or holes
  - Lots of worms, DOS (denial of service) attacks, known exploits to compromise security

7-59