

Networks

- A *network* is a communication system that provides correct, efficient, and robust data exchange between 2 or more hosts
- *Local area network* (LAN) —connects nodes in a small geographic area (e.g., single building, single campus)
 - Must be fast with low error rate
 - Media — twisted-pair, coaxial cable, fiber optic cable
- *Wide area network* (WAN) —connects nodes in a wide geographic area (e.g., across the country)
 - May be slower with higher error rate
 - Media — leased telephone lines (T1 & T3 service), microwave links, satellite channels

1

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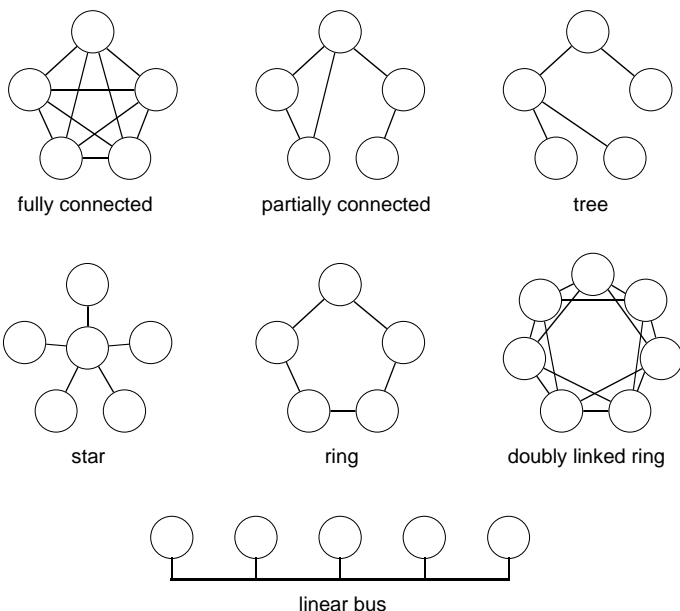
Network Transmission Rates

- Slow = low data rate
 - Modems, etc. (into home, out of home)
 - Modem = 56 Kbps / 33.6 Kbps
 - ISDN = 128 Kbps / 128 Kbps
 - ADSL (asymmetric digital subscriber line) = 1.5–9 Mbps / 0.640–2 Mbps
 - Time Warner’s Roadrunner in Akron is 27 Mbps / 3 Mbps
 - Cable modems = 1.5-30 / 0.3-10 Mbps
 - Dedicated lines
 - T1 = 1.5 Mbps
 - T3 = 45 Mbps (backbone, some sites)
 - New optical backbone: 155 Mbps, soon 600 Mbps, eventually more
- Fast = high data rate
 - Ethernet = 10 Mbps (originally 3 Mbps)
 - Fast Ethernet = 100 Mbps
 - Gigabit Ethernet = 1000 Mbps = 1 Gbps

2

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Network Topologies



3

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Network Topologies (cont.)

- Point-to-point — links to specific nodes
 - Fully connected — each node connects to all other nodes
 - ✓ Each message is fast; it takes only a single “hop” to reach its destination
 - ✓ Failure of any one node does not affect communication except to it
 - ✗ Expensive!
 - Partially connected — each node connects to some, but not all, nodes
 - ✓ Less expensive
 - ✗ A message may have to go through several other nodes
 - ✗ Less tolerant to failure
 - Tree — network hierarchy
 - ✓ Messages between direct descendants are fast
 - ✗ Messages between “cousins” must go up to a common ancestor and back down
 - ✗ Not tolerant of failures

4

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Network Topologies (cont.)

- **Star**— all nodes connect to a single centralized node
 - Central node is generally dedicated to network traffic
 - ✓ Inexpensive
 - ✓ Each message takes only two hops
 - ✗ Failure of central node disconnects entire network
- **Ring** — all nodes connect in a circle
 - One directional ring — each node can send in only one direction
 - ✓ Inexpensive
 - ✗ Message may need to take n hops
 - ✗ Not tolerant of failures
 - Bi-directional ring — each node can send in either direction
 - ✓ Inexpensive
 - ✓ Tolerates a single failure
 - Message may need at most $n/2$ hops

5

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Network Topologies (cont.)

- **Ring** — all nodes connect in a circle
 - Doubly linked ring — each node connects to 1-node and 2-node-away neighbors
 - ✓ Message may need at most $n/4$ hops
 - ✓ Tolerates multiple failures
 - ✗ Expensive
- **Bus** — all nodes connect to common network
 - Nodes connect directly to each other over a shared common bus using multiaccess bus technology
 - ✓ Inexpensive, linear in number of nodes
 - ✓ Tolerant of node failures
 - ✗ Only one node can send data at a time

6

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Putting it All Together...

- In practice, we often use some combination of these structures:

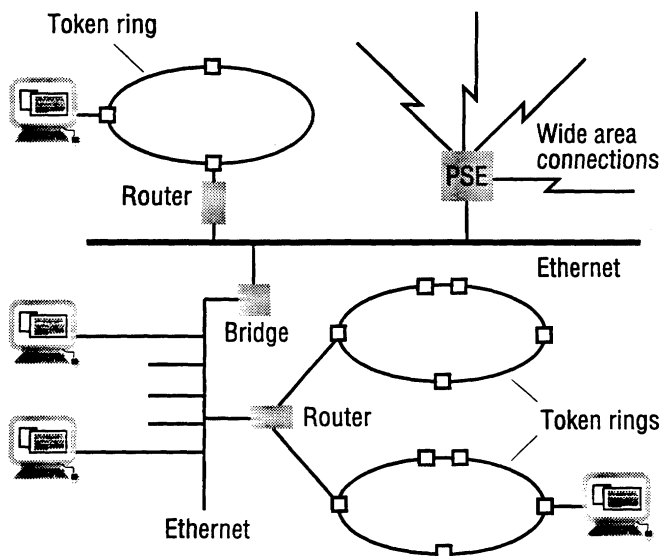
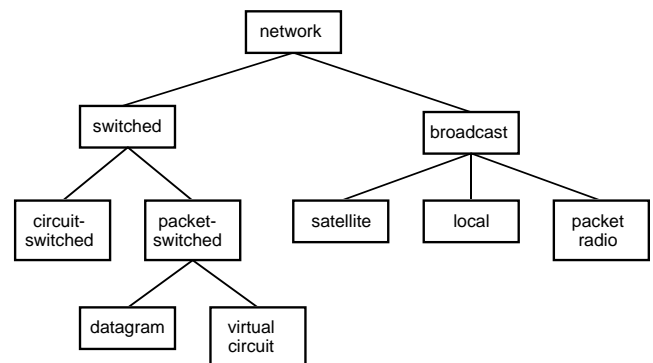


Diagram from *Distributed Systems*, Coulouris et. al., Addison-Wesley, 1994

7

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Network Communication



- **Connection-oriented communication**
 - Information delivered as a *stream* of bytes, in correct order
 - Connect, exchange data, release
- **Connectionless communication**
 - Information delivered as a set of *packets*
 - Packets may be delivered out of sequence, must be reassembled

8

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Switching Technologies

- In a *broadcast* (or *multiaccess*) network, all hosts directly connect to a single shared communication medium
 - Each host check the destination address on every message to decide whether or not to read that message
- In a *switched* network, there is a partially-connected topology, and there may be multiple paths between two hosts
 - Messages may have to pass through intermediate nodes to reach destination
- *Circuit switching* — a dedicated communication path is reserved, and then used to send the entire message
 - Connection occupies a fixed capacity (not necessarily entire capacity) of each link for the entire lifetime of the connection
 - Connection-oriented communication

9

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Switching Technologies(cont.)

- *Packet switching* — data is broken up into a sequence of fixed-size *packets*
 - Each packet is passed through the network from source to destination along some (possibly different) *route* (path)
 - At each node, the entire packet is received, stored briefly, and then forwarded to the next node
 - *Datagram package switching*
 - Packets are called *datagrams*
 - Each packet is routed independently
 - A sequence of packets can be received out of order
 - Connectionless communication
 - *Virtual circuit package (message) switching*
 - All packets from one packet stream are sent along the same path (= *virtual circuit*)
 - Guarantees packets are received in sequence
 - Connection-oriented communication

10

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Asynchronous Transfer Mode (ATM)

- Designed for wide variety of data, including multimedia (voice, video)
- ATM is a fast packet-switching network
 - Connected communication
 - Establishes a connection (*virtual circuit*) for all packets to use
 - Uses *cell relay* to achieve higher speed
 - No flow control or error checking at intermediate nodes
 - Transmits small, fixed-length packets called *cells*
 - Guaranteed bandwidth — connects only if sufficient resources are available
- Main protocol layers
 - ATM adaptation layer — packet assembly
 - ATM layer — connection-oriented transmission of packets called cells

11

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Routing

- *Routing* software decides *which* path to use to move a message from the destination to source
- Routing is usually *hop-by-hop*, meaning each host chooses the next host to send the message to
- *Static (fixed)* routing — routing tables are stored, and change very infrequently (e.g., after major the network changes)
 - ✓ Low setup cost, packets arrive in order
 - ✗ Can't react to changes in network load
- *Dynamic* routing — routing tables are updated frequently
 - ✓ Can react to changes in network load
 - ✗ Higher setup cost for each packet
 - ✗ Packets can arrive out of order

12

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