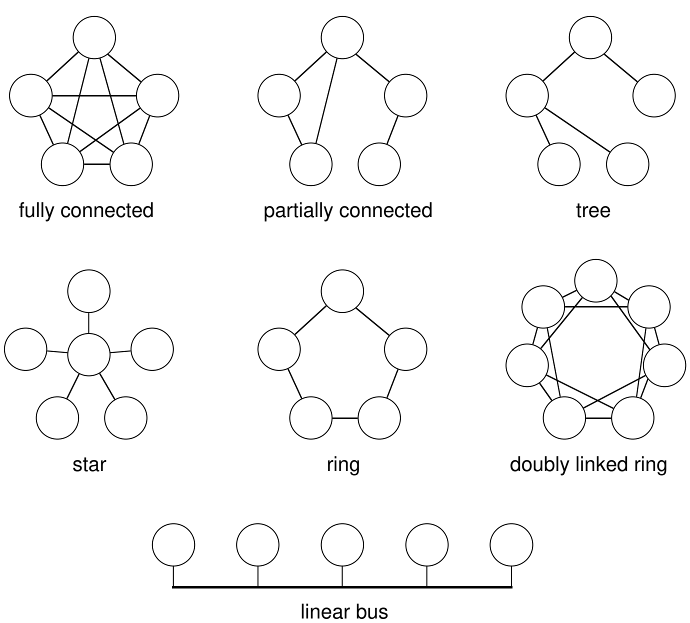
Networks

- 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

Network Transmission Rates

- Slow = low data rate
  - Modems, etc
    - Modem = 56 Kbps (into home)
    - ISDN = 64 Kbps
    - Cable modems = 1.5-8 Mbps into home, 16-640 Kbps from home
      - (also known as ADSL = asymmetric digital subscriber line) Roadrunner in Akron
  - 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 = 1Gbps

Network Topologies



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 though 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

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

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

Putting it All Together…

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

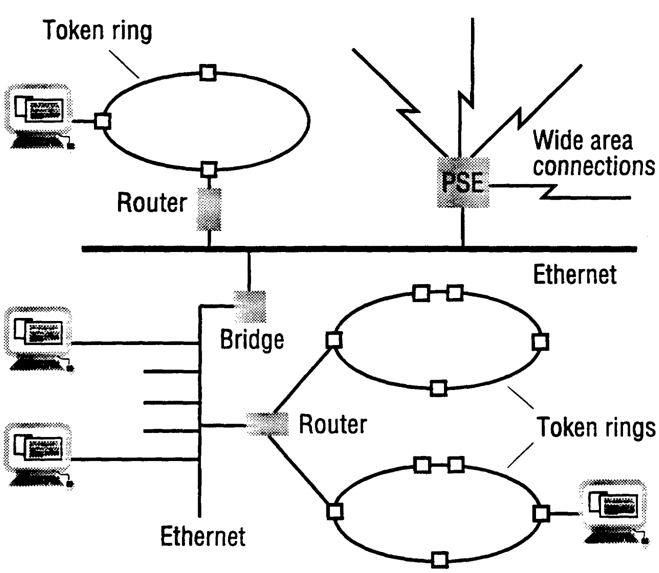
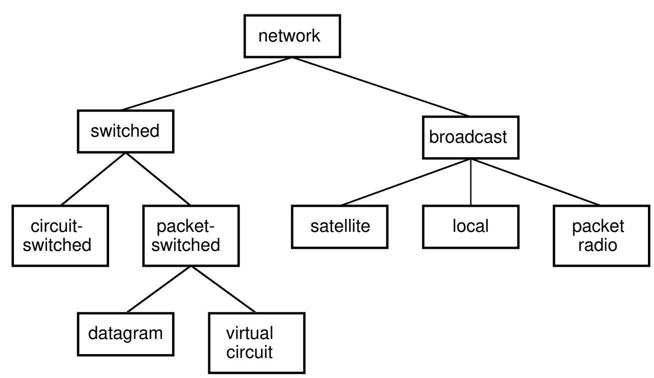


Diagram from *Distributed Systems*, Coulouris et. al., Addison-Wesley, 1994

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

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

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

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

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