## Network Communication

- Systems communicate according to a *protocol* — a set of rules that govern the sequence, format, content, and meaning of messages sent between the systems

- *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
  - May be *reliable* — data will reach destination, otherwise sender will be notified of an error
  - May be *unreliable* — data may not reach destination, sender never notified of errors

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ISO OSI 7-Layer Protocol
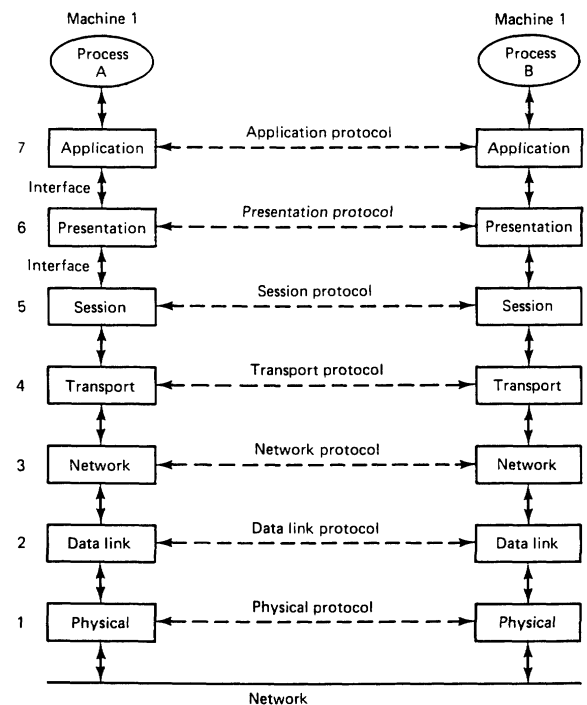
Distributed Operating Systems, Tanenbaum, Prentice Hall, 1995

ISO OSI 7-Layer Protocol Summary

- Application layer — provides network access to application programs
  - Telnet, ftp, email, web browsers

- Presentation layer — provides freedom from machine-dependent representations

- Session layer — provides communication between processes, error recovery
  - Not required in connectionless commun.
  - Example: Remote Procedure Call (RPC)

- Transport layer — reliably transfers messages (broken into *packets*) between hosts, error control for out-of-sequence and missing packets
  - Examples: TCP (connection-oriented), UDP (connectionless)

ISO OSI 7-Layer Protocol Summary (cont.)

- Network layer — provides switching and routing needed to (1) establish, maintain, and terminate switched connections, and (2) transfer data (packets) between end systems
  - Examples: IP (connectionless), X.25 (connection-oriented)

- Data link layer — reliably transfers packets (broken up into *frames*) over a communication link, error / flow control
  - Examples: Ethernet

- Physical layer —converts 1s and 0s into electrical or optical signals, and transmits frames of bits across a wire / cable
  - Examples: RS-232-C (serial communication lines), X.21

TCP / IP Protocol

■ Upper layers

  ● ftp — file transfer protocol
    ■ Sends files from one system to another under user command
    ■ Handles both text and binary files
    ■ Supports userids and passwords

  ● telnet — remote terminal protocol
    ■ Lets a user at one terminal log onto a remote host

  ● smtp — simple mail transfer protocol
    ■ Transfers mail messages between hosts
    ■ Handles mailing lists, forwarding, etc.
    ■ Does not specify how mail messages are created

  ● nsp — name server protocol
    ■ Maps names into IP addresses
    ■ A domain may be split into subdomains
    ■ Name severs are usually replicated to improve reliability

TCP / IP Protocol (cont.)

■ Transport layer   (messages & packets)

  ● TCP — Transmission Control Protocol
    ■ Connection-oriented (3-way handshake)
    ■ On transmit side, breaks message into *packets*, assigns sequence numbers, and and sends each packet in turn
      – Sends to a particular IP address and port
      – Flow control — doesn't send more packets than receiver is prepared to receive
    ■ On receive side, receives packets, reassembles them into messages
      – Computes a checksum for each packet and compares it to checksum sent, discards packet if checksums don't agree
      – Reorders out-of-order packets
    ■ Reliable
      – Packets must be acknowledged
      – If sender doesn't receive an acknowledgment after a short period, it retransmits that packet
    ■ Congestion control — don't overwhelm the network

TCP / IP Protocol (cont.)

■ Network layer   (routing packets)

  ● IP — Internet Protocol
    ■ Connectionless
    ■ Unreliable
      – Packets may be lost, duplicated, or delivered out of order
    ■ Forward packet from sender through some number of gateways until it reaches the final destination
      – A *gateway* accepts a packet from one network and forwards it to a host or gateway on another network
    ■ Destination has specific Internet address, which is composed of two parts:
      – network part — network the host is on
      – address part — specific host on network
    ■ Routing is dynamic — each gateway chooses the next gateway to send the packet to
      – Gateways send each other information about network congestion and gateways which are down

TCP / IP Protocol (cont.)

■ Data link /   (packets & frames)
  physical layers   (1s and 0s)

  ● Ethernet
    ■ Connectionless
    ■ Unreliable
    ■ Network is a bus
      – Broadcast to anyone who cares to listen
    ■ Transmission
      – Carrier sense: listen before broadcasting, defer until channel is clear, then broadcast
      – Collision detection: listen while broadcasting
        » If two hosts transmit at same time —*collision* — the data gets garbled
        » Each jams network, then waits a random (but increasing) amount of time, and tries again
      – This is called CSMA/CD (carrier sense multiple access, with collision detection)
      – Packets contain checksum
    ■ Every Ethernet device (everywhere in the world!) has a unique address