

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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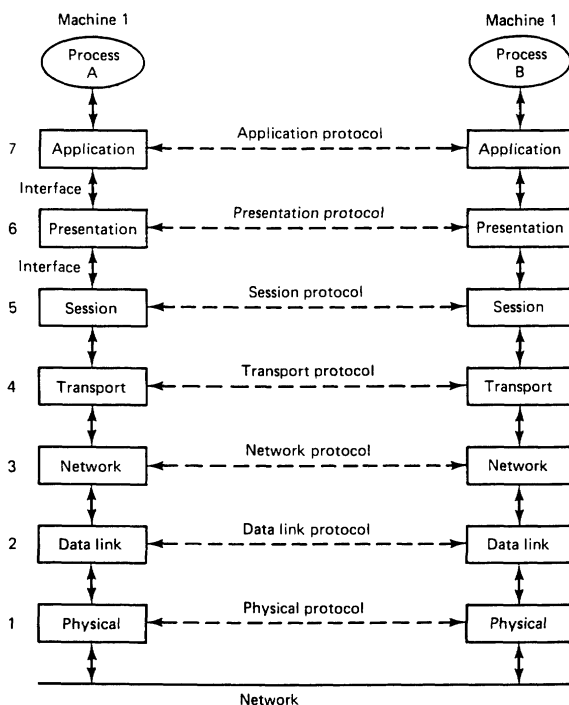
Protocol Layers

- Network communication is divided up into seven layers
 - Each layer deals with one particular aspect of the communication
 - Each layer uses a set of routines provided by the layer below it
 - Each layer ignores lower-level (and higher-level) details and problems
- Each layer takes a message handed down to it by a higher layer, adds some header information, and passes the message on to a lower layer
 - Each layer has the illusion of peer-to-peer communication
 - Eventually the message reaches the bottom layer, and get physically sent across the network

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ISO OSI 7-Layer Protocol



Distributed Operating Systems, Tanenbaum, Prentice Hall, 1995

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ISO OSI 7-Layer Protocol Summary

- Application layer — provides network access to application programs
 - Examples: telnet, ftp, email (SMTP)
- 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)

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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

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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 servers are usually replicated to improve reliability

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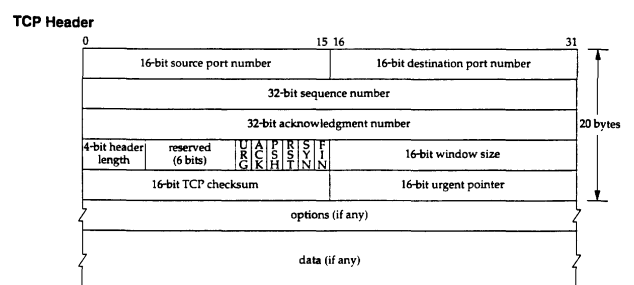
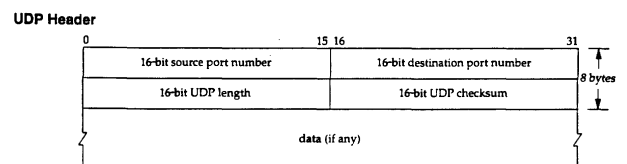
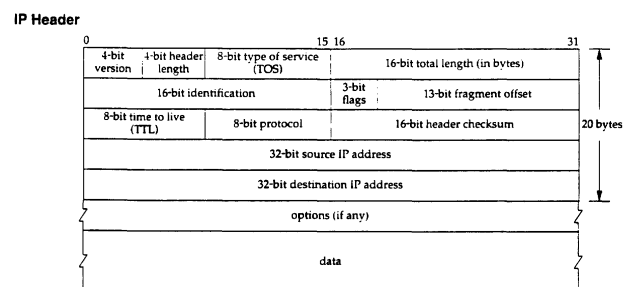
TCP / IP Protocol (cont.)

- Transport layer (messages & packets)
 - TCP — Transmission Control Protocol
 - Connection-oriented (3-way handshake)
 - On transmit side, breaks message into *packets*, assigns sequence numbers, and 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

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TCP/IP Headers



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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

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TCP / IP Protocol (cont.)

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

- Ethernet
 - 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)
 - Every Ethernet device (everywhere in the world!) has a unique address
 - The Institute of Electrical and Electronics Engineers (IEEE) allocates addresses to manufacturers, who build a unique address into each Ethernet device

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Contention

- Collision detection
 - Before sending a message, listen to see if another process is sending
 - If one is, wait a random time and try again
 - While transmitting, watch for collisions
- Token passing
 - A unique message (a token) continuously circulates through the network
 - To transmit, a host waits for a free token, attaches its message to it, sent the token status to busy, and sends it on
 - Destination removes the message, sets the token status to free, and sends it on
- Message slots
 - A number of fixed-length message slots circulate through the network
 - Wait for an empty slot and fill it

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Testing

- A part of IP that is less widely known is the Internet Control Message Protocol (ICMP)
 - Allows gateways and hosts to exchange bootstrapping information, report errors, and test the liveliness of the network
- Some useful programs using ICMP:
 - traceroute /usr/contrib/bin/traceroute
 - Displays route taken to reach destination, time for each hop
 - Sends multiple (?) 20-byte packets
 - ping /usr/sbin/ping
 - Tests that destination is up and reachable
 - Sends ICMP **echo request** to destination
 - Destination sends ICMP **echo reply**
 - Sends 64-byte packets repeatedly
 - But... watch out for the Ping of Death
 - See <http://www.sophist.demon.co.uk/ping/>

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