Introduction

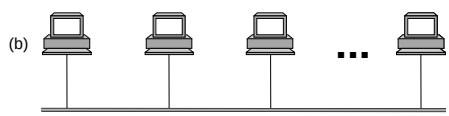
Outline

- Statistical Multiplexing
- Inter-Process Communication
- Network Architecture
- Performance Metrics
- Implementation Issues

Building Blocks

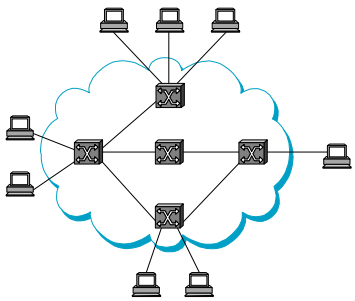
- Nodes: PC, special-purpose hardware…
  - hosts
  - switches
- Links: coax cable, optical fiber…
  - point-to-point

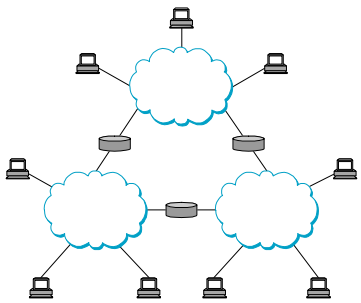
  - multiple access



Switched Networks

- A network can be defined recursively as...
  - two or more nodes connected by a link, or
  - two or more networks connected by a node





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Strategies

- Circuit switching: carry bit streams
  - original telephone network
- Packet switching: store-and-forward messages
  - Internet

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Addressing and Routing

- Address: byte-string that identifies a node
  - usually unique
- Routing: process of forwarding messages to the destination node based on its address
- Types of addresses
  - unicast: node-specific
  - broadcast: all nodes on the network
  - multicast: some subset of nodes on the network

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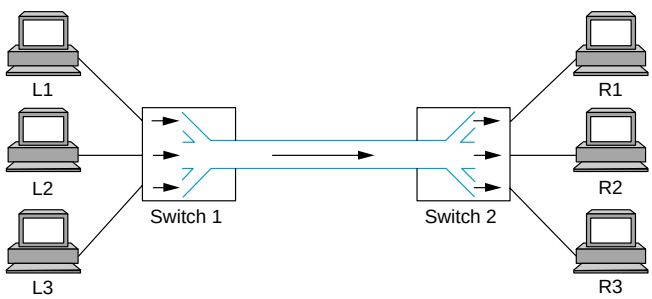
Multiplexing

- Time-Division Multiplexing (TDM)
- Frequency-Division Multiplexing (FDM)



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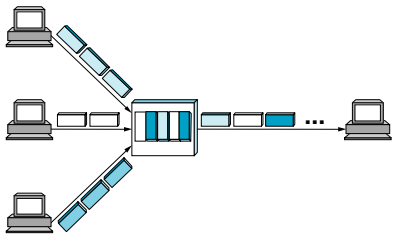
Statistical Multiplexing

- On-demand time-division
- Schedule link on a per-*packet* basis
- Packets from different sources interleaved on link
- Buffer packets that are *contending* for the link
- Buffer (queue) overflow is called *congestion*



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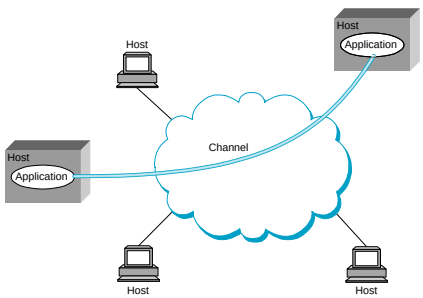
Inter-Process Communication

- Turn host-to-host connectivity into process-to-process communication.
- Fill gap between what applications expect and what the underlying technology provides.



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IPC Abstractions

- Request/Reply
  - distributed file systems
  - digital libraries (web)
  - Based on TCP
- Stream-Based
  - video: sequence of frames
    - 1/4 NTSC = 352x240 pixels
    - (352 x 240 x 24)/8=247.5KB
    - 30 fps = 7500KBps = 60Mbps
  - video applications
    - on-demand video
    - video conferencing
  - Based on UDP

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What Goes Wrong in the Network?

- Bit-level errors (electrical interference)
- Packet-level errors (congestion)
- Link and node failures

- Packets are delayed
- Packets are deliver out-of-order
- Third parties eavesdrop

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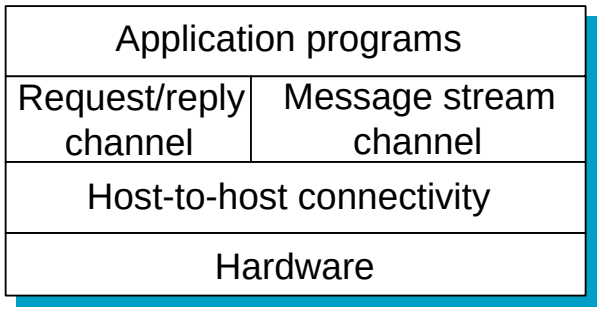
Layering

- Use abstractions to hide complexity
- Abstraction naturally lead to layering
- Alternative abstractions at each layer (extensible)



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Protocols

- Building blocks of a network architecture
- Each protocol object has two different interfaces
  - *service interface*: operations on this protocol
  - *peer-to-peer interface*: messages exchanged with peer
- Term "protocol" is overloaded
  - specification of peer-to-peer interface
  - module that implements this interface

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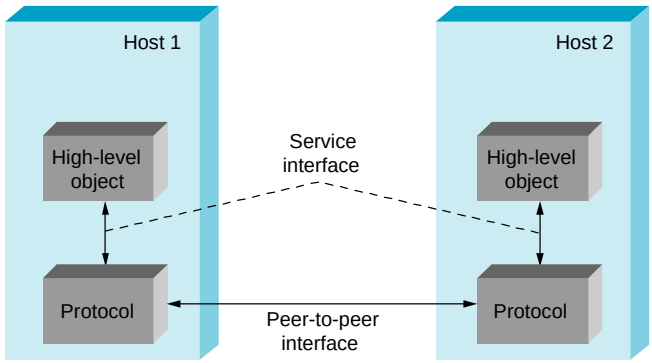
Interfaces



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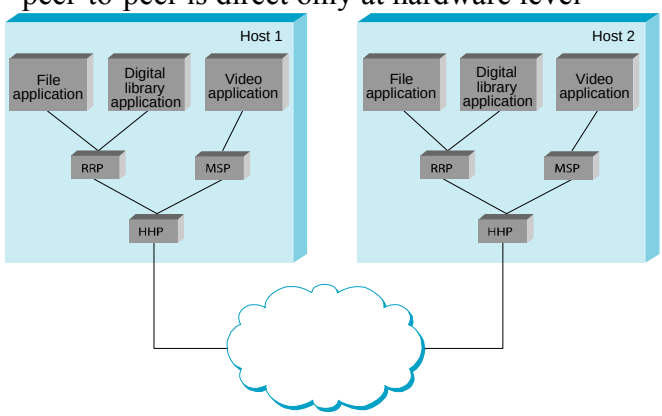
Protocol Machinery

- Protocol Graph
  - most peer-to-peer communication is indirect
  - peer-to-peer is direct only at hardware level



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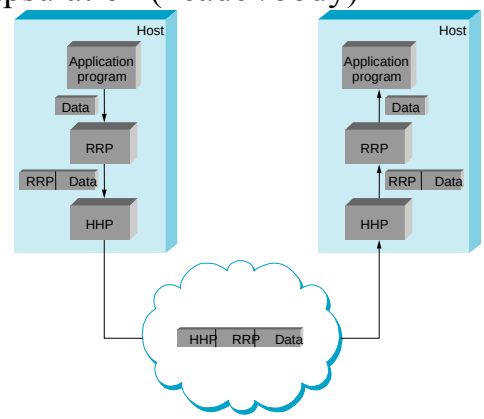
Machinery (cont)

- Multiplexing and Demultiplexing (demux key)
- Encapsulation (header/body)



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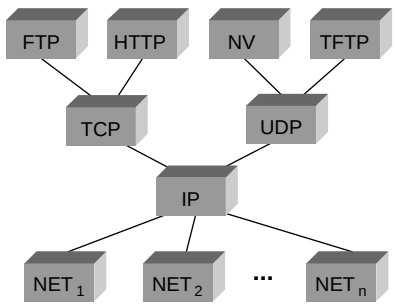
Internet Architecture

- Defined by Internet Engineering Task Force (IETF)
- Hourglass Design
- Application vs Application Protocol (FTP, HTTP)



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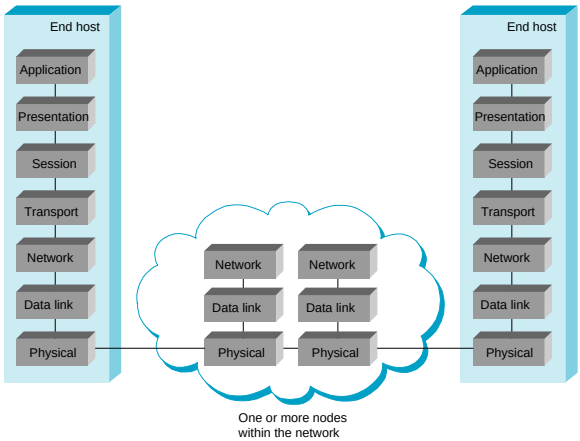
ISO Architecture



Performance Metrics

- Bandwidth (throughput)
  - data transmitted per time unit
  - link versus end-to-end
  - notation
    - KB = 2^{10} bytes
    - Mbps = 10^6 bits per second
- Latency (delay)
  - time to send message from point A to point B
  - one-way versus round-trip time (RTT)
  - components

    Latency = Propagation + Transmit + Queue

    Propagation = Distance / c

    Transmit = Size / Bandwidth

Bandwidth versus Latency

- Latency-Bound
  - 1-byte request / reply with 100ms RTT
  - 1Mbps Channel: transmit time 8 µs.
  - 100Mbps Channel: transmit time 0.08 µs.
- Bandwidth-Bound
  - 25MB transfer
  - 10Mbps Channel: transmit time 20 seconds
  - The effect of RTT is negligible.
- Throughput = TransferSize / TransferTime
- TransferTime = RTT + 1/Bandwidth x TransferSize

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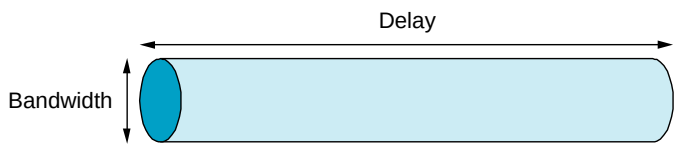
Delay x Bandwidth Product

- Amount of data “in flight” or “in the pipe”
- Usually relative to RTT
- Example: 100ms x 45Mbps = 560KB



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Socket API

- Creating a socket

  int socket(int domain, int type, int protocol)
  - domain = PF_INET, PF_UNIX
  - type = SOCK_STREAM, SOCK_DGRAM, SOCK_RAW

- Passive Open (on server)

  int bind(int socket, struct sockaddr *addr, int addr_len)

  int listen(int socket, int backlog)

  int accept(int socket, struct sockaddr *addr, int addr_len)

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Sockets (cont)

- Active Open (on client)

  int connect(int socket, struct sockaddr *addr,
  int addr_len)

- Sending/Receiving Messages

  int send(int socket, char *msg, int mlen, int flags)

  int recv(int socket, char *buf, int blen, int flags)

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