

Introduction

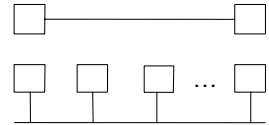
Outline

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

Building Blocks

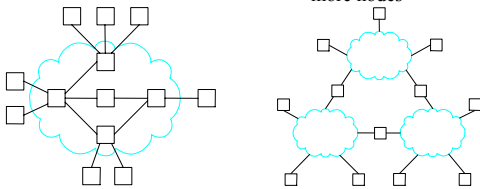
- Nodes: PC, special-purpose hardware...
 - hosts
 - switches
- Links: coax cable, optical fiber...

- 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 two or more nodes



Strategies

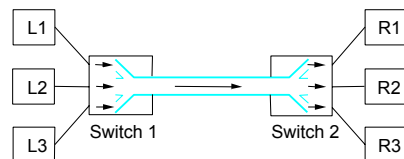
- Circuit switching: carry bit streams
 - original telephone network
- Packet switching: store-and-forward messages
 - Internet

Addressing and Routing

- Address: byte-string that identifies a node
 - usually unique
- Routing vs Forwarding
- Types of addresses
 - unicast: node-specific
 - broadcast: all nodes on the network
 - multicast: some subset of nodes on the network

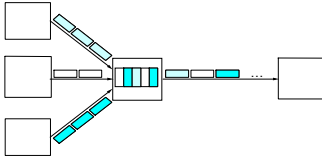
Multiplexing

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



Statistical Multiplexing

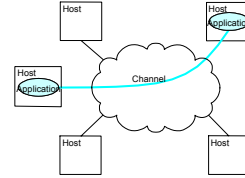
- On-demand time-division
- Schedule link on a per-packet basis
- Packets from different sources interleaved on link
- Buffer packets that are *contending* for the link
- Buffer (queue) overflow is called *congestion*



7

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.



8

IPC Abstractions

- Request/Reply
 - distributed file systems
 - digital libraries (web)
- Stream-Based
 - video: sequence of frames
 - video applications
 - on-demand video
 - video conferencing

9

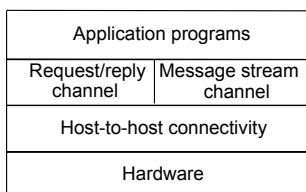
What Goes Wrong in the Network?

- Bit-level errors (electrical interference)
- Packet-level errors (congestion)
- Link and node failures
- Messages are delayed
- Messages are delivered out-of-order
- Third parties eavesdrop

10

Layering

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



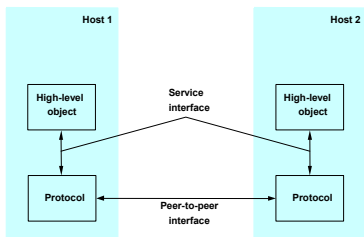
11

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

12

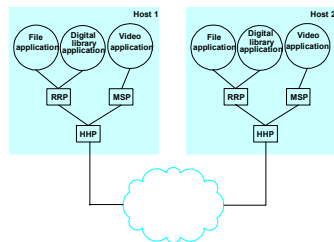
Interfaces



13

Protocol Machinery

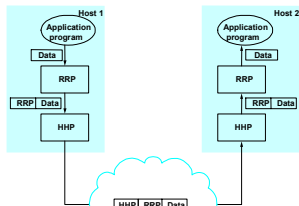
- Protocol Graph
 - most peer-to-peer communication is indirect
 - peer-to-peer is direct only at hardware level



14

Machinery (cont)

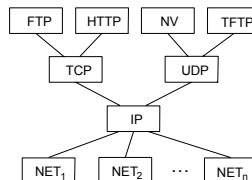
- Multiplexing and Demultiplexing (demux key)
- Encapsulation (header/body)



15

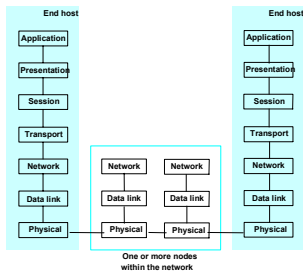
Internet Architecture

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



16

ISO Architecture



17

Performance Metrics

- Bandwidth
 - data transmitted per time unit
 - link versus end-to-end
 - notation
 - KB = 2¹⁰ bytes
 - Mbps = 10⁶ bits per second
- Latency
 - 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

18

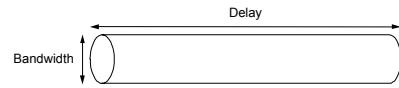
Bandwidth versus Latency

- Relative importance
 - 1-byte: 1ms vs 100ms dominates 1Mbps vs 100Mbps
 - 25MB: 1Mbps vs 100Mbps dominates 1ms vs 100ms
- Throughput
 - RTT dominates
 - $\text{Throughput} = \text{TransferSize} / \text{TransferTime}$
 - $\text{TransferTime} = \text{RTT} + 1/\text{Bandwidth} \times \text{TransferSize}$
 - 1-MB *file* to 1-Gbps link as 1-KB *packet* to 1-Mbps link

19

Delay x Bandwidth Product

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



20