The Host

Kyle Jamieson

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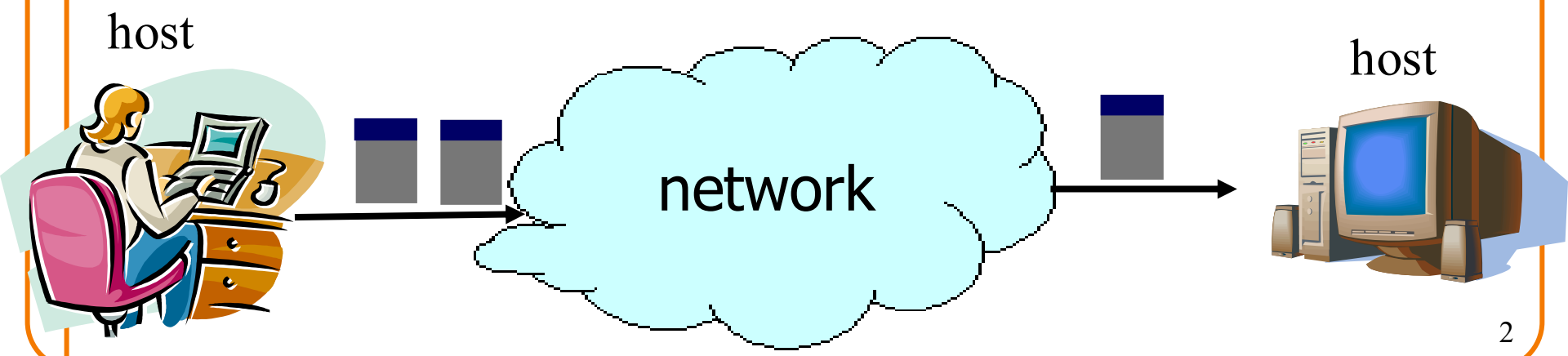
COS 561: Advanced Computer Networks

http://www.cs.princeton.edu/courses/archive/fall26/cos561/

Host-Network Division of Labor

- Network
  - Best-effort packet delivery
  - Between two (or more) end-point addresses
- Hosts
  - Everything else

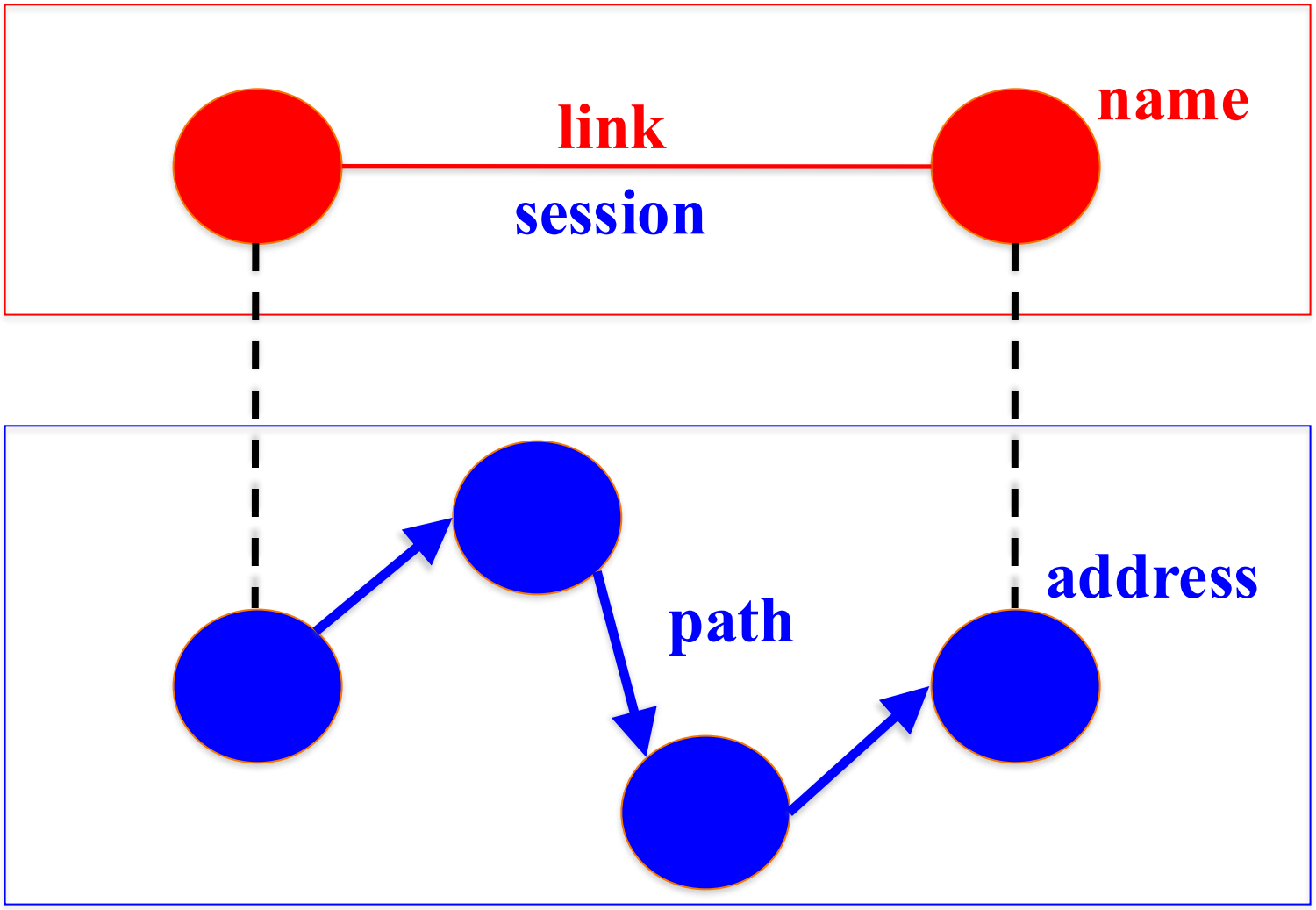


The Role of the End Host

- Network discovery and bootstrapping
  - How does the host join the network?
  - How does the host get an address?
- Interface to networked applications
  - What interface to higher-level applications?
  - How does the host realize that abstraction?
- Distributed resource sharing
  - What roles does the host play in network resource allocation decisions?

Network Discovery and Bootstrapping

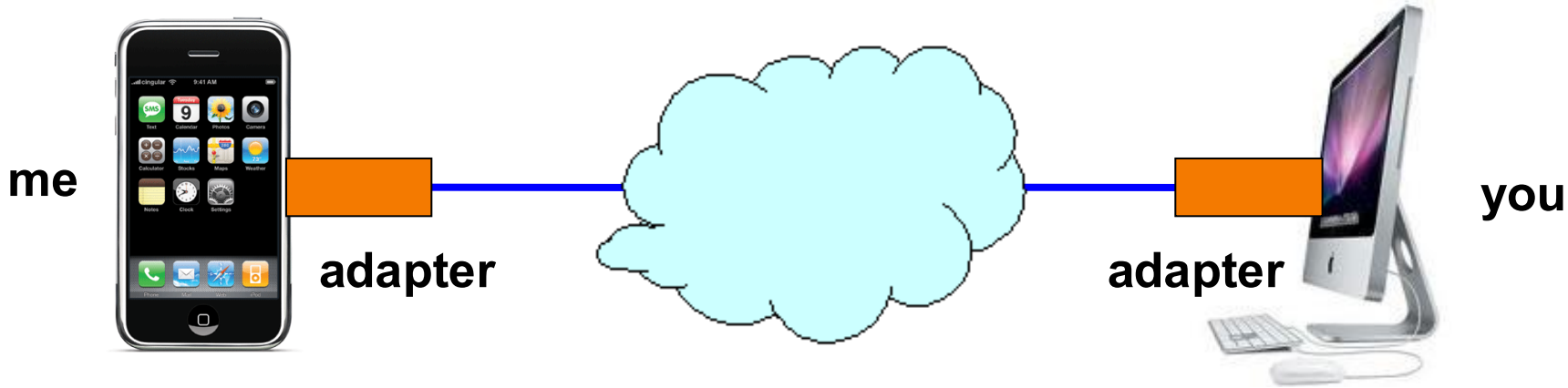
Relationship Between Layers



Three Kinds of Identifiers

	Host Name	IP Address	MAC Address
Example	www.cs.princeton.edu	128.112.7.156	00-15-C5-49-04-A9
Size	Hierarchical, human readable, variable length	Hierarchical, machine readable, 32 bits (in IPv4)	Flat, machine readable, 48 bits
Read by	Humans, hosts	IP routers	Switches in LAN
Allocation, top-level	Domain, assigned by registrar (e.g., for .edu)	Variable-length prefixes, assigned by ICANN, RIR, or ISP	Fixed-sized blocks, assigned by IEEE to vendors (e.g., Dell)
Allocation, low-level	Host name, local administrator	Interface, by DHCP or an administrator	Interface, by vendor

Learning a Host's Address



- Who am I?
  - Hard-wired: MAC address
  - Static configuration: IP interface configuration
  - Dynamically learned: IP address configured by DHCP
- Who are you?
  - Hard-wired: IP address in a URL, or in the code
  - Dynamically looked up: ARP or DNS

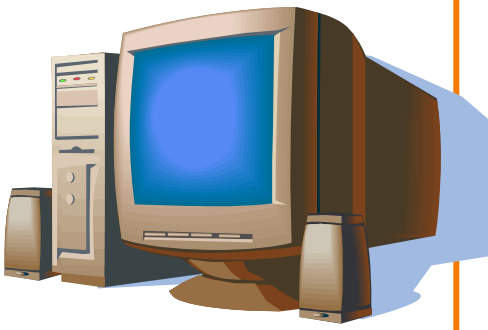
Mapping Between Identifiers

- Dynamic Host Configuration Protocol (DHCP)
  - Given a MAC address, assign a unique IP address
  - … and tell host other stuff about the Local Area Network
  - To automate the boot-strapping process
- Address Resolution Protocol (ARP)
  - Given an IP address, provide the MAC address
  - To enable communication within the Local Area Network
- Domain Name System (DNS)
  - Given a host name, provide the IP address
  - Given an IP address, provide the host name

Dynamic Host Configuration Protocol

arriving client

DHCP discover (broadcast)



DHCP server

DHCP offer

Host learns
IP address,
Subnet mask,
Gateway address,
DNS server(s),
and a lease time.

DHCP request (broadcast)

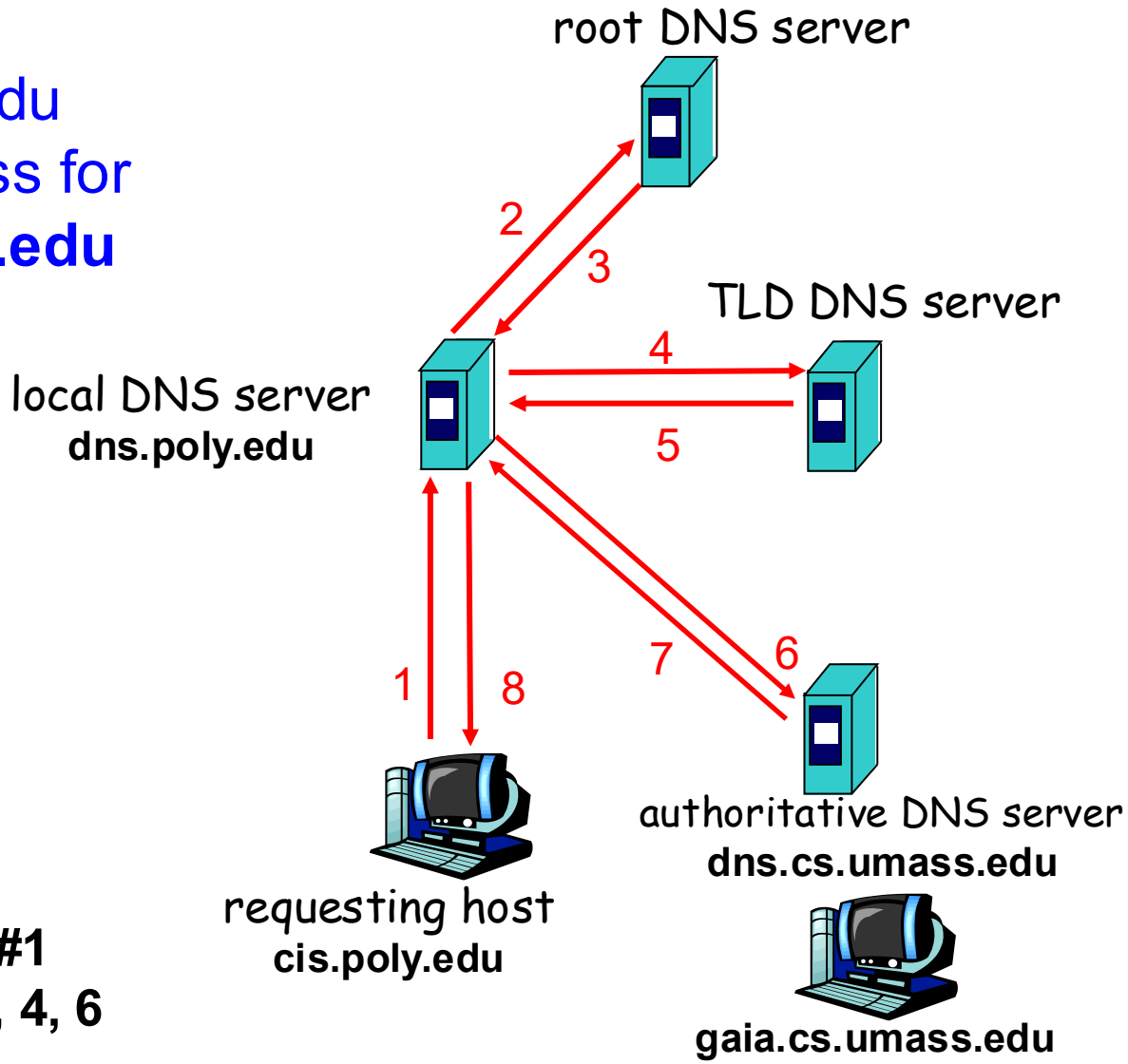
DHCP ACK

Address Resolution Protocol (ARP)

- Every host maintains an ARP table
  - (IP address, MAC address) pair
- Consult the table when sending a packet
  - Map destination IP address to destination MAC address
  - Encapsulate and transmit the data packet
- But, what if the IP address is not in the table?
  - Sender broadcasts: “Who has IP address 1.2.3.156?”
  - Receiver responds: “MAC address 58-23-D7-FA-20-B0”
  - Sender caches the result in its ARP table

Domain Name System

Host at cis.poly.edu
wants IP address for
gaia.cs.umass.edu



Recursive query: #1
Iterative queries: #2, 4, 6

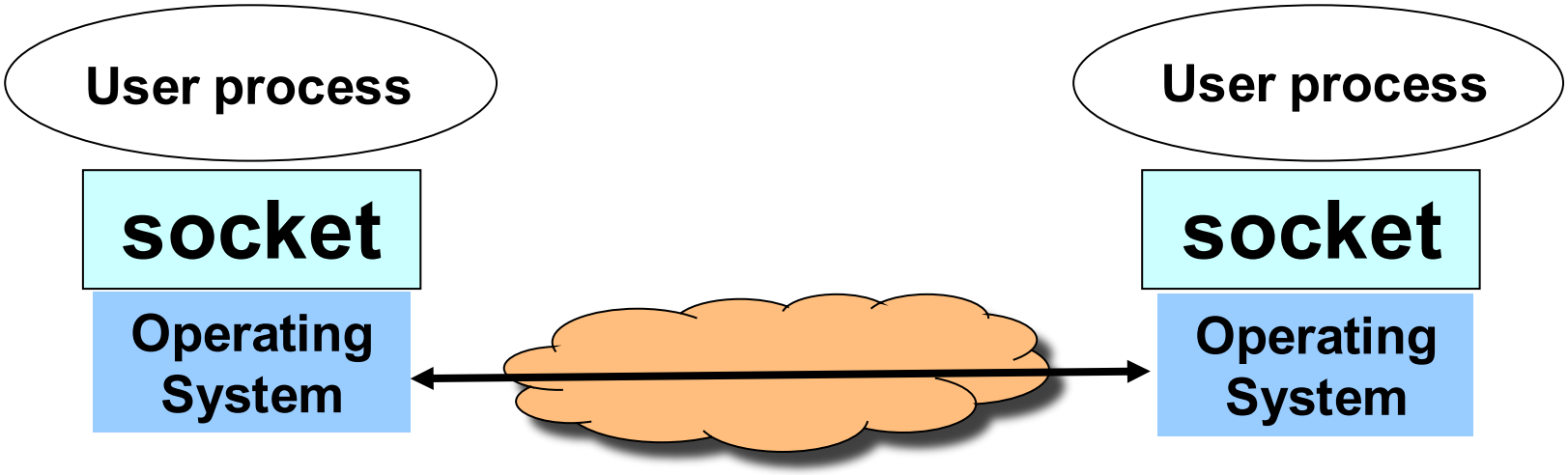
Questions

- Should addresses correspond to the interface (point of attachment) or to the host?
- Why do we have all three identifiers? Do we need all three?
- What should be done to prevent spoofing of addresses?

Interface to Applications

Socket Abstraction

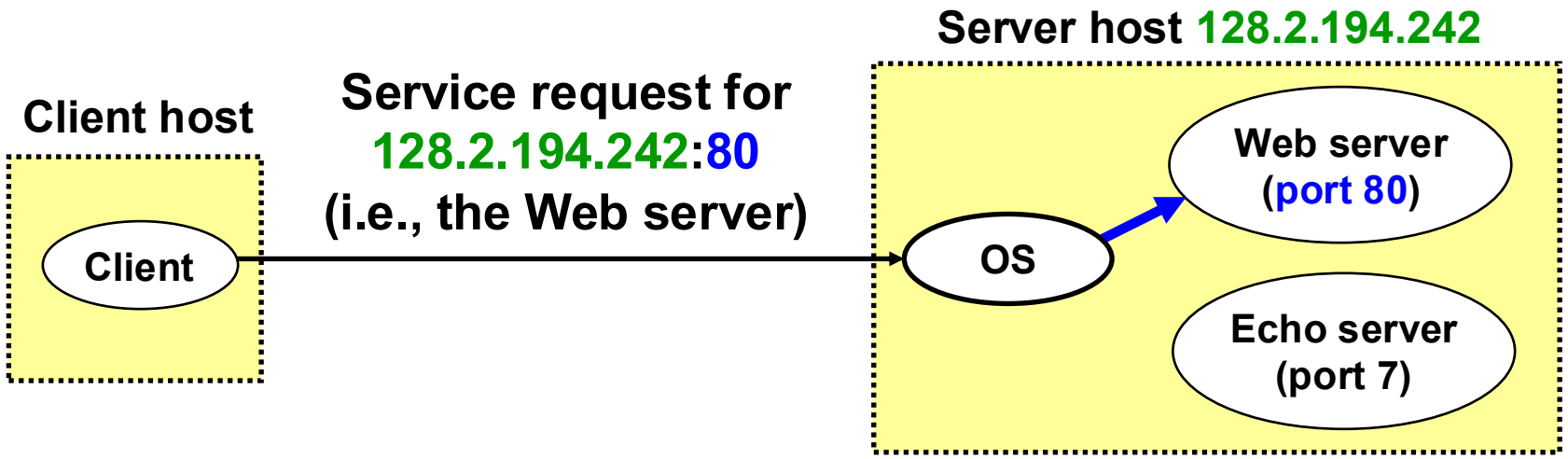
- Best-effort packet delivery is a clumsy abstraction
  - Applications typically want higher-level abstractions
  - Messages, uncorrupted data, reliable in-order delivery



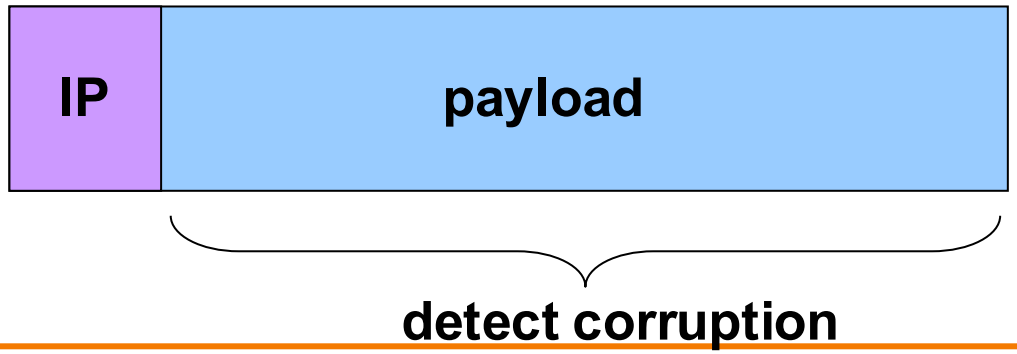
- Applications communicate using "sockets"
  - Stream socket: reliable stream of bytes (like a file)
  - Message socket: unreliable message delivery

Two Basic Transport Features

- **Demultiplexing:** port numbers



- **Error detection:** checksums



Two Main Transport Layers

- User Datagram Protocol (UDP)
  - Just provides demultiplexing and error detection
  - Header fields: port numbers, checksum, and length
  - Low overhead, good for query/response and multimedia
- Transmission Control Protocol (TCP)
  - Adds support for a “stream of bytes” abstraction
  - Retransmitting lost or corrupted data
  - Putting out-of-order data back in order
  - Preventing overflow of the receiver buffer
  - Adapting the sending rate to alleviate congestion
  - Higher overhead, good for most stateful applications

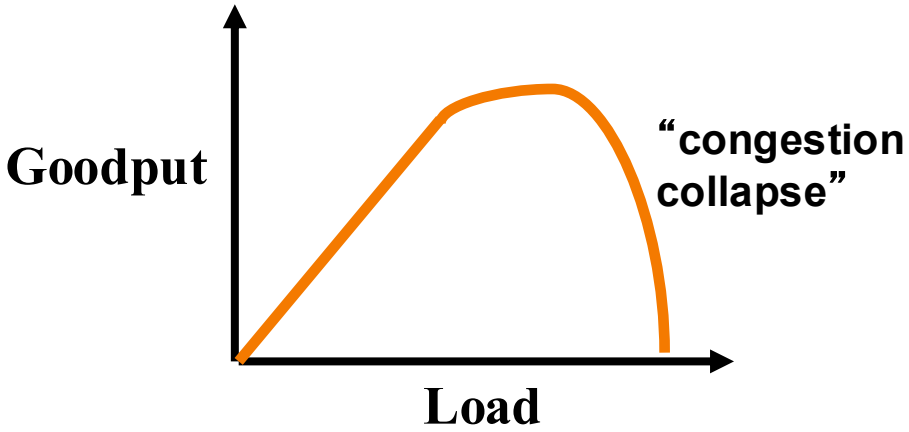
Questions

- Is a socket between two IP addresses the right abstraction?
  - Mobile hosts?
  - Replicated services?
- What does the network know about the traffic?
  - Inferring the application from the port numbers?
- Is end-to-end error detection and correction the right model?
  - High loss environments?
  - Expense of retransmitting over the entire path?

Distributed Resource Sharing

Resource Allocation Challenges

- Best-effort network easily becomes overloaded
  - No mechanism to "block" excess calls
  - Instead excess packets are simply dropped
- Examples
  - Shared Ethernet medium: frame collisions
  - Ethernet switches and IP routers: full packet buffers
- Quickly leads to congestion collapse

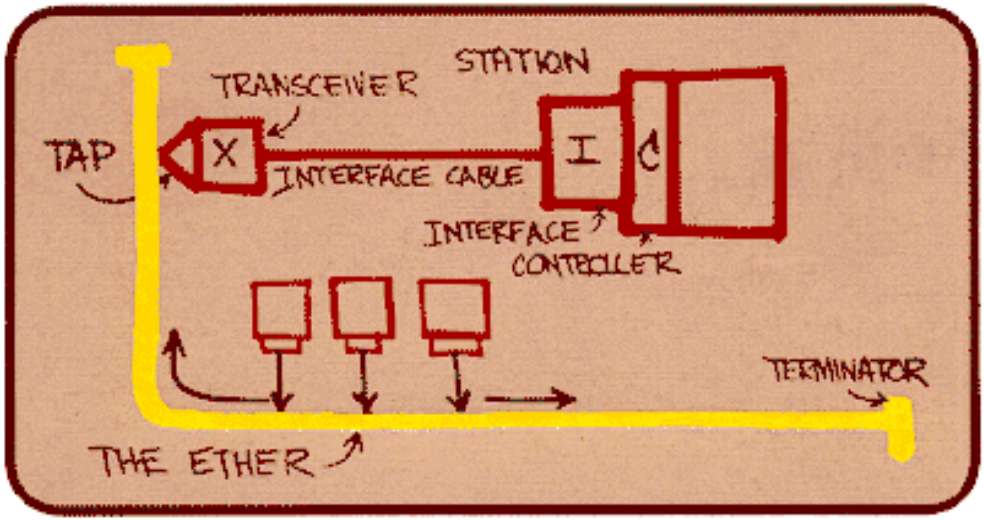


Increase in load that results in a *decrease* in useful work done.

End Hosts Adjusting to Congestion

- End hosts adapt their sending rates
  - In response to network conditions
- Learning that the network is congested
  - Shared Ethernet: carrier sense multiple access
    - Seeing your own frame collide with others
  - IP network: observing your end-to-end performance
    - Packet delay or loss over the end-to-end path
- Adapting to congestion
  - Slowing down the sending rate, for the greater good
  - But, host doesn't know how bad things might be…

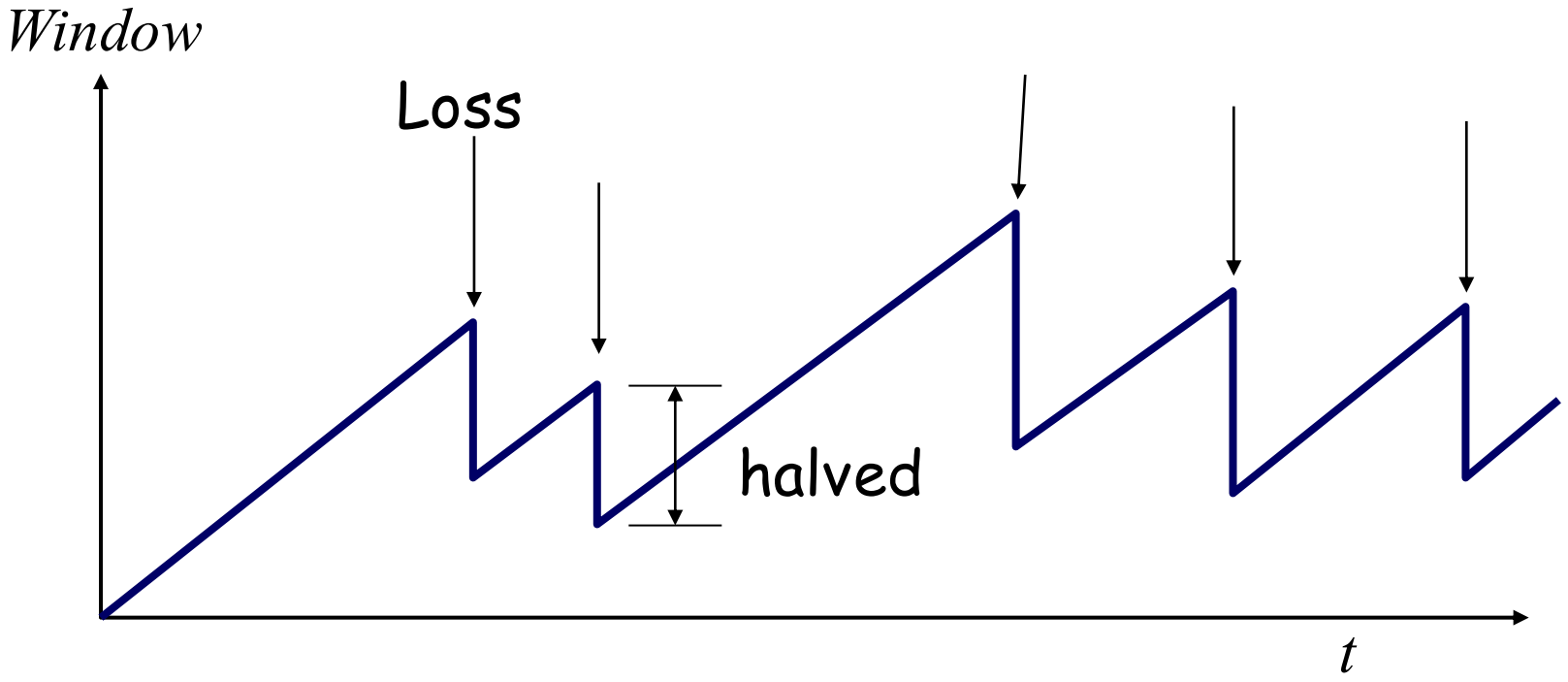
Ethernet Back-off Mechanism



- Carrier sense: wait for link to be idle
  - If idle, start sending; if not, wait until idle
- Collision detection: listen while transmitting
  - If collision: abort transmission, and send jam signal
- Exponential back-off: wait before retransmitting
  - Wait random time, exponentially larger on each retry

TCP Congestion Control

- Additive increase, multiplicative decrease
  - On packet loss, divide congestion window in half
  - On success for last window, increase window linearly



Other mechanisms: slow start, fast retransmit vs. timeout loss, etc.

Questions

- What role should the network play in resource allocation?
  - Explicit feedback to the end hosts?
  - Enforcing an explicit rate allocation?
- What is a good definition of fairness?
- What about hosts who cheat to hog resources?
  - How to detect cheating? How to prevent/punish?
- What about wireless networks?
  - Difficulty of detecting collisions
  - Loss caused by interference, not just congestion

Perusall Discuss

- "The Design Philosophy of the DARPA Internet Protocols" [Clark88]

Next Time

- A Protocol for Packet Network Intercommunication
- End-to-End Arguments in System Design