CS 43: Computer Networks

06:Distributed Systems and DNS

September 22, 2025

Slides adapted from Kurose & Ross, Vasanta Chaganti, Kevin Webb

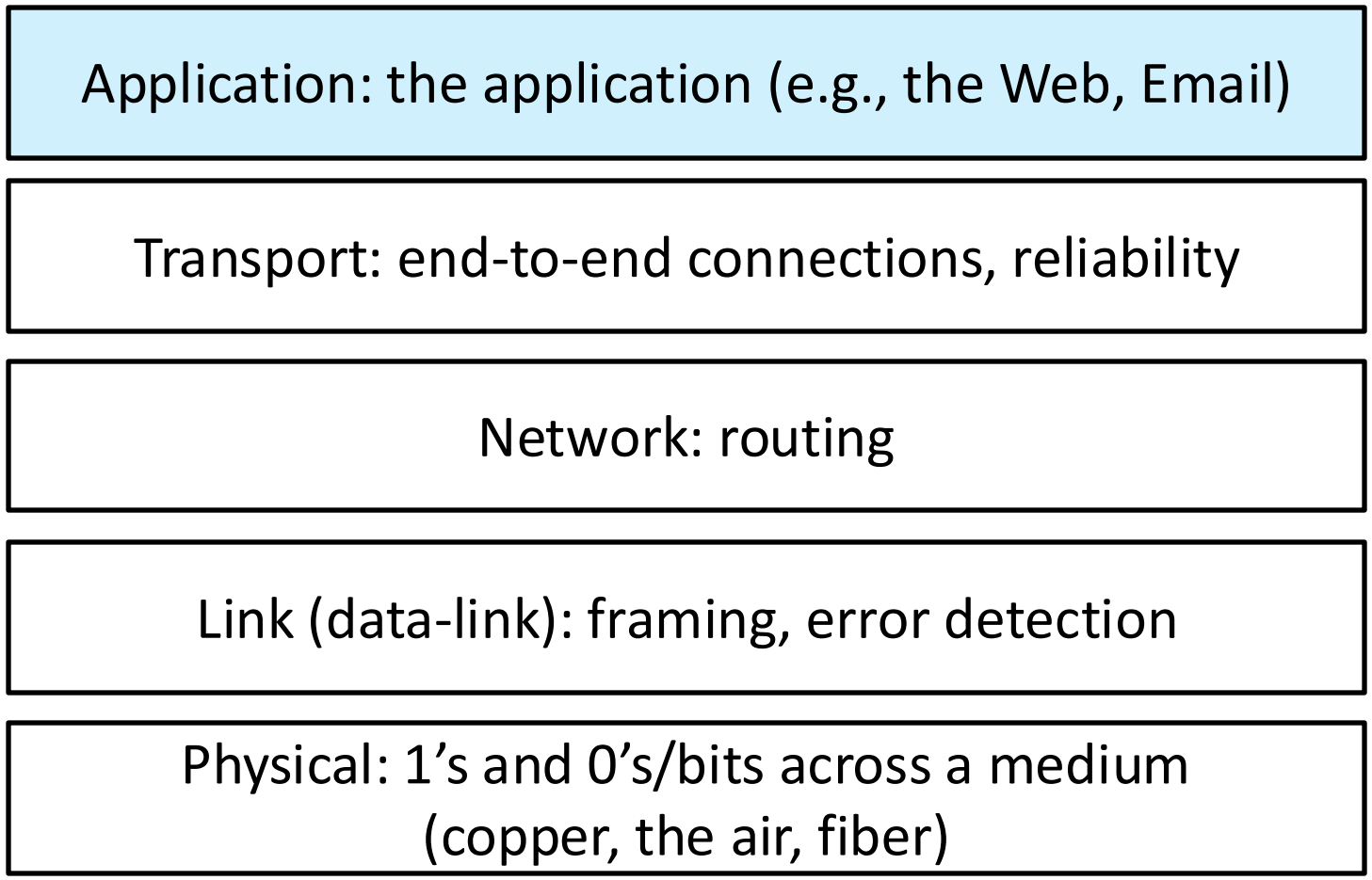
Last class

- HTTP web servers and socket programming
- Concurrency

Today

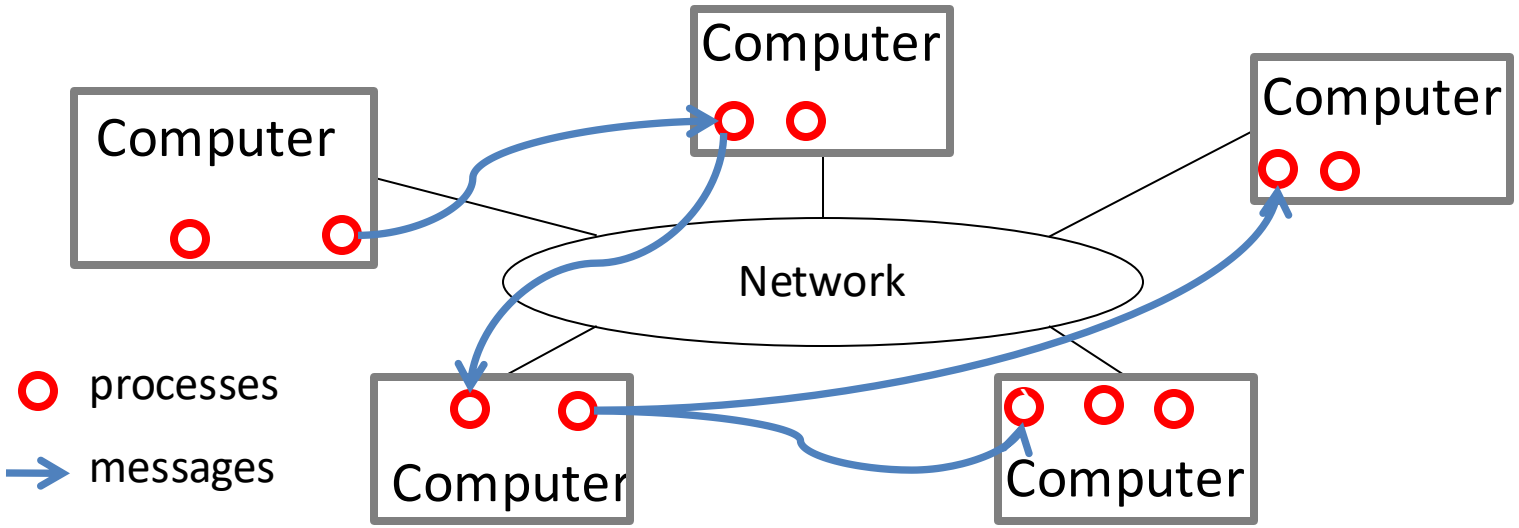
- Distributed network applications: Sources of complexity
- DNS

Where we are


Application: the application (e.g., the Web, Email)
Transport: end-to-end connections, reliability
Network: routing
Link (data-link): framing, error detection
Physical: 1's and 0's/bits across a medium
(copper, the air, fiber)

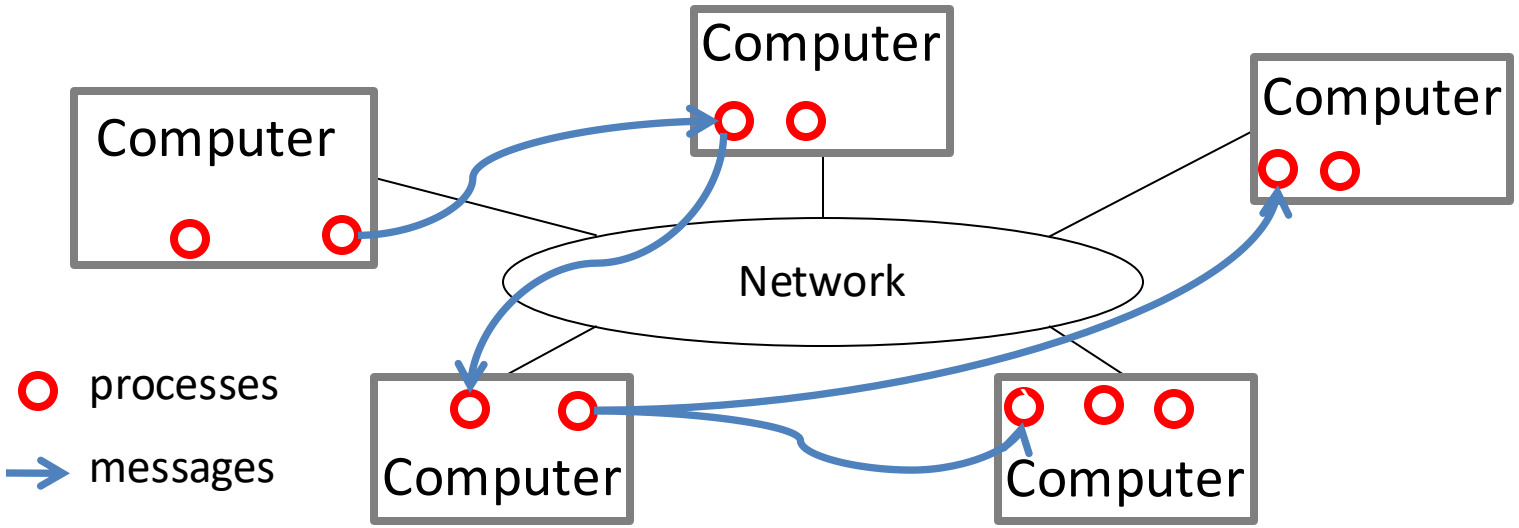
Distributed Network Applications

What is a distributed application?



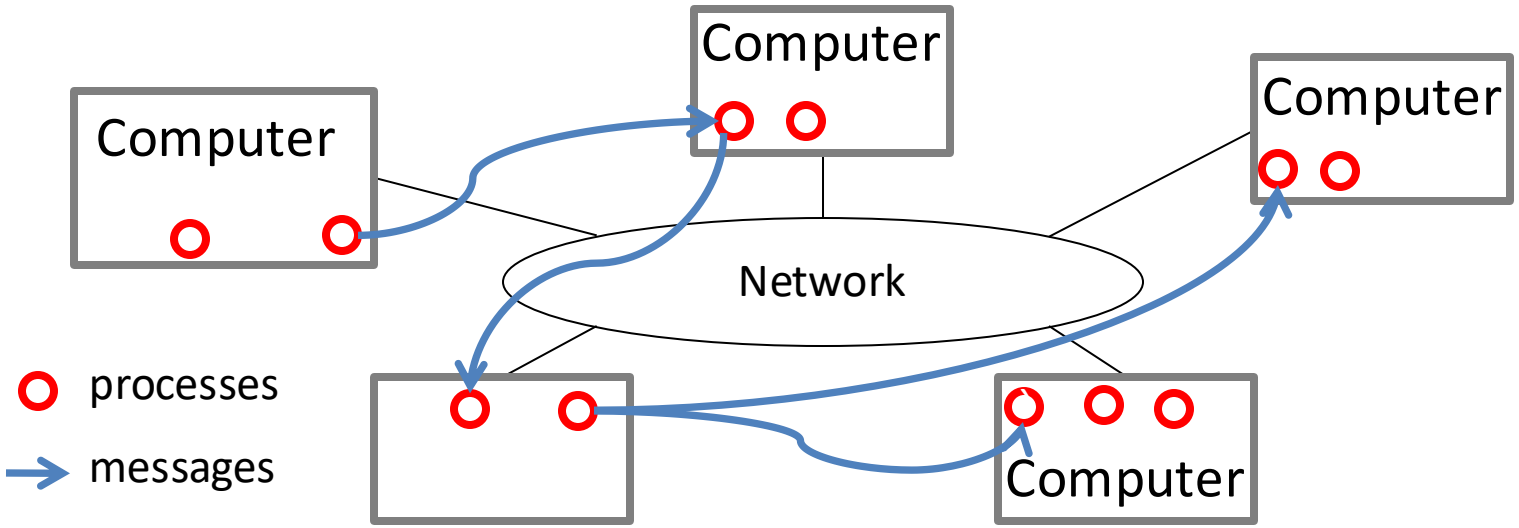
- Cooperating processes in a computer network
- Varying degrees of integration
  - Loose: email, web browsing
  - Medium: chat, Skype, remote execution, remote file systems
  - Tight: process migration, distributed file systems

Distributed Systems: Advantages



- Speed: parallelism, less contention
- Reliability: redundancy, fault tolerance
- Scalability: incremental growth, economy of scale
- Geographic distribution: low latency, reliability

Distributed Systems: Disadvantages



- Fundamental problems of decentralized control
  - State uncertainty: no shared memory or clock
  - Action uncertainty: mutually conflicting decisions
- Distributed algorithms are complex

If one machine can process requests at a rate of X per second, how quickly can two machines process requests?

A. Slower than one machine (<X)
B. The same speed (X)
C. Faster than one machine, but not double (X-2X)
D. Twice as fast (2X)
E. More than twice as fast(>2X)

If one CPU core can run a program at a rate of X, how quickly will the program run on two cores? Why?

A. Slower than one core (<X) (if we try to parallelize serial applications!)
B. The same speed (X) (some applications are not parallelizable)
C. Faster than one core, but not double (X-2X): most of the time: (some communication overhead to coordinate/synchronization of the threads)
D. Twice as fast (2X)(class of problems called embarrassingly parallel programs. E.g. protein folding, SETI)
E. More than twice as fast(>2X) (rare: possible if you have more CPU + more memory)

On a single system…

- You have a number of components
  - CPU
  - Memory
  - Disk
  - Power supply

- If any of these go wrong, you're (usually) toast.

On multiple systems…

- New classes of failures (**partial failures**).
  - A link might fail
  - One (of many) processes might fail
  - The network might be partitioned

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Introduces major complexity!

If a process sends a message, can it tell the difference between a slow link and a delivery failure?

A. Yes

B. No

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B. No

What should we do to handle a partial failure? Under what circumstances, or what types of distributed applications?

A. If one process fails or becomes unreachable, switch to a spare.
B. Pause or shut down the application until all connectivity and processes are available.
C. Allow the application to keep running, even if not all processes can communicate.
D. Handle the failure in some other way.

What should we do to handle a partial failure? Under what circumstances, or what types of distributed applications?

A. If one process fails or becomes unreachable, switch to a spare (not possible if this was a datacenter).
B. Pause or shut down the application until all connectivity and processes are available. (If it is a critical system: banking, air travel).
C. Allow the application to keep running, even if not all processes can communicate (non-critical, social network applications)
D. Handle the failure in some other way.

Desirable Properties

- Consistency
  - Nodes agree on the distributed system's state
- Availability
  - The system is able and willing to process requests
- Partition tolerance
  - The system is robust to network (dis)connectivity

The CAP Theorem

- **C**onsistency
  - Nodes agree on the distributed system's state
- **A**vailability
  - The system is able and willing to process requests
- **P**artition tolerance
  - The system is robust to network (dis)connectivity
- Choose Two
- "CAP prohibits only a tiny part of the design space: perfect availability and consistency in the presence of partitions, which are rare."*

* Brewer, Eric. "CAP twelve years later: How the" rules" have changed." Computer 45.2 (2012): 23-29.

Consistency: Event Ordering

- It's very useful if all nodes can agree on the order of events in a distributed system

- For example: Two users trying to update a shared file across two replicas

If two events occur (digitally or in the "real world"), can we always tell which happened first?

A. Yes

B. No

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B. No

"Relativity of simultaneity"

- Example: observing car crashes
- Exception: causal relationship

Consistency: Event Ordering

- It's very useful if all nodes can agree on the order of events in a distributed system
- For example: Two users trying to update a shared file across two replicas
- "Time, Clocks, and the Ordering of Events in a Distributed System" by Leslie Lamport (1978)
  - Establishes causal orderings
  - Cited > 8000 times

Causal Consistency Example

- Suppose we have the following scenario:
  - Sally posts to Facebook, “Bill is missing!”
  - (Bill is at a friend’s house, sees message, calls mom)
  - Sally posts new message, “False alarm, he’s fine”
  - Sally’s friend James posts, “What a relief!”

Causal Consistency Example

- Suppose we have the following scenario:
  - Sally posts to Facebook, “Bill is missing!”
  - Sally’s friend James posts, “What a relief!
- NOT causally consistent:
  - Third user, Henry, sees only:
  - Sally posts to Facebook, “Bill is missing!”
  - Sally’s friend James posts, “What a relief!”

Causal Consistency Example

- Suppose we have the following scenario:
  1. Sally posts to Facebook, “Bill is missing!” (Bill is at a friend’s house, sees message, calls mom)
  2. Sally posts new message, “False alarm, he’s fine”
  3. Sally’s friend James posts, “What a relief!”

- Causally consistent version:
  - Because James had seen Sally’s second post (which caused his response), Henry must also see it prior to seeing James’s.

Summary

- Distributed systems are hard to build!
  - Partial failures
  - Ordering of events

- Take CS 87 for more details!

Today

- Identifiers and addressing

- Domain Name System
  - Telephone directory of the Internet
  - Protocol format
  - Caching: Load balancing
  - Security Challenges

DNS: Domain Name System

People: many identifiers:

- name, swat ID, SSN, passport #

Internet hosts (endpoints), routers (devices inside a n/w):

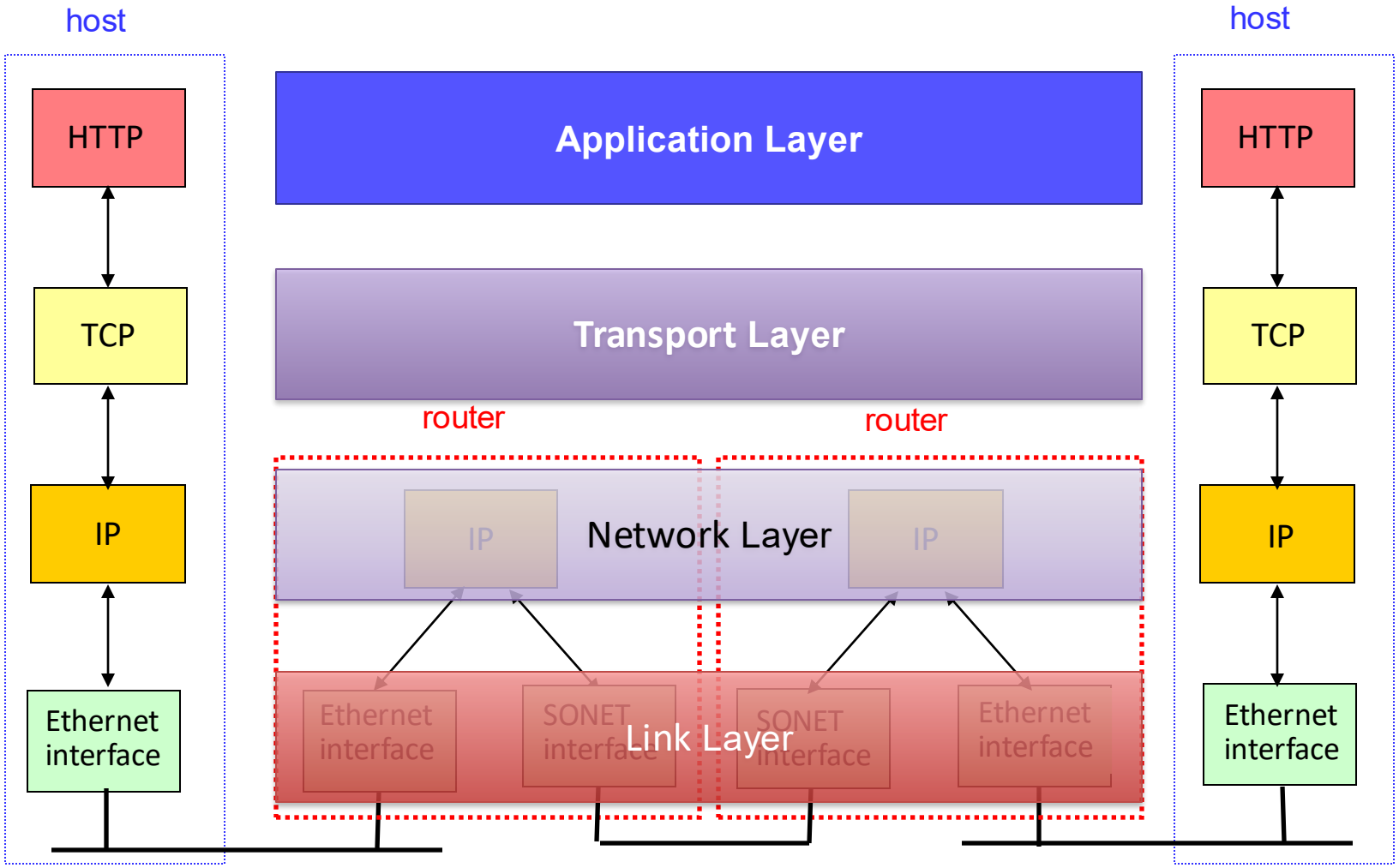
- "name", e.g., www.google.com - used by humans
- IP address (32 bit) - used for addressing packets

How do we map between IP address and name, and vice versa ?

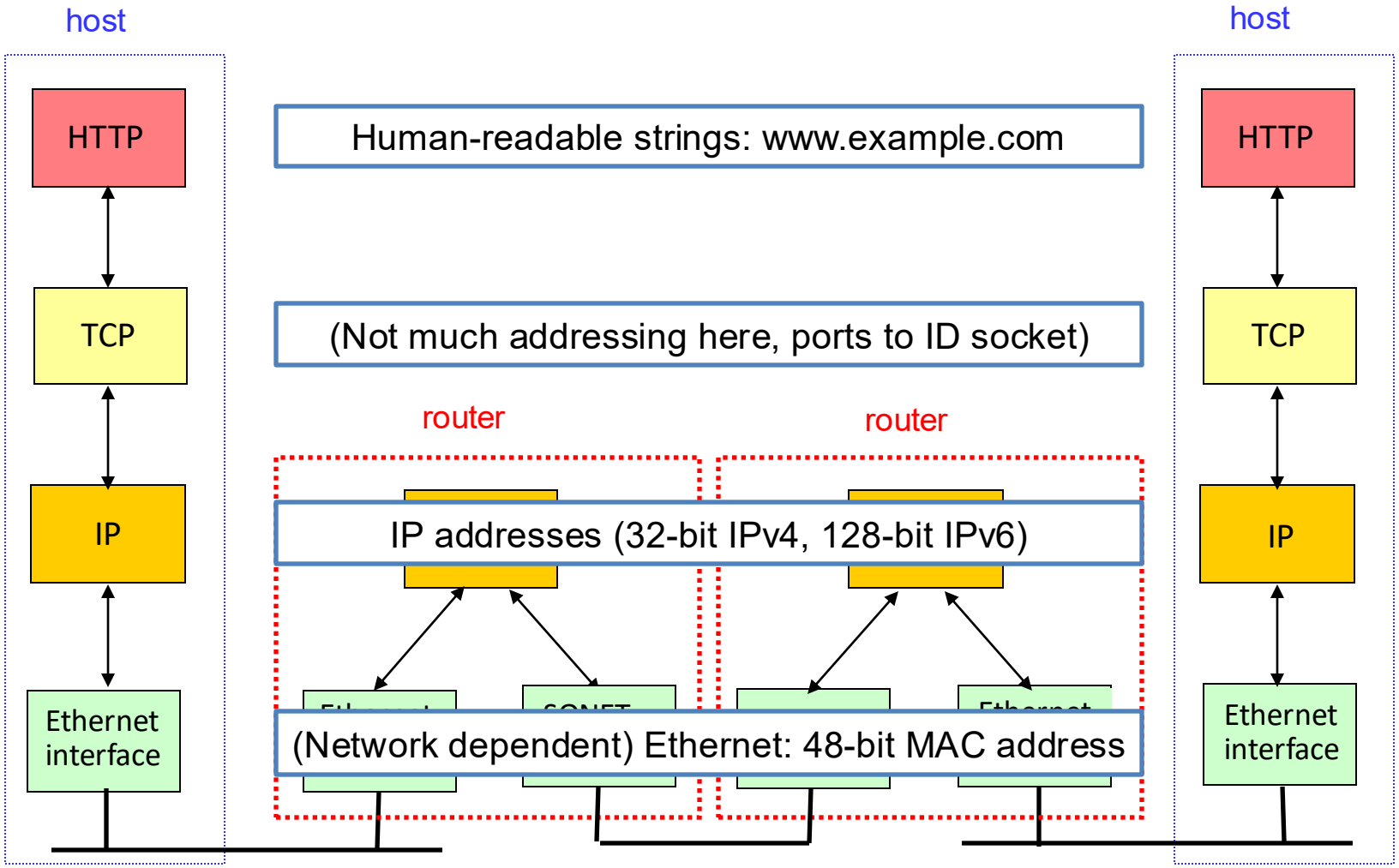
DNS: Application Layer Protocol

- distributed database
  - implemented in hierarchy of many name servers.
- application-layer protocol:
  - hosts communicate to name servers
  - resolve names → addresses
- *note: core Internet function, implemented as application-layer protocol*

Where


host
host
HTTP
TCP
IP
Ethernet interface
Application Layer
Transport Layer
router
router
IP
Network Layer
IP
Ethernet interface
SONET interface
Link Layer
SONET interface
Ethernet interface
HTTP
TCP
IP
Ethernet interface

Recall: TCP/IP Protocol Stack



DNS: domain name system

- distributed database implemented in hierarchy of many name servers.
- application-layer protocol: hosts, name servers communicate to resolve names → addresses
  - *note: core Internet function, implemented as application-layer protocol*
  - *complexity at network's "edge"*

Why do we need to map names to IP addresses? Why not route on names at the network layer?

A. Domain names are hierarchical, so we can route on domain names too.
B. Domain names are variable length, vs IP are fixed length, some changes will be required to switch.
C. With domain names we wouldn't know where to route to geographically.
D. Some other reason.

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A. Domain names are hierarchical, so we can route on domain names too (Named Data Networking Efforts).
B. Domain names are variable length, vs IP are fixed length, some changes will be required to switch.
C. With domain names we wouldn't know where to route to geographically (mostly true).
D. Some other reason.

Identifiers

- Host name (e.g., www.swarthmore.edu)
  - Used by humans to specify host of interest
  - Unique, selected by host administrator
  - Hierarchical, variable-length string of alphanumeric characters
- IP address (e.g., 130.58.68.164)
  - Used by routers to forward packets
  - Unique, topologically meaningful locator
  - Hierarchical namespace of 32 bits

Mapping Between Identifiers

- Domain Name System (DNS)
  - Given a host name, provide the IP address
  - Given an IP address, provide the host name

What's the biggest challenge for DNS?

A. It's old.

B. The fact that the Internet is global.

C. The fact that DNS is now critical infrastructure.

D. The sheer number of name lookups happening at any given time.

E. How and when the name -> IP address mapping should change.

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In the old days…

- Pre-1982, everyone downloads a "hosts.txt" file from Standford Research Institute
- Pre-1998, Jon Postel, researcher at USC, runs the Internet Assigned Numbers Authority (IANA)
  - RFCs 882 & 883 in 1983
  - RFCs 1034 & 1035 in 1987

Emailed 8/12 root DNS servers, asked change to his authority. They did.

http://www.wired.com/wiredenterprise/2012/10/joe-postel/

Since 1998…

- Control of Internet Assigned Numbers Authority (IANA) transferred to Internet Corporation for Assigned Names and Numbers (ICANN)
  - ICANN is a private non-profit (formerly) blessed by US Department of Commerce
  - Global advisory committee for dealing with international issues
  - 2000's: Many efforts for UN control, US resisted
  - 2016: ICANN no longer partnered with DOC

Who should control DNS?

A. US government

B. UN / International government

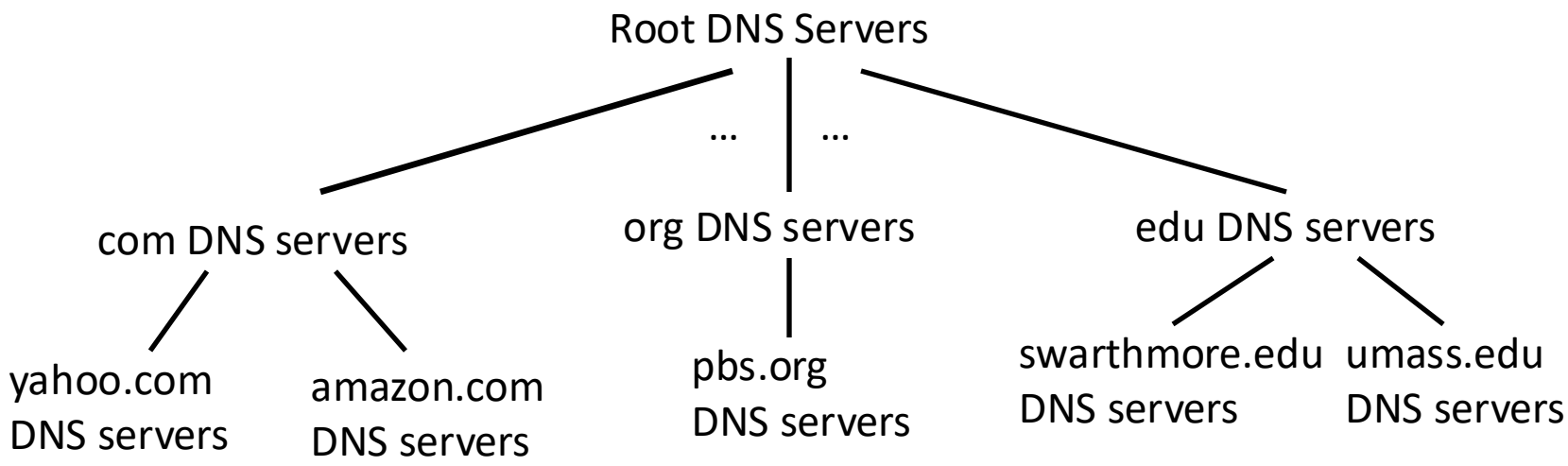
C. Private corporation

D. Someone else

DNS Services

- DNS is an application-layer protocol. E2E design!
- It provides:
  - Hostname to IP address translation
  - Host aliasing (canonical and alias names)
  - Mail server aliasing
  - Load distribution (one name may resolve to multiple IP addresses)
  - Lots of other stuff that you might use a directory service to find. (Wikipedia: List of DNS record types)

DNS: a distributed, hierarchical database



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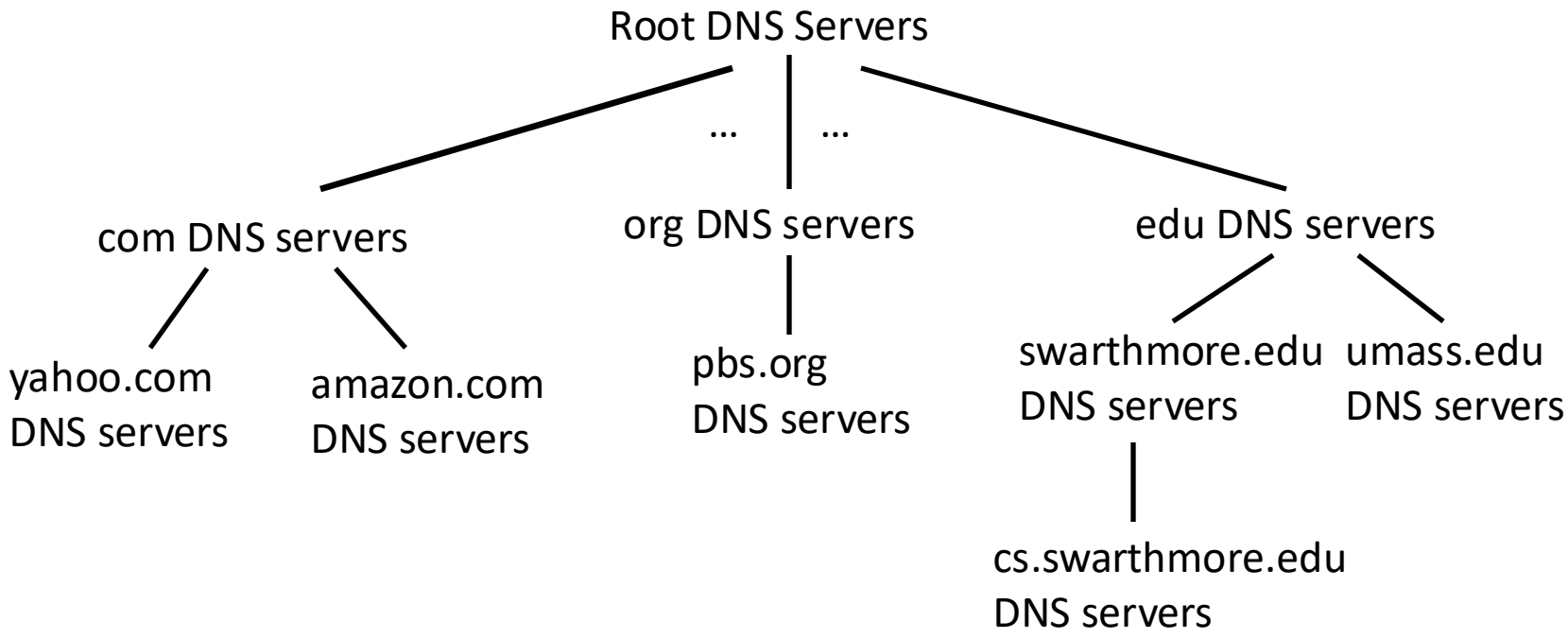

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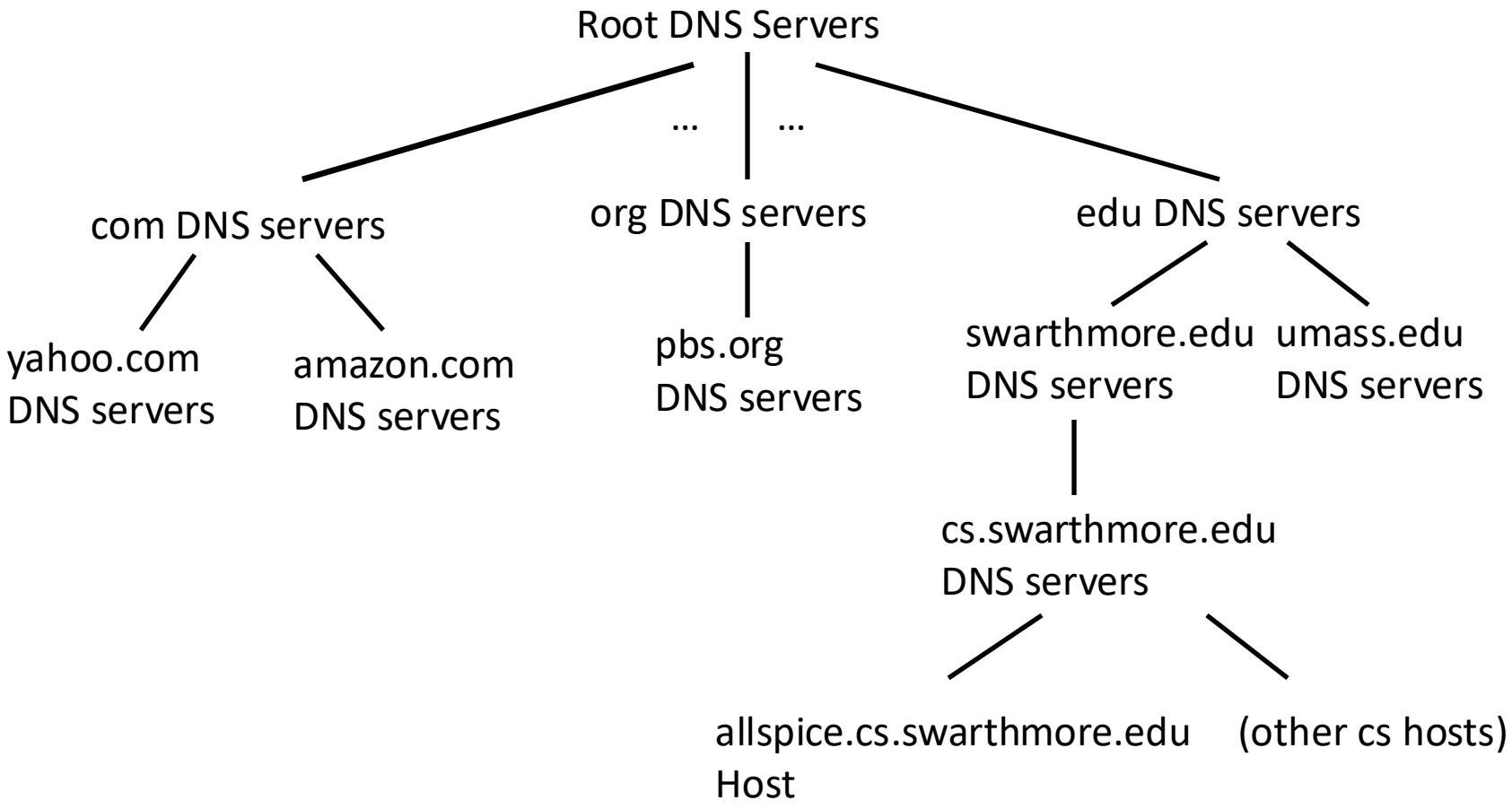

- allspice.cs.swarthmore.edu.

Nameless root,
Usually implied.

Domain Name System (DNS)

- Distributed administrative control
  - Hierarchical name space divided into zones
  - Distributed over a collection of DNS servers
- Hierarchy of DNS servers
  - Root servers
  - Top-level domain (TLD) servers
  - Authoritative DNS servers
- Performing the translations
  - Local DNS servers
  - Resolver software

Why do we structure DNS like this? Which of these helps the most? Drawbacks?

A. It divides up responsibility among parties.

B. It improves performance of the system.

C. It reduces the size of the state that a server needs to store.

D. Some other reason.

Why do we structure DNS like this? Which of these helps the most? Drawbacks?

A. It divides up responsibility among parties.

B. It improves performance of the system overall but individual end hosts (assuming no caching) have a look-up overhead of traversing the hierarchy .

C. It reduces the size of the state that a server needs to store.

D. Some other reason.