CS 43: Computer Networks
Naming and DNS

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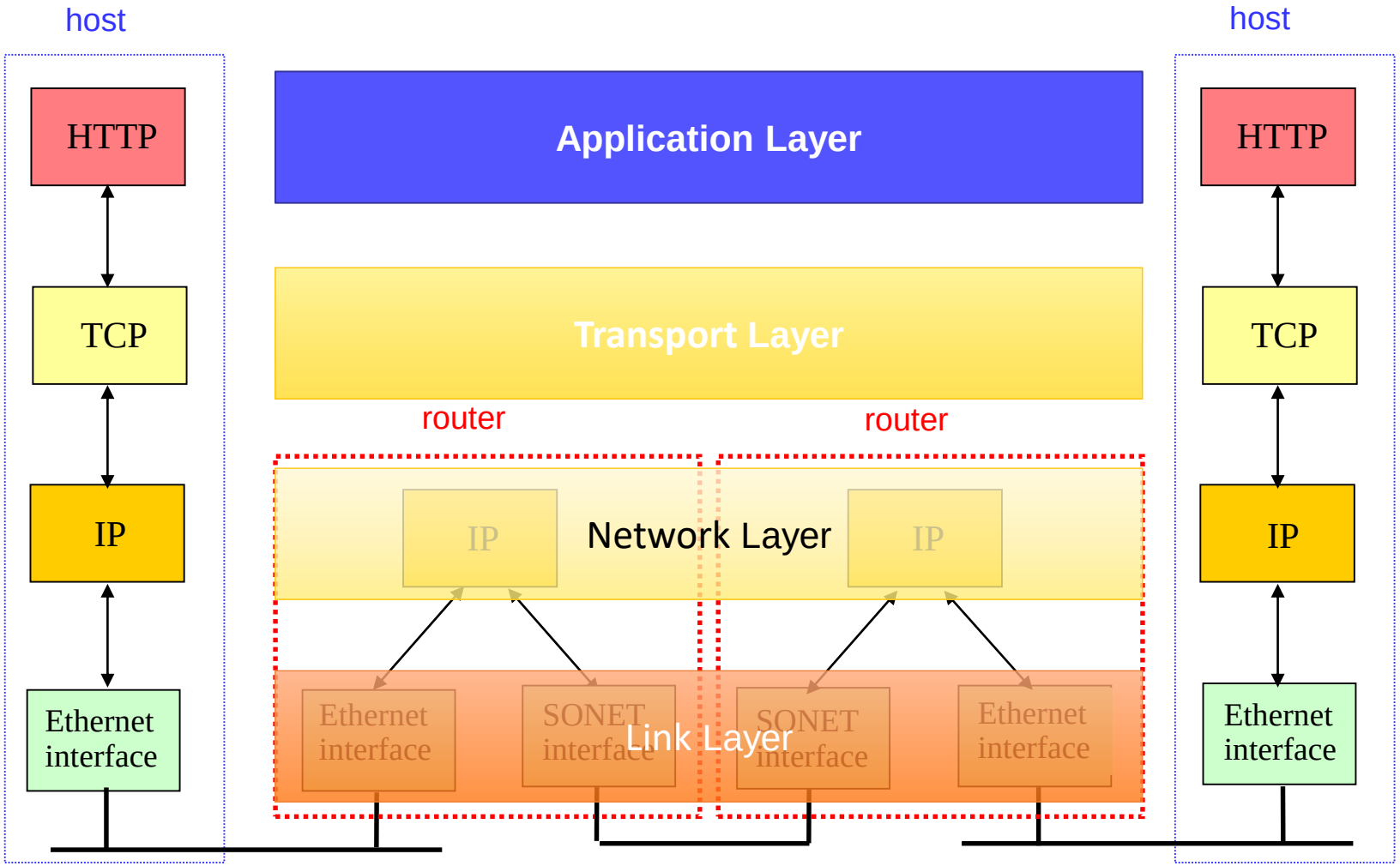
Agenda

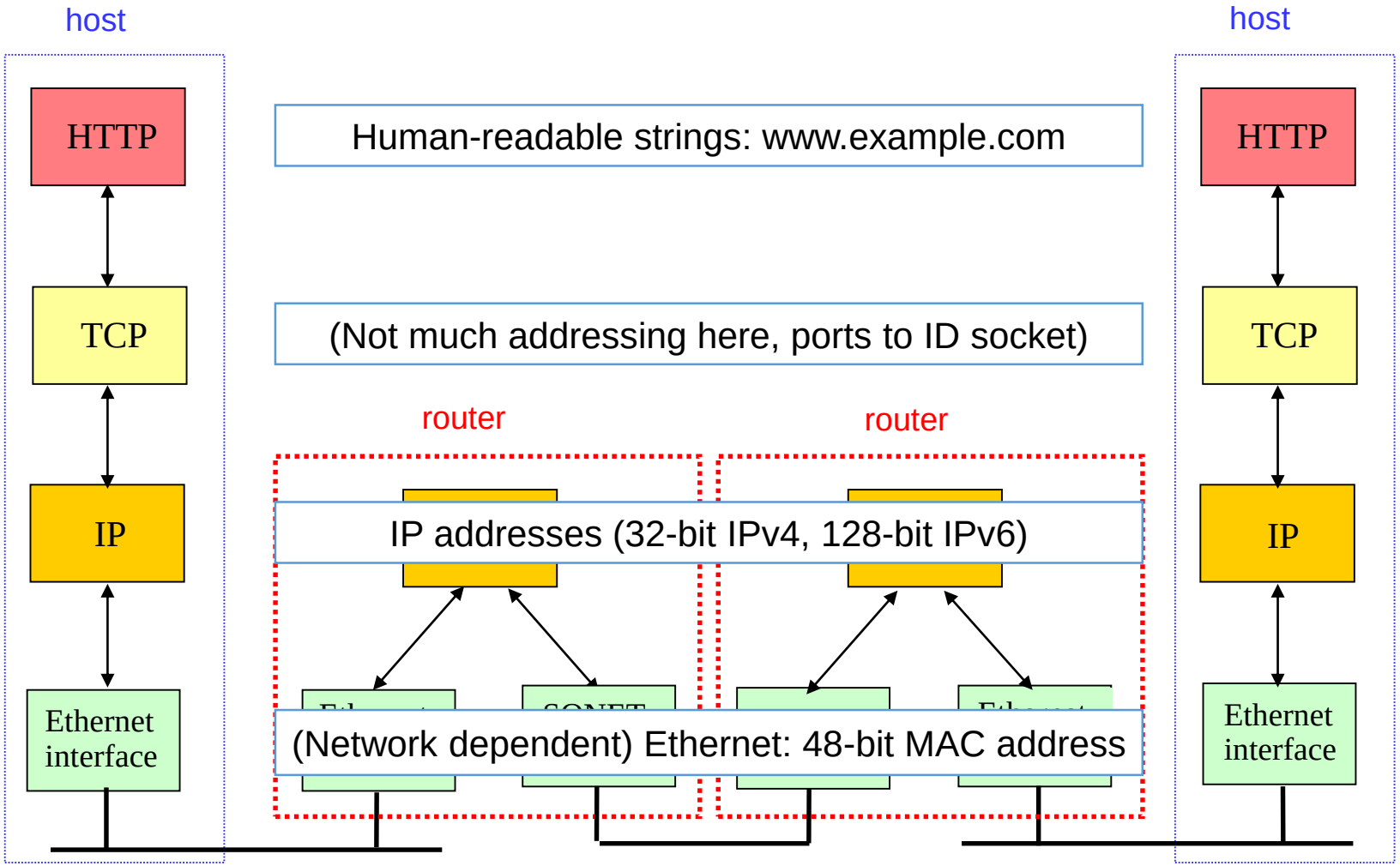
- Identifiers and addressing

- Domain Name System
  - History
  - Query sequences
  - Record types
  - Load balancing

Recall: TCP/IP Protocol Stack



Recall: TCP/IP Protocol Stack



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
- MAC address (e.g., D8:D3:85:94:5F:1E)
  - Used by *network adaptors (a.k.a. interfaces)* to identify interesting frames
  - Unique, hard-coded identifier burned into network adaptor
  - Flat name space (of 48 bits in Ethernet)

Identifiers

- Host name (e.g., www.swarthmore.edu)
  - Each section, separated by dots, indicates one level of administrative control
- IP address (e.g., 130.58.68.164)
  - Prefixes: ICANN, regional Internet registries, and ISPs
  - Hosts: static configuration, or dynamic using DHCP
  - NOTE: not always split this way!
- MAC address (e.g., D8:D3:85:94:5F:1E)
  - OIDs: assigned to vendors by the IEEE
  - Adapters: assigned by the vendor from its block

Identifiers

- Host name (e.g., www.swarthmore.edu) (today)
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Mapping Between Identifiers

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

What’s the biggest challenge for DNS?

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.

In the old days…

- Pre-1982, everyone downloads a “hosts.txt” file from SRI
- 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 DOC
  - Global advisory committee for dealing with international issues
  - 2000's: Many efforts for UN control, US resisted
  - 2016: ICANN no longer partnered with DOC
- Lots of geopolitics here…

Who should control DNS?

(Why? What are the trade-offs or concerns?)

A. US government

B. UN / International government

C. Private corporation

D. Someone else

Recent Controversy

- Is ICANN working in the world's best interest?
- New "top level domains" added, for auction
- Example: the ".sucks" TLD (+ many others, e.g., .amazon)

Reality

- As computer scientists, it’s probably not up to us to decide. ☹
- Let’s focus on the technical aspects of DNS. ☺

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 Records

DNS: distributed DB storing resource records (RR)

RR format: `(name, value, type, ttl)`

type=A

- **name** is hostname
- **value** is IP address

type=NS

- **name** is domain (e.g., foo.com)
- **value** is hostname of authoritative name server for this domain

type=CNAME

- **name** is alias name for some "canonical" (the real) name
- **www.ibm.com** is really **servereast.backup2.ibm.com**
- **value** is canonical name

type=MX

- **value** is name of mail server associated with **name**

DNS protocol, messages

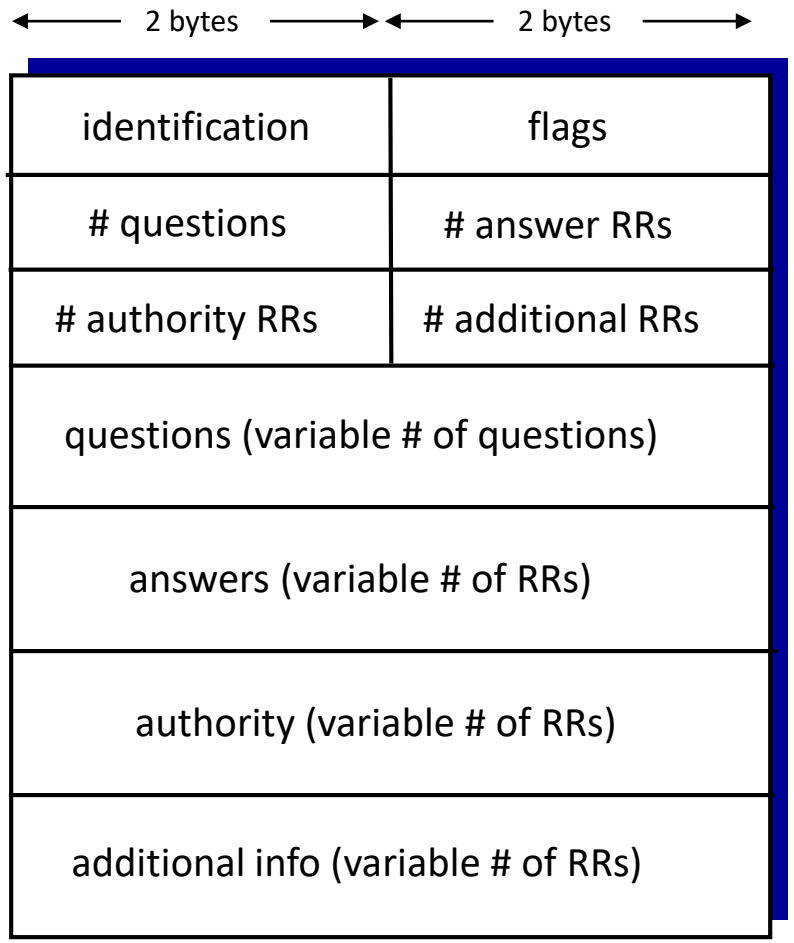
- *query* and *reply* messages, both with same *message format*

Message header

- identification: 16 bit # for query, reply to query uses same #
- flags:
  - query or reply
  - recursion desired
  - recursion available
  - reply is authoritative

Sent via UDP

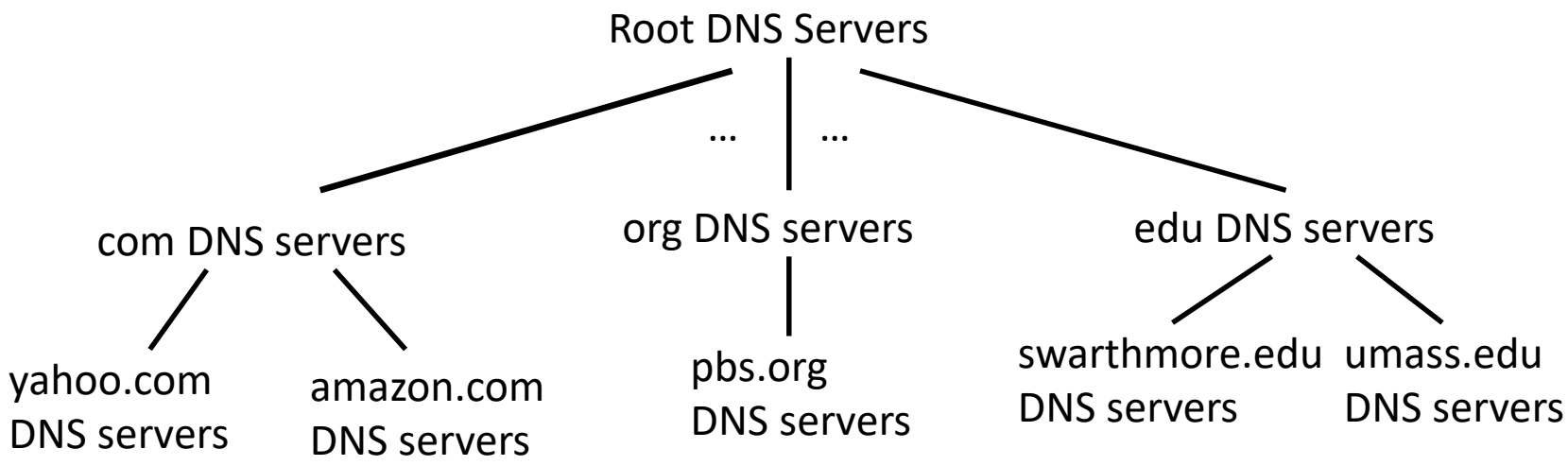
- No connection established
- Not reliable



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

DNS: a distributed, hierarchical database



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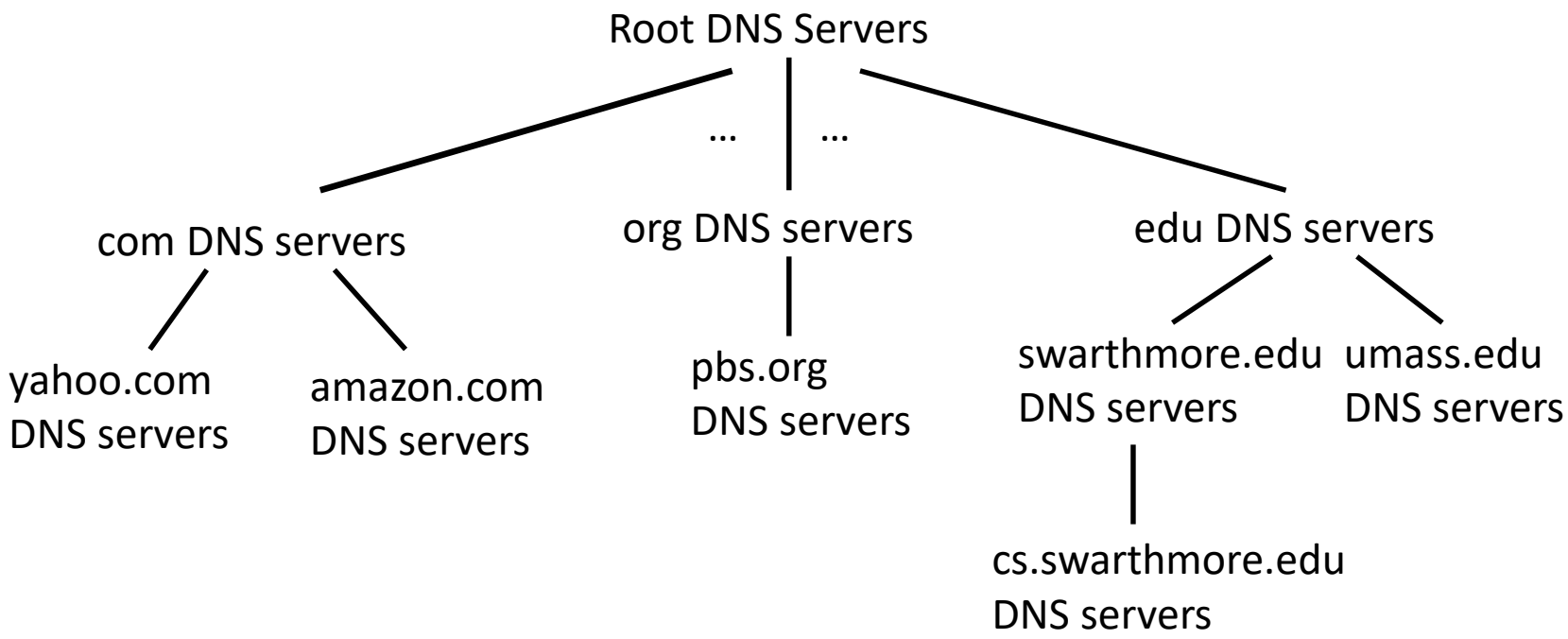

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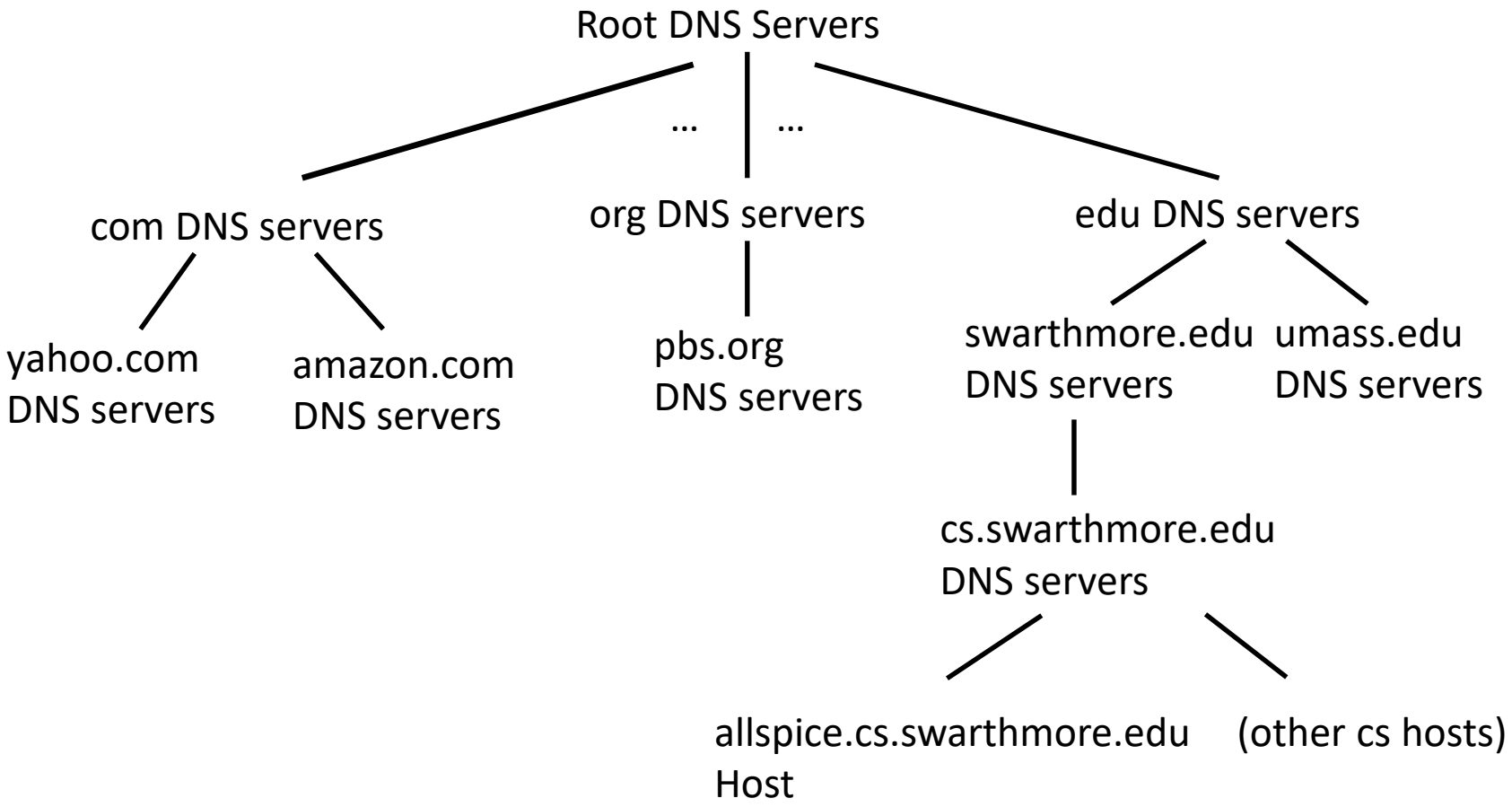


- allspice.cs.swarthmore.edu.

Nameless root,
Usually implied.

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

A. It divides up responsibility among parties.

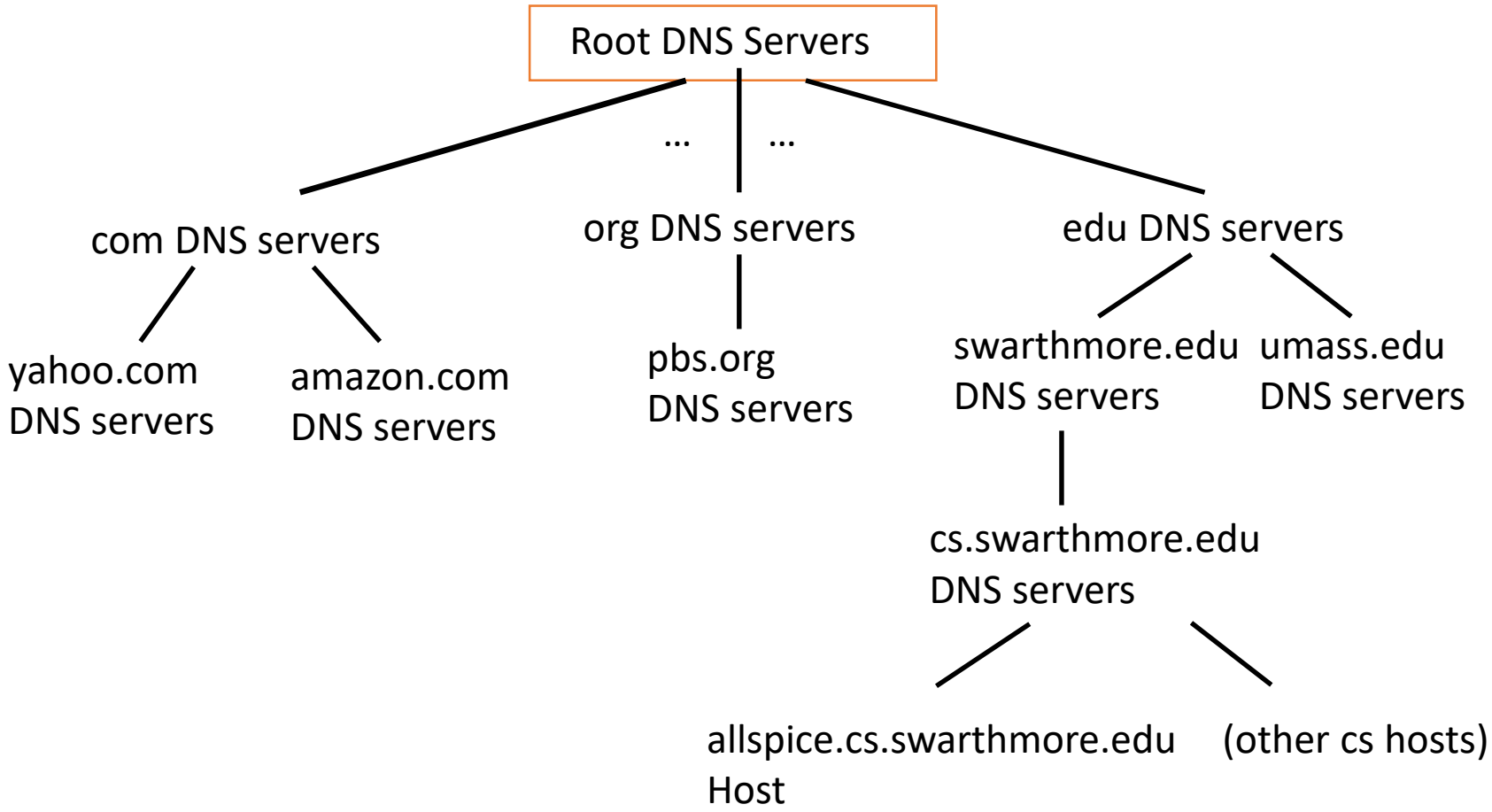
B. It improves the performance of the system.

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

D. Some other reason.

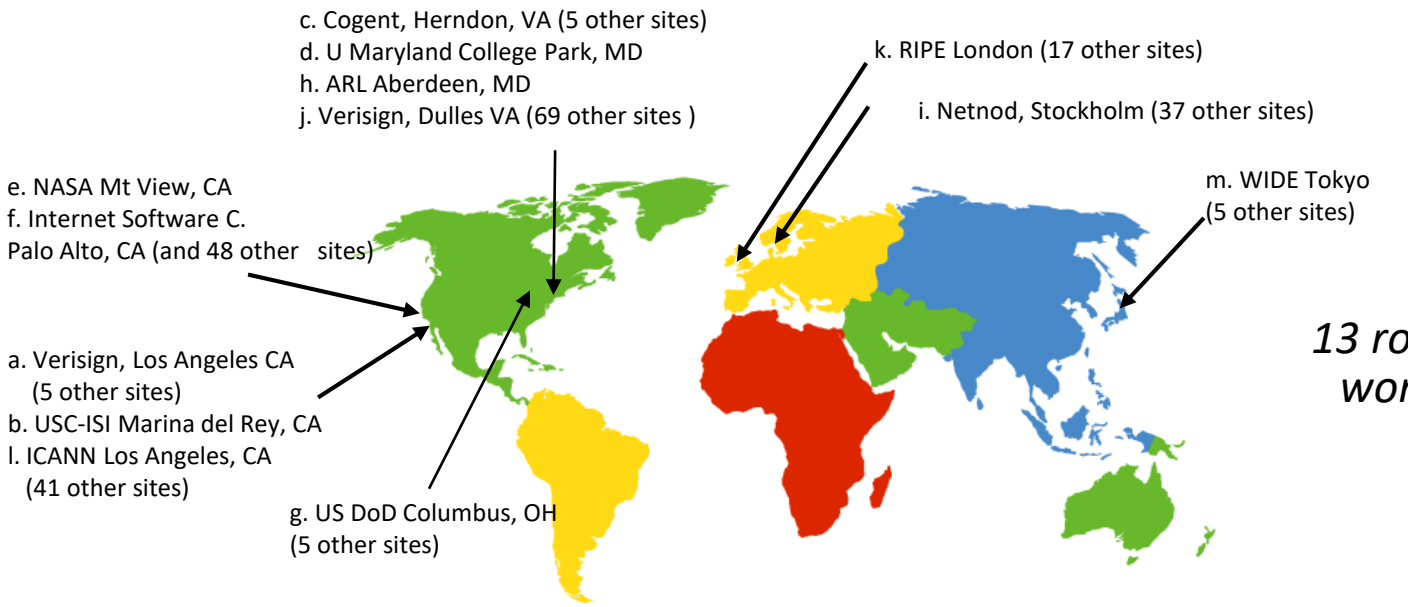
Drawbacks to this approach?

DNS: a distributed, hierarchical database



DNS: Root Name Servers

- Root name server:
  - Knows how to find top-level domains (.com, .edu, .gov, etc.)
  - How often does the location of a TLD change?



13 root name "servers" worldwide

DNS: Root Name Servers

- Root name server:
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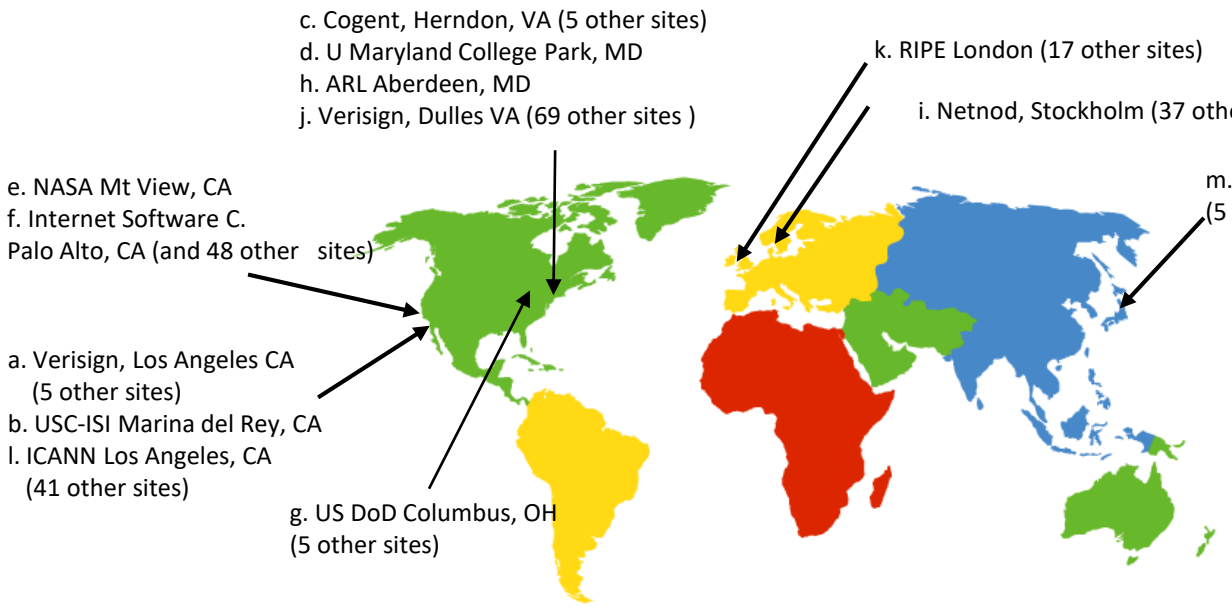
  - How often does the location of a TLD change?
  - ~300 total root servers
  - Significant amount of traffic is not legitimate



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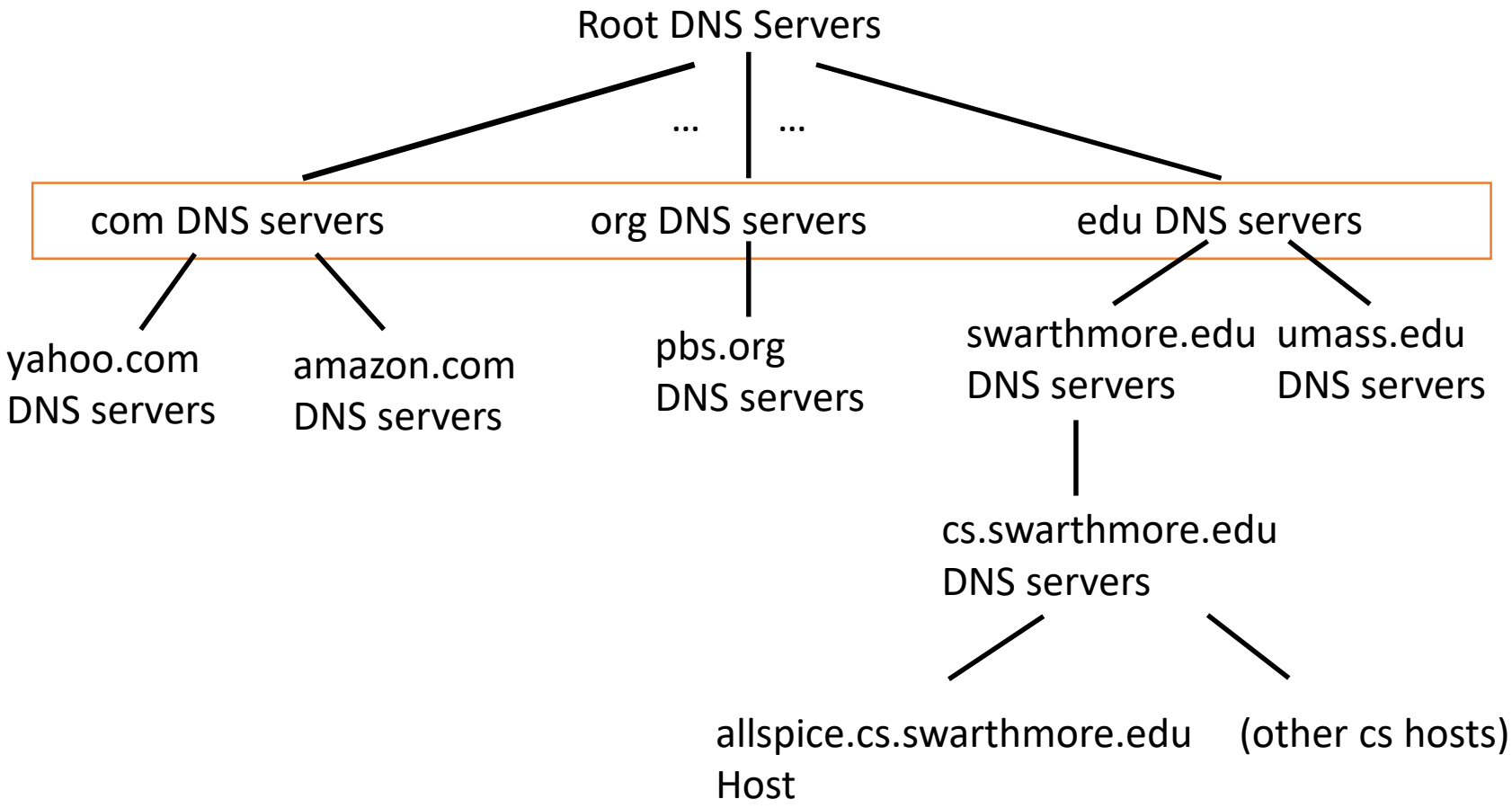
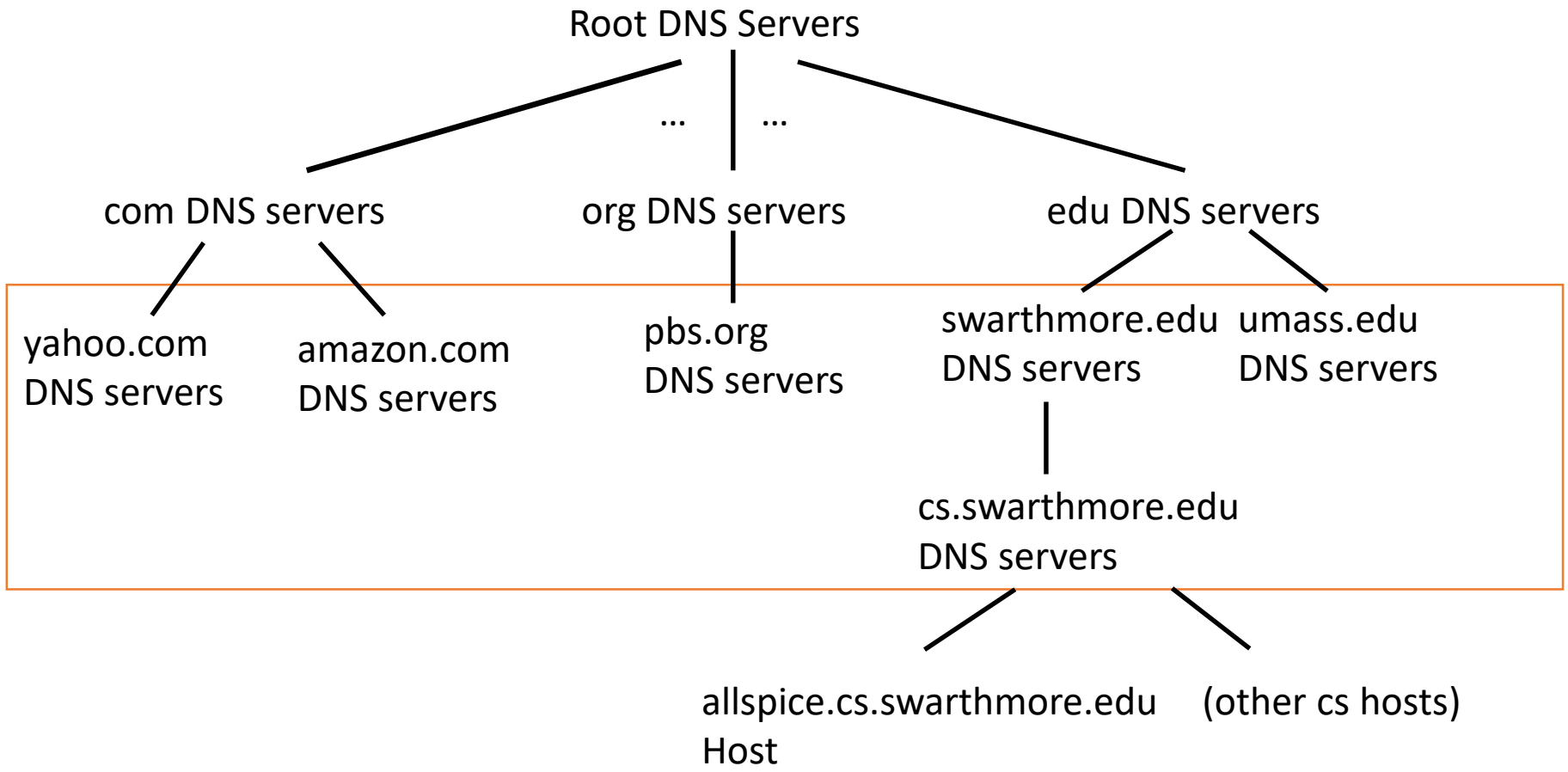


Top Level Domains

Top-level domain (TLD) servers:

- Responsible for com, org, net, edu, gov, aero, jobs, museums, and all top-level country domains, e.g.: uk, fr, de, ca, jp, etc.
- Verisign maintains servers for .com and .net TLD
- Educause for .edu TLD (Verisign actually runs backend)
- Others managed by corresponding entity (e.g., local governments or companies)

DNS: a distributed, hierarchical database



Authoritative Servers

Authoritative DNS servers:

- Organization's own DNS server(s), providing authoritative hostname to IP mappings for organization's named hosts
- Can be maintained by organization or service provider, easily changing entries
- Often, but not always, acts as organization's local name server (for responding to look-ups)

Resolution Process

- End host wants to look up a name, who should it contact?
  - It could traverse the hierarchy, starting at a root
  - More efficient for ISP to provide a local server
- ISP’s local server for handling queries not necessarily a part of the pictured hierarchy

Local DNS Name Server

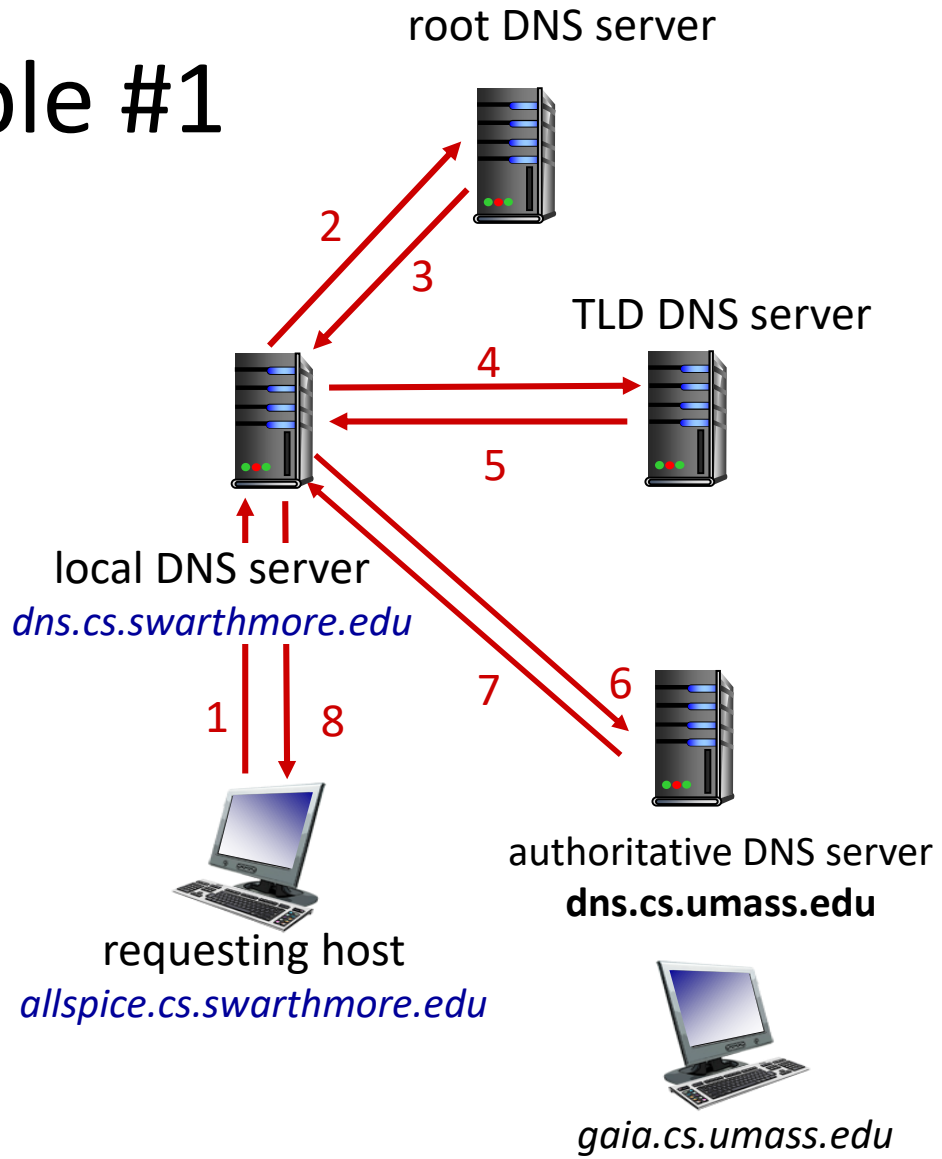
- Each ISP (residential ISP, company, university) has (at least) one
  - also called “default name server”
- When host makes DNS query, query is sent to its local DNS server
  - has local cache of recent name-to-address translation pairs (but may be out of date!)
  - acts as proxy, forwards query into hierarchy

DNS name resolution example #1

- allspice wants IP address for gaia.cs.umass.edu

iterative query:

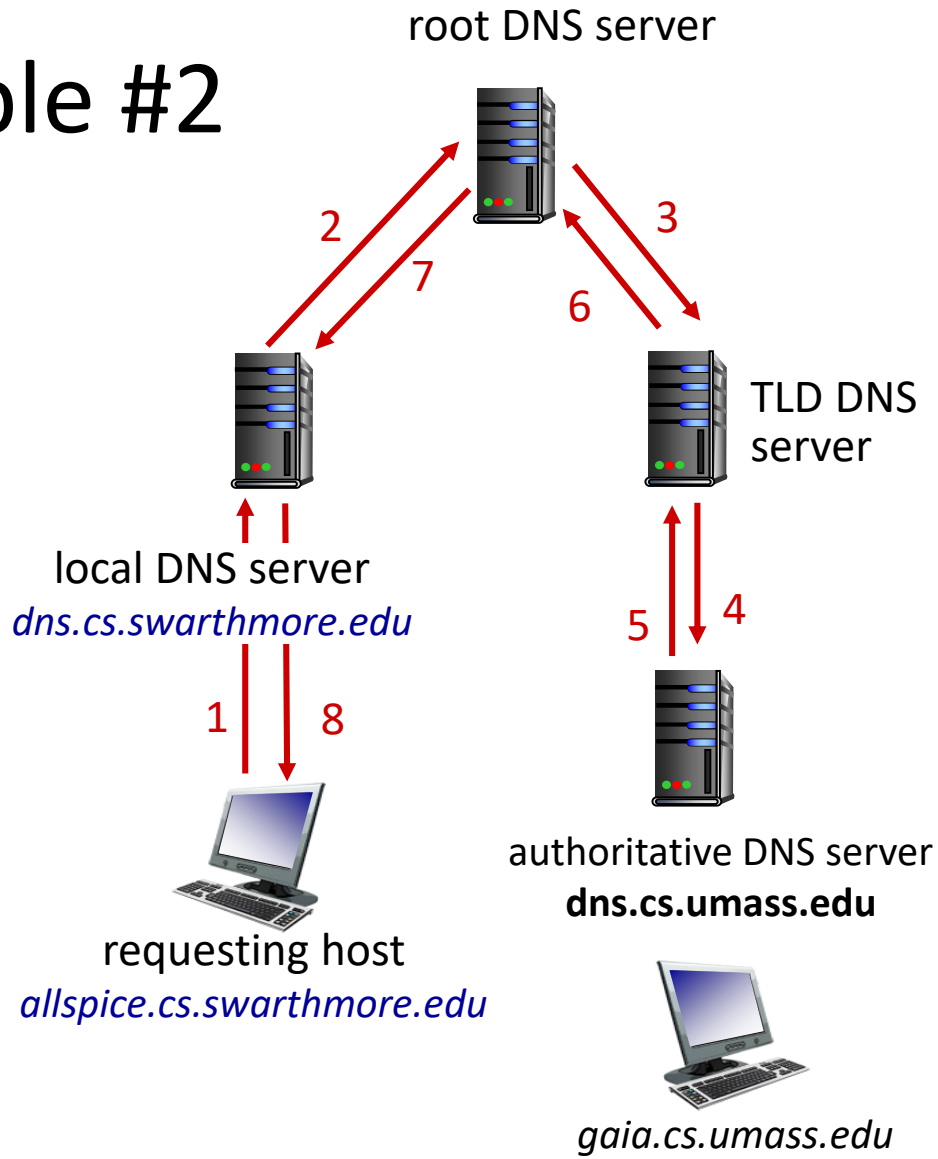
- contacted server replies with name of server to contact
- "I don't know this name, but ask this server"



DNS name resolution example #2

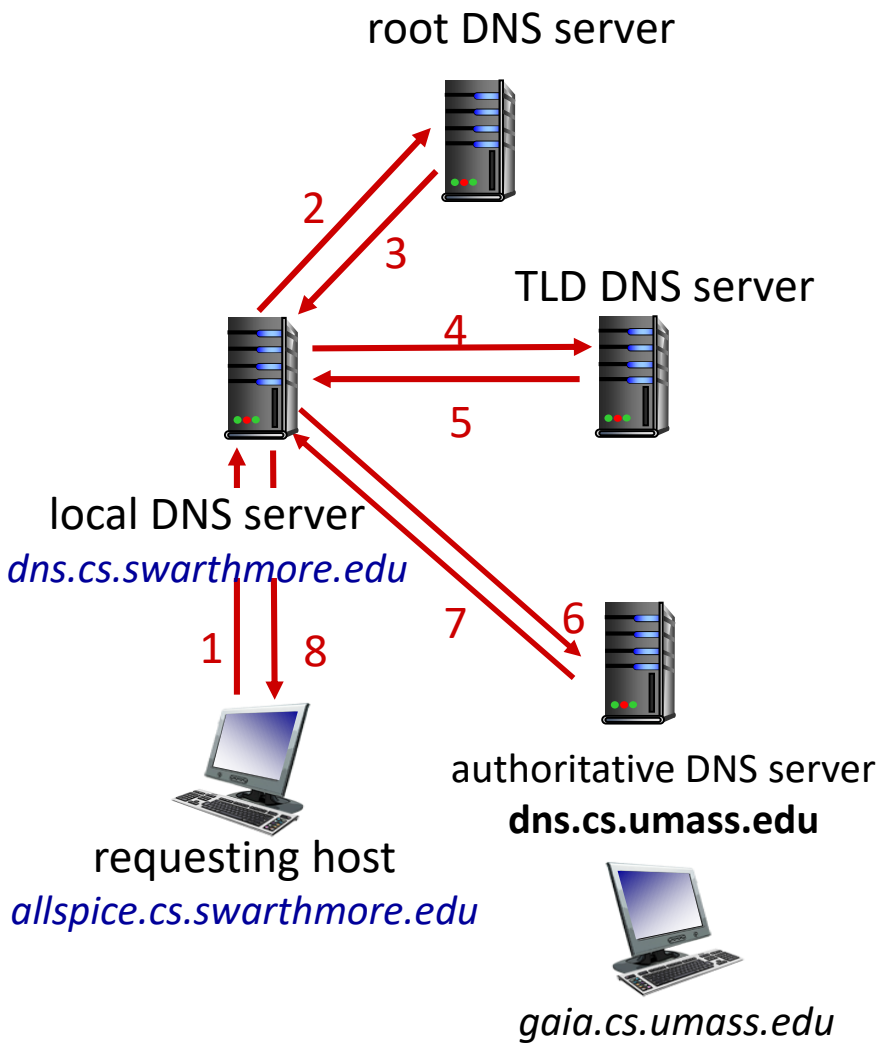
recursive query:

- each server asks the next one, in a chain

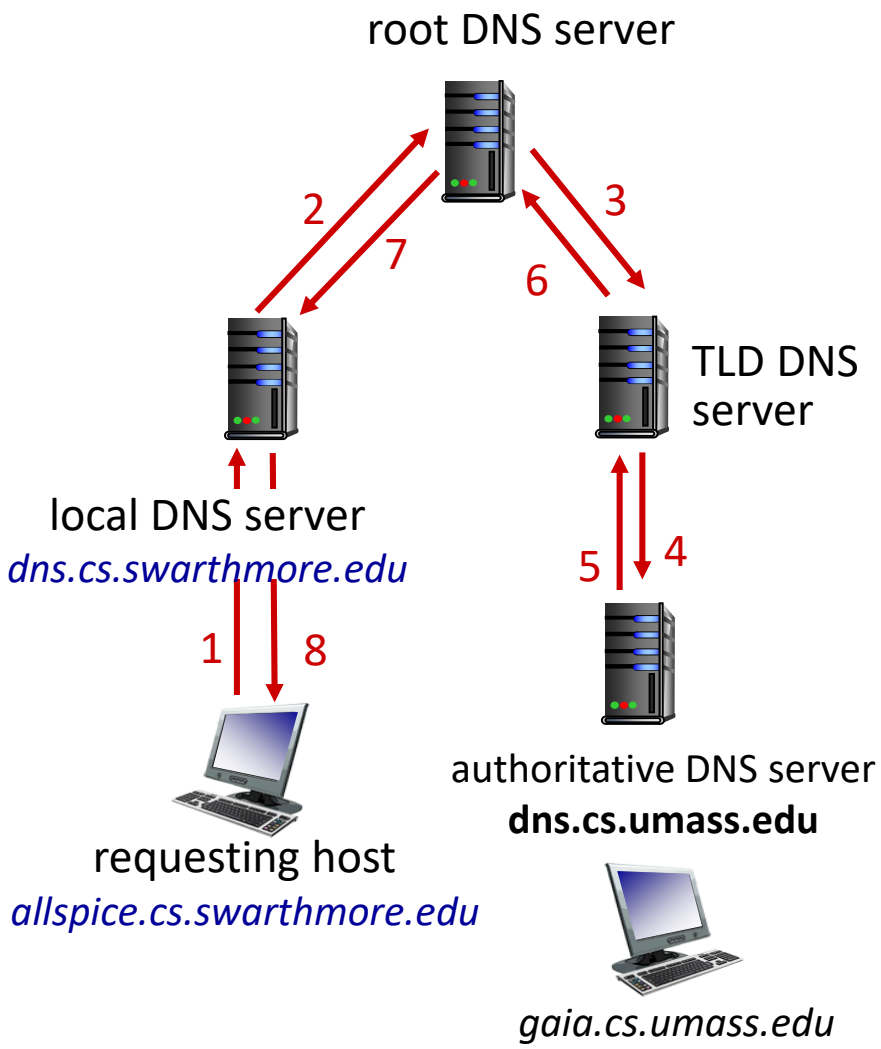


Which would you use? Why?

A. Iterative



B. Recursive



Caching

- Once (any) name server learns a mapping, it *caches* mapping
  - cache entries timeout (disappear) after some time (TTL: time to live)
  - TLD servers typically cached in local name servers
    - Thus root name servers not often (legitimately) visited

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    - Thus root name servers not often (legitimately) visited
- (+) Subsequent requests need not burden DNS
- (-) Cached entries may be *out-of-date* (best effort!)
  - If host's name or IP address changes, it may not be known Internet-wide until all TTLs expire

The TTL value should be…

A. Short, to make sure that changes are accurately reflected

B. Long, to avoid re-queries of higher-level DNS servers

C. Something else

Inserting (or changing) records

- Example: new startup “Network Utopia”
- Register networkuptopia.com at *DNS registrar*
  - provide names, IP addresses of authoritative name server (primary and secondary)
  - registrar inserts two RRs into .com TLD server:
    (networkutopia.com, dns1.networkutopia.com, NS)
    (dns1.networkutopia.com, 212.212.212.1, A)
- Set up authoritative server at that name/address
  - Create records for the services:
    - type A record for www.networkuptopia.com
    - type MX record for @networkutopia.com email

DNS Load Balancing

- One load balancing option (others use routing)

- When the authoritative name server responds
  - Round robin between servers
  - Take server load into account?
  - Take location into account (content distribution)

Public DNS Resolvers

- Recently, some companies have started hosting public resolvers
  - Google: 8.8.8.8
  - Cloudflare: 1.1.1.1

- Potentially allows users to hide DNS from their ISP

Summary

- DNS maps human names to IP addresses
- DNS arranged into a hierarchy
  - Scalability / distributed responsibility
  - Autonomous control of local name servers
- Caching crucial for performance