Lecture 03-2: Application Layer – DNS

CS 326 Elements of Networking

Mikyung Han

mhan@cs.utexas.edu

Internet Reference Model

Example Protocols		Responsible for
FTP, HTTP, SMTP	Application	application specific needs
TCP, UDP	Transport	process to process data transfer
IP	Network	host to host data transfer across different network
Ethernet, WiFi	Link	data transfer between physically adjacent nodes
802.3 PHY	Physical	bit-by-bit or symbol-by-symbol delivery

2

Hands-on 1 : DNS Dig is assigned

- Due this Sunday!
- 30 pts worth
- No late submission allowed
- Pre-req: Log into UTCS
  - Any VPN problems?
  - VPN is NOT needed when you are on campus
  - You can use VSCode (Open Remote Explorer and connect!)

What is DNS: Domain Name System

people: many identifiers:

- SSN, name, passport #

Internet hosts, routers:

- IP address (32 bit) - used for addressing datagrams
- "name", e.g., cs.umass.edu - used by humans

Q: how to map between IP address and name, and vice versa ?

Domain Name System (DNS):

- distributed database implemented in hierarchy of many name servers
- application-layer protocol: hosts, DNS servers communicate to resolve names (address/name translation)
  - note: core Internet function, implemented as application-layer protocol
  - complexity at network's "edge"

DNS also provides other services

Besides hostname-to-IP address translation

- host aliasing
  - You will find out what it is via Hands-on!
- mail server aliasing
  - Two different mailing addresses (user@ex.com and user@ex.org) delivered to same mail server)
- load distribution
  - How?
  - replicated Web servers: many IP addresses correspond to one name

Why don't we have a single powerful DNS server?

Q: Why not centralize DNS?

- single point of failure
- traffic volume
- distant centralized database
- maintenance

A: doesn't scale!

- Comcast DNS servers alone: 600B DNS queries/day
- Akamai DNS servers alone: 2.2T DNS queries/day

Engineering questions about the DNS

humongous distributed database:

- ~ billion records, each simple

handles many trillions of queries/day:

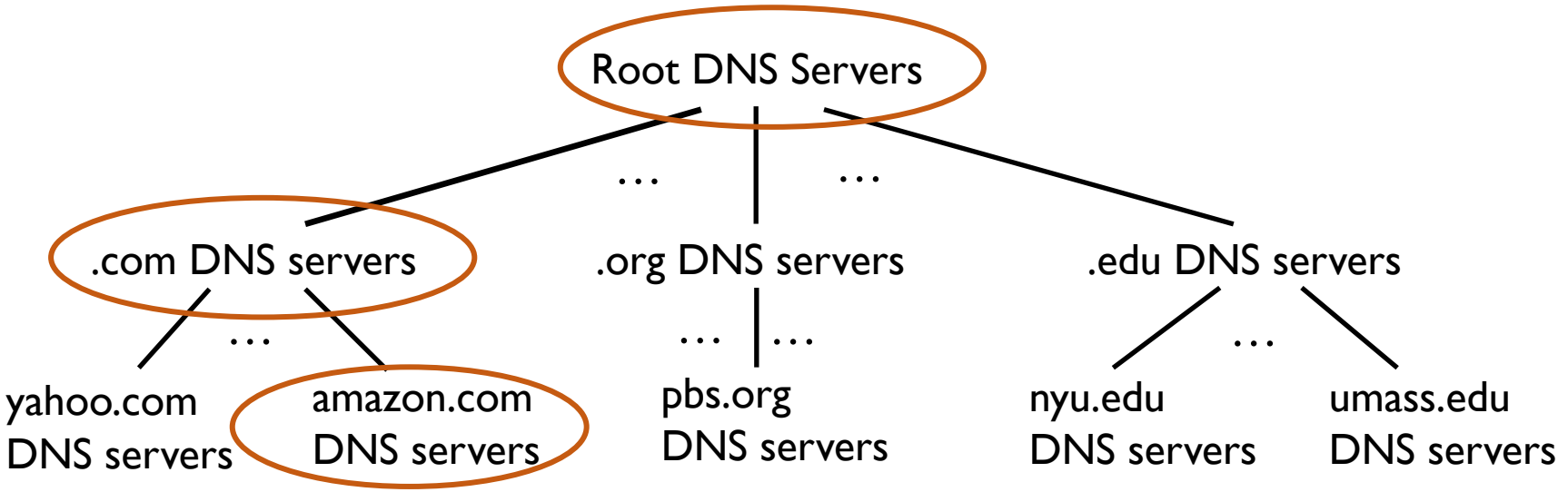
- many more reads than writes
- performance matters: almost every Internet transaction interacts with DNS - msecs count!

organizationally, physically decentralized:

- millions of different organizations responsible for their records

"bulletproof": reliability, security

DNS: a distributed, hierarchical "database"



Root

Top Level Domain

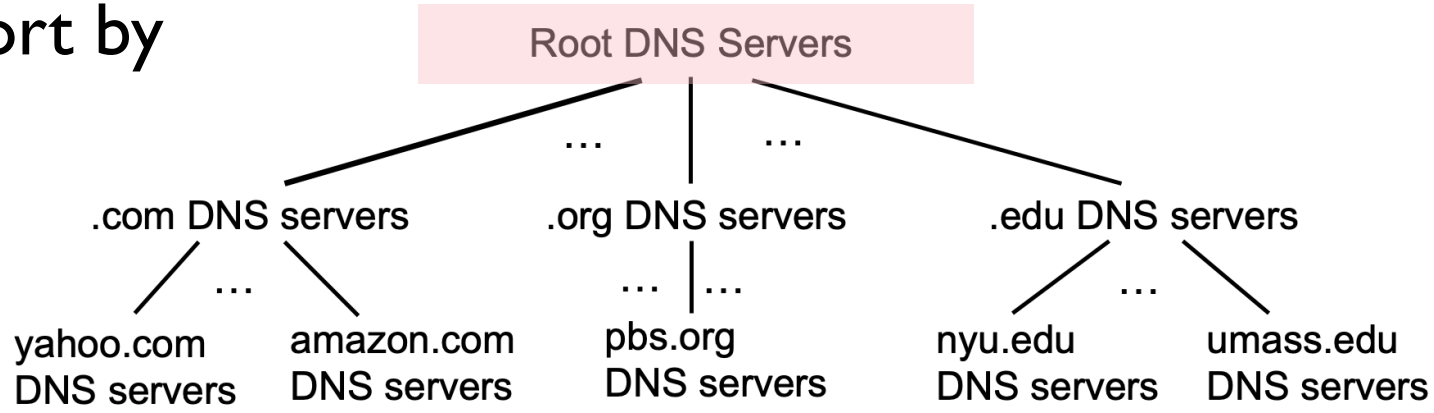
Authoritative

Client wants IP address for www.amazon.com thus asks its local DNS resolver

- First root server is queried
- Next .com DNS server is queried
- Last amazon.com DNS server is queried

DNS: root name servers

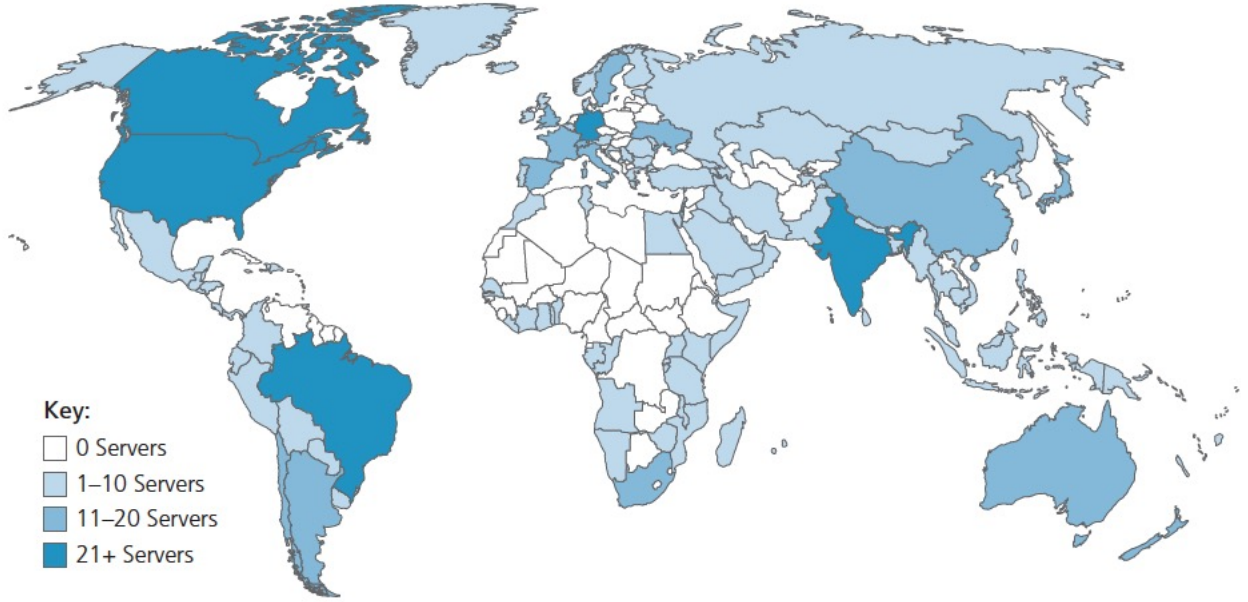
- official, contact-of-last-resort by name servers that can not resolve name



DNS: root name servers

- official, contact-of-last-resort by name servers that can not resolve name
- incredibly important Internet function
  - Internet couldn't function without it!
  - DNSSEC – provides security (authentication, message integrity)
- ICANN (Internet Corporation for Assigned Names and Numbers) manages root DNS domain

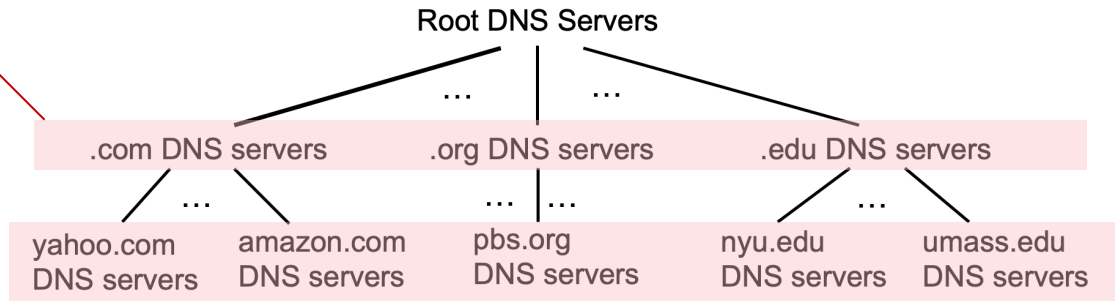
13 logical root name "servers" worldwide each "server" replicated many times (~200 servers in US)



Top-Level Domain, and authoritative servers

Top-Level Domain (TLD) servers:

- responsible for .com, .org, .net, .edu, .aero, .jobs, .museums, and all top-level country domains, e.g.: .cn, .uk, .fr, .ca, .jp



authoritative DNS servers:

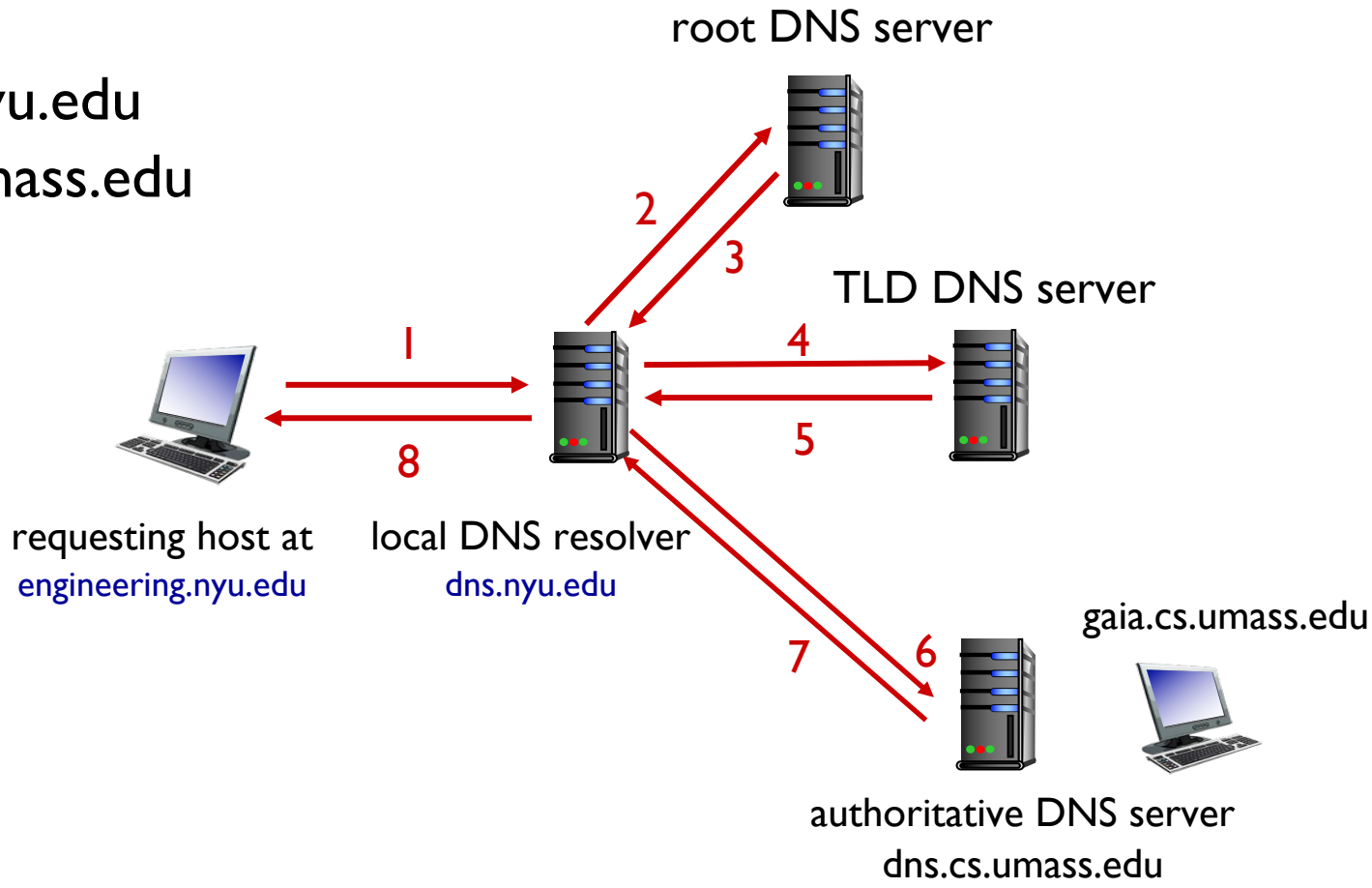
- organization's own DNS server(s), providing authoritative hostname to IP mappings for organization's named hosts
- can be maintained by organization or service provider

DNS name resolution: iterated query

Example: host at engineering.nyu.edu wants IP address for gaia.cs.umass.edu

Iterated query:

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



That is a lot of querying. How to improve performance?

Use cache to improve performance!

- Who does caching?
  - Local host
  - Local DNS resolver
- Who does NOT do caching? Why?
  - Root name server
  - TLD servers
  - Authoritative DNS servers

Caching in DNS significantly improves response time

- once s name server gives out the mapping, DNS resolver caches the mapping
- Next time upon asked the same query it can return the answer immediately from its cache
- Also, caching can shorten response time for similar query

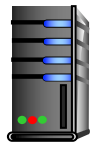
DNS name resolution with cache (example 1)

Example: host at engineering.nyu.edu queries again for gaia.cs.umass.edu

Local Cache lookup!

- Host itself has cache
- Very fast
- No need to go to DNS resolver

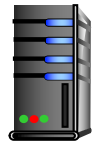
requesting host at engineering.nyu.edu



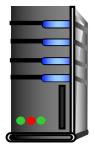
local DNS resolver dns.nyu.edu

root DNS server

TLD DNS server



gaia.cs.umass.edu

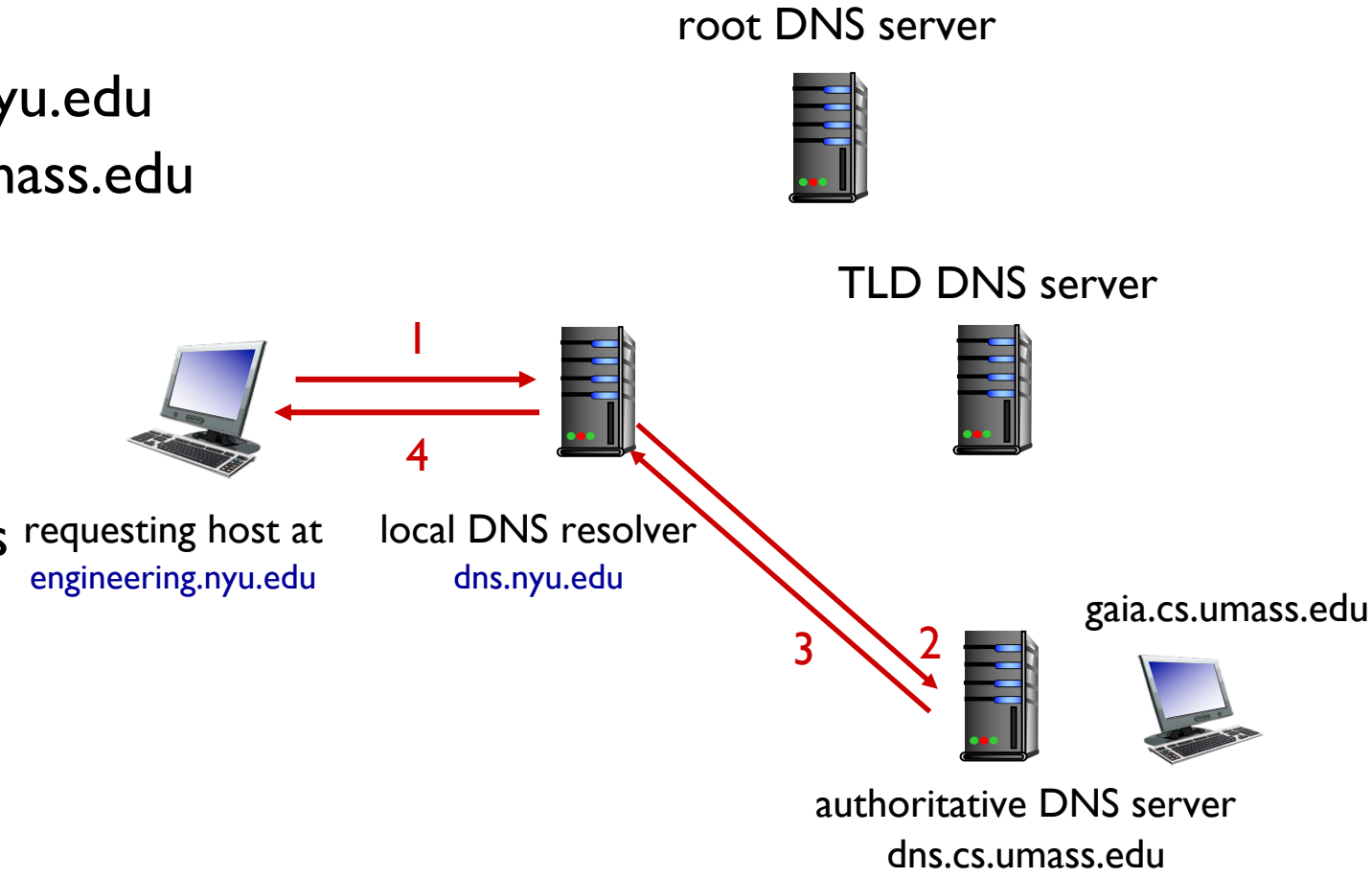


authoritative DNS server dns.cs.umass.edu

DNS name resolution with cache (example 2)

Example: host at engineering.nyu.edu wants IP address for abc.cs.umass.edu

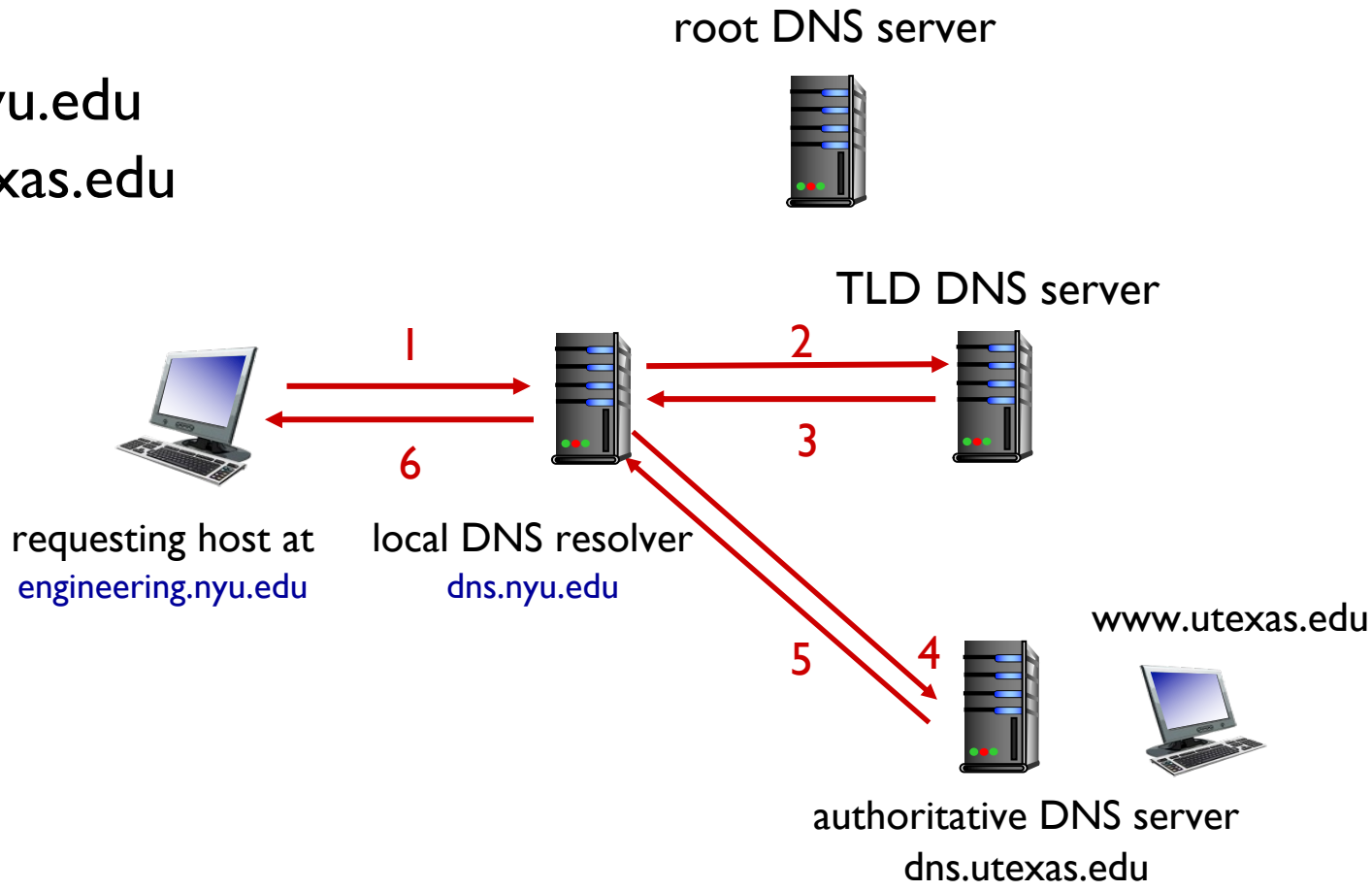
- host cache miss
- Local DNS resolver cached the authoritative DNS server's IP for cs.umass.edu
- Skip asking root DNS or TLD



DNS name resolution with cache (example 3)

Example: host at engineering.nyu.edu wants IP address for www.utexas.edu

- Host cache miss
- Local DNS resolver knows from cache which TLD to query for .edu
- TLD give authoritative DNS server for www.utexas.edu
- Authoriative DNS server gives the answer
- Skip root DNS server query



What can go wrong with caching?

What if cached entry becomes out-of-date?

Stale cache clears out after TTL

- cache entries timeout (disappear) after some time (TTL)
- TLD servers typically cached in local name servers
  - if named host changes IP address, may not be known Internet-wide until all TTLs expire!
  - best-effort name-to-address translation!

Things to think about

What could go wrong in DNS?

DDoS attacks

- bombard root servers
  - not successful to date
  - traffic filtering
  - local DNS resolver caches IPs of TLD servers, allowing root server bypass
- bombard TLD servers
  - potentially more dangerous

Spoofing attacks

- intercept DNS queries, returning bogus replies
  - DNS cache poisoning
  - RFC 4033: DNSSEC authentication services

How DNS similar/different to/from database service?

- What is similar?
- What is different?

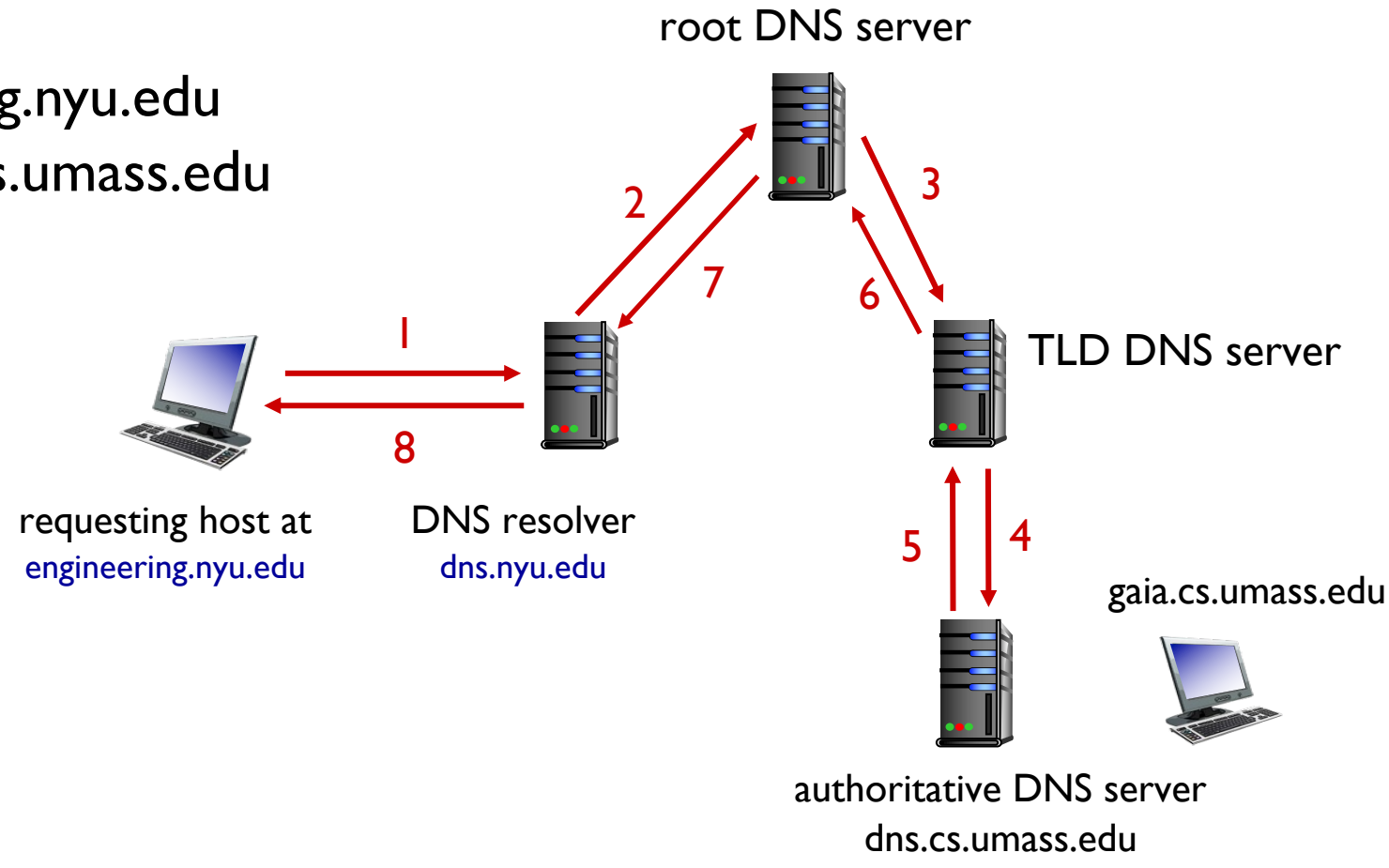
Backup Slides

What could be the other option? recursive query

Example: host at engineering.nyu.edu wants IP address for gaia.cs.umass.edu

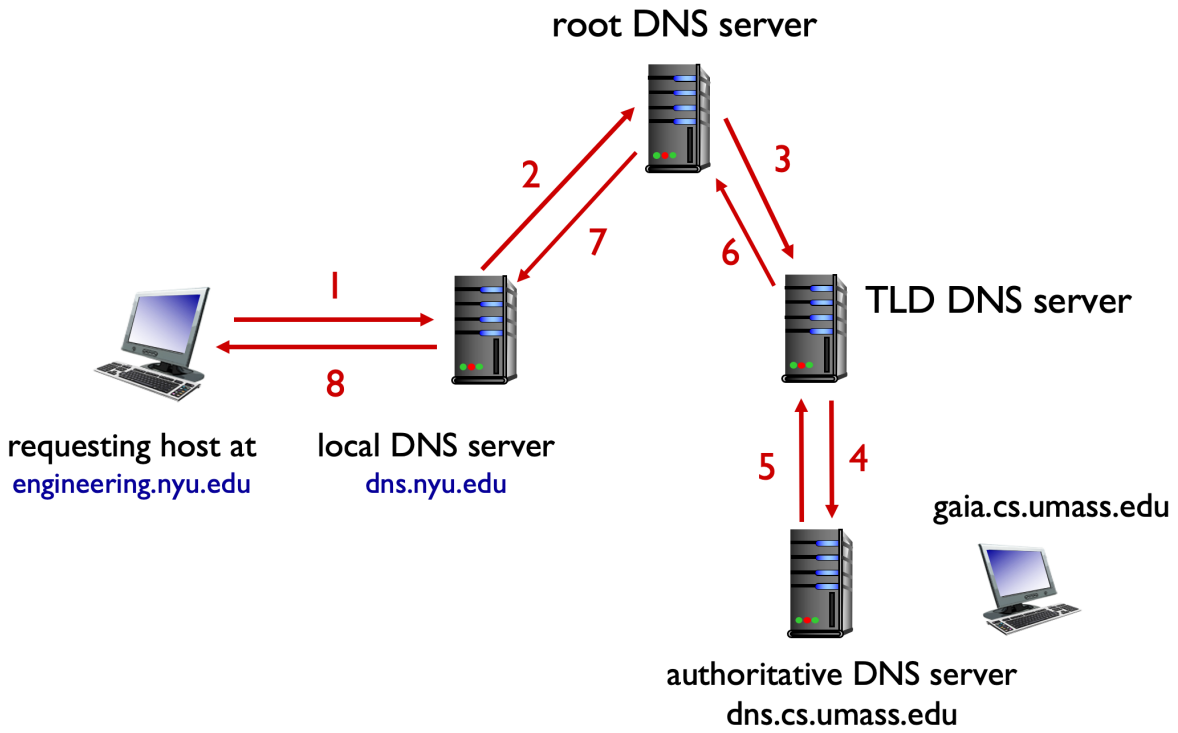
Recursive query:

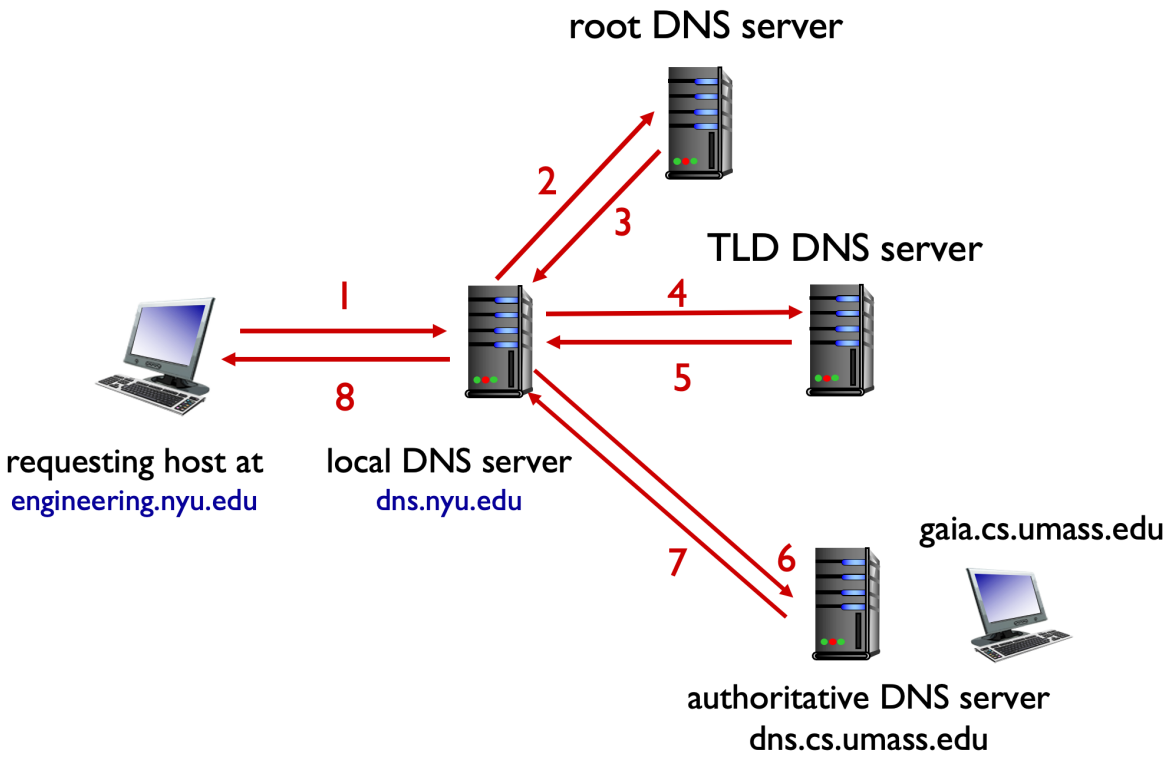
- puts burden of name resolution on contacted name server



Heavy load at upper levels

Assume everybody does caching (not true in reality) Which type of query works better?





Recursive vs Iterated

Who knows the final answer?

DNS records

DNS: distributed database 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

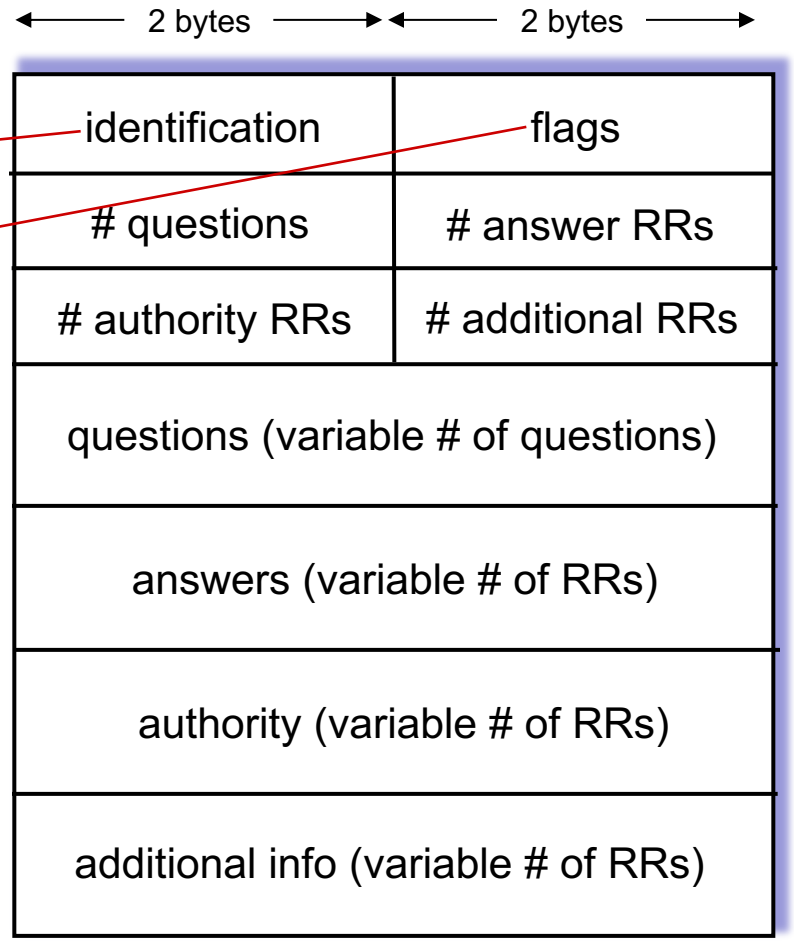
- value is name of SMTP mail server associated with name

DNS protocol messages

DNS *query* and *reply* messages, both have same *format:*

message header:

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



Acknowledgements

Slides are adopted from Kurose' Computer Networking Slides