Domain Name System

Lecture 4

http://www.cs.rutgers.edu/~sn624/352-F24

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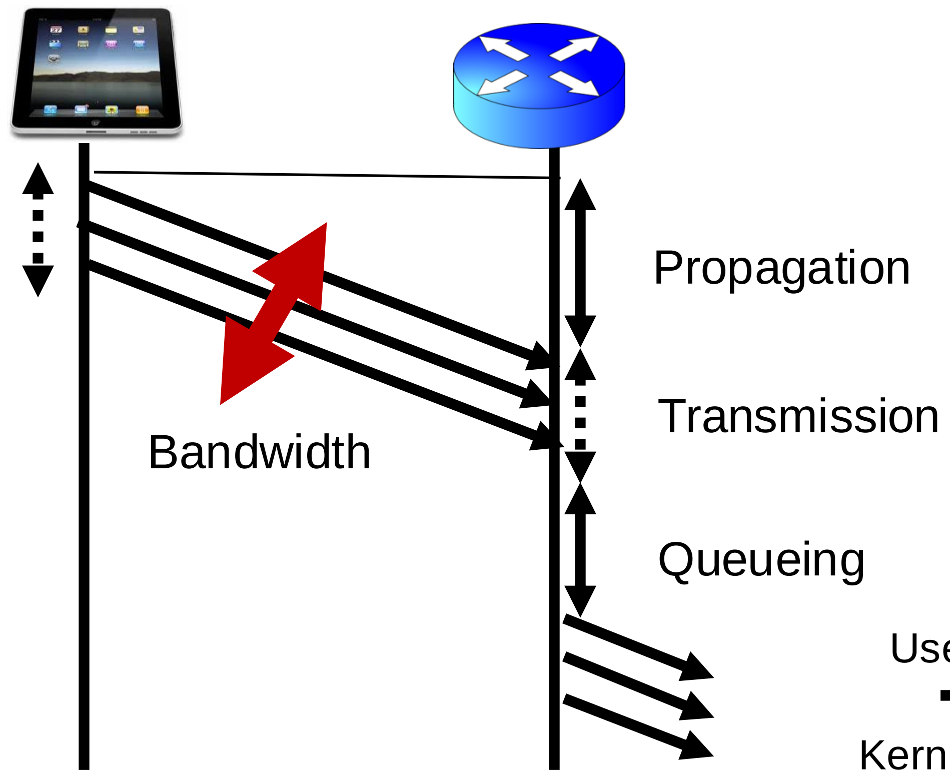
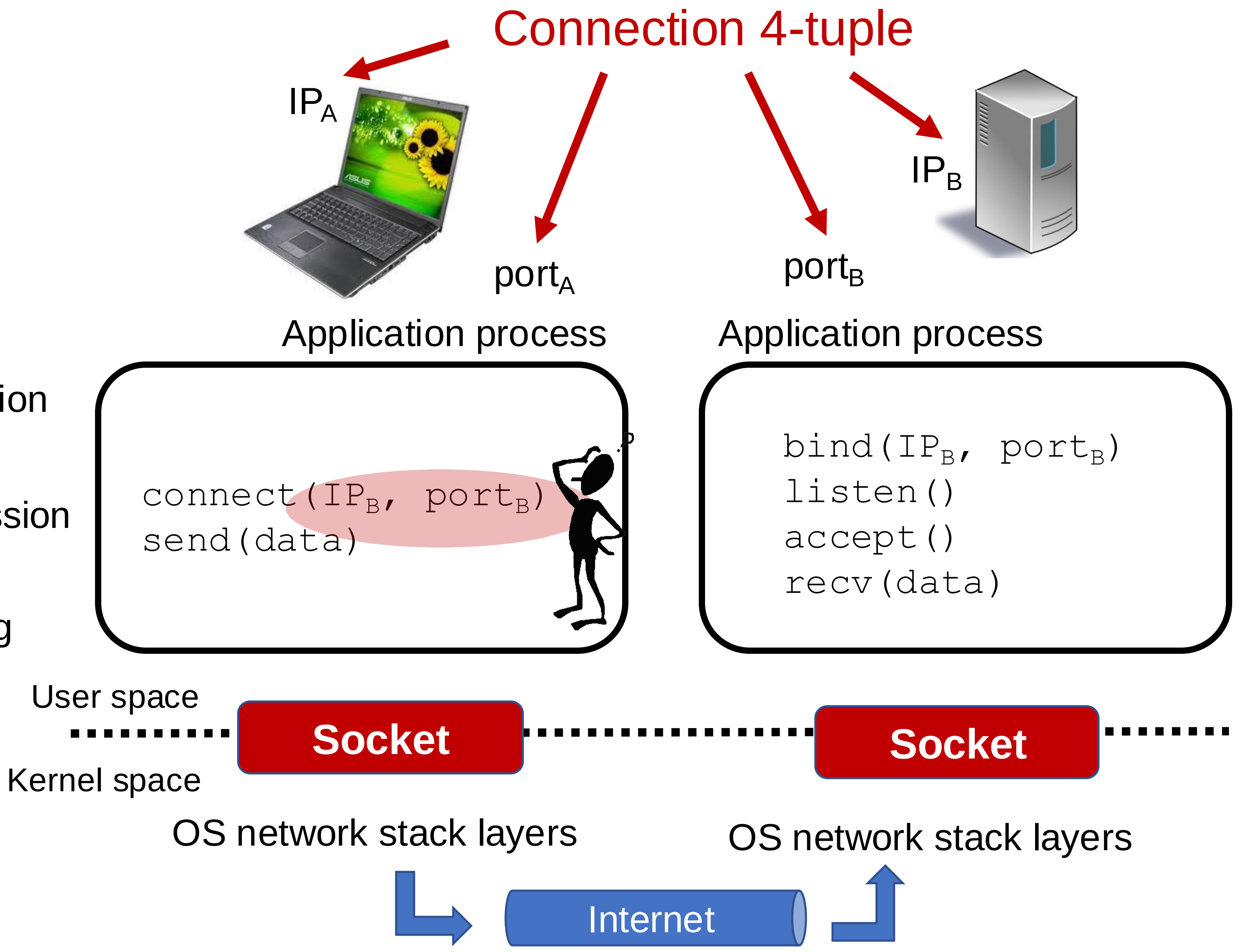
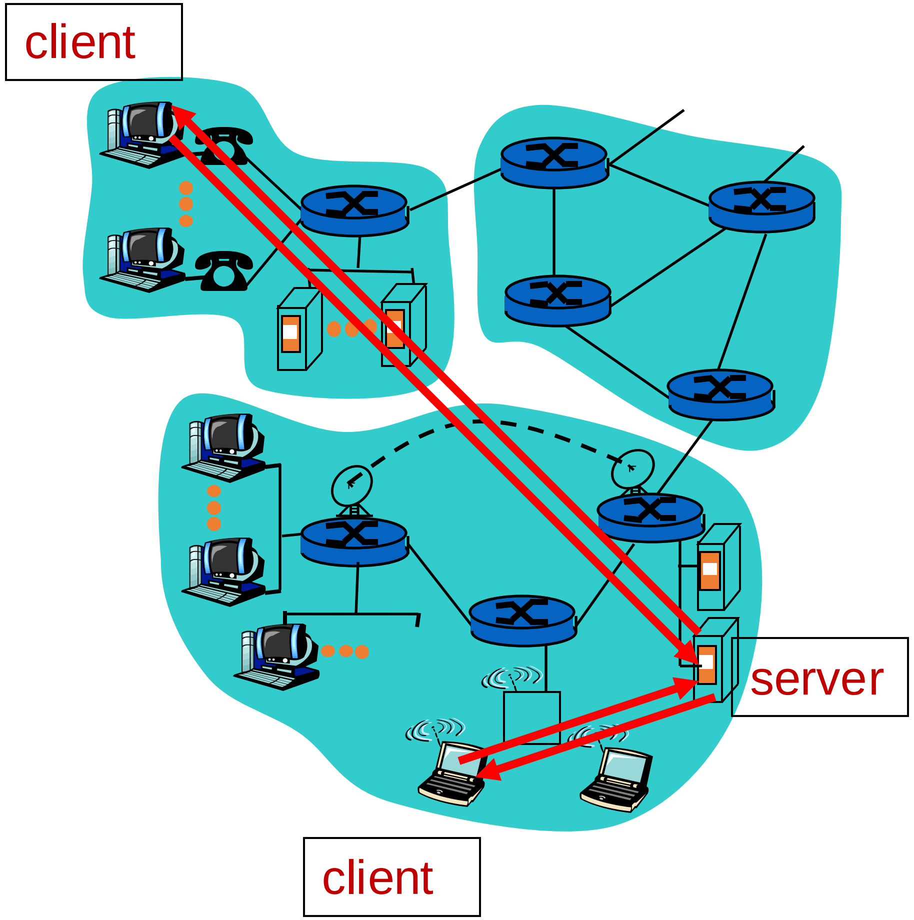
Review


Propagation
Transmission
Queueing
Bandwidth


Connection 4-tuple
IP_A
$port_A$
$port_B$
IP_B
Application process
Application process
connect(IP_B, $port_B$)
send(data)
bind(IP_B, $port_B$)
listen()
accept()
recv(data)
User space
Kernel space
Socket
Socket
OS network stack layers
OS network stack layers
Internet

Common Architectures of Applications

Client-server architecture



Server:

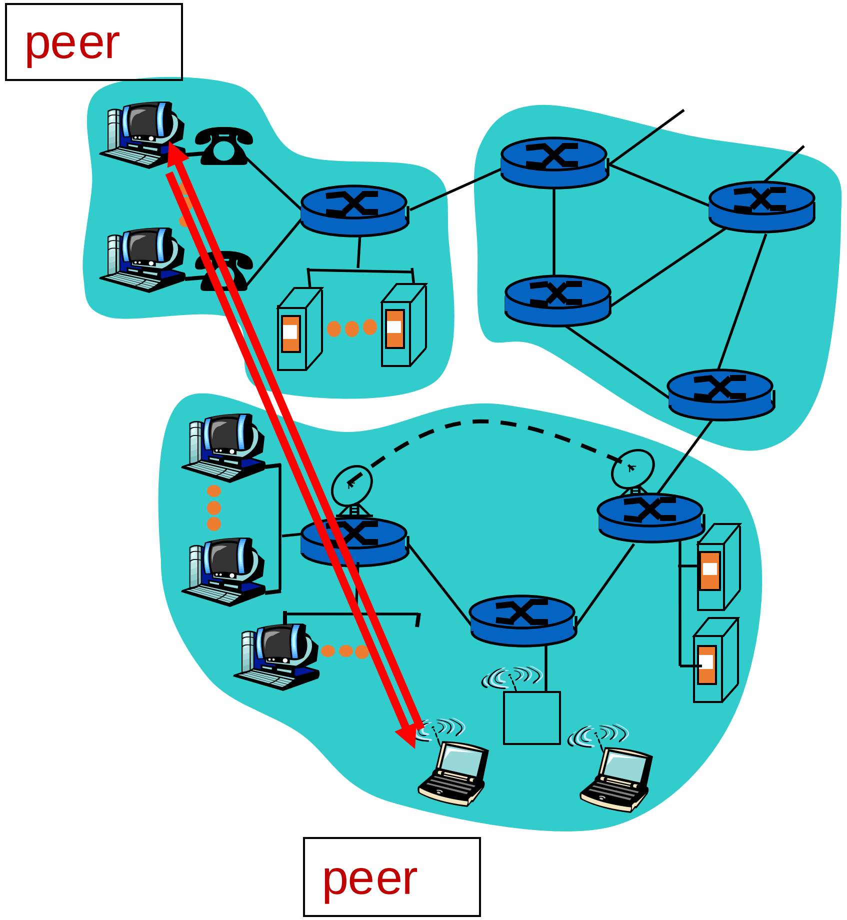
- Always-on endpoint
- Provides a “service” to the world
- Typically, a permanent IP address
- Hosted in clusters to scale to many users

Clients:

- A “customer” of the service
- Maybe intermittently connected
- May have dynamic IP addresses
- Typically, do not communicate directly with other clients

- The web and most mobile apps use a client-server architecture

Peer-to-peer (P2P) architecture



- Peers:
  - Intermittently connected hosts
  - Directly talking to each other
- Little to no reliance on always-up servers
  - Examples: BitTorrent
- Today, many applications use a hybrid model: servers to set up connectivity, communicate directly afterward
  - Example: (webRTC) Google meet

Going forward: A few app-layer protocols

- Domain Name System
- The web
- Streaming video

Domain Name System

Domain Name System (DNS)

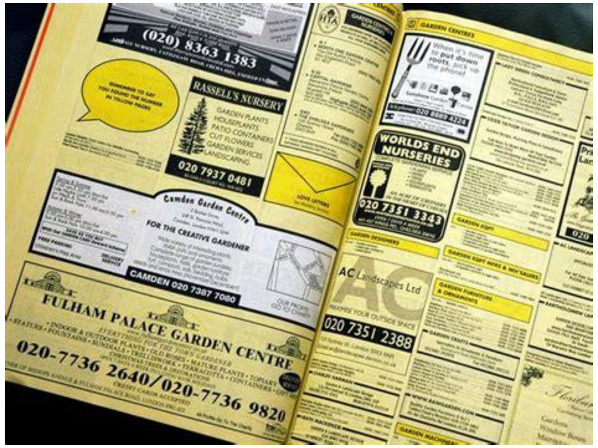
- Problem: Humans cannot remember Internet (IP) addresses
  - The average human brain can remember 7 digits for a few names
  - On average, IP addresses have 12 digits

- Solution: Use human-friendly names to refer to endpoints
  - Alphanumeric names (e.g. www.cs.rutgers.edu)
  - Called host names or domain names

- A new problem! We need a directory (address book) to translate human-friendly names to IPs

You have a name. Can you lookup an address?

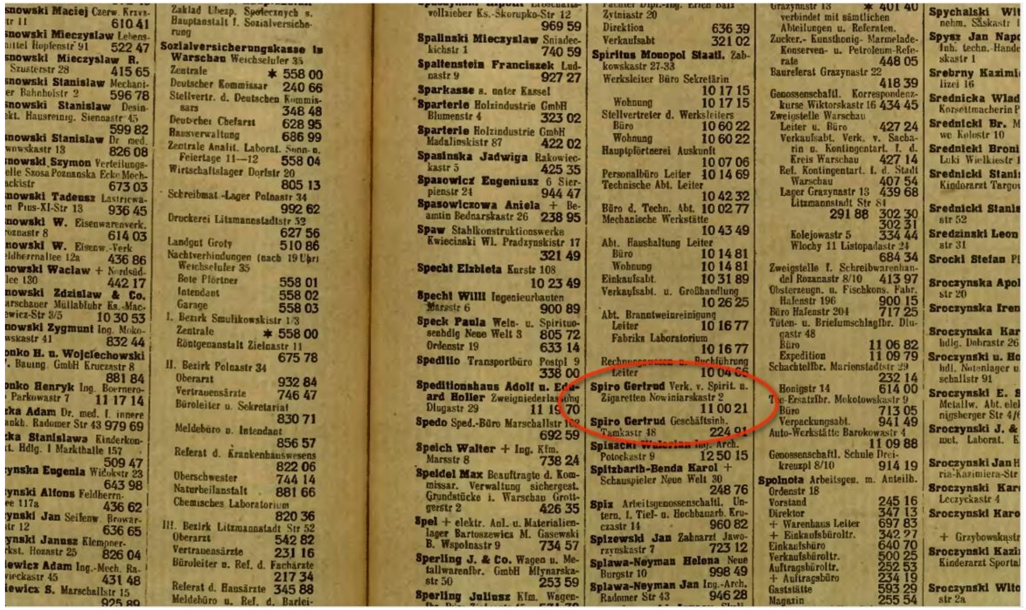
Directories



- Directories map a *name* to an *address*
- We call this process Address Resolution
- Simplistic designs
  - Central directory
  - Ask everyone (flooding)
  - Tell everyone (e.g., push to a file like /etc/hosts)
- Scalable distributed designs
  - Hierarchical namespace (e.g., Domain Name System (DNS))
  - Flat namespace (e.g., Distributed Hash Table)

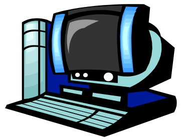
Simple DNS ("tell everyone")

- What if every endpoint has a local directory?
- `/etc/hosts.txt:` how DNS worked in the early days of the Internet
- Q: What if endpoints changed addresses? How do you keep this up to date?



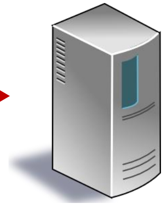
Simple DNS

DOMAIN NAME	IP ADDRESS
spotify.com	98.138.253.109
cs.rutgers.edu	128.6.4.2
www.google.com	74.125.225.243
www.princeton.edu	128.112.132.86



<Client IP, CPort, DNS server IP, 53>

QUERY cs.rutgers.edu



Name server

<DNS server, 53, Client IP, Cport>

RESPONSE 128.6.4.2

Pre-designated DNS server port: 53

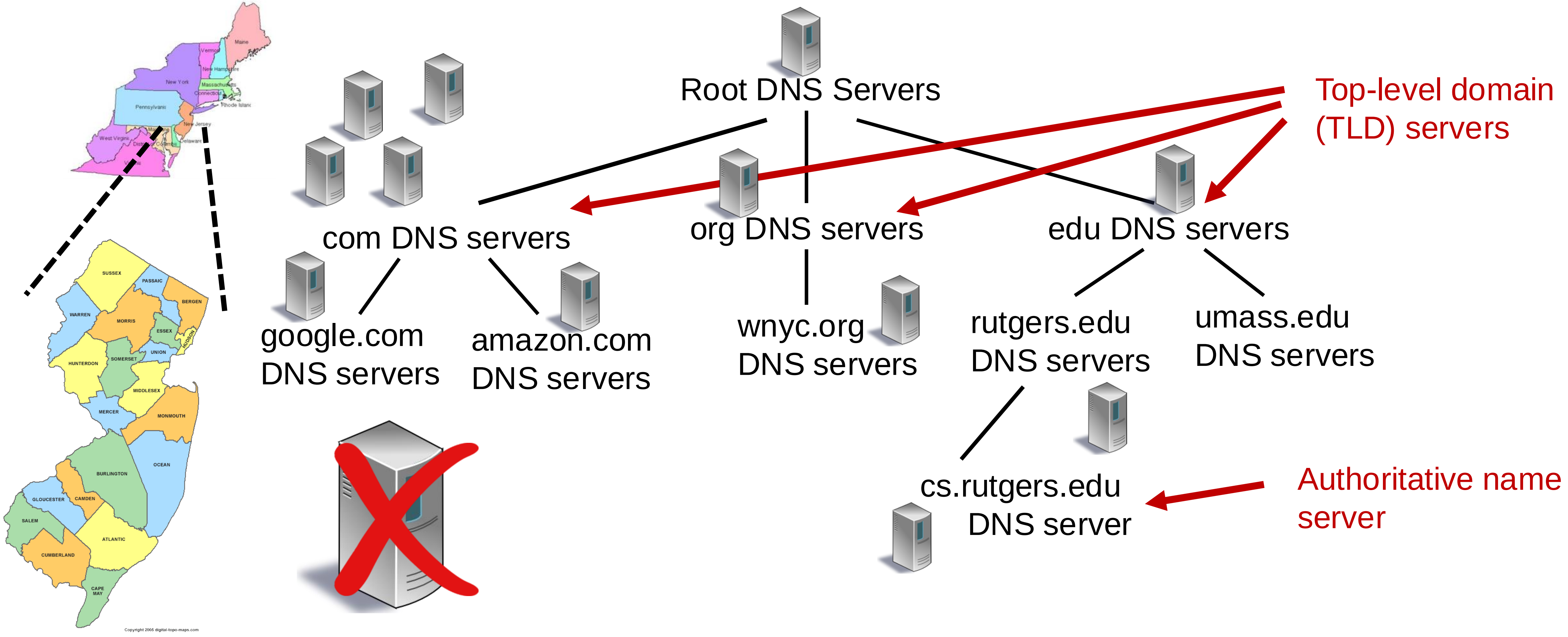
- Key idea: Implement a server that looks up a table.
- Would this work?
  - Every new (changed) host needs to be entered in this table
  - Performance: can the server serve billions of Internet users
  - Failure: what if the server or the database crashes?
  - How to secure this server?

Ideas to make DNS work for the Internet

- Idea #1. Hierarchy
  - Organize names hierarchically so we can divide the work of resolution
  - Internet: some names under “.com”, others with “.org”, “.edu”, …
  - Called top-level domains (TLD)
  - TLDs may contain sub-domains, sub-sub-domains, …
  - Lowest level: fully qualified domain name (e.g. people.cs.rutgers.edu)

- Idea #2. Distribution
  - Each node in the hierarchy served separately (name servers)
  - Lowest level: Manage changes in IP addresses of endpoints
    - Authoritative name server

Distributed and Hierarchical database



RFC 1034

Hierarchy

Replication

DNS Protocol

- Client-server application
- Client connects to (known) port 53 on server
- For now, assume the DNS server IP is known
- Two types of messages
  - Queries
  - Responses
- Type of Query (OPCODE)
  - Standard query (0x0)
    - e.g., Request IP address for a given domain name
  - Updates (0x5)
    - Provide a binding of IP address to domain name

DNS in action

- `dig <domain-name>`
- `dig +trace <domain-name>`
- `dig @<dns-server> <domain-name>`

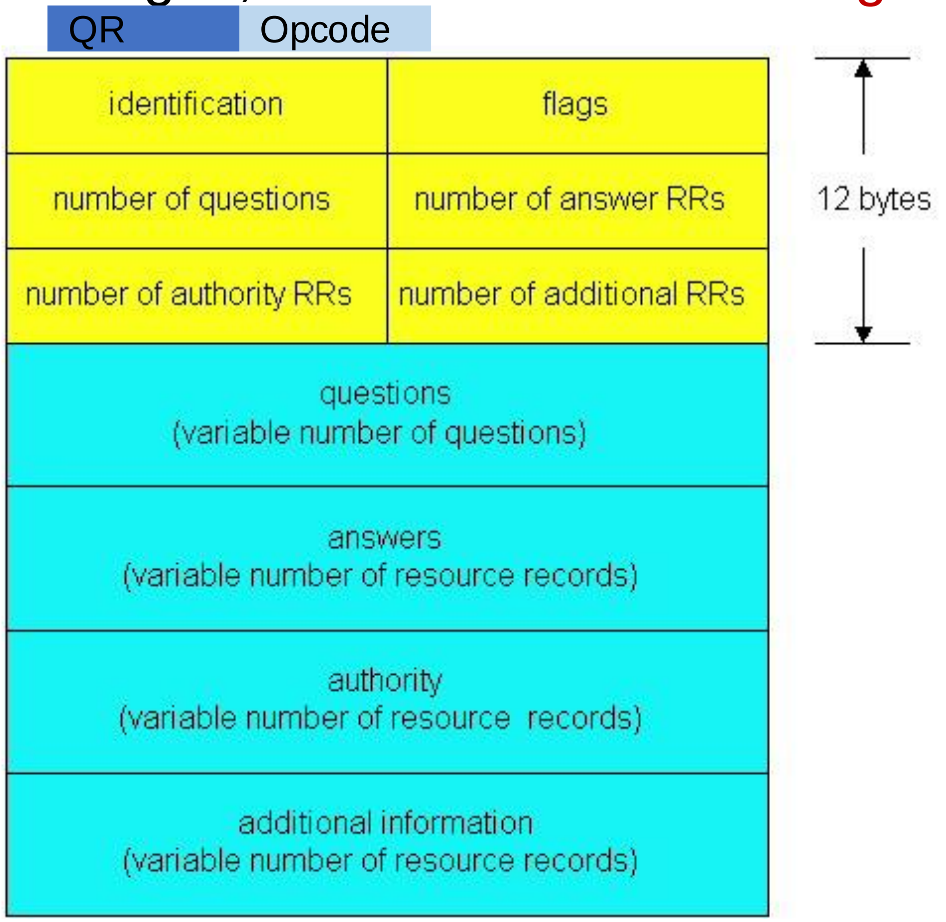
- Don’t just watch; try it!

DNS protocol: Message format

DNS protocol : query and reply messages, both with same message format

Message header

- QR = 0 for Query, 1 for response
- Opcode= 0 standard
- identification: 16 bit # for query, reply to query uses same #
- flags:
  - Authoritative answer
  - recursion desired
  - recursion available
  - reply is authoritative



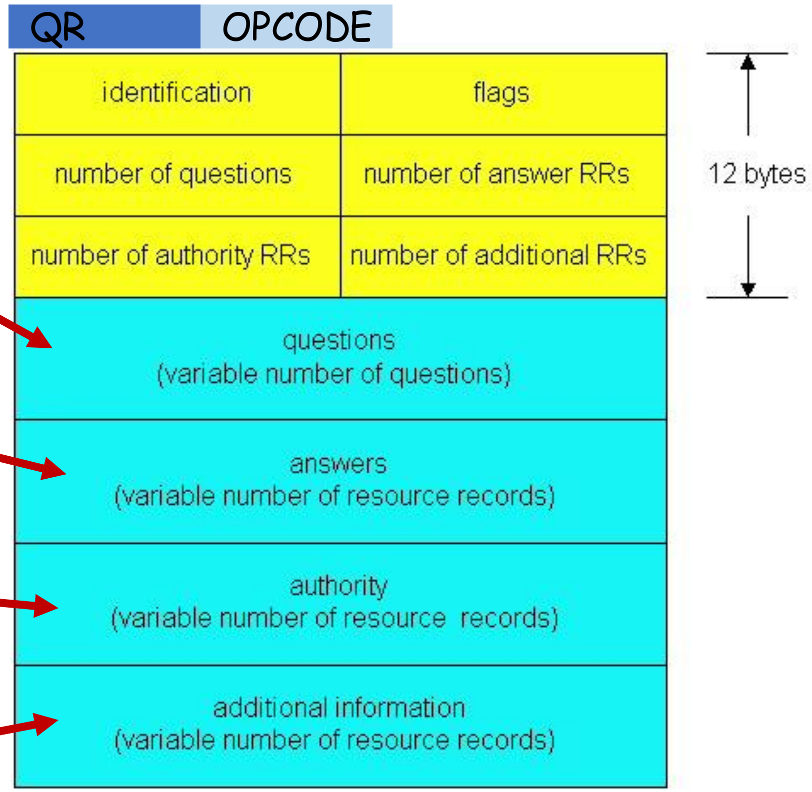
DNS protocol: Message format

Name, class, type fields for a query

Resource records in response to query

records for authoritative servers

additional helpful info that relates to the query (but not the answer)



DNS Protocol: Actions

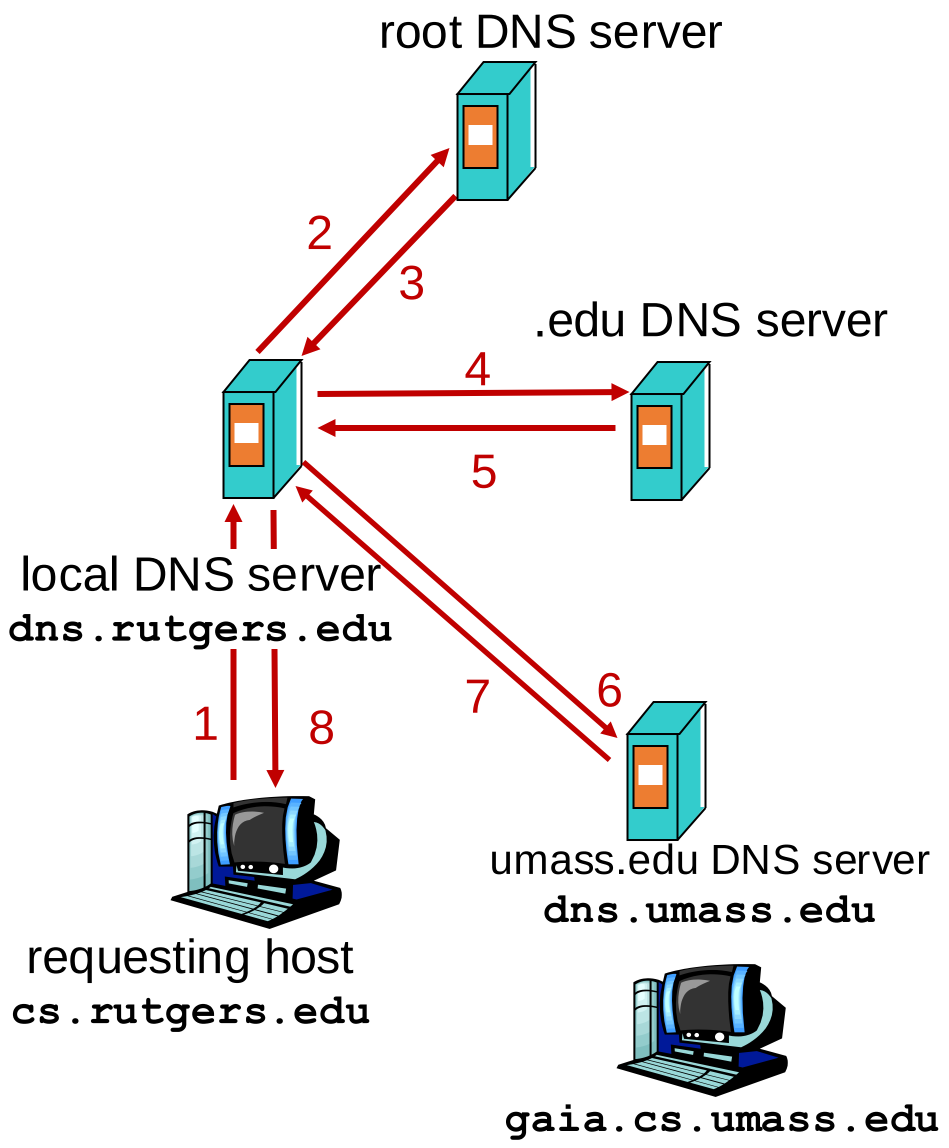
- When client wants to know an IP address for a host name

  - Client sends a DNS query to the “local” name server in its network
  - If name server contains the mapping, it returns the IP address to the client
  - Otherwise, the name server forwards the request to the root name server
  - The request works its way down the DNS hierarchy until it reaches a name server with a mapping for the requested name

Example

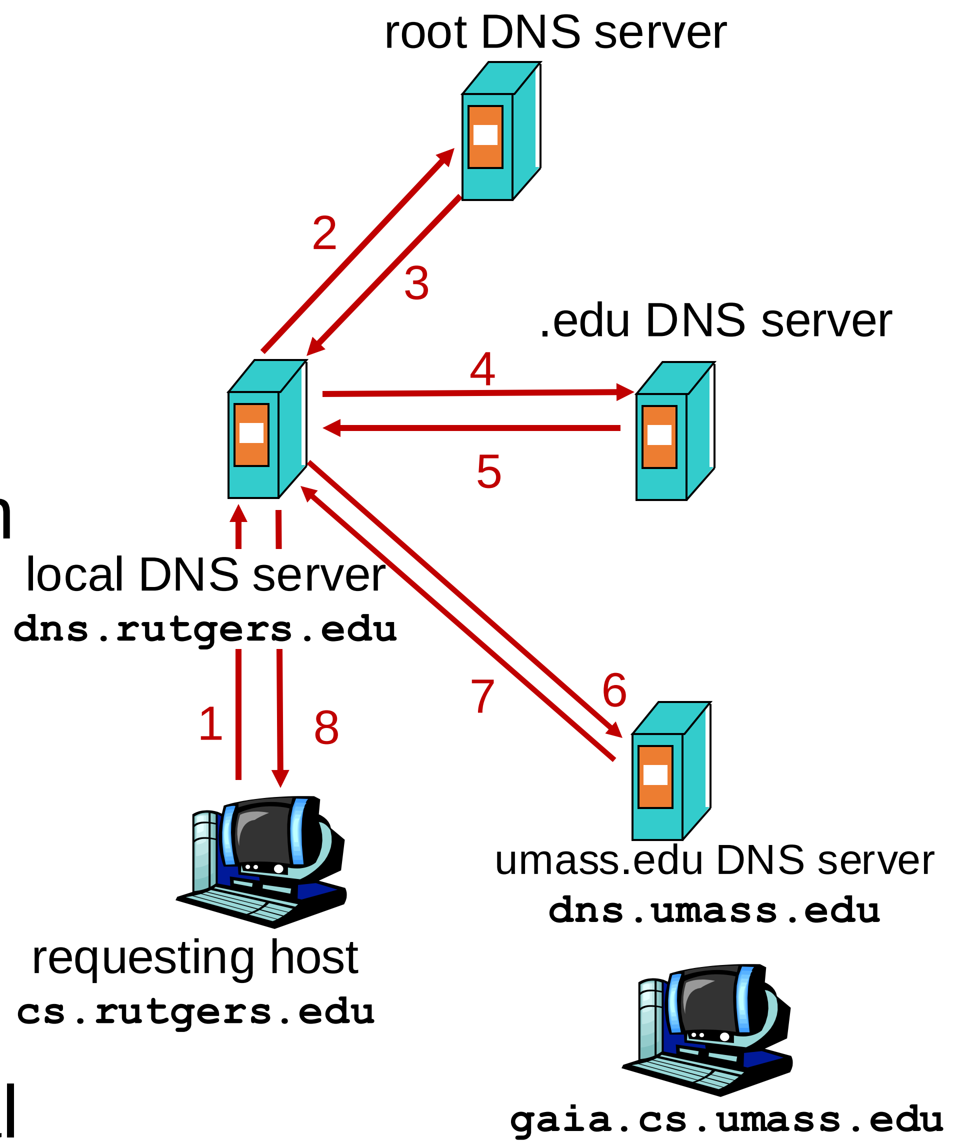
- Host at cs.rutgers.edu wants IP address for gaia.cs.umass.edu

- Local DNS server
- Root DNS server
- TLD DNS server
- Authoritative DNS server



Query type

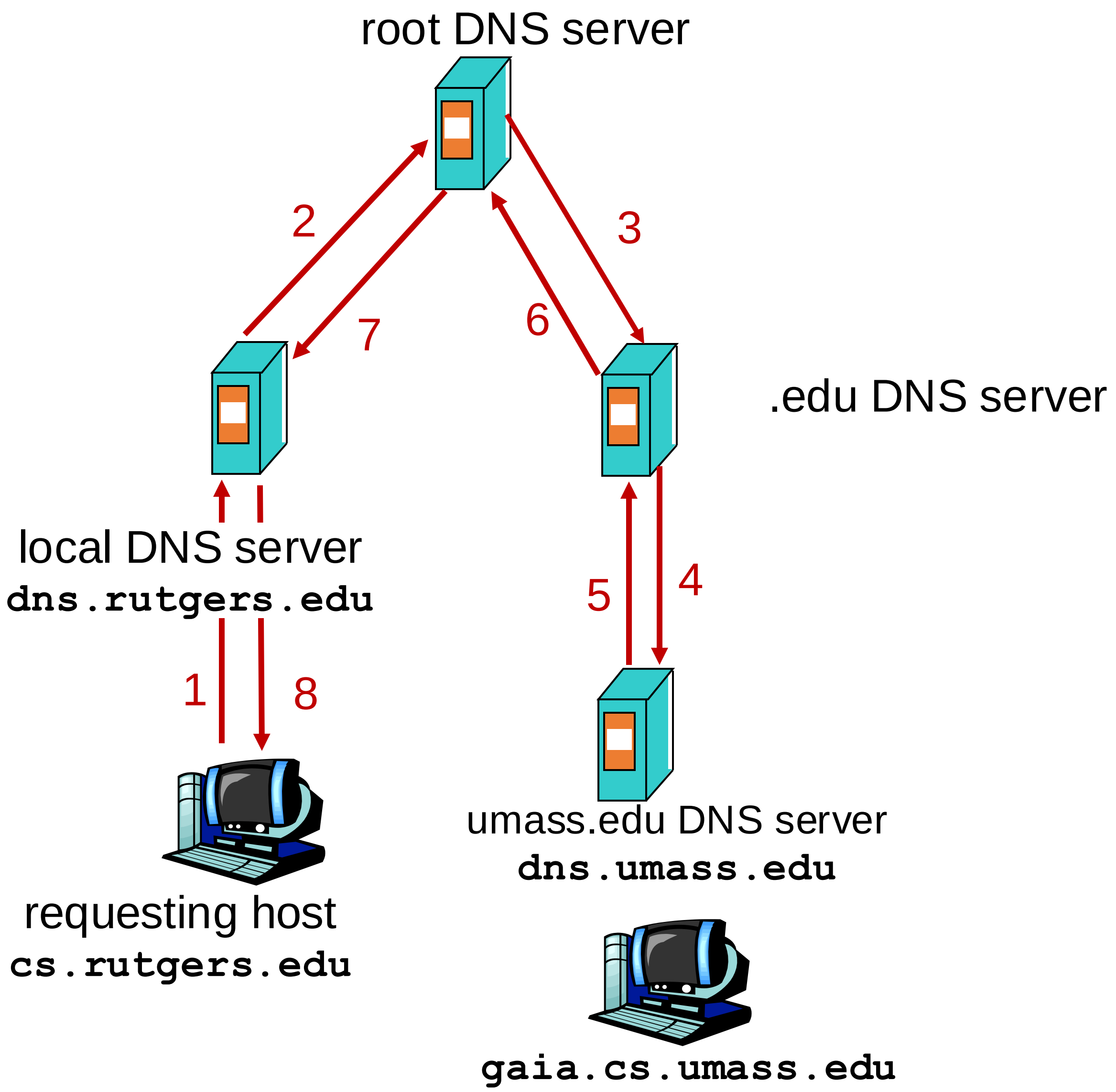
- Iterative query
- Contacted server replies with name of server to contact
- “I don’t know this name, but ask this other server”
- Queries 2,4,6 are iterative from point of view of the local DNS server



Query type

Recursive query:

- Puts burden of name resolution on the contacted (e.g., root) name server
- Query 2 (to root DNS server) is recursive from the local server
- In general, recursive is not preferred for higher levels of the DNS hierarchy



Problem: Load on Higher Levels of DNS

Think about the query load on the root DNS server (regardless of recursive/iterative)

- Must root server answer every DNS query?

DNS caching

- Once (any) name server learns a name to IP address mapping, it *caches* the mapping
  - Cache entries timeout (disappear) after some time
  - TLD servers typically cached in local name servers
  - In practice, root name servers aren’t visited often!
- Caching is pervasive in DNS

Bootstrapping DNS

- How does a host contact the name server if all it has is the domain name and no (name server) IP address?
- IP address of at least 1 nameserver (usually, a local name server) must be known a priori
- The local name server may be bootstrapped "statically", e.g.,
  - File `/etc/resolv.conf` in unix
  - `Start -> settings-> control panel-> network ->TCP/IP -> properties` in windows
- The local name server or with another protocol!
  - DHCP: Dynamic Host Configuration Protocol

DNS may seem “basic”, low level, but …

Gone in Minutes, Out for Hours: Outage Shakes Facebook

Akamai DNS outage knocks many major websites and services offline: PSN, Steam, Fidelity, more [U]

Overloaded Azure DNS Servers to Blame For Microsoft Outage

April 5, 2021

POSTED ON OCTOBER 5, 2021 TO NETWORKING & TRAFFIC

More details about the October 4 outage

DNS Resource Records

DNS is a distributed database

- DNS stores resource records (RRs)

- (Incomplete) message format for each resource record (RR):
  - Class, type, name, value, TTL

- You can read all the gory details of the message format at https://www.iana.org/assignments/dns-parameters/dns-parameters.xhtml

DNS records

Type=A

- **name** is hostname
- **value** is IPv4 address

Type=AAAA

- **name** is hostname
- **value** is IPv6 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

  e.g., www.ibm.com is really servereast.backup2.ibm.com
- **value** is canonical name

Type=MX

- **value** is name of mailserver associated with **name**

More complete info at https://www.iana.org/assignments/dns-parameters/dns-parameters.xhtml

DNS record example

RRs in response to query

NAME	Design.cs.rutgers.edu
TYPE	A
CLASS	IN
TTL	1 day(86400)
ADDRESS	192.26.92.30

records for authoritative servers
Information about nameserver

NAME	Cs.rutgers.edu
TYPE	NS
CLASS	IN
TTL	1 day(86400)
NSDNAME	Ns-lcsr.rutgers.edu

DNS serves as a general repository of information for the Internet!

DNS record types

- `dig -t <type> <domain-name>`

Summary of DNS

- Hostname to IP address translation via a global network of servers
- Embodies several scaling principles
  - Partition through a hierarchy to silo query load
  - Replication to scale out at each level of hierarchy
  - Caching to reduce query load
- Once you have a reliable DB, can implement many useful things on top!
- Example 1: Scaling large web services, e.g., google search, by redirecting different clients to different servers (IP addresses)
  - Reliability, load balancing, performance optimization
- Example 2: Associating certificates, keys (security info) with domain names
  - https://www.rfc-editor.org/rfc/rfc8162.html
  - https://datatracker.ietf.org/doc/draft-ietf-dnsop-svcb-https/00/