# The Application Layer: Sockets, DNS

CS 352, Lecture 3, Spring 2020

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

Srinivas Narayana

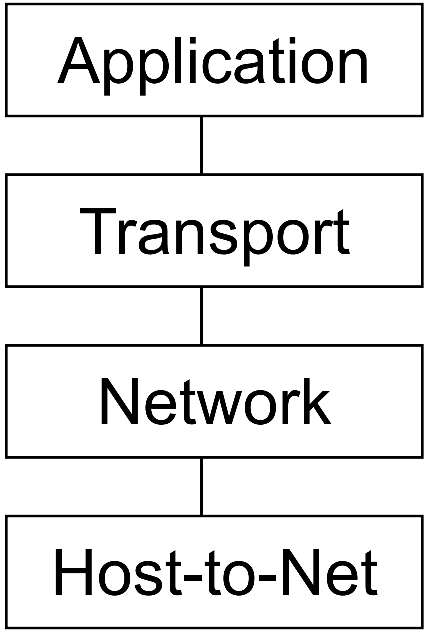
RUTGERS
UNIVERSITY | NEW BRUNSWICK

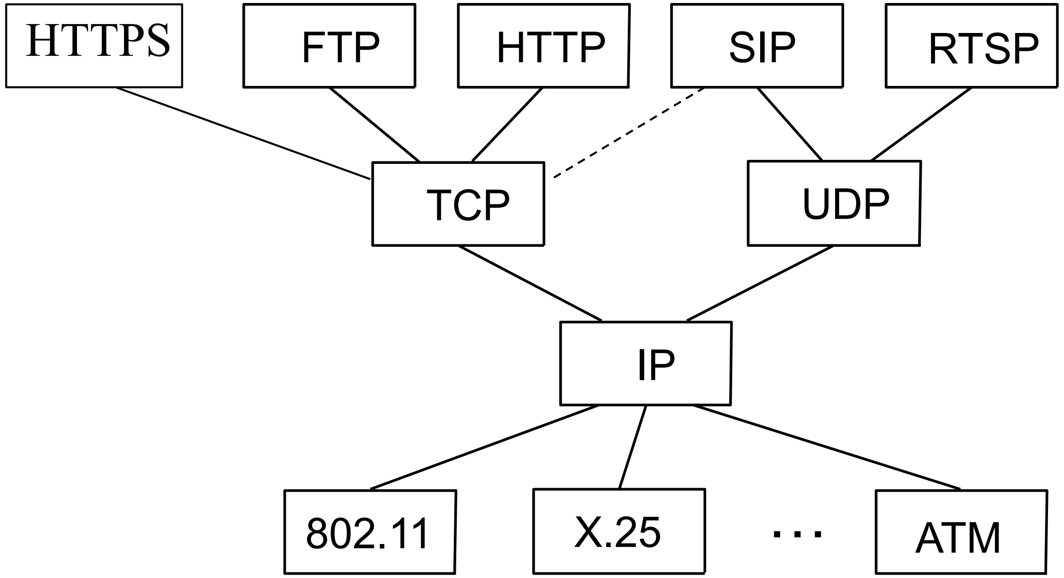
# Course announcements

- Sakai, Piazza, course web page are up
- TAs assigned to recitation sections
  - Office hours will be finalized soon
- Start looking for programming project partners
- Go over lecture materials for quiz prep
  - Estimated 3 hours of prep in addition to attending lecture
    - Your mileage may vary
  - Work on the textbook problems and test yourself
  - Attend recitations for problem practice
  - Quizzes are timed: they close 30 minutes after you start
  - Quizzes will test both concepts and problem solving

# Review of concepts

- Switching: circuit, message, packet
- Measuring: bandwidth, propagation + transmission + queueing
- Layering and modularity




# Intro to app-layer concepts

Protocols, Addressing, Connections

# Application-layer protocol

- Types of messages exchanged,
  - e.g., request, response
- Message format:
  - Syntax: what fields in messages & how fields are delineated
  - Semantics: meaning of information in fields
- Actions: when and how processes send & respond to messages

Public-domain protocols:

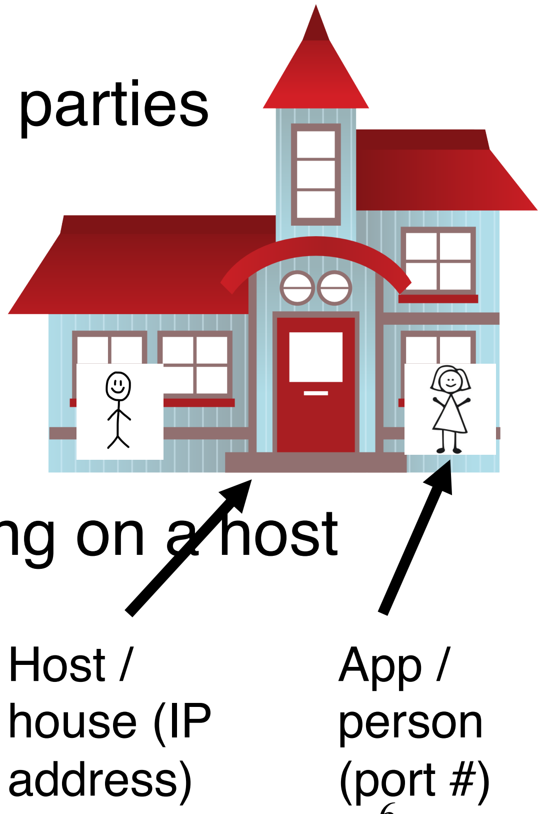
- defined in RFCs
- allows for interoperability
- e.g., HTTP, SMTP

Proprietary protocols:

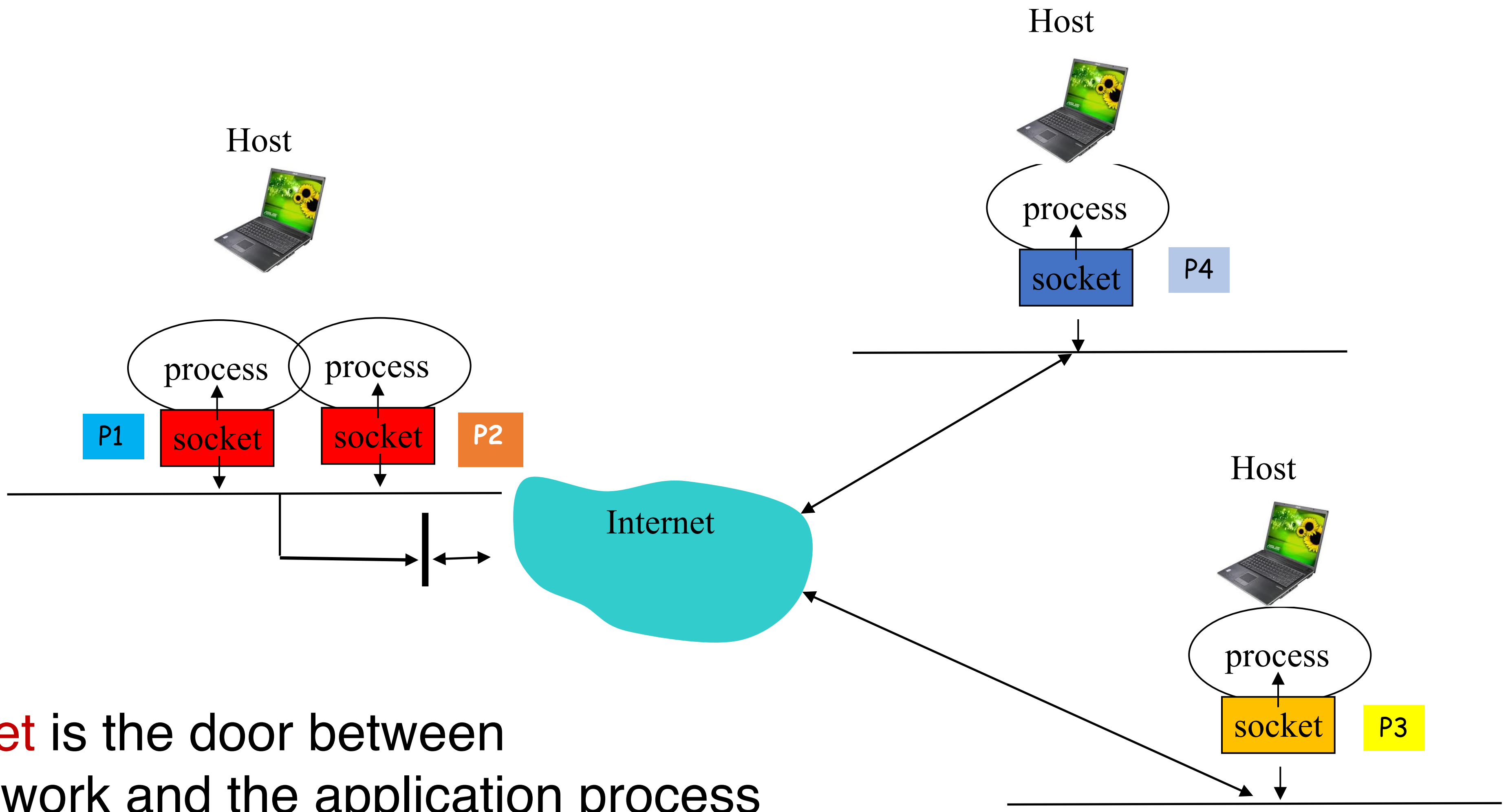
- e.g., Skype, Microsoft Exchange

# Application "addresses"

- We usually think of an application executing on a single endpoint
- However, applications can reside on, say, 2 different endpoints connected by a network
- In order to communicate, need to identify the communicating parties
- Telephone network: phone number (10 digits)
- Computer network: IP address
  - IPv4  (32 bits) 128.6.24.78
  - IPv6 (128 bits)  2001:4000:A000:C000:6000:B001:412A:8000
- Suppose there is more than one networked program executing on a host
  - In addition to host address, we need one more address
  - "Which Program to talk to?"
- Another identity for an application: port number

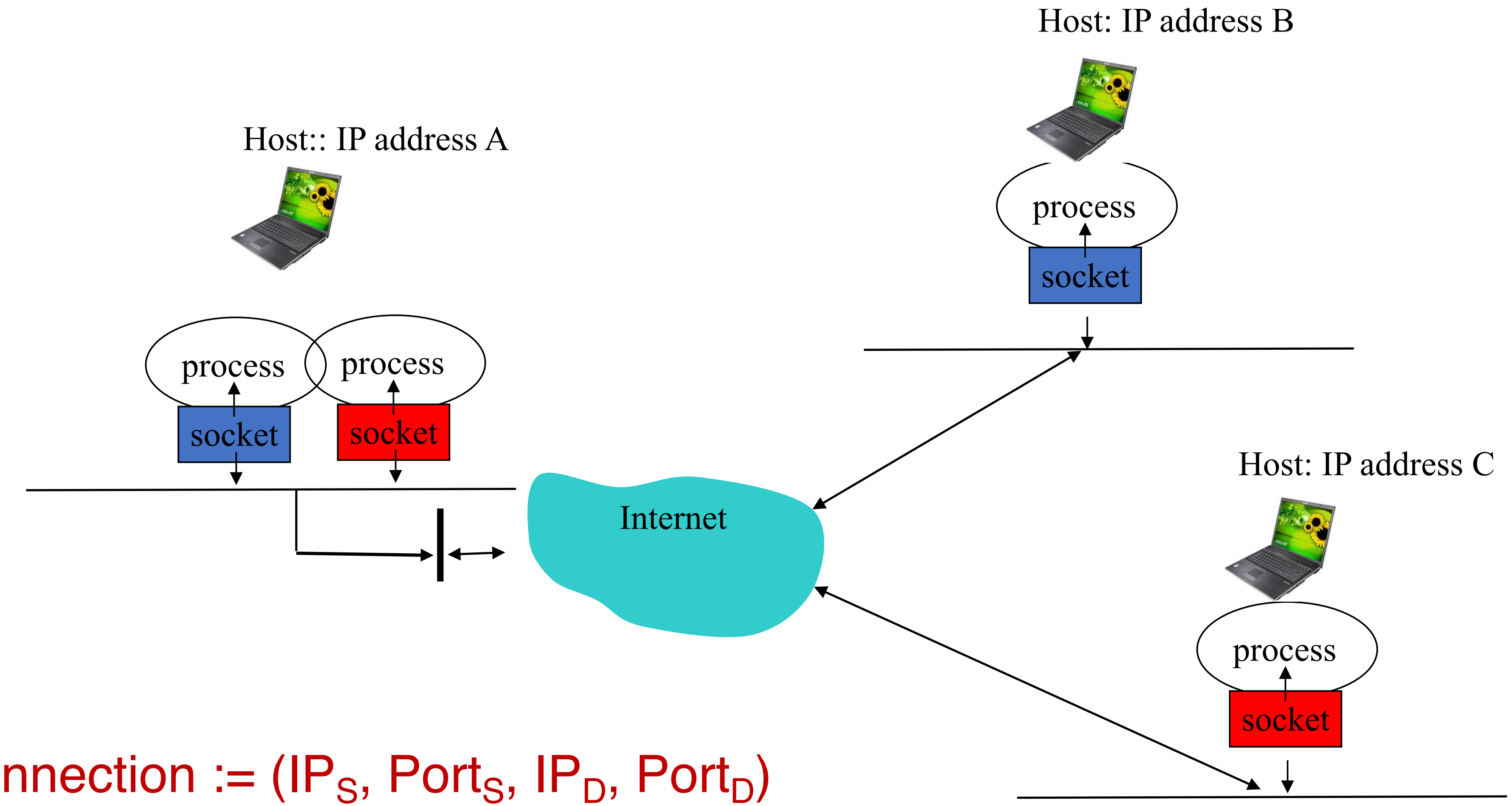


# IP address & port number




A socket is the door between
OS/network and the application process
The application's programming interface to the network

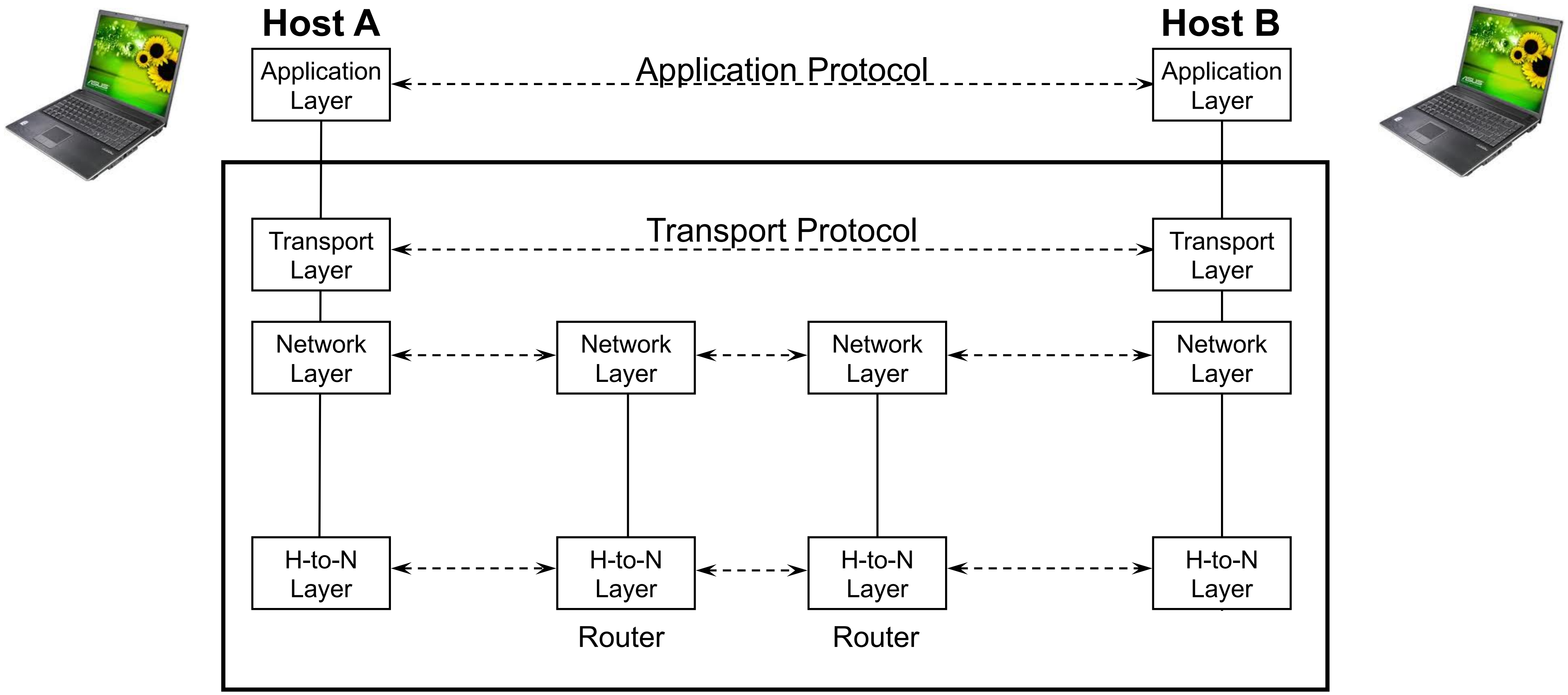
# An app-layer connection is a 4-tuple




Connection := ($IP_S$, $Port_S$, $IP_D$, $Port_D$)

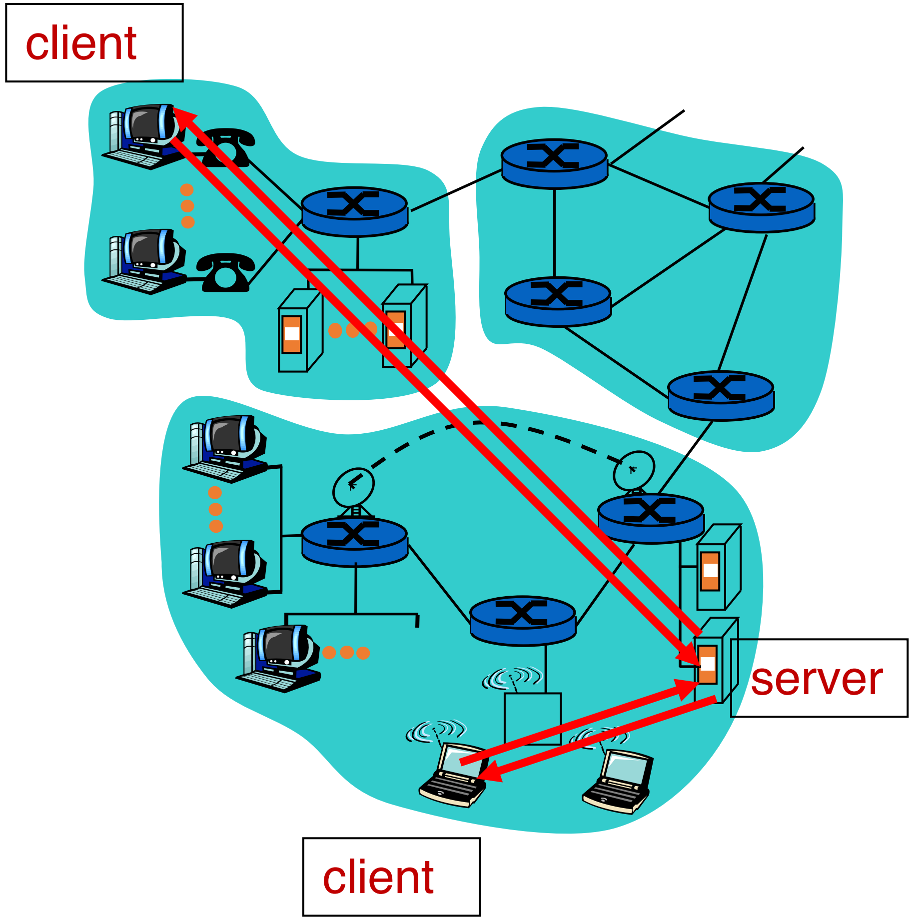
(S = source, D = destination)

# Recall: Services provided by lower layers



# Application architectures

# Client-server architecture



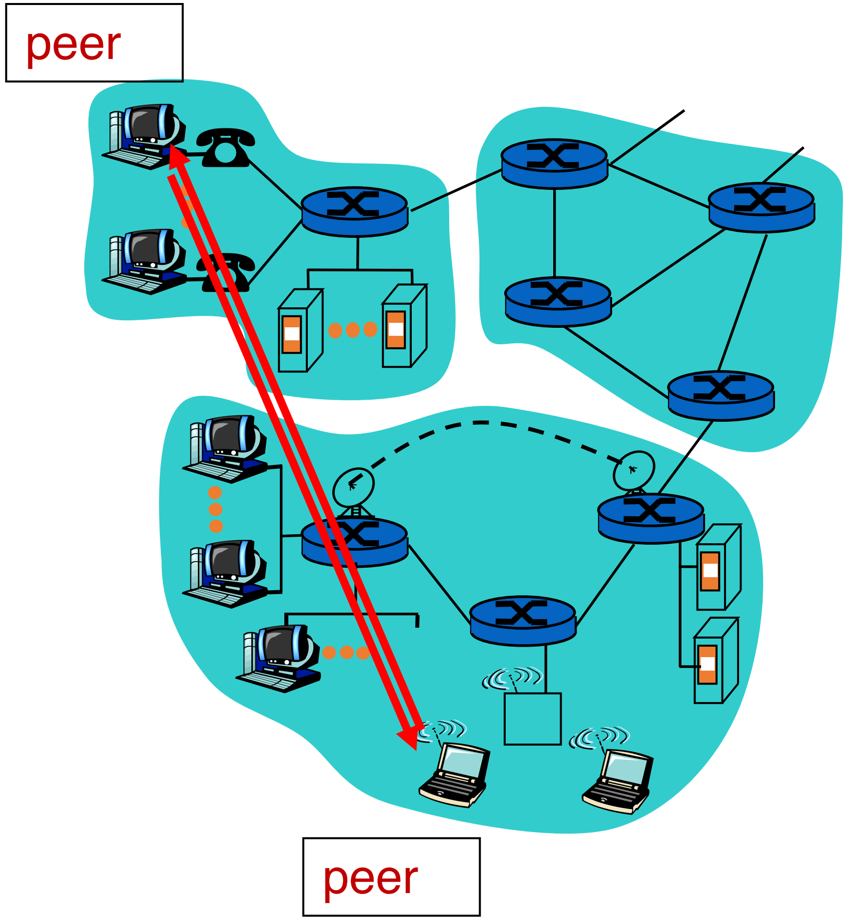

## Server:

- always-on host
- permanent IP address
- server farms ("data centers") for scaling

## Clients:

- communicate with server
- may be intermittently connected
- may have dynamic IP addresses
- do not communicate directly with each other

# Peer-to-peer (P2P) architecture




- Peers:
  - Intermittently connected hosts
  - Directly talking to each other
- Little to no reliance on always-up servers
  - Examples: BitTorrent, Skype
- Today, many applications use a hybrid model
  - Example: Skype “supernodes”

# Going forward: A few applications

- Domain Name System
- The web: HTTP
- Mail
- File transfer

# Domain Name System (DNS)

“You have my name. Can you lookup my number?”

# Domain Name System (DNS)

- Problem statement:
  - Average brain can easily remember 7 digits for a few names
  - On average, IP addresses have 12 digits
  - We need an easier way to remember IP addresses

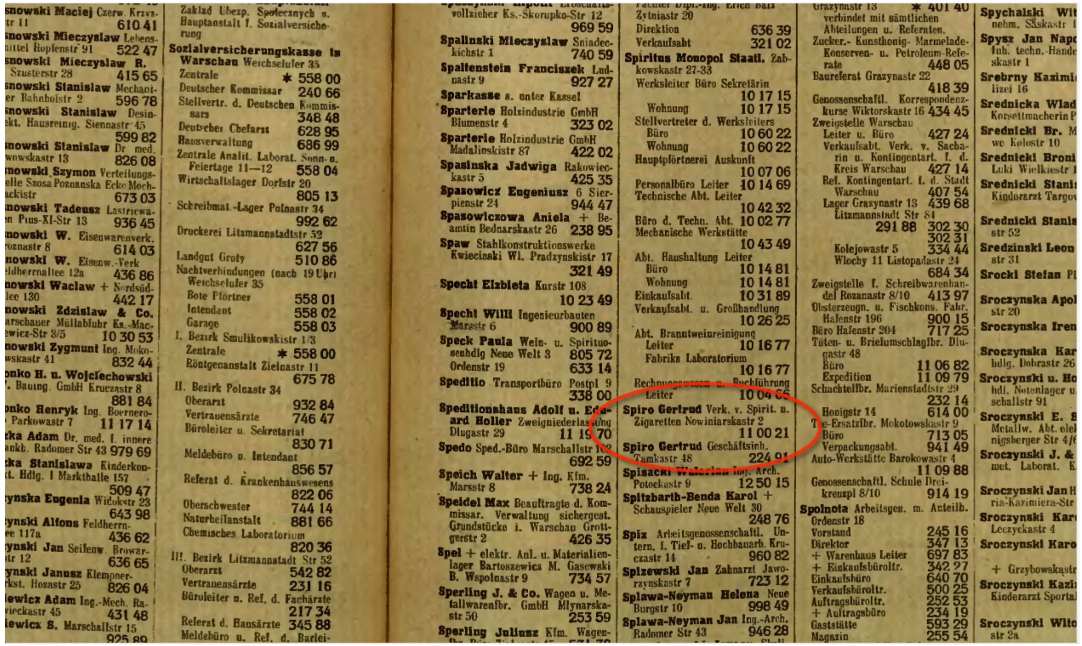
- Solution:
  - Use alphanumeric names to refer to hosts
  - We need a directory: add a service to map between alphanumeric host names and binary IP addresses
  - We call this process Address Resolution

# Types of Directories


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

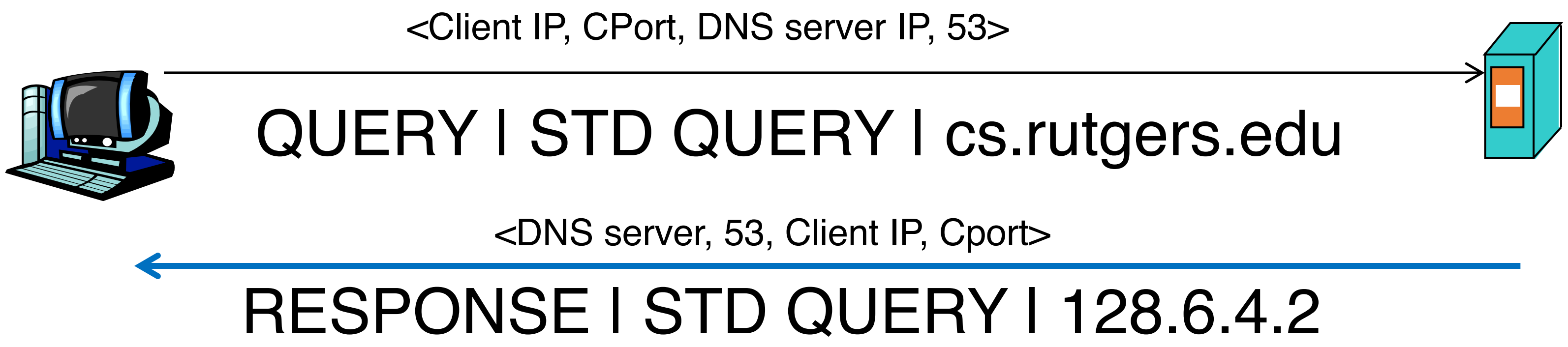
# Simple DNS

- What if every host has a local directory?
- `/etc/hosts.txt`
  - How things worked in the early days of the Internet!
- What if hosts moved around? How do you keep this up to date?



# Simple DNS

| DOMAIN NAME | IP ADDRESS |
|---|---|
| www.yahoo.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 |




- Idea (2): Implement a server that looks up a table
  - Simple, but does not scale
- Every new host needs to be entered in this table
- Performance?
- Failure?

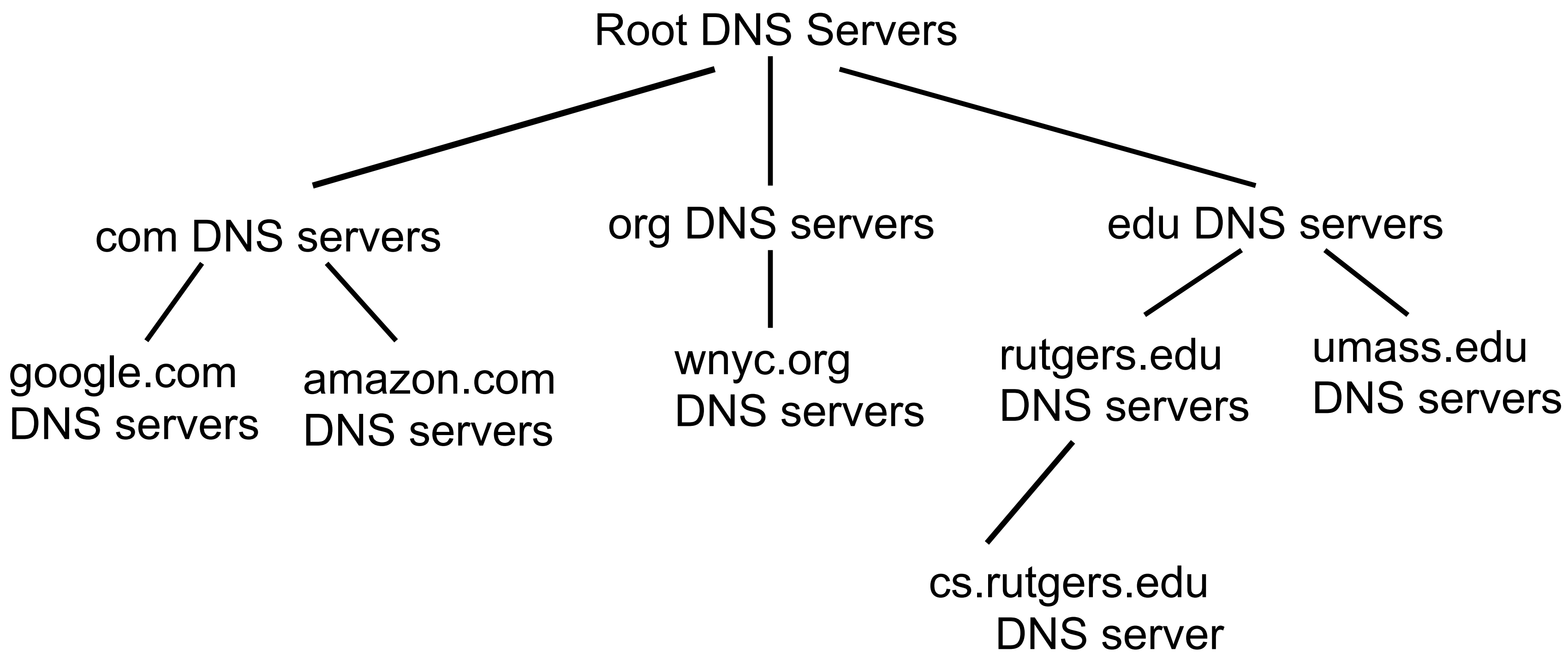
# DNS design

A centralized DNS design (ex: single server) is problematic.

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

It doesn’t *scale* to the requirements of the Internet.

# Distributed and hierarchical database




RFC 1034: Distribution through hierarchy enables scaling

# DNS protocol

- Client and Server
- Client connects to Port 53 on server
- DNS server IP address should be known. How?
  - Either manually configured or automatically (more on this to come…)
- Two types of messages
  - Queries
  - Responses
- Type of Query (OPCODE) methods
  - Standard query (0x0)
    - Request domain name for a given IP address
  - Updates (0x5)
    - Provide a binding of IP address to domain name
- Each type has a common message format that follows the header

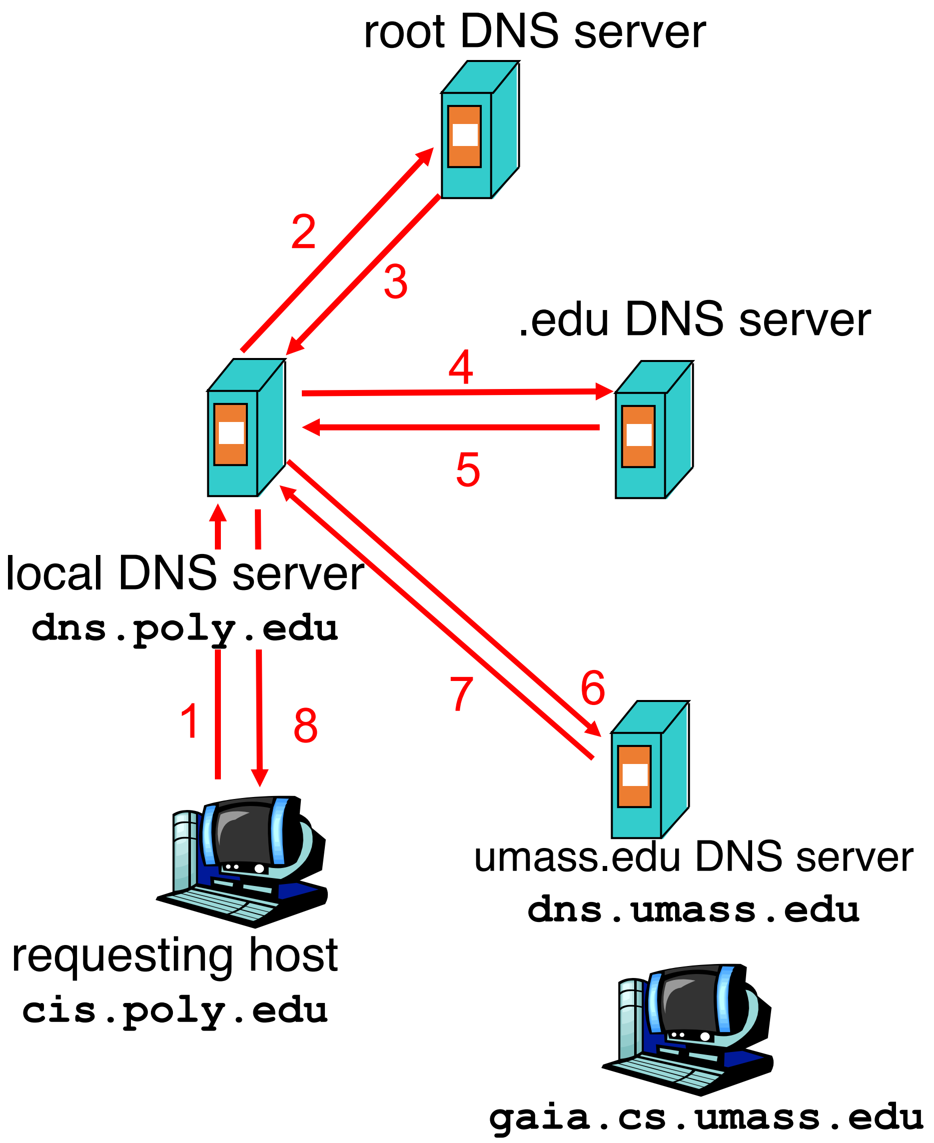
# DNS Protocol

- 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 tree toward the host until it reaches a name server with the correct mapping

# Example

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

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



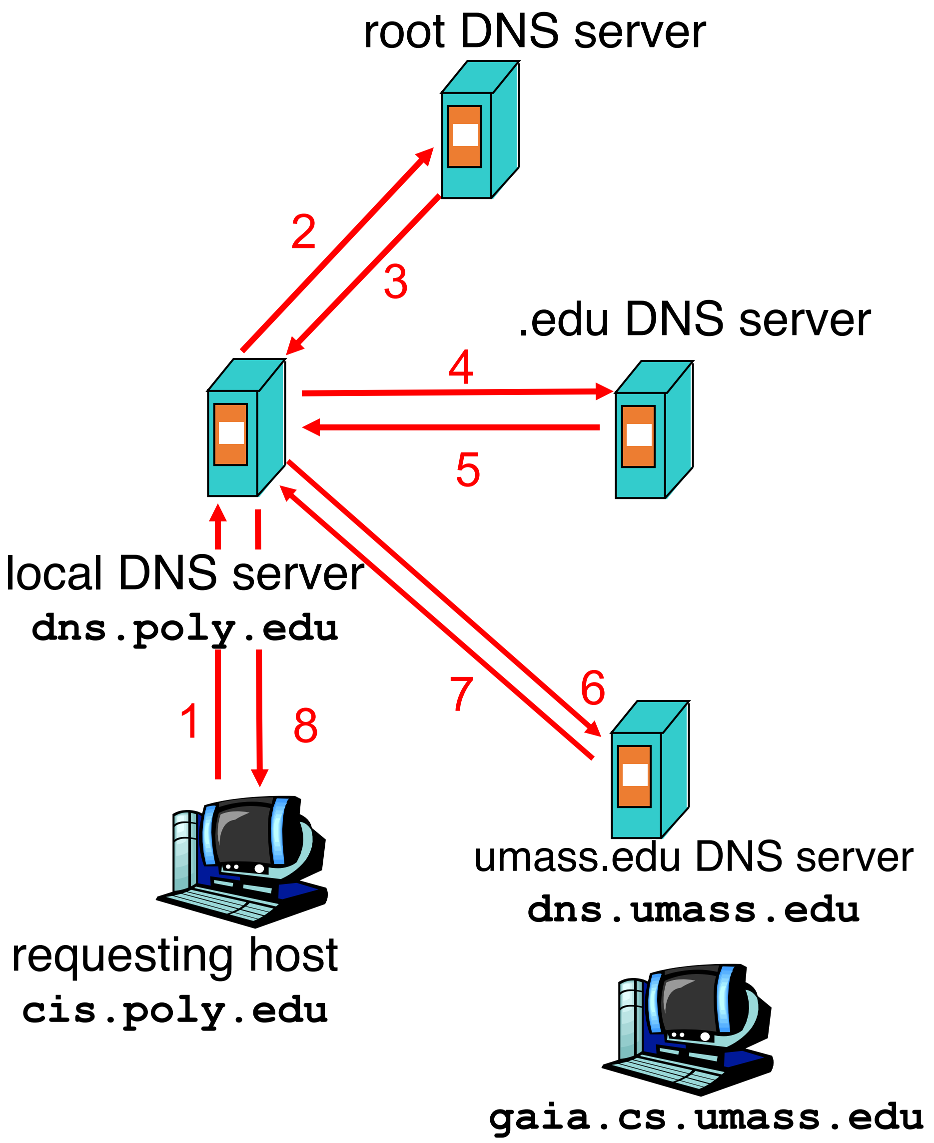
# Query type

Iterative query:

- Contacted server replies with name of server to contact

- “I don’t know this name, but ask this server”

- Queries are iterative for the local DNS server



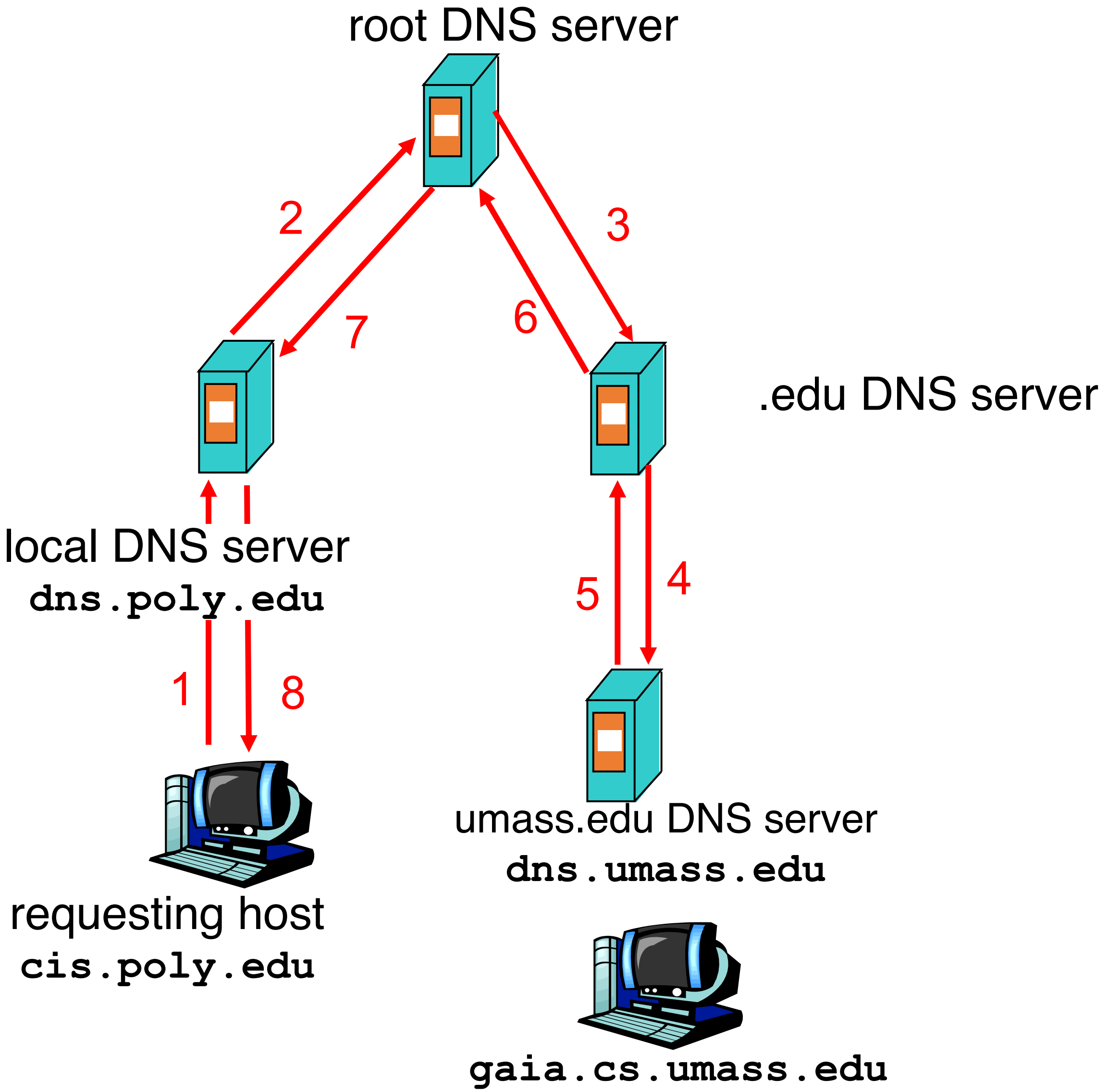
# Query type

## Recursive query:

- Puts burden of name resolution on the contacted name server

Problem: think about the root DNS server.

- Must it answer every DNS query?



# DNS Records

# DNS records

DNS: distributed db storing resource records (RR)

RR format: **(name, type, class, ttl, addr)**

Type=A
- **name** is hostname
- **value** is IP 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

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

Type=MX
- **value** is name of mailserver associated with **name**

# 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 caching and updating records

- 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

# Bootstrapping DNS

- How does a host contact the name server if all it has is the name and no IP address?
- IP address of at least 1 nameserver must be given a priori
    - or with another protocol (DHCP, bootp)
- File **`/etc/resolv.conf`** in unix
- `Start -> settings-> control panel-> network ->TCP/IP -> properties` in windows

# DNS summary

DNS service:

- Hostname to IP address translation
- Caching
- Hierarchical structure for scaling
- Multiple layers of indirection

- Host aliasing
  - Canonical and alias names
- Mail server aliasing
- Load distribution
  - Replicated Web servers: set of IP addresses for one canonical name

# Themes

- Request/response nature of protocols
- How Messages are structured
  - HTTP, SMTP, FTP - simple ASCII protocols
- Caching
- Name Lookup
  - Division of concerns (e.g. zones)
  - Hierarchy structure