

The Application Layer: Sockets, DNS

CS 352, Lecture 3, Spring 2020

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

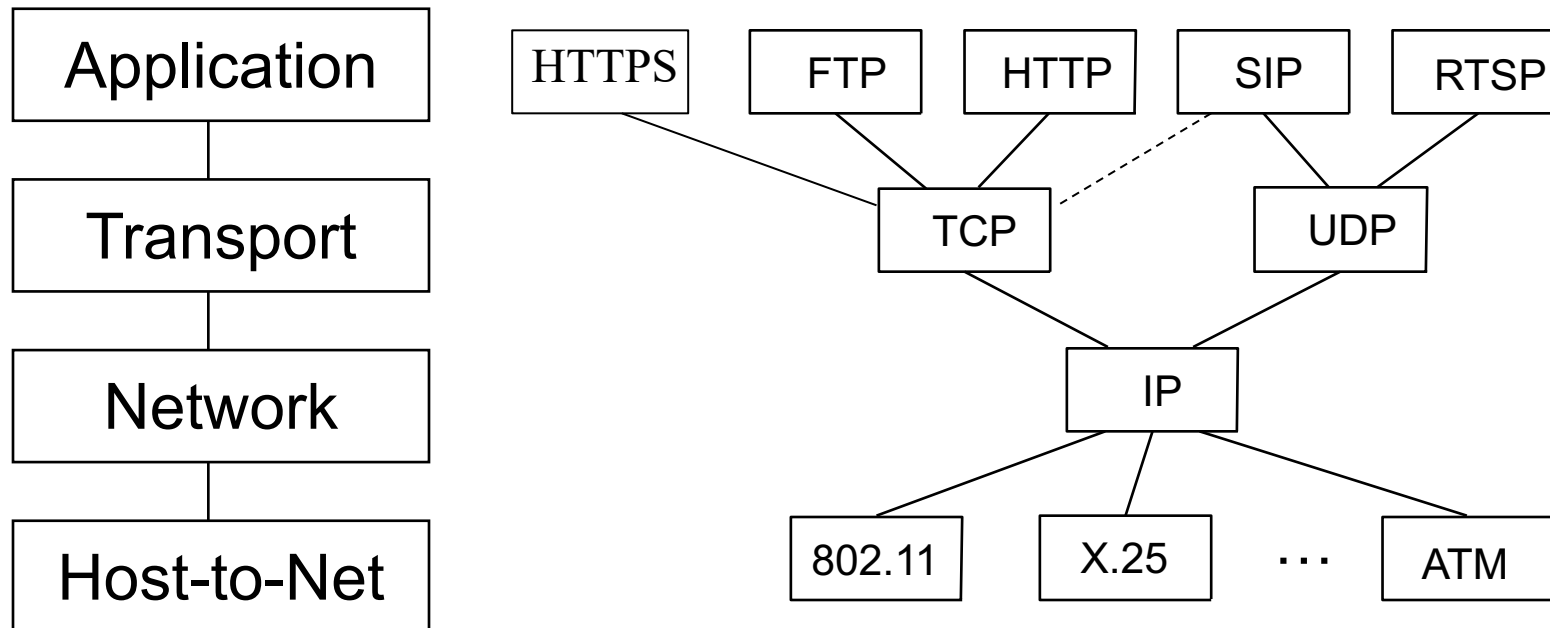
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Course announcements

- 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:

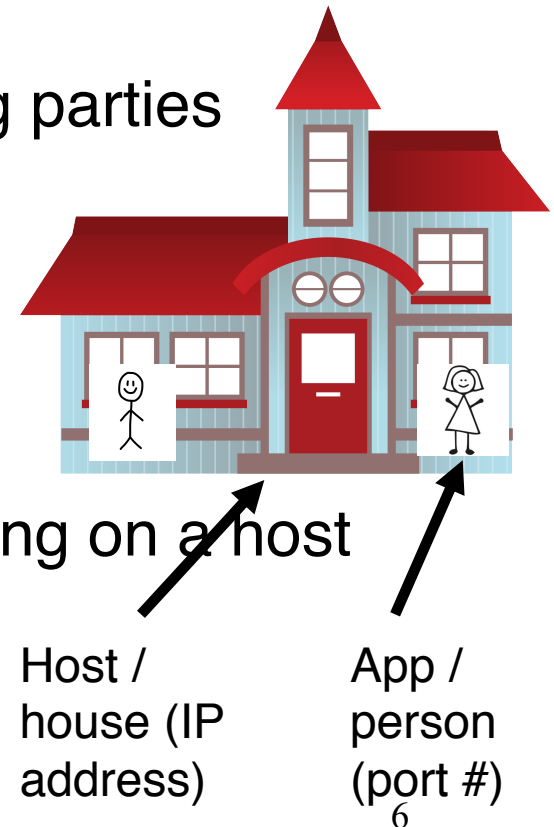
- defined in RFCs
- allows for interoperability
- e.g., HTTP, SMTP

Proprietary protocols:

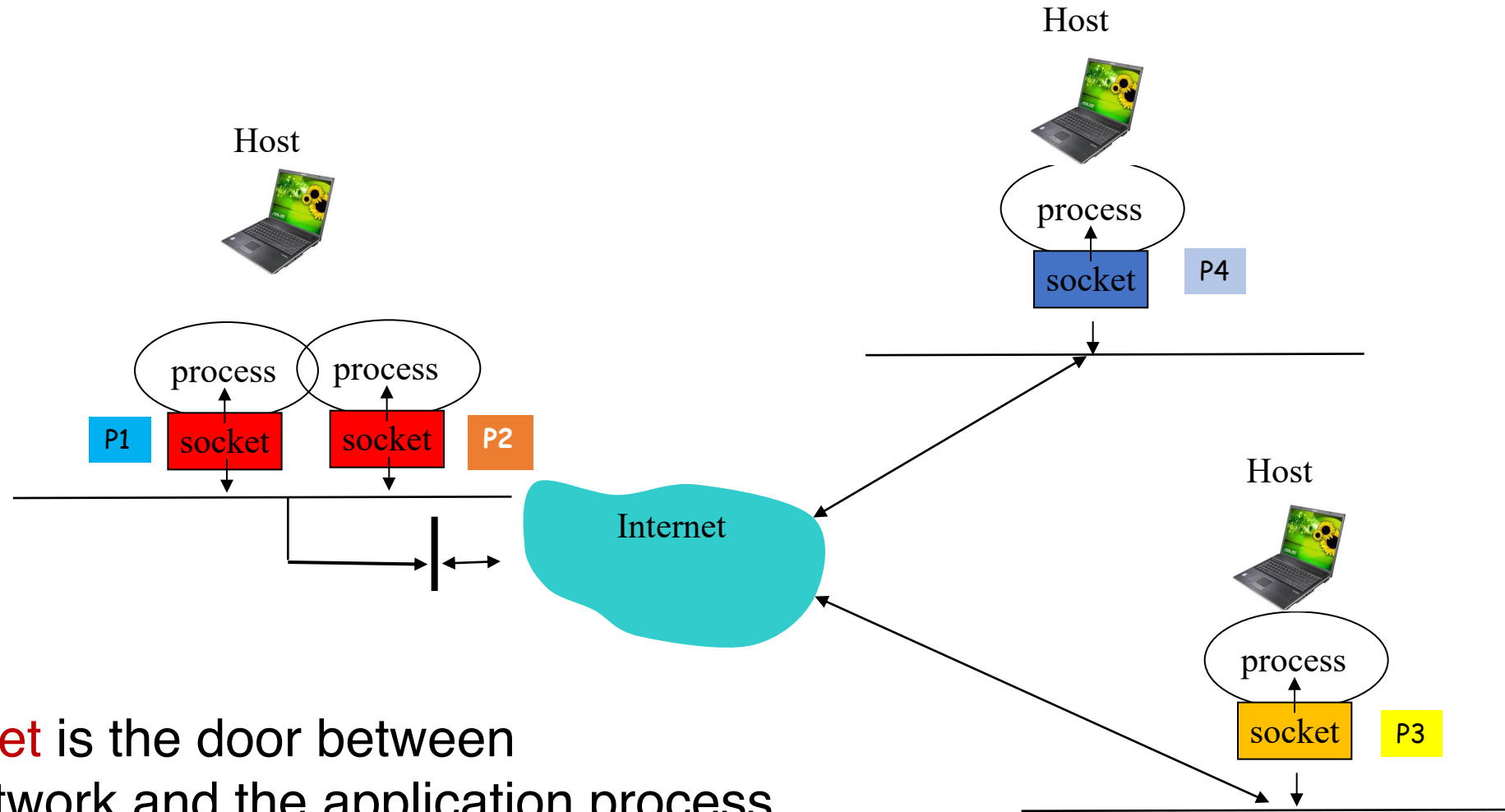
- e.g., Skype, Microsoft Exchange

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**



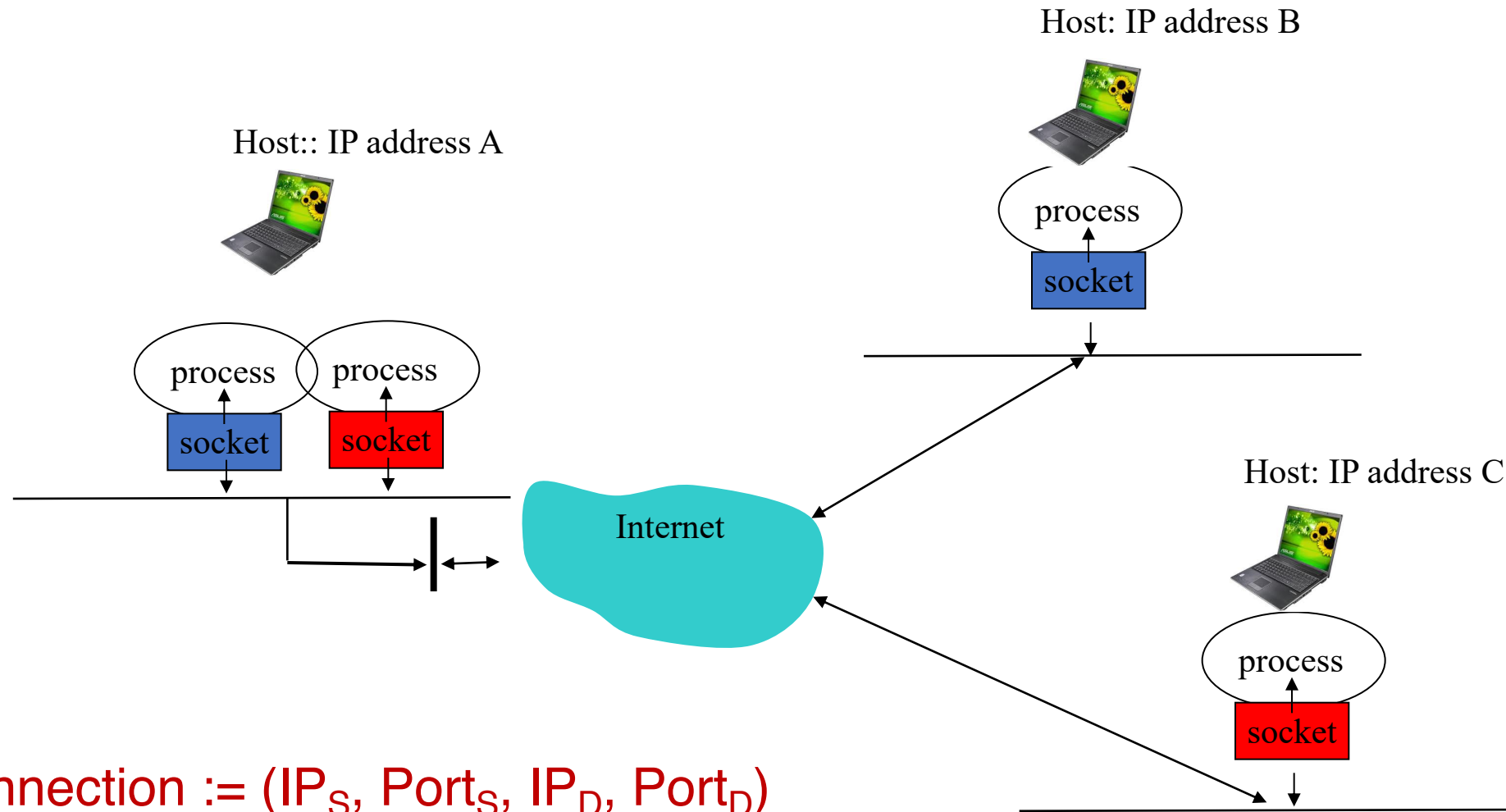
IP address & port number



A **socket** is the door between
OS/network and the application process

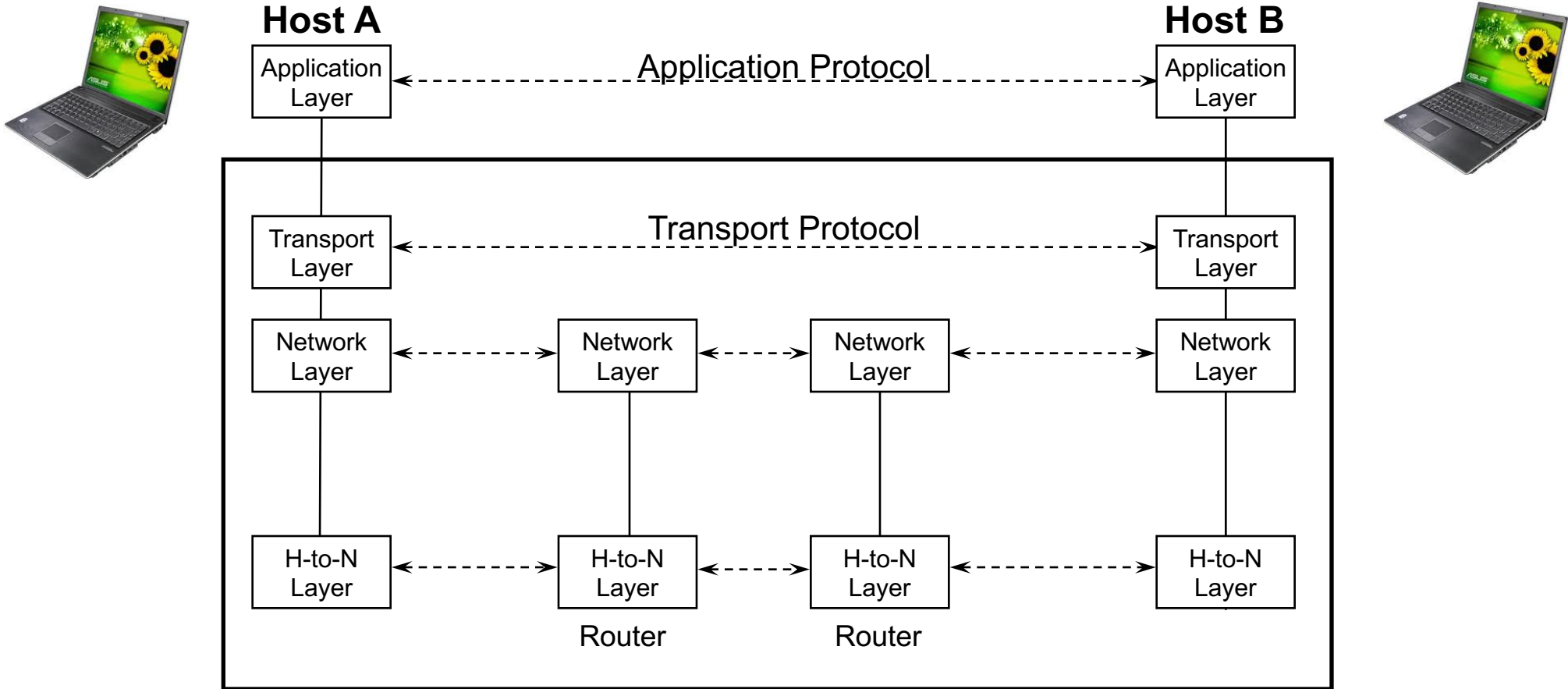
The **application's programming interface** to the network

An app-layer connection is a 4-tuple



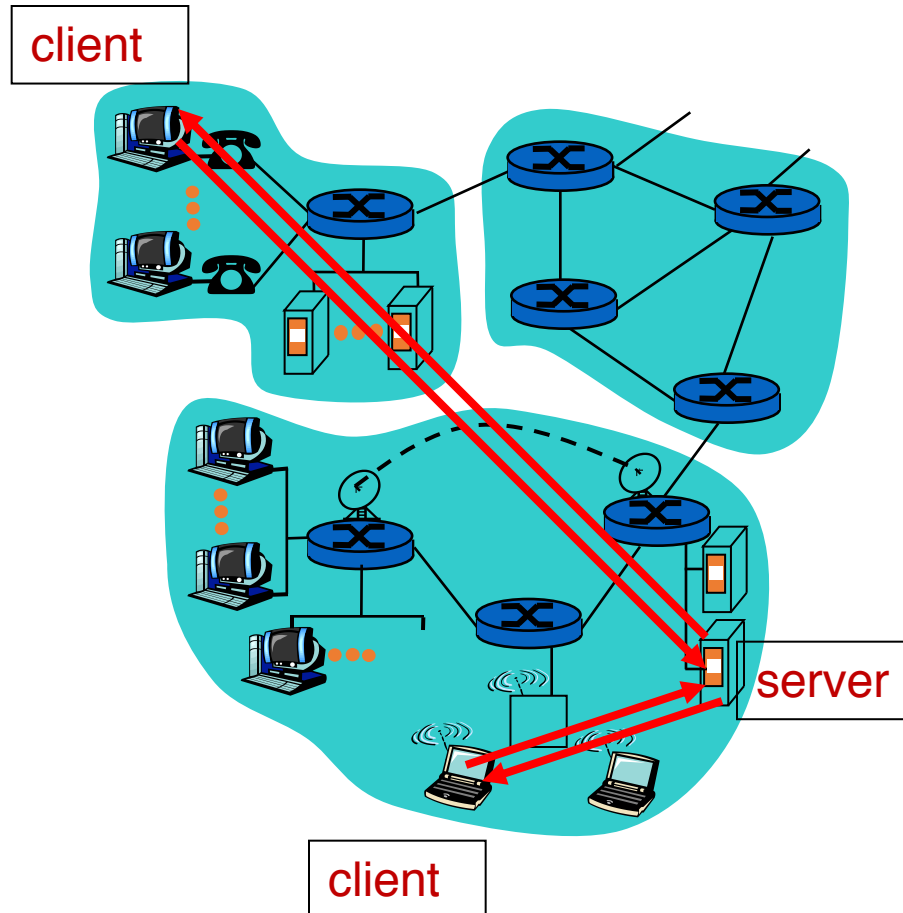
Connection := $(IP_S, Port_S, IP_D, Port_D)$
(S = source, D = destination)

Recall: Services provided by lower layers



Application architectures

Client-server architecture



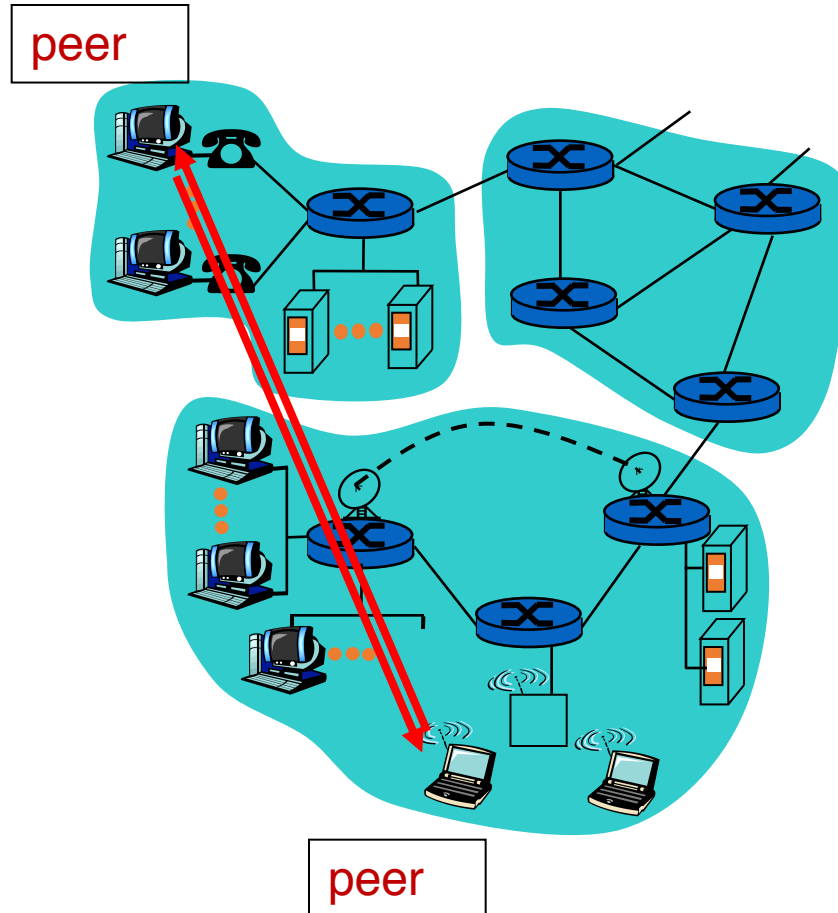
Server:

- 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)

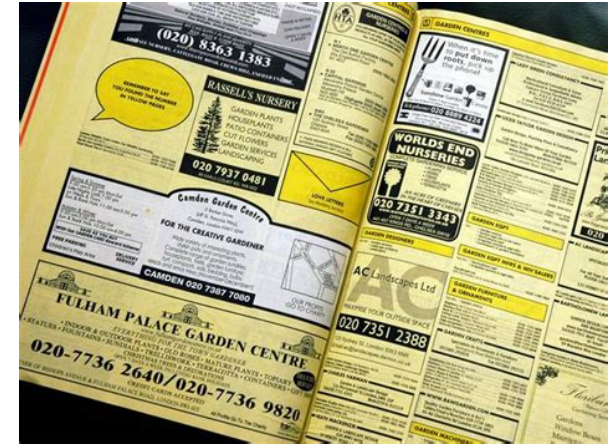
“You have my name. Can you lookup my number?”

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)



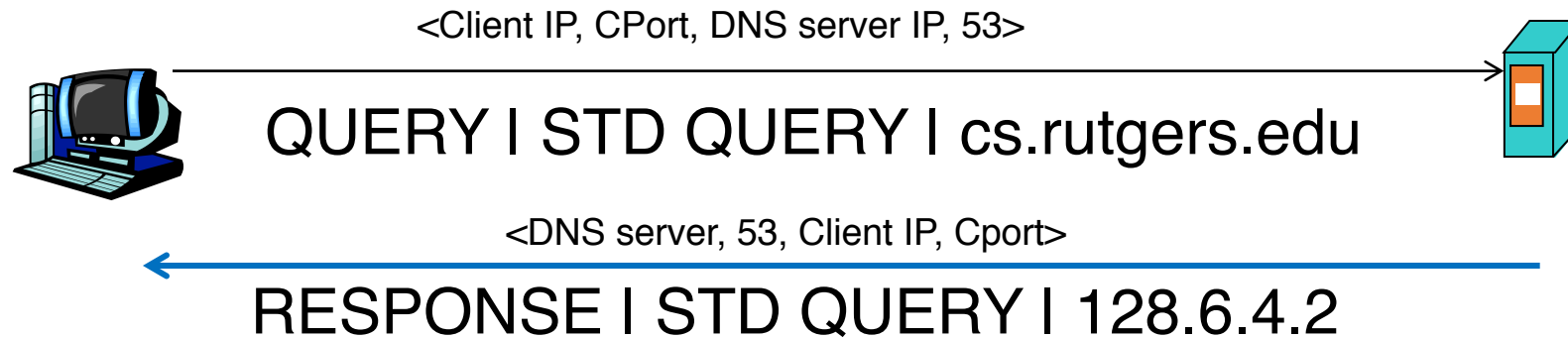
Simple DNS

- 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?

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Pietekstr 9 12 50 15 Spitzbarth-Benda Karol + Schauspieler Neue Welt 30 248 76 Spix Arbeitsgenossenschaftl. Un- tern. I. Tief- u. Hochbauar. Kro- cassstr 14 960 62 Spizowski Jan Zahnarzt Javo- rinskistr 7 723 12 Splawa-Neyman Helena Neue Burgstr 10 998 49 Splawa-Neyman Jan Ing.-Arch. Radomer Str 43 946 28	Grasynstr 15 * 401 40 verbindet mit sämtlichen Abteilungen u. Referaten. Zucker-, Kunststoffe-, Narmelade- Konserven- u. Petroleum-Ref- erale 448 05 Baureferat Grasynstr 22 418 39 Genossenschaftl. Korrespondenz- kurse Wiktorskistr 16 434 45 Zweigstelle Warschau 427 24 Leiter u. Büro 427 14 Verkaufsabt. Verk. v. Sacha- rin u. Kontingentart. I. d. Kreis Warschau 427 14 Ref. Kontingentart. I. d. Stadt Warschau 407 54 Lager Grasynstr 19 439 68 Litmannstadt Str 81 291 88 302 30 Kolejowastr 5 334 44 Wlochy 11 Listopadstr 24 684 34 Zweigstelle I. Schreibwarenhan- del Rosanskistr 8/10 413 97 Ölsterzeugn. u. Fischkons. Fabr. Halestr 196 900 15 Büro Halestr 264 717 25 Tulow. u. Briefumschlagfabr. Dlu- gustr 48 Büro 11 06 82 Expedition 11 09 79 Schachtelbr. Marionettstr 23 232 14 Hosigstr 14 614 00 Le Exztrakt. Mokolowskistr 9 Verpackungsabt. 941 49 Auto-Werkstätte Barokwastr 4 11 09 88 Genossenschaftl. Schule Drei- kreuzpl 8/10 914 19 Ordnungsabteilung m. Anteilb. Vorstand 245 16 Direktor 247 13 + Warenhaus Leiter 697 63 + Einkaufsbüro 242 27 Einkaufsbüro 640 70 Verkaufsbüro 500 25 Auftragbüro 452 53 + Auftragbüro 234 19 Gaststätte 593 29 Magazin 255 54	Psychiatrik Wit- solim. Skakast 1 Spyra Jan Nap- Inh. techn. Hand- skastr 1 Srebrny Kazimi- lusz 16 Srednicka Wlad Korsettmacherin F Srednicki Br. M we Kolost 10 Srednicki Broni Loki Wlochystr 1 Srednicki Stani Kinderarzt Targow- str 52 Srednicki Leon str 31 Srocki Stefan Pl str 20 Sroczyńska Apol str 20 Sroczyńska Iren Sroczyńska Kar bldg. Lebnstr 26 Sroczyński u. He bld. Nienlager u schallstr 91 Sroczyński E. S Medizin. Abt. eiel nigskerger Str 4/4 Sroczyński J. & med. Laborat. E Sroczyński Jan H ria-Kosmiera-Str Sroczyński Kar Lecykaskastr 4 Sroczyński Karo + Grybowkasta Sroczyński Kazi Kinderarzt Sporta Sroczyński Wito str 2a
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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?

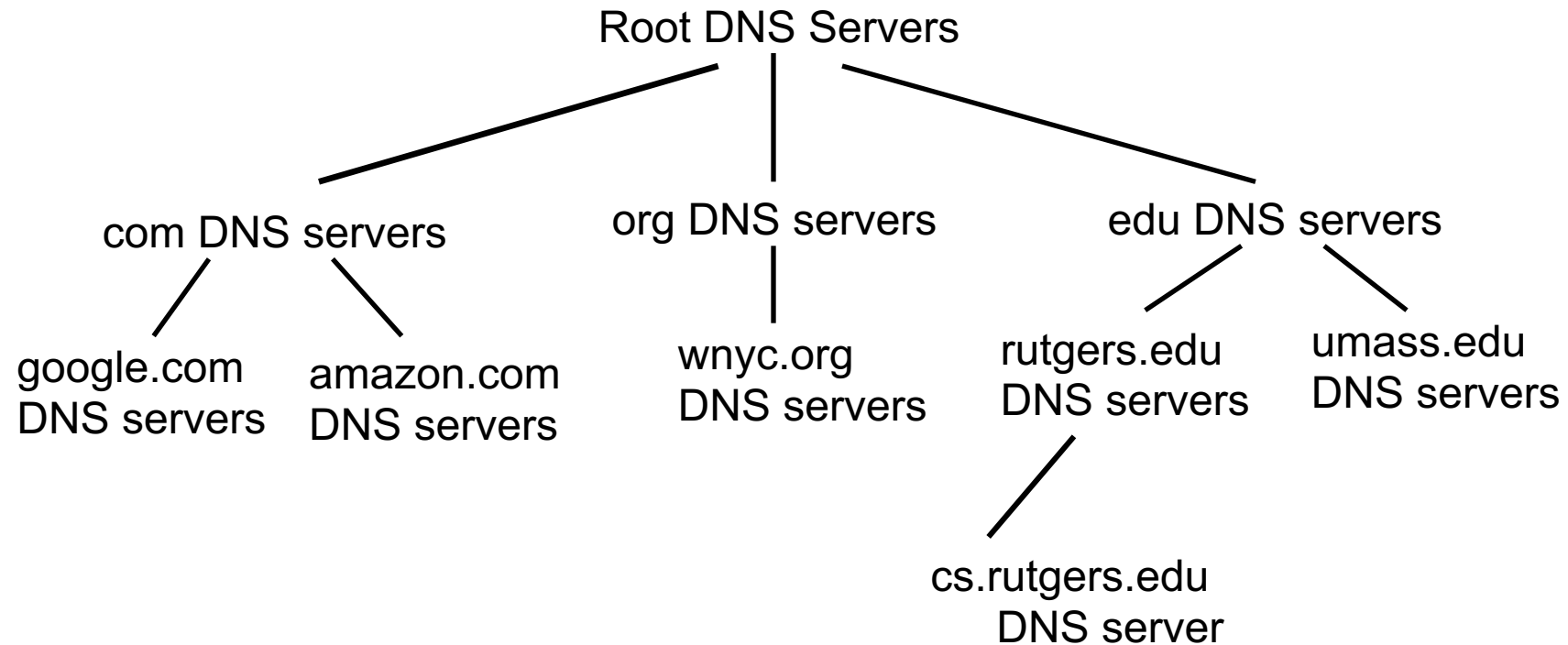
DNS design

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

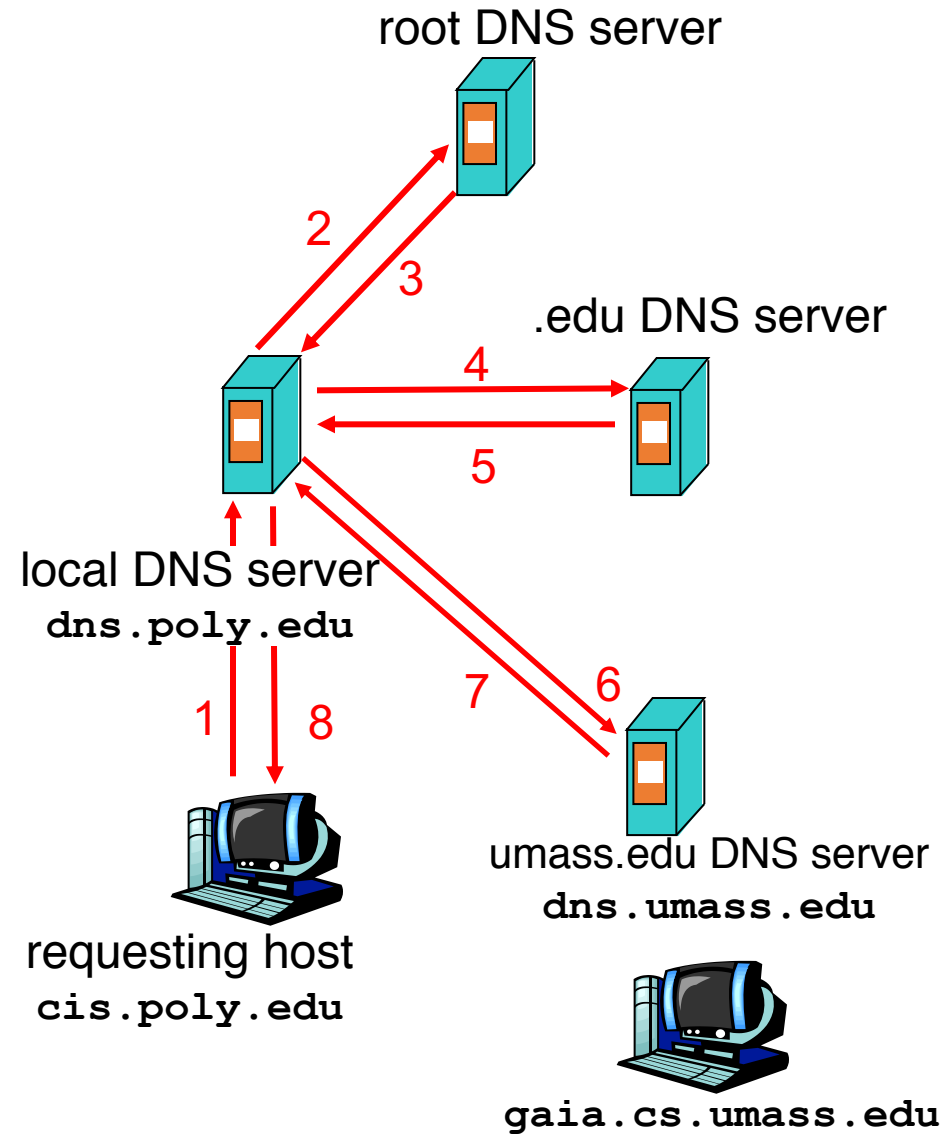
- Client and Server
- Client connects to Port 53 on server
- DNS server IP address should be known. How?
 - Either manually configured or automatically (more on this to come...)
- Two types of messages
 - Queries
 - Responses
- Type of Query (OPCODE) methods
 - Standard query (0x0)
 - Request domain 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

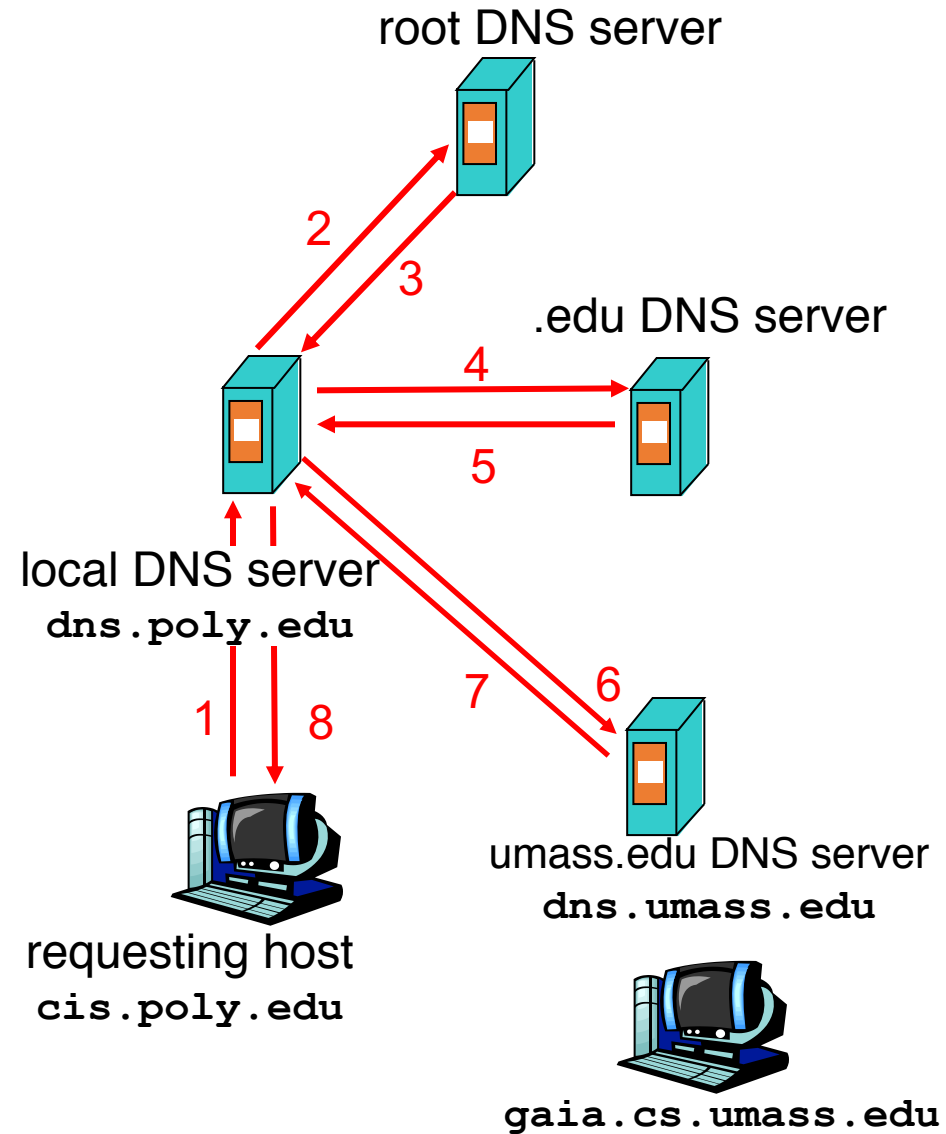
- Host at cis.poly.edu wants IP address for gaia.cs.umass.edu
- Local DNS server
- Root DNS server
- TLD DNS server
- **Authoritative** DNS server



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



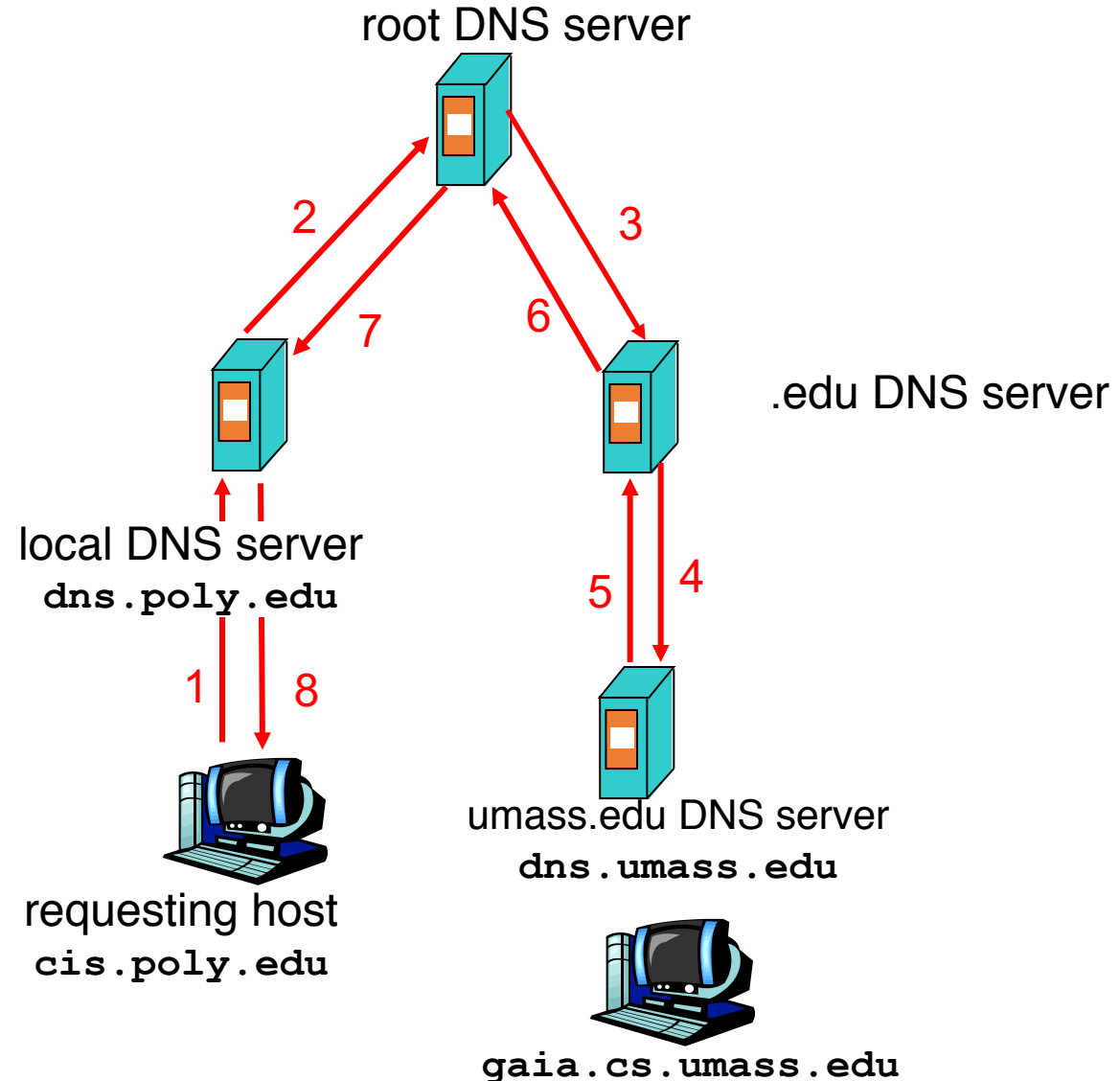
Query type

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
serveeast.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