Computer Networks
Chapter 2.3 ~2.4

Jong-won Lee

Handong University

Chapter 2: Application layer

- 2.1 Principles of network applications
- 2.2 Web and HTTP
- 2.3 Electronic Mail (SMTP, POP3, IMAP)
- 2.4 DNS
- 2.5 P2P applications
- 2.6 Video streaming and content distribution networks (CDNs)
- 2.7 Socket programming with TCP and UDP

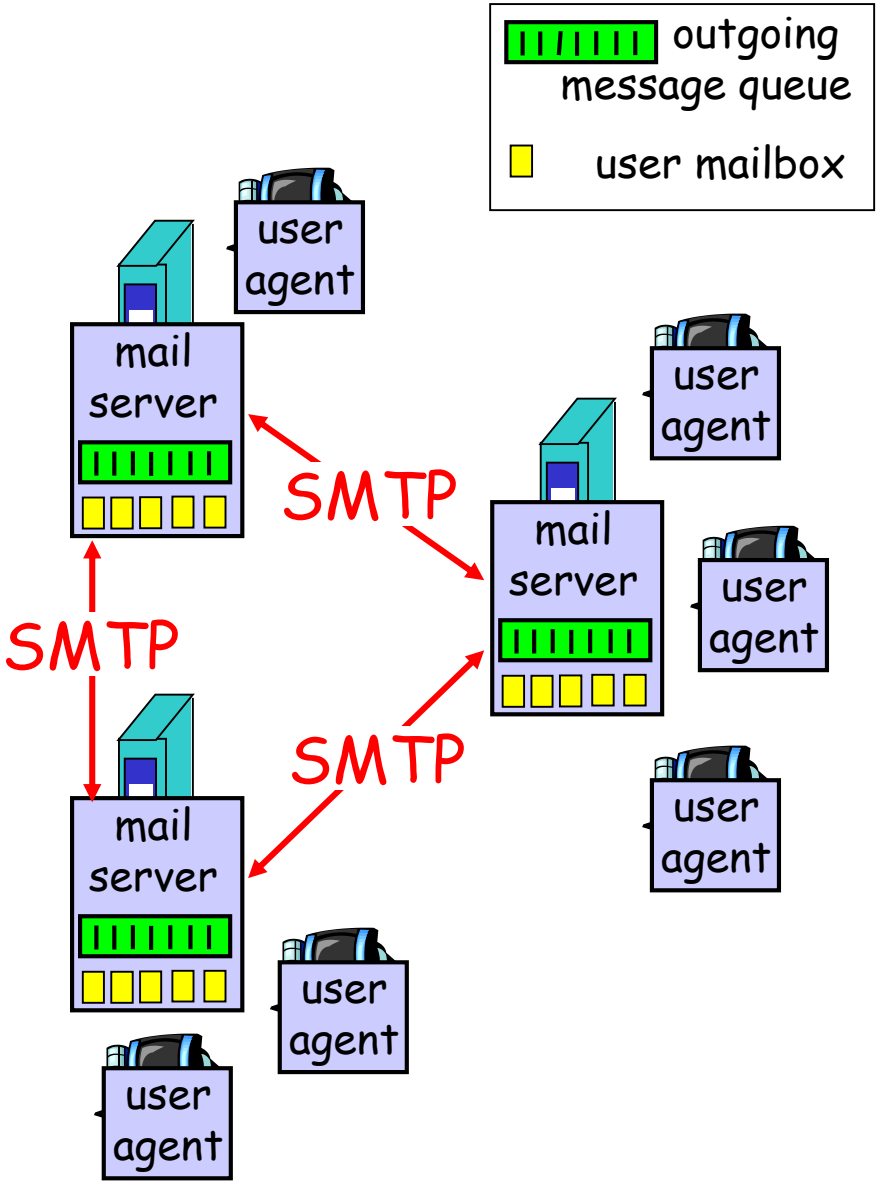
Electronic Mail

Three major components:

- user agents
- mail servers
- simple mail transfer protocol: SMTP

User Agent

- a.k.a. "mail reader"
- composing, editing, reading mail messages
- e.g., Outlook, elm, Netscape Messenger
- outgoing, incoming messages stored on server



Electronic Mail: mail servers

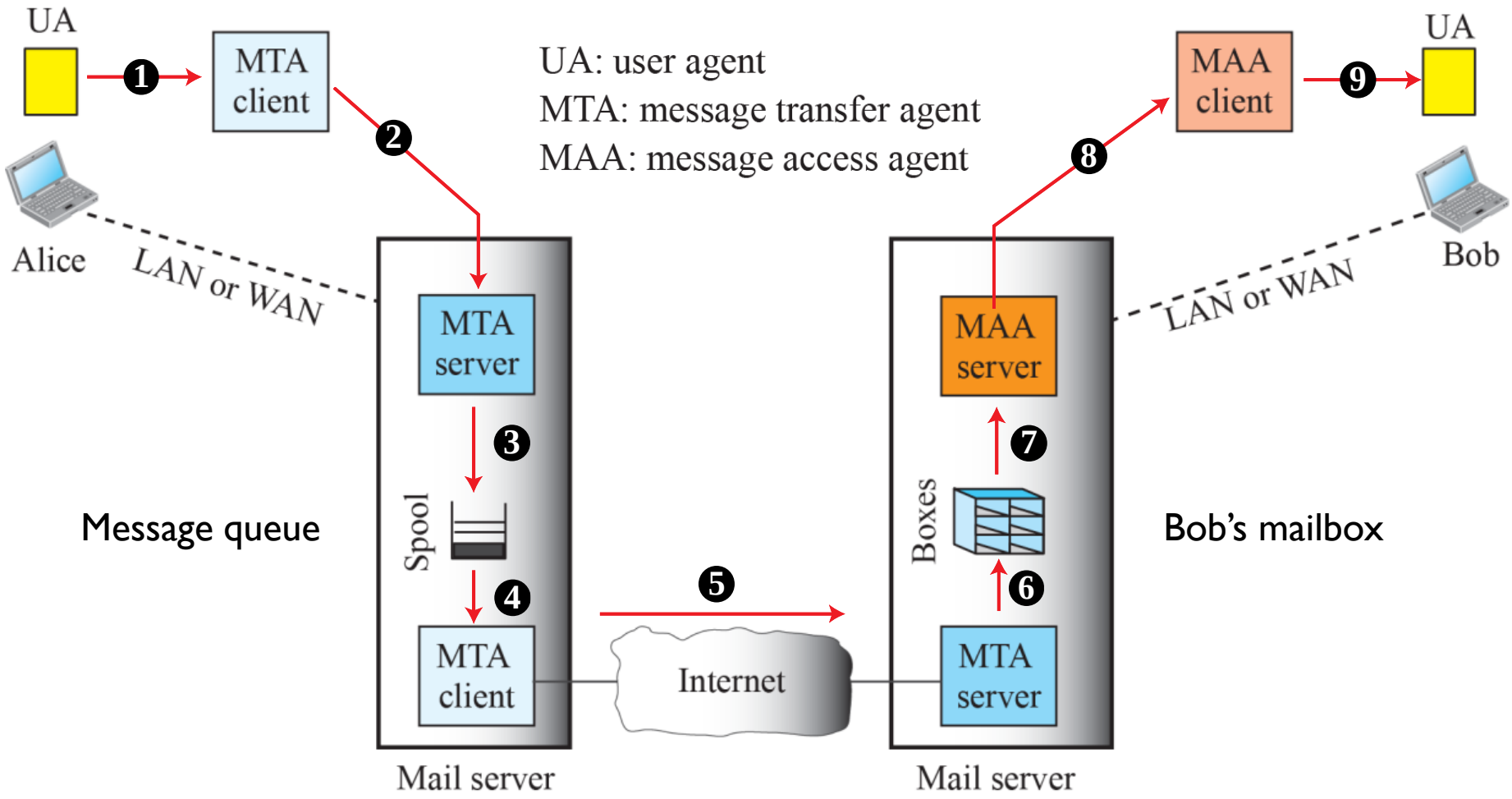
Mail Servers

- mailbox contains incoming messages for user
- message queue of outgoing (to be sent) mail messages
- SMTP protocol between mail servers to send email messages
  - client: sending mail server
  - "server": receiving mail server

SMTP [RFC 2821]

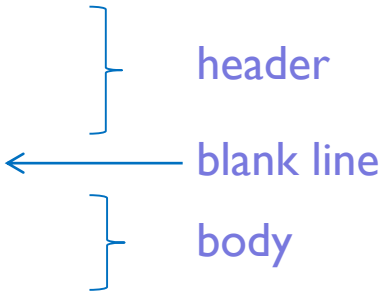
- uses to reliably transfer email message from client to server on port
  - three phases of transfer
    - handshaking (greeting)
    - transfer of messages
    - closure
- SMTP uses persistent connections
  - Can send several messages over the same TCP connection
  - direct transfer: sending server to receiving server
- The message must be in
- command/response interaction
  - commands: ASCII text
  - response: status code and phrase

E-mail scenario



Sample SMTP interaction

```
S: 220 hamburger.edu
C: HELO crepes.fr
S: 250  Hello crepes.fr, pleased to meet you
C: MAIL FROM: <alice@crepes.fr>
S: 250 alice@crepes.fr... Sender ok
C: RCPT TO: <bob@hamburger.edu>
S: 250 bob@hamburger.edu ... Recipient ok
C: DATA
S: 354 Enter mail, end with "." on a line by itself
C: Subject: sample message
C: From: alice@crepes.fr
C: To: bob@hamburger.edu
C:
C: Do you like ketchup?
C: How about pickles?
C: .
S: 250 Message accepted for delivery
C: QUIT
S: 221 hamburger.edu closing connection
```

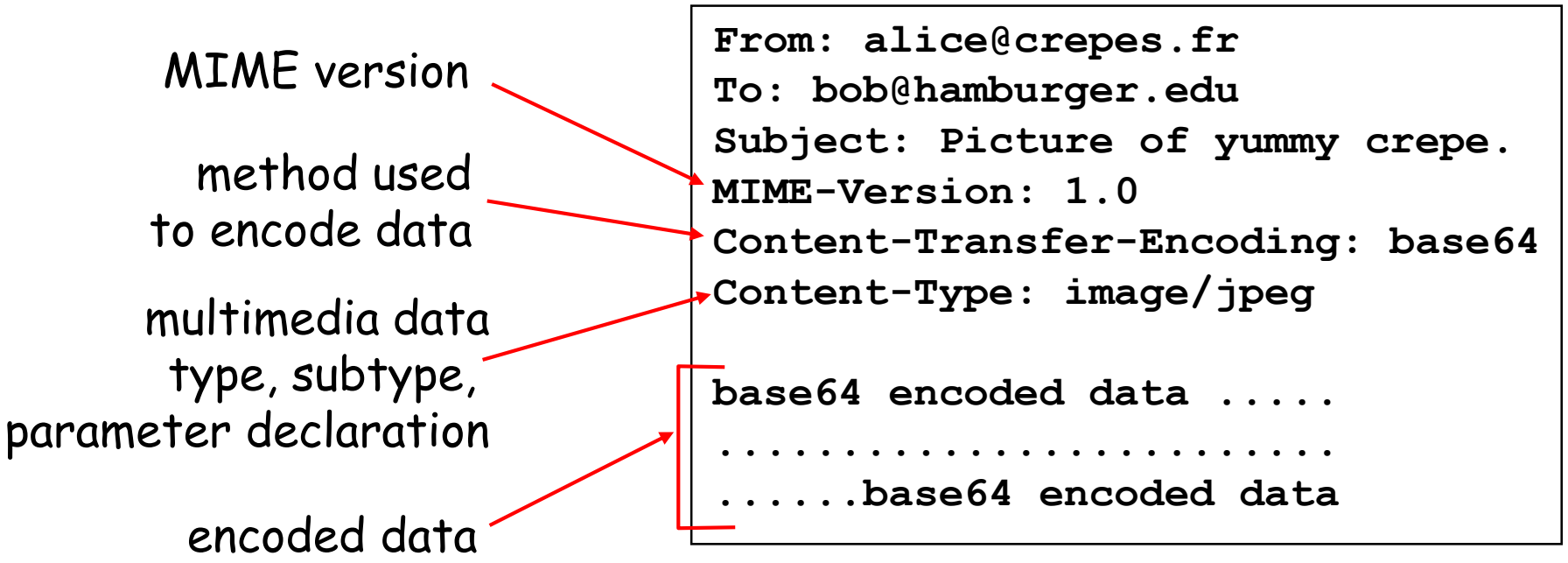


Comparison with HTTP

- HTTP 1.1 and SMTP: persistent connection
- HTTP:
- SMTP:
- both have ASCII command/response interaction, status codes
- HTTP: each object encapsulated in its own HTTP response msg
- SMTP: multiple objects sent in multipart msg

Mail message format

- The message must be in 7-bit ASCII
- for non-ASCII data
  - RFC 2045, 2056
  - additional lines in msg header declare MIME content type

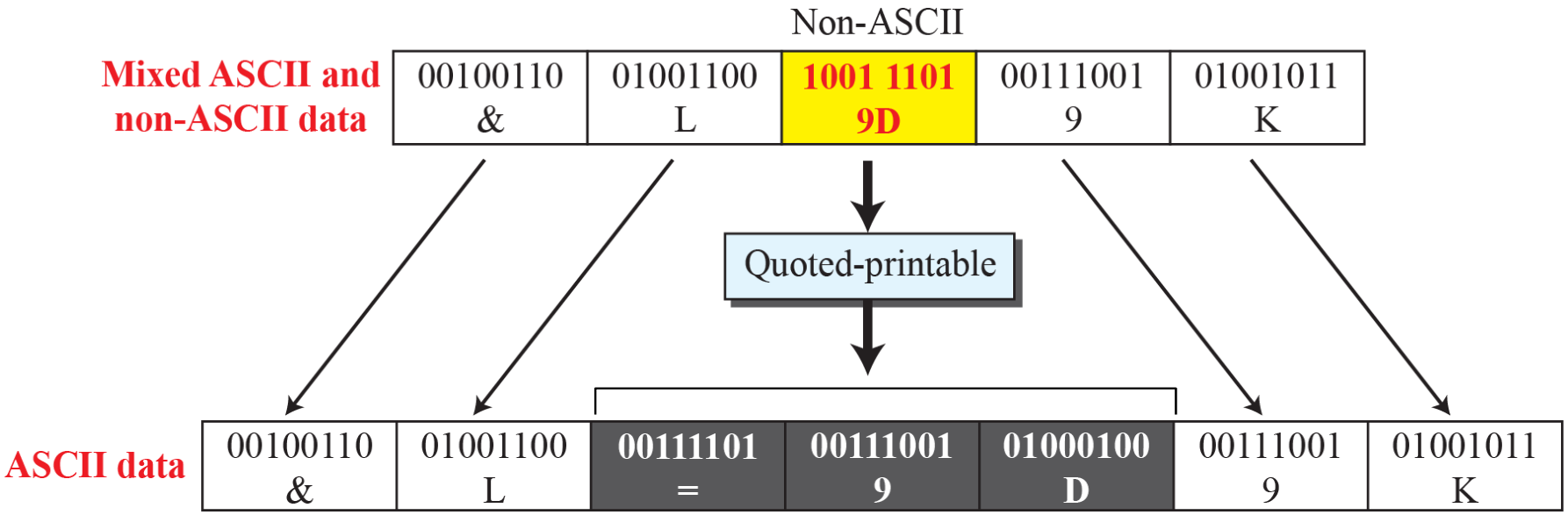


Message format: multimedia extensions

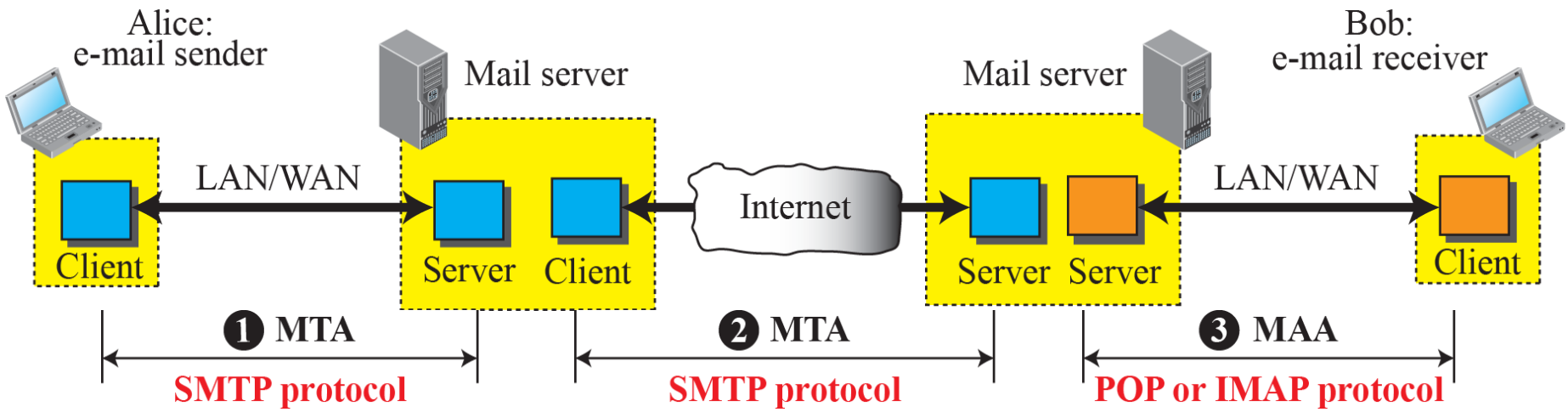
- encoding

Value	*Code*	*Value*	*Code*	*Value*	*Code*	*Value*	*Code*	*Value*	*Code*	*Value*	*Code*
0	**A**	11	**L**	22	**W**	33	**h**	44	**s**	55	**3**
1	**B**	12	**M**	23	**X**	34	**i**	45	**t**	56	**4**
2	**C**	13	**N**	24	**Y**	35	**j**	46	**u**	57	**5**
3	**D**	14	**O**	25	**Z**	36	**k**	47	**v**	58	**6**
4	**E**	15	**P**	26	**a**	37	**l**	48	**w**	59	**7**
5	**F**	16	**Q**	27	**b**	38	**m**	49	**x**	60	**8**
6	**G**	17	**R**	28	**c**	39	**n**	50	**y**	61	**9**
7	**H**	18	**S**	29	**d**	40	**o**	51	**z**	62	+
8	**I**	19	**T**	30	**e**	41	**p**	52	**0**	63	/
9	**J**	20	**U**	31	**f**	42	**q**	53	**1**		
10	**K**	21	**V**	32	**g**	43	**r**	54	**2**		

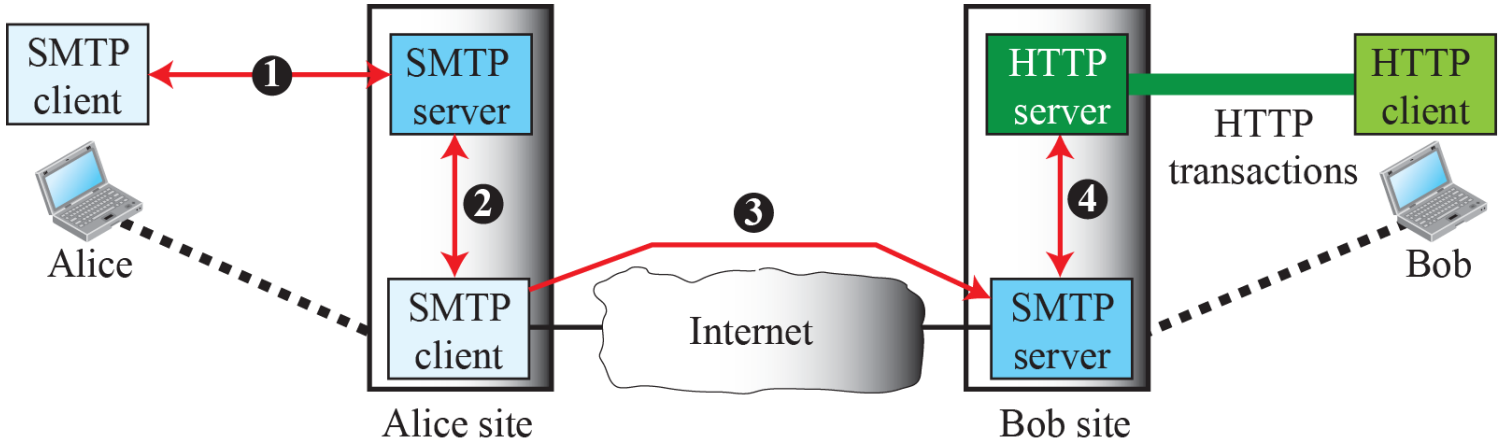
Message format: multimedia extensions



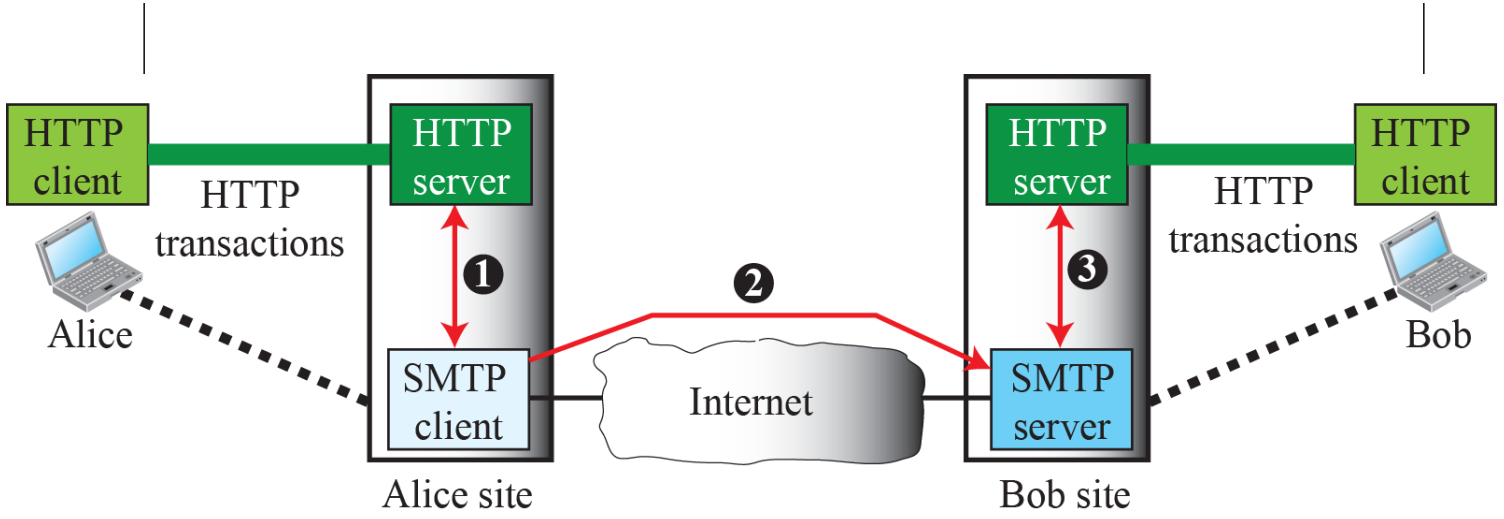
Protocols related to Mail



Web-based e-mail



Case 1: Only receiver uses HTTP



Case 2: Both sender and receiver use HTTP

Mail access protocols

- SMTP: delivery/storage to receiver's server
- Mail access protocol: retrieval from server
  - POP3: Post Office Protocol [RFC 1939]
    - authorization (agent <-->server) and download
    - Use TCP connection on port 110
  - IMAP4: Internet Mail Access Protocol [RFC 1730]
    - more features (more complex)
    - manipulation of stored msgs on server
      - provide the folder functionality
  - HTTP: gmail, Hotmail , Yahoo! Mail, etc.

POP3 protocol

authorization phase

- client commands:
  - `user`: declare username
  - `pass`: password
- server responses
  - `+OK`
  - `-ERR`

transaction phase, client:

- `list`: list message numbers
- `retr`: retrieve message by number
- `dele`: delete
- `quit`

```
S: +OK POP3 server ready
C: user bob
S: +OK
C: pass hungry
S: +OK user successfully logged on
```

```
C: list
S: 1 498
S: 2 912
S: .
C: retr 1
S: <message 1 contents>
S: .
C: dele 1
C: retr 2
S: <message 1 contents>
S: .
C: dele 2
C: quit
S: +OK POP3 server signing off
```

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DNS: Domain Name System

- Name & Address
  - Name
    - Character string for human use, e.g. www.naver.com
    - Mnemonic
  - Address: Where you are
    - IP address (32 bit string) : used by a machine

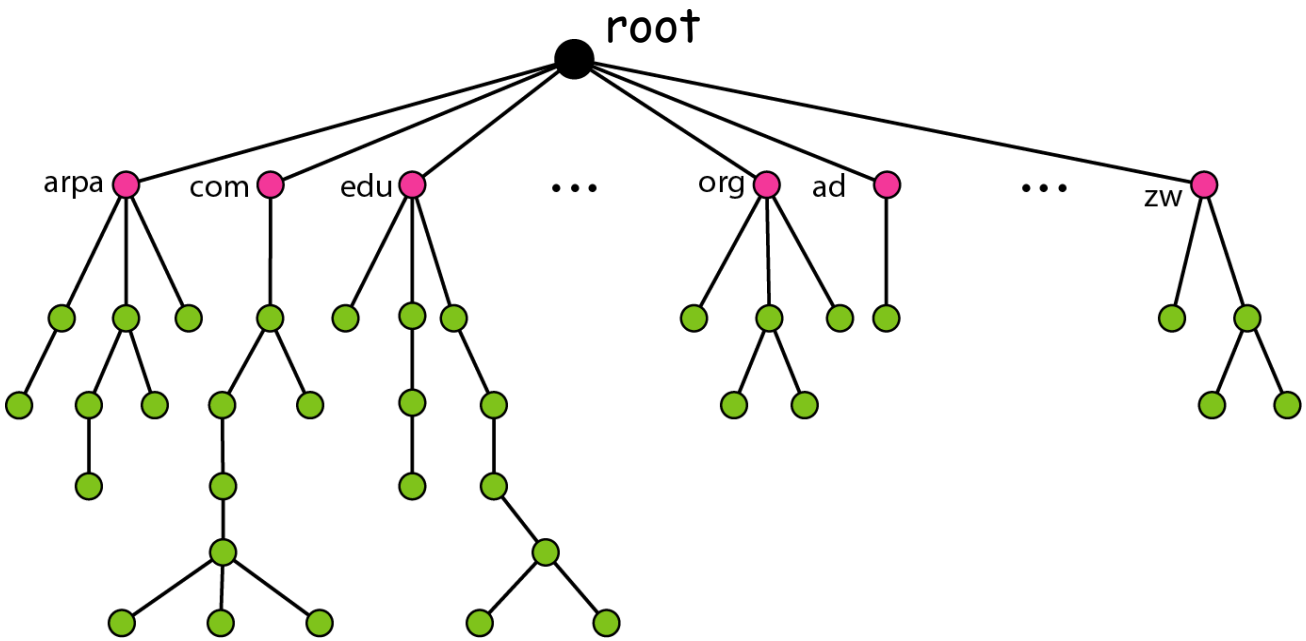
Q: How to map between IP addresses and name ?

Mapping a name to an address or an address to a name is called name-address resolution.

DNS

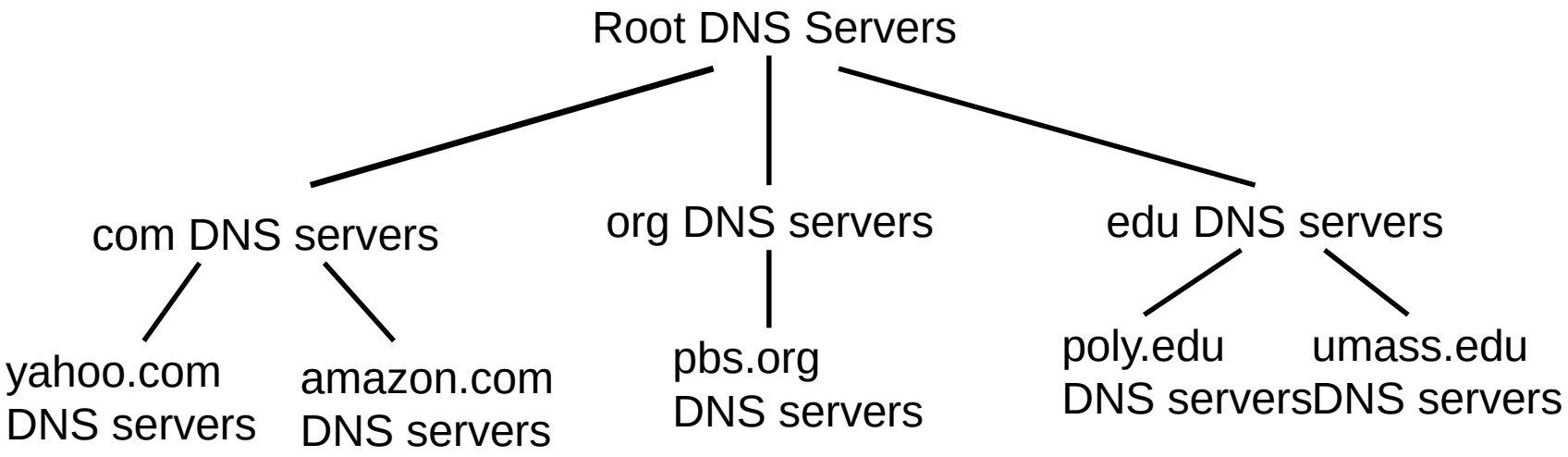
- Name resolution
  - Solution 1: Static Mapping
    - Hostname to address mapping file or *hosts* file. (ARPANET)
  - Solution 2: Dynamic Mapping (DNS)
    - The Internet has too many objects for a single management center
    - uses distributed database system
      - Scalability, maintenance
    - Partition the name space into a hierarchical tree
      - Domain hierarchy

DNS



- The tree can have only 128 levels
  - level 0 (root) to level 127.
- In the Internet, the domain name space (tree) is divided into three different sections:
  - generic domains, country domains, and the inverse domain.

Overview of DNS



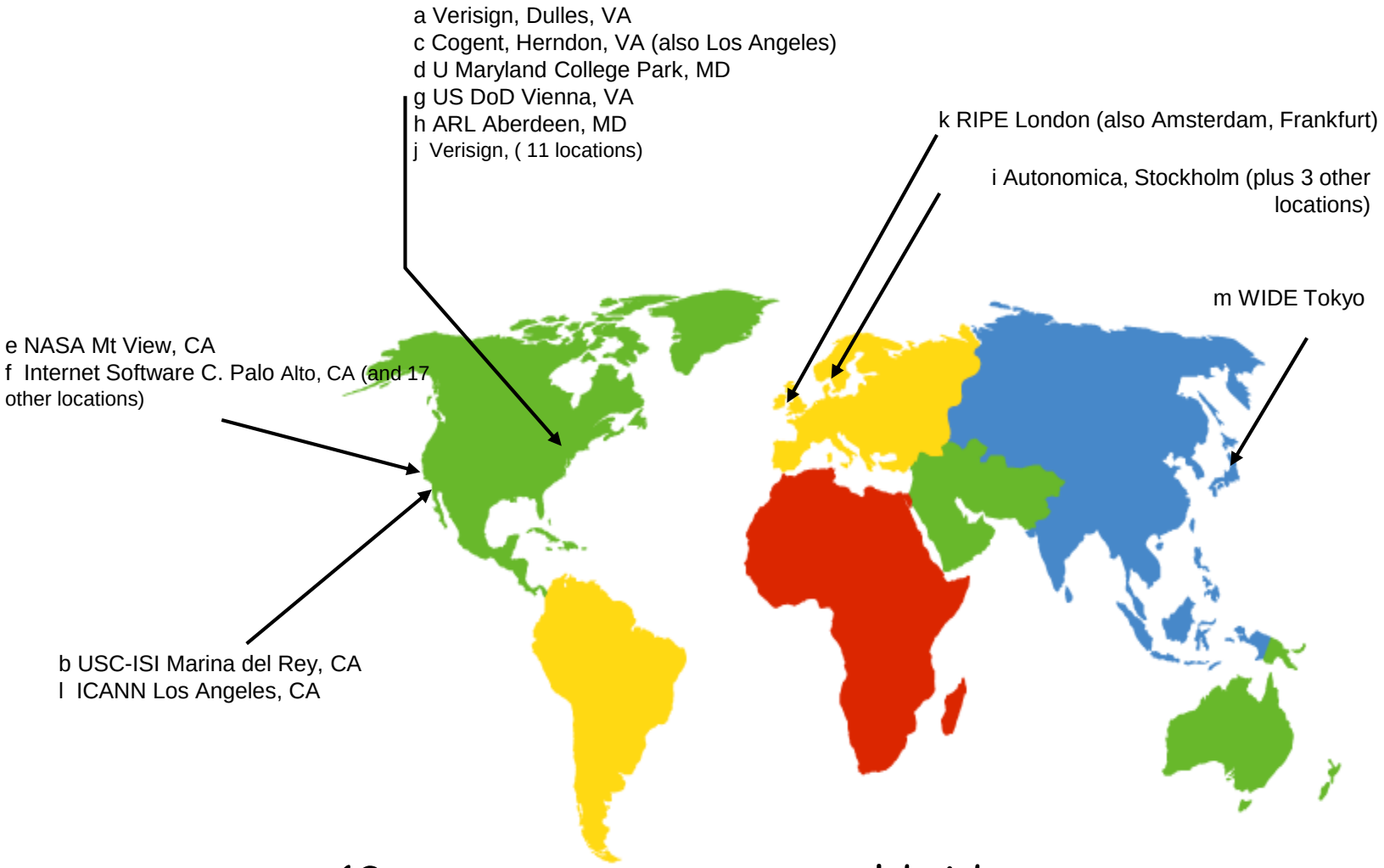
Client wants IP for www.amazon.com; 1st approx:

- Client queries a root server to find **com DNS server**
- Client queries **com DNS server** to get **amazon.com DNS server**
- Client queries **amazon.com DNS server** to get IP address for **www.amazon.com**

Overview of DNS

- Root DNS servers
  - 13 root servers (A-M) in the Internet
    - www.root-servers.org
  - Each server is actually a cluster of replicated servers
- Top-level Domain (TLD) servers
  - Responsible for com, org, net, edu, etc, and all top-level country domains uk, fr, ca, jp.
- Authoritative DNS servers:
  - organization's DNS servers, providing authoritative hostname to IP mappings for organization's servers
  - Can be maintained by organization or service provider

DNS: Root name servers



13 root name servers worldwide

.kr DNS

- 15 .KR name servers

.kr DNS

호스트명	배치기관	위치	IPv4/IPv6 지원
b.dns.kr	KT	서울 혜화	IPv4
c.dns.kr	LG U+	경기 안양	IPv4
d.dns.kr	ISC(Internet Systems Consortium)	미국	IPv4
	KINX	서울 도곡	
	드림라인	서울 삼성	
	KT	경기 성남	
e.dns.kr	한국과학기술정보연구원(KISTI)	대전	IPv4/IPv6
	CNNIC	중국	
	Registro.br	브라질	
	세종텔레콤	서울 역삼	IPv4
f.dns.kr	SK브로드밴드	서울 동작	IPv4
g.dns.kr	한국인터넷진흥원(KISA)	서울 서초	IPv4/IPv6
	DENIC	독일	IPv4/IPv6
	SK브로드밴드	서울 서초	IPv4

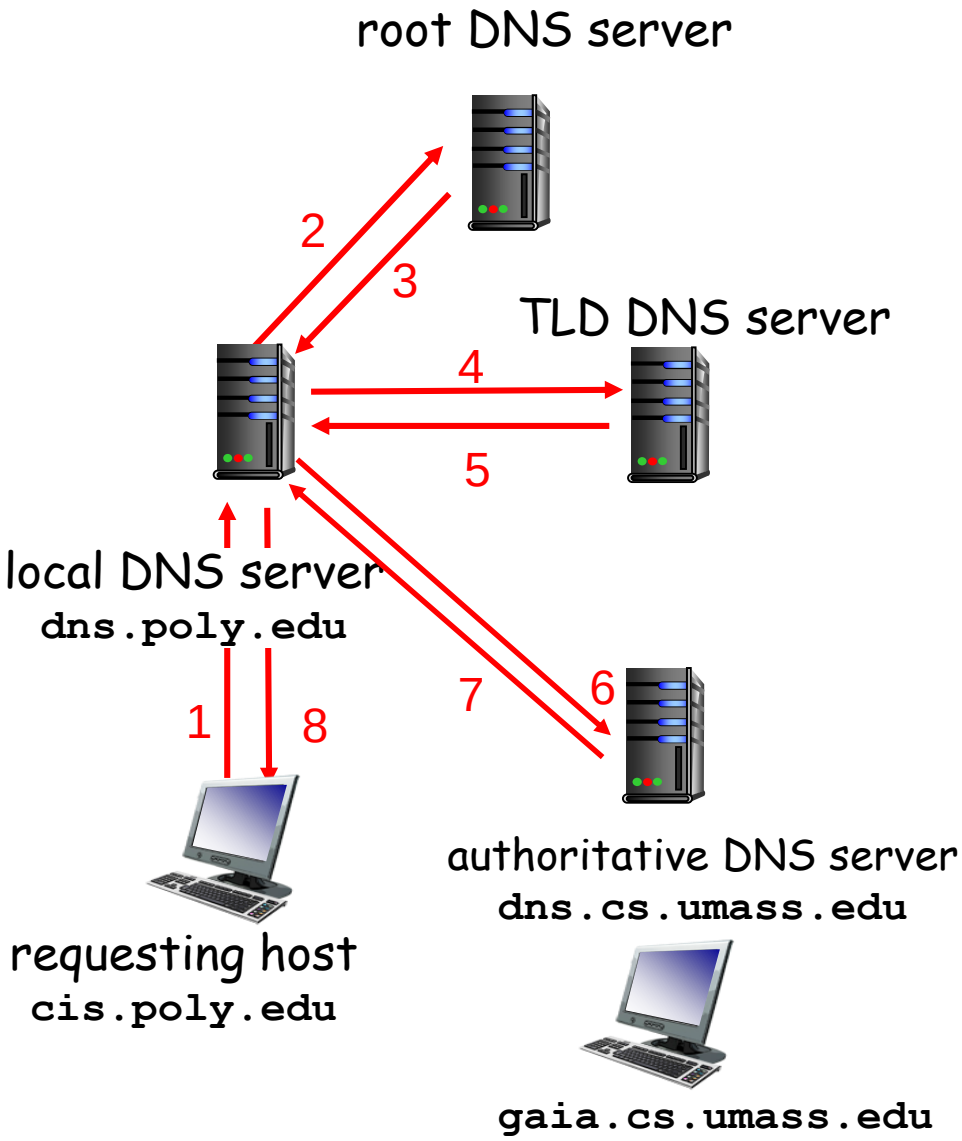
Local Name Server

- does not strictly belong to hierarchy
- Each ISP (residential ISP, company, university) has one.
  - Also called "default name server"
- When a host makes a DNS query, query is sent to its local DNS server
  - acts as proxy, forwards query into hierarchy

Name Resolution: Iterative Queries

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

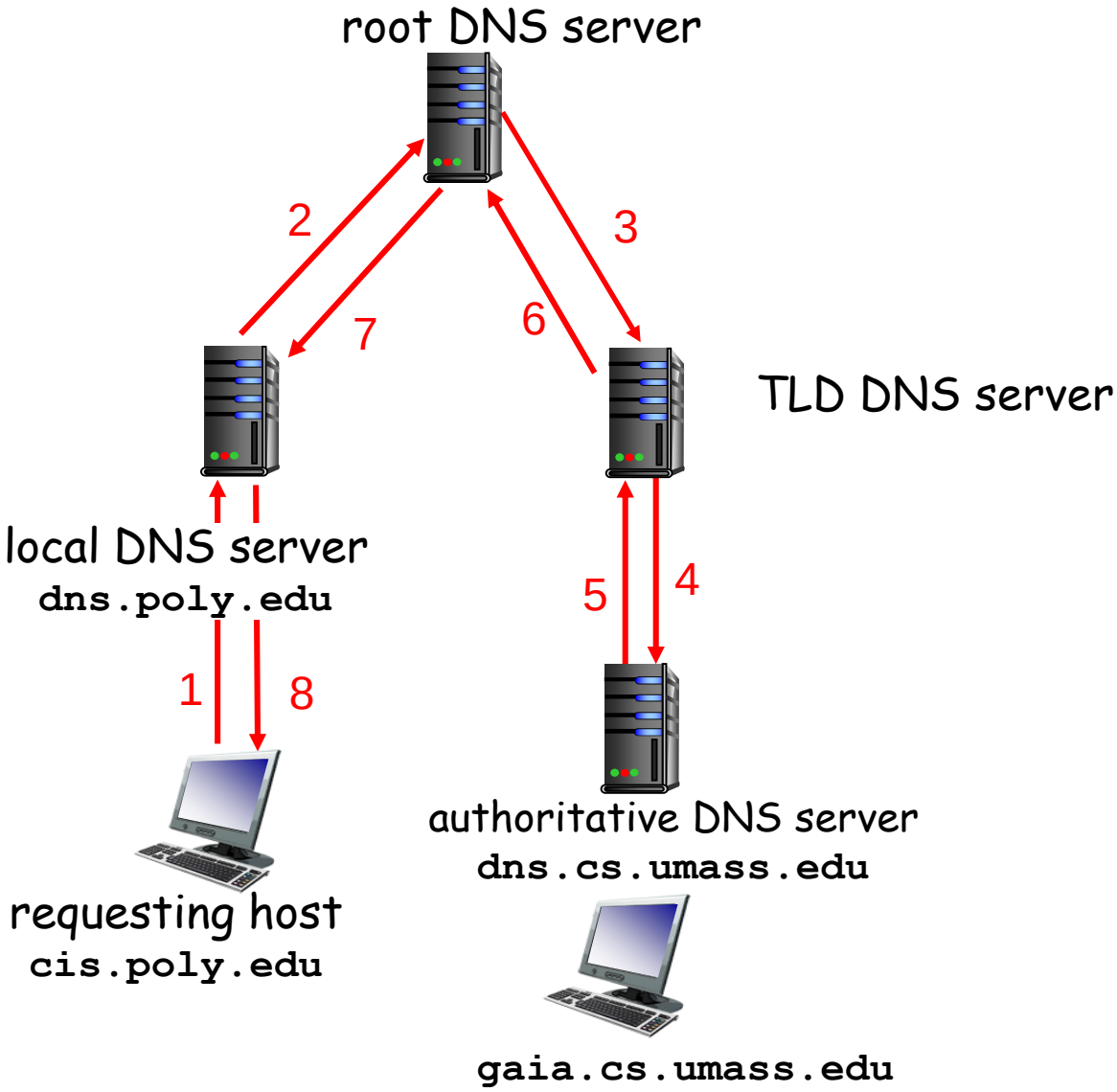
- Iterative queries
  - contacted server replies with name of server to contact
  - "I don't know this name, but ask this server"
  - Typical method



Name Resolution: Recursive Queries

recursive query:

- puts burden of name resolution on contacted name server
- heavy load at upper levels of hierarchy



DNS Caching and Update Recoreds

- once (any) name server learns mapping, it *caches* mapping
  - cache entries timeout (disappear) after some time (TTL)
  - TLD servers typically cached in local name servers
    - thus root name servers not often visited
- cached entries may be *out-of-date* (best effort name-to-address translation!)
  - if name host changes IP address, may not be known Internet-wide until all TTLs expire
- update/notify mechanisms proposed IETF standard
  - RFC 2136

Services Provided by DNS

- DNS
  - DNS can use the services of UDP or TCP using the well-known port 53.
- DNS identify objects on the Internet
  - Host name
    - Canonical hostname
    - Alias hostnames
  - Name server
  - Mail server
  - Information

DNS records

DNS: distributed db storing resource records (RR)

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

- Type: Specifies the types of the value
  - A: name=host, value = IPv4 address
  - NS (Name server): name = domain name, value= IP address of authoritative name server for this domain
  - CNAME: name = alias name, value = Canonical name
  - MX (Mail server): **value** = name of mailserver associated with **name**
  - HINFO: host information (CPU and OS)
  - TXT: text (uninterpreted ascii text)
- TTL: TTL: how long the resource record is valid

DNS records: Example

```
; Authoritative data for cs.vu.nl
cs.vu.nl.       86400  IN SOA    star boss (952771,7200,7200,2419200,86400)
cs.vu.nl.       86400  IN TXT    "Faculteit Wiskunde en Informatica."
cs.vu.nl.       86400  IN TXT    "Vrije Universiteit Amsterdam."
cs.vu.nl.       86400  IN MX     1 zephyr.cs.vu.nl.
cs.vu.nl.       86400  IN MX     2 top.cs.vu.nl.

flits.cs.vu.nl. 86400  IN HINFO  Sun Unix
flits.cs.vu.nl. 86400  IN A      130.37.16.112
flits.cs.vu.nl. 86400  IN A      192.31.231.165
flits.cs.vu.nl. 86400  IN MX     1 flits.cs.vu.nl.
flits.cs.vu.nl. 86400  IN MX     2 zephyr.cs.vu.nl.
flits.cs.vu.nl. 86400  IN MX     3 top.cs.vu.nl.
www.cs.vu.nl.86400     IN CNAME  star.cs.vu.nl
ftp.cs.vu.nl.   86400  IN CNAME  zephyr.cs.vu.nl

rowboat                IN A      130.37.56.201
                       IN MX     1 rowboat
                       IN MX     2 zephyr
                       IN HINFO  Sun Unix

little-sister          IN A      130.37.62.23
                       IN HINFO  Mac MacOS

laserjet               IN A      192.31.231.216
                       IN HINFO  "HP Laserjet IIISi" Proprietary
```

<Domain_name Time_to_live Class Type Value>

Inserting records into DNS

- How are new domains added to DNS?
  - This is done through a registrar, a commercial entity accredited by ICANN.
  - A registrar first verifies that the requested domain name is unique and then enters it into the DNS database.
    - Need to provide registrar with names and IP addresses of your authoritative name server (primary and secondary)
    - Registrar inserts two RRs into the com TLD server:
      (networkutopia.com, dns1.networkutopia.com, NS)
      (dns1.networkutopia.com, 212.212.212.1, A)
  - A fee is charged.

Accredited Registrar in KOREA

- Asadal, Inc.Korea,
- Cydentity, Inc. dba Cypack.com
- DotForce Corp. dba DotForce.com
- Dotname Korea Corp.
- Gabia, Inc.
- HANGANG Systems, Inc. dba Doregi.com
- INAMES Corp. (Korea)Korea,
- Information Certificate Authority, Inc. dba DomainCA.com
- Netpia.com, Inc.
- Today and Tomorrow Co., Ltd.
- WOOHO T&C CO., LTD. dba RGNAMES.COM
- YESNIC CO. LTD.