CS 330: Network Applications & Protocols

Application Layer: FTP, SMTP, DNS

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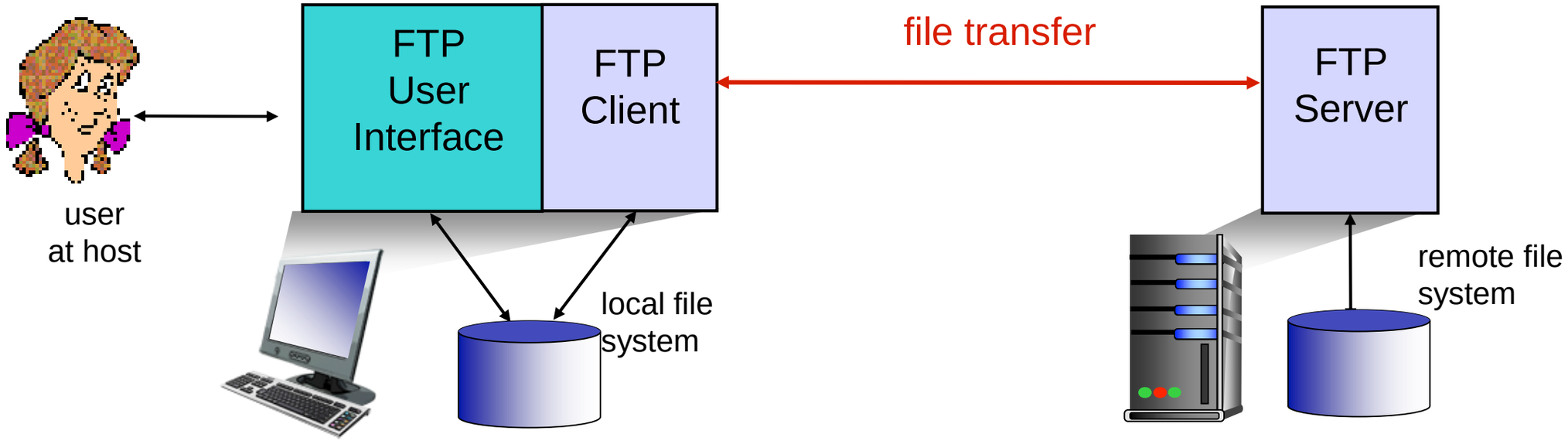
Overview of Application Layer

- **Network Application Architectures**
- **HyperText Transfer Protocol (HTTP)**
- **File Transfer and Email protocols (FTP, SMTP)**
  - FTP
  - SMTP, POP3, IMAP
- **Domain Name System (DNS)**
- **Peer-to-Peer Applications (P2P)**

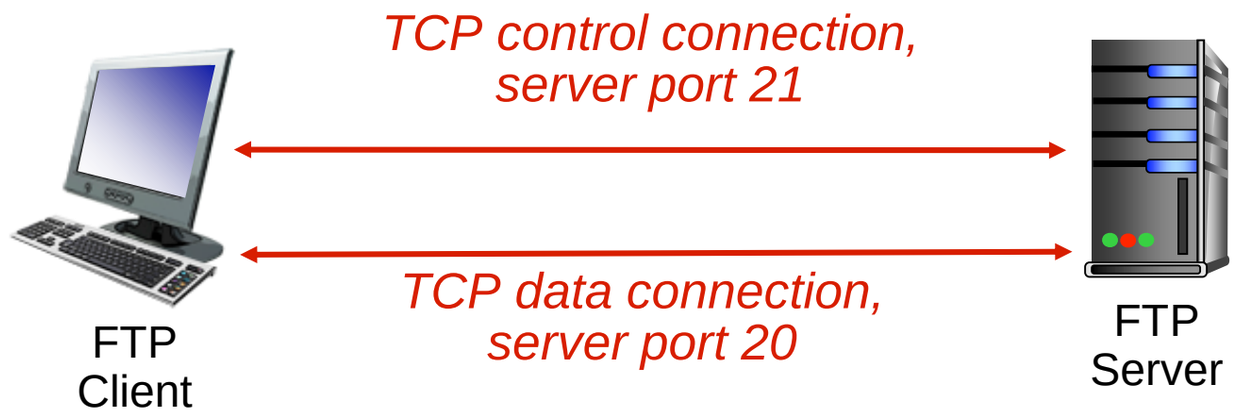
FTP: File Transfer Protocol



- **Used to transfer files to/from a remote host**
- **Client/server model**
  - Client: side that initiates transfer (either to/from remote)
  - Server: remote host
- **ftp: RFC 959**
- **ftp server: port 21**

FTP: Separate Control / Data Connections

- **FTP client contacts FTP server on port 21, using TCP**
- **Uses two parallel TCP connections: Control and Data**
- **Client authorized over control connection**
- **Client browses remote directory, sends commands over control connection**
- **Control connection is persistent**
- **FTP server maintains "state": (i.e. current directory, authentication information)**



- **When server receives file transfer command, server opens 2nd TCP data connection (for file) to client**
- **After transferring one file, server closes data connection**
  - A separate TCP data connection is opened for each transferred file

FTP Commands / Responses

- **Commands are sent as plain ASCII text over the control channel**

  `USER username` : sends username to server

  `PASS password` : sends password to server **in plain text!!**

  `LIST` : returns a list of files in current directory

  `RETR filename` : retrieves (gets) file

  `STOR filename` : stores (puts) file onto remote host

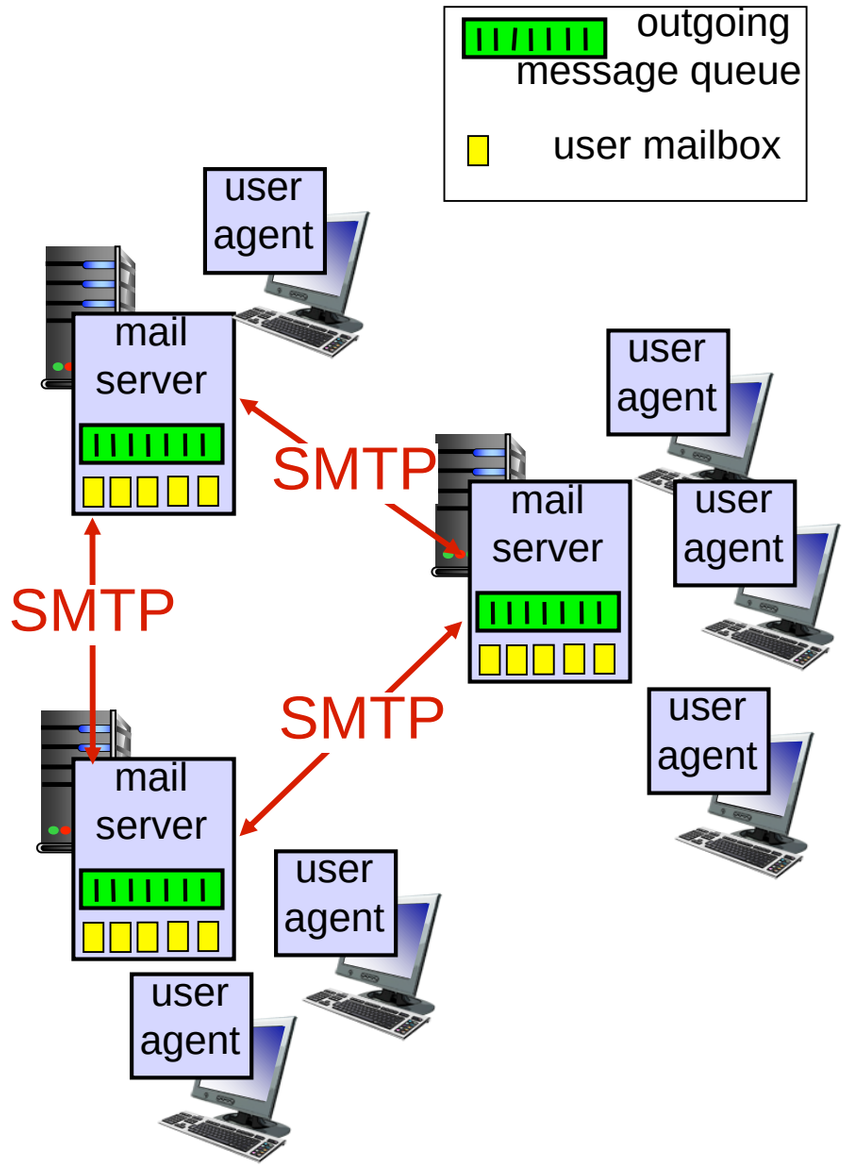
- **FTP server responds with status codes on the control channel**

```
331 Username OK, password required
125 data connection already open; transfer starting
425 Can't open data connection
452 Error writing file
```

Electronic Mail

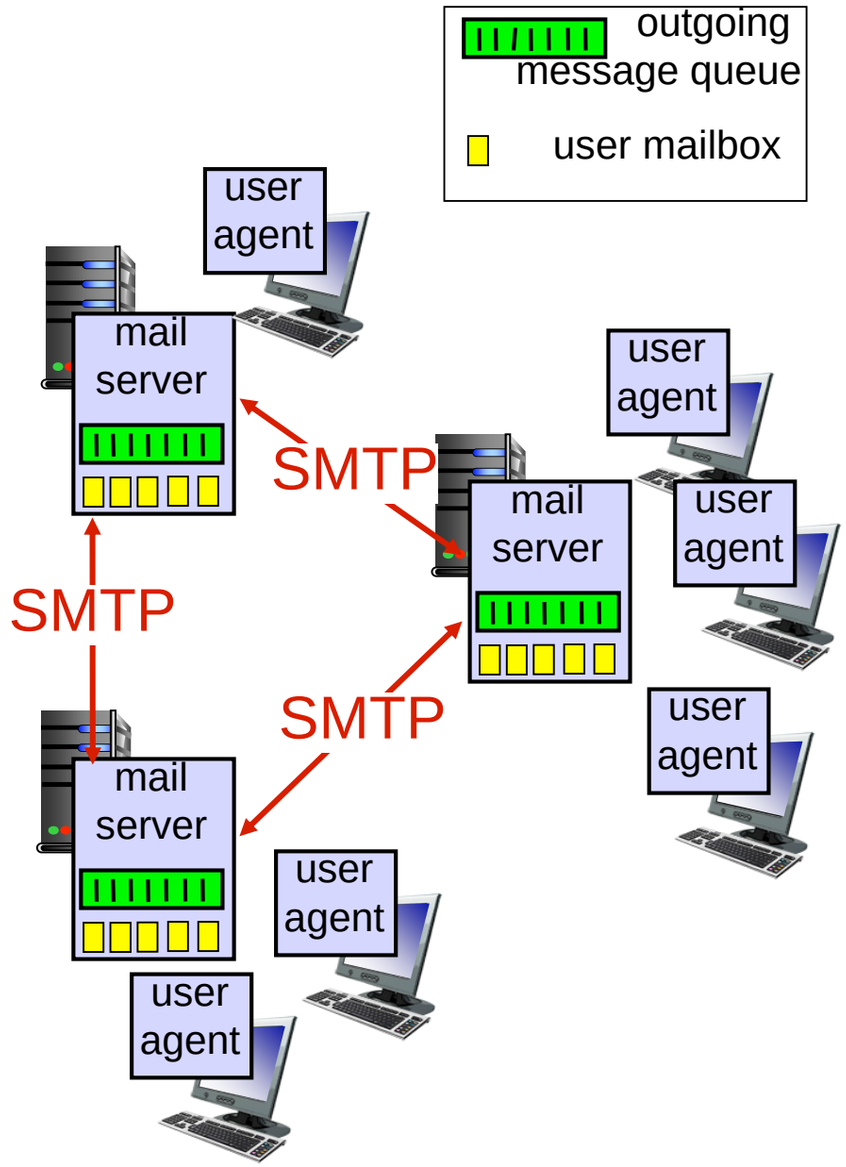
- **Three major components:**
  - User agents
  - Mail servers
  - Simple mail transfer protocol: SMTP

- **User Agent**
  - Composing, editing, reading mail messages
  - e.g. Outlook, Thunderbird, iPhone mail client
  - 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
  - Uses SMTP protocol between mail servers to send email messages
    - Client: sending mail server
    - "Server": receiving mail server



Electronic Mail: SMTP

- **Uses TCP to reliably transfer email message from client to server on port 25**
- **Direct transfer: sending server to receiving server**
- **Three phases of transfer**
  - Handshaking (greeting)
  - Transfer of messages
  - Closure
- **Command/response interaction (like HTTP, FTP)**
  - Commands are in ASCII text
  - Server responds with status code and phrase
- **Messages must be in 7-bit ASCII**
  - All binary objects (i.e. attachments MUST be converted to ASCII to send)

Scenario: Alice Sends Message to Bob

(1) Alice uses her mail client to compose message "to" bob@someschool.edu

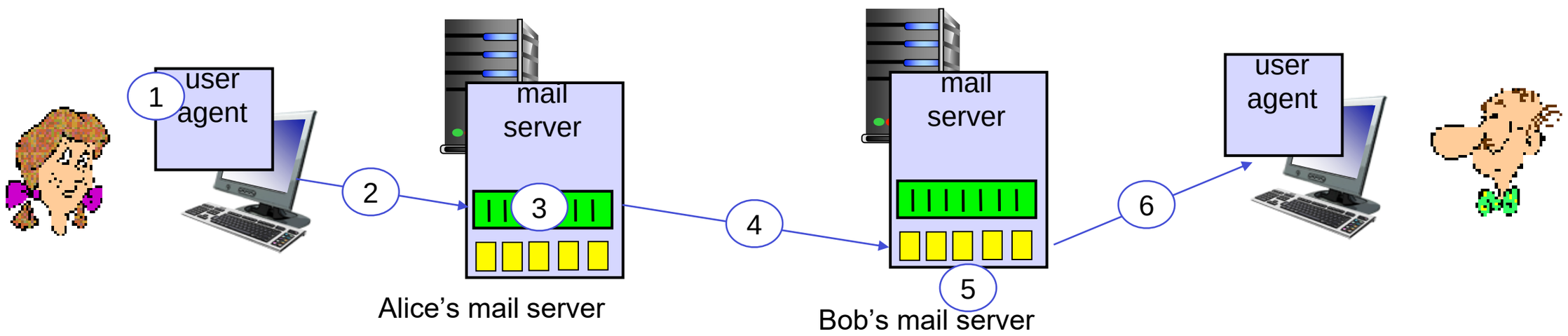
(2) Alice's mail client sends her message to her mail server; the message is placed in a message queue

(3) Client side of SMTP opens TCP connection with Bob's mail server

(4) SMTP client sends Alice's message over the TCP connection

(5) Bob's mail server places the message in Bob's mailbox

(6) Bob invokes his mail client to read message



Sample SMTP Interaction

```
C: telnet smtp.fakeplace.edu 25

S: 220 fakeplace.edu
C: HELO ycp.edu
S: 250  Hello ycp.edu, pleased to meet you
C: MAIL FROM: alice@ycp.edu
S: 250 alice@ycp.edu... Sender ok
C: RCPT TO: bob@fakeplace.edu
S: 250 bob@fakeplace.edu ... Recipient ok
C: DATA
S: 354 Enter mail, end with "." on a line by itself
C: This is a test email.
   More testing.
   .
S: 250 Message accepted for delivery
C: QUIT
S: 221 fakeplace.edu closing connection
```

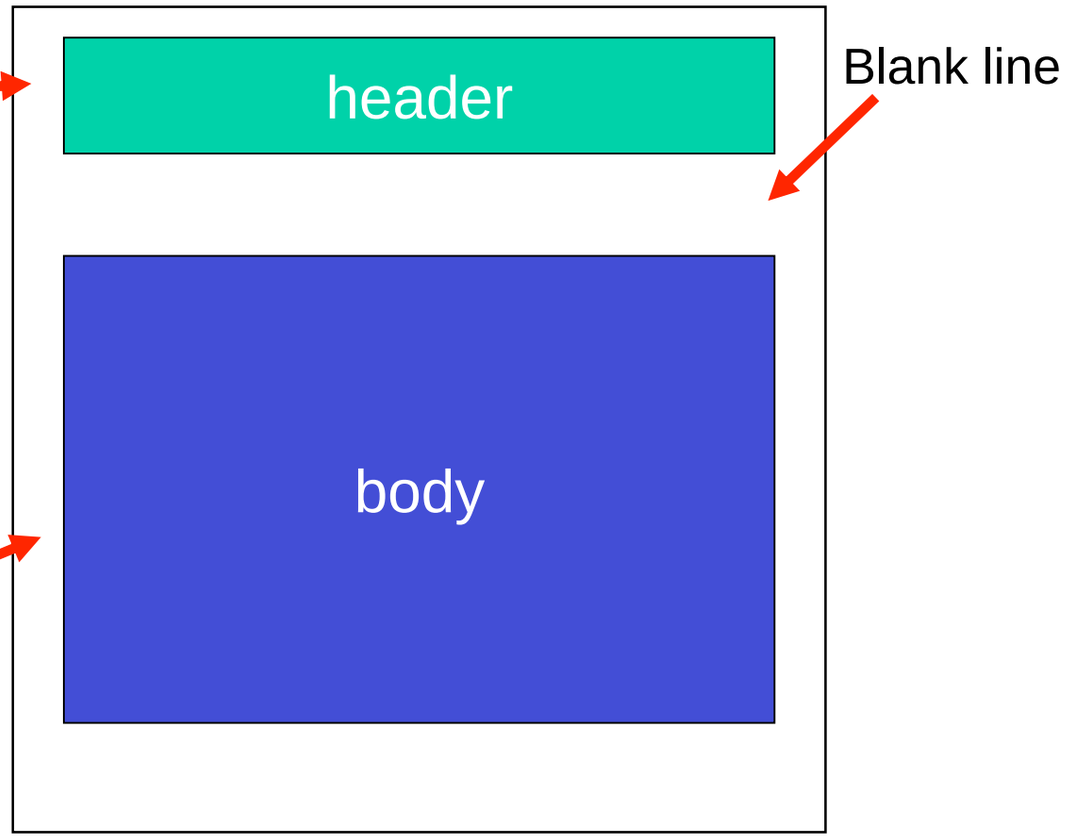
SMTP: Final Words

- **SMTP uses persistent connections**
- **SMTP requires message (header & body) to be in 7-bit ASCII**
- **SMTP server uses `CRLF.CRLF` to determine end of message**
- **Comparison with HTTP:**

HTTP	SMTP
Persistent/Non-persistent connections	Persistent connections
Pulls data from server	Pushes data to server
Accepts binary objects	Accepts only 7-bit ASCII
Each object in its own response msg	Multiple objects sent in multipart msg

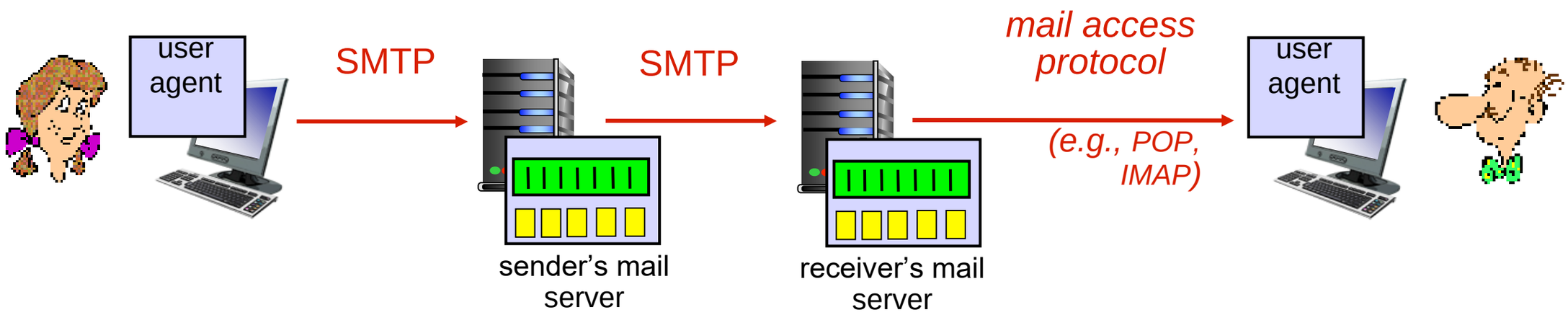
Mail Message Format

- **SMTP: protocol for exchanging email msgs**
- **RFC 822: standard for text message format:**
  - Header lines, e.g.
    - To:
    - From:
    - Subject:
  - Different from SMTP '**`MAIL FROM`**', '**`RCPT TO`**' commands!
- **Body: the "message"**
  - ASCII characters only



Mail Access Protocols

- **SMTP - used for delivery/storage of message to receiver's mail server**
- **Mail access protocols used to retrieve messages from mail server**
  - **POP**: Post Office Protocol [RFC 1939]: authorization, download
  - **IMAP**: Internet Mail Access Protocol [RFC 1730]: more features, including manipulation of stored msgs on server
  - **HTTP**: gmail, Hotmail, Yahoo! Mail, etc.



POP3 Protocol

- **Authorization phase**
  - Client commands:
    - **`user`** : declare username
    - **`pass`** : password
  - Server responses
    - **`+OK`**
    - **`-ERR`**

- **Transaction phase**
  - Client commands:
    - **`list`** : list message numbers
    - **`retr`** : retrieve message by number
    - **`dele`** : delete message
    - **`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
```

IMAP

- **Internet Mail Access Protocol**
- **More sophisticated than POP3 (POP3 is stateless across sessions)**
- **Allows user to organize messages in folders**
- **Messages can be moved from one folder to another**
- **Users can get only headers or other components of the message**

Overview of Application Layer

- **Network Application Architectures**
- **HyperText Transfer Protocol (HTTP)**
- **File Transfer and Email protocols (FTP, SMTP)**
- **Domain Name System (DNS)**
  - Function
  - Distributed Structure
  - DNS Caching
  - DNS Records
  - DNS Vulnerabilities
- **Peer-to-Peer Applications (P2P)**

DNS: Domain Name System

- **DNS servers translate a host name to IP address**
  - e.g. www.ycp.edu ➔ 192.245.87.37
  - Would be painful to browse Internet and remember IP addresses
- **Hosts and name servers communicate to resolve names**
  - address ➔ name translation

- **Distributed database of all hosts in the universe**
  - Avoids single point of failure
  - Distributes name resolution traffic
  - Geographically distributed
  - Easier to maintain

- **Often used by other application-layer protocols (e.g. SMTP, HTTP, FTP) to translate hostnames to IP addresses**

Other Services Provided By DNS

- **Host aliasing**
  - Provides canonical name when alias name is provided
  - www.gmail.com ➔ googlemail.l.google.com
- **Mail server aliasing**
- **Load distribution**
  - Why not centralize DNS?
  - Replicated web servers, many IP addresses correspond to one name

DNS Example

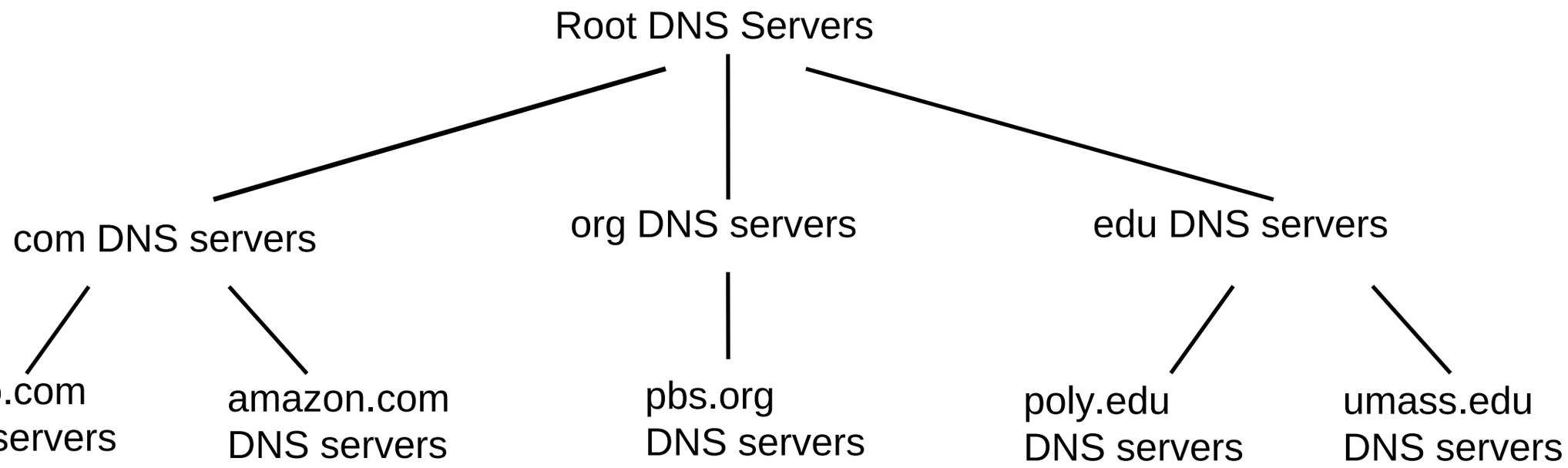
```
> nslookup www.ycp.edu
Server:  192.168.1.1          <-- my name server
Address: 192.168.1.1#53

Non-authoritative answer:
www.ycp.edu   canonical name = calypso.ycp.edu.
Name: calypso.ycp.edu
Address:  192.245.87.37

> nslookup www.google.com
Server:  192.168.1.1
Address: 192.168.1.1#53

Non-authoritative answer:
Name: www.google.com
Address:  173.194.73.106
Name: www.google.com
Address:  173.194.73.147
Name: www.google.com          <-- Many servers
Address:  173.194.73.103
Name: www.google.com
Address:  173.194.73.105
Name: www.google.com
Address:  173.194.73.99
Name: www.google.com
Address:  173.194.73.104
```

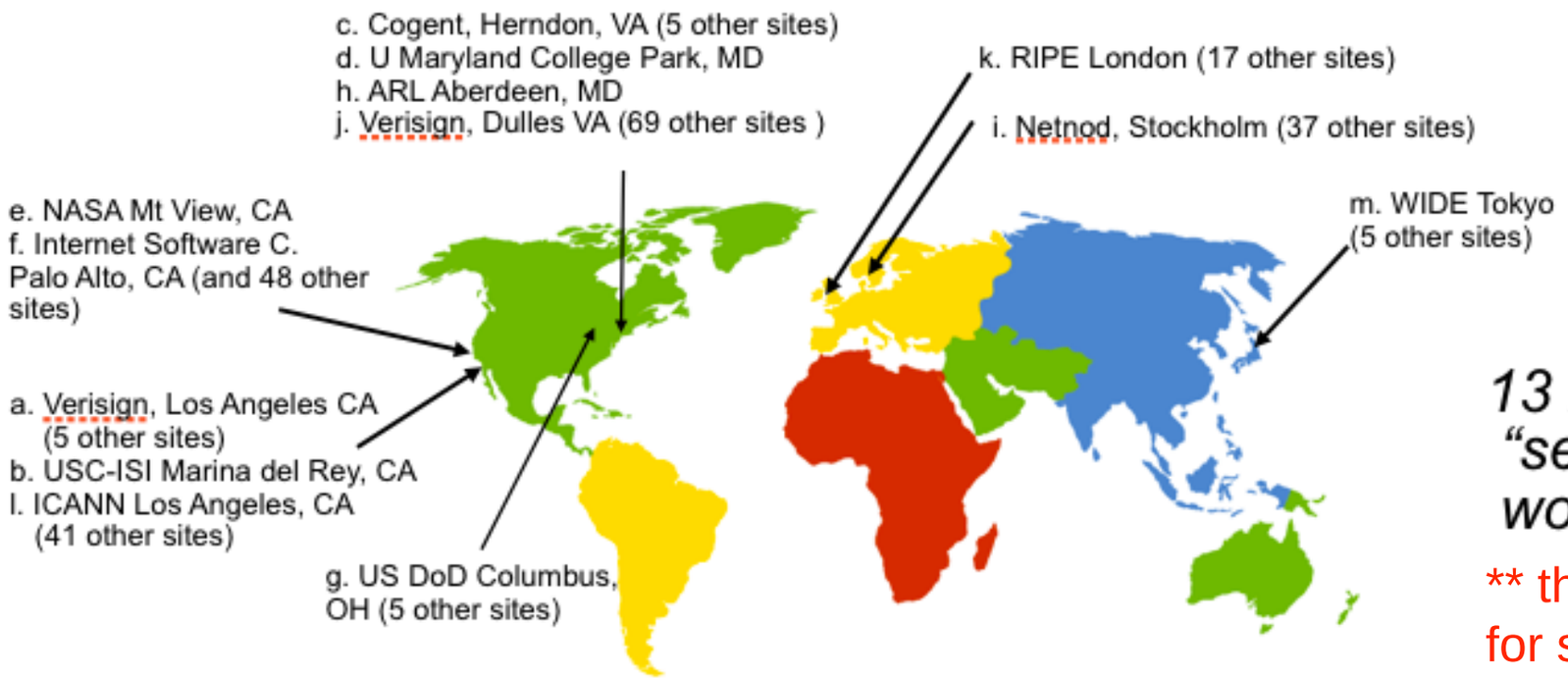
DNS: A Distributed, Hierarchical Database



- **Client wants IP for www.amazon.com**
  - Client queries 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

Root DNS Servers

- **Contacted by local name server that can not resolve name**
- **Root name server:**
  - Contacts authoritative name server if name mapping not known
  - Gets mapping
  - Returns mapping to local name server



13 root name "servers" worldwide

** though they are replicated for security and reliability

Top-Level Domain & Authoritative DNS servers

- **Top-Level Domain (TLD) Servers**
  - Responsible for com, org, net, edu, aero, jobs, museums, and all top-level country domains (e.g. uk, fr, ca, jp)
  - Verisign maintains servers for .com TLD (and many others)
  - Educause maintains servers for .edu TLD

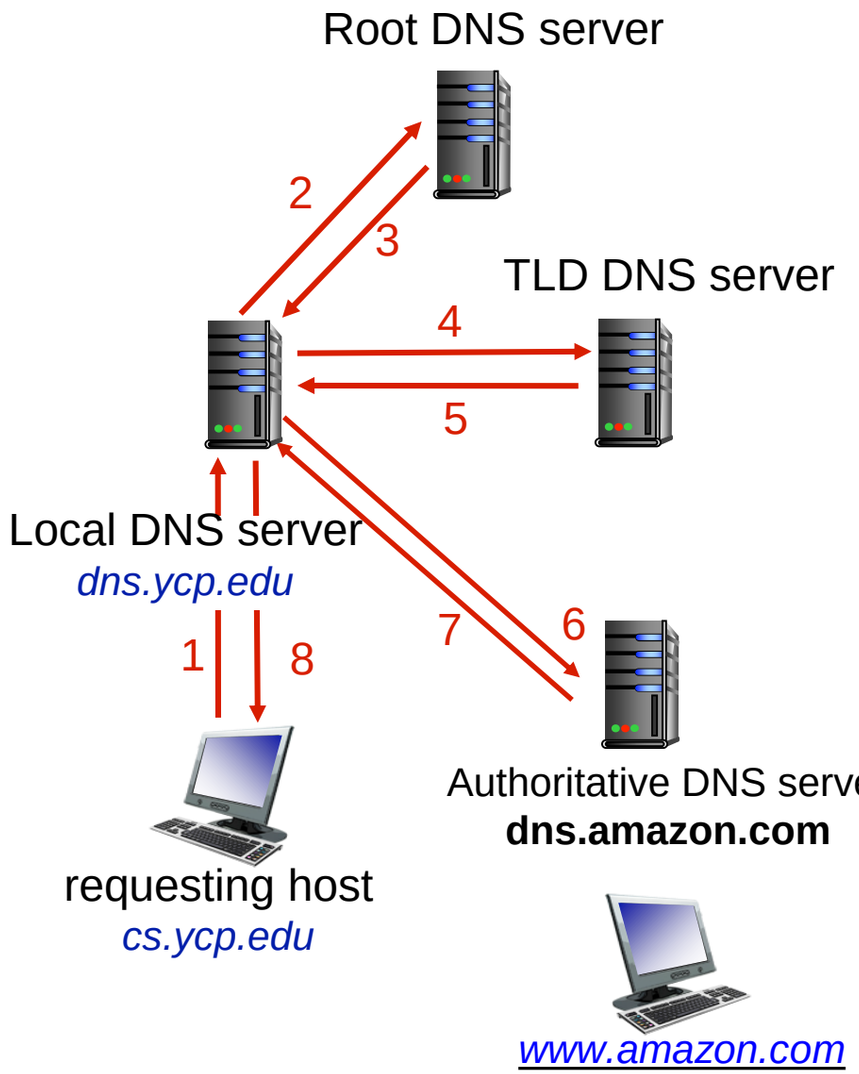
- **Authoritative DNS Servers**
  - Organization's own DNS server(s), providing authoritative hostname to IP mappings for organization's named hosts
  - Can be maintained by organization or service provider

Local DNS Name Server

- **Does not strictly belong to the DNS hierarchy**
- **Each ISP (residential ISP, company, university) has one**
  - Also called “default name server”
- **When host makes DNS query, query is sent to its local DNS server**
  - Has local cache of recent name-to-address translation pairs (but may be out of date!)
  - Acts as proxy, forwards query into hierarchy

DNS Name Resolution Example

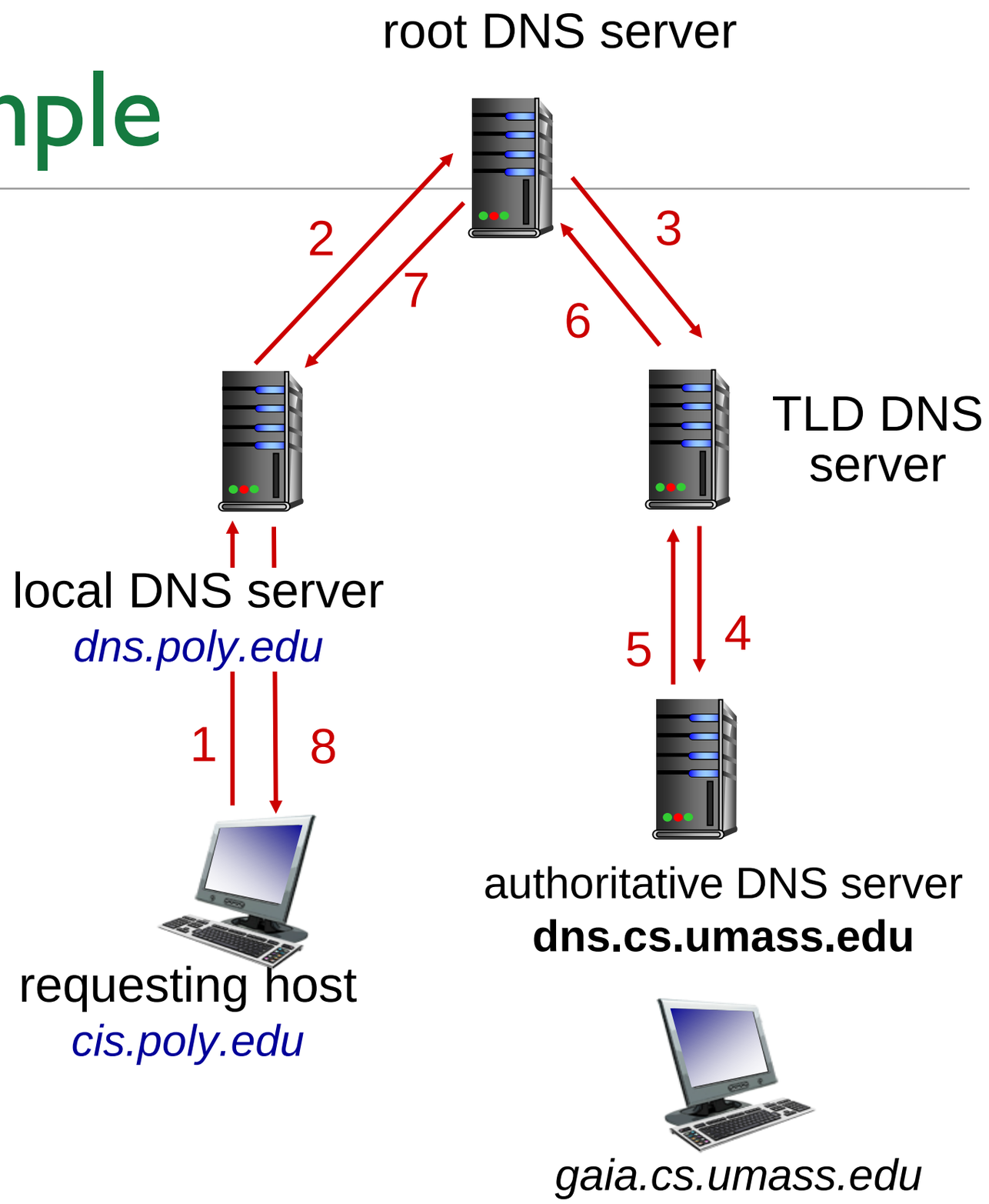
- **Host at cs.ycp.edu wants IP address for www.amazon.com**
- **Iterated query:**
  - Contacted server replies with name/address of server to contact
  - "I don't know this name, but ask this server"



DNS name resolution example

recursive query:

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



DNS Caching / Updating Records

- **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 a named host changes its IP address, may not be known Internet-wide until all TTLs expire

DNS Records

- **Resource Record (RR) format stored by DNS servers**
  - **`RR: (name, value, type, ttl)`**
- **Four different RR types**

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 mail server associated with **`name`**

DNS Message Format

- **Query and Reply messages, both use same message format**
  - Message Header
    - **Identification**: 16 bit # for query, reply includes same #
    - **Flags**:
      - Query or reply
      - Recursion desired
      - Recursion available
      - Reply is authoritative
- **Question section**: contains name and type fields for the query
- **Answer section**: contains RRs in response to a query
- **Authority section**: contains RR for authoritative servers

Identification	Flags
# Questions	# Answer RRs
# Authority RRs	# Additional RRs
Questions (variable # of questions)	
Answers (variable # of answers)	
Authority (variable # of RRs)	
Additional Info (variable # of RRs)	

Inserting records into DNS

- **example: new startup "Network Utopia"**
- **register name networkuptopia.com at *DNS registrar* (e.g., Network Solutions)**
  - provide names, IP addresses of authoritative name server (primary and secondary)
  - registrar inserts two RRs into .com TLD server:
    (networkutopia.com, dns1.networkutopia.com, NS)

    (dns1.networkutopia.com, 212.212.212.1, A)
- **create authoritative server type A record for www.networkuptopia.com; type MX record for networkutopia.com**

DNS Vulnerabilities

- **Distributed Denial of service attacks on name server**
  - Bombard root servers with traffic
    - Not successful to date
    - Root servers are protected by traffic filters
    - Local DNS servers cache IP addresses of TLD servers, allowing root server bypass
  - Bombard TLD servers
    - Potentially more dangerous
- **Redirect attacks**
  - Man-in-middle
    - Intercept queries and return bogus replies
  - DNS poisoning
    - Send bogus replies to DNS server which then caches that info