Lecture 5,6: HTTP, SMTP, DNS @September 7, 2021

Web

1990s, on-demand service, easy to publish and gather information.

HTTP (Hypertext Transfer Protocol)

It is web's application layer protocol. Implemented in 2 programs - a client program and a server program.

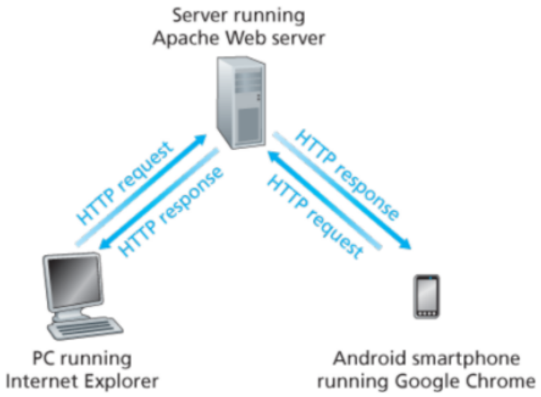
Web page - A collection of objects (HTML pages, images, videos, java applets) accessible via a single URL. Each URL (example - www.schoolname.edu/departmentname/picture.png) has 2 components - the hostname of the server (www.schoolname.edu) and object's path name (/departmentname/picture.png).

Web browsers - implement the client side of HTTP.

Web servers - implement the server side of HTTP.

HTTP defines how web browsers request web pages and how web servers transfer the web pages to clients.

When a user requests a Web page (for example, clicks on a hyperlink), the browser sends HTTP request messages for the objects in the page to the server. The server receives the requests and responds with HTTP response messages that contain the objects. HTTP uses TCP as its underlying transport protocol.

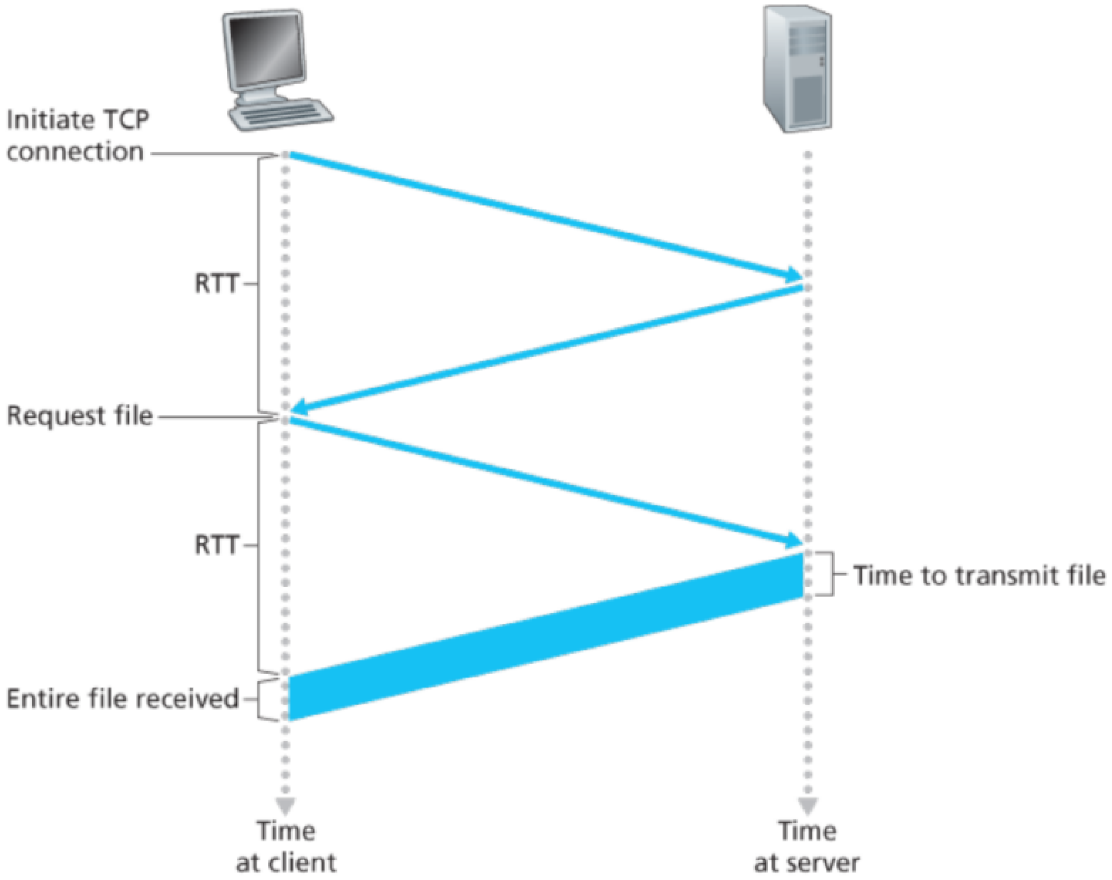


1. A TCP connection is established between the client and the server. **Default port number: 80**.
2. The client sends the http request into the socket interface to the TCP.
3. The server receives the request via TCP from its socket interface and sends a response message into the socket interface to the TCP.
4. TCP provides reliable data transfer to HTTP.
5. The server sends the requested files to clients without storing any state information i.e. when was the page accessed by the client last etc. and hence it is said to be a **stateless protocol.**

Non-persistent and Persistent Connections

1. Non-persistent connections - When multiple objects between client and server are served with multiple TCP connections. Each TCP connection sends exactly one object, if a web page has 1 HTML page and 5 images, 5 TCP connections are opened and closed sharing exactly 1 request and 1 response message. The TCP connections can be serial or parallel, and users can configure the web browser for the level of parallelism.

   RTT (Round trip time) - Trip from client to server and back to client - the following communication takes 2 RTTs for 3-way handshake and transmission of requested web page.



Non-persistent connection put significant burden on the web server.

2. HTTP 1.1 Persistent connections - All the request and responses between a client and server are served with a single TCP connection. The requests for objects can be made back-to-back without waiting for replies (**pipelining)** and connection is terminated when nothing has been sent or received for a specified time interval.

   The default mode of HTTP uses persistent connections with pipelining. HTTP/2 allows multiple requests and replies to be interleaved(mixed) in the same connection.

HTTP Message Format

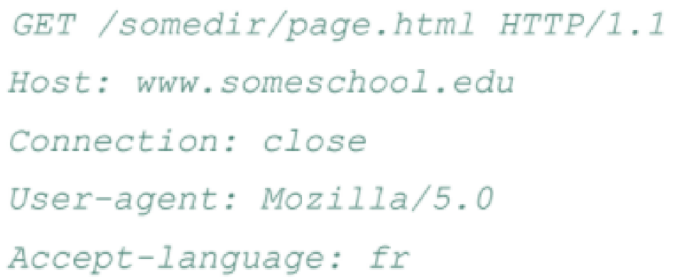
HTTP Request Message -

Written in ASCII text,

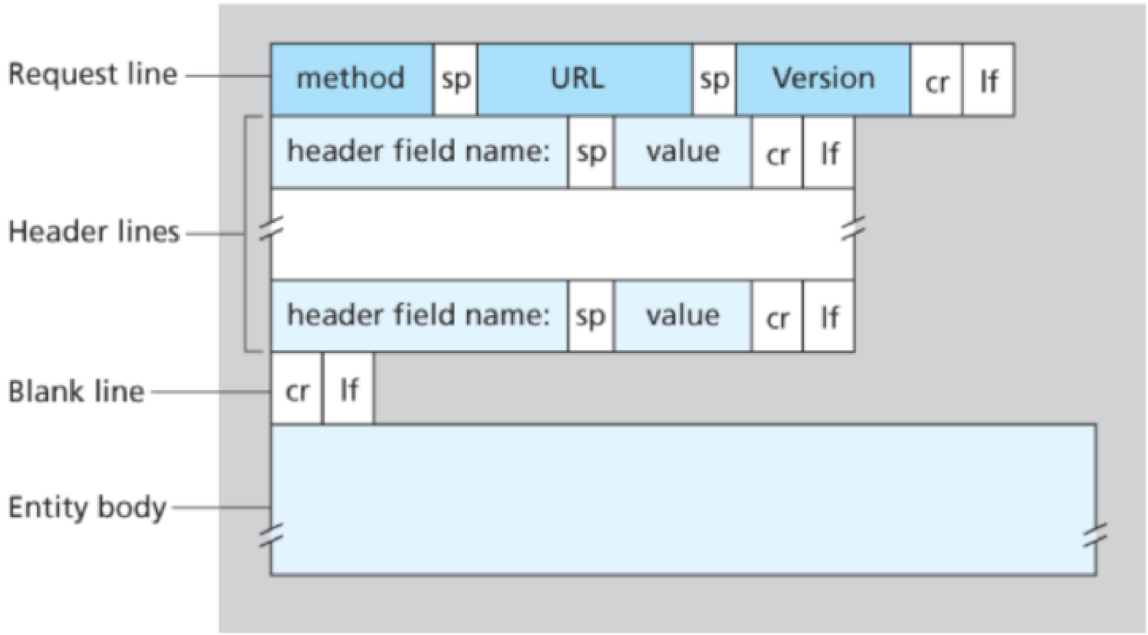
1st line - Request line - the

method field (GET, POST, HEAD, PUT, DELETE), the URL field and the HTTP version field.

Subsequent lines - header lines - specifies host (used by web proxy caches); tells the server to close the connection after sending this object; browser type; language.



```
GET /somedir/page.html HTTP/1.1
Host: www.someschool.edu
Connection: close
User-agent: Mozilla/5.0
Accept-language: fr
```



cr: carriage return ; lf: line feed.

1. POST Method - to send the user input from browser to the server such as form inputs, search words.
2. GET Method - nothing in the entity body.

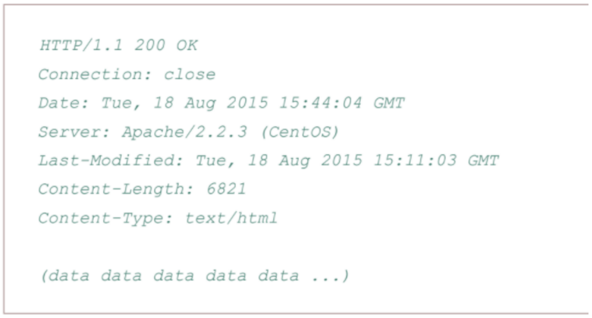
3. HEAD Method - used for debugging while application development, uses extended URL, responds with a HTTP message but leaves out the requested object.
4. DELETE Method - to allow user to delete an object on a web server.

HTTP Response Message Format

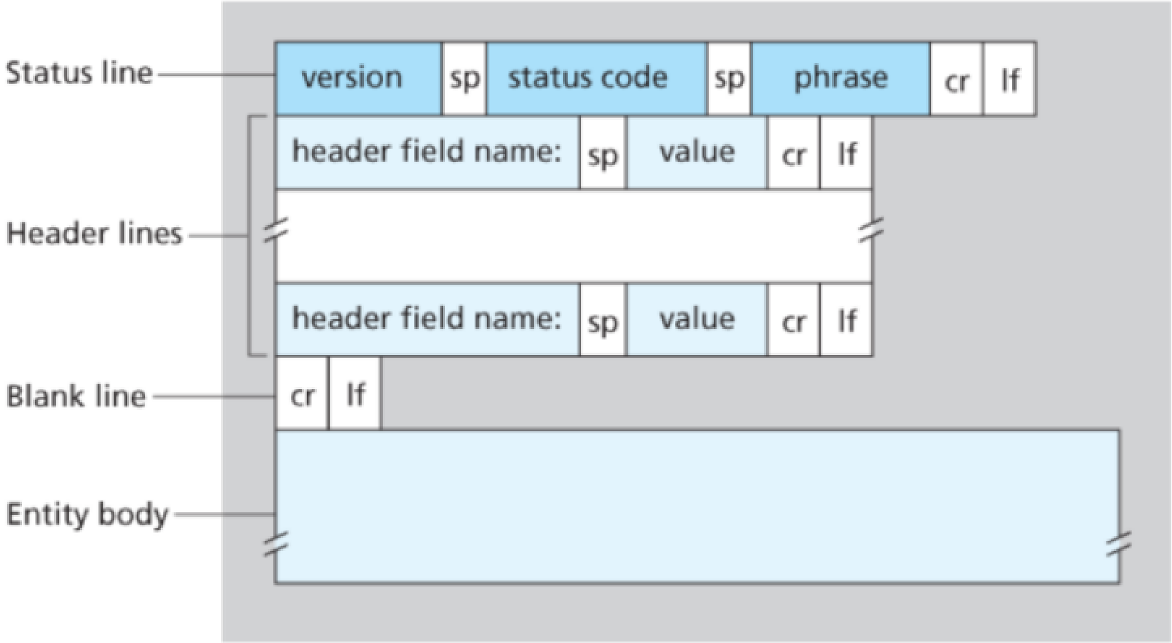
1st line - Status line - protocol version, status code, corresponding status message.

Subsequent lines - Header lines - Persistent/Non-persistent connection, date and time of object being retrieved last, Server, Last modified, Content length and content type.

Entity Body - Data



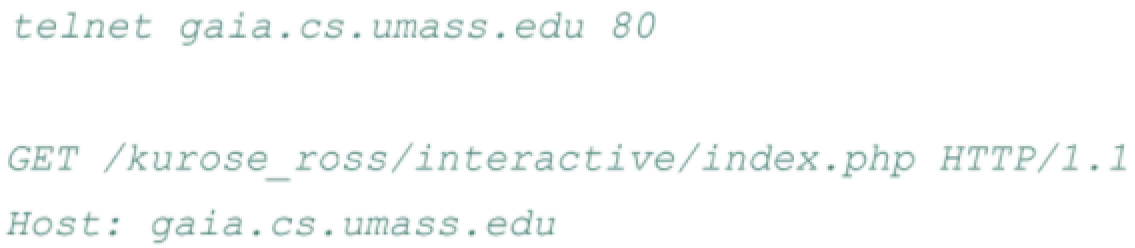
```
HTTP/1.1 200 OK
Connection: close
Date: Tue, 18 Aug 2015 15:44:04 GMT
Server: Apache/2.2.3 (CentOS)
Last-Modified: Tue, 18 Aug 2015 15:11:03 GMT
Content-Length: 6821
Content-Type: text/html

(data data data data data ...)
```



Status codes and associated phrase - 200 OK, 301 Moved permanently, 400 Bad Request, 404 Not found, 505 HTTP Version not supported.

Using telnet -

telnet webserver's name → tenet www.luddy.indiana.edu (Connect to a remote server)



```
telnet gaia.cs.umass.edu 80

GET /kurose_ross/interactive/index.php HTTP/1.1
Host: gaia.cs.umass.edu
```

Replace GET with HEAD.

Cookies

Cookie technology has 4 components -

1. A cookie header line in the response message
2. A cookie header line in the request message
3. A cookie file kept on user's end system, managed by the browser.
4. A back end database at the website storing the user data.

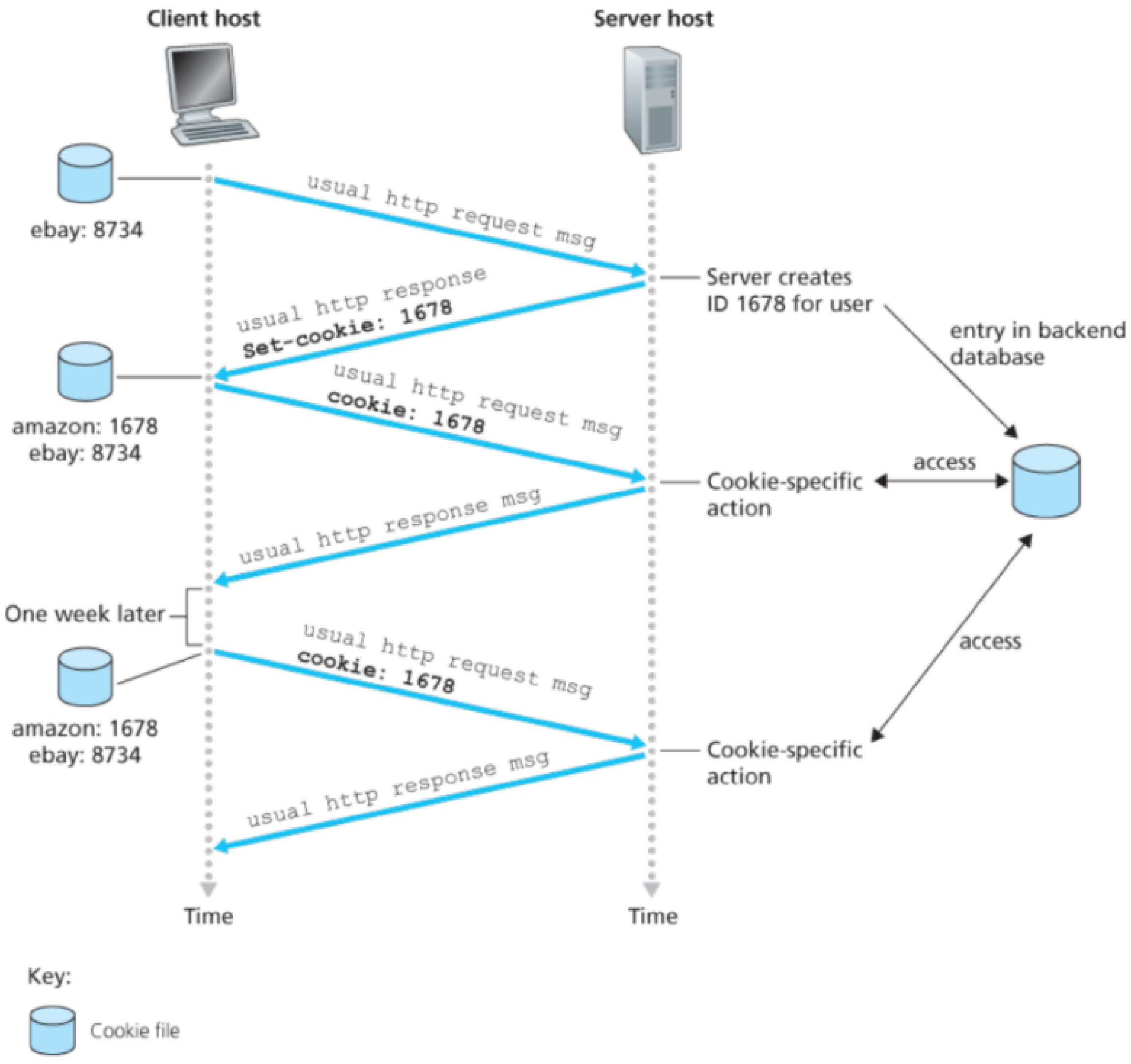
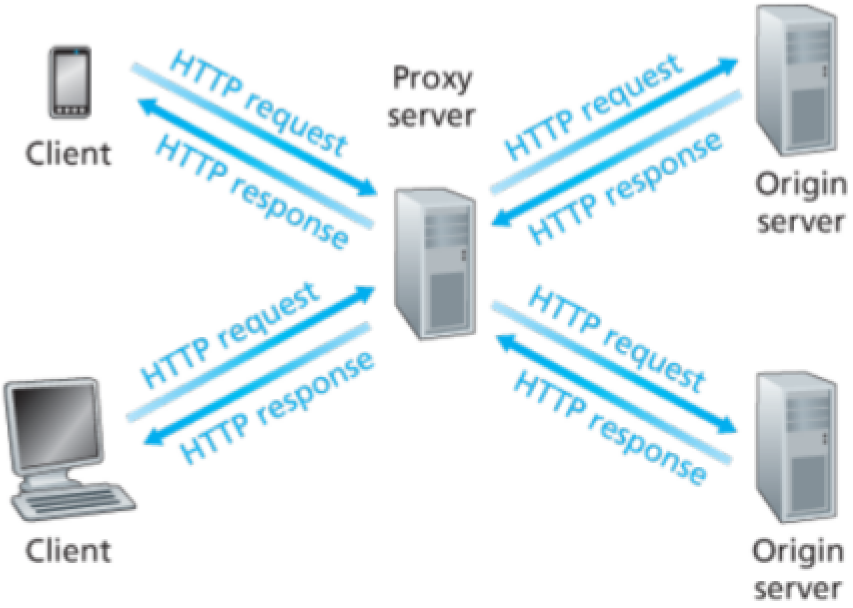


Figure 2.10 Keeping user state with cookies

HTTP server is stateless. Cookies help the server identify users.

Web Caching

Web Cache - proxy server - it satisfies HTTP request on behalf of the origin web server - it has its own disk space which store recently accessed objects.



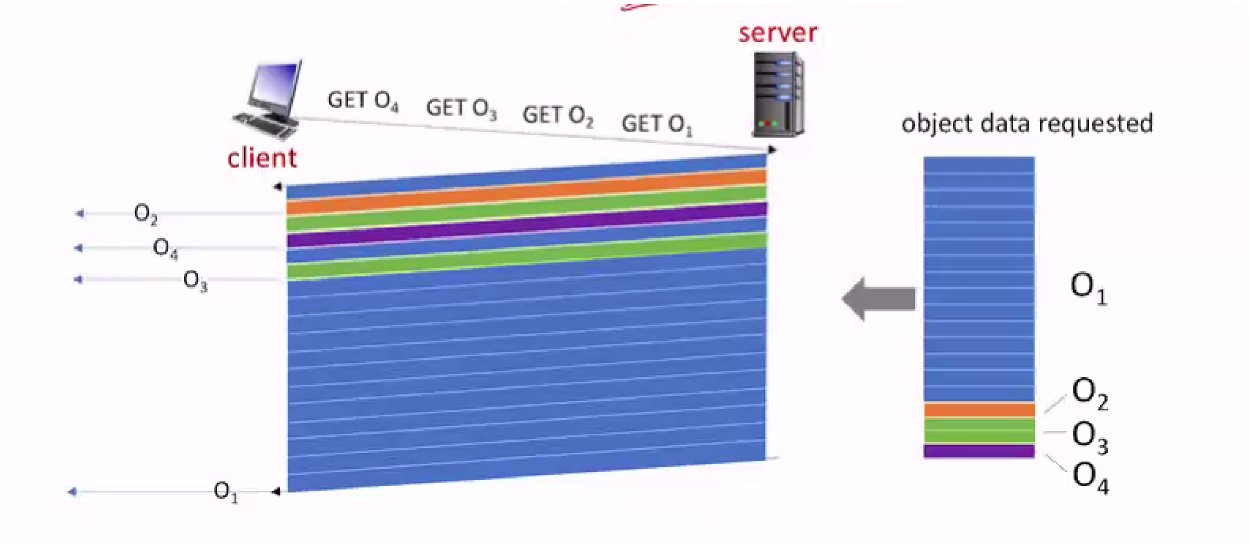
The requests made by user's browser's are directed to the proxy server, if it has the object, it sends that object in the response. If not, it opens the connection to original server, requests the object, stores a copy and sends the response to the user. Cache is both server and client at the same time.

Reduces response time, reduces traffic on institutional access link if we keep an institutional cache.

Content Distribution Networks (CDNs) - Geographically distributed caches throughout the Internet.

The Conditional GET - GET + If modified since

HTTP/2 - Mitigating HOL blocking; divides larger object into smaller chunks for transmission



HTTP/3 - adds security

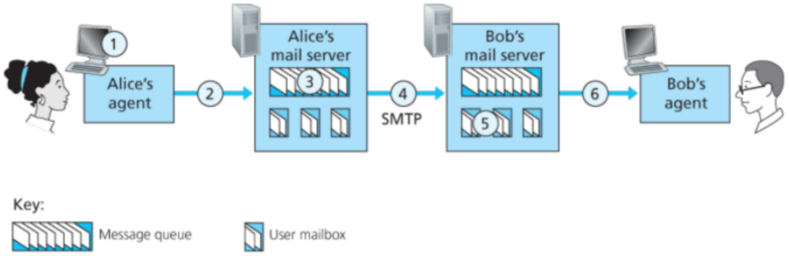
E-mail in the Internet

Components of Internet mailing system -

1. User agents - allow users to read, reply to, forward, save and compose messages.
2. Mail Servers - holds the mails of many users, a user's mailbox manages the mails sent to him/her.
3. SMTP (Simple Mail Transfer Protocol) - application layer protocol, uses reliable data transfer service. Each mail server has both sides of SMTP, the client side (when it is sending a message to another user) and the server side (when it receives a message from another user).

SMTP

Requires the data to be 7-bit ASCII; converts even the multimedia data to binary and then to ASCII before transport.



SMTP uses TCP connection and forms a direct connection between client and server mail servers, no matter how far are the two located geographically. Uses port 25. The sender's and receiver's mail server is an always on mail server maintained by an ISP or institution, capable of storing the mail till it is delivered to the receiver.

Establish connection - telnet serverName 25

Commands - HELO, MAIL FROM, RCPT TO, DATA, QUIT, .

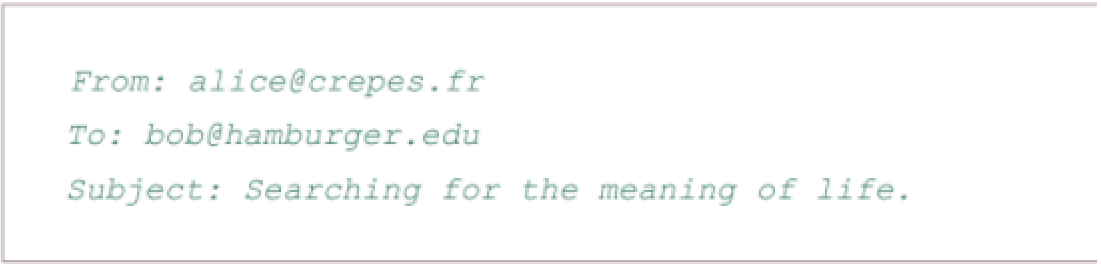
Persistent connection, QUIT is issued after all the messages have been sent.

Comparison with HTTP -

Similarities - Transfer protocol, uses persistent connections

Differences - HTTP (connection between a web client and a web server) - pull protocol - each response message contains 1 object; SMTP (connection between 2 mail servers) - push protocol - each msg is in ASCII format, and all the contents of the mail are in 1 message.

SMTP Message Header -



```
From: alice@crepes.fr
To: bob@hamburger.edu
Subject: Searching for the meaning of life.
```

Mail Access Protocols - Sending the mail from receiver's mail server to receiver's user agent -

1. POP3 (Post Office Protocol - Version 3)

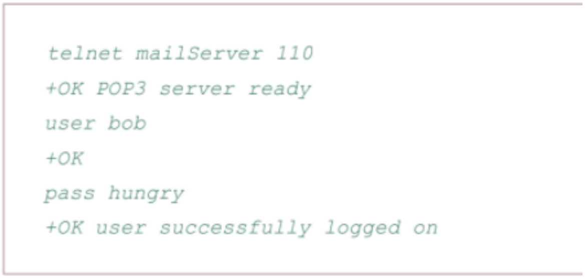
2. IMAP (Internet Mail Access Protocol)
3. HTTP

POP3

User agent opens TCP connection to the mail server on port 110.

3 phases of POP - authorization (username and password to authenticate the user);

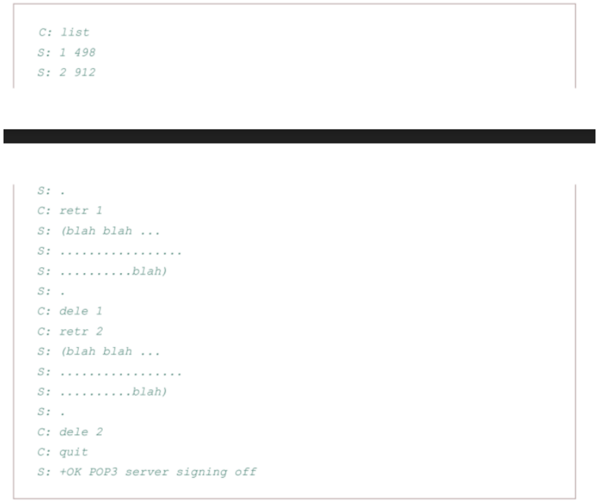
Commands - user, pass



```
telnet mailServer 110
+OK POP3 server ready
user bob
+OK
pass hungry
+OK user successfully logged on
```

transaction (retrieval of messages, deletion, obtain mail statistics);

Commands - list, retr, dele, quit



```
C: list
S: 1 498
S: 2 912
S: .
C: retr 1
S: (blah blah ...
S: ................
S: ..........blah)
S: .
C: dele 1
C: retr 2
S: (blah blah ...
S: ................
S: ..........blah)
S: .
C: dele 2
C: quit
S: +OK POP3 server signing off
```

update (after QUIT command is issued, mail server deletes the messages marked for deletion.)

The two modes of reading messages - download and delete (the messages are read and saved to a machine at once); download and keep (the messages can be retrieved at various machines.)

POP3 tracks state for one session (to update the deleted messages) but doesn't track the state across multiple sessions. Therefore, POP3 doesn't let a user make and maintain mail folders in a remote mail server, which can be accessed by multiple user agents.

IMAP

IMAP is more complex than POP3.

It assigns any message that arrives at the server to a folder, it is initially a recipient's inbox folder, and later can be moved to a user created folder, and also allows the search for messages satisfying a certain criteria. It is achieved by maintaining user state information over various IMAP sessions.

It also allows the users to obtain only a few components of the mail that he/she finds useful and not download the entire mail.

DNS (Domain Name System) -

Identifiers for a host - hostname (web address) ; IP addresses

IP addresses - 4 bytes (0-255), each byte separated by a "." ; hierarchical.

DNS - directory service to translate hostnames to IP addresses - it is a distributed database implemented in a hierarchy of DNS servers - an application layer protocol that allows hosts to query the distributed database - Uses UDP and port 53 - used by other application layer protocols such as HTTP and SMTP.

DNS adds an additional delay, but caching usually helps reduce it.

Host Aliasing - A canonical or complicated hostname can be aliased with a more mnemonic (easy to remember) name.

Mail Server Aliasing - It is desirable that email addresses be mnemonic. A company's web server and mail server can have same aliased hostname.

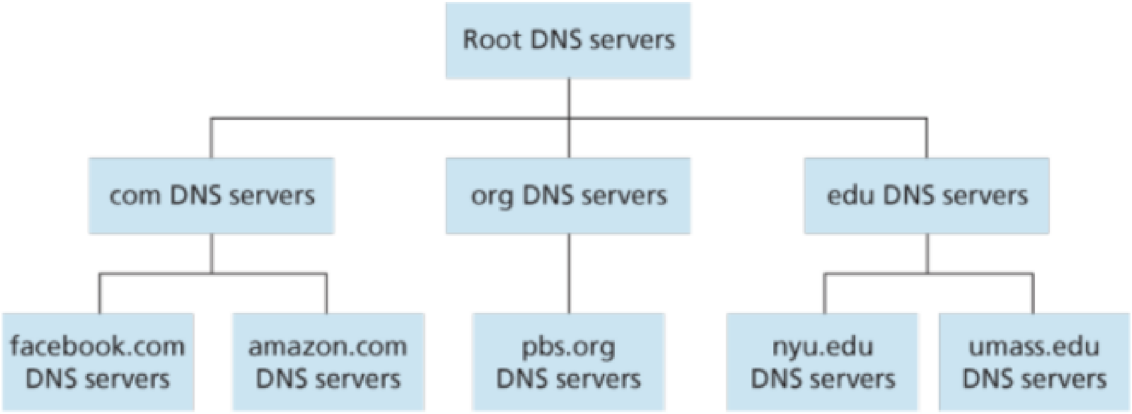
Load Distribution - For busy websites, one hostname is associated with a set of IP addresses (corresponding to various servers the website is replicated on) and each request is directed to different IP address to distribute the load. The rotation of IP addresses for each reply to a DNS query is called as DNS rotation.

Distributed Hierarchical Database

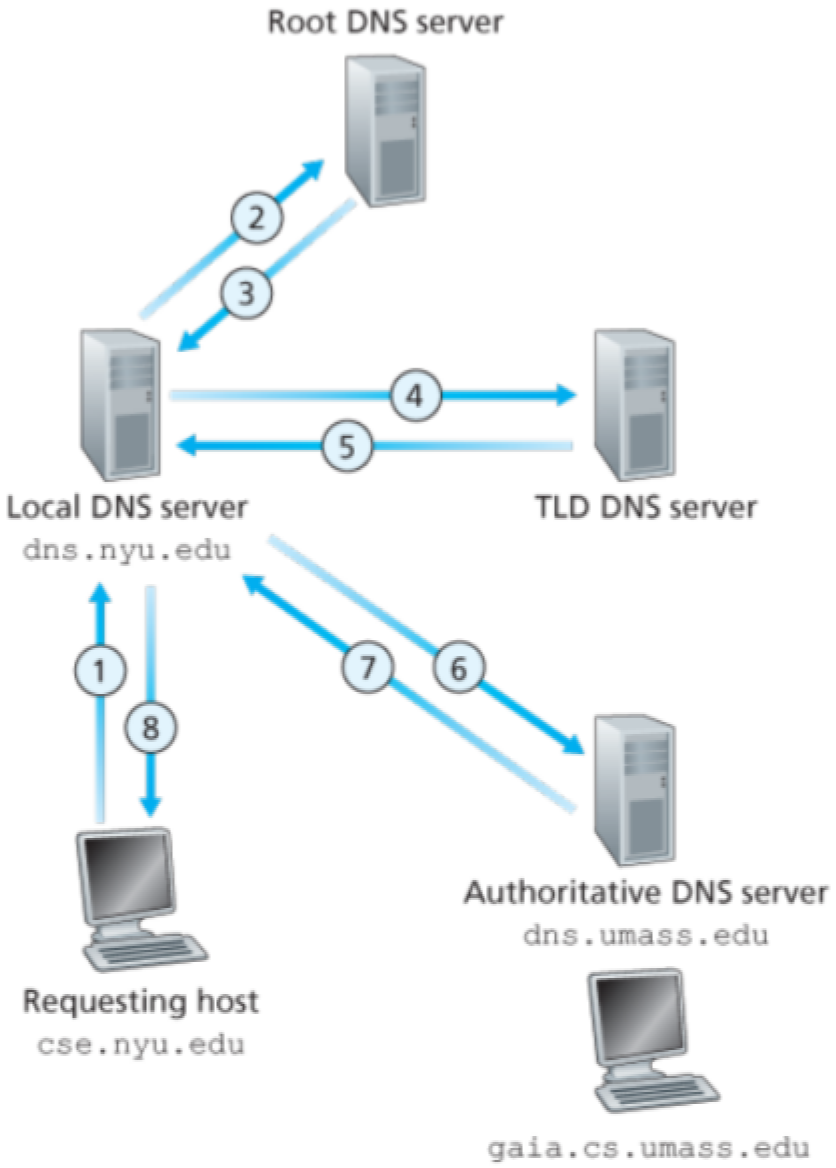
Why not a centralized design? It wont scale.

1. Single point of failure
2. Traffic volume
3. Queries from around the globe (distance will lead to more delays)
4. Maintenance, frequent updates.

Classes of DNS Servers -



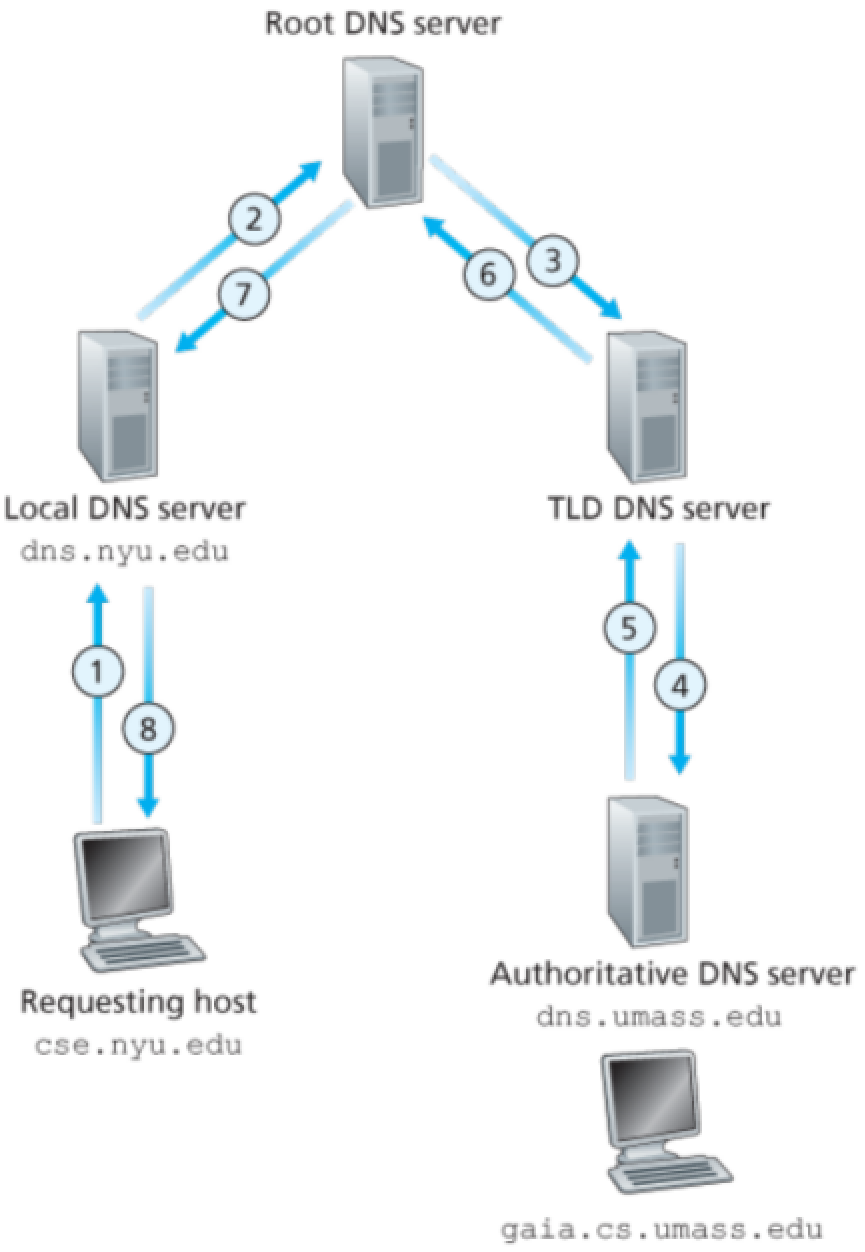
1. Root Name Servers - 13 logical root name servers (~400 all over the world), each server replicated many times. (~200 in US)
2. Top-level Domain (TLD) Server - .org, .net, .edu, .com and country domains such as .in, .us etc.
3. Authoritative DNS Servers - contain mapping of names of host to IP addresses for various organizations.
4. Local DNS Server - doesn't belong to the hierarchy. Each ISP has a local DNS server which acts as a proxy and forwards the DNS query.



TLD server may only know the address of an intermediate DNS server.

cse.nyu.edu → dns.nyu.edu :: recursive call

dsn.nyu.edu → root DNS server; TLD CNS server; authoritative DNS server :: iterative calls



All recursive calls.

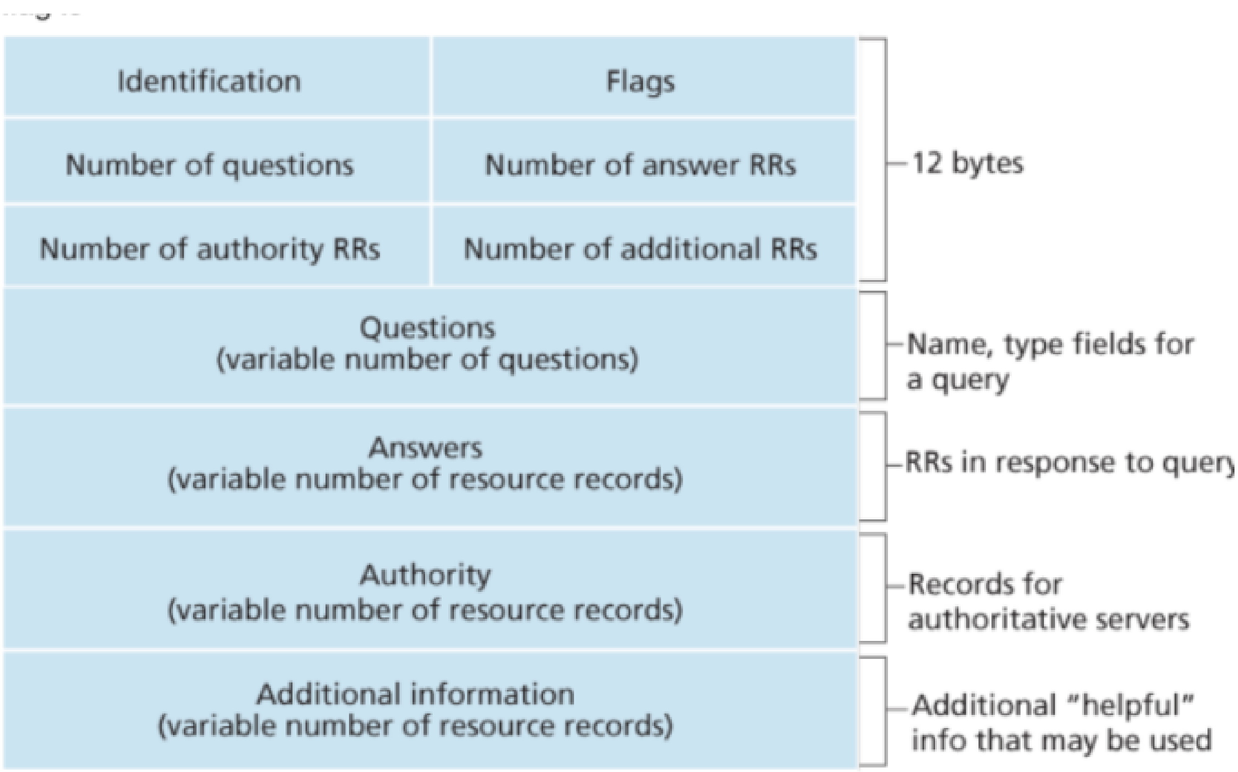
DNS Caching - when a query is made, a hostname/IP address pair can be cached in the DNS server, but because these mappings are not permanent, cached information is deleted every 2 days or so. A DNS cache server can also store the address of a TLD server, thereby bypassing the root server.

DNS Records and Messages - DNS servers store resource records (RR), which include hostname-to-IP address mappings.

A DNS record is a four-tuple - (name, value, type, TTL). TTL - time to live (in cache); type - A (hostname-IP address; contained by authoritative DNS server and cache), NS(domain name-authoritative DNS server), CNAME (canonical host name-alias hostname), MX (alias hostname-canonical host name).

DNS query and reply messages are of the same format. 12-byte header followed by the information.

Header has an identification number, and flag field has flags to show if a message is a reply or query, if recursion was done or not.



Identification	Flags	12 bytes
Number of questions	Number of answer RRs	
Number of authority RRs	Number of additional RRs	
Questions (variable number of questions)		Name, type fields for a query
Answers (variable number of resource records)		RRs in response to quer
Authority (variable number of resource records)		Records for authoritative servers
Additional information (variable number of resource records)		Additional “helpful” info that may be used

You can send a DNS query from your system to DNS server using `nslookup` program.

DNS Database - A registrar verifies the uniqueness of the domain name and enters it to the DNS database. ICANN (Internet Corporation for Assigned Names and Number) accredits various registrars.

DNS Security - DNS is susceptible to DDoS bandwidth flooding attack and man-in-the-middle attack.

Peer-to-peer File Distribution

- Client-Server Architecture to distribute an F bit file to N peers -

  Upload speed of server - u_s

  Server sends all F bit to all N peers - N*F

  Upload time - N*F/u_s

  Download speed of slowest client - d_min

  Download time - F/d_min

  Distribution time ≥ min(FN/u_s , F/d_min)

  ⇒ For an N large enough, distribution time is directly proportional to N.

- Peer-to-Peer Architecture to distribute an F bit file to N peers -

  Upload speed of server - u_s

  Server sends each bit atleast once - F

  Upload time = F/u_s

  Download speed of slowest peer - d_min

  Download time - F/d_min

  Upload capacity of the entire system - u_s + u_1 + u_2 ... u_N

  Distribution time ≥ max(F/u_s, F/d_min, N*F/u_s + u_1+u_2 .. u_N

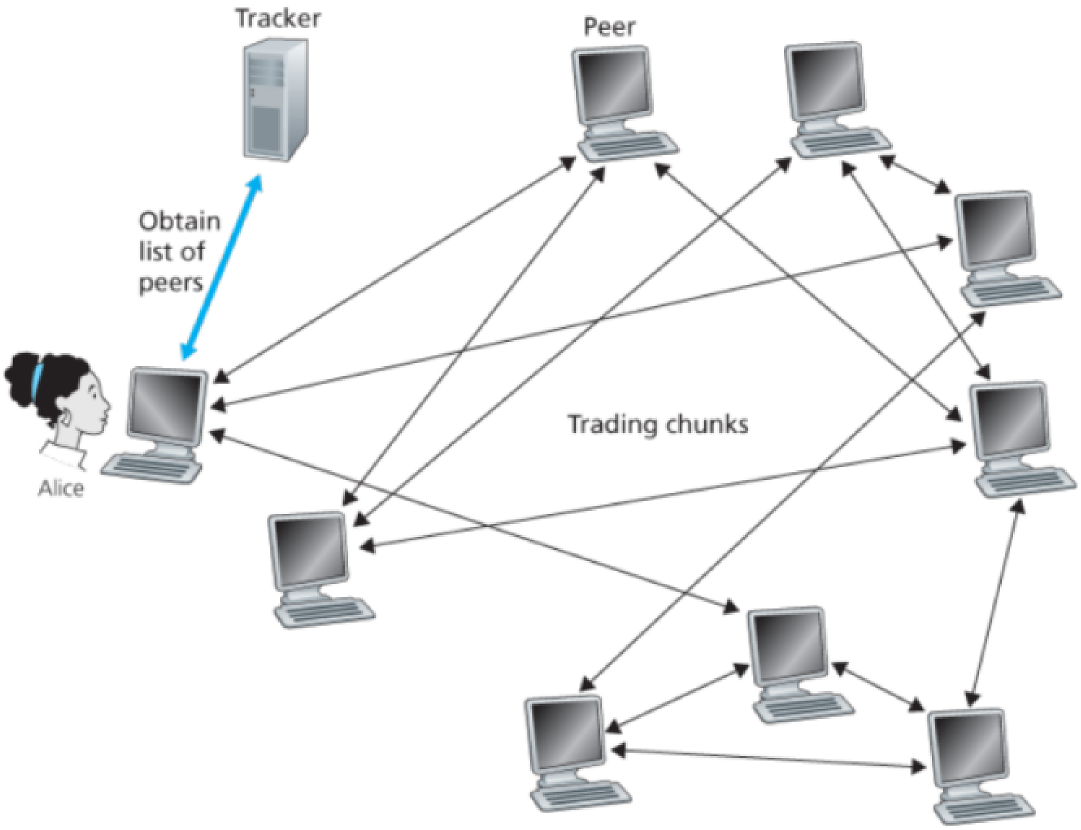
Distribution time for P2P is 10 times less that time for client server architecture.

BitTorrent by Bram Cohen -

Torrent is a collection of all peers participating in the distribution of a particular file.

Each peer downloads equal size chunks.
A peer may leave at any point in my time and re-join.

Infrastructure node - tracker, keeps track of all peers and gives a subset of peers to connect to and get packets, the packets are asked in order of rarest first.



Video Streaming

Videos - 24-30 Images per sec, each image is an array of pixels, each pixel is made of its color and luminance levels. Videos can be compressed at different rates.

HTTP Streaming

The video is stored as an ordinary file at a specific URL. The client establishes a TCP connection and puts a GET request for the URL. The server, sends the video file in the response, and bytes are collected in the buffer. When the client begins playback, the later parts of video keeps getting stored in the buffer.

HTTP-based Streaming / Dynamic Adaptive Streaming over HTTP (DASH)

The video is encoded in chunks at the different bit rates and quality and stored at a different URL. When client dynamically requests chunks, the chunk is provided according to the current available bandwidth. A manifest files keeps track of each version and the URL.

Content Distribution Networks

1. Enter Deep
2. Home

Socket Programming -

Code is written in a pair of programs the client and server programs.