Module1: Application Layer

5.1 Principles of Network Applications

- Network-applications are the driving forces for the explosive development of the internet.
- Examples of network-applications:

1) Web
2) File transfers
3) E-mail
4) P2P file sharing
5) Social networking (Facebook, Twitter)
6) Video distribution (YouTube)
7) Real-time video conferencing (Skype)
8) On-line games (World of Warcraft)

In network-applications, program usually needs to
→ run on the different end-systems and
→ communicate with one another over the network.

- For ex: In the Web application, there are 2 different programs:

1) The browser program running in the user's host (Laptop or Smartphone).
2) The Web-server program running in the Web-server host.

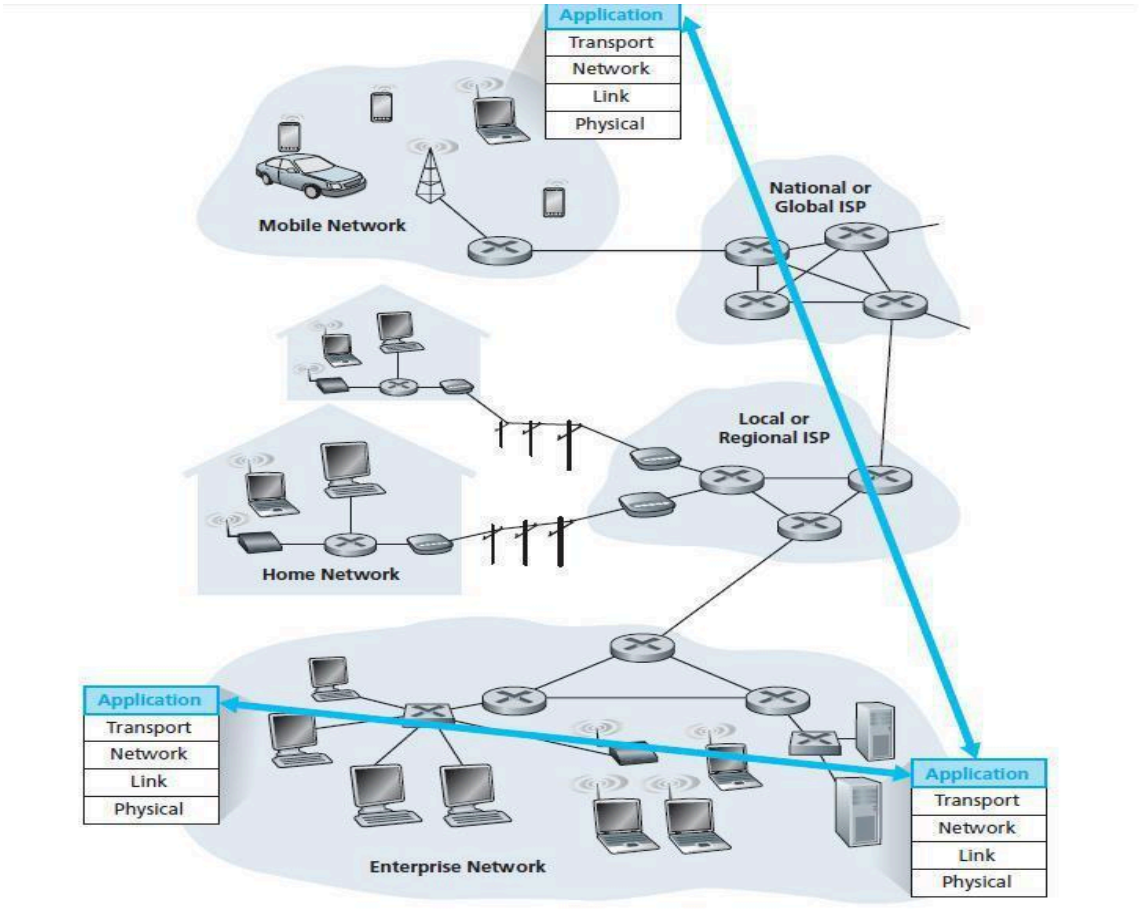


Figure 2.1 ♦ Communication for a network application takes place between end systems at the application layer

5.1.1 Network Application Architectures

Two approaches for developing an application:

1) Client-Server architecture 2) P2P (Peer to Peer) architecture

5.1.1.1 Client-Server Architecture

In this architecture, there is a server and many clients distributed over the network (Figure 1.1a)

SERVER

The server is always-on and listening on the network for client request to provide certain services to the client.

The server has a fixed IP address.

CLIENT

Client initializes the communication with the server by sending a request packet to the server's IP address.

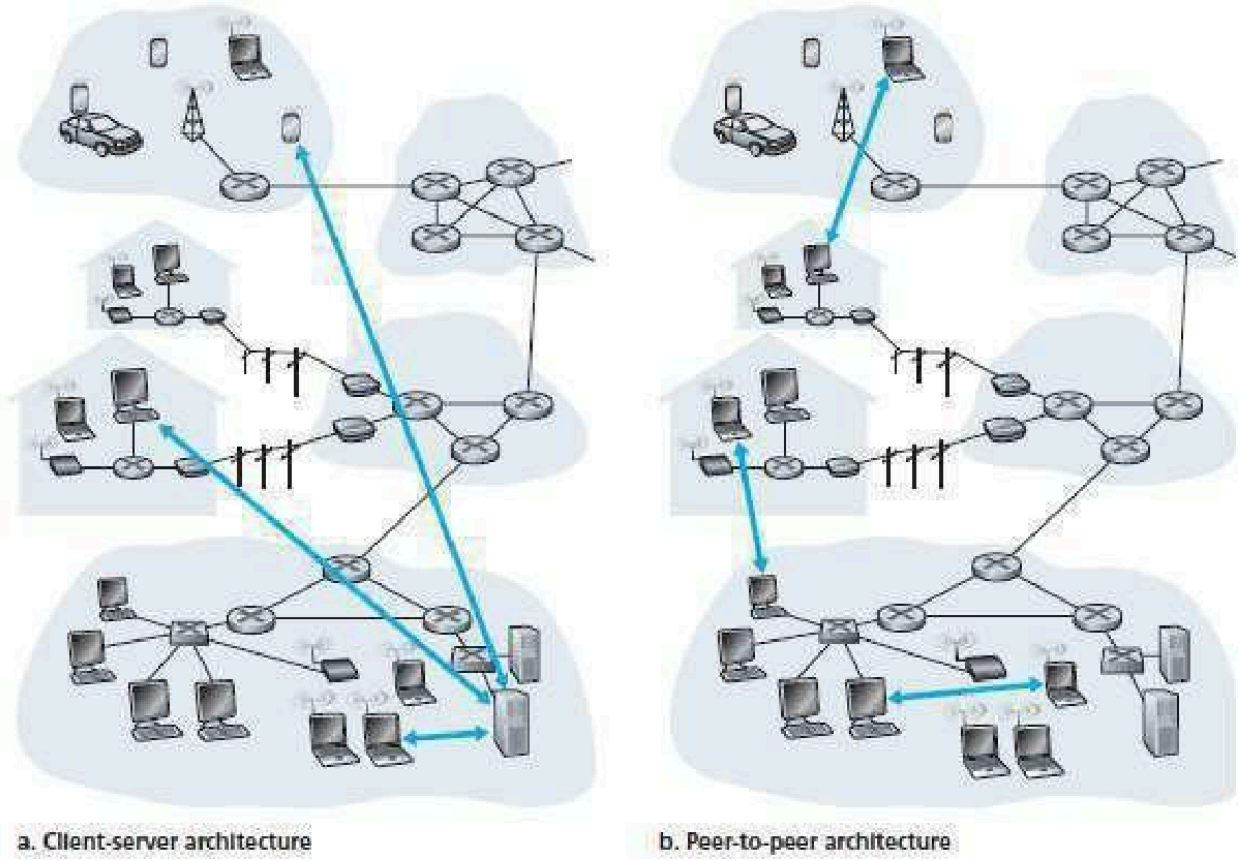
The applications such as Web browser, FTP, telnet, Web, e-mail etc use the client-server architecture.

5.1.1.1.1 Data Center

Earlier, client-server architecture had a single-server host. But now, a single-server host is unable to keep up with all the requests from large no. of clients. For this reason, data-centers are used. A data-center contains a large number of hosts which creates a powerful virtual server. In date center, hundreds of servers must be powered and maintained.

- For example:

Google has around 50 data-centers distributed around the world. These 50 data-centers handle search, YouTube, Gmail, and other services.



5.1.1.2 P2P Architecture

There is no dedicated server (Figure 1.1b). Pairs of hosts are called peers. The peers communicate directly with each other. The peers are not owned by the service-provider. Rather the peers can be laptops controlled by users. Many of today's most popular and traffic-intensive applications are based on P2P architecture. Examples include file sharing (BitTorrent), Internet telephone (Skype) etc.

- Main feature of P2P architectures:

  self-scalability -- For ex: In a P2P file-sharing system,

  Each peer generates workload by requesting files.

  Each peer also adds service-capacity to the system by distributing files to other peers.

- Advantage: Cost effective - Normally, server-infrastructure & server bandwidth are not required.
- Three challenges of the P2P applications:
  - ☐ **ISP friendly** - Most residential ISPs have been designed for asymmetrical bandwidth usage. Asymmetrical bandwidth means there is more downstream-traffic than upstream-traffic. But P2P applications shift upstream-traffic from servers to residential IPs, which stress on the ISPs
  - ☐ **Security -** Since the highly distribution and openness, P2P applications can be a challenge to security

- **Incentive -** Success of P2P depends on convincing users to volunteer bandwidth & resources to the applications

Peer-to-Peer Applications

• In P2P network there is no reliance on **always-on** server host, rather any node can (called peers) acts as a client and server at the same time.
• The peers are not owned by a service-provider.
• The peers not supposed to be always listening on the Internet.
• The peers are dynamic, i.e., some peers will join some peers will leave from time to time.

- .

5.1.2 Processes Communicating

5.1.2.1 Process

- A process is an instance of a program running in a computer.(IPC inter-process communication).
- The processes may run on the 1) same system or 2) different systems.

1) The processes running on the same end-system can communicate with each other using IPC.
2) The processes running on the different end-systems can communicate by exchanging messages.
i) A sending-process creates and sends messages into the network.
ii) A receiving-process receives the messages and responds by sending messages back.

5.1.2.1.1 Client & Server Processes

- A network-application consists of pairs of processes:

1) The process that initiates the communication is labeled as the client.
2) The process that waits to be contacted to begin the session is labeled as the server.

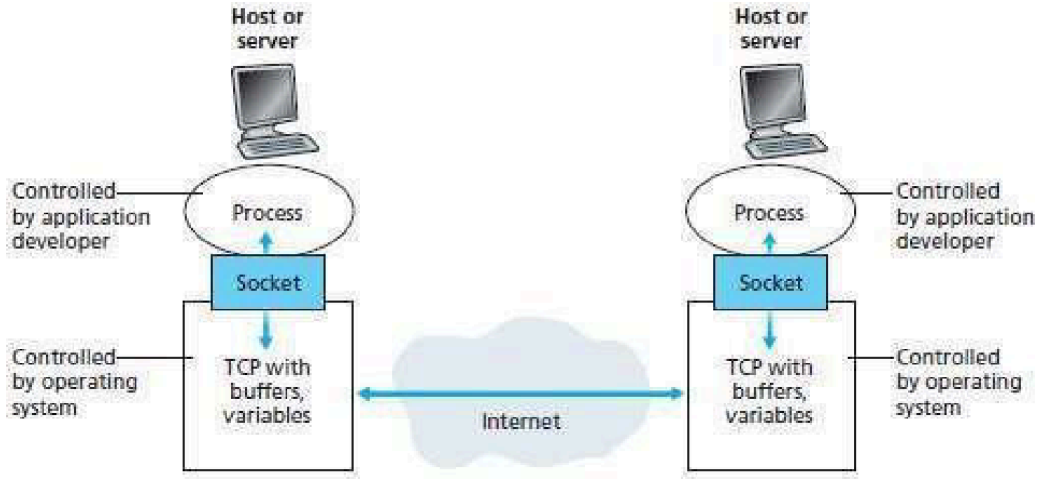
- For example:

1) In Web application, a client-browser process communicates with a Web-server-process.
2) In P2P file system, a file is transferred from a process in one peer to a process in another peer.

5.1.2.1.2 Interface between the Process and the Computer Network Socket

- Any message sent from one process to another must go through the underlying-network.
- A process sends/receives message through a software-interface of underlying-network called socket.
- Socket is an API between the application-layer and the transport layer within a host (Figure 1.2).
- The application-developer has complete control at the application-layer side of the socket.
- But, the application-developer has little control of the transport-layer side of the socket.

1) The choice of transport-protocol: TCP or UDP. (API Application Programming Interface)
2) The ability to fix parameters such as maximum-buffer & maximum-segment-sizes.



5.1.2.1.3 Addressing Processes

- To identify the receiving-process, two pieces of information need to be specified:
  1) IP address of the destination-host.
  2) Port-number that specifies the receiving-process in the destination-host.
- In the Internet, the host is identified by unique identifier assigned for each device called IP address representing a 32-bit quantity.
- a destination port-number - Sending-process needs to identify receiving-process because runs several network-applications for different clients

EG. A Web-server is identified by port-number 80. A mail-server is identified by port-number 25.

5.1.3 Transport Services Available to Applications

Networks usually provide more than one transport-layer protocols (TCP/UDP) for different applications. An application-developer should choose certain protocol according to the type of applications. Different protocols may provide different services.

5.1.3.1 Reliable and UnReliable Data Transfer

- Reliable means guaranteed delivery of correct data from the sender to the receiver. For ex: TCP provides reliable service to an application like files, mails, etc.
- Unreliable means the data from the sender to the receiver may arrive or never arrive. Unreliability may be acceptable for loss-tolerant applications, such as multimedia applications. In multimedia applications, the lost data might result in a small glitch in the audio/video.

5.1.3.2 Throughput

- Throughput is the rate at which the sending-process can deliver bits to the receiving-process.
- Since other hosts are using the network, the throughput can fluctuate with time.
- Two types of applications:

1) Bandwidth Sensitive Applications

These applications need a guaranteed throughput. For ex: Multimedia applications

Some transport-protocol provides guaranteed throughput at some specified rate (r bits/sec).

2) Elastic Applications

These applications may not need a guaranteed throughput. For ex: Electronic mail, File transfer & Web transfers.

5.1.3.3 Timing

- A transport-layer protocol can provide timing-guarantees.
- For ex: guaranteeing every bit arrives at the receiver in less than 100 msec.
- Timing constraints are useful for real-time applications such as

→ Internet telephony, Virtual environments, Teleconferencing and Multiplayer games

5.1.3.4 Security

- A transport-protocol can provide one or more security services.
- For example,

1) In the sending host, a transport-protocol can encrypt all the transmitted-data.
2) In the receiving host, the transport-protocol can decrypt the received-data.

5.1.4 Transport Services Provided by the Internet

- The Internet makes two transport-protocols available to applications, UDP and TCP.
- An application-developer who creates a new network-application must use either: UDP or TCP.
- Both UDP & TCP offers a different set of services to the invoking applications.
- Figure 2.4 shows the service requirements for some selected applications.

Application	Data Loss	Throughput	Time-Sensitive
File transfer/download	No loss	Elastic	No
E-mail	No loss	Elastic	No
Web documents	No loss	Elastic (few kbps)	No
Internet telephony/ Video conferencing	Loss-tolerant	Audio: few kbps–1Mbps Video: 10 kbps–5 Mbps	Yes: 100s of msec
Streaming stored audio/video	Loss-tolerant	Same as above	Yes: few seconds
Interactive games	Loss-tolerant	Few kbps–10 kbps	Yes: 100s of msec
Instant messaging	No loss	Elastic	Yes and no

Figure 2.4 ♦ Requirements of selected network applications

Application	Application-Layer Protocol	Underlying Transport Protocol
Electronic mail	SMTP [RFC 5321]	TCP
Remote terminal access	Telnet [RFC 854]	TCP

5.1.4.1 TCP Services

An application using transport-protocol TCP, receives following 2 services.
Before the start of communication, client & server need to exchange control-information. This phase is called **handshaking phase**.

Then, the two processes can send messages to each other over the connection. After the end of communication, the applications must tear down the connection.

2) Reliable Data Transfer Service

The communicating processes must deliver all data sent without error & in the proper order.

- TCP also includes a congestion-control.
- The congestion-control throttles a sending-process when the network is congested.

5.1.4.2 UDP Services

UDP is a lightweight transport-protocol, providing minimal services. It is connectionless, so there is no handshaking before the 2 processes start to communicate and provides an unreliable data transfer service. Unreliable means providing no guarantee that the message will reach the receiving-process.Furthermore, messages that do arrive at the receiving-process may arrive out-of-order. UDP does not include a congestion-control. UDP can pump data into the network-layer at any rate.

5.2 Application -Layer Protocols

An **application-layer protocol** defines how an application's processes, running on different end systems, pass messages to each other. In particular, an application-layer protocol defines:

- The types of messages exchanged, for example, request messages and response messages
- The syntax of the various message types, such as the fields in the message and how the fields are delineated.
- The semantics of the fields, that is, the meaning of the information in the fields
- Rules for determining when and how a process sends messages and responds to messages.

The Web & HTTP

The appearance of Web dramatically changed the Internet. Web has many advantages for a lot of applications.

- It operates on demand so that the users receive what they want, when they want it.

- It provides an easy way for everyone make information available over the world.
- Hyperlinks and search engines help us navigate through an ocean of Web-sites.
- Forms, JavaScript, Java applets, and many other devices enable us to interact with pages and sites.
- The Web serves as a platform for many killer applications including YouTube, Gmail, and Facebook.

5.2.1 Overview of HTTP

5.2.1.1 Web

A web-page consists HTML (Hyper Text Markup Language) tags. Each page consists of many objects. An object is a file such as an HTML file, a JPEG image, a Java applet, a video chip. The object is addressable by a single URL (Uniform Resource Locator).
Most Web-pages consist of a base HTML file & several referenced objects.

- For example:

If a Web-page contains HTML text and five JPEG images; then the Web-page has six objects:
1) Base HTML file and
2) Five images.

- The base HTML file references the other objects in the page with the object's URLs.

- URL has 2 components:

1) The hostname of the server that houses the object and
2) The object‘s path name.

- For example:

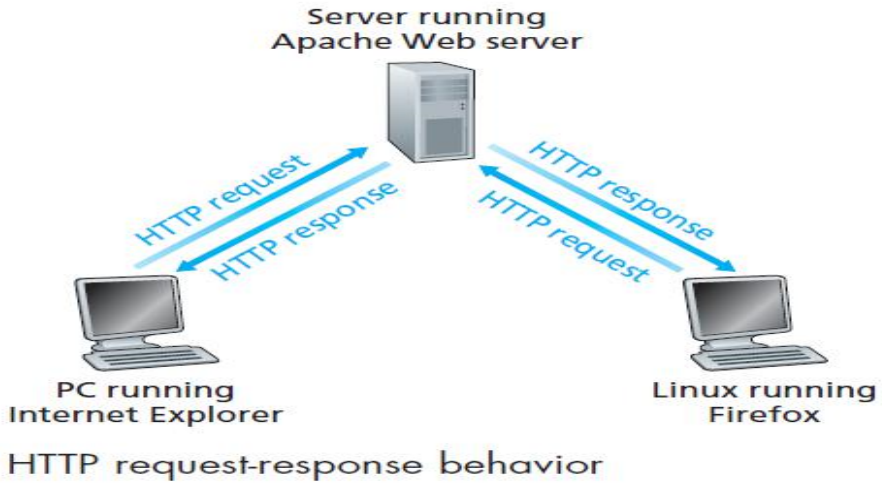
—http://www.someSchool.edu/someDepartment/picture.gif In above URL,
1) Hostname = www.someSchool.edu
2) Path name = /someDepartment/picture.gif.

- The web browsers implement the client-side of HTTP. For ex: Google Chrome, Internet Explorer
- The web-servers implement the server-side of HTTP. For ex: Apache

5.2.1.2 HTTP

- HTTP (HyperText Transfer Protocol) is Web‘s application-layer protocol (Figure 1.3).
- HTTP defines

→ how clients request Web-pages from servers and
→ how servers transfer Web-pages to clients.



HTTP request-response behavior

When a user requests a Web-page, the browser sends HTTP request to the server.

- Then, the server responds with HTTP response that contains the requested-objects.
- HTTP uses TCP as its underlying transport-protocol.
- The HTTP client first initiates a TCP connection with the server.
- After connection setup, the browser and the server-processes access TCP through their sockets.
- HTTP is a stateless protocol.
- Stateless means the server sends requested-object to client w/o storing state-info about the client.
- HTTP uses the client-server architecture:

Client - Browser that requests receive and displays Web objects.

Server - Web-server sends objects in response to requests.

5.2.2 Non-Persistent & Persistent Connections

In many internet applications, the client and server communicate for an extended period of time.When this client-server interaction takes place over TCP, a decision should be made:

1) Should each request/response pair be sent over a separate TCP connection or
2) Should all requests and their corresponding responses be sent over same TCP connection?

- These different connections are called
  1. non-persistent connections
  2. persistent connections.
- Default mode: HTTP uses persistent connections.

5.2.2.1 HTTP with Non-Persistent Connections

A non-persistent connection is closed after the server sends the requested-object to the client. In other words, the connection is used exactly for one request and one response. For downloading multiple objects, multiple connections must be used.

Suppose user enters URL: "http://www.someSchool.edu/someDepartment/home.index"

- Assume above link contains text and references to 10 jpeg images.

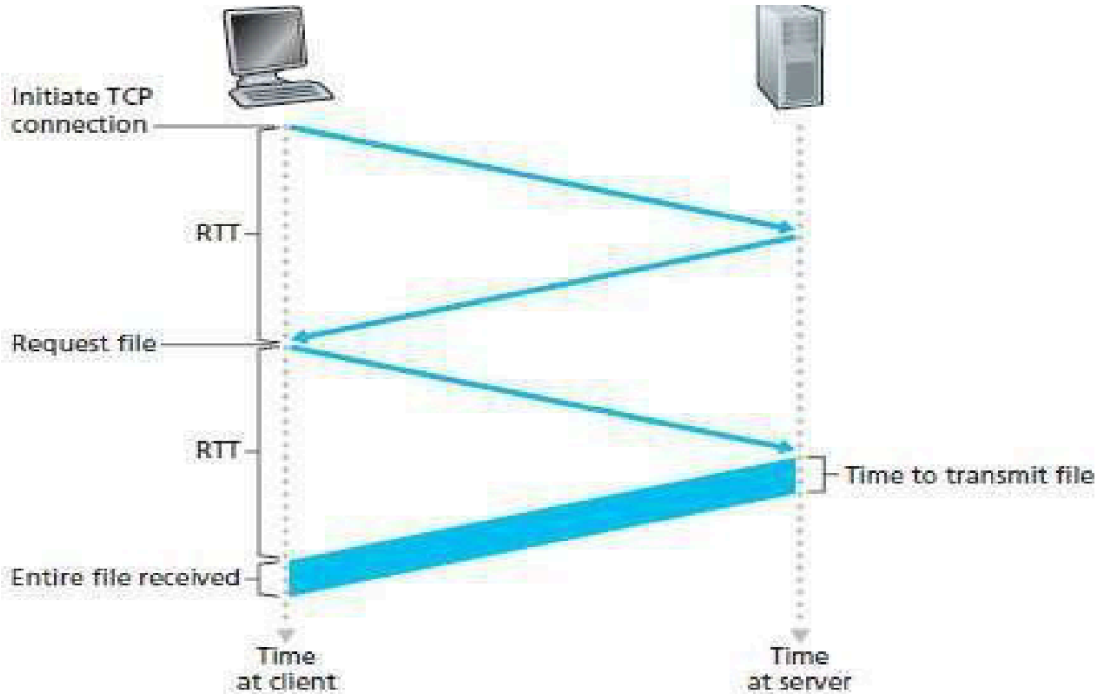
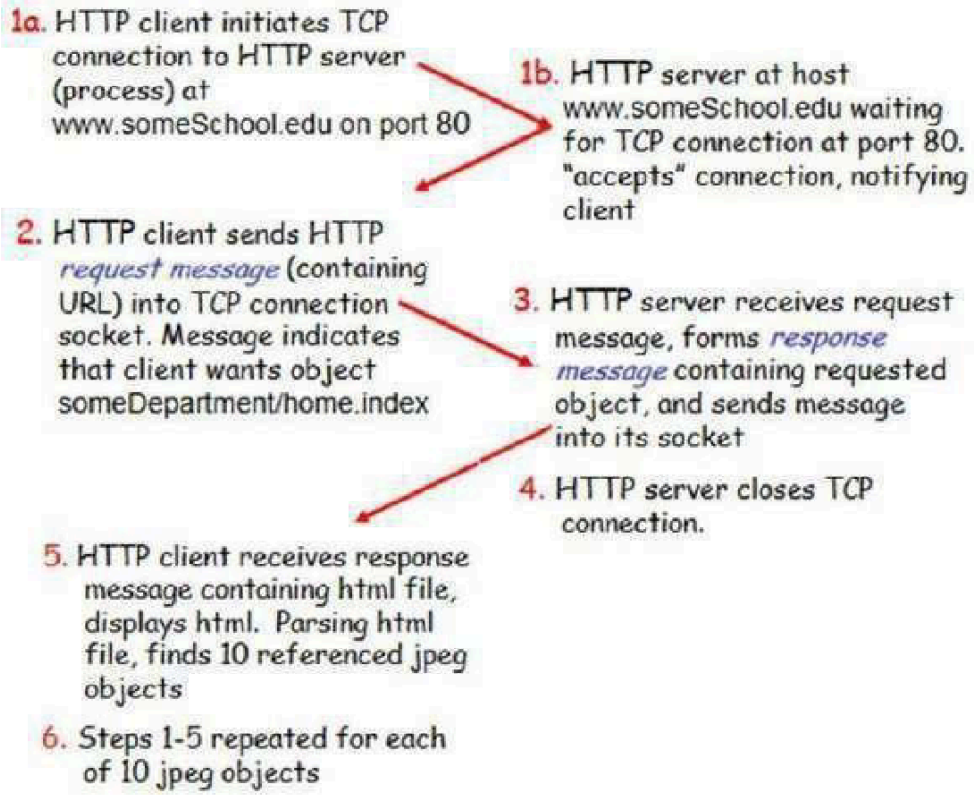


Figure 1.4: Back-of-the-envelope calculation for the time needed to request and receive an HTML file

Here is how it works:



- RTT is the time taken for a packet to travel from client to server and then back to the client.
- The total response time is sum of following (Figure 1.4):

i) One RTT(Round Trip Time) to initiate TCP connection.
ii) One RTT for HTTP request and first few bytes of HTTP response to return.
iii) File transmission time.
i.e. Total response time = 1 RTT+ 1 RTT+ File transmission time = 2(RTT) + File transmission time

5.2.2.2 HTTP with Persistent Connections

- Problem with Non-Persistent Connections:

1) A new connection must be established and maintained for each requested-object.

Hence, buffers must be allocated and state info must be kept in both the client and server.

This results in a significant burden on the server.

2) Each object suffers a delivery delay of two RTTs:
i) One RTT to establish the TCP connection and
ii) One RTT to request and receive an object.

- Solution: Use persistent connections.

With persistent connections, the server leaves the TCP connection open after sending responses. Hence, subsequent requests & responses b/w same client & server can be sent over same connection. The server closes the connection only when the connection is not used for a certain amount of time. Default mode of HTTP: Persistent connections with pipelining.

- Advantages:

1) This method requires only one RTT for all the referenced-objects.
2) The performance is improved by 20%

.

5.2.3 HTTP Message Format

Two types of HTTP messages: 1) Request-message and 2) Response-message.

5.2.3.1 HTTP Request Message

An example of request-message is as follows:
GET /somedir/page.html HTTP/1.1
Host: www.someschool.edu
Connection: close
User-agent: Mozilla/5.0
Accept-language: us-en

The request-message contains 3 sections (Figure 1.5):
1) Request-line
2) Header-line
3) Carriage return.
4) Entity body
The first line of message is called the request-line. The subsequent lines are called the header-lines.

- The request-line contains 3 fields. The meaning of the fields is as follows:

1) Method

 GET: This method is used when the browser requests an object from the server.

2) URL

 /somedir/page.html‖: This is the object requested by the browser.

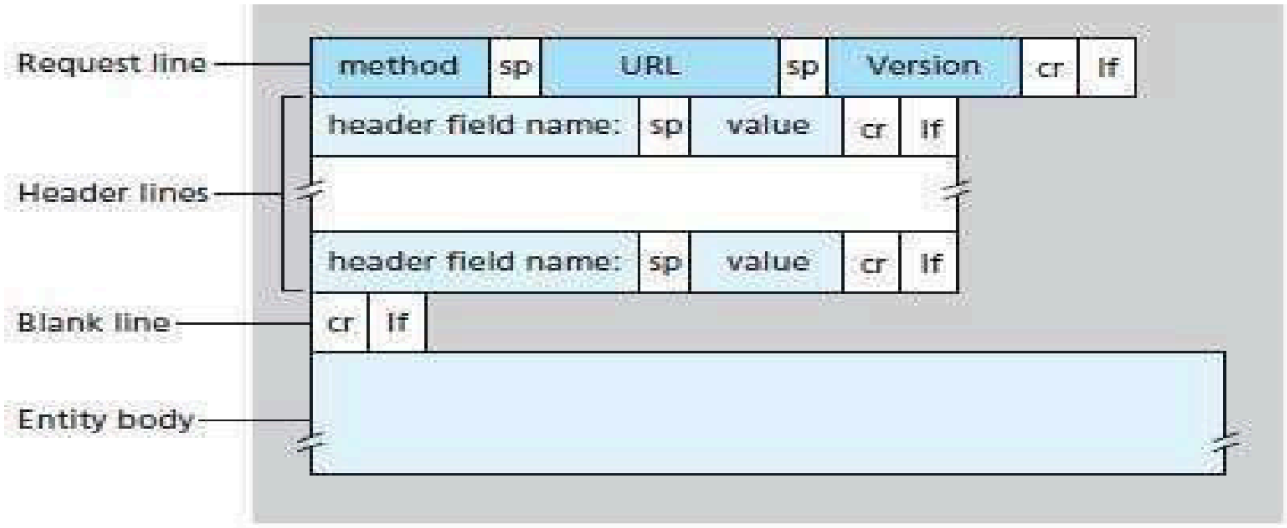


Figure 1.5: General format of an HTTP request-message

 HTTP/1.1: This is version used by the browser.

- The request-message contains 4 header-lines. The meaning of the header-lines is as follows:

1) —Host: www.someschool.edu‖ specifies the host on which the object resides.
2) —Connection: close means requesting a non-persistent connection.
3) —User-agent:Mozilla/5.0 means the browser used is the Firefox.
4) —Accept-language:US-en means English is the preferred language.

The method field can take following values: GET, POST, HEAD, PUT and DELETE.

1) GET is used when the browser requests an object from the server.
2) POST is used when the user fills out a form & sends to the server.
3) HEAD is identical to GET except the server must not return a message-body in the response.
4) PUT is used to upload objects to servers.
5) DELETE allows an application to delete an object on a server.

5.2.3.2 HTTP Response Message

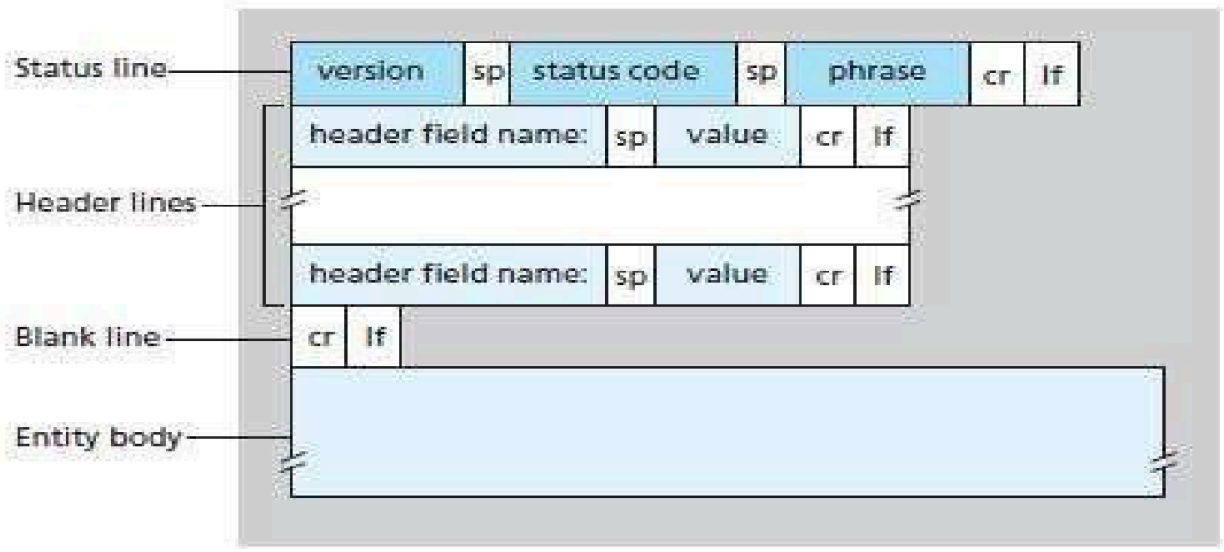


Figure 1.6: General format of an HTTP response-message
An example of response-message is as follows:
HTTP/1.1 200 OK
Connection: close
Date: Tue, 09 Aug 2011 15:44:04 GMT
Server: Apache/2.2.3 (CentOS)
Last-Modified: Tue, 09 Aug 2011 15:11:03 GMT
Content-Length: 6821
Content-Type: text/html

(data data data data data ...)

- The response-message contains 3 sections (Figure 1.6):

1) Status line
2) Header-lines and
3) Data (Entity body).

- The status line contains 3 fields:

1) Protocol version
2) Status-code and
3) Status message.

- Some common status-codes and associated messages include:

1) 200 OK: Standard response for successful HTTP requests.
2) 400 Bad Request: The server cannot process the request due to a client error.
3) 404 Not Found: The requested resource cannot be found.

- The meaning of the Status line is as follows:

HTTP/1.1 200 OK: This line indicates the server is using HTTP/1.1 & that everything is OK.

- The response-message contains 6 header-lines. The meaning of the header-lines is as follows:

1) Connection: This line indicates browser requesting a non-persistent connection.

2) Date: This line indicates the time & date when the response was sent by the server.
3) Server: his line indicates that the message was generated by an Apache Web-server.
4) Last-Modified: This line indicates the time & date when the object was last modified.
5) Content-Length: This line indicates the number of bytes in the sent-object.
6) Content- type: This line indicates that the object in the entity body is HTML text.

5.2.4 User-Server Interaction: Cookies

- Cookies refer to a small text file created by a Web-site that is stored in the user's computer.
- Cookies are stored either temporarily for that session only or permanently on the hard disk.
- Cookies allow Web-sites to keep track of users.

Cookie technology has four components:
1) A cookie header-line in the HTTP response-message.
2) A cookie header-line in the HTTP request-message.
3) A cookie file kept on the user‘s end-system and managed by the user‘s browser.
4) A back-end database at the Web-site.

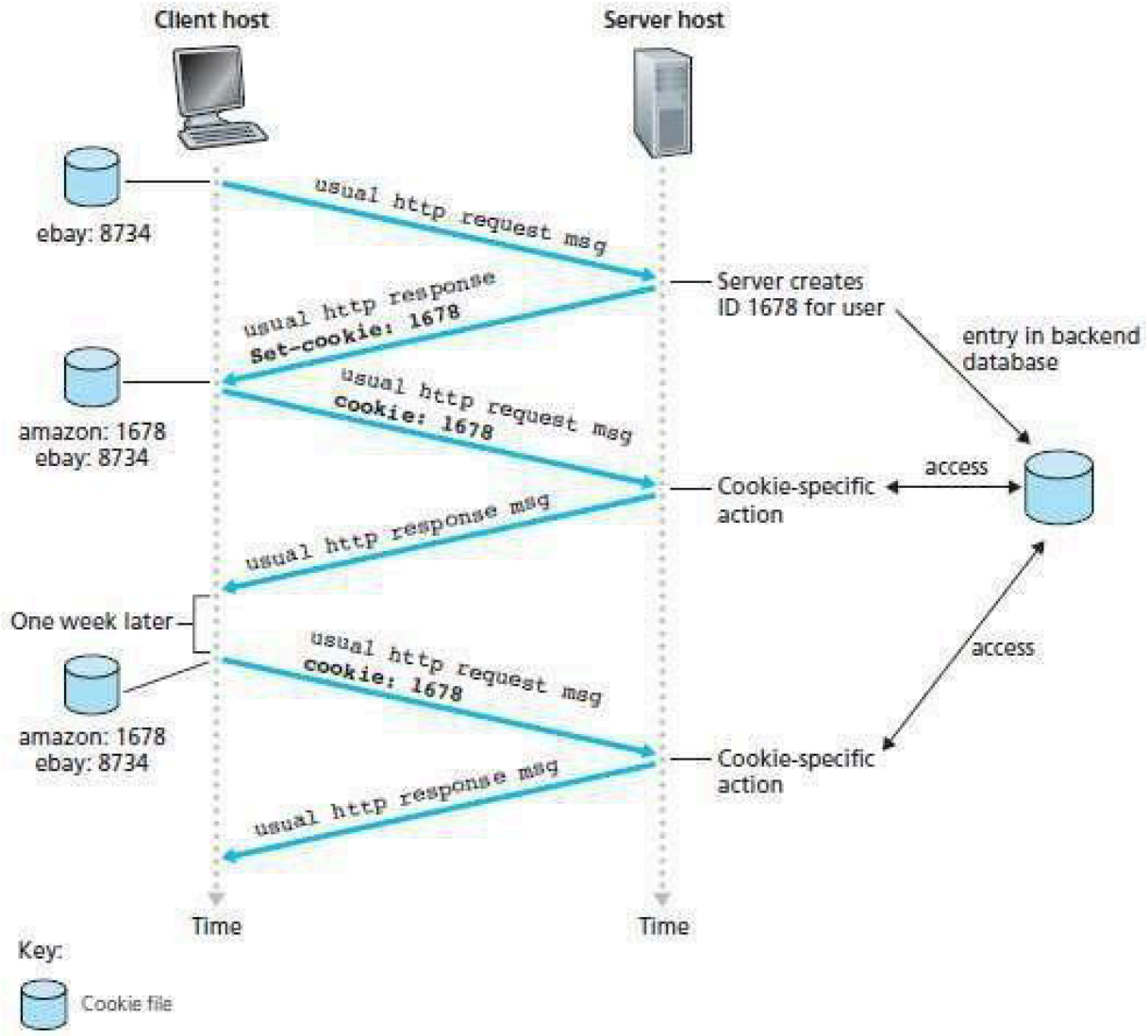


Figure 1.7: Keeping user state with cookies

- Here is how it works (Figure 1.7):

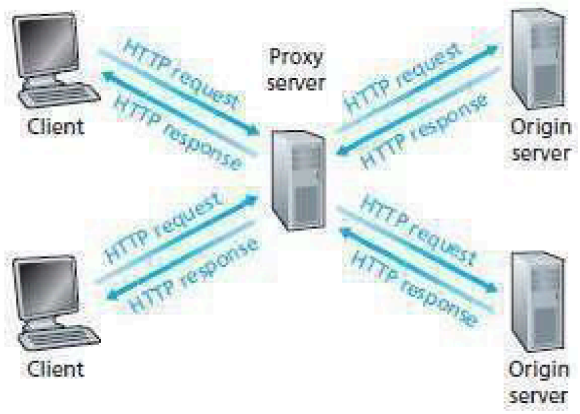
1) When a user first time visits a site, the server
   → creates a unique identification number (1678) and
   → creates an entry in its back-end database by the identification number.
2) The server then responds to user‘s browser.

   H P response includes Set-cookie: header which contains the identification number (1678)

3) The browser then stores the identification number into the cookie-file.
4) Each time the user requests a Web-page, the browser
   → extracts the identification number from the cookie file, and
   → puts the identification number in the HTTP request.
5) In this manner, the server is able to track user‘s activity at the web-site.

5.2.5 Web Caching

A **Web cache**—also called a **proxy server** is a network entity that satisfies HTTP requests on the behalf of an original Web-server. The Web cache has its own disk storage and keeps copies of recently requested objects in this storage. a user's browser can be configured so that all of the user's HTTP requests are first directed to the Web cache. Once a browser is configured, each browser request for an object is first directed to the Web cache.



1.8: Clients requesting objects through a Web-cache (or Proxy erver)

- Here is how it works (Figure 1.8):

1) The user's HTTP requests are first directed to the web-cache.
2) If the cache has the object requested, the cache returns the requested-object to the client.
3) If the cache does not have the requested-object, then the cache
   → connects to the original server and
   → asks for the object.
4) When the cache receives the object, the cache
   → stores a copy of the object in local-storage and
   → sends a copy of the object to the client.

- A cache acts as both a server and a client at the same time.

1) The cache acts as a server when the cache
   → receives requests from a browser and
   → sends responses to the browser.
2) The cache acts as a client when the cache
   → requests to an original server and
   → receives responses from the origin server.

- Advantages of caching:

1) To reduce response-time for client-request.
2) To reduce traffic on an institution's access-link to the Internet.
3) To reduce Web-traffic in the Internet.

5.2.6 The Conditional GET

- Conditional GET refers a mechanism that allows a cache to verify that the objects are up to date.
- An HTTP request-message is called conditional GET if

1) Request-message uses the GET method and
2) Request-message includes an If-Modified-Since: header-line.

- The following is an example of using conditional GET:
  GET /fruit/kiwi.fig HTTP1.1
  Host: www.exoriguecuisine.com
  If-modified-since: Wed, 7 Sep 2011 09:23:24

- The response is:
  HTTP/1.1 304 Not Modified
  Date: Sat, 15 Oct 2011 15:39:29

5.3 File Transfer: FTP

- FTP is used by the local host to transfer files to or from a remote-host over the network.

The user must provide user identification and a password. After providing this authorization information, the user can transfer files from the local file system to the remote file system and vice versa.

The user first provides the hostname of the remote host, causing the FTP client process in the local host to establish a TCP connection with the FTP server process in the remote host. The user then provides the user identification and password, which are sent over the TCP connection as part of FTP commands. Once the server has authorized the user, the user copies one or more files stored in the local file system into the remote file system (or vice versa).

- FTP uses client-server architecture (Figure 1.9) and uses 2 stages namely authorization and transactions for file transfer .
- FTP uses 2 parallel TCP connections (Figure 1.10):

1) Control Connection

The control-connection is used for sending control-information b/w local and remote-hosts.

The control-information includes:

→ user identification
→ password
commands to change directory and
→ commands to put & get files.

2) Data Connection

The data-connection is used to transfer files.

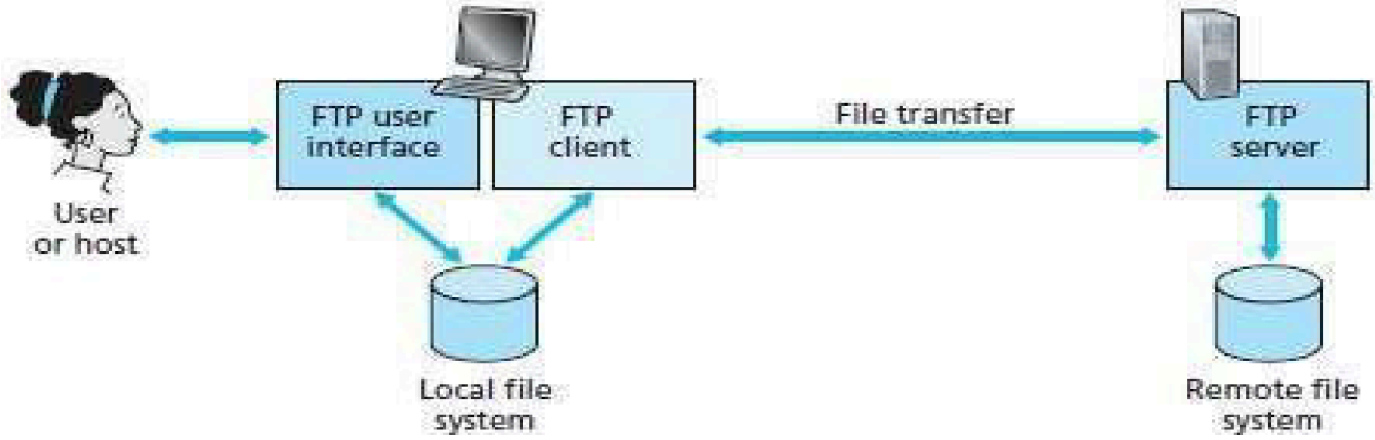


Figure 1.9: FTP moves files between local and remote file systems

Figure 1.10: Control and data-connections

Here is how it works:

1) When session starts, the client initiates a control-connection with the server on port 21.
2) The client sends user-identity and password over the control-connection.
3) Then, the server initiates data-connection to the client on port 20.
4) FTP sends exactly one file over the data-connection and then closes the data-connection.
5) Usually, the control-connection remains open throughout the duration of the user-session.
6) But, a new data-connection is created for each file transferred within a session.

- During a session, the server must maintain the state-information about the user.
- For example:

The server must keep track of the user's current directory.

- Disadvantage:

Keeping track of state-info limits the no. of sessions maintained simultaneously by a server.

5.3.1 FTP Commands & Replies

- The commands are sent from client to server.
- The replies are sent from server to client.
- The commands and replies are sent across the control-connection in 7-bit ASCII format.
- Each command consists of 4-uppercase ASCII characters followed by optional arguments.
- For example:

1) USER username -Used to send the user identification to the server.

2) PASS password- Used to send the user password to the server.

3) LIST - Used to ask the server to send back a list of all the files in the current remote directory.

4) RETR filename - Used to retrieve a file from the current directory of the remote-host.

5) STOR filename - Used to store a file into the current directory of the remote-host.

- Each reply consists of 3-digit numbers followed by optional message.
- For example:

1) 331 Username OK, password required
2) 125 Data-connection already open; transfer starting
3) 425 Can‘t open data-connection
4) 452 Error writing file

1.4 Electronic Mail in the Internet

- e-mail is an asynchronous communication medium in which people send and read messages.
- e-mail is fast, easy to distribute, and inexpensive.
- e-mail has features such as
  → messages with attachments
  → hyperlinks
  → HTML-formatted text and
  → embedded photos.
- Three major components of an e-mail system (Figure 1.11):

1.**User-agents** allow users to read, reply to, forward, save and compose messages.

For example: Microsoft Outlook and Apple Mail

2. Mail-servers contain mailboxes for users.

A message is first sent to the sender's mail-server.

 Then, the sender‘s mail-server sends the message to the receiver's mail-server.

 If the sender‘s server cannot deliver mail to receiver‘s server, the sender‘s server
  → holds the message in a message queue and
  → attempts to transfer the message later.

3) SMTP (Simple Mail Transfer Protocol)

SMTP is an application-layer protocol used for email.

 SMTP uses TCP to transfer mail from the sender‘s mail-server to the recipient‘s mail-server.

SMTP has two sides:

1) A client-side, which executes on the sender‘s mail-server.
2) A server-side, which executes on the recipient‘s mail-server.

Both the client and server-sides of SMTP run on every mail-server.

When a mail-server receives mail from other mail-servers, the mail-server acts as a server. When a mail-server sends mail to other mail-servers, the mail-server acts as a client.

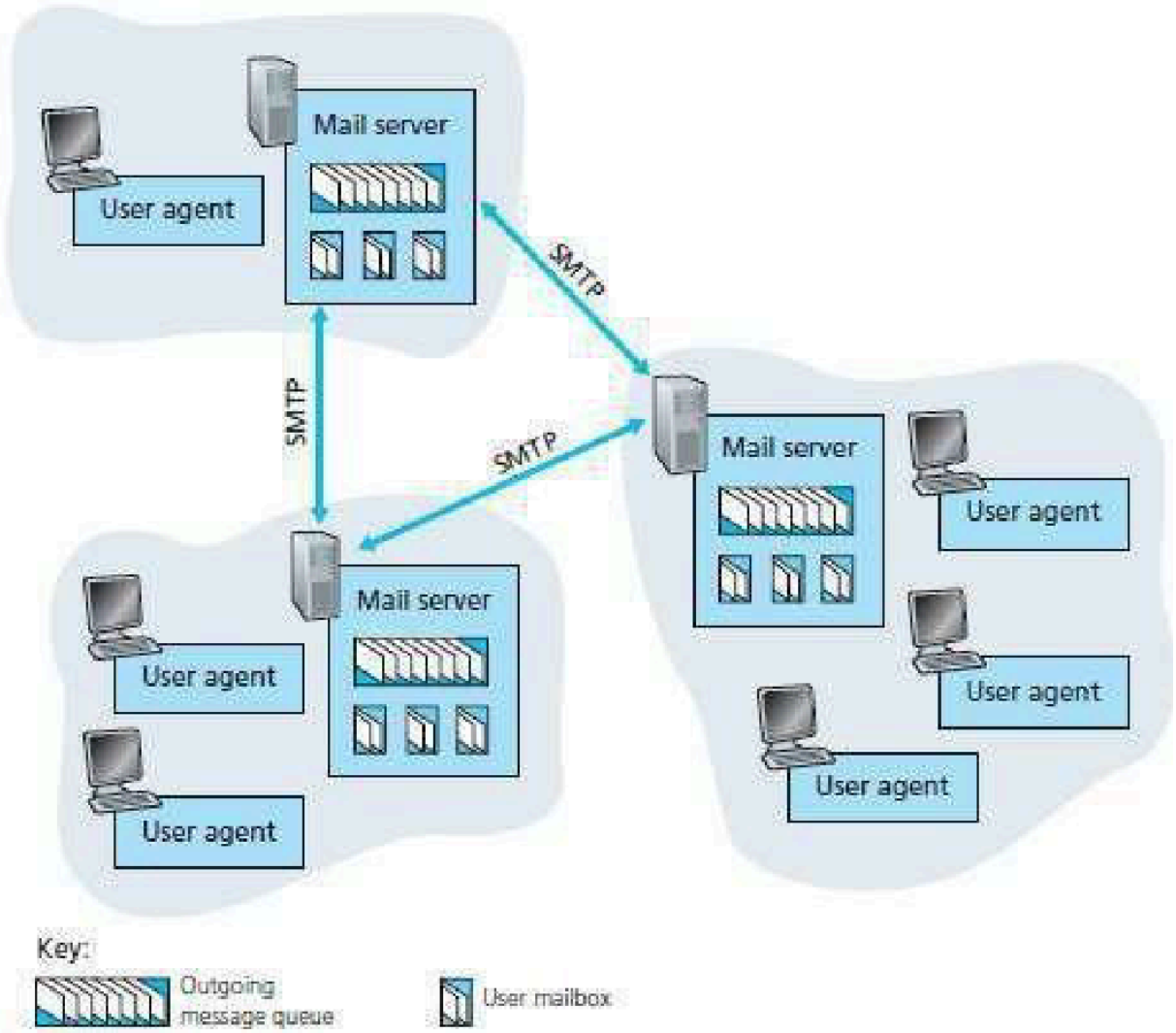


Figure 1.11: A high-level view of the Internet e-mail system

5.4.1 SMTP

- SMTP is the most important protocol of the email system.
- Three characteristics of SMTP (that differs from other applications):
    1) Message body uses 7-bit ASCII code only.
    2) Normally, no intermediate mail-servers used for sending mail.
    3) Mail transmissions across multiple networks through mail relaying.
- Here is how it works:
    1) Usually, mail-servers are listening at port 25.
    2) The sending server initiates a TCP connection to the receiving mail-server.
    3) If the receiver's server is down, the sending server will try later.
    4) If connection is established, the client & the server perform application-layer handshaking.

5) Then, the client indicates the e-mail address of the sender and the recipient.
6) Finally, the client sends the message to the server over the same TCP connection.

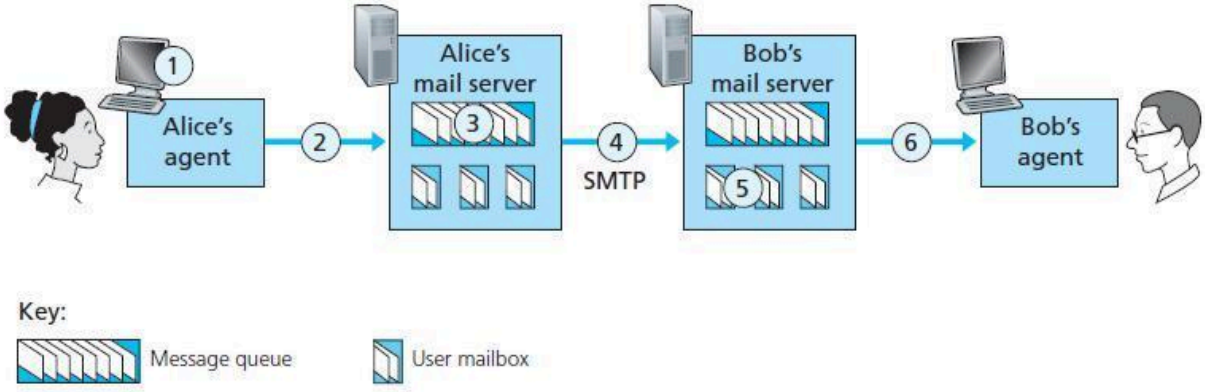


Figure 2.17 ♦ Alice sends a message to Bob

Alice wants to send Bob a simple ASCII message.

1. Alice invokes her user agent for e-mail, provides Bob's e-mail address (for example, bob@someschool.edu), composes a message, and instructs the user agent to send the message.
2. Alice's user agent sends the message to her mail server, where it is placed in a message queue.
3. The client side of SMTP, running on Alice's mail server, sees the message in the message queue. It opens a TCP connection to an SMTP server, running on Bob's mail server.
4. After some initial SMTP handshaking, the SMTP client sends Alice's message into the TCP connection.
5. At Bob's mail server, the server side of SMTP receives the message. Bob's mail server then places the message in Bob's mailbox.
6. Bob invokes his user agent to read the message at his convenience.

5.4.2 Comparison of SMTP with HTTP

1) HTTP is mainly a pull protocol. This is because
→ someone loads information on a web-server and
→ users use HTTP to pull the information from the server.

 On the other hand, SMTP is primarily a push protocol. This is because

→ the sending mail-server pushes the file to receiving mail- server.

2) SMTP requires each message to be in seven-bit ASCII format.

 If message contains binary-data, the message has to be encoded into 7-bit ASCII format.

 HTTP does not have this restriction.

3) HTTP encapsulates each object of message in its own response-message.

 SMTP places all of the message's objects into one message.

1.4.3 Mail Access Protocols

- It is not realistic to run the mail-servers on PC & laptop. This is because
  → mail-servers must be always-on and
  → mail-servers must have fixed IP addresses
- Problem: How a person can access the email using PC or laptop?
- Solution: Use mail access protocols.
- Three mail access protocols:

1) Post Office Protocol (POP)
2) Internet Mail Access Protocol (IMAP) and
3) HTTP.

5.4.3.1 POP

- POP is an extremely simple mail access protocol, defined in [RFC 1939]. POP server will listen at port 110.
- Here is how it works:

The user-agent at client's computer opens a TCP connection to the main server. POP then progresses through three phases:

1) Authorization

The user-agent sends a user name and password to authenticate the user.

2) Transaction

The user-agent retrieves messages. Also, the user-agent can

→ mark messages for deletion
→ remove deletion marks &
→ obtain mail statistics.

The user-agent issues commands, and the server responds to each command with a reply.

There are two responses:

i) +OK: used by the server to indicate that the previous command was fine.
ii) –ERR: used by the server to indicate that something is wrong.

2) Update

After user issues a quit command, the mail-server removes all messages marked for deletion.

- Disadvantage:

The user cannot manage the mails at remote mail-server. For ex: user cannot delete messages.

5.4.3.2 IMAP

- IMAP is another mail access protocol, which has more features than POP.An IMAP server will associate each message with a folder. When a message first arrives at server, the message is associated with recipient's INBOX folder. Then, the recipient can

→ move the message into a new, user-created folder
→ read the message
→ delete the message and
→ search remote folders for messages matching specific criteria.

- An IMAP server maintains user state-information across IMAP sessions.

- IMAP permits a user-agent to obtain components of messages.

For example, a user-agent can obtain just the message header of a message.

5.4.3.3 Web-Based E-Mail

- HTTPs are now used for Web-based email accessing.
- The user-agent is an ordinary Web browser.
- The user communicates with its remote-server via HTTP.
- Now, Web-based emails are provided by many companies including Google, Yahoo etc.

1.5 DNS — The Internet's Directory Service

DNS is an internet service that **translates domain-names into IP addresses.** It uses a large number of servers, organized in a hierarchical fashion and distributed around the world. No single DNS server has all of the mappings for all of the hosts in the Internet. Instead, the mappings are distributed across the DNS servers.

For ex: the domain-name ―www.google.com‖ might translate to IP address ―198.105.232.4‖.

- Because domain-names are alphabetic, they are easier to remember for human being.
- But, the Internet is really based on IP addresses (DNS Domain Name System).

1.5.1 Services Provided by DNS

- The DNS is

1) A distributed database implemented in a hierarchy of DNS servers.

2) An application-layer protocol that allows hosts to query the distributed database.

- DNS servers are often UNIX machines running the BIND software.
- The DNS protocol runs over UDP and uses port 53. (BIND Berkeley Internet Name Domain)
- DNS is used by application-layer protocols such as HTTP, SMTP, and FTP.
- Assume a browser requests the URL www.someschool.edu/index.html.
- Next, the user's host must first obtain the IP address of www.someschool.edu
- This is done as follows:

1) The same user machine runs the client-side of the DNS application.
2) The browser
   → extracts the hostname ―www.someschool.edu‖ from the URL and
   → passes the hostname to the client-side of the DNS application.
3) The client sends a query containing the hostname to a DNS server.
4) The client eventually receives a reply, which includes the IP address for the hostname.
5) After receiving the IP address, the browser can initiate a TCP connection to the HTTP server.

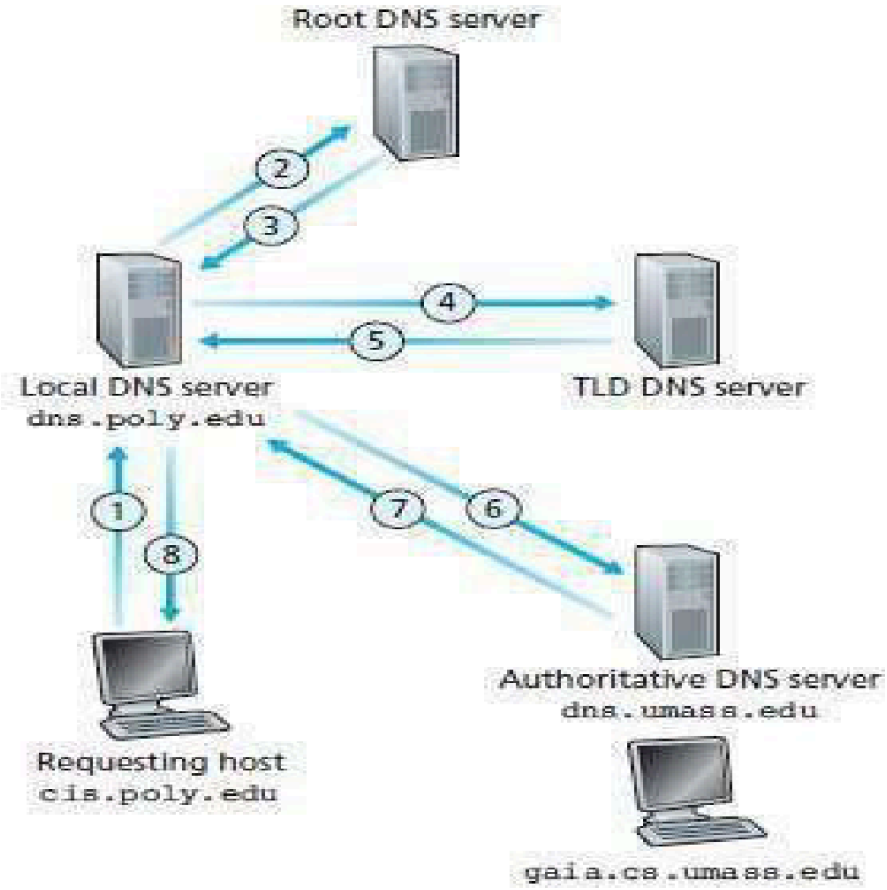


Figure 1.13: Interaction of the various DNS servers

- DNS also provides following services:

1) Host Aliasing : A host with a complicated hostname can have one or more alias names.

2) Mail Server Aliasing : For obvious reasons, it is highly desirable that e-mail addresses be mnemonic.

3) Load Distribution : DNS is also used to perform load distribution among replicated servers.

Busy sites are replicated over multiple servers & each server runs on a different system.

1.5.2 Overview of How DNS Works

- Distributed database design is more preferred over centralized design because:

1) A Single Point of Failure : If the DNS server crashes then the entire Internet will not stop.

2) Traffic Volume : A Single DNS Server cannot handle the huge global DNS traffic.

But with distributed system, the traffic is distributed and reduces overload on server.

3) Distant Centralized Database : A single DNS server cannot be ―close to‖ all the querying clients.

If we put the single D S server in Mysore,then all queries from USA must travel to the other side of the globe. This can lead to significant delays.

4) Maintenance : The single DNS server would have to keep records for all Internet hosts. This centralized database has to be updated frequently to account for every new host.

5.5.2.1 A Distributed, Hierarchical Database

There are three classes of DNS servers—root DNS servers, top-level domain (TLD) DNS servers, and authoritative DNS servers

Root DNS servers. In the Internet there are 13 root DNS servers (labeled A through M), most of which are located in North America.

Top-level domain (TLD) servers. These servers are responsible for top-level domains such as com, org, net, edu, and gov, and all of the country top-level domains such as uk, fr, ca, and jp. The company Verisign Global Registry Services maintains the TLD servers for the com top-level domain, and the company Educause maintains the TLD servers for the edu top-level domain.

Authoritative DNS servers. Every organization with publicly accessible hosts (such as Web servers and mail servers) on the Internet must provide publicly accessible DNS records that map the names of those hosts to IP addresses. An organization's authoritative DNS server houses these DNS records.

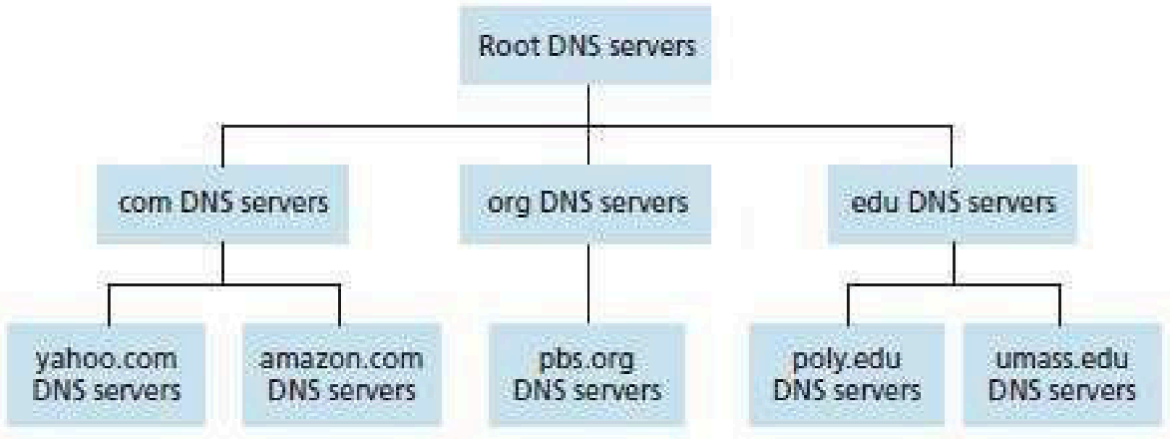


Figure 1.12: Portion of the hierarchy of DNS servers

- Suppose a client wants to determine IP address for hostname ―www.amazon.com‖ (Figure 1.12):

1) The client first contacts one of the root servers, which returns IP addresses for TLD servers

2) Then, the client contacts one of these TLD servers.

 The TLD server returns the IP address of an authoritative-server for ―amazon.com‖.

3) Finally, the client contacts one of the authoritative-servers for amazon.com.

 The authoritative-server returns the IP address for the hostname ―www.amazon.com‖.

5.5.2.1.1 Recursive Queries & Iterative Queries

- The example shown in Figure 1.13 makes use of both recursive queries and iterative queries.
- The query 1 sent from cis.poly.edu to dns.poly.edu is a recursive query. This is because

→ the query asks dns.poly.edu to obtain the mapping on its behalf.

- But the subsequent three queries 2, 4 and 6 are iterative. This is because

→ all replies are directly returned to dns.poly.edu.

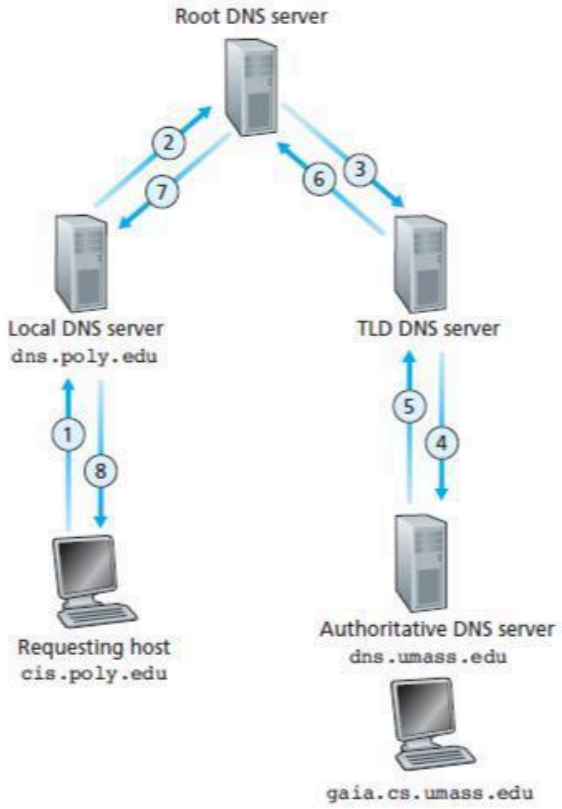


Figure 2.22 ♦ Recursive queries in DNS

5.5.3 DNS Records & Messages

- The DNS server stores resource-records (RRs).
- RRs provide hostname-to-IP address mappings.
- Each DNS reply message carries one or more resource-records.
- A resource-record is a 4-tuple that contains the following fields: (Name, Value, Type, TTL)
- TTL (time to live) determines when a resource should be removed from a cache.
- The meaning of Name and Value depend on Type:

1) If Type=A, then Name is a hostname and Value is the IP address for the hostname.
Thus, a Type A record provides the standard hostname-to-IP address mapping. For ex:

(relay1.bar.foo.com, 145.37.93.126, A)

2) If Type=NS, then
i) Name is a domain (such as foo.com) and
ii) Value is the hostname of an authoritative DNS server.

This record is used to route DNS queries further along in the query chain.

3) If Type=CNAME, then Value is a canonical hostname for the alias hostname Name.
This record can provide querying hosts the canonical name for a hostname. For ex: (foo.com, relay1.bar.foo.com, CNAME) is a CNAME record.

4) If Type=MX, Value is the canonical name of a mail-server that has an alias hostname Name. MX records allow the hostnames of mail-servers to have simple aliases.

For ex: (foo.com, mail.bar.foo.com, MX) is an MX record.

1.5.3.1 DNS Messages

- Two types of DNS messages: 1) query and 2) reply.
- Both query and reply messages have the same format.

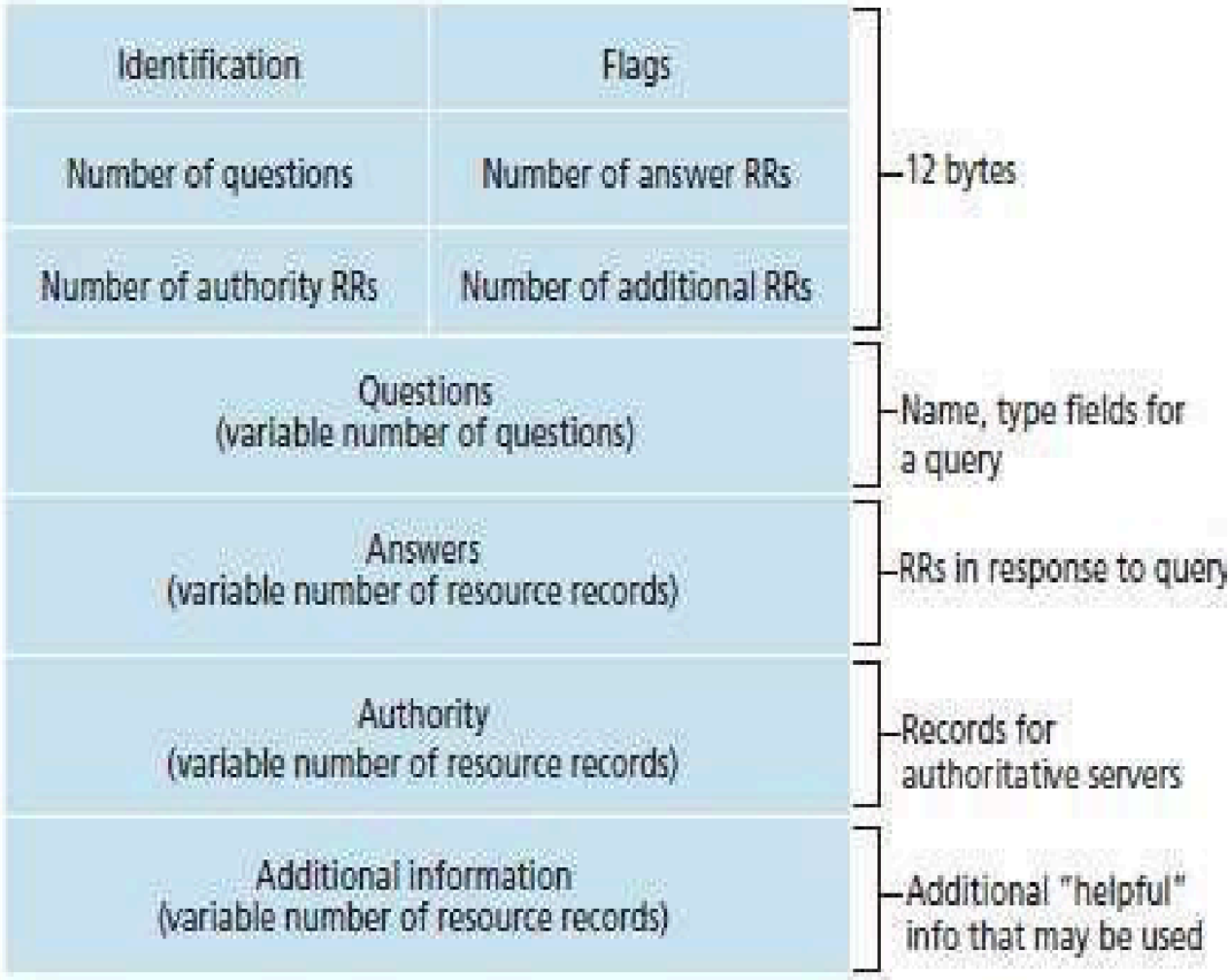


Figure 1.14: DNS message format

- The various fields in a DNS message are as follows (Figure 1.14):

1) Header Section

- The first 12 bytes is the header-section.
- This section has following fields:

i) Identification

This field identifies the query.

This identifier is copied into the reply message to a query.

This identifier allows the client to match received replies with sent queries.

ii) Flag

This field has following 3 flag-bits:

a) Query/Reply
¤ This flag-bit indicates whether the message is a query (0) or a reply (1). **b) Authoritative** flag-bit is set in a reply message when a DNS server is an authoritative-server.
c) Recursion Desired
¤ This flag-bit is set when a client desires that the DNS server perform recursion.

iii) Four Number-of-Fields

These fields indicate the no. of occurrences of 4 types of data sections that follow the header.

2) Question Section

- This section contains information about the query that is being made.
- This section has following fields:

i) Name : This field contains the domain-name that is being queried.

ii) Type : This field indicates the type of question being asked about the domain-name.

3) Answer Section

- This section contains a reply from a DNS server.
- This section contains the resource-records for the name that was originally queried.
- A reply can return multiple RRs in the answer, since a hostname can have multiple IP addresses.

4) Authority Section

- This section contains records of other authoritative-servers.
- This section contains other helpful records.

QUESTION BANK

1. Explain briefly about the Network Application architecture with neat diagrams (hint client server and P2P architecture)
2. With block diagram explain how application process communicates between client and server through a socket. Or Explain the interface between process and computer network
3. Explain the transport services available to application layer.
4. With diagram explain working of web and http
5. Compare Non persistent and persistent connections for transfer of 2 web pages with neat diagrams.
6. With general format explain http request and response messages
7. Write Short Notes on user server interaction and cookies
8. What is web caching? Explain with neat diagram.
9. Write short notes on FTP
10. Explain about Electronic mail and SMTP.
11. Compare SMTP, FTP and HTTP
12. Mention different MAP. Write Short notes on each of it.
13. Explain about DNS services and recursive query mapping.
14. Explain about the general format of DNS messages.
15. Explain about P2P file distribution and application (bitTorrent)
16. Explain about Distributed hash table
17. With flow diagram for client server application describe the Socket programing using TCP and UDP with code.