



6 : Application Networking Services

IT4506 – Computer Networks

Level II - Semester 4

Overview

- In this topic we discuss the protocols used in the application layer.

Intended Learning Outcomes

- At the end of this lesson, you will be able to;
 - Discuss the protocols in the application layer.
 - Describe the Domain Name Systems.
 - Explain the architecture and services of electronic mails including the SMTP and IMAP protocols.
 - Summarise the architecture of the World Wide Web.

List of sub topics

6. Application Networking Services

6.1 Domain Name System

6.1.1 The DNS Name Space

6.1.2 Domain Resource Records

6.1.3 Name Servers

6.2 Electronic Mail

6.2.1 Architecture and Services

6.2.2 The User Agent

6.2.3 SMTP and Extensions

6.2.4 IMAP

6.3 World Wide Web

6.3.1 Architectural Overview

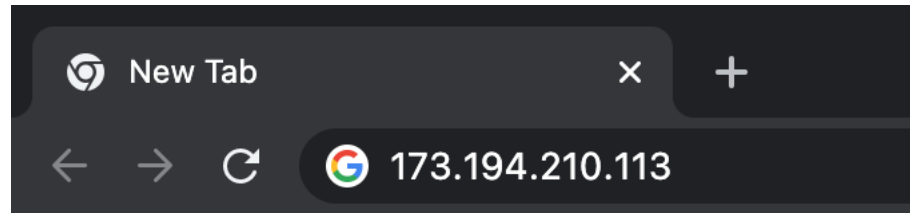
The Application Layer

- Layers below the application layer provide the transport services.
- Application layer helps the users to do the real work.
- There are number of protocols which help the applications to work. Following are some of them,
 - DNS - Domain Name System
 - SMTP - Simple Mail Transfer Protocol
 - IMAP - Internet Message Access Protocol
 - WWW - World Wide Web

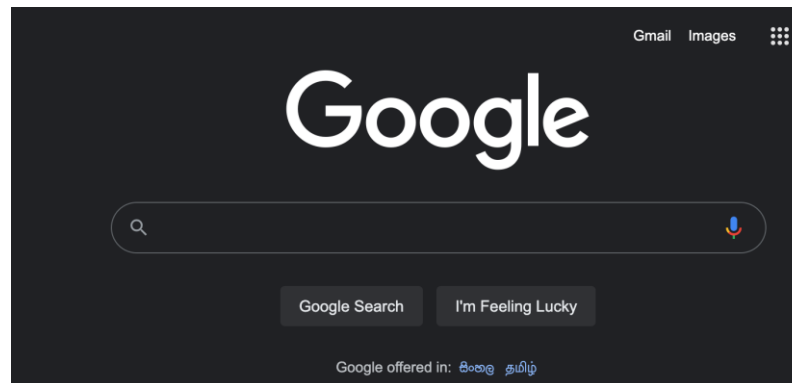
DNS - Domain Name System

- Type the following IP address on the address bar of the web browser and press enter.

173.194.210.113



- It will load the home page of Google.



DNS - Domain Name System...(2)

- The applications, services or resources such as web pages, mailboxes are stored in computers.
- Programs use the network (IP) address to communicate with the computers through the network.
- But it is not practical to use the IP address to access these resources or applications.
 - It is difficult to remember the IP addresses.
 - If the resource or the service is moved to some other computer, every one should be informed with the new IP address of the new computer.
- Because of these issues, high-level, readable names were introduced in order to decouple machine names from machine addresses.
 - As in the previous example the web site is known as google.com not with the IP address 173.194.210.113.

DNS - Domain Name System...(3)

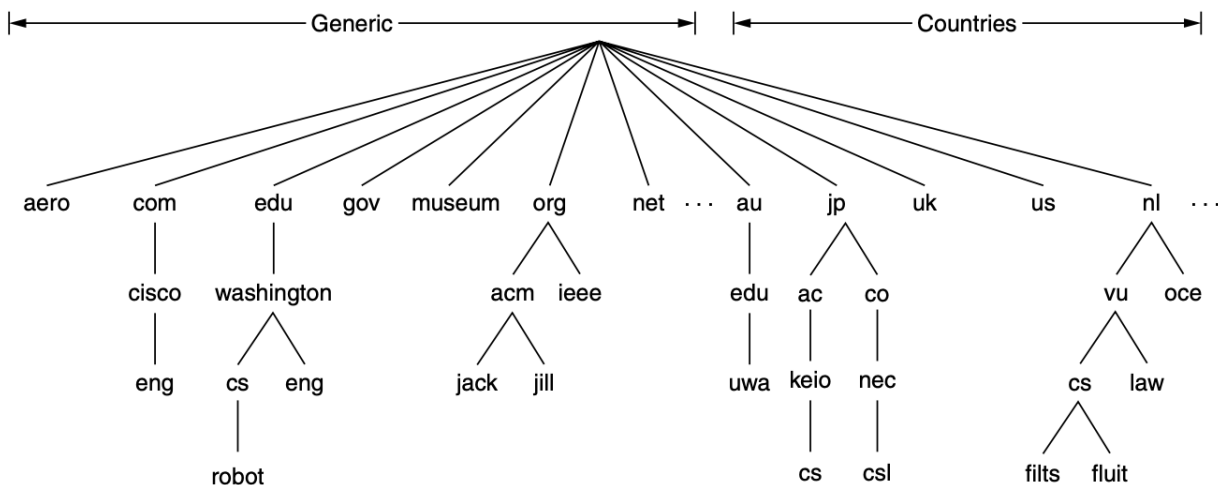
- The high-level, readable names can only be understood by the humans. Computers understand the numbers.
- Therefore there has to be a mechanism to map the names to IP addresses.
 - Initially there was a file (host.txt) which list the name and their IP addresses.
 - When the number of computers connected to the internet increases the size of the become too large to handle.
- As a solution for this problem, DNS (Domain Name System) was introduced in 1983.

DNS - Domain Name System...(4)

- DNS is a hierarchical, domain based naming scheme.
- It uses a distributed database system for implementing the naming scheme.
- Primary use is to map the host name with IP addresses.
- To map a name to IP address,
 - Application program calls a library procedure called the **resolver** passing it the name as a parameter.
 - The resolver sends a query containing the name to a local DNS server.
 - It will look up the name and returns a response containing the IP address to the resolver.
 - Resolver returns it to the caller.
 - The query and response messages are sent as UDP packets.

DNS Name Space

- The naming hierarchy of the internet is maintained by the **ICANN** (Internet Corporation for Assigned Names and Numbers).
- The internet has divided into 250 top level domains.
- Each domain is partitioned into subdomains.
- All these domains can be represented by a tree.



Ref 1: pg 613

DNS Name Space...(2)

- Top level domains has two types
 - Generic - include original domains from the 1980s and domains introduced via applications to ICANN.
 - Countries - one entry for every country.
- Obtaining a second level domain (name-of-company.com)
 - The top-level domains are run by **registrars** appointed by ICANN.
 - Need to contact a corresponding registrar (eg: .com) and check whether the name is available and not somebody else's trademark.
 - If there are no problems, the requester pays the registrar a small annual fee and gets the name.

DNS Name Space...(3)

- Following are some of the generic top level domains.

Domain	Intended Use
com	Commercial
edu	Educational Institutions
gov	Government
net	Network Providers
org	Non profit organisations
biz	Businesses
info	Informational

- Cybersquatting - registering a domain only to turn around and sell it off to an interested party at a much higher price.

DNS Name Space...(4)

- Each domain is named by the path upward from it to the (unnamed) root.
- The components are separated by periods.
- Domain names are case-insensitive. (com, Com, and COM has the same meaning)

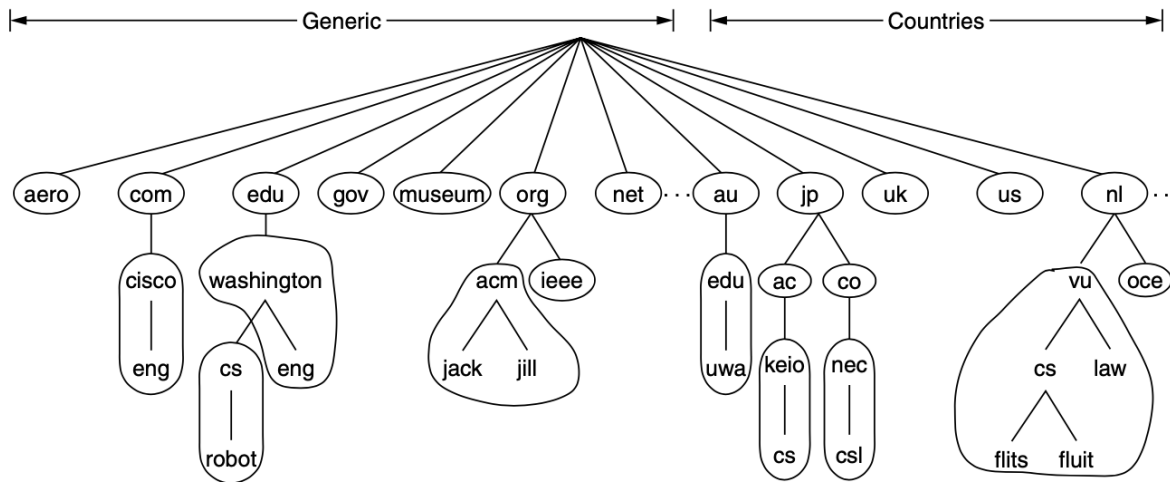
Domain Resource Records

- Resource records are the DNS database.
- Resource record has five tuples
 - Domain name - is the domain which this record applies.
 - Time to live - field gives an indication of how stable the record is.
 - Class - *IN* is used for internet information.
 - Type and Value,

Type	Meaning	Value
SOA	Start of authority	Parameters for this zone
A	IPv4 address of a host	32-Bit integer
AAAA	IPv6 address of a host	128-Bit integer
MX	Mail exchange	Priority, domain willing to accept email
NS	Name server	Name of a server for this domain
CNAME	Canonical name	Domain name
PTR	Pointer	Alias for an IP address
SPF	Sender policy framework	Text encoding of mail sending policy
SRV	Service	Host that provides it
TXT	Text	Descriptive ASCII text

Name Servers

- In theory, single name server could contain the entire DNS database and respond to all queries about it.
- In practice, this server would be so overloaded as to be useless and if it went down, the entire Internet would be crippled.
- DNS name space is divided into non-overlapping **zones**.

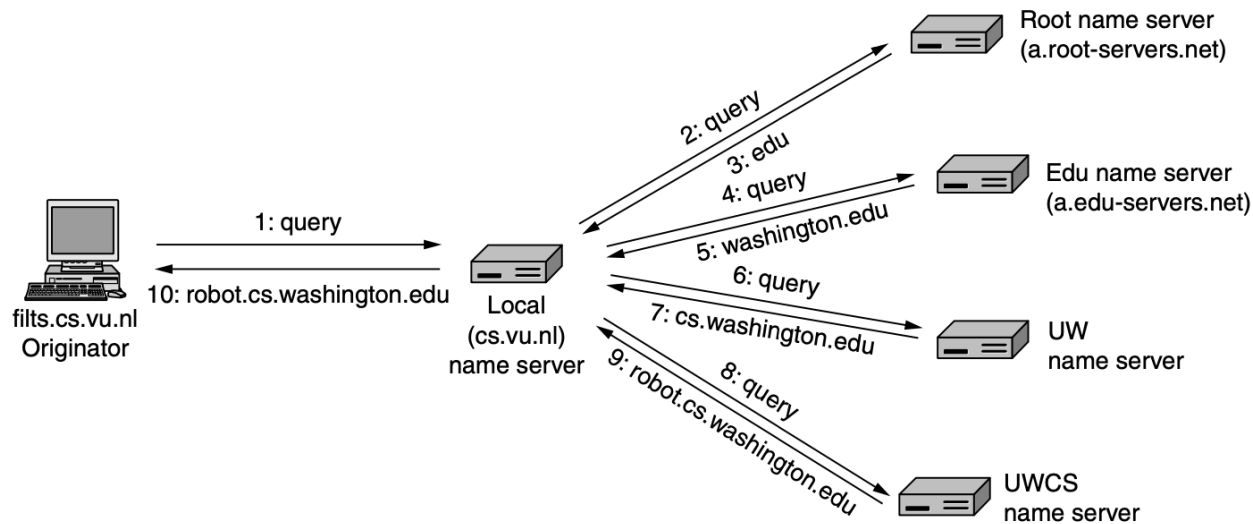


Name Servers...(2)

- Each zone is associated with one or more Name Servers.
 - Primary Name Server gets information from a file on its disk.
 - One or more secondary name servers, get their information from the primary name server.
 - Some of the secondary name servers will locate outside the zone to improve reliability.
- The process of looking up a name and finding an address is called **name resolution**.
- When a resolver has a query about a domain name, it passes the query to a local name server.
- If there is no cached information about the domain available locally, the name server begins a remote query.

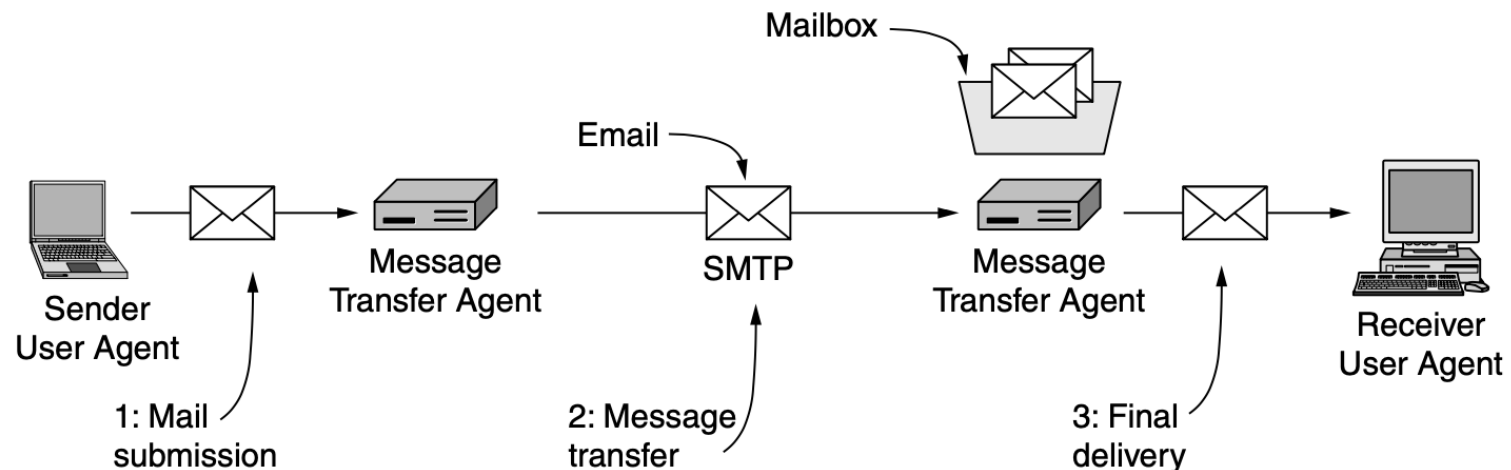
Name Servers...(3)

- The following diagram shows the *flits.cs.vu.nl* searching the IP address of *robot.cs.washington.edu* with ten steps.



Electronic Mail: Architecture and Services

- User Agent
 - Allow people to read and send email.
 - This is a graphical interface based or text based interface which allows the users to display incoming mails, compose mails, reply to the mails, filter or search the mails and discard the mails.



Electronic Mail: Architecture and Services...(2)

- Message Transfer Agents (mail servers)
 - Move the messages from the source to the destination (use SMTP (Simple Mail Transfer Protocol)).
 - They are typically system processes which run in the background on mail server machines and are intended to be always available.
 - It has mailing lists which an identical copy of a message is delivered to everyone on a list of email addresses.
 - Advanced features
 - carbon copies
 - blind carbon copies
 - high-priority email
 - encrypted email
 - alternative recipients

Electronic Mail: Architecture and Services...(3)

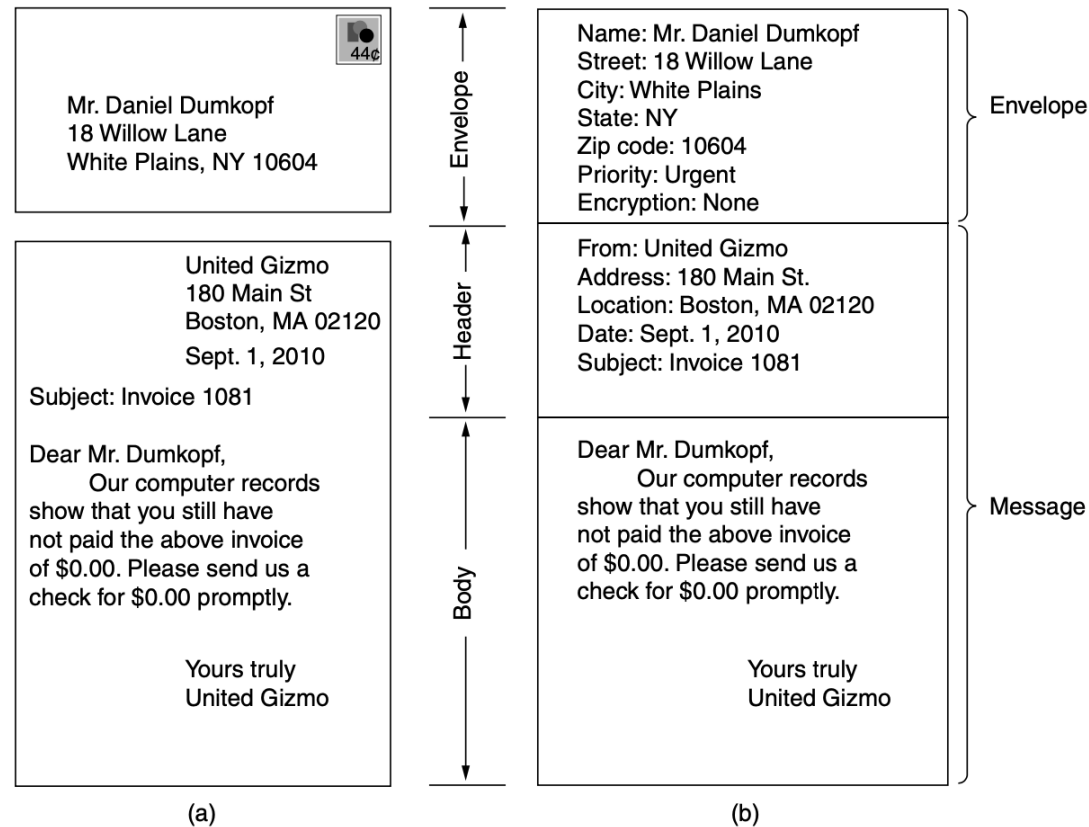
- Mailboxes
 - store the email that is received for a user.
 - Maintained by the mail servers.
 - User agents present users with a view of the contents of their mailboxes.

Electronic Mail: Architecture and Services...(4)

- Message format
 - Envelop - encapsulates the message. It contains all the information needed for transporting the message.
 - Destination address
 - Priority
 - Security level
 - Header - contains control information for the user agents.
 - Body - it is for the user to create the message (email).

Electronic Mail: Architecture and Services...(5)

- Message format



(a) Paper mail. (b) Electronic mail.

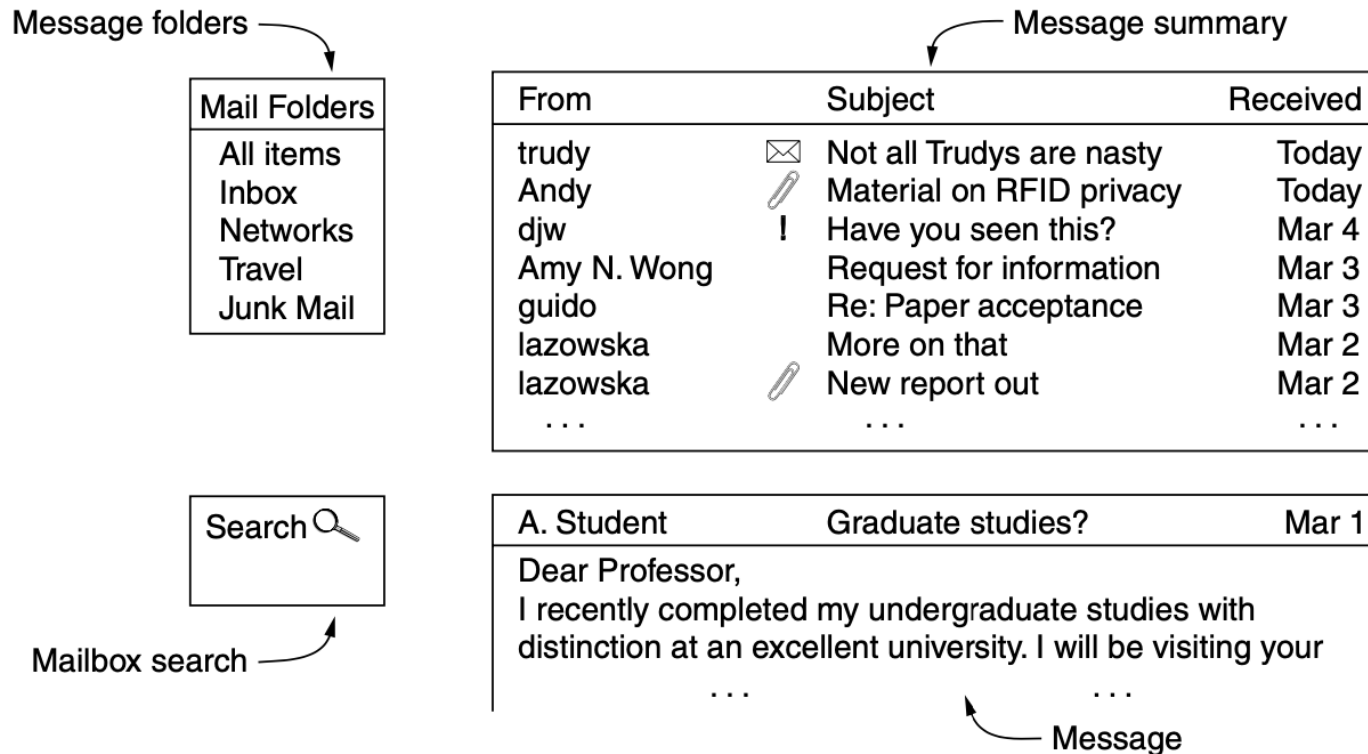
Electronic Mail: User Agents

- User agent (email reader) is a program that accepts a variety of commands for composing, receiving, replying to messages, and manipulating mailboxes.
- Examples
 - Google gmail
 - Microsoft Outlook
 - Mozilla Thunderbird
 - Apple Mail



Electronic Mail: User Agents...(2)

- Elements of the user agent interface



Electronic Mail: User Agents - Features

- User Agents
 - Has menu or icon driven graphical interface which is compatible with mouse or touch input.
 - Provide a summary of the messages in the user's mailbox.
 - The summary include icons which shows whether the mail include attachments, or whether the mail is unread or important.
 - Can save mails in different folders.
- Message disposition - After a message has been read, the user can decide what to do with it.
 - Deleting the message
 - Sending a reply
 - Forwarding the message to another user
 - Keeping the message for later reference

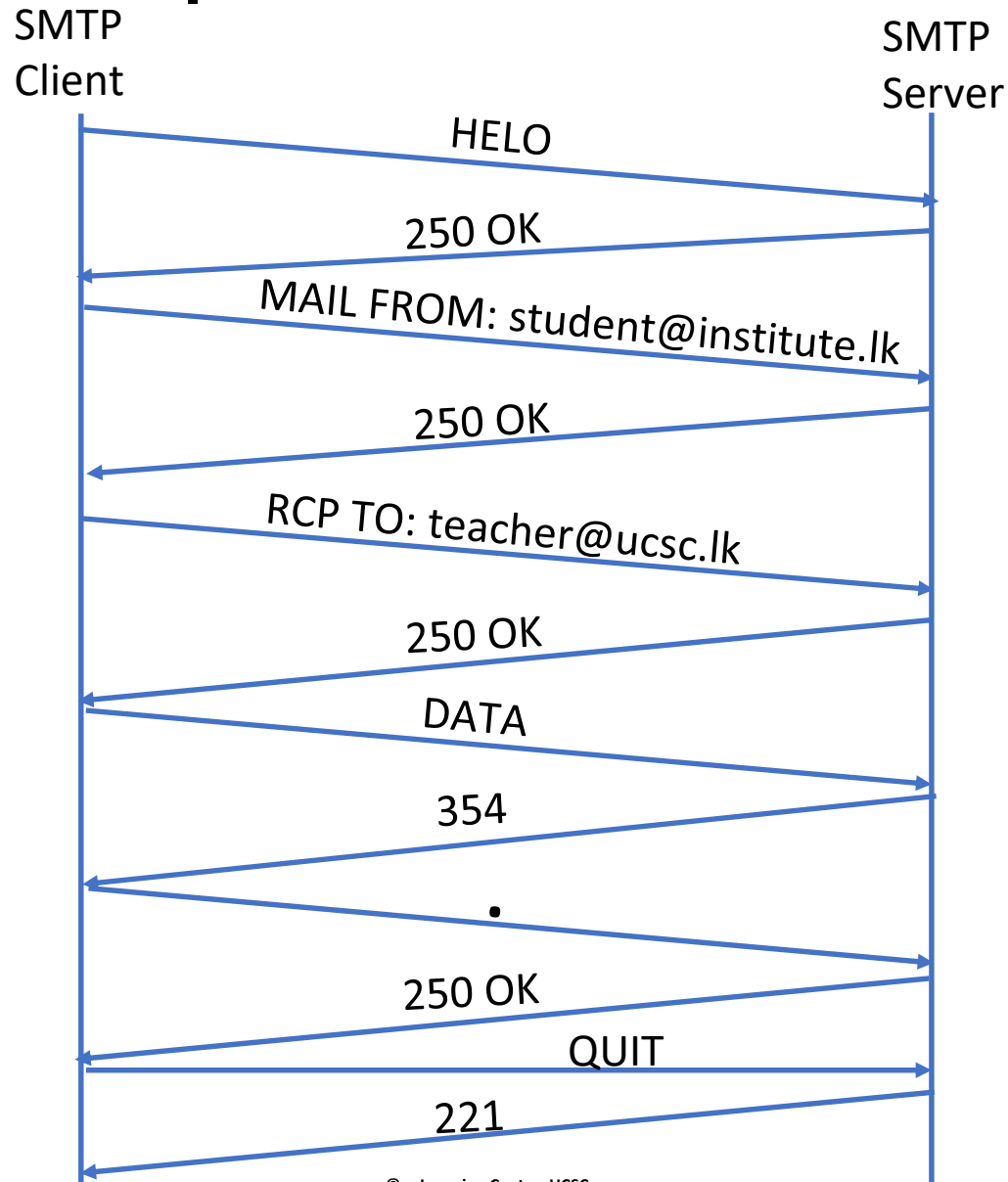
Electronic Mail: User Agents - Features...(2)

- Spam
 - ISPs and companies runs applications to label the mails as important or spam so that the user agent can file it in the corresponding mailbox.
- Auto responders
 - One response is forwarded to the mails received.
- Signature block

SMTP (Simple Mail Transfer Protocol)

- SMTP is a simple ASCII protocol.
- SMTP uses 25 as the port number.
- Client who needs to send an email need to establish a TCP connection with the server running SMTP server.
- Server accepts incoming connections, subject to some security checks, and accepts messages for delivery.
 - If a message cannot be delivered, an error report containing the first part of the undeliverable message is returned to the sender.
- After establishing the TCP connection to port 25, the sending machine (client), waits for the receiving machine (server), to talk first.
- The server starts by sending a line of text giving its identity and telling whether it is prepared to receive mail.
- If it is not, the client releases the connection and tries again later.

SMTP (Simple Mail Transfer Protocol)...(2)



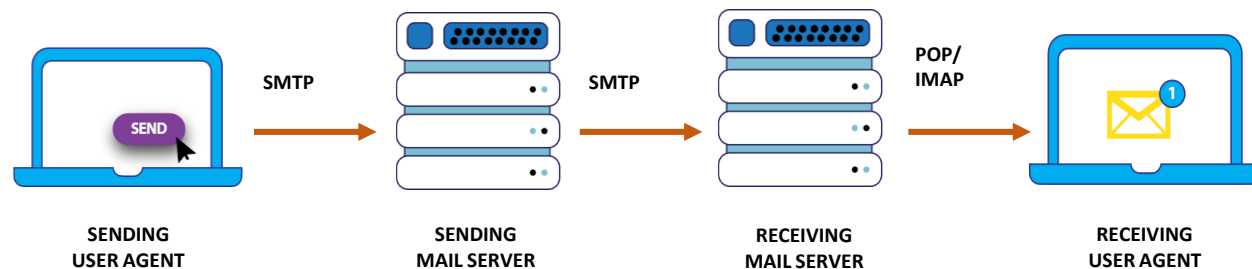
SMTP (Simple Mail Transfer Protocol)...(3)

- In the example only one recipient is used in *RCPT* command.
- But it allow multiple recipients and each one has to be individually acknowledged or rejected.
- The SMTP with extensions is called ESMTP (Extended SMTP).
 - In ESMTP, *EHLO* message is send instead of *HELO*.
 - If the server reject *EHLO* it will use SMTP.
 - Some extensions,

Keyword	Description
AUTH	Client authentication
BINARYMIME	Server accepts binary messages
CHUNKING	Server accepts large messages in chunks
SIZE	Check message size before trying to send
ST ARTTLS	Switch to secure transport
UTF8SMTP	Internationalized addresses

SMTP (Simple Mail Transfer Protocol)...(4)

- Mail submission
 - SMTP is normally used for mail submission with the AUTH extension.
 - This extension lets the server check the credentials of the client to confirm that the server should be providing mail service.
- Mail transfer
 - Once the sending mail transfer agent receives a message from the user agent, it will deliver it to the receiving mail transfer agent using SMTP.



IMAP (Internet Message Access Protocol)

- IMAP server listens to port 143.
- The client connects to the server and begins to issue commands.
 - With the commands the client can perform many tasks including
 - Fetch messages
 - Mark messages with flags for later deletion
 - Organize messages into folders

IMAP (Internet Message Access Protocol)...(2)

ICMP Command	Description
CAPABILITY	List server capabilities
STARTTLS	Start secure transport
LOGIN	Log on to server
AUTHENTICATE	Log on with other method
SELECT	Select a folder
EXAMINE	Select a read-only folder
CREATE	Create a folder
DELETE	Delete a folder
RENAME	Rename a folder
SUBSCRIBE	Add folder to active set
UNSUBSCRIBE	Remove folder from active set
LIST	List the available folders
STATUS	Get the status of a folder
APPEND	Add a message to a folder
CHECK	Get a checkpoint of a folder
FETCH	Get messages from a folder
SEARCH	Find messages in a folder
STORE	Alter message flags
COPY	Make a copy of a message in a folder
EXPUNGE	Remove messages flagged for deletion
CLOSE	Remove flagged messages and close folder
LOGOUT	Log out and close connection

World Wide Web

- From the users' point of view, the Web consists of a vast, worldwide collection of content in the form of Web pages.
- Each page may contain links to other pages anywhere in the world.
- Hypertext is the idea of having one page point to another.
- Some parts of the page are associated with links to other pages. A piece of text, icon, image, and so on associated with another page is called a **hyperlink**.
- Web pages are views by the applications known as **browsers**.

- Chrome

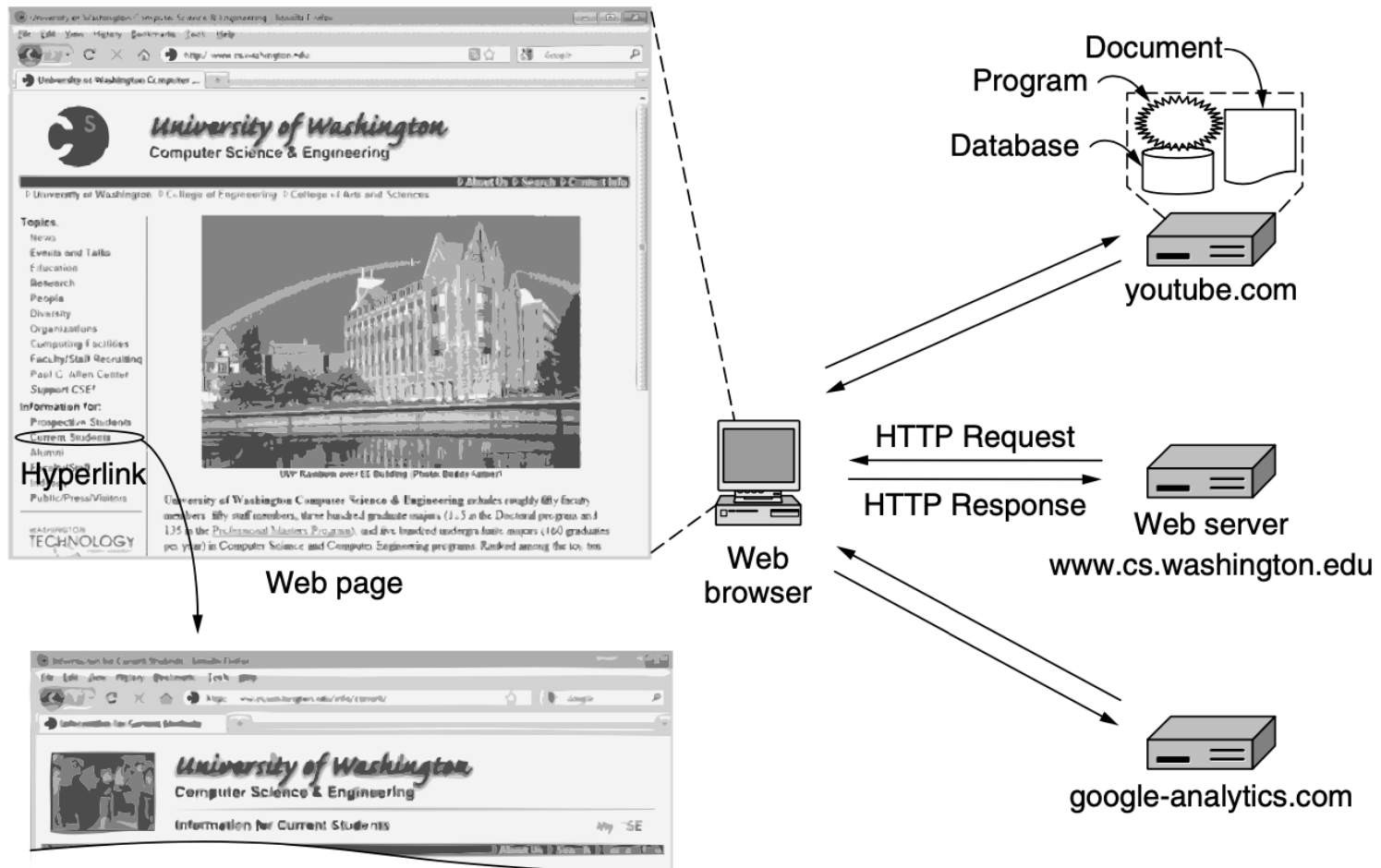
- Firefox

- Safari

- Microsoft Edge, are some examples for browsers.



World Wide Web: Architecture



World Wide Web: Architecture...(2)

- The browser displays the web page on the clients machine.
- Each page is fetched by sending a request to one or more servers, which respond with the contents of the page.
- HTTP (HyperText Transfer Protocol) is used to fetch the data from the servers by simple request and response model.
- These pages are in two types
 - Static pages - the page is same every time it is displayed.
 - Dynamic pages - page is generated on demand by a program or contains a program.
- The content from different servers is integrated for display by the browser.
 - This content can be text, graphics, videos and so on.

World Wide Web: Client side

- Each page in the web is assigned with an URL (Uniform Resource Locator) which serves as the page's worldwide name.
 - URL has three parts
 - Protocol (http)
 - DNS name (www.bit.lk)
 - Path uniquely indicating the specific page (index.html)

`http://www.bit.lk/index.html`

World Wide Web: Client side...(2)

- When user clicks a link browser carries out the following series of steps.
 - Browser determines the URL.
 - The browser asks DNS for the IP address of the server
 - DNS replies with the ip address.
 - The browser makes a TCP connection to the ip address on port 80 (HTTP protocol).
 - It sends over an HTTP request asking for the page /index.html.
 - The www.bit.lk server sends the page as an HTTP response, for example, by sending the file /index.html.
 - If the page includes URLs that are needed for display, the browser fetches the other URLs using the same process. In this case, the URLs include multiple embedded images also fetched from www.bit.lk, an embedded video from youtube.com, and a script from google-analytics.com.
 - The browser displays the page /index.html
 - The TCP connections are released if there are no other requests to the same servers for a short period

World Wide Web: Client side...(3)

- Common URL schemes

Name	Used for	Example	Description
http	Hypertext (HTML)	http://www.ee.uwa.edu/~rob/	Web server and client communicate using HTTP (Hyper Text Transfer Protocol)
https	Hypertext with security	https://www.bank.com/accounts/	Secure version of HTTP
ftp	FTP	ftp://ftp.cs.vu.nl/pub/minix/README	Used to access files
file	Local file	file:///usr/suzanne/prog.c	Access a local file as a Web page by using the file protocol
mailto	Sending email	mailto:JohnUser@acm.org	Allows users to send email from a Web browser.
rtsp	Streaming media	rtsp://youtube.com/montypython.mpg	Establishing streaming media sessions and audio and video calls.
sip	Multimedia calls	sip:eve@adversary.com	
about	Browser information	about:plugins	Provides information about the browser.

World Wide Web: Client side...(4)

- HTML pages contain rich content elements such as MPEG format, PDF documents, JPEG images, MP3 and so on.
- Rather than building the interpreters to the browser, a simple solution is used.
- When server returns a page, it also returns some additional information about the page.
- This information includes the MIME (Multipurpose Internet Mail Extensions) type of the page.
- Based on the MIME types, browser determine how to display the page. It uses,
 - Plug-ins
 - Helper applications

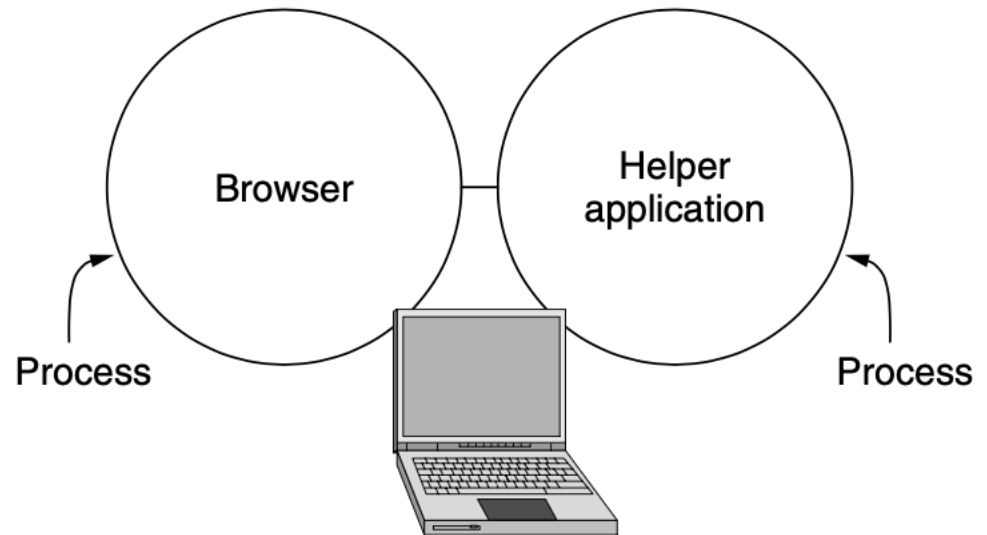
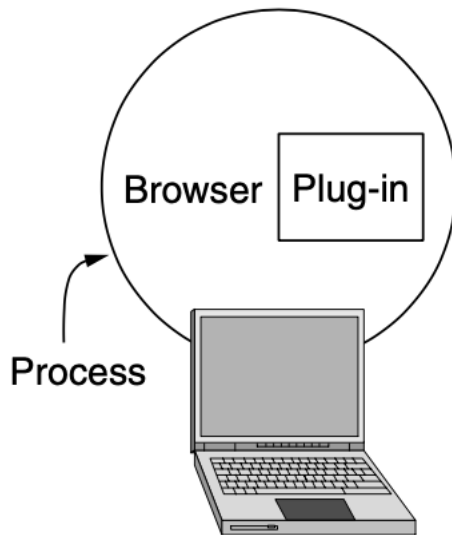
World Wide Web: Client side...(5)

- MIME types

Type	Example subtypes	Description
text	plain, html, xml, css	Text in various formats
image	gif, jpeg, tiff	Pictures
audio	basic, mpeg, mp4	Sounds
video	mpeg, mp4, quicktime	Movies
model	vrml	3D model
application	octet-stream, pdf, javascript, zip	Data produced by applications
message	http, rfc822	Encapsulated message
multipart	mixed, alternative, parallel, digest	Combination of multiple types

World Wide Web: Client side...(6)

- Plug-ins and helper applications



World Wide Web: Server side

- Actions performed by the server.
 - Accept a TCP connection from a client (a browser).
 - Get the path to the page, which is the name of the file requested.
 - Get the file (from disk).
 - Send the contents of the file to the client.
 - Release the TCP connection.

World Wide Web: Cookies

- The cookie is a small, named string that the server can associate with a browser.
- Cookies are just strings, not executable programs.
- A cookie may contain up to five fields,
 - Domain
 - Path
 - Content
 - Expires
 - Secure

Domain	Path	Content	Expires	Secure
toms-casino.com	/	CustomerID=297793521	15-10-10 17:00	Yes
jills-store.com	/	Cart=1-00501;1-07031;2-13721	11-1-11 14:22	No
aportal.com	/	Prefs=Stk:CSCO+ORCL;Spt:Jets	31-12-20 23:59	No
sneaky.com	/	UserID=4627239101	31-12-19 23:59	No

World Wide Web: Cookies...(2)

- Before a browser sends a request for a page to some Web site, it checks its cookie directory to see if any cookies there were placed by the domain the request is going to.
- If so, all the cookies placed by that domain, and only that domain, are included in the request message.
- When the server gets them, it can interpret them any way it wants to.
 - It can use to
 - Identify the customer
 - Store details about the shopping cart
 - Web tracking and so on.

References

- Ref 01. Computer Networks by Andrew Tannenbaum, 5th edition, Pearson