COMPUTER NETWORK

B.TECH CSE

3rd Year – 1st Sem

UNIT – V

APPLICATION LAYER

DEPARTMENT OF CSE

VIGNAN INSTITUTE OF TECHNOLOGY & SCIENCE

DESHMUKHI

Application Layer

The Application Layer, residing at the top of the OSI model, serves as a vital interface between end-user applications and the underlying network infrastructure. It encompasses protocols and standards facilitating communication among applications, such as HTTP, FTP, SMTP, and DNS, ensuring seamless data exchange. Handling data formatting and abstraction of network complexities, this layer enables developers to focus on application functionality. It encapsulates data for transmission and provides mechanisms for security, encryption, and authentication, ensuring secure communication. Examples of applications operating at this layer include web browsers, email clients, and file transfer utilities. By fostering interoperability and enabling end-to-end communication, the Application Layer plays a crucial role in facilitating efficient network services for users.

The Application Layer is topmost layer in the **Open System Interconnection** (OSI) model.

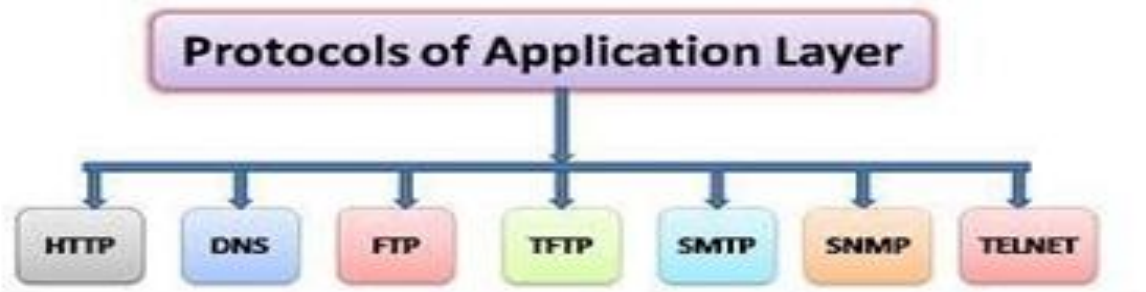
The application layer transmits the data in the form of a user-readable format. It provides many services to the user. It transfers data to the presentation layer. Furthermore, it either provides services to the presentation layer or takes services from the presentation layer.

- ✓ The application layer programs are based on client and servers.

The **application Layer**:

- ✓ determines the communication partner to whom data will be transmitted.
- ✓ specifies the availability of resources, i.e., it checks whether adequate network resources are available or not.
- ✓ delivers protocols that are accountable for creating seamless transmission between applications.
- ✓ serves as an interface between user applications and the network.
- ✓ delivers directory services, which means it permits access to any sort of data from a distributed database.
- ✓ delivers several facilities to the users for multiple email forwarding and storage facilities.
- ✓ lets users log into a remote host and access any type of application.
- ✓ provides file transfer access and management.
- ✓ communicates with the operating system and guarantees that data is saved properly.
- ✓ enables users to communicate with other software applications.

Protocols of the application layer



- ✓ ***SMTP:*** SMTP is a TCP/IP protocol used to organize email.
- ✓ Data is sent from one email address to another. SMTP is accountable for the transmission of email messages over the Internet. SMTP is a valid protocol for ensuring the delivery of email messages and also provides security for email transmission by supporting authentication mechanisms.

- ✓ ***HTTP:*** HTTP allows users to access Internet data.
- ✓ It is accountable for the conversation between the client and the web server. HTTP is a user requests data, the browser transmits an HTTP request to a server hosting the data. The server replies with an HTTP response, which holds the requested data or an error notification if the data is not found or cannot be accessed.

- ✓ ***FTP:*** FTP is used to send files between server and client using the internet.
- ✓ ETP is a client-server model, where the client requests a file, and the server responds with the requested file. It uses TCP to share data as TCP delivers error-free transmission of data.

- ✓ ***TFTP:*** TFTP is a User Datagram Protocol (UDP) based protocol, which means it is unreliable and connectionless.
- ✓ It transmits all commands and data over a single UDP port. It is used when a lightweight and fast file transfer protocol is required. It is uncomplicated to use and configure.

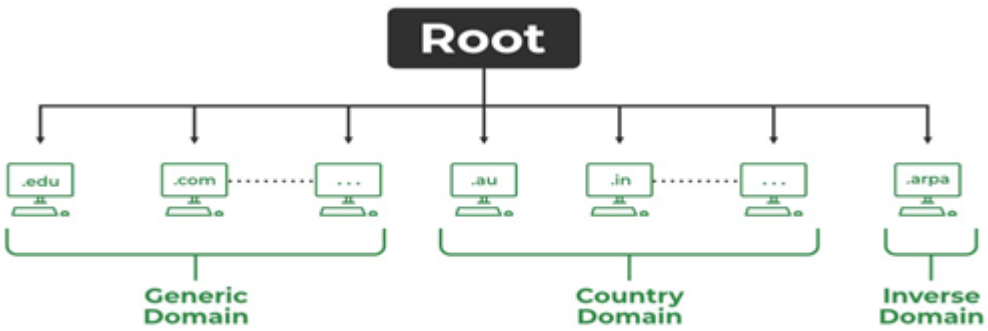
- ✓ ***DNS:*** DNS translates human-readable domain names into IP addresses so that web browsers can comprehend what a user desires to access on the Internet.

- ✓ ***SNMP:*** SNMP used for managing and monitoring network devices and systems.
- ✓ Using this protocol, network administrators gather data about network performance, identify and troubleshoot problems, and remotely configure network tools.

DNS—THE DOMAIN NAME SYSTEM

Domain Name System (DNS) is a hostname for **IP address** translation service. DNS is a distributed database implemented in a hierarchy of name servers.

- ✓ It is an application layer protocol for message exchange between clients and servers. It is required for the functioning of the Internet. Every **host** is identified by the **IP address** but remembering numbers is very difficult for people also the IP addresses are not static therefore a mapping is required to change the domain name to the IP address.
- ✓ So DNS is used to convert the domain name of the websites to their numerical IP address.



Kinds of Domain

i. **Generic domains:** .com(commercial),

- ✓ .edu(educational), .mil(military), .org(nonprofit organization), .net(similar to commercial) all these are generic domains.

ii. **Country domain:** .in (India) .us .uk

iii. **iii. Inverse domain:** if we want to know what is the domain name of the website.

- ✓ IP to domain name mapping.

Generic top-level domain

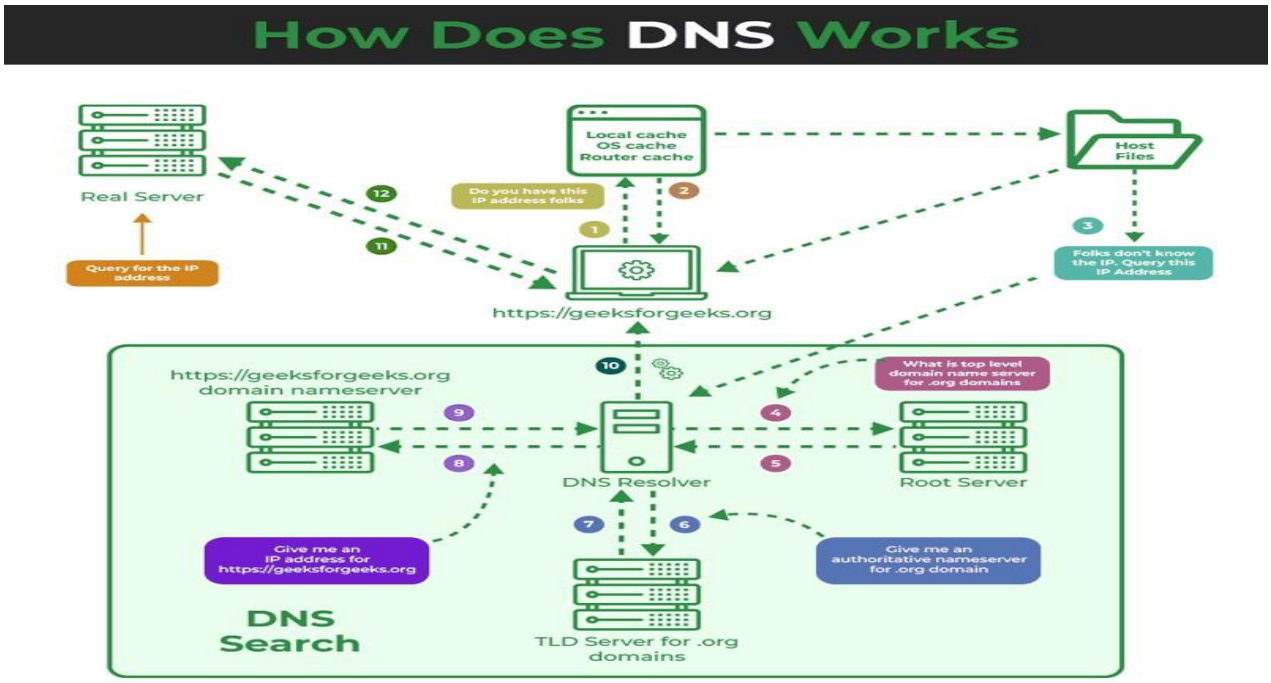
Domain	Intended use	Start date	Restricted?
com	Commercial	1985	No
edu	Educational institutions	1985	Yes
gov	Government	1985	Yes
int	International organizations	1988	Yes
mil	Military	1985	Yes
net	Network providers	1985	No
org	Non-profit organizations	1985	No
aero	Air transport	2001	Yes
biz	Businesses	2001	No
coop	Cooperatives	2001	Yes
info	Informational	2002	No
museum	Museums	2002	Yes
name	People	2002	No
pro	Professionals	2002	Yes
cat	Catalan	2005	Yes
jobs	Employment	2005	Yes
mobi	Mobile devices	2005	Yes
tel	Contact details	2005	Yes
travel	Travel industry	2005	Yes
xxx	Sex industry	2010	No

Figure 7-2. Generic top-level domains.

The principal DNS resource record types

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

Figure 7-3. The principal DNS resource record types.

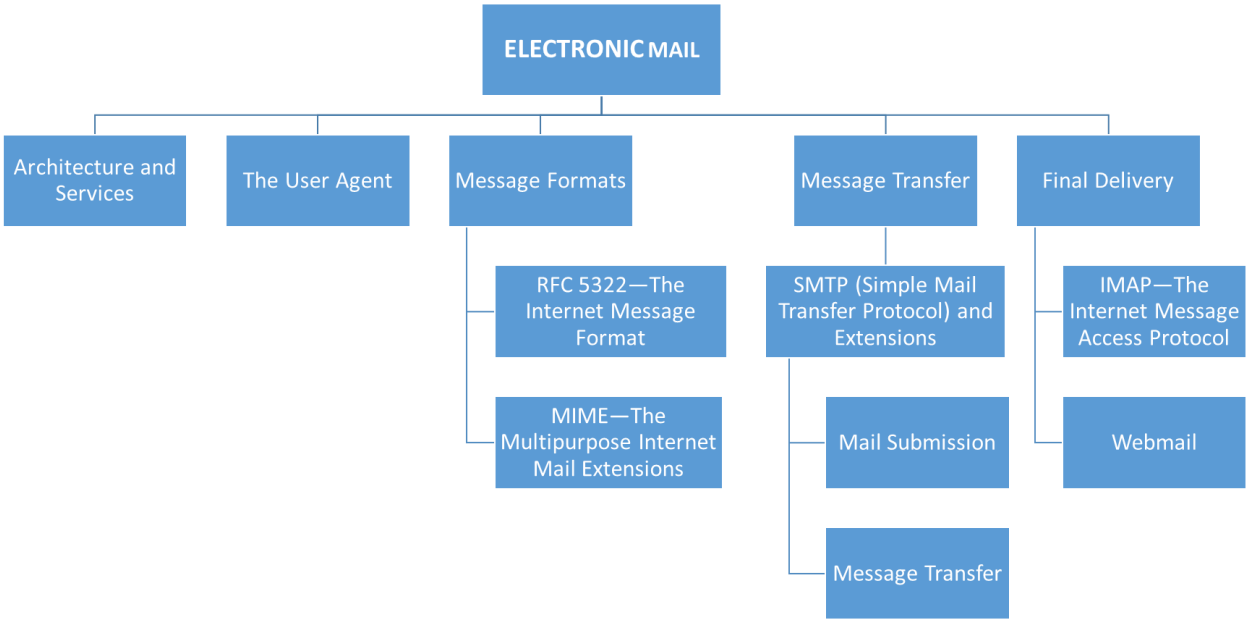


ELECTRONIC MAIL

Electronic mail, commonly known as email, is a fundamental communication tool facilitated by computer networks, particularly the internet. It allows users to send and receive digital messages and files quickly and efficiently. At its core, email operates through the Simple Mail Transfer Protocol (SMTP) for sending messages and the Post Office Protocol (POP) or Internet Message Access Protocol (IMAP) for retrieving them. Email addresses serve as unique identifiers for both senders and recipients, enabling the delivery of messages to specific destinations. Features such as attachments, formatting options, and forwarding capabilities enhance the versatility of email for various communication needs. Additionally, email clients and web-based interfaces provide user-friendly platforms for composing, managing, and organizing emails. Despite the advent of alternative communication methods, email remains a ubiquitous and indispensable tool for personal, professional, and organizational correspondence.

Electronic mail is a method of **transmitting** and **receiving** messages using electronic devices. It was conceived in the late 20th century as the digital version of mail.

- ✓ In 1970-71s, when **Ray Tomlinson** created a way to transmit messages between computer systems on the ARPNET.
- ✓ Nowadays email is one of the popular way of digital communication.



Architecture and Services

It consists of two kinds of subsystems:

i. The **user agents**, which allow people to read and send email, and ii. the **message transfer agents**, which move the messages from the source to the destination.

ii. Also refer to message transfer agents informally as **mail servers**.

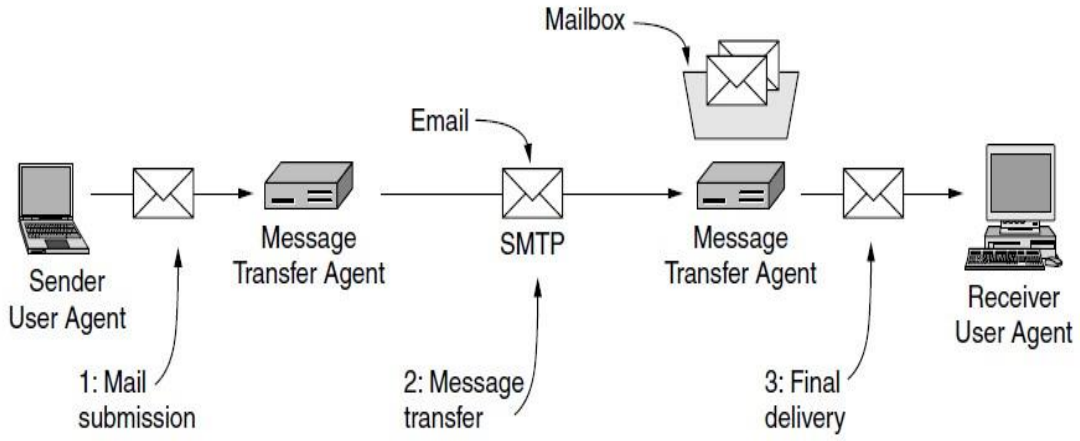


Figure 7-7. Architecture of the email system.

The **user agent** is a program that provides a graphical interface, or sometimes a text- and command-based interface that lets users interact with the email system. It includes a means to compose messages and replies to messages, display incoming messages, and organize messages by filing, searching, and discarding them. The act of sending new messages into the mail system for delivery is called **mail submission**.

The User Agent

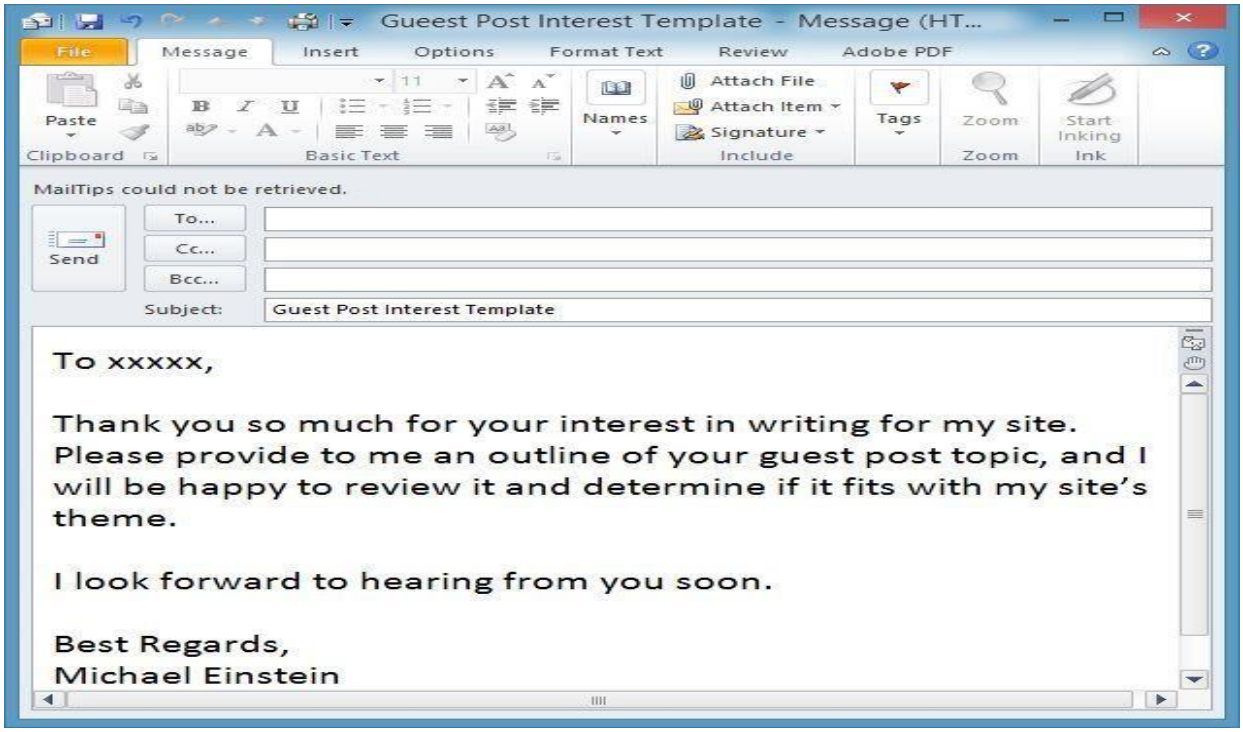
- A **user agent** is a program (sometimes called an **email reader**) that accepts a variety of commands for composing, receiving, and replying to messages, as well as for manipulating mailboxes.

There are many popular user agents, including Google gmail, Microsoft Outlook, Mozilla Thunderbird, and Apple Mail.

Message Formats

In email communication, messages are typically formatted in various ways to accommodate different content types and user preferences. The primary formats include plain text, which consists of ASCII characters without any formatting, ensuring universal compatibility; HTML, enabling rich text formatting with fonts, colors, and multimedia elements for visually engaging content; multipart, facilitating the inclusion of multiple formats within a single message to cater to diverse recipient capabilities; and attachments, allowing users to append files such as documents, images, and multimedia for supplementary information. Each format serves specific purposes, with plain text providing simplicity and reliability, HTML offering enhanced visual appeal, multipart ensuring flexibility, and attachments enabling the sharing of additional resources. These formats collectively contribute to the effectiveness and versatility of email communication across various platforms and devices.

Messages sent by the **user agent** must be placed in a standard format to be handled by the message transfer agents.



RFC 5322—The Internet Message Format

To: field gives the DNS address of the primary recipient ***Cc:*** field gives the addresses of any secondary recipients.
Bcc: (Blind carbon copy) field is like the *Cc:* field,
From: and ***Sender:***, tell who wrote and sent the message, respectively. ***Received:*** is added by each message transfer agent along the way. ***Return-Path:*** field is added by the final message transfer agent and was intended to tell how to get back to the sender.
Reply-To: field is sometimes used when neither the person composing the message nor the person sending the message wants to see the reply.
Message-Id: is an automatically generated number that is used to link messages together (e.g., when used in the ***In-Reply-To:*** field) and to prevent duplicate delivery.

Header	Meaning
To:	Email address(es) of primary recipient(s)
Cc:	Email address(es) of secondary recipient(s)
Bcc:	Email address(es) for blind carbon copies
From:	Person or people who created the message
Sender:	Email address of the actual sender
Received:	Line added by each transfer agent along the route
Return-Path:	Can be used to identify a path back to the sender

Figure 7-10. RFC 5322 header fields related to message transport.

Header	Meaning
Date:	The date and time the message was sent
Reply-To:	Email address to which replies should be sent
Message-Id:	Unique number for referencing this message later
In-Reply-To:	Message-Id of the message to which this is a reply
References:	Other relevant Message-Ids
Keywords:	User-chosen keywords
Subject:	Short summary of the message for the one-line display

Figure 7-11. Some fields used in the RFC 5322 message header.

Header	Meaning
MIME-Version:	Identifies the MIME version
Content-Description:	Human-readable string telling what is in the message
Content-Id:	Unique identifier
Content-Transfer-Encoding:	How the body is wrapped for transmission
Content-Type:	Type and format of the content

Figure 7-12. Message headers added by MIME.

MIME—The Multipurpose Internet Mail Extensions

***MIME-Version**:* is dealing with a MIME message, and which version of MIME it uses.
***Content-Description**:* header is an ASCII string telling what is in the message.
***Content-Id**:* header identifies the content.
***Content-Transfer-Encoding**:* tells how the body is wrapped for transmission through the network.

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

Figure 7-13. MIME content types and example subtypes.

Message Transfer

The mail transfer is done with the SMTP protocol.

- ✓ The simplest way to move messages is to establish a transport connection from the source machine to the destination machine and then just transfer the message.
- ✓ This is how SMTP originally worked.

SMTP (Simple Mail Transfer Protocol) and Extensions

SMTP (Simple Mail Transfer Protocol) is a communication protocol widely used for sending email messages between servers over a network. It operates on the application layer of the OSI model and follows a client-server architecture. SMTP facilitates the transfer of email messages by specifying how they should be formatted, transferred, and delivered. The protocol typically utilizes TCP port 25 for communication. While the core SMTP protocol is relatively simple, various extensions and enhancements have been developed to improve functionality, security, and efficiency. Some notable SMTP extensions include SMTP Authentication (SMTP AUTH) for authenticating users before allowing email transmission, SMTP STARTTLS for securing email communication with encryption, and SMTPUTF8 for supporting internationalized email addresses and content in different character sets. These extensions enhance the capabilities of SMTP and ensure reliable and secure email delivery in modern email systems.

Within the Internet, **email** is delivered by having the sending computer establish a **TCP connection** to port 25 of the receiving computer.

- ✓ Listening to this port is a mail server that speaks **SMTP** (**Simple Mail Transfer Protocol**).

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
STARTTLS	Switch to secure transport (TLS; see Chap. 8)
UTF8SMTP	Internationalized addresses

Figure 7-16. Some SMTP extensions.

Final Delivery

IMAP—The Internet Message Access Protocol

- ✓ One of the main protocols that is used for final delivery is **IMAP** (**Internet Message Access Protocol**).
- ✓ Version 4 of the protocol is defined in RFC 3501.
- ✓ To use IMAP, the mail server runs an **IMAP server** that listens to port 143. The user agent runs an IMAP client.

Command	Description
CAPABILITY	List server capabilities
STARTTLS	Start secure transport (TLS; see Chap. 8)
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
LSUB	List the active 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
UID	Issue commands using unique identifiers
NOOP	Do nothing
CLOSE	Remove flagged messages and close folder
LOGOUT	Log out and close connection

Figure 7-17. IMAP (version 4) commands.

POP3 - (Post Office Protocol, version 3)

POP3 (Post Office Protocol, version 3) is a protocol used for retrieving emails from a remote server to a client device. It operates on the application layer, typically using TCP port 110. Users access their emails through POP3 clients, which establish connections with the server, authenticate users, and download emails to the local device. Unlike IMAP, POP3 usually removes emails from the server after downloading them to the client.

- ✓ POP3 is a simpler protocol but supports fewer features and is less secure in typical usage.
- ✓ Mail is usually downloaded to the **user agent** computer, instead of remaining on the mail server.
- ✓ This makes life easier on the server, but harder on the user.
- ✓ It is not easy to read mail on multiple computers, plus if the user agent computer breaks, all email may be lost permanently.
- ✓ Nonetheless, you will still find **POP3** in use.

THE WORLD WIDE WEB

The World Wide Web (WWW or simply the Web) is a global system of interconnected documents and resources accessible via the Internet. It operates on the application layer of the OSI model and relies on protocols such as HTTP (Hypertext Transfer Protocol) for data transmission. The Web is built upon the concept of hypertext, allowing users to navigate between different resources through hyperlinks. It encompasses a vast array of websites, web pages, multimedia content, and web applications hosted on servers worldwide. Tim Berners-Lee, a British computer scientist, is credited with inventing the World Wide Web in 1989 while working at CERN. The Web has transformed communication, information dissemination, commerce, entertainment, and numerous other aspects of modern life, becoming an indispensable tool for billions of users globally.

The Web, as the World Wide Web is popularly known, is an architectural framework for accessing linked content spread out over millions of machines all over the Internet.

- ✓ In 1994, CERN and M.I.T. signed an agreement setting up the W3C (World Wide Web Consortium), an organization devoted to further developing the Web, standardizing protocols, and encouraging interoperability between sites.

WWW was a what you see is what you get (WYSIWYG) hypertext browser/editor that ran in the NextStep environment. The **World Wide Web** (**WWW** or simply the **Web**) is an information system that enables content sharing over the Internet . It allows documents and other web resources to be accessed over the Internet according to specific rules of the Hypertext Transfer Protocol (HTTP).

World Wide Web, which is also known as a Web, is a collection of websites or web pages stored in web servers and connected to local computers through the internet. These websites contain text pages, digital images, audios, videos, etc.

History of the World Wide Web:

The World Wide Web was invented by a British scientist, Tim Berners-Lee in 1989. He was working at CERN at that time. Originally, it was developed by him to fulfill the need of automated information sharing between scientists across the world, so that they could easily share the data and results of their experiments and studies with each other.

Architectural Overview

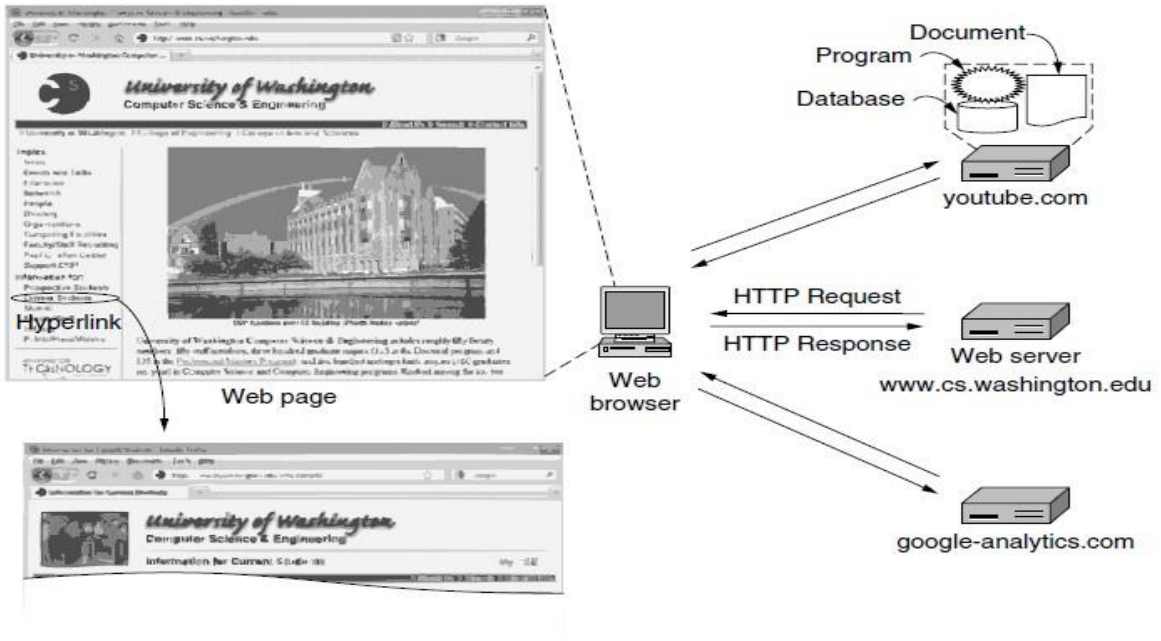


Figure 7-18. Architecture of the Web.

The Web consists of a vast, worldwide collection of content in the form of **Web pages**, often just called **pages** for short. Each page may contain links to other pages anywhere in the world.

- ✓ Pages are generally viewed with a program called a **browser.**
- ✓ A piece of text, icon, image, and so on associated with another page is called a **hyperlink.**

The URL design is open-ended in the sense that it is straightforward to have browsers use multiple protocols to get at different kinds of resources. In fact, URLs for various other protocols have been defined. Slightly simplified forms of the common ones are listed.

The ***http*** protocol is the Web's native language, the one spoken by Web servers. **HTTP** stands for **Hyper Text Transfer Protocol**.

Name	Used for	Example
http	Hypertext (HTML)	http://www.ee.uwa.edu/~rob/
https	Hypertext with security	https://www.bank.com/accounts/
ftp	FTP	ftp://ftp.cs.vu.nl/pub/minix/README
file	Local file	file:///usr/suzanne/prog.c
mailto	Sending email	mailto:JohnUser@acm.org
rtsp	Streaming media	rtsp://youtube.com/montypython.mpg
sip	Multimedia calls	sip:eve@adversary.com
about	Browser information	about:plugins

Figure 7-19. Some common URL schemes.

A **plug-in** is a third-party code module that is installed as an extension to the browser.
To tackle the problem of serving a single request at a time, one strategy is to make the server **multithreaded**. In one design, the server consists of a front-end module that accepts all incoming

requests and *k* processing modules, as shown in Fig. 7-21. The *k* + 1 threads all belong to the same process, so the processing modules all have access to the cache within the process' address space. When a request comes in, the front end accepts it and builds a short record describing it. It then hands the record to one of the processing modules.

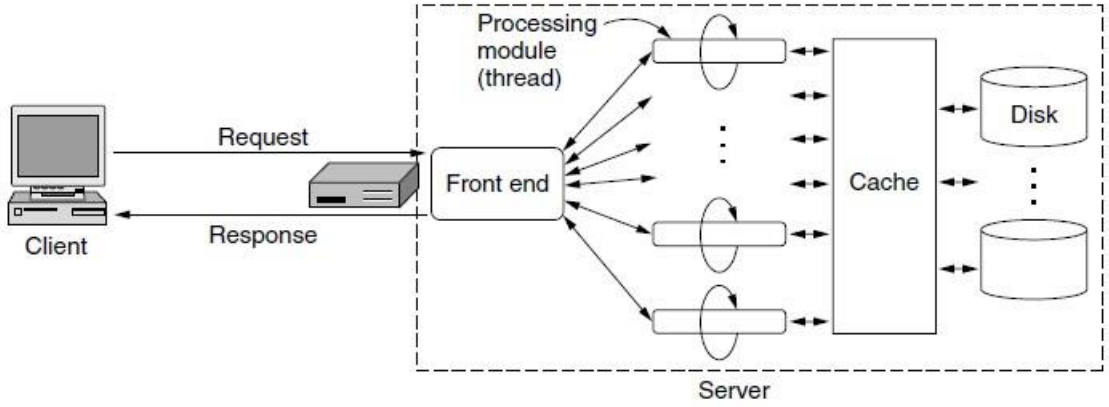


Figure 7-21. A multithreaded Web server with a front end and processing modules.

Cookies

Cookies are small pieces of data stored on a user's device by a web browser while browsing a website. They serve various purposes, including remembering user preferences, enabling personalized experiences, and tracking user behavior. Cookies contain information such as session identifiers, user preferences, and browsing history, which are sent back to the website's server with each subsequent request. There are different types of cookies, including session cookies, which expire when the user closes the browser, and persistent cookies, which remain on the device for a specified duration. While cookies enhance website functionality and user experience, they also raise privacy concerns, as they can be used for tracking user activities across different websites. As such, many web browsers offer options for users to manage and delete cookies, and regulations such as the General Data Protection Regulation (GDPR) in the European Union require websites to obtain user consent before storing cookies.

- **An HTTP cookie stores information in a user's web browser**. Web servers generate cookies and send them to browsers, which then include the cookies in future HTTP requests.

- **HTTP cookies** (also called **web cookies**, **Internet cookies**, **browser cookies**, or simply **cookies**) are small blocks of data created by a web server while a user is browsing a website and placed on the user's computer or other device by the user's web browser.

- An *HTTP cookie* (also called *web cookie*, *Internet cookie*, *browser cookie*, or simply *cookie*) is a small piece of data sent from a website and stored on the user's computer by the user's web browser while the user is browsing. Cookies were designed to be a reliable mechanism for websites to remember stateful information (such as items added in the shopping cart in an online store) or to record the user's browsing activity (including clicking particular buttons, logging in, or recording which pages were visited in the past).

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

Figure 7-22. Some examples of cookies.

HTML—The HyperText Markup Language

HTML (Hypertext Markup Language) is the standard markup language used to create and design web pages. It provides a structured format for defining the content and layout of a webpage using tags and attributes. HTML documents consist of elements, which are enclosed within opening and closing tags, and can include text, images, links, forms, and multimedia content. HTML utilizes a hierarchical structure, with elements nested within each other to create a meaningful document outline. The language supports various features such as hyperlinks, lists, tables, and semantic markup to describe the purpose and structure of content. Additionally, HTML works in conjunction with CSS (Cascading Style Sheets) and JavaScript to enhance the presentation and interactivity of web pages. As the backbone of the World Wide Web, HTML is essential for creating accessible, well-structured, and visually appealing web content.

HTML (**HyperText Markup Language**) was introduced with the Web. It allows users to produce Web pages that include text, graphics, video, pointers to other Web pages, and more. HTML is a markup language, or language for describing how documents are to be formatted. The term ‘‘markup’’ comes from the old days when copyeditors actually marked up documents to tell the printer— in those days, a human being—which fonts to use, and so on. Markup languages thus contain explicit commands for formatting**.**

✓ Hypertext Markup Language (HTML) is the standard markup language for creating web pages and web applications. With Cascading Style Sheets (CSS) and JavaScript, it forms a triad of cornerstone technologies for the World Wide Web

Item	HTML 1.0	HTML 2.0	HTML 3.0	HTML 4.0	HTML 5.0
Hyperlinks	x	x	x	x	x
Images	x	x	x	x	x
Lists	x	x	x	x	x
Active maps & images		x	x	x	x
Forms		x	x	x	x
Equations			x	x	x
Toolbars			x	x	x
Tables			x	x	x
Accessibility features				x	x
Object embedding				x	x
Style sheets				x	x
Scripting				x	x
Video and audio					x
Inline vector graphics					x
XML representation					x
Background threads					x
Browser storage					x
Drawing canvas					x

Figure 7-24. Some differences between HTML versions.

Server-Side Dynamic Web Page Generation

The static page model we have used so far treats pages as multimedia documents that are conveniently linked together.

It was a fitting model in the early days of the Web, as vast amounts of information were put online.

✓ To act as applications, Web pages can no longer be static. Dynamic content is needed.

✓ A ***static web page*** (sometimes called a *flat page/stationary page*) is a web page that is delivered to the user exactly as stored, in contrast to dynamic web pages which are generated by a web application.

✓ A ***server-side dynamic web page*** is a web page whose construction is controlled by an application server processing server-side scripts. In server-side scripting, parameters determine how the assembly of every new web page proceeds, including the setting up of more client-side processing.

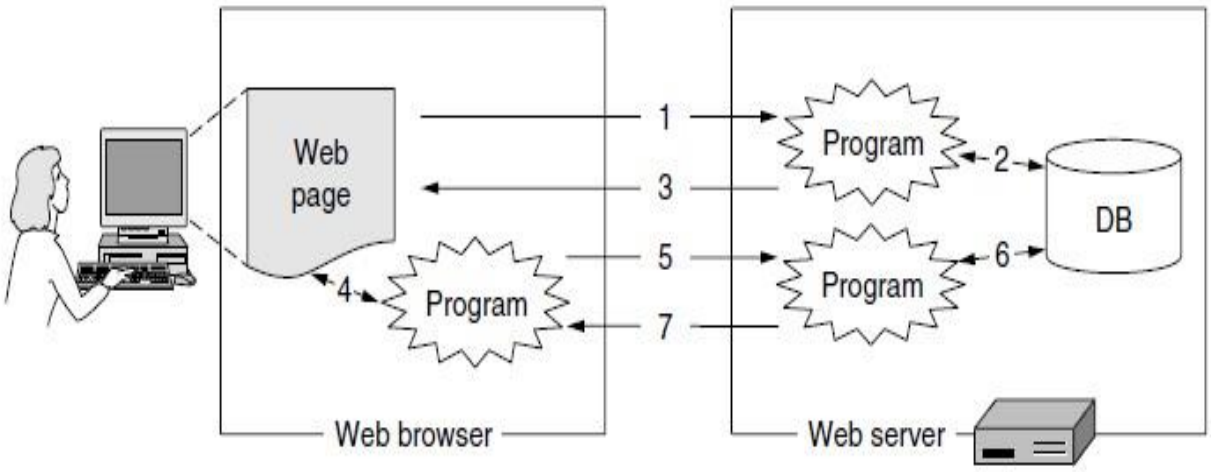


Figure 7-29. Dynamic pages.

STREAMING AUDIO AND VIDEO

Streaming is a method of viewing video or listening to audio content without actually downloading the media files. Streaming performance can be improved, and buffering time reduced, if the owner of the files uses a CDN.

✓ The term **streaming** refers to the continual transmission of audio and video files from a server to a client.

In video streams, content is sent in a compressed form over the internet and is displayed by the viewer in real time. The media is sent in a continuous stream of data and is played as it arrives. Video streaming is a continuous transmission of video files from a server to a client. Video streaming enables users to view videos online without having to download them. Video streams normally begin with a prerecorded media file hosted on a remote server. Once the server receives a client request, the data in the video file is compressed and sent to the requesting device in pieces.

Audio and video files are broken into data packets, where each packet contains a small piece of data. An explosion of voice data carried over Internet networks that is called **voice over IP** or Internet telephony.

✓ The variation in delay, called **jitter**, still matters.

✓ It must be masked by the player or the audio will sound unintelligible and the video will look jerky.

✓ The term **multimedia** is often used in the context of the Internet to mean video and audio.

Digital Audio

- ✓ An audio (sound) wave is a one-dimensional acoustic (pressure) wave. When an acoustic wave enters the ear, the eardrum vibrates, causing the tiny bones of the inner ear to vibrate along with it, sending nerve pulses to the brain.
- ✓ These pulses are perceived as sound by the listener.
    - o The frequency range of the human ear runs from 20 Hz to 20,000 Hz.
- ✓ **Digital audio** is a representation of sound recorded in, or converted into, digital form. In digital audio, the sound wave of the audio signal is typically encoded as numerical samples in a continuous sequence. **Digital audio** technologies are used in the recording, manipulation, mass-production, and distribution of sound, including recordings of songs, instrumental pieces, podcasts, sound effects, and other sounds.
- ✓ **Digital audio** is a digital representation of an audio wave that can be used to recreate it. Audio waves can be converted to digital form by an ADC (Analogto-Digital Converter). An ADC takes an electrical voltage as input and generates a binary number as output.

- ✓ Two key factors in the quality of digital audio are the audio sample rate and bit depth.
- ✓ The **audio sample rate** refers to the number of samples of audio that are taken per second and is measured in **Hertz (Hz).**
- ✓ Common sample rates for digital audio include **44.1 kHz, 48 kHz, and 96 kHz**.

Audio Compression

- **Audio** is often compressed to reduce bandwidth needs and transfer times, even though audio data rates are much lower than video data rates. All **compression** systems require two algorithms: one for compressing the data at the source, and another for decompressing it at the destination.
- These algorithms are referred to as the **encoding** and **decoding** algorithms, respectively. Probably the most popular formats are **MP3** (**MPEG audio layer 3**) and **AAC** (**Advanced Audio Coding**) as carried in **MP4** (**MPEG-4**) files.

Digital Video

Digital video is an electronic representation of moving visual images (video) in the form of encoded digital data.

- ✓ **Digital video** comprises a series of digital images displayed in rapid succession, usually at 24, 30, or 60 frames per second.
- ✓ Digital video has many **advantages** such as easy copying, multicasting, sharing and storage.
- ✓ **Digital video** was **first introduced** commercially in **1986** with the Sony D1 format, which recorded an uncompressed standard-definition component video signal in digital form.
- ✓ In addition to uncompressed formats, popular compressed digital video formats today include MPEG-2, H.264 and AV1. Modern interconnect standards used for playback of digital video include HDMI, DisplayPort, Digital Visual Interface (DVI) and serial digital interface (SDI).

- **Digital video** is a type of video recording system that works by using a digital video signal rather than an analog one. (The terms *camera*, *video camera*, and *camcorder* are used interchangeably in this article.)

- Digital videos can be copied multiple times, with practically no degradation in quality, and they can be edited using readily available **hardware and software**. The tape stock for digital video costs significantly less than 35 mm film. Digital video is used not only for digital television (including HDTV) but also for mobile phones, video conferencing systems, and the Internet distribution of media.

- **Digital video** (DV) is video that is captured and stored in a digital format as ones and zeros, rather than a series of still pictures captured in film. Digital, versus **analog**, signals are used. Information is processed and stored as a sequence of digital data for easy manipulation by computers, but the video is still presented to the viewer through a screen in analog form. **Digital video** is composed of a series of orthogonal bitmap (BMP) images displayed in constant rapid succession with common frequencies of 15, 24, 30 and 60 frames per second (FPS); the more frames the DV has, the more movement details are captured or displayed.

Video Compression

Video compression is a process used to reduce the size of digital video files, allowing for efficient storage and transmission. This compression technique is essential for various applications, including **video streaming**, **video conferencing**, and **digital television broadcasting**.

- There are two main types of video compression: **lossy** and **lossless**.
  - ✓ **Lossy compression** methods achieve higher compression ratios but sacrifice some video quality, while **lossless compression** methods preserve video quality but typically achieve **lower compression ratios**.

- Common video compression standards include **MPEG** (Moving Picture Experts Group), **H.264/AVC** (Advanced Video Coding), and H.265/HEVC (High-Efficiency Video Coding).

The JPEG Standard

The JPEG (Joint Photographic Experts Group) standard is a widely used compression method for digital images, developed to reduce file sizes while preserving visual quality. Employing lossy compression, JPEG discards some image data, resulting in smaller files but potential loss of detail. It supports grayscale and color images with various compression levels to balance size and quality. JPEG compression is efficient for photographs and commonly used in digital cameras, online image sharing, and various applications. However, it may lead to artifacts or degradation, prompting the development of alternatives like JPEG 2000 and WebP to address limitations.

The **JPEG** (**Joint Photographic Experts Group**) standard for compressing continuous-tone still pictures (e.g., photographs) was developed by photographic experts working under the joint auspices of ITU, ISO, and IEC, another standards body. It is widely used (look for files with the extension jpg) and often provides **compression ratios of 10:1** or better for natural images.

- ✓ The **JPEG** input is a 640 × 480 **RGB image** with **24 bits/pixel**,

The MPEG Standard

The MPEG (Moving Picture Experts Group) standard encompasses a suite of compression algorithms and formats devised for digital audio and video content transmission. It comprises various standards, notably MPEG-1, MPEG-2, MPEG-4, and MPEG-7, tailored for different applications. MPEG-1 is ideal for low-bitrate video and audio compression, such as VCDs and digital audio encoding. MPEG-2 is versatile, supporting broadcast television, DVDs, and digital satellite TV. MPEG-4 offers advanced compression for high-quality multimedia, enabling applications like video conferencing and streaming media. MPEG-7 focuses on multimedia content description, enhancing search, retrieval, and management. Continuously evolving, MPEG standards adapt to emerging technologies to ensure efficient compression, high-quality playback, and interoperability across platforms.

The **MPEG** (**Motion Picture Experts Group**) standards. Though there are many proprietary algorithms, these standards define the main algorithms used to **compress videos**. They have been **international standards** since **1993**. Because movies contain **both** images and sound, **MPEG** can **compress both** audio and video.

- ✓ The **MPEG-1** standard (which includes **MP3 audio**) was first published in 1993 and is still widely used. Its goal was to produce **video-recorder-quality output** that was **compressed 40:1** to rates of around **1 Mbps**.

Streaming Stored Media

Streaming stored media involves delivering multimedia content, like audio or video files, over a network in a continuous stream. Unlike traditional downloading, streaming allows users to start consuming content immediately while it's being transmitted. This is done by continuously sending data packets from the server to the client device, where they're decoded and played back in real-time. Streaming technology relies on protocols such as RTSP, HTTP, or HLS to facilitate delivery. It offers benefits like instant access to content, adaptive streaming for varying network conditions, and support for live broadcasting. Popular streaming platforms use advanced algorithms to ensure smooth playback and minimize buffering, providing a seamless user experience.

Streaming stored video refers to the delivery of pre–recorded video content over a network without having to download it first.

- ✓ This process allows users to begin watching the video before it has fully downloaded, as opposed to traditional downloading methods where the user must first wait for the entire file to download before watching it.