

## **APPLICATION LAYER**

The application layer in the OSI model is the closest layer to the end user which means that the application layer and end user can interact directly with the software application. The application layer programs are based on client and servers.

The Application layer includes the following functions:

- **Identifying communication partners:** The application layer identifies the availability of communication partners for an application with data to transmit.
- **Determining resource availability:** The application layer determines whether sufficient network resources are available for the requested communication.
- **Synchronizing communication:** All the communications occur between the applications requires cooperation which is managed by an application layer.

### Services of Application Layers

- **Network Virtual terminal:** An application layer allows a user to log on to a remote host. To do so, the application creates a software emulation of a terminal at the remote host. The user's computer talks to the software terminal, which in turn, talks to the host. The remote host thinks that it is communicating with one of its own terminals, so it allows the user to log on.
- **File Transfer, Access, and Management (FTAM):** An application allows a user to access files in a remote computer, to retrieve files from a computer and to manage files in a remote computer. FTAM defines a hierarchical virtual file in terms of file structure, file attributes and the kind of operations performed on the files and their attributes.
- **Addressing:** To obtain communication between client and server, there is a need for addressing. When a client made a request to the server, the request contains the server address and its own address. The server response to the client request, the request contains the destination address, i.e., client address. To achieve this kind of addressing, DNS is used.
- **Mail Services:** An application layer provides Email forwarding and storage.
- **Directory Services:** An application contains a distributed database that provides access for global information about various objects and services.
- **Authentication:** It authenticates the sender or receiver's message or both.

### Network Application Architecture

Application architecture is different from the network architecture. The network architecture is fixed and provides a set of services to applications. The application

architecture, on the other hand, is designed by the application developer and defines how the application should be structured over the various end systems.

### **Application architecture is of two types:**

- **Client-server architecture:** An application program running on the local machine sends a request to another application program is known as a client, and a program that serves a request is known as a server. For example, when a web server receives a request from the client host, it responds to the request to the client host.

### **Characteristics of Client-server architecture:**

- In Client-server architecture, clients do not directly communicate with each other. For example, in a web application, two browsers do not directly communicate with each other.
- A server is fixed, well-known address known as IP address because the server is always on while the client can always contact the server by sending a packet to the sender's IP address.

### **Disadvantage Of Client-server architecture:**

It is a single-server based architecture which is incapable of holding all the requests from the clients. For example, a social networking site can become overwhelmed when there is only one server exists.

- **P2P (peer-to-peer) architecture:** It has no dedicated server in a data center. The peers are the computers which are not owned by the service provider. Most of the peers reside in the homes, offices, schools, and universities. The peers communicate with each other without passing the information through a dedicated server, this architecture is known as peer-to-peer architecture. The applications based on P2P architecture includes file sharing and internet telephony.

### **Features of P2P architecture**

- **Self scalability:** In a file sharing system, although each peer generates a workload by requesting the files, each peer also adds a service capacity by distributing the files to the peer.
- **Cost-effective:** It is cost-effective as it does not require significant server infrastructure and server bandwidth.

### **Client and Server processes**

- A network application consists of a pair of processes that send the messages to each other over a network.

- In P2P file-sharing system, a file is transferred from a process in one peer to a process in another peer. We label one of the two processes as the client and another process as the server.
- With P2P file sharing, the peer which is downloading the file is known as a client, and the peer which is uploading the file is known as a server. However, we have observed in some applications such as P2P file sharing; a process can be both as a client and server. Therefore, we can say that a process can both download and upload the files.

## **File Transfer, Access and Management**

FTAM is an OSI standard that provides file transfer services between client (initiator) and server (responder) systems in an open environment. It also provides access to files and management of files on diverse systems. In these respects, it strives to be a universal file system. FTAM has worked well as a way to bring mainframe information systems into distributed environments, but FTAM has not caught on otherwise.

FTAM is designed to help users access files on diverse systems that use compatible FTAM implementations. It is similar to FTP (File Transfer Protocol) and NFS (Network File System), both of which operate in the TCP/IP environment. Users can manipulate files down to the record level, which is how FTAM stores files. In this respect, FTAM has some relational database features. For example, users can lock files or lock individual records.

FTAM is a system in which connection-oriented information about the user and the session is maintained by a server until the session is taken down. In a stateless system, such as NFS, requests are made independently of one another in a connectionless manner. There are advantages to stateless operation. If the server crashes, the request simply goes away and the client makes another request. This simplifies recovery after the crash. In a stateful system, both systems must be aware that one or the other has crashed so they can restore the states and prevent data corruption.

Files are transferred between systems by first establishing a connection-oriented session. The FTAM client contacts the FTAM server and requests a session. Once the session is established, file transfer can take place. FTAM uses the concept of a virtual filestore, which provides a common view of files. The FTAM file system hides the differences between different vendor systems. FTAM specifies document types as files with straight binary information or text files in which each line is terminated with a carriage return. Data is interpreted as records and FTAM provides the virtual filestore capabilities that store record-oriented structured files.

So far, FTAM, like other OSI protocols, has not caught on as a useful system for transferring files between different vendor systems in the LAN environment. Many of the implementations so far have failed to interoperate with one another. FTAM

has worked well as a way to bring mainframe information systems into distributed environments.

## FTP

- FTP stands for File transfer protocol.
- FTP is a standard internet protocol provided by TCP/IP used for transmitting the files from one host to another.
- It is mainly used for transferring the web page files from their creator to the computer that acts as a server for other computers on the internet.
- It is also used for downloading the files to computer from other servers.

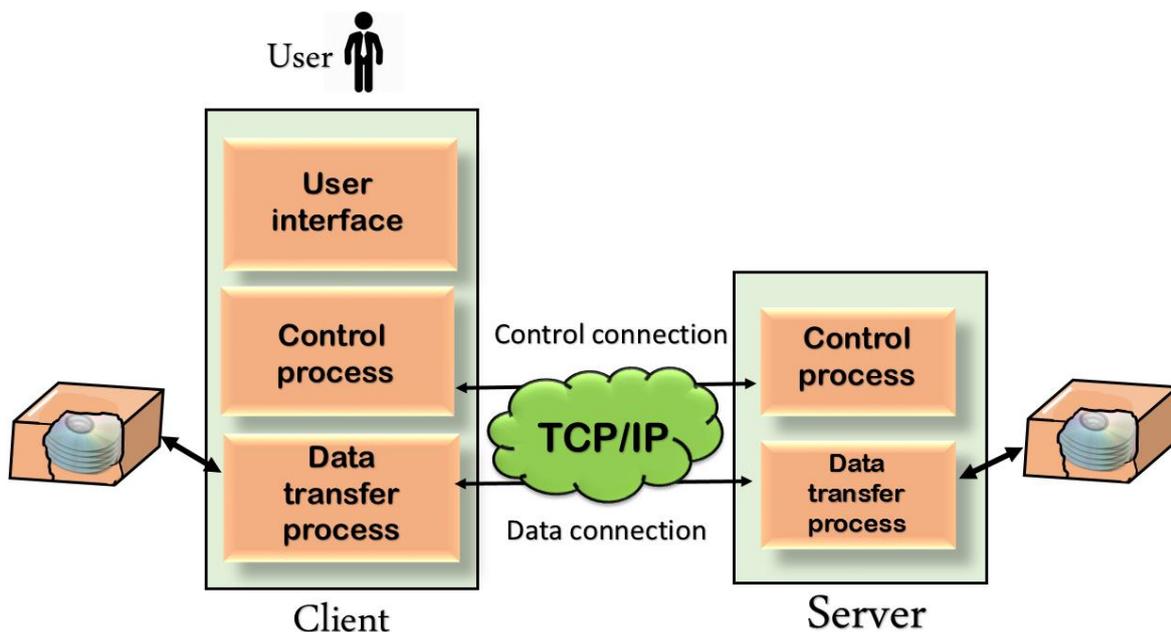
### Objectives of FTP

- It provides the sharing of files.
- It is used to encourage the use of remote computers.
- It transfers the data more reliably and efficiently.

### Why FTP?

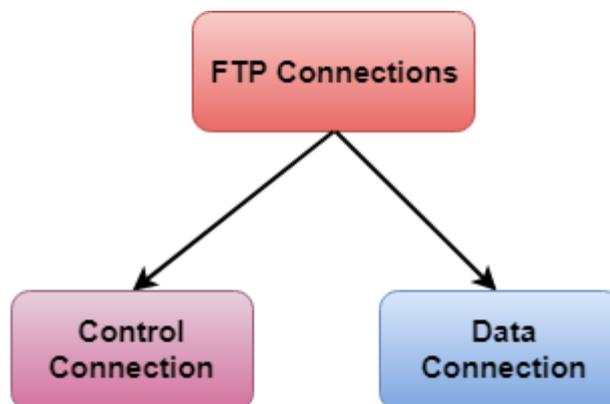
Although transferring files from one system to another is very simple and straightforward, but sometimes it can cause problems. For example, two systems may have different file conventions. Two systems may have different ways to represent text and data. Two systems may have different directory structures. FTP protocol overcomes these problems by establishing two connections between hosts. One connection is used for data transfer, and another connection is used for the control connection.

### Mechanism of FTP



The above figure shows the basic model of the FTP. The FTP client has three components: the user interface, control process, and data transfer process. The server has two components: the server control process and the server data transfer process.

### There are two types of connections in FTP:



- **Control Connection:** The control connection uses very simple rules for communication. Through control connection, we can transfer a line of command or line of response at a time. The control connection is made between the control processes. The control connection remains connected during the entire interactive FTP session.
- **Data Connection:** The Data Connection uses very complex rules as data types may vary. The data connection is made between data transfer processes. The data connection opens when a command comes for transferring the files and closes when the file is transferred.

### FTP Clients

- FTP client is a program that implements a file transfer protocol which allows you to transfer files between two hosts on the internet.
- It allows a user to connect to a remote host and upload or download the files.
- It has a set of commands that we can use to connect to a host, transfer the files between you and your host and close the connection.
- The FTP program is also available as a built-in component in a Web browser. This GUI based FTP client makes the file transfer very easy and also does not require to remember the FTP commands.

### Advantages of FTP:

- **Speed:** One of the biggest advantages of FTP is speed. The FTP is one of the fastest way to transfer the files from one computer to another computer.
- **Efficient:** It is more efficient as we do not need to complete all the operations to get the entire file.
- **Security:** To access the FTP server, we need to login with the username and password. Therefore, we can say that FTP is more secure.

- **Back & forth movement:** FTP allows us to transfer the files back and forth. Suppose you are a manager of the company, you send some information to all the employees, and they all send information back on the same server.

Disadvantages of FTP:

- The standard requirement of the industry is that all the FTP transmissions should be encrypted. However, not all the FTP providers are equal and not all the providers offer encryption. So, we will have to look out for the FTP providers that provides encryption.
- FTP serves two operations, i.e., to send and receive large files on a network. However, the size limit of the file is 2GB that can be sent. It also doesn't allow you to run simultaneous transfers to multiple receivers.
- Passwords and file contents are sent in clear text that allows unwanted eavesdropping. So, it is quite possible that attackers can carry out the brute force attack by trying to guess the FTP password.
- It is not compatible with every system.

**E-mail Protocols** are set of rules that help the client to properly transmit the information to or from the mail server. Here in this tutorial, we will discuss various protocols such as **SMTP, POP, and IMAP.**

## SMTP

**SMTP** stands for **Simple Mail Transfer Protocol**. It was first proposed in 1982. It is a standard protocol used for sending e-mail efficiently and reliably over the internet.

### Key Points:

- SMTP is application level protocol.
- SMTP is connection oriented protocol.
- SMTP is text based protocol.
- It handles exchange of messages between e-mail servers over TCP/IP network.
- Apart from transferring e-mail, SMTP also provides notification regarding incoming mail.
- When you send e-mail, your e-mail client sends it to your e-mail server which further contacts the recipient mail server using SMTP client.
- These SMTP commands specify the sender's and receiver's e-mail address, along with the message to be send.
- The exchange of commands between servers is carried out without intervention of any user.

- In case, message cannot be delivered, an error report is sent to the sender which makes SMTP a reliable protocol.

## SMTP Commands

The following table describes some of the SMTP commands:

S.N.	Command Description
1	<b>HELLO</b> This command initiates the SMTP conversation.
2	<b>EHELLO</b> This is an alternative command to initiate the conversation. ESMTP indicates that the sender server wants to use extended SMTP protocol.
3	<b>MAIL FROM</b> This indicates the sender's address.
4	<b>RCPT TO</b> It identifies the recipient of the mail. In order to deliver similar message to multiple users this command can be repeated multiple times.
5	<b>SIZE</b> This command let the server know the size of attached message in bytes.
6	<b>DATA</b> The <b>DATA</b> command signifies that a stream of data will follow. Here stream of data refers to the body of the message.
7	<b>QUIT</b> This commands is used to terminate the SMTP connection.
8	<b>VERFY</b> This command is used by the receiving server in order to verify whether the given username is valid or not.

9	<p><b>EXPN</b> It is same as VRFY, except it will list all the users name when it used with a distribution list.</p>
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## IMAP

**IMAP** stands for **Internet Mail Access Protocol**. It was first proposed in 1986.

### Key Points:

- IMAP allows the client program to manipulate the e-mail message on the server without downloading them on the local computer.
- The e-mail is hold and maintained by the remote server.
- It enables us to take any action such as downloading, delete the mail without reading the mail.It enables us to create, manipulate and delete remote message folders called mail boxes.
- IMAP enables the users to search the e-mails.
- It allows concurrent access to multiple mailboxes on multiple mail servers.

## IMAP Commands

The following table describes some of the IMAP commands:

S.N.	Command Description
1	<p><b>IMAP_LOGIN</b> This command opens the connection.</p>
2	<p><b>CAPABILITY</b> This command requests for listing the capabilities that the server supports.</p>
3	<p><b>NOOP</b> This command is used as a periodic poll for new messages or message status updates during a period of inactivity.</p>
4	<p><b>SELECT</b> This command helps to select a mailbox to access the messages.</p>

5	<b>EXAMINE</b> It is same as SELECT command except no change to the mailbox is permitted.
6	<b>CREATE</b> It is used to create mailbox with a specified name.
7	<b>DELETE</b> It is used to permanently delete a mailbox with a given name.
8	<b>RENAME</b> It is used to change the name of a mailbox.
9	<b>LOGOUT</b> This command informs the server that client is done with the session. The server must send BYE untagged response before the OK response and then close the network connection.

## POP

POP stands for Post Office Protocol. It is generally used to support a single client. There are several versions of POP but the POP 3 is the current standard.

### Key Points

- POP is an application layer internet standard protocol.
- Since POP supports offline access to the messages, thus requires less internet usage time.
- POP does not allow search facility.
- In order to access the messaged, it is necessary to download them.
- It allows only one mailbox to be created on server.
- It is not suitable for accessing non mail data.
- POP commands are generally abbreviated into codes of three or four letters. Eg. STAT.

### POP Commands

The following table describes some of the POP commands:

S.N.	Command Description
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1	<b>LOGIN</b> This command opens the connection.
2	<b>STAT</b> It is used to display number of messages currently in the mailbox.
3	<b>LIST</b> It is used to get the summary of messages where each message summary is shown.
4	<b>RETR</b> This command helps to select a mailbox to access the messages.
5	<b>DELE</b> It is used to delete a message.
6	<b>RSET</b> It is used to reset the session to its initial state.
7	<b>QUIT</b> It is used to log off the session.

### Comparison between POP and IMAP

S.N.	POP	IMAP
1	Generally used to support single client.	Designed to handle multiple clients.
2	Messages are accessed offline.	Messages are accessed online although it also supports offline mode.
3	POP does not allow search facility.	It offers ability to search emails.

4	All the messages have to be downloaded.	It allows selective transfer of messages to the client.
5	Only one mailbox can be created on the server.	Multiple mailboxes can be created on the server.
6	Not suitable for accessing non-mail data.	Suitable for accessing non-mail data i.e. attachment.
7	POP commands are generally abbreviated into codes of three or four letters. Eg. STAT.	IMAP commands are not abbreviated, they are full. Eg. STATUS.
8	It requires minimum use of server resources.	Clients are totally dependent on server.
9	Mails once downloaded cannot be accessed from some other location.	Allows mails to be accessed from multiple locations.
10	The e-mails are not downloaded automatically.	Users can view the headings and sender of e-mails and then decide to download.
10	POP requires less internet usage time.	IMAP requires more internet usage time.

## E-mail System

E-mail system comprises of the following three components:

- Mailer
- Mail Server
- Mailbox

Mailer

It is also called **mail program, mail application** or **mail client**. It allows us to manage, read and compose e-mail.

## Mail Server

The function of mail server is to receive, store and deliver the email. It is must for mail servers to be Running all the time because if it crashes or is down, email can be lost.

## Mailboxes

Mailbox is generally a folder that contains emails and information about them.

## Working of E-mail

Email working follows the client server approach. In this client is the mailer i.e. the mail application or mail program and server is a device that manages emails.

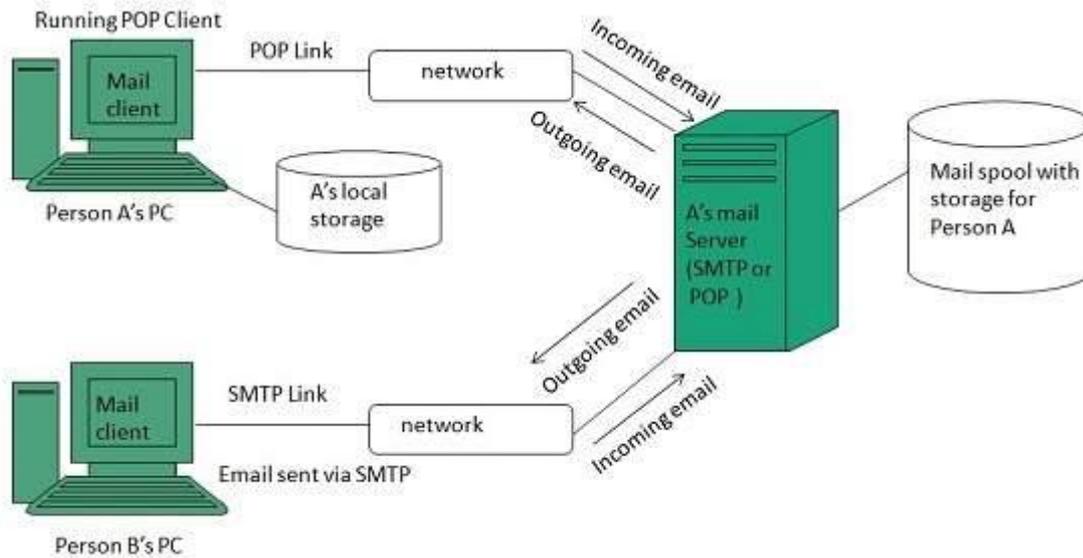
Following example will take you through the basic steps involved in sending and receiving emails and will give you a better understanding of working of email system:

- Suppose person A wants to send an email message to person B.
- Person A composes the messages using a mailer program i.e. mail client and then select Send option.
- The message is routed to **Simple Mail Transfer Protocol** to person B's mail server.
- The mail server stores the email message on disk in an area designated for person B.

The disk space area on mail server is called mail spool.

- Now, suppose person B is running a POP client and knows how to communicate with B's mail server.
- It will periodically poll the POP server to check if any new email has arrived for B. As in this case, person B has sent an email for person B, so email is forwarded over the network to B's PC. This is message is now stored on person B's PC.

The following diagram gives pictorial representation of the steps discussed above:

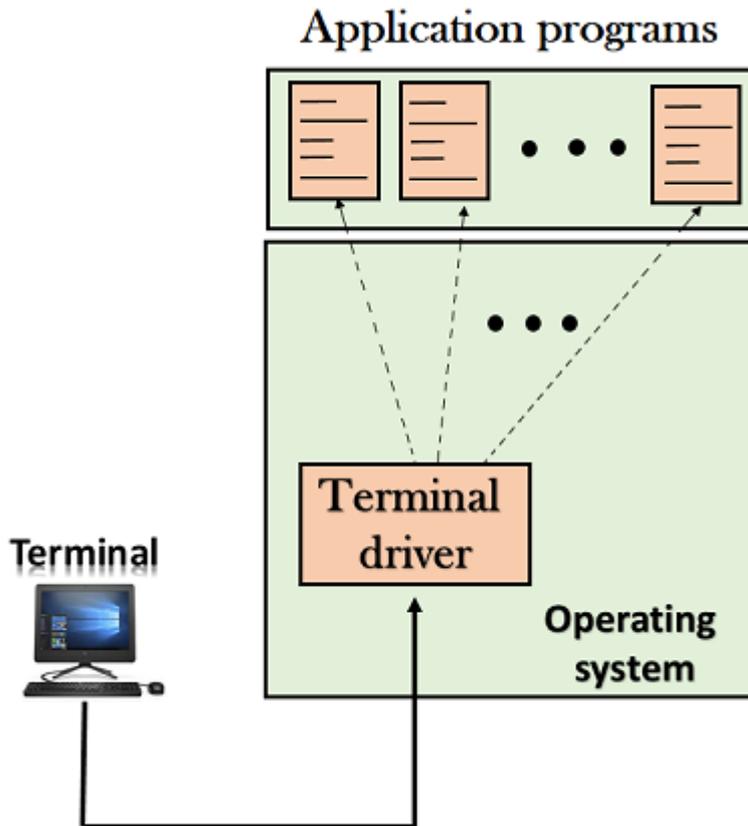


## Telnet

- The main task of the internet is to provide services to users. For example, users want to run different application programs at the remote site and transfers a result to the local site. This requires a client-server program such as FTP, SMTP. But this would not allow us to create a specific program for each demand.
- The better solution is to provide a general client-server program that lets the user access any application program on a remote computer. Therefore, a program that allows a user to log on to a remote computer. A popular client-server program Telnet is used to meet such demands. Telnet is an abbreviation for **Terminal Network**.
- Telnet provides a connection to the remote computer in such a way that a local terminal appears to be at the remote side.

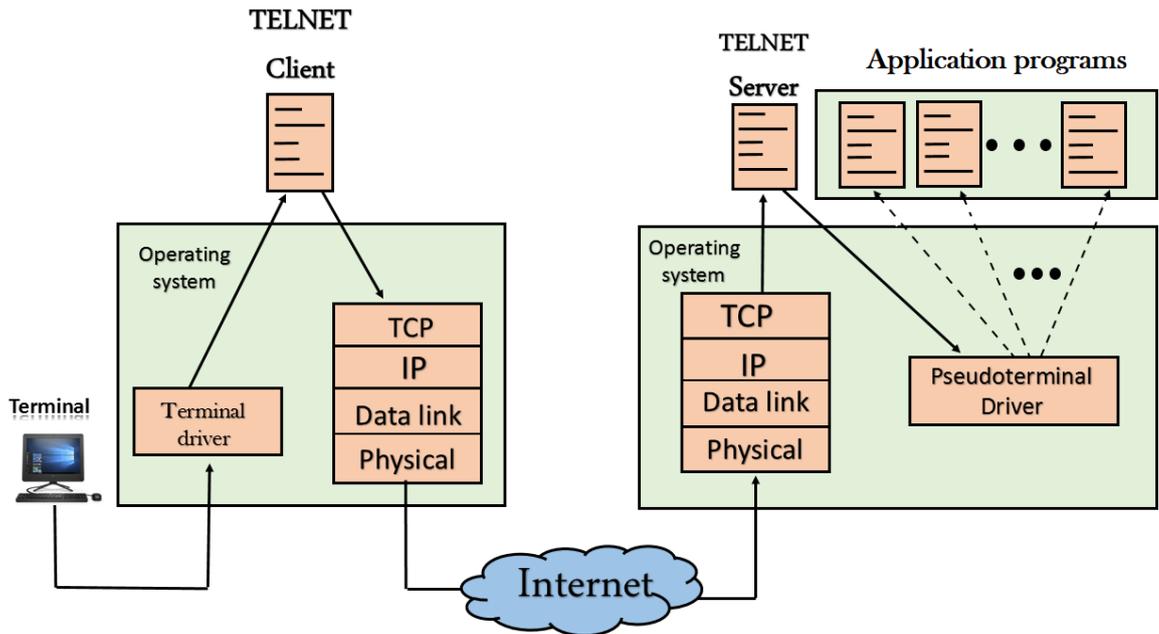
There are two types of login:

Local Login



- When a user logs into a local computer, then it is known as local login.
- When the workstation running terminal emulator, the keystrokes entered by the user are accepted by the terminal driver. The terminal driver then passes these characters to the operating system which in turn, invokes the desired application program.
- However, the operating system has special meaning to special characters. For example, in UNIX some combination of characters have special meanings such as control character with "z" means suspend. Such situations do not create any problem as the terminal driver knows the meaning of such characters. But, it can cause the problems in remote login.

## Remote login



- When the user wants to access an application program on a remote computer, then the user must perform remote login.

How remote login occurs

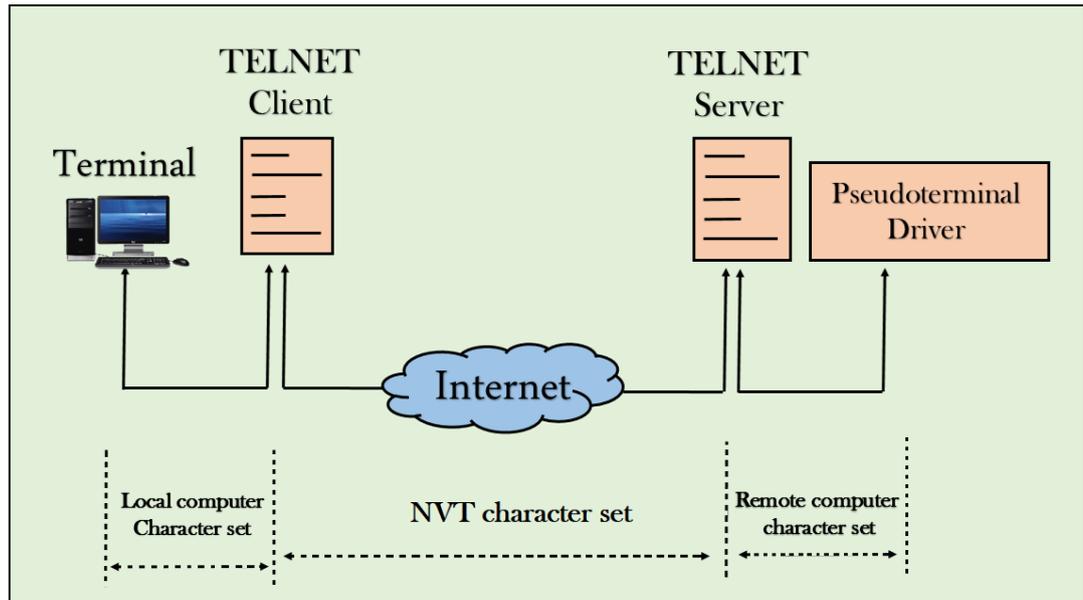
At the local site

The user sends the keystrokes to the terminal driver, the characters are then sent to the TELNET client. The TELNET client which in turn, transforms the characters to a universal character set known as network virtual terminal characters and delivers them to the local TCP/IP stack

At the remote site

The commands in NVT forms are transmitted to the TCP/IP at the remote machine. Here, the characters are delivered to the operating system and then pass to the TELNET server. The TELNET server transforms the characters which can be understandable by a remote computer. However, the characters cannot be directly passed to the operating system as a remote operating system does not receive the characters from the TELNET server. Therefore it requires some piece of software that can accept the characters from the TELNET server. The operating system then passes these characters to the appropriate application program.

**Network Virtual Terminal (NVT)**



- The network virtual terminal is an interface that defines how data and commands are sent across the network.
- In today's world, systems are heterogeneous. For example, the operating system accepts a special combination of characters such as end-of-file token running a DOS operating system *ctrl+z* while the token running a UNIX operating system is *ctrl+d*.
- TELNET solves this issue by defining a universal interface known as network virtual interface.
- The TELNET client translates the characters that come from the local terminal into NVT form and then delivers them to the network. The Telnet server then translates the data from NVT form into a form which can be understandable by a remote computer.

## HTTP

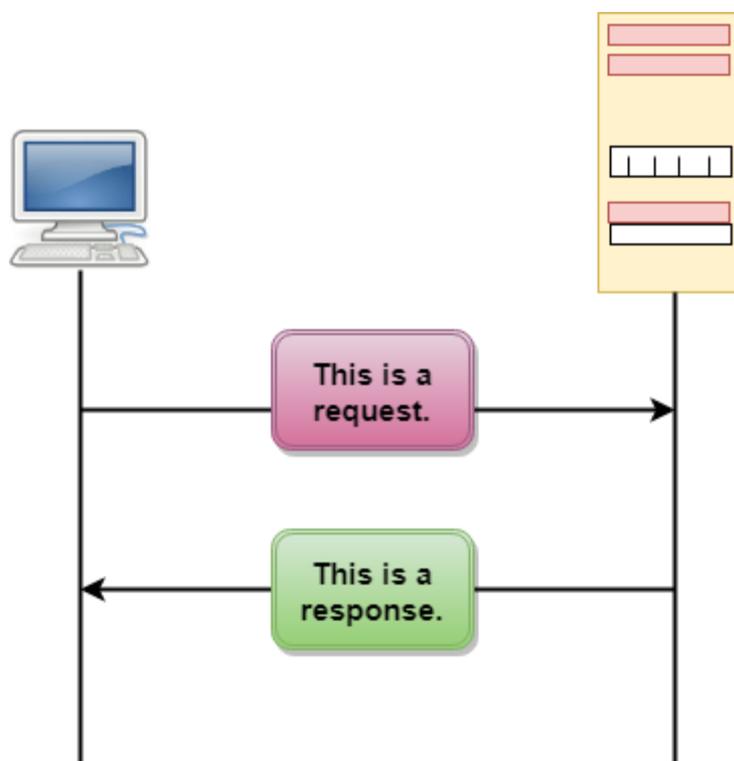
- HTTP stands for **HyperText Transfer Protocol**.
- It is a protocol used to access the data on the World Wide Web (www).
- The HTTP protocol can be used to transfer the data in the form of plain text, hypertext, audio, video, and so on.
- This protocol is known as HyperText Transfer Protocol because of its efficiency that allows us to use in a hypertext environment where there are rapid jumps from one document to another document.
- HTTP is similar to the FTP as it also transfers the files from one host to another host. But, HTTP is simpler than FTP as HTTP uses only one connection, i.e., no control connection to transfer the files.
- HTTP is used to carry the data in the form of MIME-like format.
- HTTP is similar to SMTP as the data is transferred between client and server. The HTTP differs from the SMTP in the way the messages are sent from the

client to the server and from server to the client. SMTP messages are stored and forwarded while HTTP messages are delivered immediately.

### Features of HTTP:

- **Connectionless protocol:** HTTP is a connectionless protocol. HTTP client initiates a request and waits for a response from the server. When the server receives the request, the server processes the request and sends back the response to the HTTP client after which the client disconnects the connection. The connection between client and server exist only during the current request and response time only.
- **Media independent:** HTTP protocol is a media independent as data can be sent as long as both the client and server know how to handle the data content. It is required for both the client and server to specify the content type in MIME-type header.
- **Stateless:** HTTP is a stateless protocol as both the client and server know each other only during the current request. Due to this nature of the protocol, both the client and server do not retain the information between various requests of the web pages.

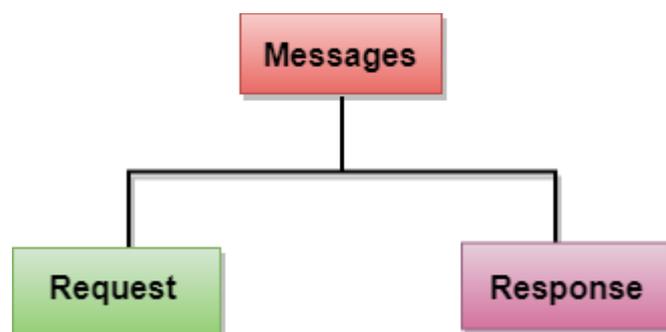
### HTTP Transactions



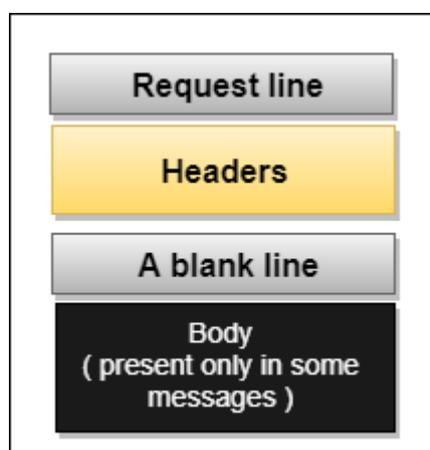
The above figure shows the HTTP transaction between client and server. The client initiates a transaction by sending a request message to the server. The server replies to the request message by sending a response message.

### Messages

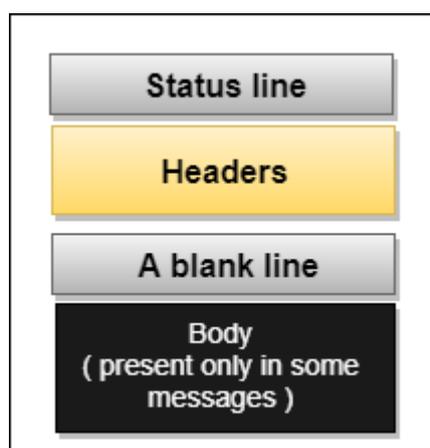
HTTP messages are of two types: request and response. Both the message types follow the same message format.



**Request Message:** The request message is sent by the client that consists of a request line, headers, and sometimes a body.



**Response Message:** The response message is sent by the server to the client that consists of a status line, headers, and sometimes a body.



### Uniform Resource Locator (URL)

- A client that wants to access the document in an internet needs an address and to facilitate the access of documents, the HTTP uses the concept of Uniform Resource Locator (URL).
- The Uniform Resource Locator (URL) is a standard way of specifying any kind of information on the internet.

- The URL defines four parts: method, host computer, port, and path.



- **Method:** The method is the protocol used to retrieve the document from a server. For example, HTTP.
- **Host:** The host is the computer where the information is stored, and the computer is given an alias name. Web pages are mainly stored in the computers and the computers are given an alias name that begins with the characters "www". This field is not mandatory.
- **Port:** The URL can also contain the port number of the server, but it's an optional field. If the port number is included, then it must come between the host and path and it should be separated from the host by a colon.
- **Path:** Path is the pathname of the file where the information is stored. The path itself contain slashes that separate the directories from the subdirectories and files.

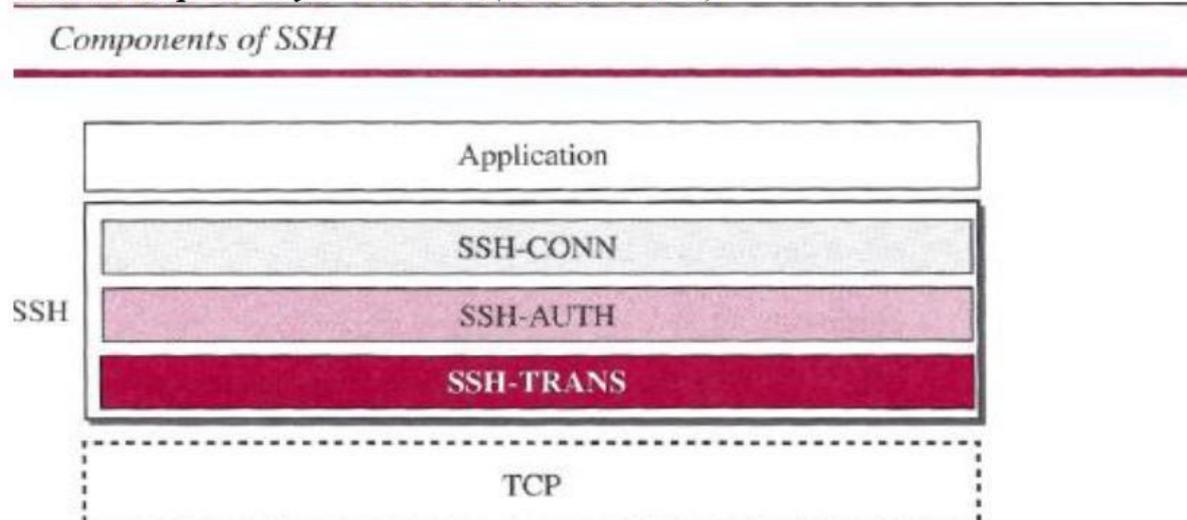
## SECURE SHELL (SSH)

Secure Shell (SSH) is a secure application program that can be used today for several purposes such as remote logging and file transfer; it was originally designed to replace TELNET.

There are two versions of SSH: SSH-1 and SSH-2

### Components

#### *SSH Transport-Layer Protocol (SSH-TRANS)*



## ***SSH Transport-Layer Protocol (SSH-TRANS)***

SSH first uses a protocol that creates secured channel on top of the TCP. When the procedure implementing this protocol is called, the client and server first use the TCP protocol to establish an insecure connection.

### *SSH Authentication Protocol (SSH-AUTH)*

- After a secure channel is established between the client and the server and the server is authenticated for the client
- SSH can call another procedure that can authenticate the client for the server. The client authentication process in SSH is very similar to what is done in Secure Socket Layer (SSL)
- The request includes the user name, server name, the method of authentication, and the required data.

The server responds with either a success message, which confirms that the client is authenticated, or a failed message

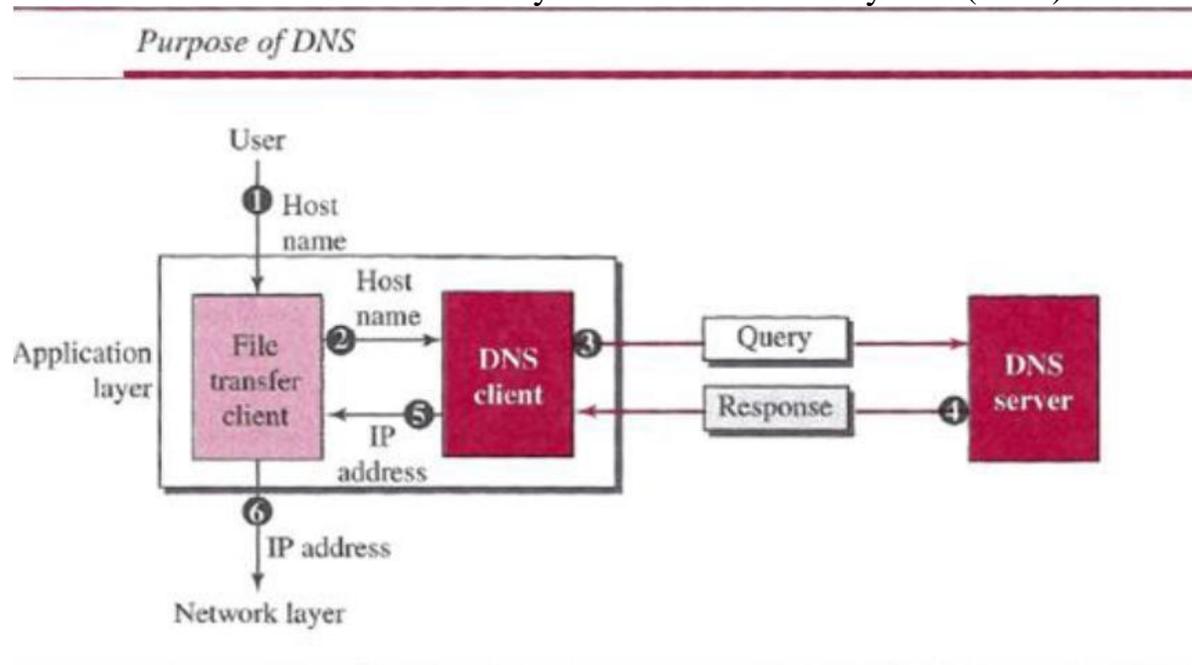
## ***SSH Connection Protocol (SSH-CONN)***

One of the services provided by the SSH-CONN protocol is multiplexing. SSH-CONN takes the secure channel established by the two previous protocols and lets the client create multiple logical channels over it.

Each channel can be used for a different purpose, such as remote logging, file transfer, and so on

## **DOMAIN NAME SYSTEM (DNS)**

The host that needs mapping can contact the closest computer holding the needed information. This method is used by the Domain Name System (DNS).



A user wants to use a file transfer client to access the corresponding file transfer

server running on a remote host.

The user knows only the file transfer server name, such as *afileservice.com*.

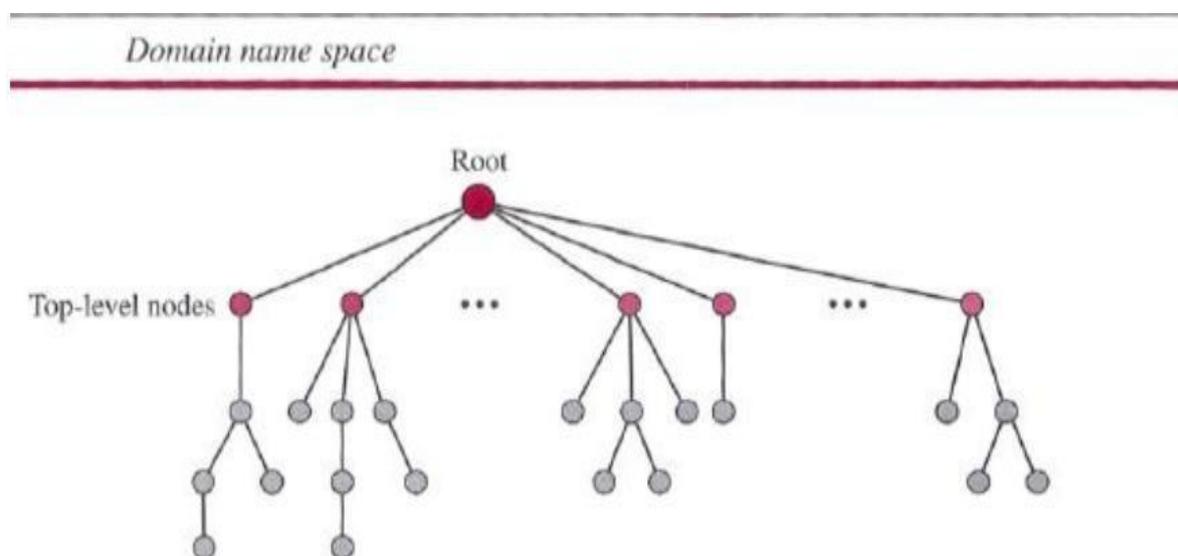
## Name Space

A **name** space that maps each address to a unique name can be organized in two ways: flat or hierarchical.

In a *flat name space*, a name is assigned to an address. A name in this space is a sequence of characters without structure.

In a *hierarchical name space*, each name is made of several parts.

## Domain Name Space



## Domain Name Space

To have a hierarchical name space, a domain name space was designed. In this design the names are defined in an inverted-tree structure with the root at the top.

## Label

Each node in the tree has a label, which is a string with a maximum of 63 characters. The root label is a null string (empty string).

## Domain Name

If a label is terminated by a null string, it is called a fully qualified domain name (FQDN).

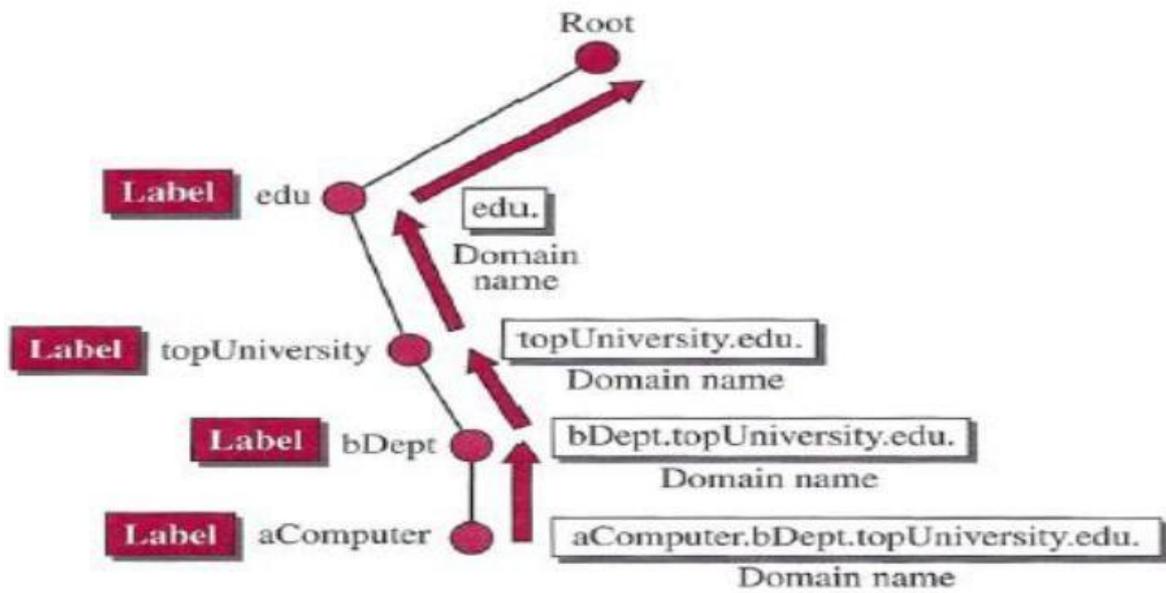
If a label is not terminated by a null string, it is called a partially qualified domain name (PQDN).

## Domain

A domain is a sub tree of the domain name space. The name of the domain is the name of the node at the top of the sub tree.

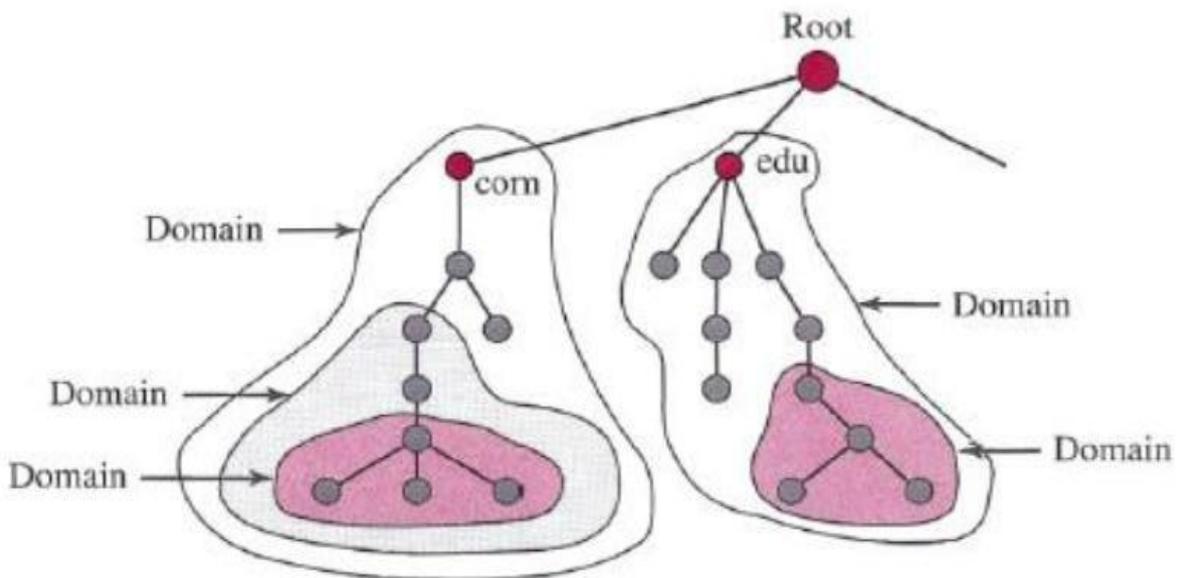
## Domain names and labels

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## Domains

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## *Distribution of Name Space*

The information contained in the domain name space must be stored. However, it is very inefficient and also not reliable to have just one computer store such a huge amount of information. It is inefficient because responding to requests from all over the world places a heavy load on the system it is not reliable because any failure makes the data inaccessible.

## *Zone*

Since the complete domain name hierarchy cannot be stored on a single server, it is divided among many servers. What a server is responsible for or has authority over is called a *zone*.

The server makes a database called a *zone file* and keeps all the information for every node under that domain.

## *Zone*

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