JEPPIAAR INSTITUTE OF TECHNOLOGY

"Self-Belief | Self Discipline | Self Respect"

DEPARTMENT

OF

ELECTRONICS AND COMMUNICATION ENGINEERING

LECTURE NOTES

EC8551– Communication Networks

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Application Layer Paradigms – Client Server Programming – World Wide Web and HTTP - DNS- - Electronic Mail (SMTP, POP3, IMAP, MIME) – Introduction to Peer to Peer Networks – Need for Cryptography and Network Security – Firewalls.

Applications

- Applications are part network protocol - exchange messages with their peers on other machines.
- traditional application program - interact with the windowing system, the file system, and ultimately, the user.
- explores some of the most popular network applications available today.

Types of Applications

- Traditional Applications
- Multimedia Applications
- Infrastructure Services
- Overlay Networks

5.1 TRADITIONAL APPLICATIONS

- Two of the most popular—

->The World Wide Web and

->Email.

- These applications use the request/reply paradigm.
- users send requests to servers, which then respond accordingly.

Difference Between Application Protocol and Application Program

- The HTTP is an application protocol that is used to retrieve Web pages from remote servers.
- Many different application programs—that is, Web clients like Internet Explorer, Chrome, Firefox, and Safari etc.
- Provide users with a different look and feel, but all of them use the same HTTP protocol to communicate with Web servers over the Internet.

Application Protocol

- Two very widely-used, standardized application protocols:

SMTP: Simple Mail Transfer Protocol is used to exchange electronic mail.

HTTP: Hyper Text Transport Protocol is used to communicate between Web browsers and Web servers.

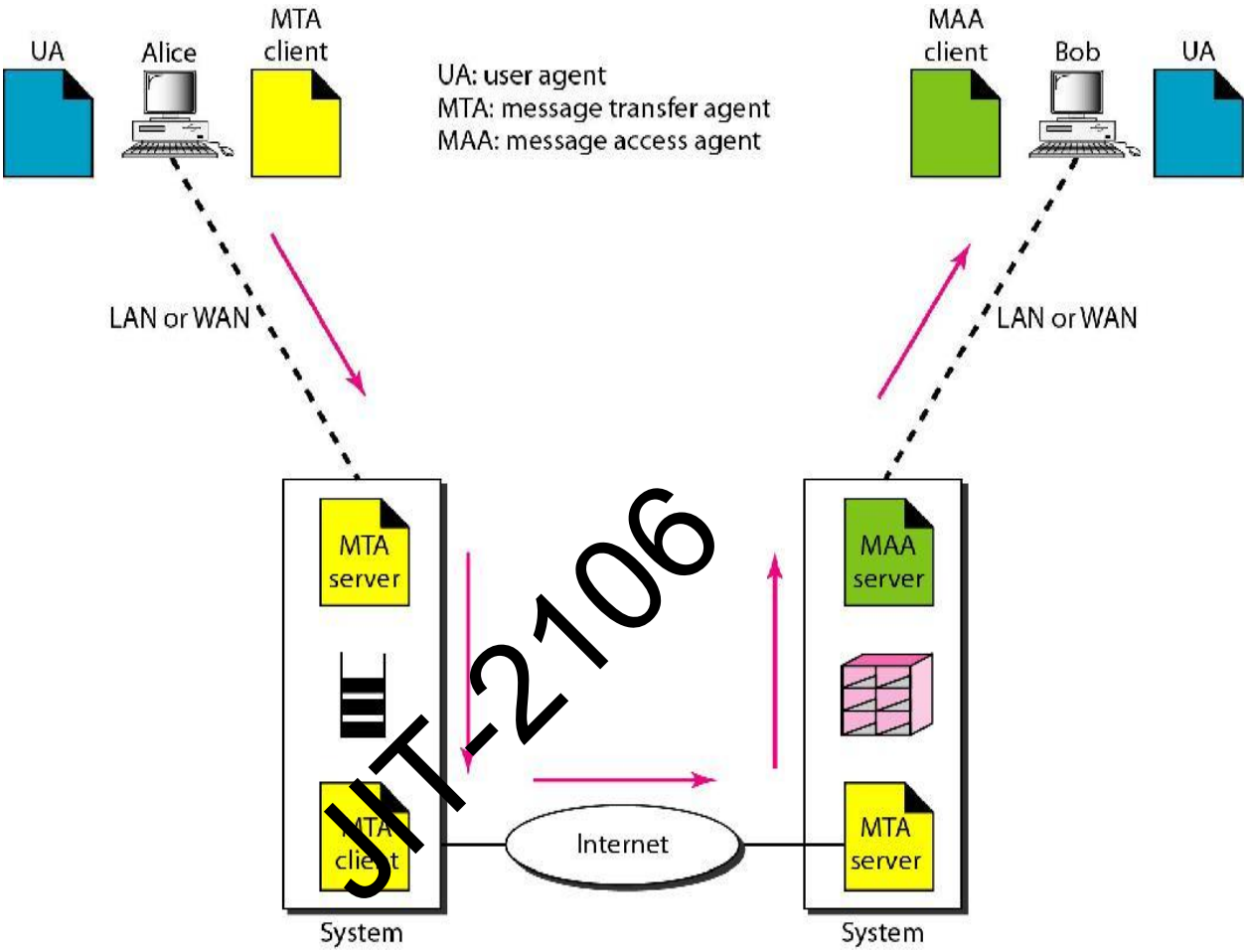
5.2 ELECTRONIC MAIL –SMTP, MIME, IMAP

- Electronic Mail (SMTP, MIME, IMAP)
- Email is one of the oldest network applications
- Distinguish the user interface (i.e., your mail reader) from the underlying message transfer protocols -SMTP or IMAP
- Distinguish between this transfer protocol and a companion protocol - defines the format of the messages being exchanged - MIME

5.2.1 E-Mail System

User Agent

- Software that is either command (eg. pine, elm) or GUI based (eg. Microsoft Outlook, Netscape).
- Compose : helps to compose messages
- Read : checks mail in the incoming box and provides information such as sender, size, subject and flag (read, new).
- Reply : allows user to reply back to sender
- Forward : forwarding message to a third party.



Mailboxes creates two mailboxes for each user, namely inbox (to store received emails) and outbox (to keep all sent mails).

- From - user who sent the message
- To - identifies the message recipient(s).
- Subject- Purpose of the message
- Date - when the message was transmitted
- E-mail address consists of user_name@domain_name where domain_name is hostname of the *mail server*.
- The body of the message contains the actual information
- Languages - French, German, Chinese, Japanese were not supported.

Message Transfer

- For many years, the majority of email was moved from host to host using only SMTP.
- While SMTP continues to play a central role, it is now just one email protocol of several operations
- IMAP and POP3 being two other important protocols for retrieving mail messages.
    - To place SMTP in the right context, we need to identify the key players.
    - First, users interact with a mail reader *when they compose, file, search, and read their email.*
    - In the early days of the Internet, users typically logged into the machine on which their mailbox resided and the mail reader they invoked was a local application program that extracted messages from the file system.
    - Today, of course, users remotely access their mailbox from their laptop or smart phone; they do not first log into the host that stores their mail (a mail server).

5.2.2 MIME

- MIME is a supplementary protocol that allows non-ASCII data to be sent through e-mail.
- MIME transforms non-ASCII data to NVT ASCII and delivers to client MTA.
- MIME defines five headers. They are:
- Version, Content Type, Content transfer Encoding , Content id, Content Description

Message Format

- RFC 822 defines messages to have two parts: a header and a body. Both parts are represented in ASCII text.
- RFC 822 has been augmented by MIME to allow the message body to carry all sorts of data.
- This data is still represented as ASCII text, but because it may be an encoded version .(JPEG image) it's not necessarily readable by human users.
- Many of these header lines are familiar to users - when they compose an email message.
- RFC 822 was extended in 1993 to allow email messages to carry many different types of data: audio, video, images, PDF documents, and so on.

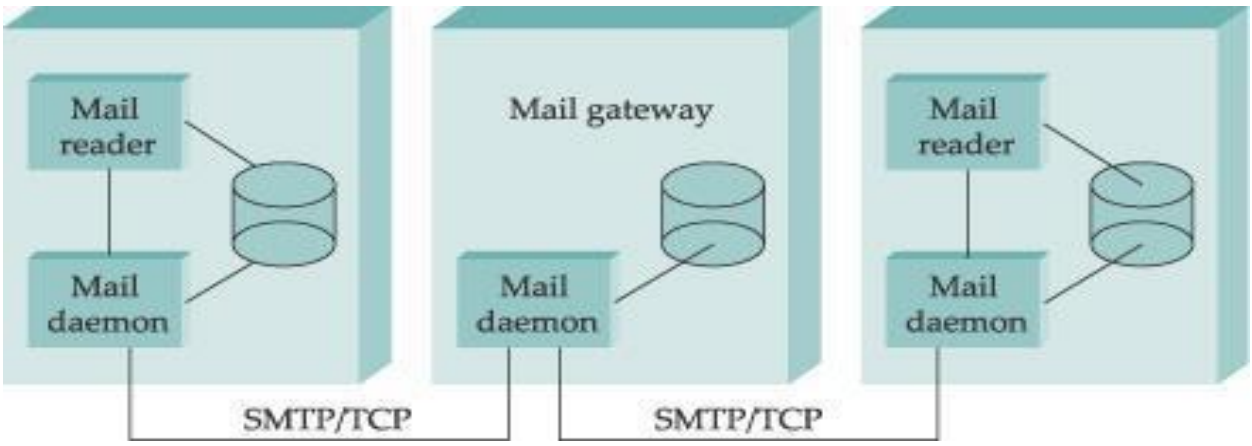
MIME Message Format

- MIME Version : version of MIME being used.
- Content-Description : a human-readable description of what's in the message, and describes type of the message body.
- Content-Type: type of data in message.
- Content-Transfer- Encoding :how the data in the message body is encoded.
- Content id : unique identifier the whole message in a multiple message type.

Example

- MIME-Version: 1.0
- Content-Type: multipart/mixed; boundary="--------417CA6E2DE4ABCAFBC5" From: Alice Smith <Alice@cisco.com>
- To: Bob@cs.Princeton.edu Subject: promised material
- Date: Mon, 07 Sep 1998 19:45:10 -0400
- ---------417CA6E2DE4ABCAFBC5 Content-Type: text/plain; charset=us-ascii Content-Transfer-Encoding: 7bit
- ---------417CA6E2DE4ABCAFBC5 Content-Type: image/jpeg Content-Transfer-Encoding: base64

Sequence of Mail Gateway



- SMTP uses TCP connection on port 25 to forward the entire message and store at intermediate mail servers/mail gateways until it reaches the recipient mail server.

SMTP Commands and Response

Command	Description
MAIL FROM	Sender of the message
RCPTTO	Recipient of the message
DATA	Body of the mail
QUIT	Terminate
VRFY	Name of recipient to be verified before forwarding
EXPN	Mailing list to be expanded

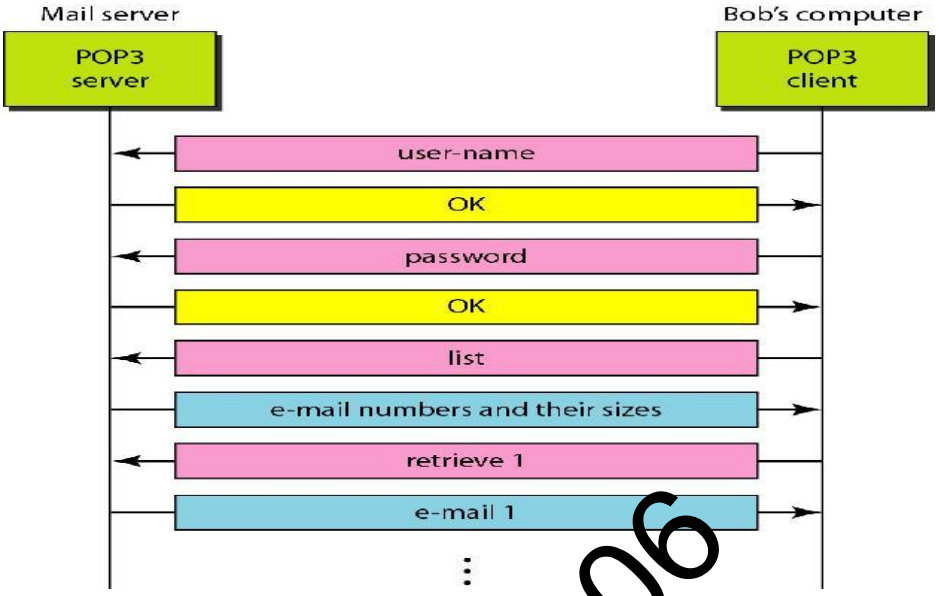
Common Responses from MTA

Code	Description
220	Service ready
250	Request completed
354	Start mail input
450	Mailbox not available
500	Syntax error; unrecognized command
551	User not local

Message Access Agent- POP&IMAP

- MAA or mail reader allows user to retrieve messages from the mailbox, so that user can perform actions such as reply, forwarding, etc.
- The two message access protocols are:
- Post Office Protocol, version 3 (POP3)
- Internet Mail Access Protocol, version 4 (IMAP4)
- SMTP is a push type protocol whereas POP3 and IMAP4 are pop type protocol.

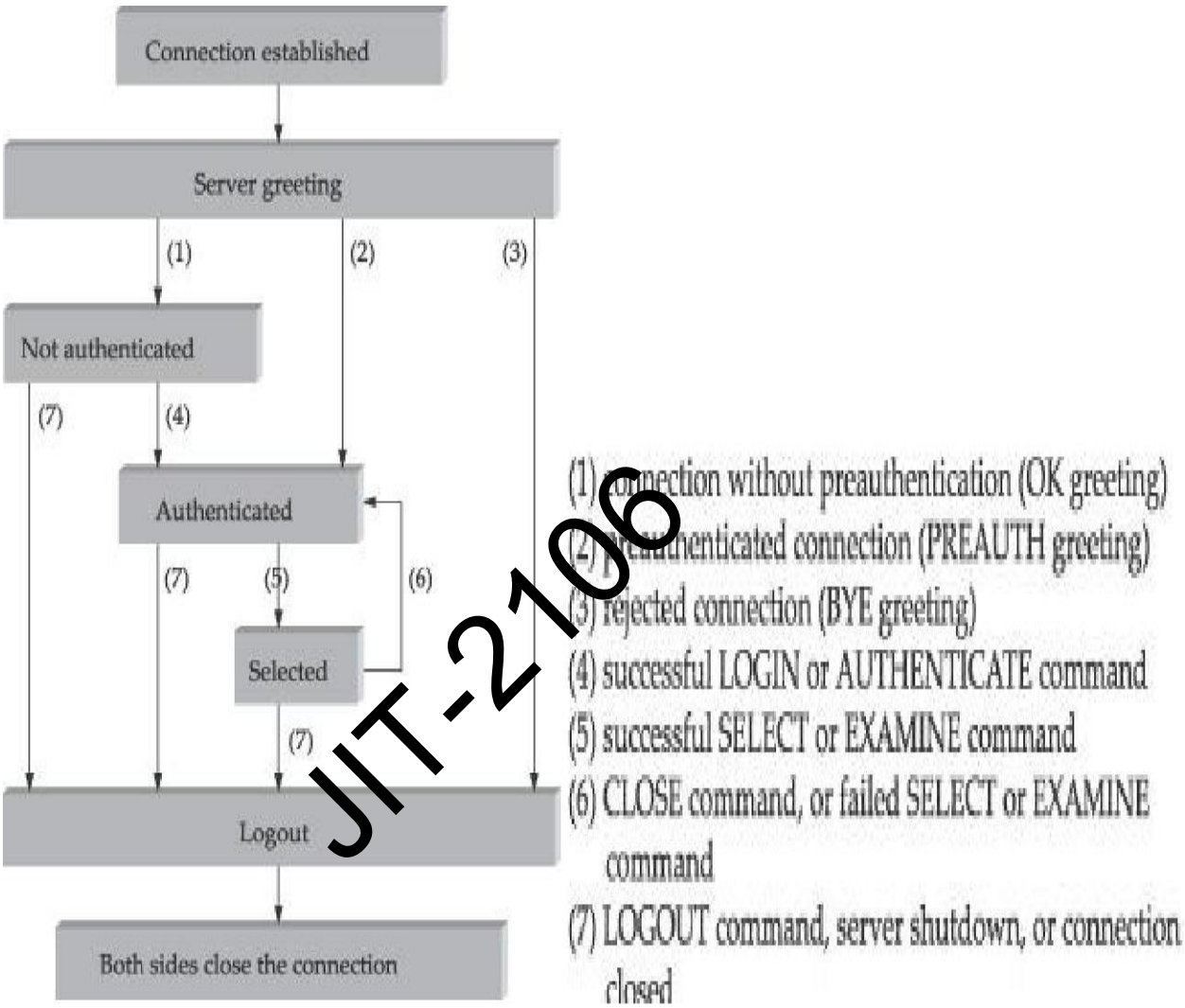
5.2.4 POP 3



- POP3 works in two modes namely, delete and keep mode.
- In delete mode, mail is deleted from the mailbox after retrieval
- In keep mode, mail after reading is kept in mailbox for later retrieval.

5.2.5 IMAP 4

- IMAP is a client/server protocol running over TCP. The client issues commands and the mail server responds.
- The exchange begins with the client authenticating itself to access the mailbox.
- When the user asks to FETCH a message, server returns it in MIME format and the mail reader decodes it.


Connection established
Server greeting
(1)
(2)
(3)
Not authenticated
(7)
(4)
Authenticated
(7)
(5)
(6)
Selected
(7)
Logout
Both sides close the connection
(1) connection without preauthentication (OK greeting)
(2) preauthenticated connection (PREAUTH greeting)
(3) rejected connection (BYE greeting)
(4) successful LOGIN or AUTHENTICATE command
(5) successful SELECT or EXAMINE command
(6) CLOSE command, or failed SELECT or EXAMINE command
(7) LOGOUT command, server shutdown, or connection closed

5.3 WORLD WIDE WEB

- It has made the Internet accessible to so many people that sometimes it seems to be synonymous with the Internet.
    - The original goal of the Web was to find a way to organize and retrieve information, drawing on ideas about hypertext, interlinked documents
    - Hypertext is that one document can link to another document, and the protocol (HTTP) and document language (HTML) were designed to meet that goal.
    - if you want to organize information into a system of linked documents or objects, you need to be able to retrieve one document to get started.
    - any Web browser has a function that allows the user to obtain an object by "opening a URL."
    - They provide information that allows objects on the Web to be located, and they look like the following:
        - http://www.annauniv.edu/index.html
    - If you opened that particular URL, your Web browser would open a TCP connection to the Web server at a machine called www.cs.princeton.edu and immediately retrieve and display the file called index.html.
    - When you ask your browser to view a page, your browser (the client) fetches the page from the server using HTTP running over TCP.
    - Like SMTP, HTTP is a text oriented protocol.
    - At its core, HTTP is a request/response protocol, where every message has the general form

      START_LINE <CRLF> MESSAGE_HEADER <CRLF>

      <CRLF> MESSAGE_BODY <CRLF>
    - START LINE indicates whether this is a request message or a response message.

5.3.1 URL

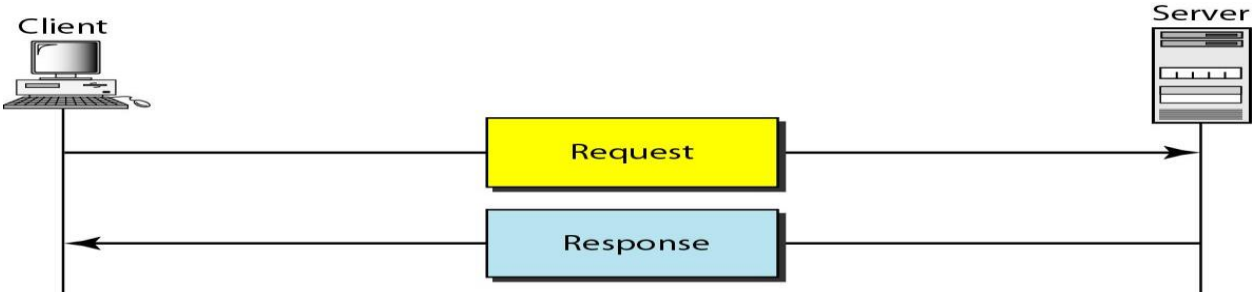
- A URI is a character string that identifies a resource, where a resource can be anything that has identity, such as a document, an image, or a service.
- The first part of a URI is a *scheme* - identifying a certain kind of resource, such as mailto for email addresses or file for file names.

5.4 HTTP Protocol

- WWW is a distributed client/server service, in which a client (web browser) can access a service through a server.
- Web browsers allow to access files URL.
- When user enters URL, the browser forms a request message and sends to the server.
- The server retrieves the requested URL and sends it as a response message. The browser displays the response in HTML / appropriate format.

5.4.1 HTTP Request Operations

Operation	Description
OPTIONS	Request information about available options
GET	Retrieve document identified in URL
HEAD	Retrieve metainformation about document identified in URL
POST	Give information (e.g., annotation) to server
PUT	Store document under specified URL
DELETE	Delete specified URL
TRACE	Loopback request message
CONNECT	For use by proxies

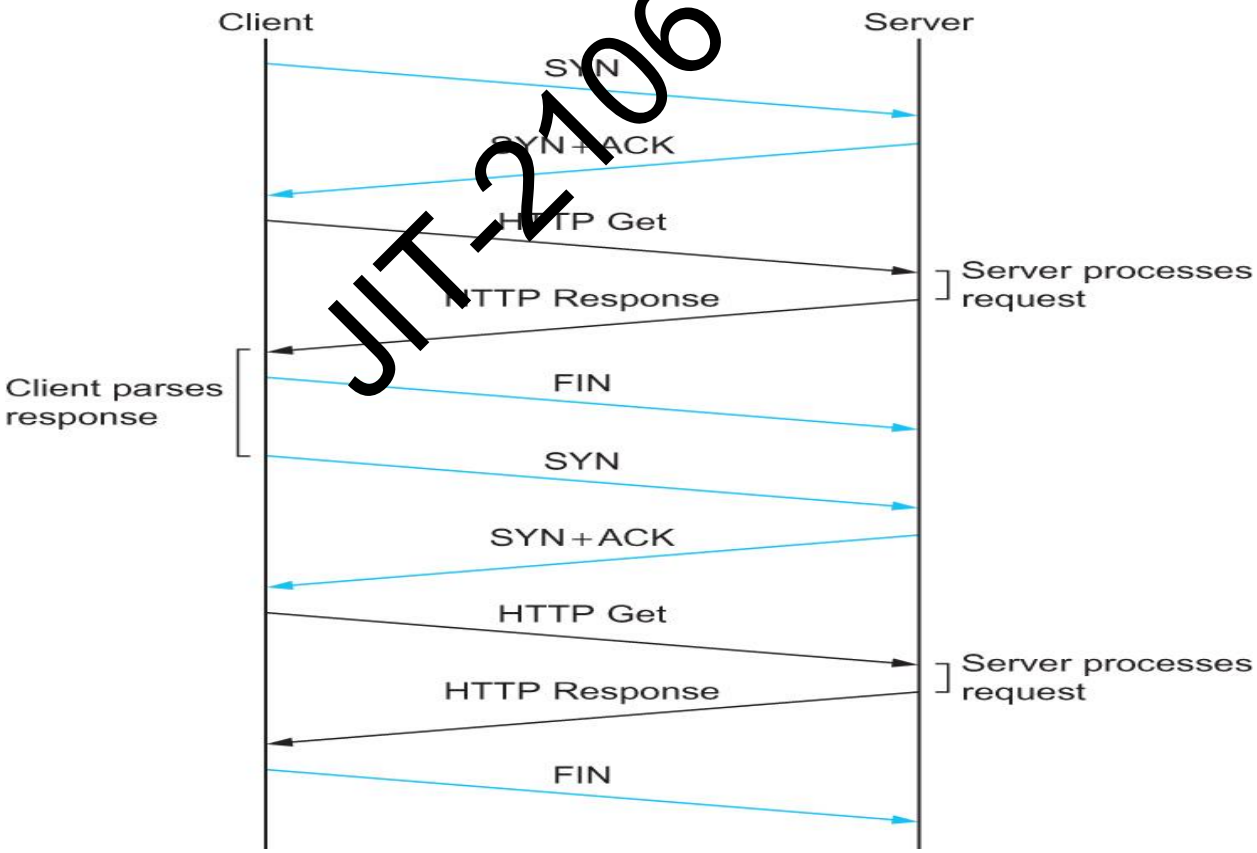


Request Type URL HTTP version

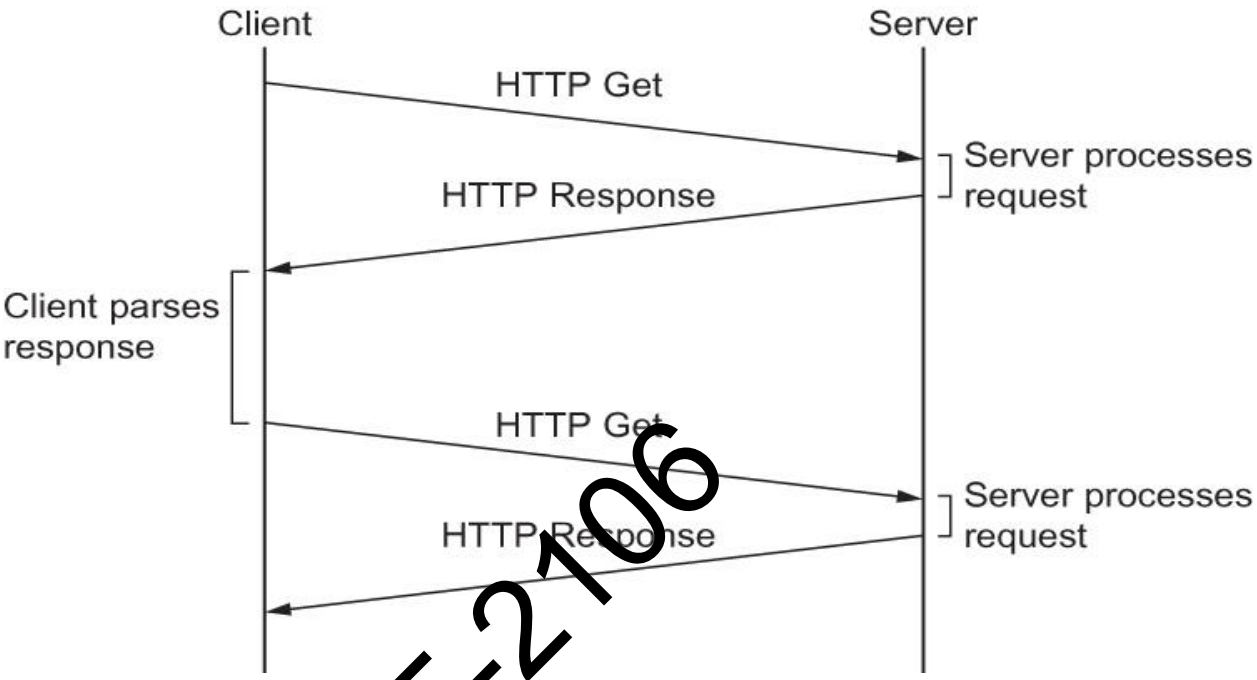
5.4.3 TCP Connections

- The original version of HTTP (1.0) established a separate TCP connection for each data item retrieved from the server.
- Retrieving a page that included some text and a dozen icons or other small graphics would result in 13 separate TCP connections being established and closed.
- To overcome this situation, HTTP version 1.1 introduced *persistent connections*— the client and server can exchange multiple request/response messages over the same TCP connection.

TCP Connections in HTTP - Non – Persistent Connections



Persistent Connection in HTTP



Caching

- Caching enables the client to retrieve document faster and reduces load on the server.
- Proxy server is a host that keeps copies responses to recent requests. The client sends request to the proxy server. The proxy server either responds to client or forwards the request to the server.
- Therefore prior to caching a page, its expiration date is checked. If a cached page reaches its expiration, then the page is deleted.

Web Services

- Enabling direct application-to-application communication comes from the business world.
- Interactions between enterprises—businesses or other organizations—have involved some manual steps such as filling out an order form or making a phone call to determine whether some product is in stock.
- Even within a single enterprise it is common to have manual steps between software systems that cannot interact directly because they were developed independently.

- An ordering application at enterprise A would send a message to an order fulfillment application at enterprise B, which would respond immediately indicating whether the order can be filled.
- Both architectures SOAP and REST are called *Web Services*, taking their name from the term for the individual applications that offer a remotely-accessible service to client applications to form network applications.
- REST - Web Services as WWW resources—identified by URIs and accessed via HTTP.

5.4.4 Custom Application Protocol (WSDL ,SOAP)

- Web services Description Language
- Simple Object Access Protocol
- Implementing transport and Application Protocol
- Defining Application Protocol
- Message Exchange Pattern (Hotel Reservation)
- Defining Transport Protocol
- Message Framework ,Format using XML Schema
    - SOAP Features Like

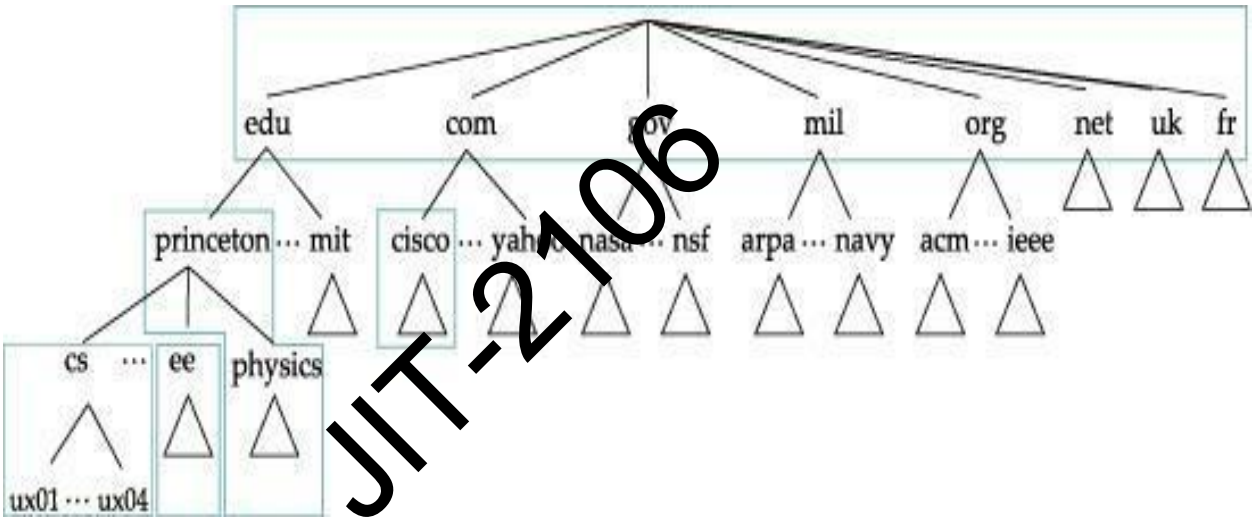
Reliability, Security, Correlation,Routing,MEP such as Request/Response, One-way and peer to peer conversation.

SOAP features specification include

- A URL identifies the feature
- The state information &Processing Abstractly described.
- The information to be relayed to the next node.
- REST- Representational State Transport

5.5 DNS – DOMAIN NAME SYSTEM

- The name service is used to translate host names into host addresses.
- Application allows the users of other applications to refer to remote hosts by name rather than by address.
- unique name is also typically assigned to each host in a network.
- Mapping of host names to machine's IP



- DNS names are processed from right to left and use *periods* (.) as separator.
- DNS can be used to map names to values, not necessarily domain names to IP address.

5.5.1 Name Service

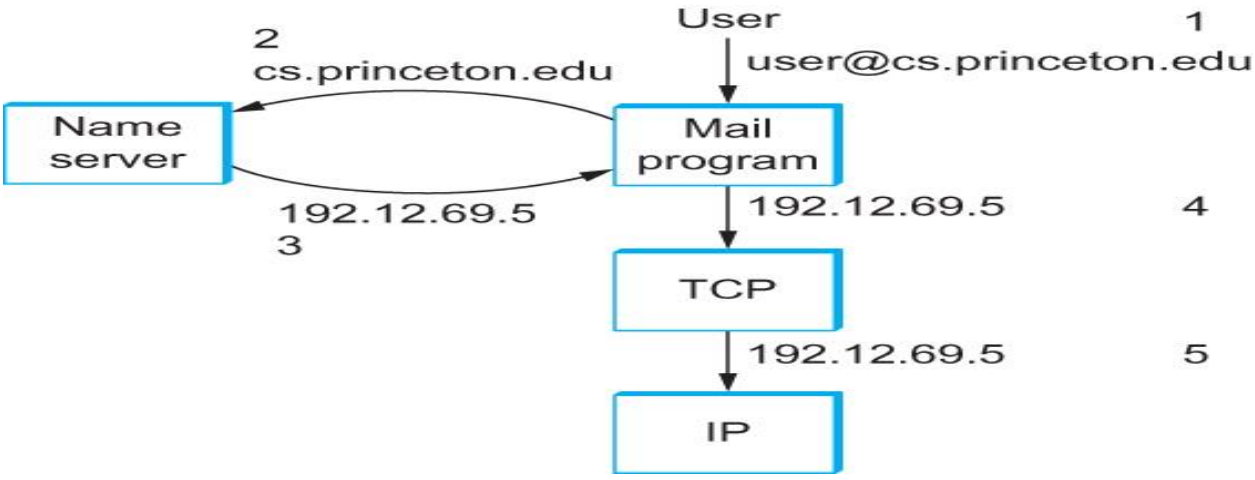
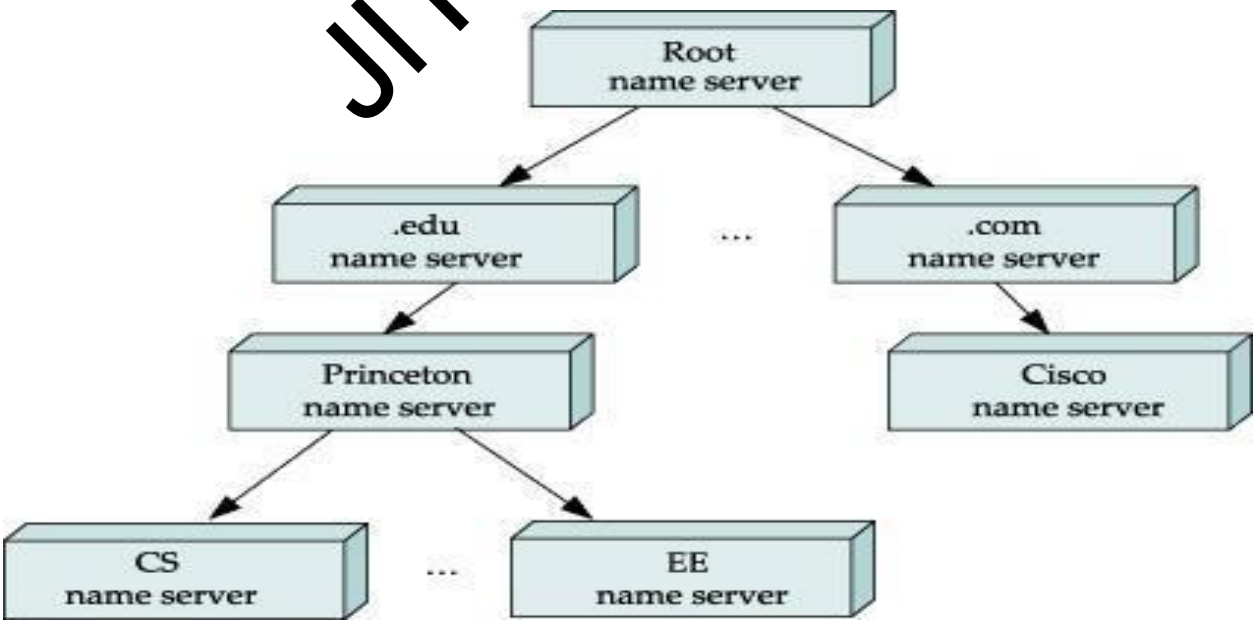


Figure : Names translated into addresses, where the numbers 1–5 show the sequence of steps in the process

Name Server

- The first step is to partition the hierarchy into sub trees called *zones.*
- Each zone can be thought of as corresponding to some administrative authority that is responsible for that portion of the hierarchy.
- For example, the top level of the hierarchy forms a zone that is managed by the Internet Corporation for Assigned Names and Numbers (ICANN).
- Topmost domains are managed by NIC. Each zone acts as *central* authority for that part of the sub-tree.
- In the .edu hierarchy, *princeton* is a zone.
- Each zone can be further sub-divided that manage using their own name servers such as CS department under princeton university.



- A network is a complex system-the number of nodes that are involved .
- The nodes within a single administrative domain, such as a campus, there might be dozens of routers and hundreds—or even thousands—of hosts to keep track of.

5.6 SNMP

- SNMP is a framework for managing devices in an internet using TCP/IP.
- A manager is a host that runs the SNMP client program.
- A managed station called an agent, is a router that runs the SNMP server program SNMP is an application layer protocol
- SNMP management includes:
- A manager forces an agent to perform a task by setting/resetting values in the agent database.

1.Structure of Management Information -SMI

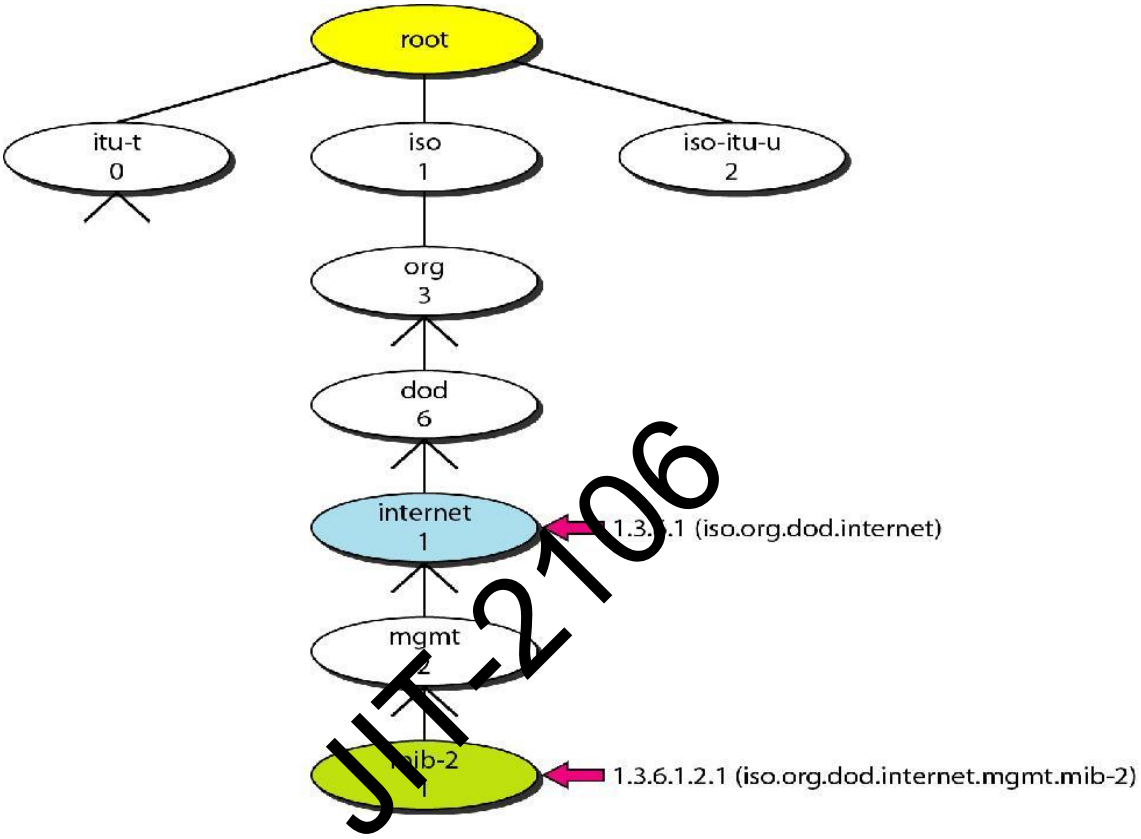
2.Management Information Base-MIB

- Define format of the packet to be sent from a manager to an agent .
- Interprets the result and creates statistics
- Responsible for reading and setting object

The role of SMI is to

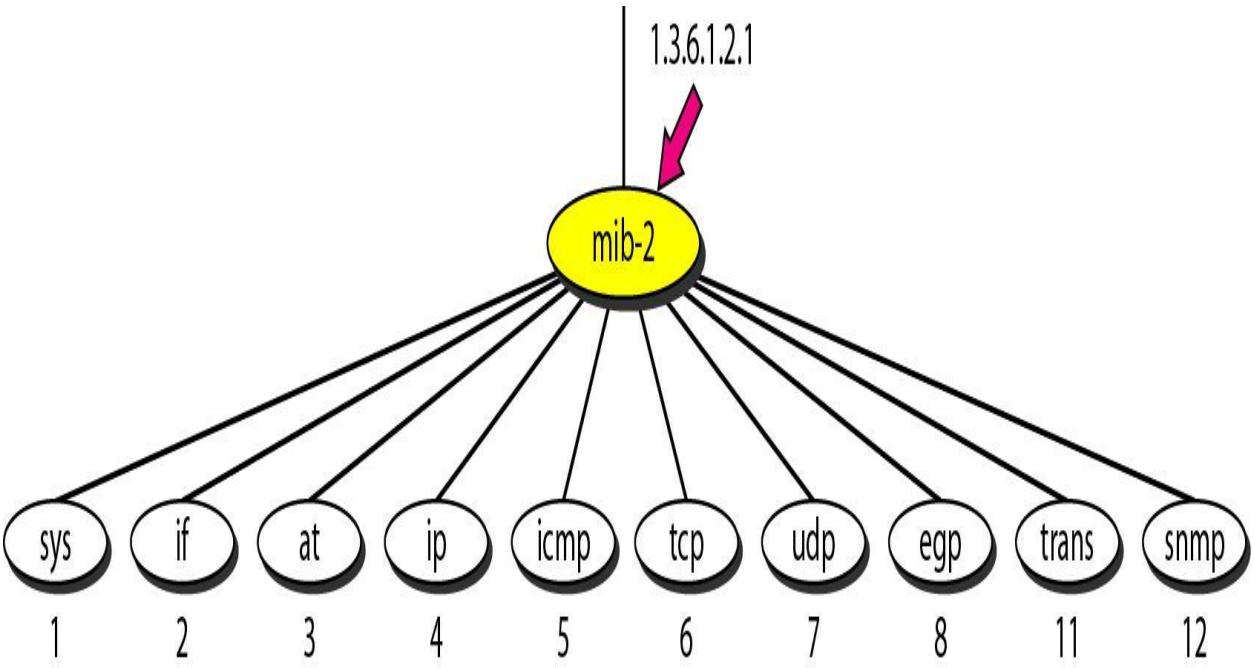
- Define rules for naming objects and object types.
- Uses Basic Encoding Rules to encode data to be transmitted over the network.
- The role of MIB is to
- creates a collection of named objects, their types, and their relationships to each other in an entity to be managed

5.6.1 Object Identifier



5.6.2 MIB Groups

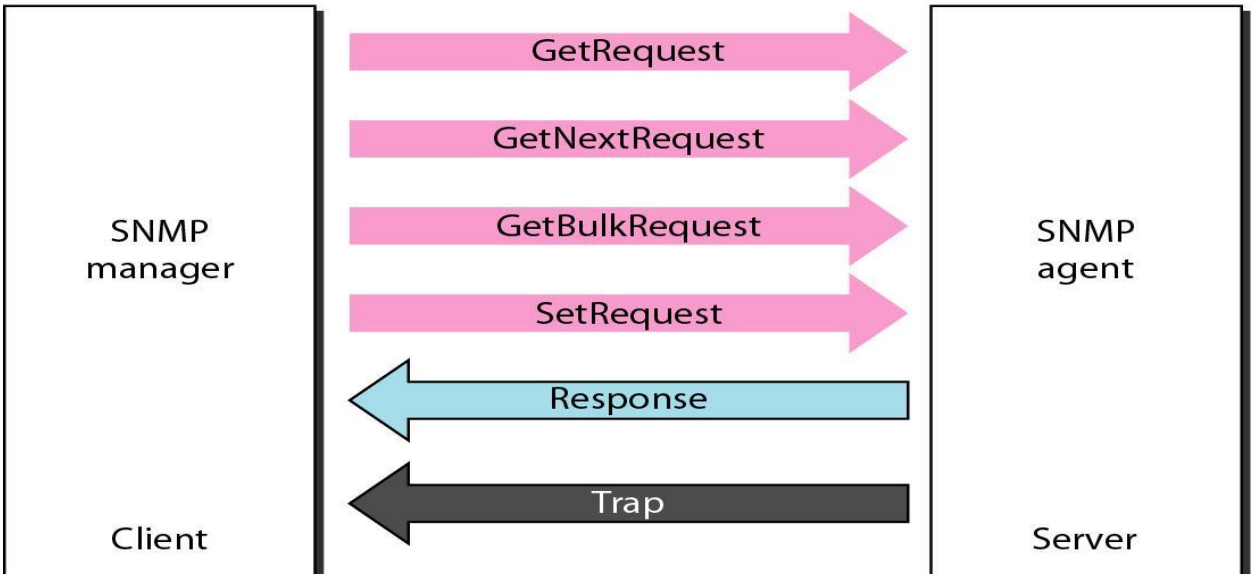
- system, interface, address translation, ip, icmp, tcp, udp, egp, transmission, and snmp.



- System – name, location and lifetime of node
- Interface- Physical and IP address
- Address Translation- ARP Table
- IP- Routing table, Datagram forwarding, drop
- TCP-Connection table, time out, no of ports
- UDP- Total no of UDP packet sent & Received
- Transmission
- SNMP-Network Management

5.6.3 SNMPv3 PDU

- SNMP is request/reply protocol that defines PDUs GetRequest, GetNextRequest,
- GetBulkRequest, SetRequest, Response and Trap.



- GetRequest : used by manager to retrieve value of agent's variable(s)
- GetNextRequest : to retrieve next entries in a agent's table

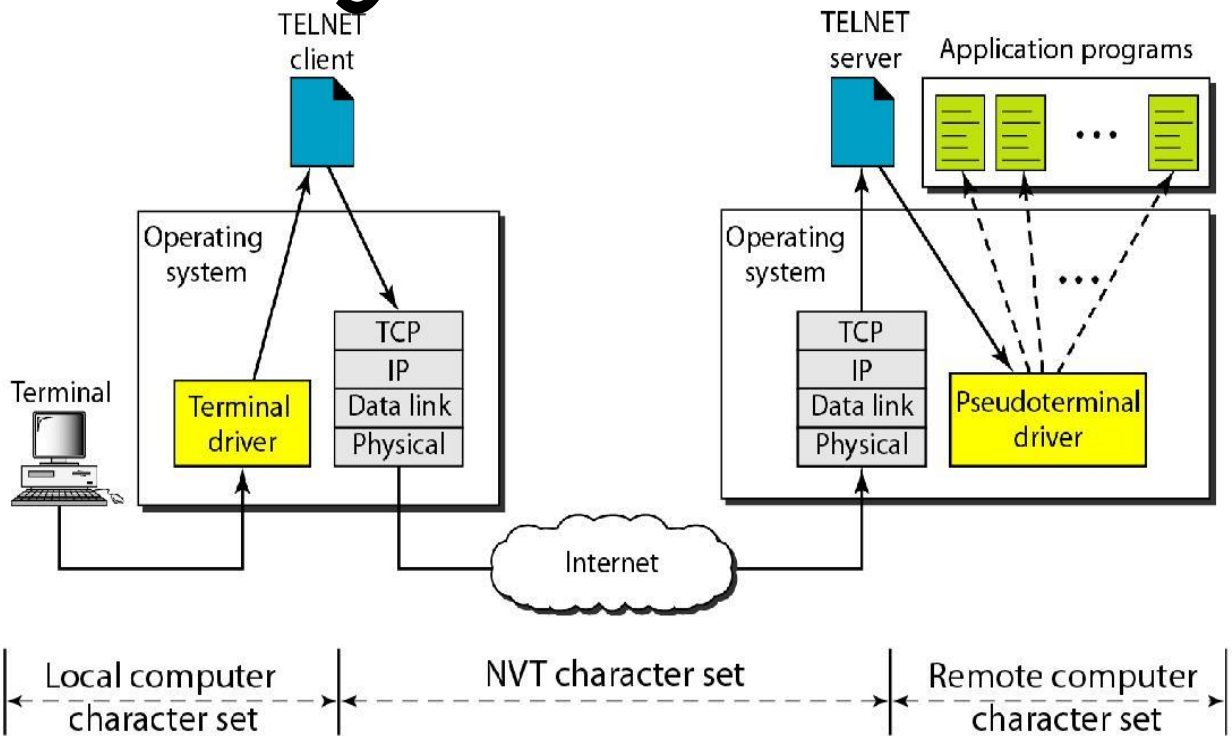
- SetRequest: to set value of an agent's variable
- Response : sent from an agent to manager in response to GetRequest/ GetNextRequest that contains value of variables
- Trap : sent from an agent to the manager to report an event such as reboot.

5.6.4 TELNET

- Terminal NETwork -general-purpose client/server application program.
- TELNET is the standard TCP/IP protocol for virtual terminal.
- TELNET enables connection to a remote system .
- TELNET was designed during days of time-sharing environment in which a large computer supported multiple users.
- Each user has an identification name and a password. To access, user id / log-in name.

Remote Login

- The user keystrokes are sent to the terminal driver, where the local operating system accepts the characters but does not interpret them.



- The characters are sent to the TELNET *client*, which transforms the characters to a universal character set called Network Virtual Terminal (NVT) characters and puts it over the network.

NVT Character set

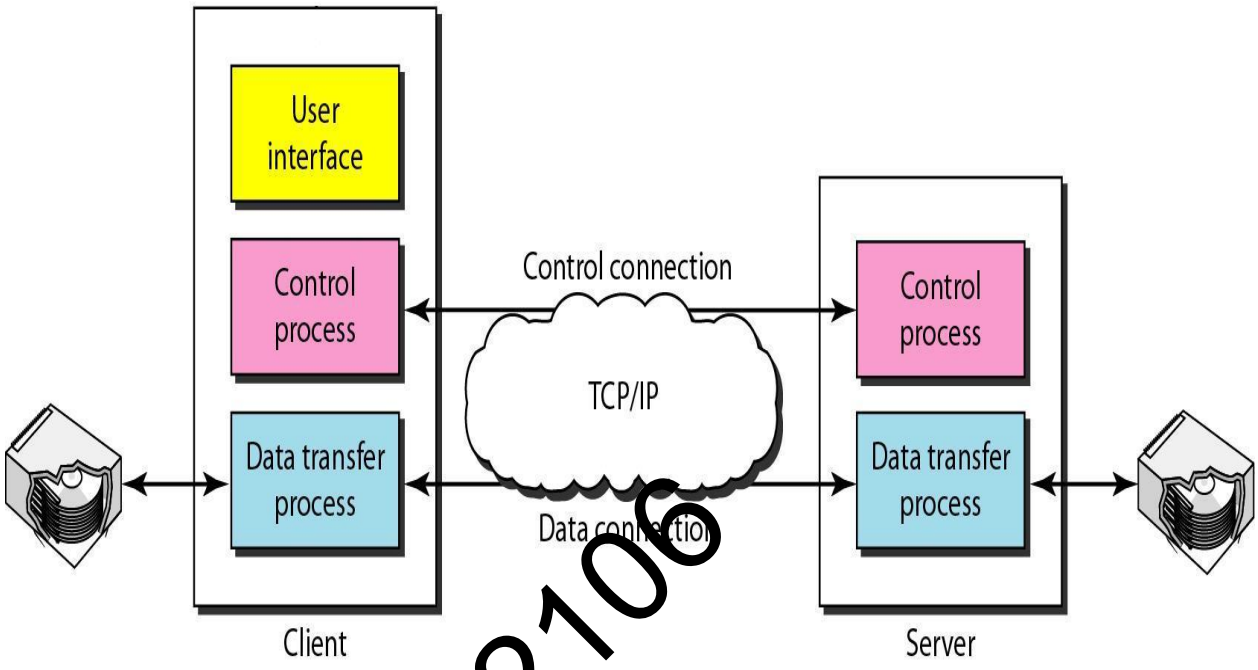
Character	Purpose
EOF	End of file
EOR	End of record
IP	Interrupt process
AYT	Are you there
EC	Erase character
EL	Erase line
IAC	Interrupt as control

5.6.5 Options and Modes

- TENET operate in three modes namely default, character and line mode.
- Default mode -the client sends characters only after the line is typed.
- character mode- each character typed is sent by the client to the server.
- Line mode-line editing is done by the client and sends after a line is typed

Options	Purpose
Echo	Echo the received data to the sender
Status	Request the status of TELNET
Line mode	Change to line mode.

5.6.6 FTP



- File Transfer Protocol (FTP) is the standard provided by TCP/IP for copying a file from one host to another.
- FTP establishes two connections between hosts
- *Data* connection is used for data transfer
- *Control* connection is used for control information.
- FTP uses two well-known TCP ports, 21 for control and 20 for data connection.

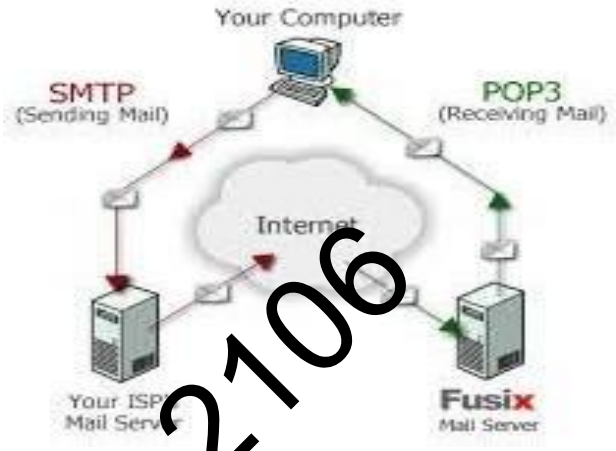
Control Connection

- FTP uses 7-bit NVT ASCII character set to communicate across the control connection.
- Communication is achieved through commands and responses.
- When a user starts an FTP session, the control connection opens.
- While the control connection is open, the data connection can be opened and closed multiple times if several files are transferred.

UNIT V

APPLICATION LAYER

Traditional Applications:



Electronic Mail: SMTP

Major application layer components

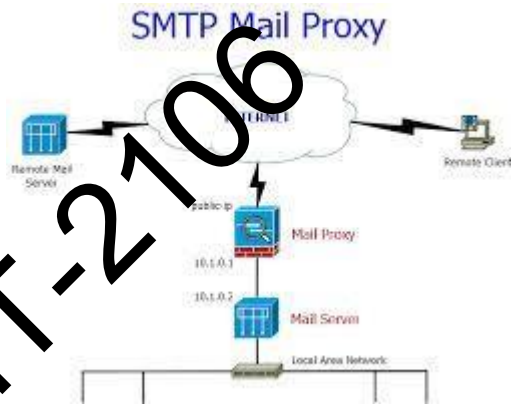
- user agent : the software you use to read, compose, and organize email
- mail server : the server that interacts with user agents and other mail servers to deliver and store email
- Snail-mail analogy: Each post office is a mail server, post boxes are user agents.
- Note that mail server acts as both client and server; client when it sends to another mail server, server when it receives from another mail server
- Mail servers communicate using application layer protocol **SMTP**
- Note that email is "push" oriented, while Web is "pull" oriented

SMTP : Simple Mail Transfer Protocol

- Set of protocols used by mail servers to communicate with each other
- Defined in RFC 2821
- It is old (like 1970s old), and indeed very simple!
- Based on 7-bit ASCII codes (codes 0-127)
- Anything other than ASCII text has to be translated into ASCII by sending server, and back by receiver
- Not fun for transmitting multimedia!
- Basic protocol for message delivery
    1. sender's user agent sends message (M) to sender's mail server (SMS)
    2. SMS places M in its message queue

3. SMS attempts TCP connection with recipient's mail server (RMS)
4. If RMS valid but connection not possible, SMS backs off while and tries again later
5. Once connected, SMS and RMS exchange pleasantries and SMS transmits M to RMS
6. RMS places M into recipient's mailbox, located in RMS.
7. Recipient accesses mailbox via user agent and reads M.

- Protocol takes place in plain text, see textbook example
- Client sends SMTP commands such as HELO, MAIL FROM, RCPT TO, DATA, QUIT
- Server responds to each command with one-liner containing response code and message
- It is possible to spoof being a sending mail server by using port 25 (gotta know the mail server names)



SMTP mail message format

- Message starts with first character sent after receiving code 354 response to DATA command
- Message ends with period character '.' on a line by itself!
- Message consists of header and body, separated by a blank line.
- Header line syntax resembles HTTP header line: attribute then colon then value (e.g. To: PSanderson@otterbein.edu)
- Example header lines are: To:, From:, Subject:
- The header line values are the ones displayed by mail reader
- Note that header lines are not part of SMTP delivery protocol, so you can give them any value!
- **MIME**, MultImedia Mail Extensions, are used to transmit non-ASCII content
    - Header lines describe the content type so receiver knows how to interpret the content
    - The Content-Transfer-Encoding: line tells receiver how original content was translated to ASCII, so it will know how to undo the translation
    - The Content-Type: line tells receiver what kind of content it is: HTML, JPEG, Word document, whatever
    - Receiver's mail agent is responsible for rendering the content

- Multiple MIME components can be included in the same message
- Non-text email message bodies and attachments are both handled this way
- For more info about MIME, see RFC 2045 and RFC 2046

Mail Access Protocols

- Delivery of received message from receiver's mail server to receiver's user agent is a different matter
- For one thing, this final delivery is a "pull" not a "push" operation and SMTP is push-only
- For another, authentication is of utmost importance
- Several such protocols have been defined: **POP3**, **IMAP**, **HTTP**-based
- Post Office Protocol (POP)
    - The original mail access protocol, see RFC 1939
    - Very primitive; only 12 possible commands and little security
    - Server only maintains in-box, any saved-message organization must be performed by the user agent (client), very inflexible
    - Session is established by TCP connection to port 110
    - Session proceeds through several states:
        - AUTHORIZATION - entered upon TCP connect, establish client identity as valid mailbox owner (name and password transmitted in plain text)
        - TRANSACTION - entered upon authorization, interact with server to read/delete messages
        - UPDATE - entered upon QUIT command, resource clean-up on server side and TCP disconnect
    - No information state is maintained between sessions
- Internet Mail Access Protocol (IMAP)
    - Significantly more features, complexity, and security than POP; see see RFC 3501
    - Server maintains user-created folders for organizing and search for messages
    - Maintains state, such as folder organizations, between sessions
    - Like other protocols, uses plain-text commands from client and responses from server
    - Session is based on TCP connection and has several states
    - Here is state-transition diagram, copied directly from RFC 3501

        (1) connection without pre-authentication (OK greeting)
        (2) pre-authenticated connection (PREAUTH greeting)
        (3) rejected connection (BYE greeting)
        (4) successful LOGIN or AUTHENTICATE command
        (5) successful SELECT or EXAMINE command
        (6) CLOSE command, or failed SELECT or EXAMINE command
        (7) LOGOUT command, server shutdown, or connection closed

Simple Mail Transfer Protocol (SMTP)
•Defined in RFC 2821 (April 2001)
–Original definition in RFC 821 (August 1982)
•Designed for:
–Direct transfer from the sender to the receiver
(rather then go through a set of relays)
–Destination system is always up and connected
–Use TCP to transfer email from client to destination server

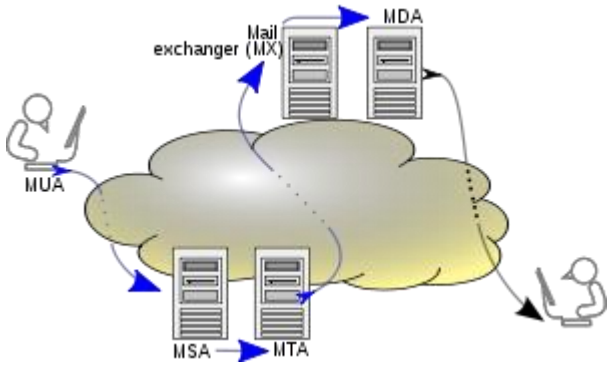
The **SMTP (Simple Mail Transfer Protocol)** protocol is used by the Mail Transfer Agent (MTA) to deliver your eMail to the recipient's mail server. The SMTP protocol can only be used to send emails, not to receive them. Depending on your network / ISP settings, you may only be able to use the SMTP protocol under certain conditions

Simple Mail Transfer Protocol (SMTP) is an Internet standard for electronic mail (email) transmission. First defined by RFC 821 in 1982, it was last updated in 2008 with the Extended SMTP additions by RFC 5321 – which is the protocol in widespread use today.

SMTP by default uses TCP port 25. The protocol for mail submission is the same, but uses port 587. SMTP connections secured by SSL, known as SMTPS, default to port 465 (nonstandard, but sometimes used for legacy reasons).

Although electronic mail servers and other mail transfer agents use SMTP to send and receive mail messages, user-level client mail applications typically use SMTP only for sending messages to a mail server for relaying. For receiving messages, client applications usually use either POP3 or IMAP.

Although proprietary systems (such as Microsoft Exchange and IBM Notes) and webmail systems (such as Outlook.com, Gmail and Yahoo! Mail) use their own non-standard protocols to access mail box accounts on their own mail servers, all use SMTP when sending or receiving email from outside their own systems.



SMTP (Simple Mail Transfer Protocol) is a TCP/IP protocol used in sending and receiving e-mail.

SMTP (Simple Mail Transfer Protocol) is a TCP/IP protocol used in sending and receiving e-mail. However, since it is limited in its ability to queue messages at the receiving end, it is usually used with one of two other protocols, POP3 or IMAP, that let the user save messages in a server mailbox and download them periodically from the server. In other words, users typically use a program that uses SMTP for sending e-mail and either POP3 or IMAP for receiving e-mail. On Unix-based systems, sendmail is the most widely-used SMTP server for e-mail. A commercial package, Sendmail, includes a POP3 server. Microsoft Exchange includes an SMTP server and can also be set up to include POP3 support.

SMTP usually is implemented to operate over Internet port 25. An alternative to SMTP that is widely used in Europe is X.400. Many mail servers now support Extended Simple Mail Transfer Protocol (ESMTP), which allows multimedia files to be delivered as e-mail.

POP3:

The **Post Office Protocol** (**POP**) is an application-layer Internet standard protocol used by local e-mail clients to retrieve e-mail from a remote server over a TCP/IP connection.[1] POP has been developed through several versions, with version 3 (**POP3**) being the current standard.

Virtually all modern e-mail clients and servers support POP3, and it along with IMAP (Internet Message Access Protocol) are the two most prevalent Internet standard protocols for e-mail retrieval,[2] with many webmail service providers such as Gmail, Outlook.com and Yahoo! Mail also providing support for either IMAP or POP3 to allow mail to be downloaded.

POP supports simple download-and-delete requirements for access to remote mailboxes (termed mail drop in the POP RFC's).[3] Although most POP clients have an option to leave mail on server after download, e-mail clients using POP generally connect, retrieve all messages, store them on the user's PC as new messages, delete them from the server, and then disconnect. Other protocols, notably IMAP, (Internet Message Access Protocol) provide more complete and complex remote access to typical mailbox operations. In the late 1990s and early 2000s, fewer Internet Service Providers (ISPs) supported IMAP due to the storage space that was required on the ISP's hardware. Contemporary e-mail clients supported POP, then over time popular mail client software added IMAP support.

A POP3 server listens on well-known port 110. Encrypted communication for POP3 is either requested after protocol initiation, using the STLS command, if supported, or by POP3S, which connects to the server using Transport Layer Security (TLS) or Secure Sockets Layer (SSL) on well-known TCP port 995.

Available messages to the client are fixed when a POP session opens the maildrop, and are identified by message-number local to that session or, optionally, by a unique identifier assigned to the message by the POP server. This unique identifier is permanent and unique to the mail drop and allows a client to access the same message in different POP sessions. Mail is retrieved and marked for deletion by message-number. When the client exits the session, the mail marked for deletion is removed from the maildrop.

The **POP (Post Office Protocol 3)** protocol provides a simple, standardized way for users to access mailboxes and download messages to their computers.

When using the POP protocol all your eMail messages will be downloaded from the mail server to your local computer. You can choose to leave copies of your eMails on the server as well. The advantage is that once your messages are downloaded you can cut the internet connection and read your eMails at your leisure without incuring further communication costs. On the other hand you might have transferred a lot of message (including spam or viruses) in which you are not at all interested at this point.

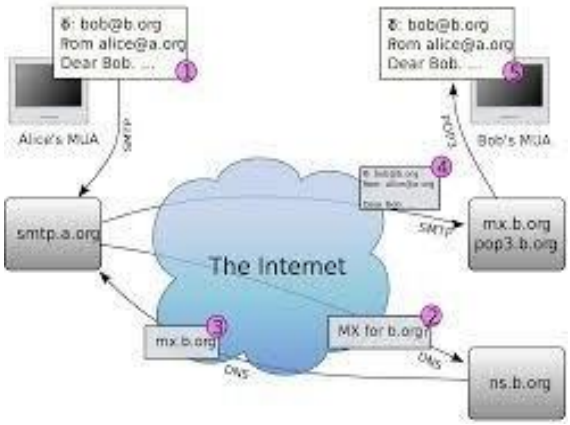
POP3 (Post Office Protocol 3) is the most recent version of a standard protocol for receiving e-mail.

POP3 (Post Office Protocol 3) is the most recent version of a standard protocol for receiving e-mail. POP3 is a client/server protocol in which e-mail is received and held for you by your Internet server. Periodically, you (or your client e-mail receiver) check your mail-box on the server and download any mail, probably using POP3. This standard protocol is built into most popular e-mail products, such as Eudora and Outlook Express. It's also built into the Netscape and Microsoft Internet Explorer browsers.

POP3 is designed to delete mail on the server as soon as the user has downloaded it. However, some implementations allow users or an administrator to specify that mail be saved for some period of time. POP can be thought of as a "store-and-forward" service.

An alternative protocol is Internet Message Access Protocol (IMAP). IMAP provides the user more capabilities for retaining e-mail on the server and for organizing it in folders on the server. IMAP can be thought of as a remote file server.

POP and IMAP deal with the receiving of e-mail and are not to be confused with the Simple Mail Transfer Protocol (SMTP), a protocol for transferring e-mail across the Internet. You send e-mail with SMTP and a mail handler receives it on your recipient's behalf. Then the mail is read using POP or IMAP.



IMAP:

The **Internet Message Access Protocol** (**IMAP**) is an Internet standard protocol used by e-mail clients to retrieve e-mail messages from a mail server over a TCP/IP connection.IMAP is defined by RFC 3501.

IMAP was designed with the goal of permitting complete management of an email box by multiple email clients. Therefore, clients generally leave messages on the server until the user explicitly deletes them. An IMAP server typically listens on port number 143. IMAP over SSL (**IMAPS**) is assigned the port number 993.

Virtually all modern e-mail clients and servers support IMAP. IMAP and the earlier POP3 (Post Office Protocol) are the two most prevalent standard protocols for email retrieval, with many webmail service providers such as Gmail, Outlook.com and Yahoo! Mail also providing support for either IMAP or POP3.

IMAP was designed by Mark Crispin in 1986 as a remote mailbox protocol, in contrast to the widely used POP, a protocol for retrieving the contents of a mailbox.[5]

IMAP was previously known as **Internet Mail Access Protocol**, **Interactive Mail Access Protocol** (RFC 1064), and **Interim Mail Access Protocol**.[6]

IMAP stands for Internet Message Access Protocol. IMAP shares many similar features with POP3. It, too, is a protocol that an email client can use to download email from an email server. However, IMAP includes many more features than POP3. The IMAP protocol is designed to let users keep their email on the server. IMAP requires more disk space on the server and more CPU resources than POP3, as all emails are stored on the server. IMAP normally uses port 143. Here is more information about IMAP.

Original IMAP

The original Interim Mail Access Protocol was implemented as a Xerox Lisp machine client and a TOPS-20 server.

No copies of the original interim protocol specification or its software exist.[7] Although some of its commands and responses were similar to IMAP2, the interim protocol lacked command/response tagging and thus its syntax was incompatible with all other versions of IMAP.

IMAP2

The interim protocol was quickly replaced by the Interactive Mail Access Protocol (IMAP2), defined in RFC 1064 (in 1988) and later updated by RFC 1176 (in 1990). IMAP2 introduced the command/response tagging and was the first publicly distributed version.

IMAP3

IMAP3 is an extremely rare variant of IMAP.[8] It was published as RFC 1203 in 1991. It was written specifically as a counter-proposal to RFC 1176, which itself proposed modifications to IMAP2.[9] IMAP3 was never accepted by the marketplace.[10][11] The IESG reclassified RFC1203 "Interactive Mail Access Protocol - Version 3" as a Historic protocol in 1993. The IMAP Working Group used RFC1176 (IMAP2) rather than RFC1203 (IMAP3) as its starting point.[12][13]

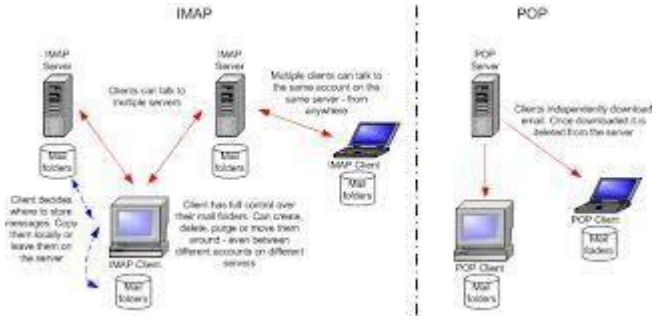
IMAP2bis

With the advent of MIME, IMAP2 was extended to support MIME body structures and add mailbox management functionality (create, delete, rename, message upload) that was absent from IMAP2. This experimental revision was called IMAP2bis; its specification was never published in non-draft form. An internet draft of IMAP2bis was published by the IETF IMAP Working Group in October 1993. This draft was based upon the following earlier specifications: unpublished IMAP2bis.TXT document, RFC1176, and RFC1064 (IMAP2).[14] The IMAP2bis.TXT draft documented the state of extensions to IMAP2 as of December 1992.[15] Early versions of Pine were widely distributed with IMAP2bis support[8] (Pine 4.00 and later supports IMAP4rev1).

IMAP4

An IMAP Working Group formed in the IETF in the early 1990s took over responsibility for the IMAP2bis design. The IMAP WG decided to rename IMAP2bis to IMAP4 to avoid confusion

Advantages over POP



Connected and disconnected modes of operation

When using POP, clients typically connect to the e-mail server briefly, only as long as it takes to download new messages. When using IMAP4, clients often stay connected as long as the user interface is active and download message content on demand. For users with many or large messages, this IMAP4 usage pattern can result in faster response times.

Multiple clients simultaneously connected to the same mailbox

The POP protocol requires the currently connected client to be the only client connected to the mailbox. In contrast, the IMAP protocol specifically allows simultaneous access by multiple clients and provides mechanisms for clients to detect changes made to the mailbox by other, concurrently connected, clients. See for example RFC3501 section 5.2 which specifically cites "simultaneous access to the same mailbox by multiple agents" as an example.

Access to MIME message parts and partial fetch

Usually all Internet e-mail is transmitted in MIME format, allowing messages to have a tree structure where the leaf nodes are any of a variety of single part content types and the non-leaf nodes are any of a variety of multipart types. The IMAP4 protocol allows clients to retrieve any of the individual MIME parts separately and also to retrieve portions of either individual parts or the entire message. These mechanisms allow clients to retrieve the text portion of a message without retrieving attached files or to stream content as it is being fetched.

Message state information

Through the use of flags defined in the IMAP4 protocol, clients can keep track of message state: for example, whether or not the message has been read, replied to, or deleted. These flags are stored on the server, so different clients accessing the same mailbox at different times can detect state changes made by other clients. POP provides no mechanism for clients to store such state information on the server so if a single user accesses a mailbox with two different POP clients (at different times), state information—such as whether a message has been accessed—cannot be synchronized between the clients. The IMAP4 protocol supports both predefined system flags and client-defined keywords.

System flags indicate state information such as whether a message has been read. Keywords, which are not supported by all IMAP servers, allow messages to be given one or more tags whose meaning is up to the client. IMAP keywords should not be confused with proprietary labels of web-based e-mail services which are sometimes translated into IMAP folders by the corresponding proprietary servers.

Multiple mailboxes on the server

IMAP4 clients can create, rename, and/or delete mailboxes (usually presented to the user as folders) on the server, and copy messages between mailboxes. Multiple mailbox support also allows servers to provide access to shared and public folders. The IMAP4 Access Control List (ACL) Extension (RFC 4314) may be used to regulate access rights.

Server-side searches

IMAP4 provides a mechanism for a client to ask the server to search for messages meeting a variety of criteria. This mechanism avoids requiring clients to download every message in the mailbox in order to perform these searches.

Built-in extension mechanism

Reflecting the experience of earlier Internet protocols, IMAP4 defines an explicit mechanism by which it may be extended. Many IMAP4 extensions to the base protocol have been proposed and are in common use. IMAP2bis did not have an extension mechanism, and POP now has one defined by RFC 2449.

Disadvantages

While IMAP remedies many of the shortcomings of POP, this inherently introduces additional complexity. Much of this complexity (e.g., multiple clients accessing the same mailbox at the same time) is compensated for by server-side workarounds such as Maildir or database backends.

The IMAP specification has been criticised for being insufficiently strict and allowing behaviours that effectively negate its usefulness. For instance, the specification states that each message stored on the server has a "unique id" to allow the clients to identify the messages they have already seen between sessions. However, the specification also allows these UIDs to be invalidated with no restrictions, practically defeating their purpose.[16]

Unless the mail storage and searching algorithms on the server are carefully implemented, a client can potentially consume large amounts of server resources when searching massive mailboxes.

IMAP4 clients need to maintain a TCP/IP connection to the IMAP server in order to be notified of the arrival of new mail. Notification of mail arrival is done through in-band signaling, which contributes to the complexity of client-side IMAP protocol handling somewhat.[17] A private proposal, push IMAP, would extend IMAP to implement push e-mail by sending the entire message instead of just a notification. However, push IMAP has not been generally accepted and current IETF work has addressed the problem in other ways (see the Lemonade Profile for more information).

Unlike some proprietary protocols which combine sending and retrieval operations, sending a message and saving a copy in a server-side folder with a base-level IMAP client requires transmitting the message content twice, once to SMTP for delivery and a second time to IMAP to store in a sent mail folder. This is remedied by a set of extensions defined by the IETF LEMONADE Working Group for mobile devices: URLAUTH (RFC 4467) and CATENATE (RFC 4469) in IMAP and BURL (RFC 4468) in SMTP-SUBMISSION. POP servers don't support server-side folders so clients have no choice but to store sent items on the client. Many IMAP clients can be configured to store sent mail in a client-side folder, or to BCC oneself and then filter the incoming mail instead of saving a copy in a folder directly. In addition to the LEMONADE "trio", Courier Mail Server offers a non-standard method of sending using IMAP by copying an outgoing message to a dedicated outbox folder.[18]

Lastly, support for message states can also cause problems for shared mailboxes; if a user on an IMAP client downloads and reads new mail from the server, the next user to download the same mail via an IMAP client as well will see the client automatically setting the status of said mail to 'Read' even though he or she has yet to do so. This can be a major issue since most IMAP clients do not provide notifications when read messages are downloaded; POP3 users do not experience such problems as the server does not store message states and as such will always have their messages delivered as new and unread mail.

IMAP (Internet Message Access Protocol) – Is a standard protocol for accessing e-mail from your local server. IMAP is a client/server protocol in which e-mail is received and held for you by your Internet server. As this requires only a small data transfer this works well even over a slow connection such as a modem. Only if you request to read a specific email message will it be downloaded from the server. You can also create and manipulate folders or mailboxes on the server, delete messages etc.

MIME:

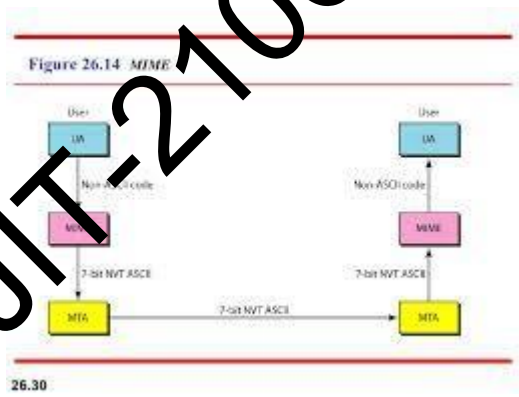
Multipurpose Internet Mail Extensions (**MIME**) is an Internet standard that extends the format of email to support:

- Text in character sets other than ASCII
- Non-text attachments: audio, video, images, application programs etc.
- Message bodies with multiple parts
- Header information in non-ASCII character sets

Virtually all human-written Internet email and a fairly large proportion of automated email is transmitted via SMTP in MIME format.

MIME is specified in six linked RFC memoranda: RFC 2045, RFC 2046, RFC 2047, RFC 4288, RFC 4289 and RFC 2049; with the integration with SMTP email specified in detail in RFC 1521 and RFC 1522.

Although MIME was designed mainly for SMTP, the content types defined by MIME standards are also of importance outside of email, such as in communication protocols like HTTP for the World Wide Web. Servers insert the MIME header at the beginning of any Web transmission. Clients use this content type or Internet media type header to select an appropriate "player" application for the type of data the header indicates. Some of these players are built into the Web client or browser (for example, almost all browsers come with GIF and JPEG image players as well as the ability to handle HTML files);



MIME headers

MIME-Version

The presence of this header indicates the message is MIME-formatted. The value is typically "1.0" so this header appears as

MIME-Version: 1.0

According to MIME co-creator Nathaniel Borenstein, the intention was to allow MIME to change, to advance to version 2.0 and so forth, but this decision led to the opposite outcome, making it nearly impossible to create a new version of the standard.

Content-Type

This header indicates the Internet media type of the message content, consisting of a type and subtype, for example

Content-Type: text/plain

Through the use of the multipart type, MIME allows mail messages to have parts arranged in a tree structure where the leaf nodes are any non-multipart content type and the non-leaf nodes are any of a variety of multipart types. This mechanism supports:

- **simple text messages using text/plain** (the default value for "Content-Type: ")
- text plus attachments (multipart/mixed with a text/plain part and other non-text parts). A MIME message including an attached file generally indicates the file's original name with the "Content-disposition:" header, so the type of file is indicated both by the MIME content-type and the (usually OS-specific) filename extension
- reply with original attached (multipart/mixed with a text/plain part and the original message as a message/rfc822 part)
- alternative content, such as a message sent in both plain text and another format such as HTML (multipart/alternative with the same content in text/plain and text/html forms)
- image, audio, video and application (for example, image/jpeg, audio/mp3, video/mp4, and application/msword and so on)
- many other message constructs

Content-Disposition

The original MIME specifications only described the structure of mail messages. They did not address the issue of presentation styles. The content-disposition header field was added in RFC 2183 to specify the presentation style. A MIME part can have:

- an inline content-disposition, which means that it should be automatically displayed when the message is displayed, or
- an attachment content-disposition, in which case it is not displayed automatically and requires some form of action from the user to open it.

In addition to the presentation style, the content-disposition header also provides fields for specifying the name of the file, the creation date and modification date, which can be used by the reader's mail user agent to store the attachment.

In HTTP, the Content-Disposition: attachment response header is usually used to hint to the client to present the response body as a downloadable file. Typically, when receiving such a response, a Web browser will prompt the user to save its content as a file instead of displaying it as a page in a browser window, with the filename parameter suggesting the default file name (this is useful for dynamically generated content, where deriving the filename from the URL may be meaningless or confusing to the user).

Content-Transfer-Encoding

MIME (RFC 1341, since made obsolete by RFC 2045) defined a set of methods for representing binary data in formats other than ASCII text format. The content-transfer-encoding: MIME header has 2-sided significance:

- It indicates whether or not a binary-to-text encoding scheme has been used on top of the original encoding as specified within the Content-Type header:

1. If such a binary-to-text encoding method has been used, it states which one.
2. If not, it provides a descriptive label for the format of content, with respect to the presence of 8-bit or binary content.

The RFC and the IANA's list of transfer encodings define the values shown below, which are not case sensitive. Note that '7bit', '8bit', and 'binary' mean that no binary-to-text encoding on top of the original encoding was used. In these cases, the header is actually redundant for the email client to decode the message body, but it may still be useful as an indicator of what type of object is being sent. Values 'quoted-printable' and 'base64' tell the email client that a binary-to-text encoding scheme was used and that appropriate initial decoding is necessary before the message can be read with its original encoding (e.g. UTF-8).

- Suitable for use with normal SMTP:
  - **7bit** – up to 998 octets per line of the code range 1..127 with CR and LF (codes 13 and 10 respectively) only allowed to appear as part of a CRLF line ending. This is the default value.
  - **quoted-printable** – used to encode arbitrary octet sequences into a form that satisfies the rules of 7bit. Designed to be efficient and mostly human readable when used for text data consisting primarily of US-ASCII characters but also containing a small proportion of bytes with values outside that range.
  - **base64** – used to encode arbitrary octet sequences into a form that satisfies the rules of 7bit. Designed to be efficient for non-text 8 bit and binary data. Sometimes used for text data that frequently uses non-US-ASCII characters.
- Suitable for use with SMTP servers that support the 8BITMIME SMTP extension (RFC 6152):
  - **8bit** – up to 998 octets per line with CR and LF (codes 13 and 10 respectively) only allowed to appear as part of a CRLF line ending.
- Suitable for use with SMTP servers that support the BINARYMIME SMTP extension (RFC 3030):
  - **binary** – any sequence of octets.

There is no encoding defined which is explicitly designed for sending arbitrary binary data through SMTP transports with the 8BITMIME extension. Thus, if BINARYMIME isn't supported, base64 or quoted-printable (with their associated inefficiency) are sometimes still useful. This restriction does not apply to other uses of MIME such as Web Services with MIME attachments or MTOM.

Multipurpose **I**nternet **M**ail **E**xtensions, a specification for formatting non-ASCII messages so that they can be sent over the Internet. Many e-mail clients now support MIME, which enables them to send and receive graphics, audio, and video files via the Internet mail system. In addition, MIME supports messages in character sets other than ASCII.

There are many predefined MIME types, such as GIF graphics files and PostScript files. It is also possible to define your own MIME types. In addition to e-mail applications, Web browsers also support various MIME types. This enables the browser to display or output files that are not in HTML format.

MIME (Multi-Purpose Internet Mail Extensions) is an extension of the original Internet e-mail protocol that lets people use the protocol to exchange different kinds of data files on the Internet: audio, video, images, application programs, and other kinds, as well as the ASCII text handled in the original protocol, the Simple Mail Transport Protocol (SMTP).

MIME (Multi-Purpose Internet Mail Extensions) is an extension of the original Internet e-mail protocol that lets people use the protocol to exchange different kinds of data files on the Internet: audio, video, images, application programs, and other kinds, as well as the ASCII text handled in the original protocol, the Simple Mail Transport Protocol (SMTP). In 1991, Nathan Borenstein of Bellcore proposed to the IETF that SMTP be extended so that Internet (but mainly Web) clients and servers could recognize and handle other kinds of data than ASCII text. As a result, new file types were added to "mail" as a supported Internet Protocol file type.

Servers insert the MIME header at the beginning of any Web transmission. Clients use this header to select an appropriate "player" application for the type of data the header indicates. Some of these players are built into the Web client or browser (for example, all browsers come with GIF and JPEG image players as well as the ability to handle HTML files); other players may need to be downloaded.

New MIME data types are registered with the Internet Assigned Numbers Authority (IANA).MIME is specified in detail in Internet Request for Comments 1521 and 1522, which amend the original mail protocol specification, RFC 821 (the Simple Mail Transport Protocol) and the ASCII messaging header, RFC 822.

HTTP:

The **Hypertext Transfer Protocol** (**HTTP**) is an application protocol for distributed, collaborative, hypermedia information systems.[1] HTTP is the foundation of data communication for the World Wide Web.

Hypertext is structured text that uses logical links (hyperlinks) between nodes containing text. HTTP is the protocol to exchange or transfer hypertext.

The standards development of HTTP was coordinated by the Internet Engineering Task Force (IETF) and the World Wide Web Consortium (W3C), culminating in the publication of a series of Requests for Comments (RFCs). The first definition of HTTP/1.1, the version of HTTP in common use, occurred in RFC 2068

HTTP functions as a request-response protocol in the client-server computing model. A web browser, for example, may be the client and an application running on a computer hosting a web site may be the server. The client submits an HTTP request message to the server. The server, which provides resources such as HTML files and other content, or performs other functions on behalf of the client, returns a response message to the client. The response contains completion status information about the request and may also contain requested content in its message body.

A web browser is an example of a user agent (UA). Other types of user agent include the indexing software used by search providers (web crawlers), voice browsers, mobile apps, and other software that accesses, consumes, or displays web content.

HTTP is designed to permit intermediate network elements to improve or enable communications between clients and servers. High-traffic websites often benefit from web cache servers that deliver content on behalf of upstream servers to improve response time. Web browsers cache previously accessed web resources and reuse them when possible to reduce network traffic. HTTP proxy servers at private network boundaries can facilitate communication for clients without a globally routable address, by relaying messages with external servers.

HTTP is an application layer protocol designed within the framework of the Internet Protocol Suite. Its definition presumes an underlying and reliable transport layer protocol,[2] and Transmission Control Protocol (TCP) is commonly used. However HTTP can use unreliable protocols such as the User Datagram Protocol (UDP), for example in Simple Service Discovery Protocol (SSDP).

HTTP resources are identified and located on the network by Uniform Resource Locators (URLs), using the URI schemes http and https. URIs and hyperlinks in Hypertext Markup Language (HTML) documents form inter-linked hypertext documents.

HTTP/1.1 is a revision of the original HTTP (HTTP/1.0). In HTTP/1.0 a separate connection to the same server is made for every resource request. HTTP/1.1 can reuse a connection multiple times to download images, scripts, stylesheets, etc after the page has been delivered. HTTP/1.1 communications therefore experience less latency as the establishment of TCP connections presents considerable overhead.

HTTP session

An HTTP session is a sequence of network request-response transactions. An HTTP client initiates a request by establishing a Transmission Control Protocol (TCP) connection to a particular port on a server (typically port 80, occasionally port 8080; see List of TCP and UDP

port numbers). An HTTP server listening on that port waits for a client's request message. Upon receiving the request, the server sends back a status line, such as "HTTP/1.1 200 OK", and a message of its own. The body of this message is typically the requested resource, although an error message or other information may also be returned.[1]

HTTP Authentication

HTTP provides multiple authentication schemes such as Basic access authentication and Digest access authentication which operate via a challenge-response mechanism whereby the server identifies and issues a challenge before serving the requested content.

HTTP provides a general framework for access control and authentication, via an extensible set of challenge-response authentication schemes, which can be used by a server to challenge a client request and by a client to provide authentication information.[10]

Authentication Realms

The HTTP Authentication spec also provides an arbitrary, implementation specific construct for further dividing resources common to a given root URI. The realm value string, if present, is combined with the canonical root URI to form the protection space component of the challenge. This in effect allows the server to define separate authentication scopes under one root URI[10]

Request methods

An HTTP 1.1 request made using telnet. The request message, response header section, and response body are highlighted.

HTTP defines methods (sometimes referred to as verbs) to indicate the desired action to be performed on the identified resource. What this resource represents, whether pre-existing data or data that is generated dynamically, depends on the implementation of the server. Often, the resource corresponds to a file or the output of an executable residing on the server. The HTTP/1.0 specification[11] defined the GET, POST and HEAD methods and the HTTP/1.1 specification[12] added 5 new methods: OPTIONS, PUT, DELETE, TRACE and CONNECT. By being specified in these documents their semantics are well known and can be depended upon.

Any client can use any method and the server can be configured to support any combination of methods. If a method is unknown to an intermediate it will be treated as an unsafe and non-idempotent method. There is no limit to the number of methods that can be defined and this allows for future methods to be specified without breaking existing infrastructure. For example, WebDAV defined 7 new methods and RFC 5789 specified the PATCH method.

GET

The GET method requests a representation of the specified resource. Requests using GET should only retrieve data and should have no other effect. (This is also true of some other HTTP methods.)[1] The W3C has published guidance principles on this distinction, saying, "Web application design should be informed by the above principles, but also by the relevant limitations."[13] See safe methods below.

HEAD

The HEAD method asks for a response identical that of a GET request, but without the response body. This is useful for retrieving meta-information written in response headers, without having to transport the entire content.

POST

The POST method requests that the server accept the entity enclosed in the request as a new subordinate of the web resource identified by the URI. The data POSTed might be, for example, an annotation for existing resources; a message for a bulletin board, newsgroup, mailing list, or comment thread; a block of data that is the result of submitting a web form to a data-handling process; or an item to add to a database.[14]

PUT

The PUT method requests that the enclosed entity be stored under the supplied URI. If the URI refers to an already existing resource, it is modified; if the URI does not point to an existing resource, then the server can create the resource with that URI.[15]

DELETE

The DELETE method deletes the specified resource.

TRACE

The TRACE method echoes the received request so that a client can see what (if any) changes or additions have been made by intermediate servers.

OPTIONS

The OPTIONS method returns the HTTP methods that the server supports for the specified URL. This can be used to check the functionality of a web server by requesting '*' instead of a specific resource.

CONNECT

[16] The CONNECT method converts the request connection to a transparent TCP/IP tunnel, usually to facilitate SSL-encrypted communication (HTTPS) through an unencrypted HTTP proxy.[17][18] See HTTP CONNECT tunneling.

PATCH

The PATCH method applies partial modifications to a resource.[19]

All general-purpose HTTP servers are required to implement at least the GET and HEAD methods,[20] and, whenever possible, also the OPTIONS method.[citation needed]

Safe methods

Some of the methods (for example, HEAD, GET, OPTIONS and TRACE) are, by convention, defined as safe, which means they are intended only for information retrieval and should not change the state of the server. In other words, they should not have side effects, beyond relatively harmless effects such as logging, caching, the serving of banner advertisements or incrementing a web counter. Making arbitrary GET requests without regard to the context of the application's state should therefore be considered safe. However, this is not mandated by the standard, and it is explicitly acknowledged that it cannot be guaranteed.

By contrast, methods such as POST, PUT, DELETE and PATCH are intended for actions that may cause side effects either on the server, or external side effects such as financial transactions or transmission of email. Such methods are therefore not usually used by conforming web robots or web crawlers; some that do not conform tend to make requests without regard to context or consequences.

Despite the prescribed safety of GET requests, in practice their handling by the server is not technically limited in any way. Therefore, careless or deliberate programming can cause non-trivial changes on the server. This is discouraged, because it can cause problems for web caching, search engines and other automated agents, which can make unintended changes on the server.

Idempotent methods and web applications

Methods PUT and DELETE are defined to be idempotent, meaning that multiple identical requests should have the same effect as a single request (note that idempotence refers to the state of the system after the request has completed, so while the action the server takes (e.g. deleting a record) or the response code it returns may be different on subsequent requests, the system state will be the same every time). Methods GET, HEAD, OPTIONS and TRACE, being prescribed as safe, should also be idempotent, as HTTP is a stateless protocol.

In contrast, the POST method is not necessarily idempotent, and therefore sending an identical POST request multiple times may further affect state or cause further side effects (such as financial transactions). In some cases this may be desirable, but in other cases this could be due to an accident, such as when a user does not realize that their action will result in sending another request, or they did not receive adequate feedback that their first request was successful. While web browsers may show alert dialog boxes to warn users in some cases where reloading a page may re-submit a POST request, it is generally up to the web application to handle cases where a POST request should not be submitted more than once. Note that whether a method is idempotent is not enforced by the protocol or web server. It is perfectly possible to write a web application in which (for example) a database insert or other non-idempotent action is triggered by a GET or other request. Ignoring this recommendation, however, may result in undesirable consequences, if a user agent assumes that repeating the same request is safe when it isn't.

Security

Implementing methods such as TRACE, TRACK and DEBUG are considered potentially insecure by some security professionals because attackers can use them to gather information or bypass security controls during attacks. Security software tools such as Tenable Nessus and Microsoft UrlScan Security Tool report on the presence of these methods as being security issues.[21] TRACK and DEBUG are not valid HTTP 1.1 verbs.[22]

Web Services:

A **Web service** is a method of communication between two electronic devices over a network. It is a software function provided at a network address over the Web with the service always on as in the concept of utility computing.

The term Web services describes a standardized way of integrating Web-based applications using the XML, SOAP, WSDL and UDDI open standards over an Internet protocol backbone. XML is used to tag the data, SOAP is used to transfer the data, WSDL is used for describing the services available and UDDI is used for listing what services are available. Used primarily as a means for businesses to communicate with each other and with clients, Web services allow organizations to communicate data without intimate knowledge of each other's IT systems behind the firewall.

Unlike traditional client/server models, such as a Web server/Web page system, Web services do not provide the user with a GUI. Web services instead share business logic, data and processes through a programmatic interface across a network. The applications interface, not the users. Developers can then add the Web service to a GUI (such as a Web page or an executable program) to offer specific functionality to users.

Web services allow different applications from different sources to communicate with each other without time-consuming custom coding, and because all communication is in XML, Web services are not tied to any one operating system or programming language. For example, Java can talk with Perl, Windows applications can talk with UNIX applications.

- A web service is any piece of software that makes itself available over the internet and uses a standardized XML messaging system. XML is used to encode all communications to a web service. For example, a client invokes a web service by sending an XML message, then waits for a corresponding XML response. As all communication is in XML, web services are not tied to any one operating system or programming language--Java can talk with Perl; Windows applications can talk with Unix applications.
- Web services are self-contained, modular, distributed, dynamic applications that can be described, published, located, or invoked over the network to create products, processes, and supply chains. These applications can be local, distributed, or web-based. Web services are built on top of open standards such as TCP/IP, HTTP, Java, HTML, and XML.
- Web services are XML-based information exchange systems that use the Internet for direct application-to-application interaction. These systems can include programs, objects, messages, or documents.
- A web service is a collection of open protocols and standards used for exchanging data between applications or systems. Software applications written in various programming languages and running on various platforms can use web services to exchange data over computer networks like the Internet in a manner similar to inter-process communication on a single computer. This interoperability (e.g., between Java and Python, or Windows and Linux applications) is due to the use of open standards.

DNS:

The **Domain Name System** (**DNS**) is a hierarchical distributed naming system for computers, services, or any resource connected to the Internet or a private network. It associates various information with domain names assigned to each of the participating entities. Most prominently, it translates domain names, which can be easily memorized by humans, to the numerical IP addresses needed for the purpose of computer services and devices worldwide. The Domain Name System is an essential component of the functionality of most Internet services because it is the Internet's primary directory service.

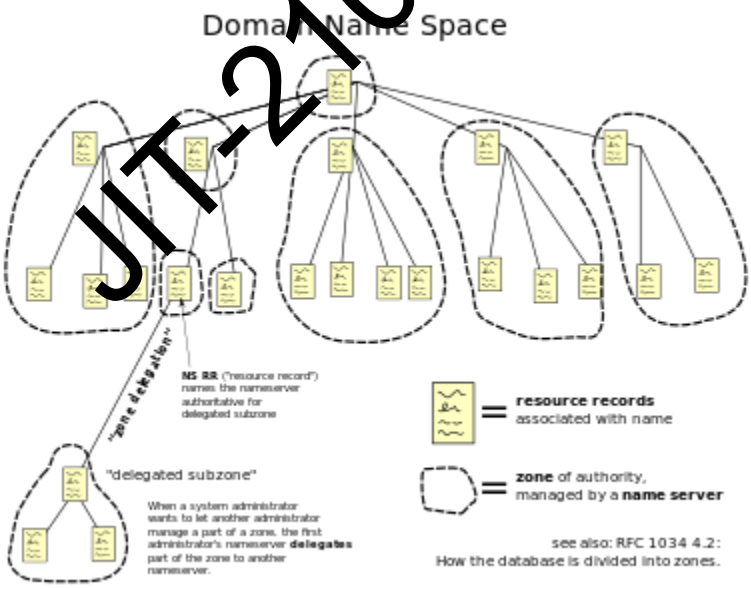
The Domain Name System distributes the responsibility of assigning domain names and mapping those names to IP addresses by designating authoritative name servers for each domain. Authoritative name servers are assigned to be responsible for their supported domains, and may delegate authority over sub-domains to other name servers. This mechanism provides distributed and fault tolerant service and was designed to avoid the need for a single central database.

The Domain Name System also specifies the technical functionality of the database service which is at its core. It defines the DNS protocol, a detailed specification of the data structures and data communication exchanges used in DNS, as part of the Internet Protocol Suite. Historically, other directory services preceding DNS were not scalable to large or global directories as they were originally based on text files, prominently the HOSTS.TXT resolver. DNS has been in wide use since the 1980s.

The Internet maintains two principal namespaces, the domain name hierarchy[1] and the Internet Protocol (IP) address spaces.[2] The Domain Name System maintains the domain name hierarchy and provides translation services between it and the address spaces. Internet name servers and a communication protocol implement the Domain Name System.[3] A DNS name server is a server that stores the DNS records for a domain name; a DNS name server responds with answers to queries against its database.

Domain name space

The domain name space consists of a tree of domain names. Each node or leaf in the tree has zero or more resource records, which hold information associated with the domain name. The tree sub-divides into zones beginning at the root zone. A DNS zone may consist of only one domain, or may consist of many domains and sub-domains, depending on the administrative authority delegated to the manager.



The hierarchical Domain Name System, organized into zones, each served by a name server

Administrative responsibility over any zone may be divided by creating additional zones. Authority is said to be delegated for a portion of the old space, usually in the form of sub-domains, to another name server and administrative entity. The old zone ceases to be authoritative for the new zone.

Domain name syntax

The definitive descriptions of the rules for forming domain names appear in RFC 1035, RFC 1123, and RFC 2181. A domain name consists of one or more parts, technically called labels, that are conventionally concatenated, and delimited by dots, such as example.com.

The hierarchy of domains descends from right to left; each label to the left specifies a subdivision, or subdomain of the domain to the right. For example: the label example specifies a subdomain of the com domain, and www is a subdomain of example.com. This tree of subdivisions may have up to 127 levels.

Each label may contain up to 63 characters. The full domain name may not exceed the length of 253 characters in its textual representation.[1] In the internal binary representation of the DNS the maximum length requires 255 octets of storage, since it also stores the length of the name.[3]

DNS names may technically consist of any character representable in an octet. However, the allowed formulation of domain names in the DNS root zone, and most other sub domains, uses a preferred format and character set. The characters allowed in a label are a subset of the ASCII character set, and includes the characters a through z, A through Z, digits 0 through 9, and the hyphen. This rule is known as the LDH rule (letters, digits, hyphen). Domain names are interpreted in case-independent manner.[8] Labels may not start or end with a hyphen.[9] An additional rule requires that top-level domain names should not be all-numeric.[9]

Internationalized domain names

The limited set of ASCII characters permitted in the DNS prevented the representation of names and words of many languages in their native alphabets or scripts. To make this possible, ICANN approved the Internationalizing Domain Names in Applications (IDNA) system, by which user applications, such as web browsers, map Unicode strings into the valid DNS character set using Punycode. In 2009 ICANN approved the installation of internationalized domain name country code top-level domains. In addition, many registries of the existing top level domain names (TLD)s have adopted the IDNA system.

Name servers

The Domain Name System is maintained by a distributed database system, which uses the client–server model. The nodes of this database are the name servers. Each domain has at least one authoritative DNS server that publishes information about that domain and the name servers of any domains subordinate to it. The top of the hierarchy is served by the root name servers, the servers to query when looking up (resolving) a TLD.

Authoritative name server

An authoritative name server is a name server that gives answers that have been configured by an original source, for example, the domain administrator or by dynamic DNS methods, in contrast to answers that were obtained via a regular DNS query to another name server. An authoritative-only name server only returns answers to queries about domain names that have been specifically configured by the administrator.

In other words, an authoritative name server lets recursive name servers know what DNS data (the IPv4 IP, the IPv6 IP, a list of incoming mail servers, etc.) a given host name (such as "www.example.com") has. As just one example, the authoritative name server for "example.com" tells recursive name servers that "www.example.com" has the IPv4 IP address 192.0.43.10.

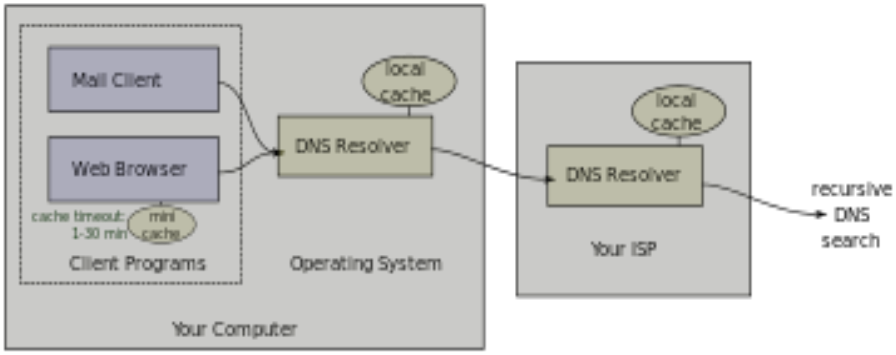
An authoritative name server can either be a master server or a slave server. A master server is a server that stores the original (master) copies of all zone records. A slave server uses an automatic updating mechanism of the DNS protocol in communication with its master to maintain an identical copy of the master records.

A set of authoritative name servers has to be assigned for every DNS zone. An NS record about addresses of that set must be stored in the parent zone and servers themselves (as self-reference).

When domain names are registered with a domain name registrar, their installation at the domain registry of a top level domain requires the assignment of a primary name server and at least one secondary name server. The requirement of multiple name servers aims to make the domain still functional even if one name server becomes inaccessible or inoperable.[10] The designation of a primary name server is solely determined by the priority given to the domain name registrar. For this purpose, generally only the fully qualified domain name of the name server is required, unless the servers are contained in the registered domain, in which case the corresponding IP address is needed as well.

Primary name servers are often master name servers, while secondary name servers may be implemented as slave servers.

An authoritative server indicates its status of supplying definitive answers, deemed authoritative, by setting a software flag (a protocol structure bit), called the Authoritative Answer (AA) bit in its responses.

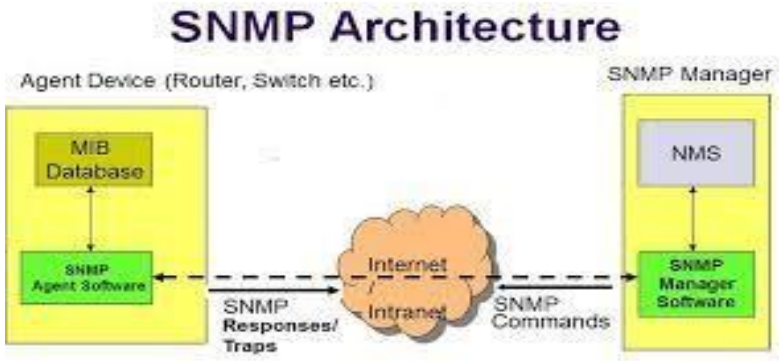


Domain **N**ame **S**ystem (or **S**ervice or **S**erver), an Internet service that translates domain names into IP addresses. Because domain names are alphabetic, they're easier to remember. The Internet however, is really based on IP addresses. Every time you use a domain name, therefore,aDNS service must translate the name into the corresponding IP address.

For example, the domain name www.example.com might translate to 198.105.232.4.

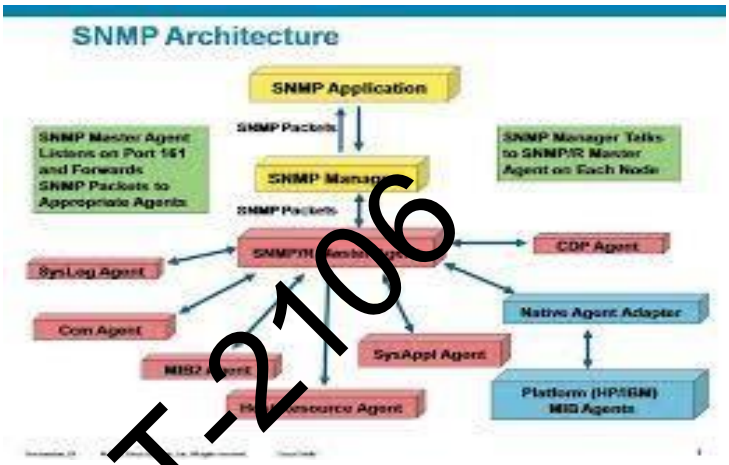
SNMP:

Simple **N**etwork **M**anagement **P**rotocol, a set of protocols for managing complex networks. The first versions of SNMP were developed in the early 80s. SNMP works by sending messages, called protocol data units (PDUs), to different parts of a network. SNMP-compliant devices, called agents, store data about themselves in Management Information Bases (MIBs) and return this data to the SNMP requesters.



Simple Network Management Protocol (**SNMP**) is an "Internet-standard protocol for managing devices on IP networks". Devices that typically support SNMP include routers, switches, servers, workstations, printers, modem racks and more. SNMP is widely used in

network management systems to monitor network-attached devices for conditions that warrant administrative attention. SNMP is a component of the Internet Protocol Suite as defined by the Internet Engineering Task Force (IETF). It consists of a set of standards for network management, including an application layer protocol, a database schema, and a set of data objects.



SNMP exposes management data in the form of variables on the managed systems, which describe the system configuration. These variables can then be queried (and sometimes set) by managing applications.

In typical uses of SNMP one or more administrative computers, called managers, have the task of monitoring or managing a group of hosts or devices on a computer network. Each managed system executes, at all times, a software component called an agent which reports information via SNMP to the manager.

SNMP agents expose management data on the managed systems as variables. The protocol also permits active management tasks, such as modifying and applying a new configuration through remote modification of these variables. The variables accessible via SNMP are organized in hierarchies. These hierarchies, and other metadata (such as type and description of the variable), are described by Management Information Bases (MIBs).

An SNMP-managed network consists of three key components:

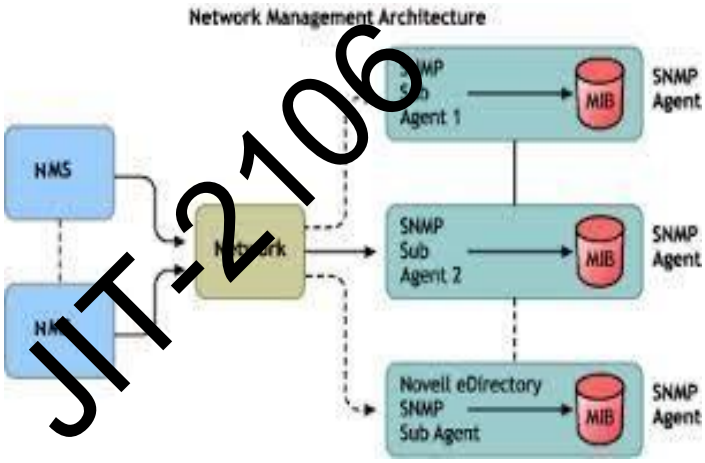
- Managed device
- Agent — software which runs on managed devices
- Network management station (NMS) — software which runs on the manager

A managed device is a network node that implements an SNMP interface that allows unidirectional (read-only) or bidirectional (read and write) access to node-specific information. Managed devices exchange node-specific information with the NMSs. Sometimes called

network elements, the managed devices can be any type of device, including, but not limited to, routers, access servers, switches, bridges, hubs, IP telephones, IP video cameras, computer hosts, and printers.

An agent is a network-management software module that resides on a managed device. An agent has local knowledge of management information and translates that information to or from an SNMP-specific form.

A network management station (NMS) executes applications that monitor and control managed devices. NMSs provide the bulk of the processing and memory resources required for network management. One or more NMSs may exist on any managed network.



SNMP operates in the Application Layer of the Internet Protocol Suite (Layer 7 of the OSI model). The SNMP agent receives requests on UDP port 161. The manager may send requests from any available source port to port 161 in the agent. The agent response will be sent back to the source port on the manager. The manager receives notifications (Traps and InformRequests) on port 162. The agent may generate notifications from any available port. When used with Transport Layer Security or Datagram Transport Layer Security requests are received on port 10161 and traps are sent to port 10162.

SNMPv1 specifies five core protocol data units (PDUs). Two other PDUs, GetBulkRequest and InformRequest were added in SNMPv2 and the Report PDU was added in SNMPv3.

All SNMP PDUs are constructed as follows:

IP header	UDP header	version	community	PDU-type	request-id	error-status	error-index	variable bindings

The seven SNMP protocol data unit (PDU) types are as follows:

GetRequest

A manager-to-agent request to retrieve the value of a variable or list of variables. Desired variables are specified in variable bindings (values are not used). Retrieval of the specified variable values is to be done as an atomic operation by the agent. A Response with current values is returned.

SetRequest

A manager-to-agent request to change the value of a variable or list of variables. Variable bindings are specified in the body of the request. Changes to all specified variables are to be made as an atomic operation by the agent. A Response with (current) new values for the variables is returned.

GetNextRequest

A manager-to-agent request to discover available variables and their values. Returns a Response with variable binding for the lexicographically next variable in the MIB. The entire MIB of an agent can be walked by iterative application of GetNextRequest starting at OID 0. Rows of a table can be read by specifying column OIDs in the variable bindings of the request.

GetBulkRequest

Optimized version of GetNextRequest. A manager-to-agent request for multiple iterations of GetNextRequest. Returns a Response with multiple variable bindings walked from the variable binding or bindings in the request. PDU specific non-repeaters and max-repetitions fields are used to control response behavior. GetBulkRequest was introduced in SNMPv2.

Response

Returns variable bindings and acknowledgement from agent to manager for GetRequest, SetRequest, GetNextRequest, GetBulkRequest and InformRequest. Error reporting is provided by error-status and error-index fields. Although it was used as a response to both gets and sets, this PDU was called GetResponse in SNMPv1.

Trap

Asynchronous notification from agent to manager. SNMP traps enable an agent to notify the management station of significant events by way of an unsolicited SNMP message. Includes current sysUpTime value, an OID identifying the type of trap and optional variable bindings. Destination addressing for traps is determined in an application-

specific manner typically through trap configuration variables in the MIB. The format of the trap message was changed in SNMPv2 and the PDU was renamed SNMPv2-Trap. While in classic communication the client always actively requests information from the server, SNMP allows the additional use of so-called "traps". These are data packages that are sent from the SNMP client to the server without being explicitly requested.

InformRequest

Acknowledged asynchronous notification. This PDU was introduced in SNMPv2 and was originally defined as manager to manager communication.[4] Later implementations have loosened the original definition to allow agent to manager communications.[5][6][7] Manager-to-manager notifications were already possible in SNMPv1 (using a Trap), but as SNMP commonly runs over UDP where delivery is not assured and dropped packets are not reported, delivery of a Trap was not guaranteed. InformRequest fixes this by sending back an acknowledgement on receipt.

Introduction of Firewall in Computer Network

A firewall is a network security device, either hardware or software-based, which monitors all incoming and outgoing traffic and based on a defined set of security rules it accepts, rejects or drops that specific traffic.
Accept : allow the traffic
Reject : block the traffic but reply with an "unreachable error"
Drop : block the traffic with no reply
A firewall establishes a barrier between secured internal networks and outside untrusted network, such as the Internet.

History and Need for Firewall

Before Firewalls, network security was performed by Access Control Lists (ACLs) residing on routers. ACLs are rules that determine whether network access should be granted or denied to specific IP address.
But ACLs cannot determine the nature of the packet it is blocking. Also, ACL alone does not have the capacity to keep threats out of the network. Hence, the Firewall was introduced.
Connectivity to the Internet is no longer optional for organizations. However, accessing the Internet provides benefits to the organization; it also enables the outside world to interact with the internal network of the organization. This creates a threat to the organization. In order to secure the internal network from unauthorized traffic, we need a Firewall.

How Firewall Works

Firewall match the network traffic against the rule set defined in its table. Once the rule is matched, associate action is applied to the network traffic. For example, Rules are defined as any employee from HR department cannot access the data from code server and at the same time another rule is defined like system administrator can access the data from both HR and technical department. Rules can be defined on the firewall based on the necessity and security policies of the organization.
From the perspective of a server, network traffic can be either outgoing or incoming. Firewall maintains a distinct set of rules for both the cases. Mostly the outgoing traffic, originated from the server itself, allowed to pass. Still, setting a rule on outgoing traffic is always better in order to achieve more security and prevent unwanted communication.
Incoming traffic is treated differently. Most traffic which reaches on the firewall is one of these three major Transport Layer protocols- TCP, UDP or ICMP. All these types have a source address and destination address. Also, TCP and UDP have port numbers. ICMP uses *type code* instead of port number which identifies purpose of that packet.
Default policy: It is very difficult to explicitly cover every possible rule on the firewall. For this reason, the firewall must always have a default policy. Default policy only consists of action (accept, reject or drop).
Suppose no rule is defined about SSH connection to the server on the firewall. So, it will follow the default policy. If default policy on the firewall is set to *accept*, then any computer outside of your office can establish an SSH connection to the server. Therefore, setting default policy as *drop* (or reject) is always a good practice.

Generation of Firewall

Firewalls can be categorized based on its generation.

1. **First Generation- Packet Filtering Firewall :** Packet filtering firewall is used to control network access by monitoring outgoing and incoming packet and allowing them to pass or stop based on source and destination IP address, protocols and ports. It analyses traffic at the transport protocol layer (but mainly uses first 3 layers).
Packet firewalls treat each packet in isolation. They have no ability to tell whether a packet is part of an existing stream of traffic. Only It can allow or deny the packets based on unique packet headers.

Packet filtering firewall maintains a filtering table which decides whether the packet will be forwarded or discarded. From the given filtering table, the packets will be Filtered according to following rules:

1. Incoming packets from network 192.168.21.0 are blocked.
2. Incoming packets destined for internal TELNET server (port 23) are blocked.
3. Incoming packets destined for host 192.168.21.3 are blocked.
4. All well-known services to the network 192.168.21.0 are allowed.

2. **Second Generation- Stateful Inspection Firewall :** Stateful firewalls (performs Stateful Packet Inspection) are able to determine the connection state of packet, unlike Packet filtering firewall, which makes it more efficient. It keeps track of the state of networks connection travelling across it, such as TCP streams. So the filtering decisions would not only be based on defined rules, but also on packet's history in the state table.

3. **Third Generation- Application Layer Firewall :** Application layer firewall can inspect and filter the packets on any OSI layer, up to the application layer. It has the ability to block specific content, also recognize when certain application and protocols (like HTTP, FTP) are being misused.
In other words, Application layer firewalls are hosts that run proxy servers. A proxy firewall prevents the direct connection between either side of the firewall, each packet has to pass through the proxy. It can allow or block the traffic based on predefined rules.

Note: Application layer firewalls can also be used as Network Address Translator(NAT).

4. **Next Generation Firewalls (NGFW) :** Next Generation Firewalls are being deployed these days to stop modern security breaches like advance malware attacks and application-layer attacks. NGFW consists of Deep Packet Inspection, Application Inspection, SSL/SSH inspection and many functionalities to protect the network from these modern threats.

Types of Firewall

Firewalls are generally of two types: *Host-based* and *Network-based.*

1. **Host- based Firewalls :** Host-based firewall is installed on each network node which controls each incoming and outgoing packet. It is a software application or suite of applications, comes as a part of the operating system. Host-based firewalls are

needed because network firewalls cannot provide protection inside a trusted network. Host firewall protects each host from attacks and unauthorized access.

2. **Network-based Firewalls :** Network firewall function on network level. In other words, these firewalls filter all incoming and outgoing traffic across the network. It protects the internal network by filtering the traffic using rules defined on the firewall. A Network firewall might have two or more network interface cards (NICs). A network-based firewall is usually a dedicated system with proprietary software installed.

Cryptography and Network Security

Security:

Security in networking is based on cryptography, the science and art of transforming messages to make them secure and immune to attack. Cryptography can provide several aspects of security related to the interchange of messages through networks. These aspects are confidentiality, integrity, authentication, and nonrepudiation.

Cryptography:

Cryptography can provide confidentiality, integrity, authentication, and non repudiation of messages. Cryptography, a word with Greek origins, means "secret writing." However, we use the term to refer to the science and art of transforming messages to make them secure and immune to attacks.

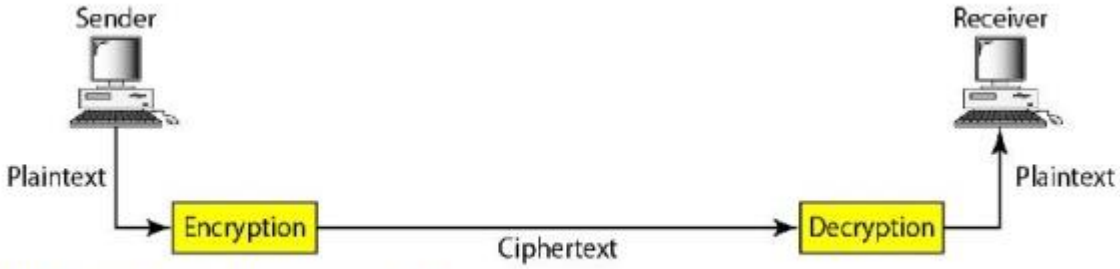


Figure 5.19 Cryptography components

Plaintext and Ciphertext

The original message, before being transformed, is called plaintext. After the message is transformed, it is called ciphertext. An encryption algorithm transforms the plaintext into ciphertext; a decryption algorithm transforms the ciphertext back into plaintext. The sender uses an encryption algorithm, and the receiver uses a decryption algorithm.

Two Categories

We can divide all the cryptography algorithms (ciphers) into two groups: symmetric key (also called secret-key) cryptography algorithms and asymmetric (also called public-key) cryptography algorithms.

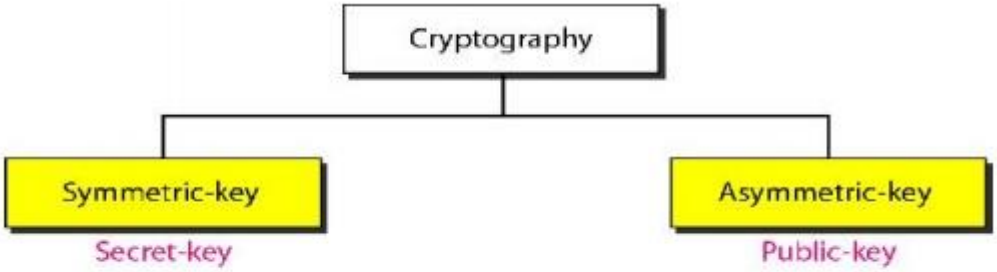


Figure 5.20 Categories of cryptography

a. Symmetric·Key Cryptography

In symmetric-key cryptography, the same key is used by both parties. The sender uses this key and an encryption algorithm to encrypt data; the receiver uses the same key and the corresponding decryption algorithm to decrypt the data

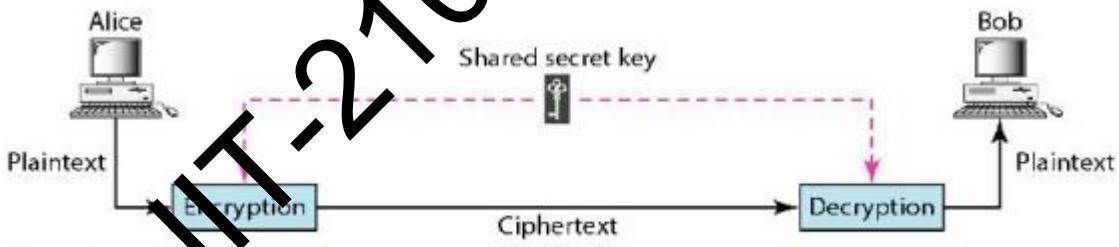


Figure 5.21 Symmetric-Key Cryptography

b. Asymmetric-Key Cryptography

In asymmetric or public-key cryptography, there are two keys: a private key and a public key. The private key is kept by the receiver. The public key is announced to the public. In public-key encryption/decryption, the public key that is used for encryption is different from the private key that is used for decryption. The public key is available to the public; the private key is available only to an individual.

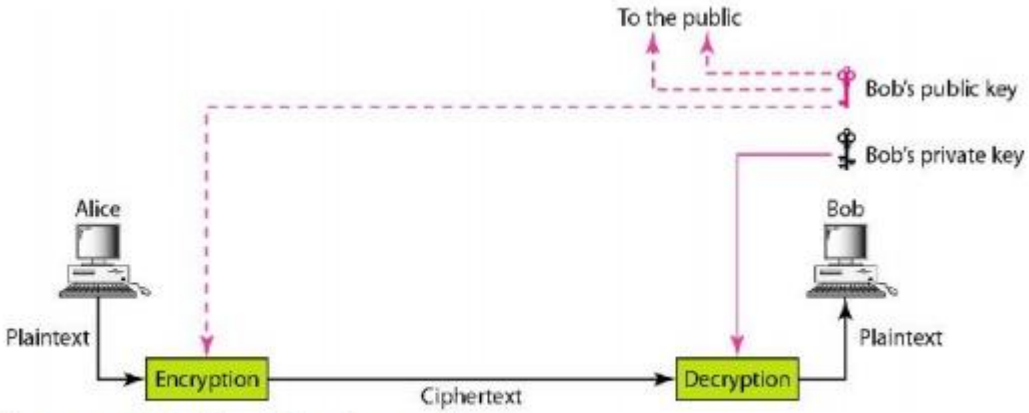


Figure 5.22 Asymmetric-Key Cryptography

Symmetric-Key Cryptography

Symmetric-key cryptography started thousands of years ago when people needed to exchange secrets (for example, in a war). We still mainly use symmetric-key cryptography in our network security.

Traditional Ciphers

The traditional ciphers are character-oriented. Although these are now obsolete, the goal is to show how modern ciphers evolved from them. We can divide traditional symmetric-key ciphers into two broad categories: substitution ciphers and transposition ciphers

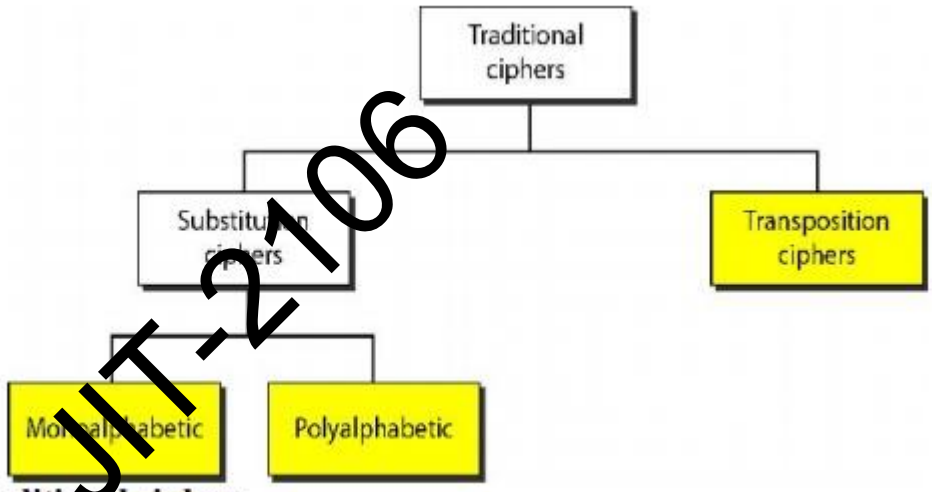


Figure 5.23 Traditional ciphers

Substitution Cipher

A substitution cipher substitutes one symbol with another. If the symbols in theplaintext are alphabetic characters, we replace one character with another. For example, we can replace character A with D, and character T with Z. If the symbols are digits (0 to 9), we can replace 3 with 7, and 2 with 6. Substitution ciphers can be categorized as either monoalphabetic or polyalphabetic ciphers. A substitution cipher replaces one symbol with another.

In a monoalphabetic cipher, a character (or a symbol) in the plaintext is alwayschanged to the same character (or symbol) in the ciphertext regardless of its position in the text. For example, if the algorithm says that character A in the plaintext is changed to character D, every character A is changed to character D.

In a polyalphabetic cipher, each occurrence of a character can have a differentsubstitute. The relationship between characters in the plaintext to a character in the ciphertext is a one-to-many relationship. For example, character A could be changed to D in the beginning of the text, but it could be changed to N at the middle.

Transposition Ciphers

In a transposition cipher, there is no substitution of characters; instead, their locations change. A character in the first position of the plaintext may appear in the tenth position of the

ciphertext. A character in the eighth position may appear in the first position. In other words, a transposition cipher reorders the symbols in a block of symbols. A transposition cipher reorders (permutes) symbols in a block of symbols.

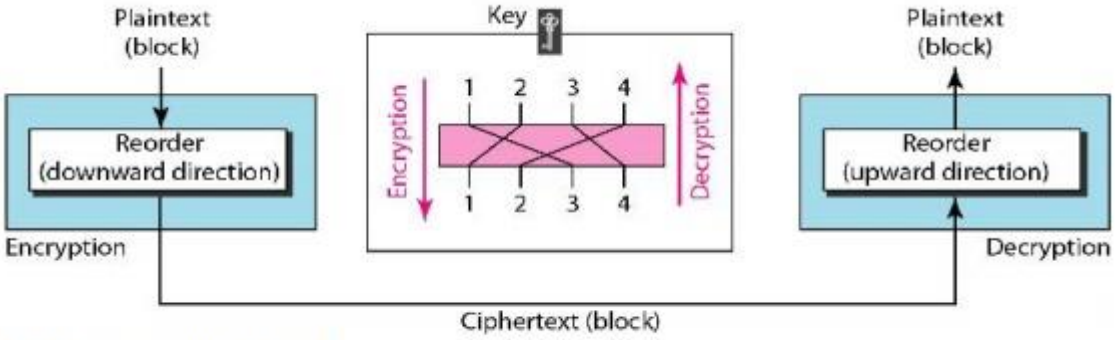


Figure 5.24 Transposition Ciphers

Asymmetric-Key Cryptography

An asymmetric-key (or public-key) cipher uses two keys: one private and one public. We discuss two algorithms: RSA and Diffie-Hellman.

RSA

The most common public-key algorithm is RSA, named for its inventors Rivest, Shamir, and Adleman (RSA). It uses two numbers, e and d, as the public and private keys.

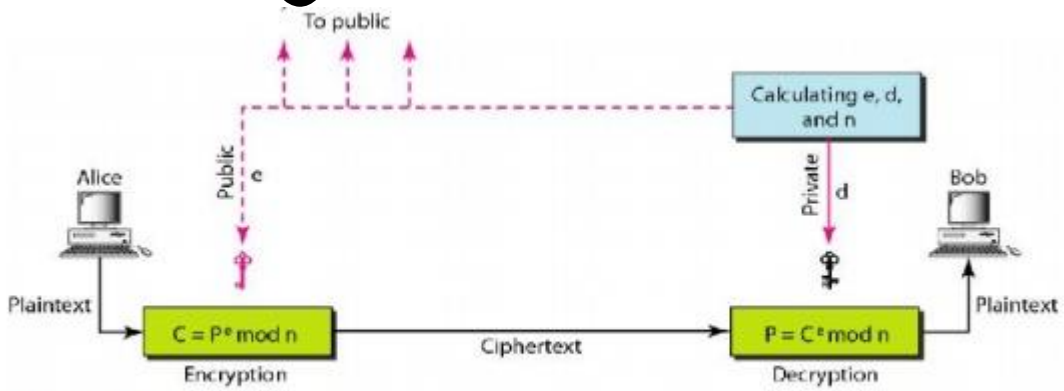


Figure 5.25 RSA

Encryption

Anyone who needs to send a message to Bob can use name *e*. For example, if Alice needs to send a message to Bob, she can change the message, usually a short one, to an integer. This is the plaintext. She then calculates the ciphertext, using *e* and *n*.

C=pe(mod n) Alice sends C, the ciphertext, to Bob.

Decryption

Bob keeps Φ and *d* private. When he receives the ciphertext, he uses his private key *d* to decrypt the message:

$P = Cd \pmod{n}$

Restriction

For RSA to work the value of *P* must be less than the value of *n*. If *P* is a large number, the plaintext needs to be divided into blocks to make *P* less than *n*.

Applications

Although RSA can be used to encrypt and decrypt actual messages, it is very slow if the message is long. RSA, therefore, is useful for short messages such as a small message digest or a symmetric key to be used for a symmetric-key cryptosystem. In particular, we will see that RSA is used in digital signatures and other cryptosystems that often need to encrypt a small message without having access to a symmetric key.RSA is also used for authentication.

Diffie-Hellman

RSA is a public-key cryptosystem that is often used to encrypt and decrypt symmetric keys. Diffie-Hellman, on the other hand, was originally designed for key exchange. In the **Diffie-Hellman** cryptosystem, two parties create a symmetric session key to exchange data withouthaving to remember or store the key for future use. They do not have to meet to agree on the key; it can be done through the Internet.

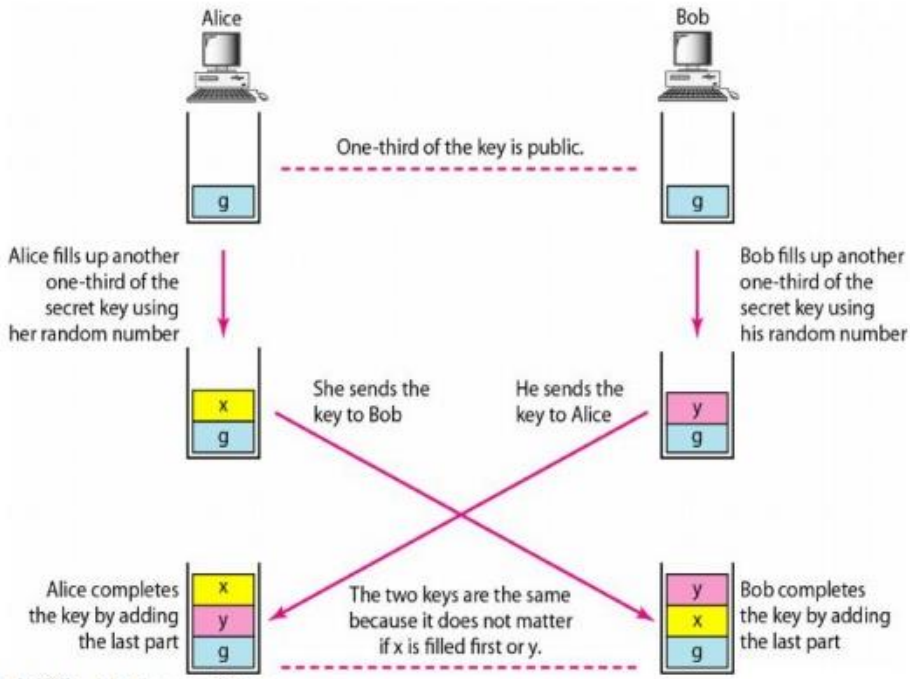
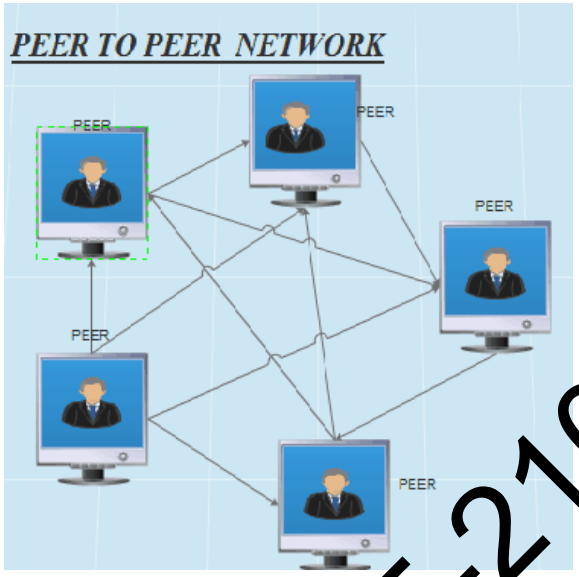


Figure 5.26 Diffie-Hellman idea

What is a Peer-to-Peer Network?

It's a network in which the computers are managed independently of one another and have equal rights for initiating communication with each other, sharing resources, and validating users.



Peer to Peer Network

How It Works

A peer-to-peer network has no special server for authenticating users. Each computer manages its own security, so a separate user account might need to be created for each computer that a user needs to access. Users usually store files on their own computers and are responsible for ensuring that those files are appropriately backed up. In a peer-to-peer network, each computer typically runs both client and server software and can be used to make resources available to other users or to access shared resources on the network.

Peer-to-peer networks are simple to set up and are often ideal for small businesses that have fewer than 10 computers and that cannot afford a server-based solution. The disadvantages of peer-to-peer networks are poor security and lack of centralized file storage and backup facilities.

Peer-to-Peer network architecture

A peer-to-peer network is designed around the notion of equal peer nodes simultaneously functioning as both "clients" and "servers" to the other nodes on the network. This model of network arrangement differs from the client–server model where communication is usually to and from a central server. A typical example of a file transfer that uses the client-server model is the File Transfer Protocol (FTP) service in which the client and server programs are distinct: the clients initiate the transfer, and the servers satisfy these requests.

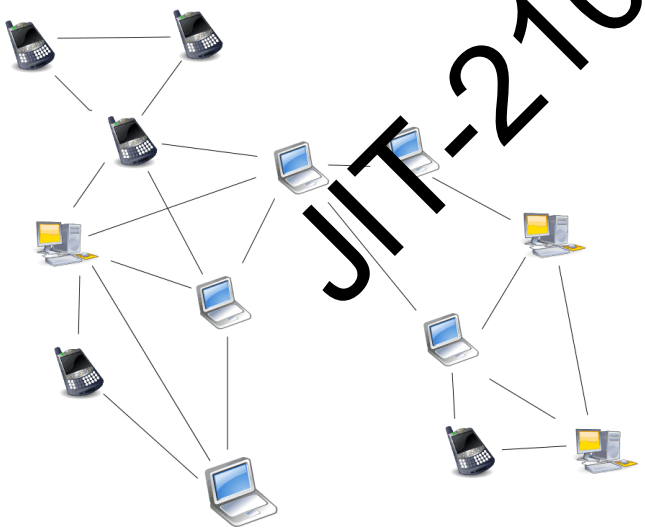
Peer-to-peer networks generally implement some form of virtual overlay network on top of the physical network topology, where the nodes in the overlay form a subset of the nodes in the physical network. Data is still exchanged directly over the underlying TCP/IP network, but at the *application layer* peers are able to communicate with each other directly, via the

logical overlay links (each of which corresponds to a path through the underlying physical network). Overlays are used for indexing and peer discovery and make the P2P system independent from the physical network topology. Based on how the nodes are linked to each other within the overlay network, and how resources are indexed and located, we can classify networks as unstructured or structured (or as a hybrid between the two).

Unstructured networks

Unstructured peer-to-peer networks do not impose a particular structure on the overlay network by design, but rather are formed by nodes that randomly form connections to each other. (*Gnutella*, *Gossip*, and *Kazaa* are examples of unstructured P2P protocols).

Because there is no structure globally imposed upon them, unstructured networks are easy to build and allow for localized optimizations to different regions of the overlay. Also, because the role of all peers in the network is the same, unstructured networks are highly robust in the face of high rates of "churn" – that is, when large numbers of peers are frequently joining and leaving the network.



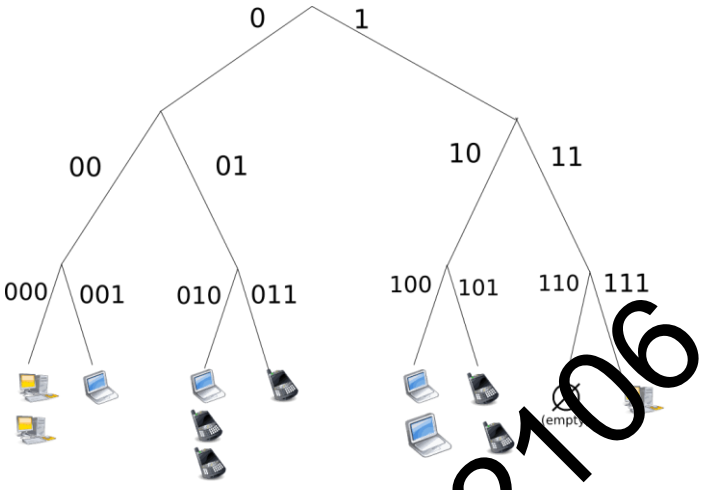
Unstructured Peer-to-Peer (P2P) network diagram

However, the primary limitations of unstructured networks also arise from this lack of structure. In particular, when a peer wants to find the desired piece of data in the network, the search query must be flooded through the network to find as many peers as possible that share the data. Flooding causes a very high amount of signaling traffic in the network, uses more CPU/memory (by requiring every peer to process all search queries), and does not ensure that search queries will always be resolved. Furthermore, since there is no correlation between a peer and the content managed by it, there is no guarantee that flooding will find a peer that has the desired data. Popular content is likely to be available at several peers and any peer searching for it is likely to find the same thing. But if a peer is looking for rare data shared by only a few other peers, then it is highly unlikely that search will be successful.

Structured networks

In structured peer-to-peer networks, the overlay is organized into a specific topology, and the protocol ensures that any node can efficiently search the network for a file/resource, even if the resource is extremely rare.

The most common type of structured P2P networks implements a distributed hash table (DHT), in which a variant of consistent hashing is used to assign ownership of each file to a particular peer. This enables peers to search for resources on the network using a hash table: that is, (key, value) pairs are stored in the DHT, and any participating node can efficiently retrieve the value associated with a given key.



Structured (DHT) Peer-to-Peer network diagram

However, in order to route traffic efficiently through the network, nodes in a structured overlay must maintain lists of neighbors that satisfy specific criteria. This makes them less robust in networks with a high rate of churn (i.e. with large numbers of nodes frequently joining and leaving the network). A more recent evaluation of P2P resource discovery solutions under real workloads has pointed out several issues in DHT-based solutions such as high cost of advertising/discovering resources and static and dynamic load imbalance.

Notable distributed networks that use DHTs include *Tixati*, an alternative to BitTorrent's distributed tracker, the *Kad network*, the *Storm botnet*, *YaCy*, and the *Coral Content Distribution Network*. Some prominent research projects include the Chord project, *Kademlia*, *PAST storage utility*, *P-Grid*, a self-organized and emerging overlay network, and *CoopNet* content distribution system. DHT-based networks have also been widely utilized for accomplishing efficient resource discovery for grid computing systems, as it aids in resource management and scheduling of applications.

Applications and examples of P2P networks

Content delivery

In P2P networks, clients both provide and use resources. This means that unlike client-server systems, the content-serving capacity of peer-to-peer networks can actually *increase* as more users begin to access the content (especially with protocols such as ***BitTorrent*** that require users to share, refer a performance measurement study). This property is one of the major advantages of using P2P networks because it makes the setup and running costs very small for the original content distributor.

File-sharing networks

Many file peer-to-peer file sharing networks, such as Gnutella, G2, and the eDonkey network popularized peer-to-peer technologies.

- Peer-to-peer content delivery networks.
- Peer-to-peer content services, e.g. caches for improved performance such as Correli Caches
- Software publication and distribution (Linux distribution, several games); via file sharing networks.

Copyright infringements

Peer-to-peer networking involves data transfer from one user to another without using an intermediate server. Companies developing P2P applications have been involved in numerous legal cases, primarily in the United States, over conflicts with copyright law. Two major cases are *Grokster vs RIAA* and *MGM Studios, Inc. v. Grokster, Ltd.*. In the last case, the Court unanimously held that defendant peer-to-peer file-sharing companies Grokster and Streamcast could be sued for inducing copyright infringement.

Multimedia

- The P2PTV and PDTP protocols.
- Some proprietary multimedia applications use a peer-to-peer network along with streaming servers to stream audio and video to their clients.
- Peercasting for multicasting streams.
- Pennsylvania State University, MIT and Simon Fraser University are carrying on a project called LionShare designed for facilitating file sharing among educational institutions globally.
- Osiris is a program that allows its users to create anonymous and autonomous web portals distributed via P2P network.

Energy trading

Companies such as Power Ledger and Bovlabs employ peer-to-peer energy trading platforms.

Bitcoin

Bitcoin and alternatives such as Ether, Nxt, and Peercoin are peer-to-peer-based digital cryptocurrencies.