Chapter 3

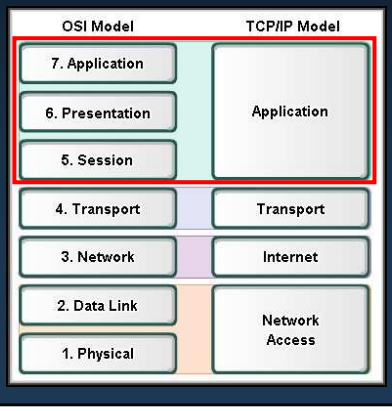
Application Layer Functionality and Protocols

Note for Instructors

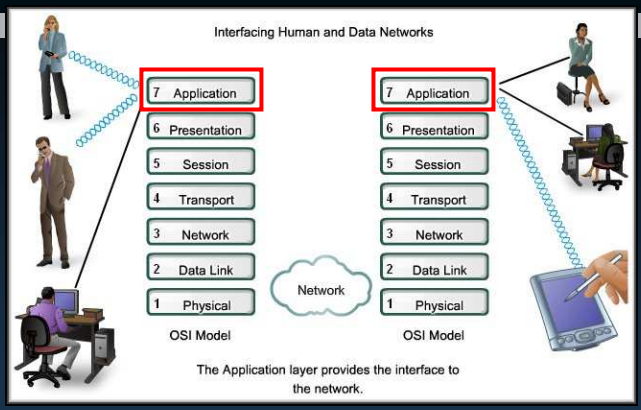
- These presentations are the result of a collaboration among the instructors at St. Clair College in Windsor, Ontario.
- Thanks must go out to Rick Graziani of Cabrillo College. His material and additional information was used as a reference in their creation.
- If anyone finds any errors or omissions, please let me know at:
  - tdame@stclaircollege.ca.

Application Layer Functionality and Protocols

Applications: The Interface Between the Networks



Application Layer – OSI and TCP/IP Models

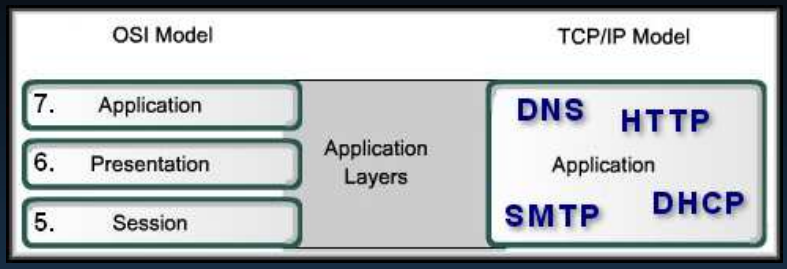


- The Application layer is the top layer of both the OSI and TCP/IP models.
- Provides the interface between the applications we use to communicate and the underlying network.

Application Layer – OSI and TCP/IP Models

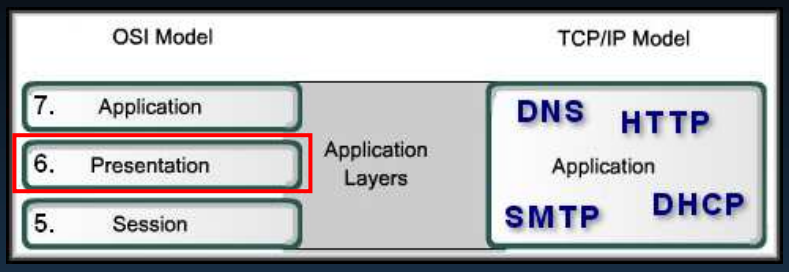
- Two important concepts:
  - Application Layer:
    - The first step for getting data on to the network.
  - Application Software:
    - The programs used to communicate over the network.
- For example:
  - When displaying a web page:
    - The Application Layer uses the HTTP Protocol.
    - The Application Software is your browser.

Application Layer – OSI and TCP/IP Models



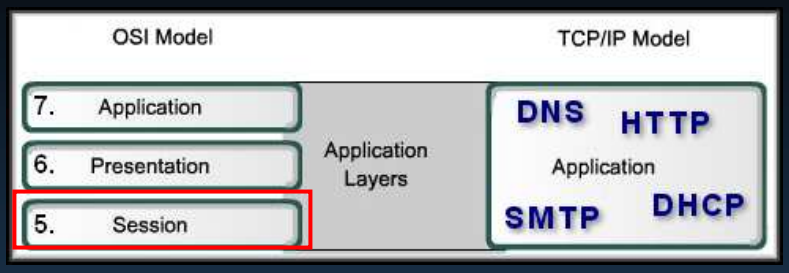
- Functionality of the TCP/IP Application Layer protocols fit roughly into the top three layers of the OSI Model.
  - Most TCP/IP application layer protocols were developed before PCs, GUIs and multimedia objects.
  - They implement very little of the Presentation and Session layer functionality.

Application Layer – OSI and TCP/IP Models



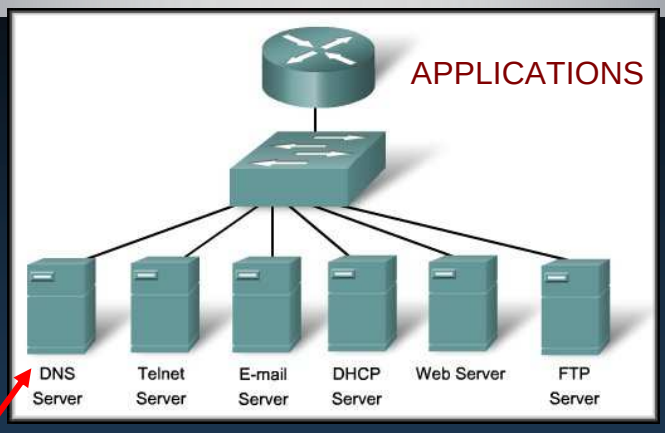
- Presentation Layer Functionality:
  - *Coding and conversion* of application layer data.
  - *Compression*.
    - Coding and compression formats: GIF, JPG, TIF
  - *Encryption*.

Application Layer – OSI and TCP/IP Models



- Session Layer Functionality:
  - *Create and maintain dialogs* between source and destination applications.
  - Handles the *exchange of information* to initiate dialogs, keep them active and restart sessions.
  - Incorporated by most applications (e.g. Web Browser).

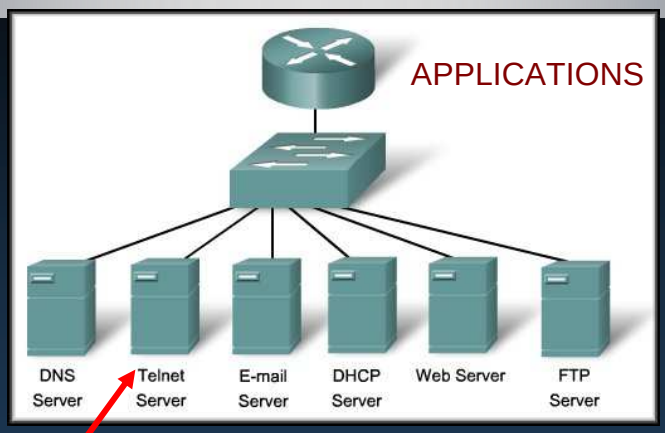
Application Layer – OSI and TCP/IP Models



DNS (Domain Name System):

Resolves Internet names (URLs) to IP Addresses.

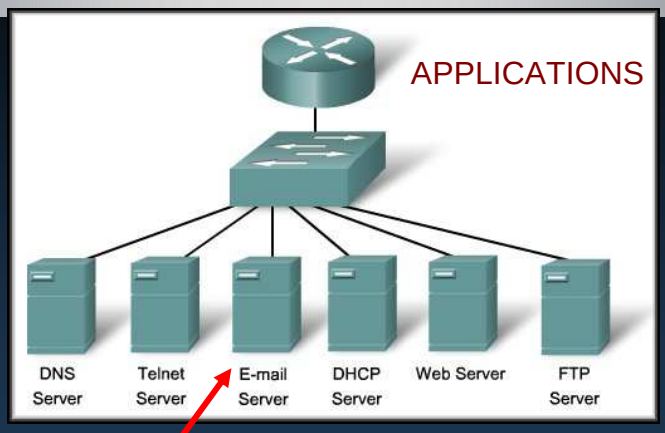
Application Layer – OSI and TCP/IP Models



Telnet:

Terminal emulation - access to servers and network devices.

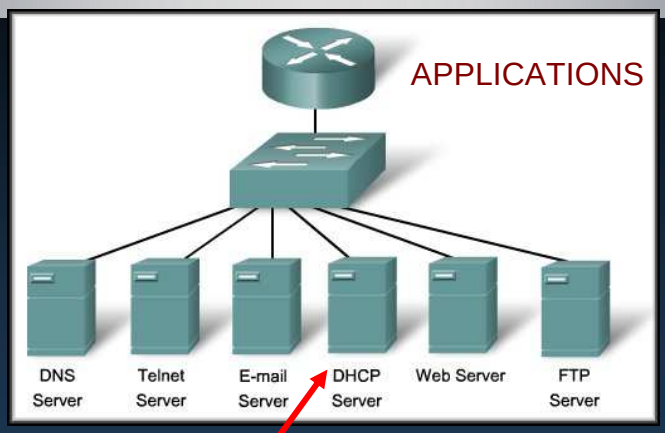
Application Layer – OSI and TCP/IP Models



SMTP (Simple Mail Transfer Protocol):

Transfer of mail messages and attachments.

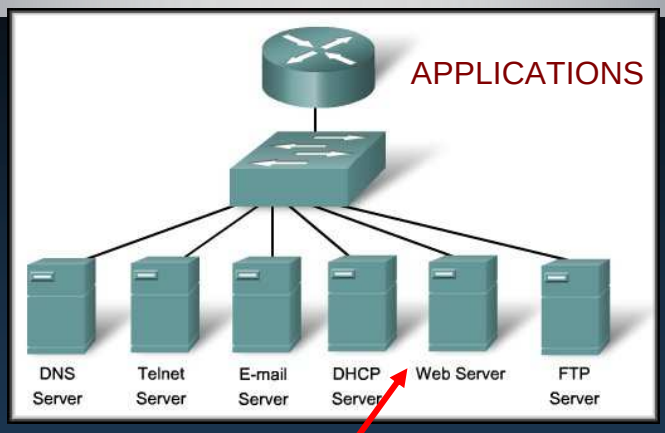
Application Layer – OSI and TCP/IP Models



DHCP (Dynamic Host Configuration Protocol):

Assigns IP Addresses and other parameters to hosts.

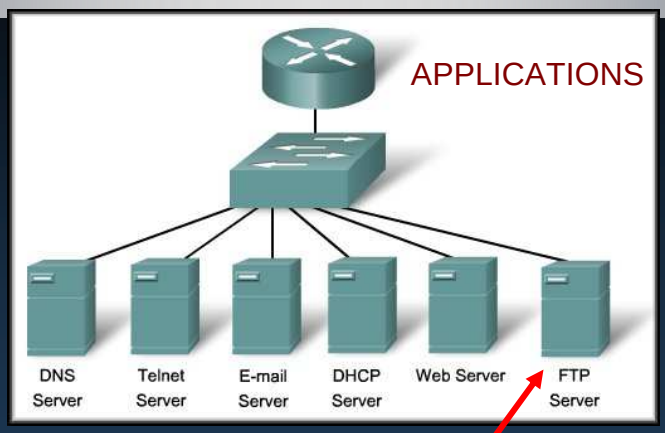
Application Layer – OSI and TCP/IP Models



HTTP (Hypertext Transfer Protocol):

Transfer files that make up web pages.

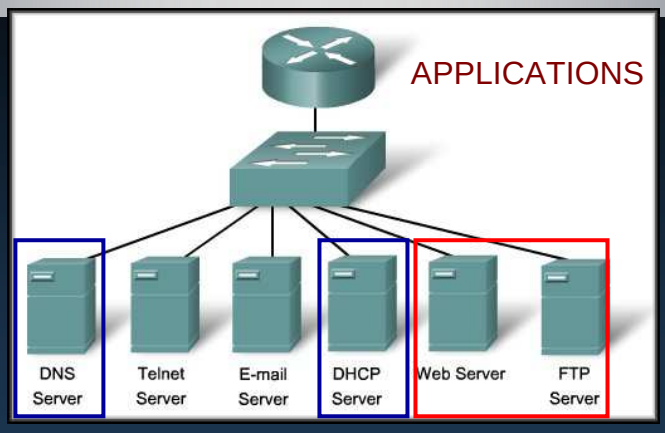
Application Layer – OSI and TCP/IP Models



FTP (File Transfer Protocol):

Interactive file transfer between systems.

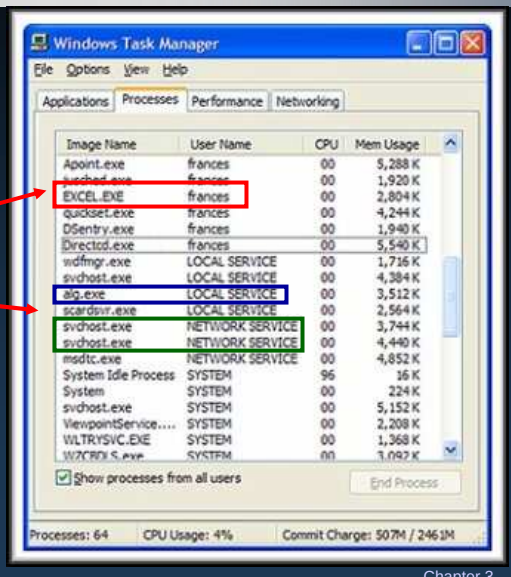
Application Layer – OSI and TCP/IP Models



Usually, a single server will function as a server for multiple application protocols.

Application Layer Software

- Within the Application layer, there are **two forms** of software programs or processes that provide access to the network:
  - **Applications**
  - **Services**



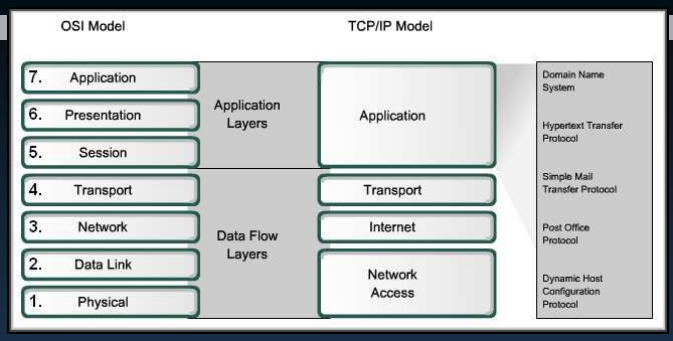
Application Layer Software

- Network-Aware Applications:
  - The software programs used by people to communicate.
  - They implement the application layer protocols and are able to communicate directly with the lower layers of the protocol stack.
    - Email Clients
    - Web Browsers

Application Layer Software

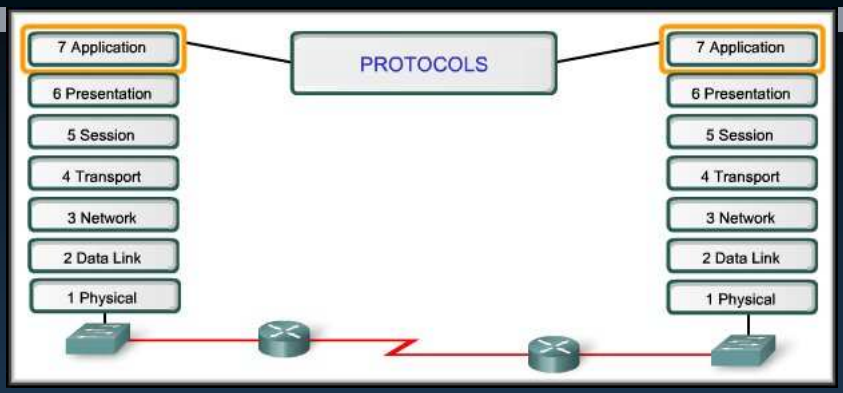
- Application Layer Services:
  - Other programs may need the assistance of Application Layer services to use network resources such as:
    - File transfer
    - Network print spooling
  - These services are the programs that interface with the network and prepare the data for transfer.

Application Layer Software



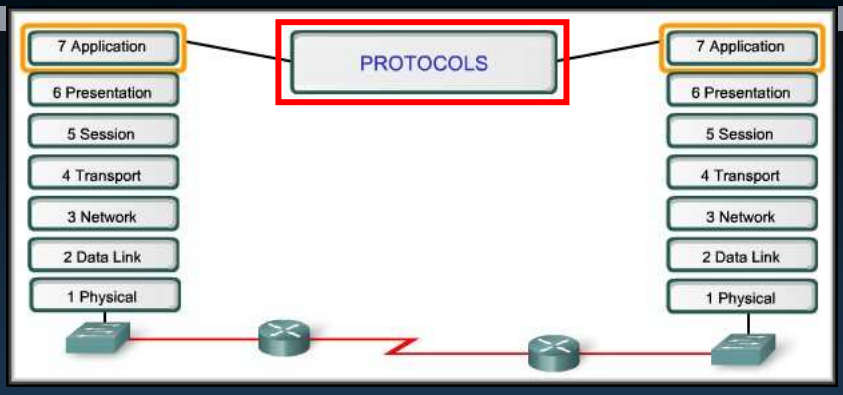
- *The Application Layer uses protocols that are implemented within applications and services.*
  - *Applications* provide people a way to create messages.
  - Application layer *services* establish an interface to the network.
  - *Protocols* provide the rules and formats that govern how data is treated.

Application Layer Software



- Application layer protocols are used by **both the source and destination** devices during a communication session.
- The application layer protocols implemented on the source and destination host **must match**.

Application Layer Software



- Establish consistent rules for data exchange.
- Specify data structure in the message and types of messages.
- Define message dialogues (appropriate responses).

Application Layer Software

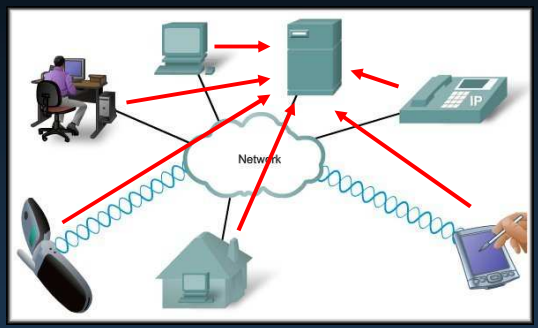
- Applications and services can use multiple protocols.
  - Encapsulate the protocol.
  - Be encapsulated by a protocol.
  - Invoke other protocols.
- For example, using a web browser (HTTP) may invoke:
  - DNS, ARP, ICMP
  - May use TCP, UDP, Ethernet, PPP *(Much More Later)*
  - Definitely uses IP

Application Layer Functionality and Protocols

Making Provisions for Applications and Services

Introduction

- When accessing information on a device, the data may not be physically stored on that device.
- If that is the case, a request must be made to the device where the data resides.

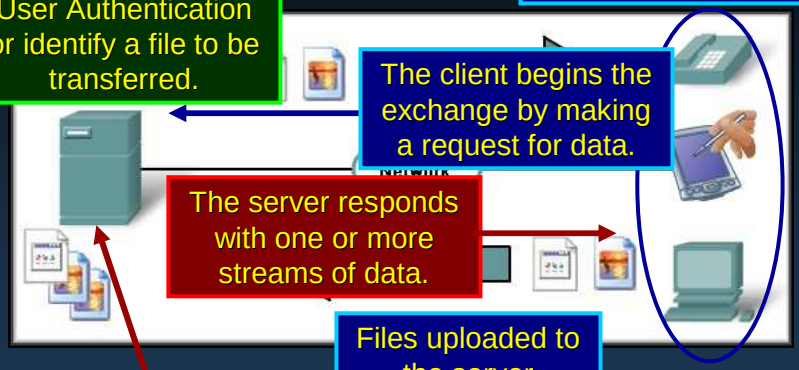


- Three methods:
  - Client/Server Model
  - Application Layer Services and Protocols
  - Peer-to-Peer (P2P) Networking and Applications

Client/Server Model

May also require control information. User Authentication or identify a file to be transferred.

Clients – hardware, software combination



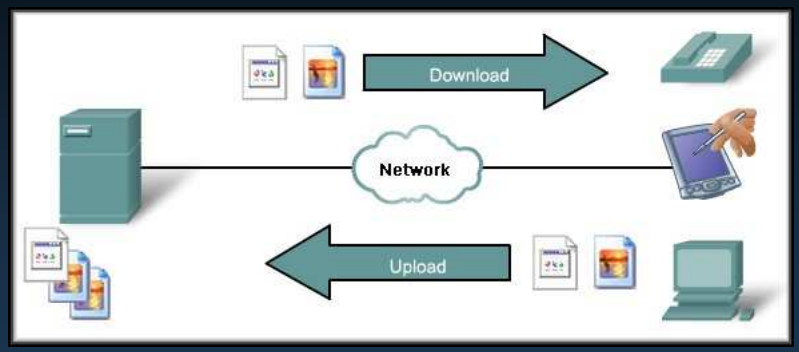
The client begins the exchange by making a request for data.

The server responds with one or more streams of data.

Files uploaded to the server

Resources are stored on the server.

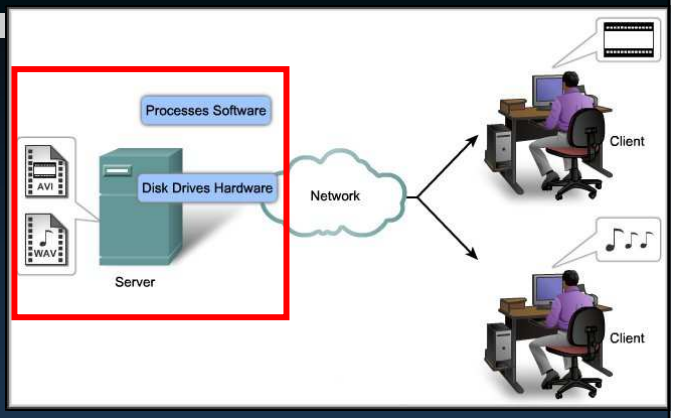
Client/Server Model



The biggest advantage of the client/server model is the centralization of resources.
User Names and Passwords, Files, Databases.

Servers

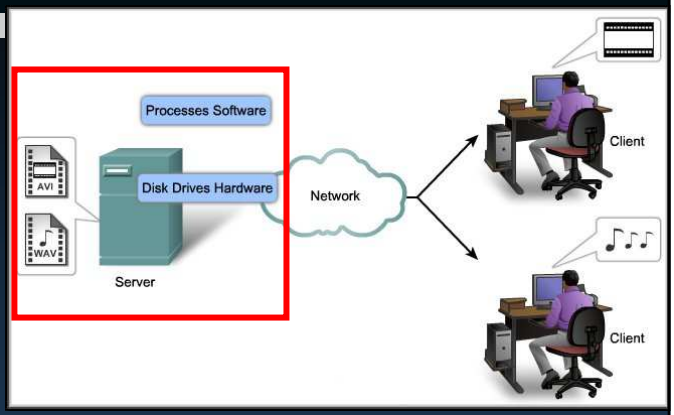
- Servers are repositories of information.
- Processes on the server control the delivery of information to the client.



- The information is usually shared with multiple clients.
  - Web Server
  - FTP Server
  - Database Server

Servers

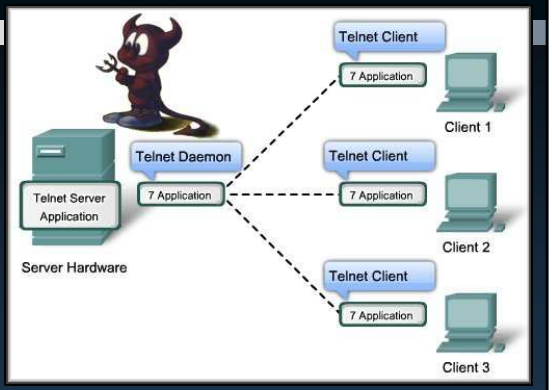
- Some servers may require user authentication to access the data or the network.
- FTP Server: May require an account and password before allowing a transfer.
- Domain Controller Server: Will require a user name and password in order to access the network.



Servers

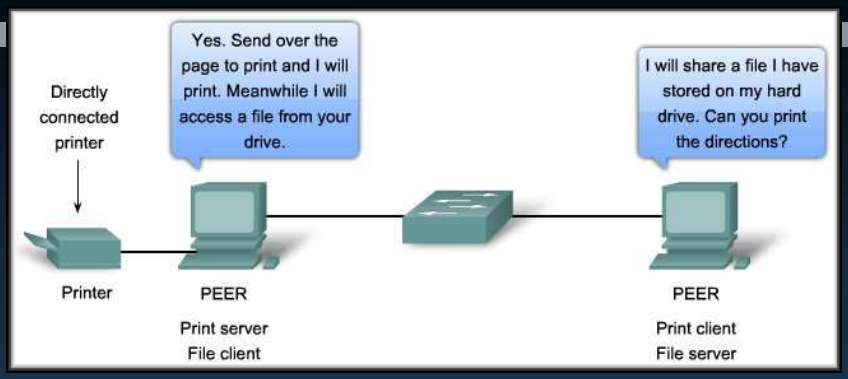
- The server runs a service, or process, sometimes called a server **daemon**.
- **Daemons** (like other services):
  - Typically run in the background.
  - Are not under an end user's direct control.
  - Are described as ***"listening"*** for a request from a client.
  - Programmed to respond whenever the server receives a request for the service provided by the daemon.
- When a daemon ***"hears"*** a request from a client:
  - It exchanges appropriate messages with the client.
  - Sends the requested data in the proper format.

Application Layer Services and Protocols



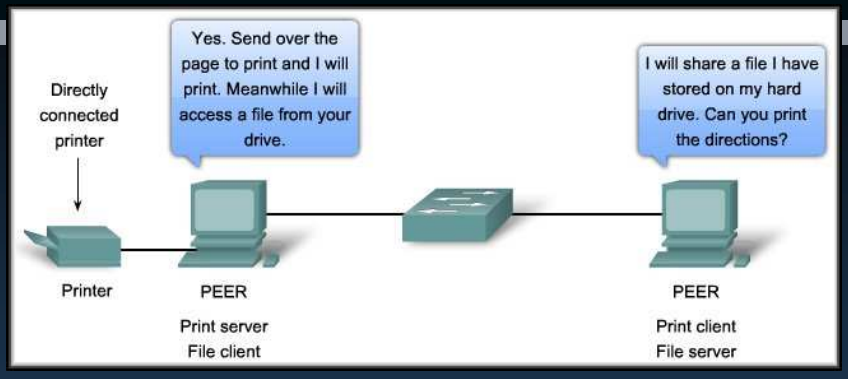
- **Typically, a server will have multiple clients requesting services at the same time.**
- For example, the **Telnet Server**.
- The Telnet daemon listens for connection requests that are received on ***port 23***.
- Connection options are negotiated with the client and a ***Child Process*** is created on the server on a different unused port.
- The Telnet daemon resumes listening and repeats the process for each unique connection.

Peer-to-Peer (P2P) Networking



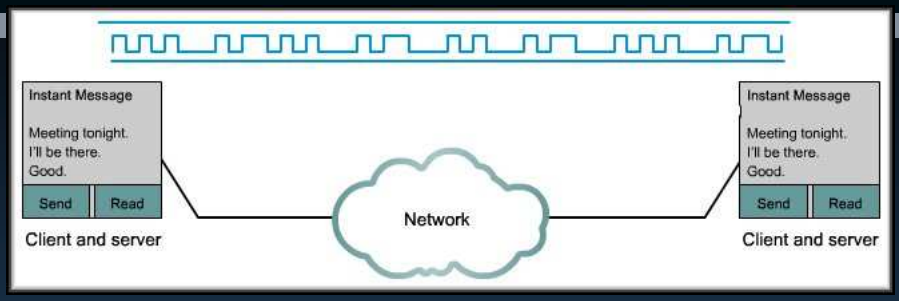
- Two or more computers are connected via a network and can share resources (such as printers and files) ***without having a dedicated server***.
- End devices (peers) can function as either a ***server or client*** depending upon the required service.

Peer-to-Peer (P2P) Networking



- One big disadvantage of P2P networking is that it ***decentralizes the services*** on a multiuser network.
- Maintaining security and access policies on a P2P network is definitely a challenge. All Policies and User Names and Passwords must be maintained on each ***peer*** device.

Peer-to-Peer (P2P) Applications

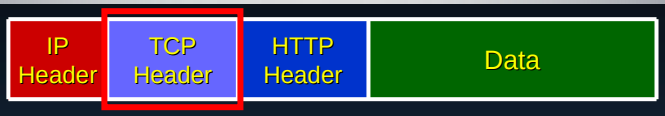


- A peer-to-peer *application*, unlike a peer-to-peer network, allows a device to act as *both a client and a server within the same communication*.
- Both can initiate a communication and are considered equal in the communication process.
- In other words, in this model, every client is a server and every server a client.

Application Layer Functionality and Protocols

Application Layer Protocols and Services Examples

Introduction



- Commonly used protocols:
  - The OSI Model Transport Layer uses an addressing scheme called a port number. *(Much More Later)*
  - Port numbers *identify applications and Application Layer services* that are the source and destination of data.
  - Server programs generally use *predefined* port numbers that are *commonly known by clients*.
  - We will be referring to these port numbers as we look at some of the Application Layer applications and services.

Commonly Used Protocols

Application / Service	Acronym	Port
Domain Name System	DNS	53
Hypertext Transfer Protocol	HTTP	80
Simple Mail Transfer Protocol	SMTP	25
Post Office Protocol	POP3	110
Telnet	Telnet	23
Dynamic Host Configuration Protocol	DHCP	67
File Transfer Protocol	FTP	20, 21

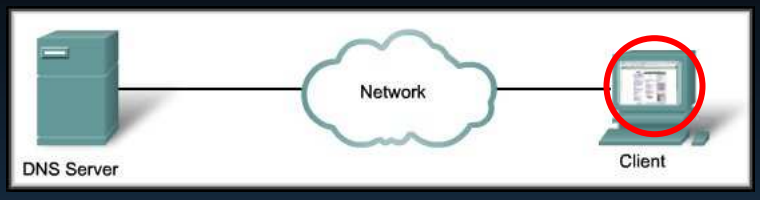
Application Layer Protocols and Services

Domain Name System
DNS

Domain Name System (DNS)

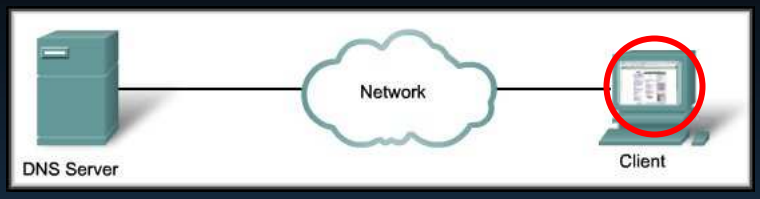
- DNS allows us to use simple, recognizable names instead of an IP Address.

Domain Name System (DNS)



- The DNS protocol defines an automated service that matches resource names with the required numeric network address.
- DNS is a client/server service. However, instead of the client being a browser or email client application, the DNS client (Resolver) runs as a service itself.
- The resolver is responsible for issuing requests and processing responses from the DNS server.

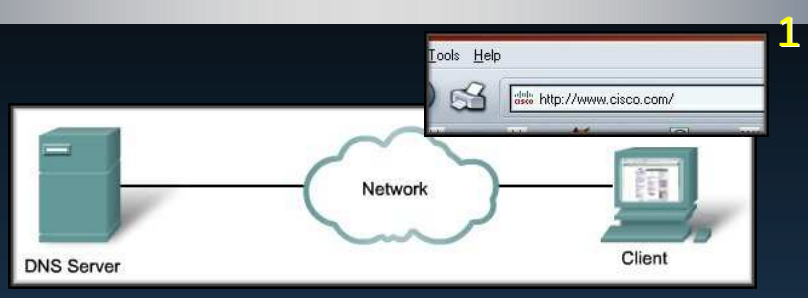
Domain Name System (DNS)



- How does the resolver know where to send the requests?
  - From the IP configuration on the device.

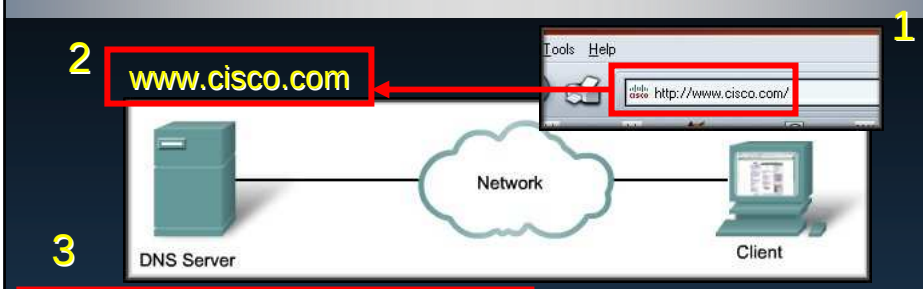
IP Address	192.168.25.25
Subnet Mask	255.255.255.0
Default Gateway	192.168.25.1
DNS Server	208.67.222.222

Domain Name System (DNS)



- DNS and the Browser:
  1. First, a domain name or URL is entered in the address field of the browser. The browser passes the name to the resolver.

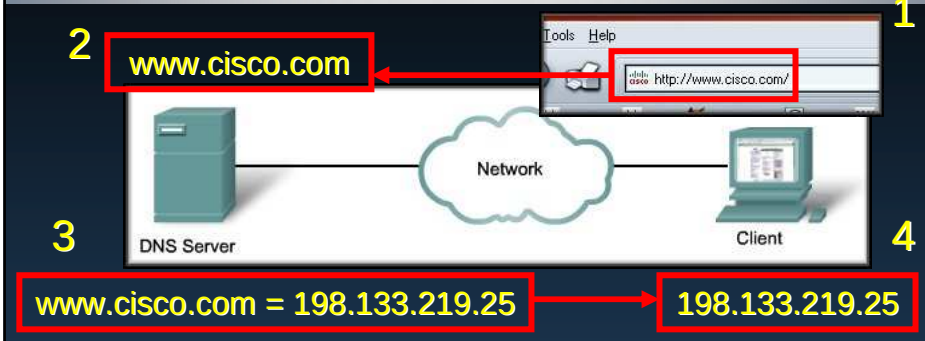
Domain Name System (DNS)



www.cisco.com = 198.133.219.25

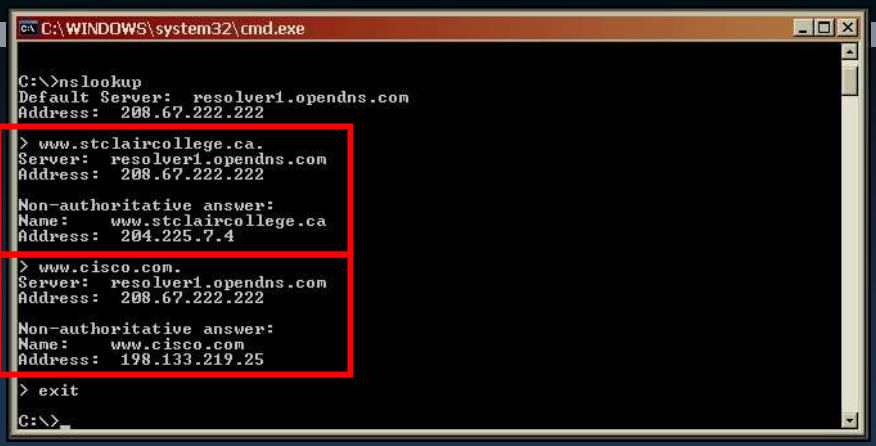
- DNS and the Browser:
  2. The resolver sends the DNS request to the DNS Server.
  3. The server then searches its records and resolves the name with to a corresponding IP Address.

Domain Name System (DNS)



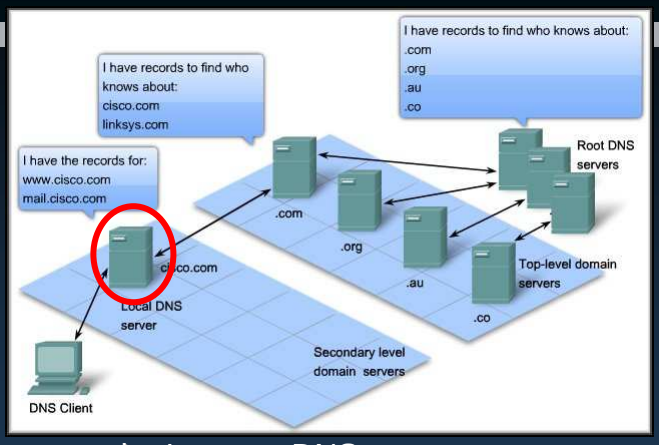
- DNS and the Browser:
  4. The DNS server then sends the IP Address back to the client that made the request. The IP Address will be used in the encapsulation process as the destination address for packets going to www.cisco.com.

Domain Name System (DNS)



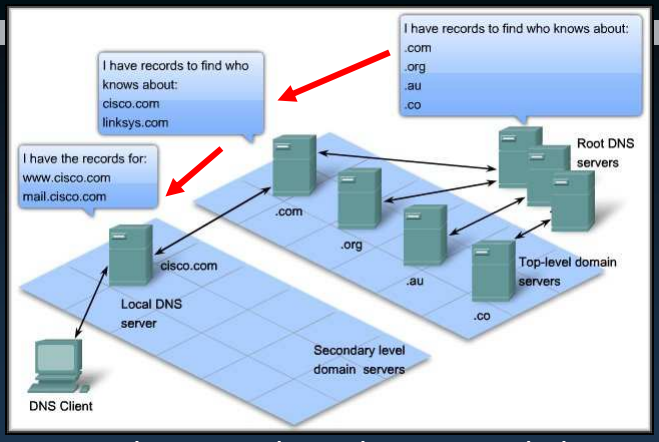
- Utility - *nslookup*:
  - Windows operating systems provide the *nslookup* utility.
  - Use to query a domain name and get the IP Address.

Domain Name System (DNS)



- For access to the Internet, DNS servers are arranged in a hierarchy.
- References to the hierarchy are included when a local DNS server is installed.

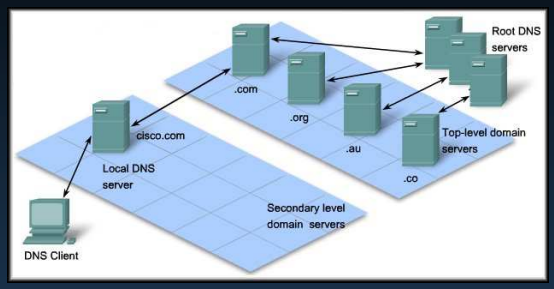
Domain Name System (DNS)



- The servers at the **"Root"** know how to reach the **"Top-level"** domain servers.
- The **top-level** servers know how to reach the **secondary** level servers and so on…..

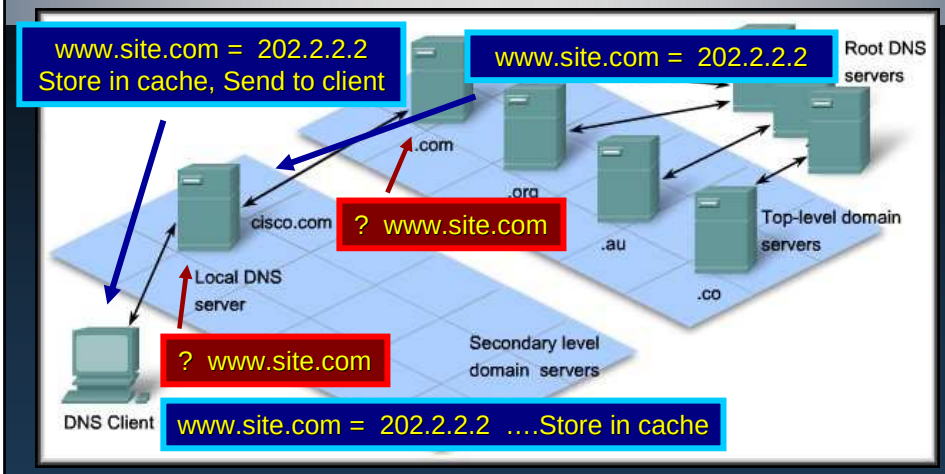
Domain Name System (DNS)

- All DNS servers store different types of resource records to resolve names.
- They contain the name, the address and the type of record.



  - A - an end device address
  - NS - an authoritative name server
  - CNAME - the Fully Qualified Domain Name
  - MX - mail exchange record to identify mail servers

Domain Name System (DNS)



- A DNS server provides the name resolution using the name daemon, which is often called named (name-dee).

Domain Name System (DNS)

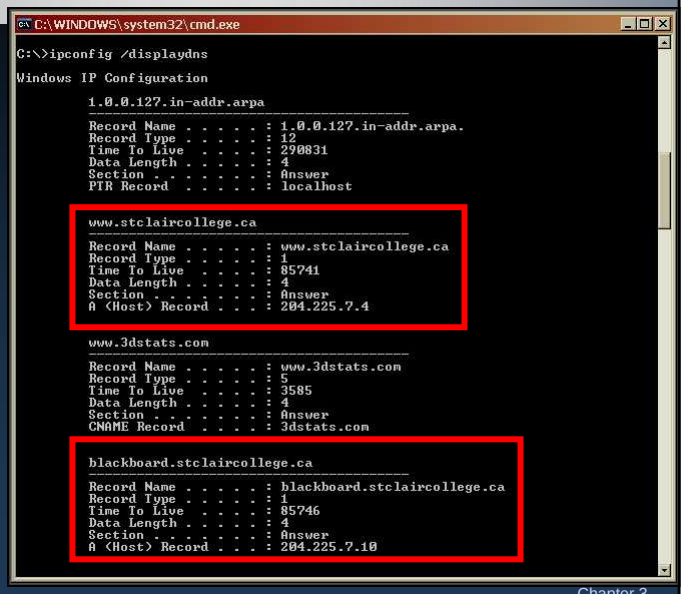
Utility:

ipconfig /displaydns

Displays the contents of the PC cache.

ipconfig /flushdns

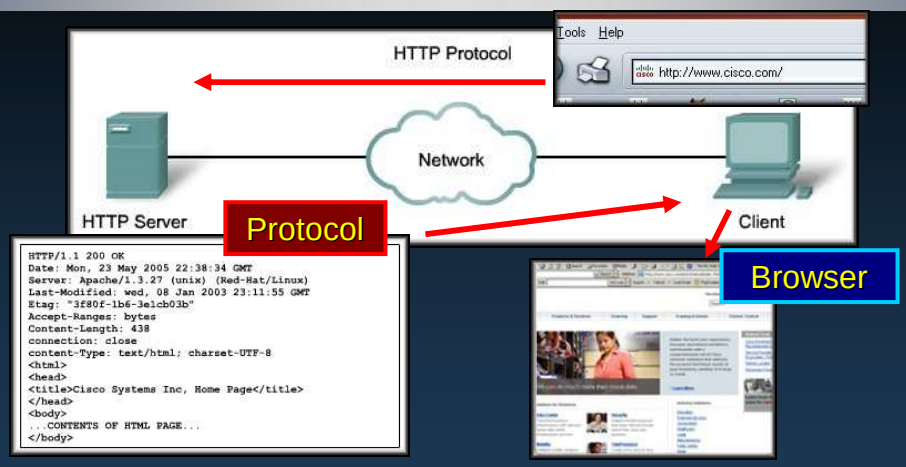
Clears the contents of the PC cache.



Application Layer Protocols and Services

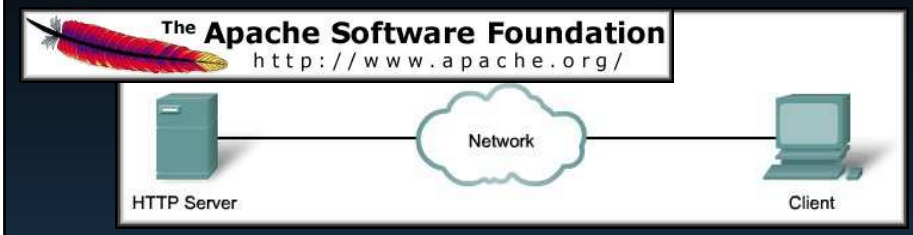
WWW Service and
Hypertext Transfer Protocol
HTTP

WWW Service and HTTP



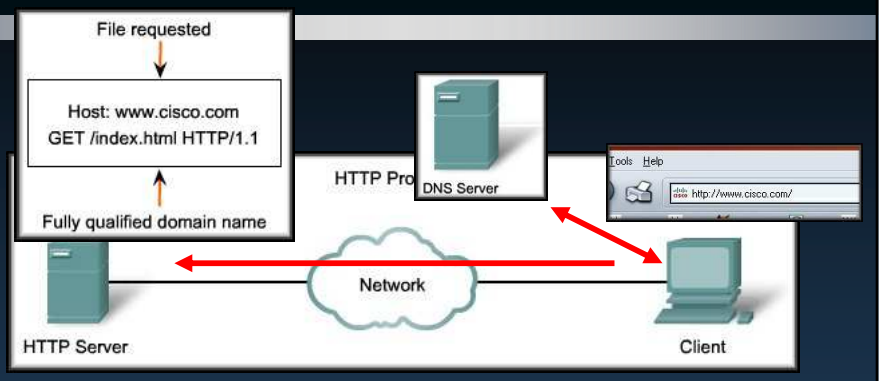
- Web browsers are the client applications used to interpret the HTTP application protocol received from a web server.

WWW Service and HTTP



- Web Server:
  - Stores the web objects (HTML, Pictures, Video, Files).
  - Each accessible by a URL.
  - Implements the server side of HTTP.
  - Examples:
    - Apache, Microsoft Internet Information Server (MIIS)

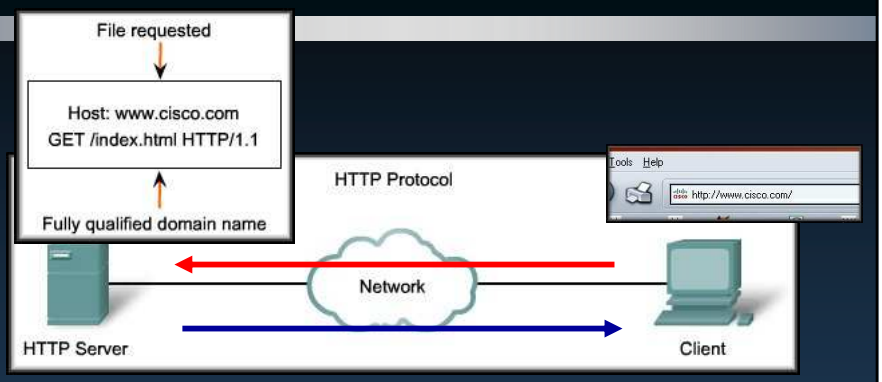
WWW Service and HTTP



- HTTP is a request/response type of protocol.
  - When a client requests a web page, HTTP defines the types of messages exchanged.

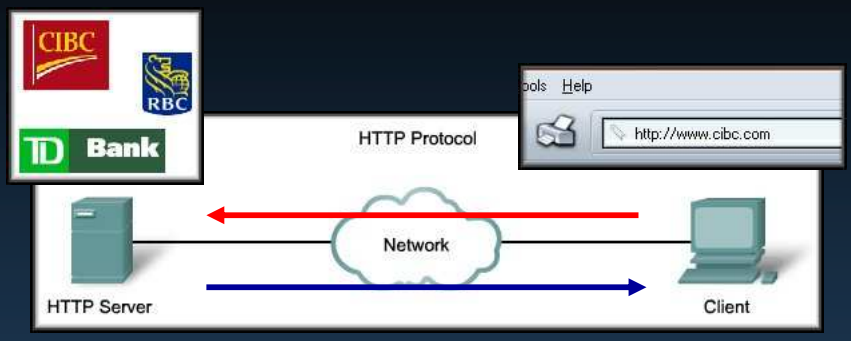
e.g. GET, PUT, POST

WWW Service and HTTP



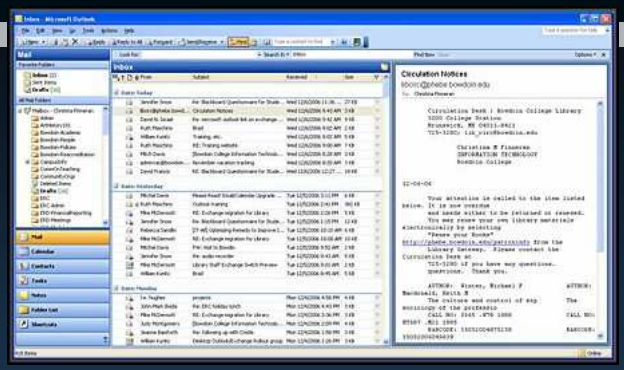
- The server responds with either:
  - The requested object.
  - An error message, if necessary.
  - Or other status messages.

WWW Service and HTTP



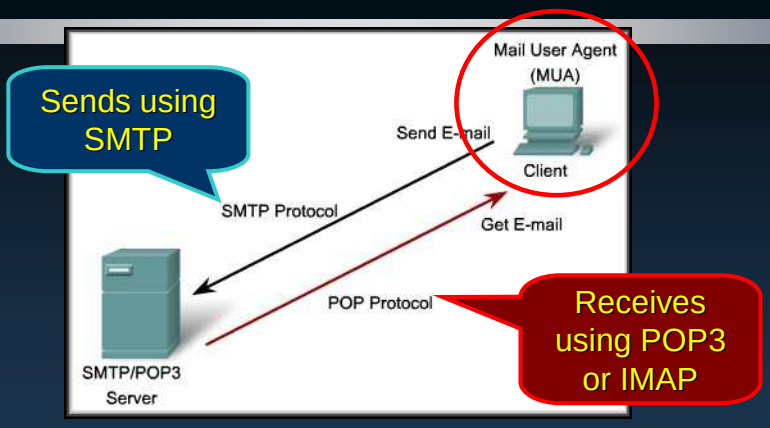
- For secure communications, **Secure HTTP (HTTPS)** is used:
  - Allows servers and clients to exchange information securely over the Internet.
  - Encryption, Authentication, additional Application and Transport Layer rules.

E-Mail Services and SMTP/POP Protocols



- Revolutionized how people communicate.
- Applications and Services.
  - **Simple Mail Transfer Protocol** (SMTP)
  - **Post Office Protocol** (POP and POP3)
  - **Internet Message Access Protocol** (IMAP)

E-Mail Services and SMTP/POP Protocols

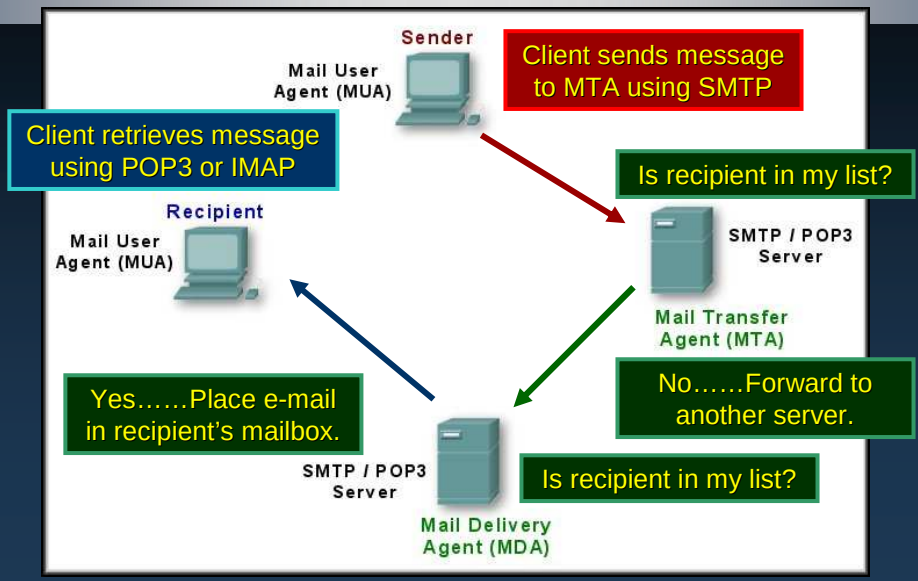


- **Mail User Agent (MUA)** is used to compose messages.
  - Also known as an email client.
  - MUA allows messages to be sent and received.
  - Messages placed in the client mailbox.

E-Mail Server Processes: MTA and MDA

- **Mail Transfer Agent (MTA):**
  - Used to forward e-mail.
  - Receives messages from an MUA or another MTA.
  - Looks at message header to determine how the message must be forwarded to reach the destination.
- **Mail Delivery Agent (MDA):**
  - Accepts mail from the MTA.
  - Places it into the appropriate user's mailbox.
- Both functions are usually available on the same server as well as SMTP and POP3 or IMAP.

E-Mail Server Processes: MTA and MDA



E-Mail Server Processes: MTA and MDA

- SMTP uses a rigid set of commands and replies.

SMTP Command	Command Syntax	Function
Hello	HELO <sending host>	ID of sending program
Extended Hello	EHLO <sending host>	HELO with service extensions
Quit	QUIT	End SMTP session
From	MAIL FROM: <sender IP address>	Sender's IP address
Recipient	RCTP TO: <receiver IP address>	Receiver's IP address
Data	DATA	Begin SMTP message
Verify	VRFY <data>	Verify user name
Expand	EXPN <data>	Expand mailing list
Help	HELP <data>	Request online help

E-Mail Server Processes: MTA and MDA

- Other alternatives with their own internal e-mail format and proprietary protocol.
  - IBM Lotus Notes
  - Novell Groupwise
  - Microsoft Exchange
- Web based e-mail:
  - Hotmail
  - Gmail

E-Mail Protocols

- Post Office Protocol (POP3):
  - Uses TCP port 110
  - Download-and-delete mode:
    - Retrieves messages from the server
    - Stores the message locally
    - Deletes the message from the server
  - Download-and-keep mode:
    - Does not delete messages on server when retrieved.
  - Difficult to access e-mail on multiple computers (e.g. work and home).
  - Some e-mail may have already been retrieved on one computer and will not appear on the other.

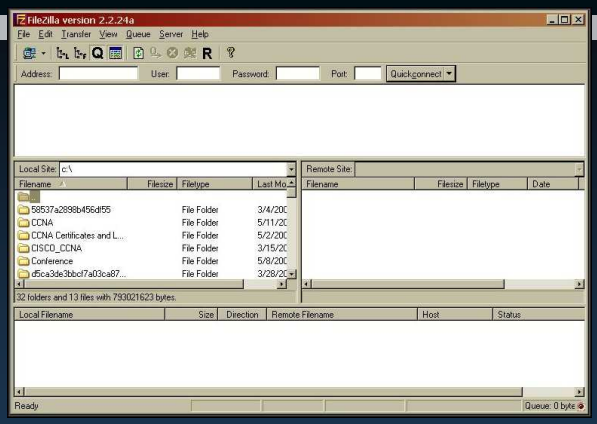
E-Mail Protocols

- Internet Message Access Protocol (IMAP):
  - E-mail is not downloaded, but retained on server
  - Any received email is associated with the user's INBOX
  - Users can create and manage remote folders
  - Users can retrieve portions of the email:
    - Message header: Subject line and Sender
- Web Based E-mail:
  - Introduced with Hotmail in mid-1990's.
  - Communicates with a remote mailbox using HTTP.
  - HTTP is used to push (client to server) and pull (server to client) the email.

Application Layer Protocols and Services

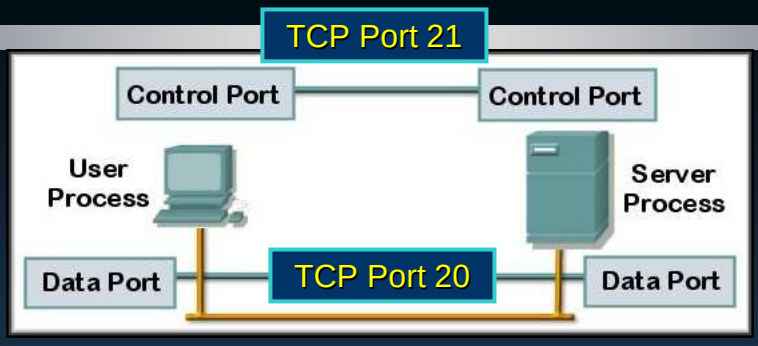
File Transfer Protocol
FTP

File Transfer Protocol (FTP)



- FTP was developed to allow for **file transfers** between a client and a server.
- Used to **push** and **pull** files from a **server** running the FTP daemon (**FTPd**).

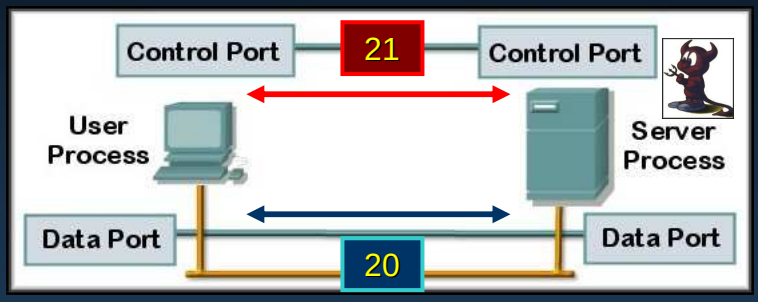
File Transfer Protocol (FTP)



- Uses two well-known ports:
  - **Port 21** is used to establish the connection and the transfer of control information.
  - **Port 20** is used for the actual data transfer.

File Transfer Protocol (FTP)

Client initiates a TCP control connection on Port 21.
Username and password….

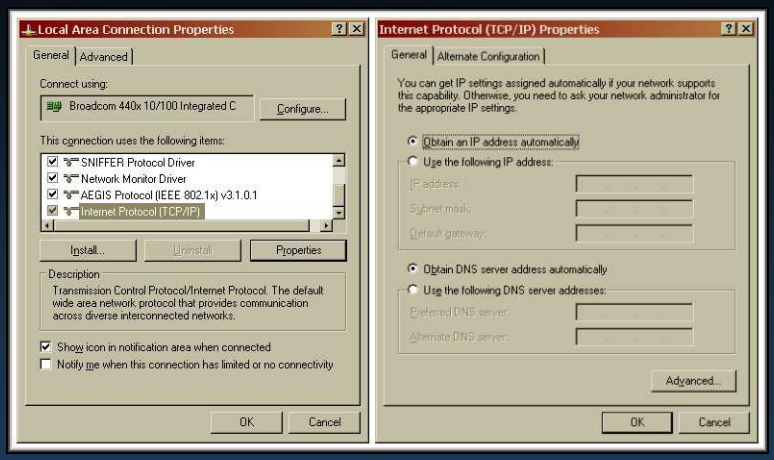


For *each file transferred*, TCP opens and closes a Data connection on Port 20.

Application Layer Protocols and Services

Dynamic Host Configuration Protocol
DHCP

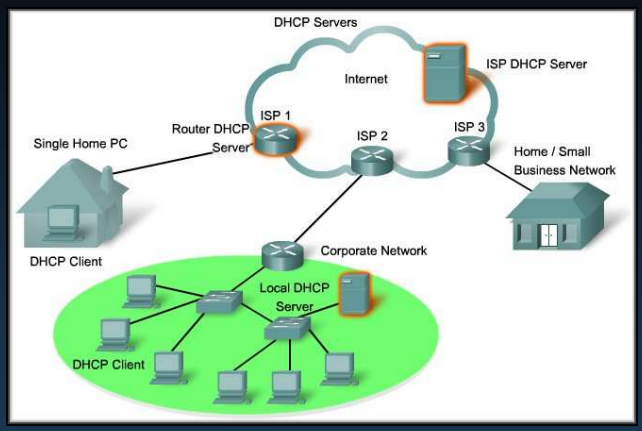
Dynamic Host Configuration Protocol (DHCP)



- IP addresses and other configuration information can be obtained dynamically.

Dynamic Host Configuration Protocol (DHCP)

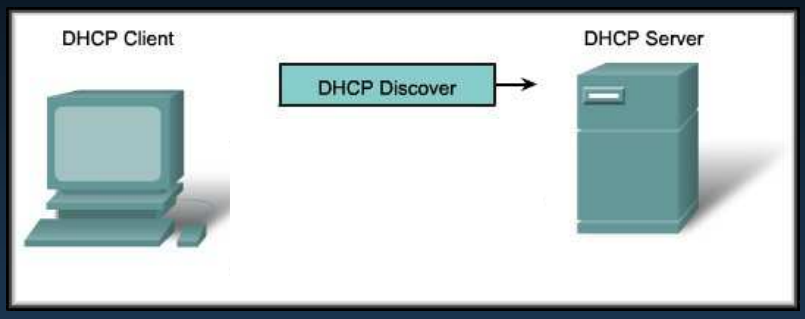
- IP address
- Subnet Mask
- Default Gateway
- Domain Name
- DNS Server
- Others….



- DHCP servers can be on a LAN, on a router or at an ISP.
- They can be accessed remotely by sites on a WAN.

Dynamic Host Configuration Protocol (DHCP)

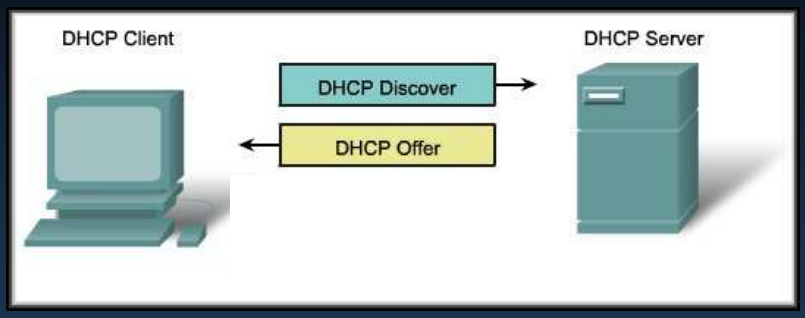
- DHCP is a four step process.



1. Client broadcasts a DHCP Discover frame to find a DHCP server. There may be more than one available.

Dynamic Host Configuration Protocol (DHCP)

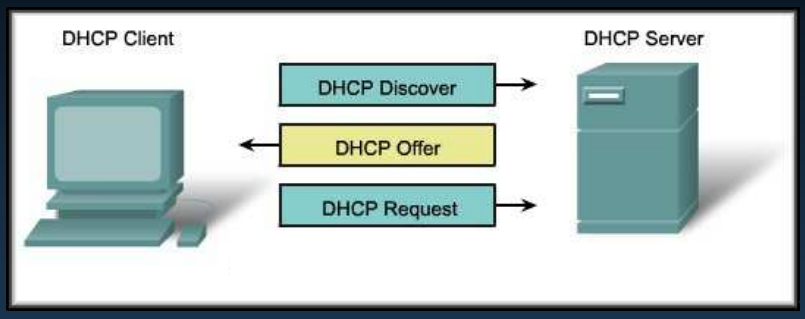
- DHCP is a four step process.



2. A DHCP server responds with a DHCP Offer frame containing a lease time, an IP Address, Subnet Mask, and addresses for a Default Gateway and DNS Server.

Dynamic Host Configuration Protocol (DHCP)

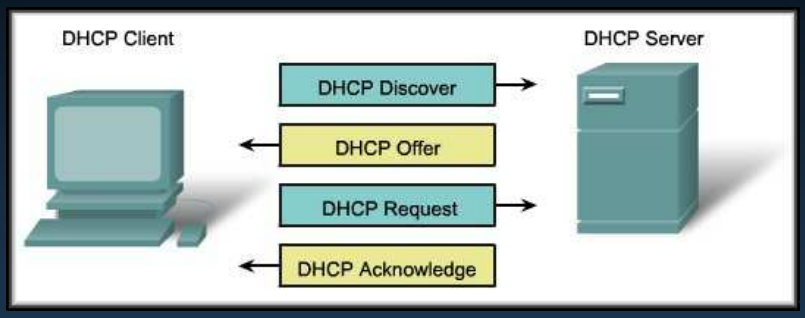
- DHCP is a four step process.



3. The client responds by broadcasting a **DHCP Request** that identifies the server and the lease offer it is accepting.

Dynamic Host Configuration Protocol (DHCP)

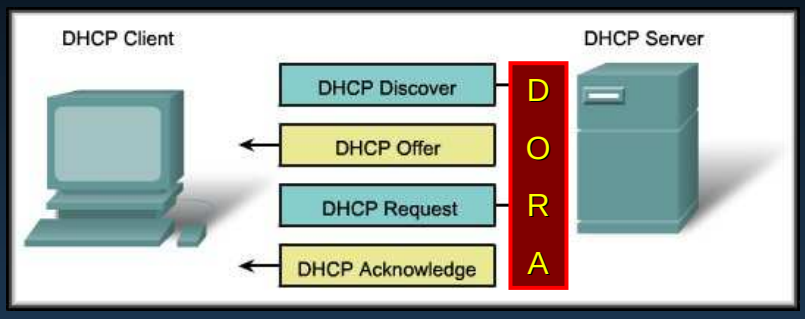
- DHCP is a four step process.



4. If the offer is still valid, the server returns a **DHCP Acknowledgement** and records that information as used. If it is no longer valid, a DHCP Negative Acknowledgement is sent and the process begins again.

Dynamic Host Configuration Protocol (DHCP)

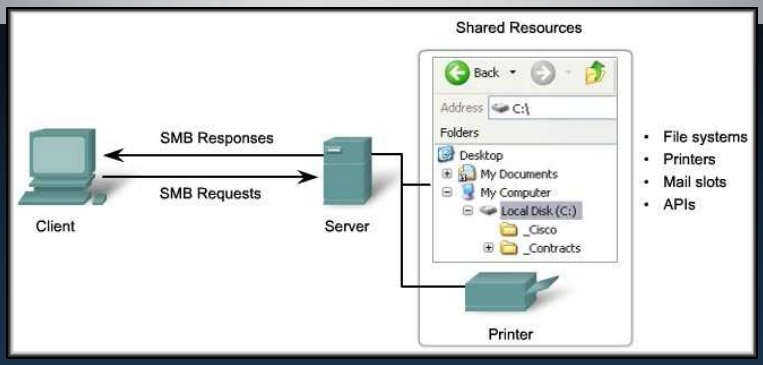
- DHCP is a four step process.



Application Layer Protocols and Services

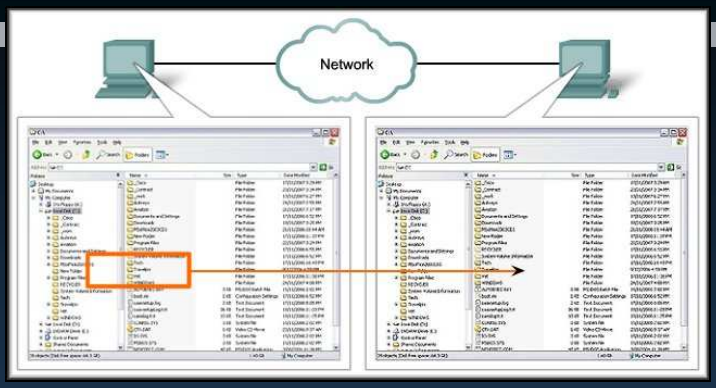
Server Message Block Protocol
SMB

Server Message Block Protocol (SMB)



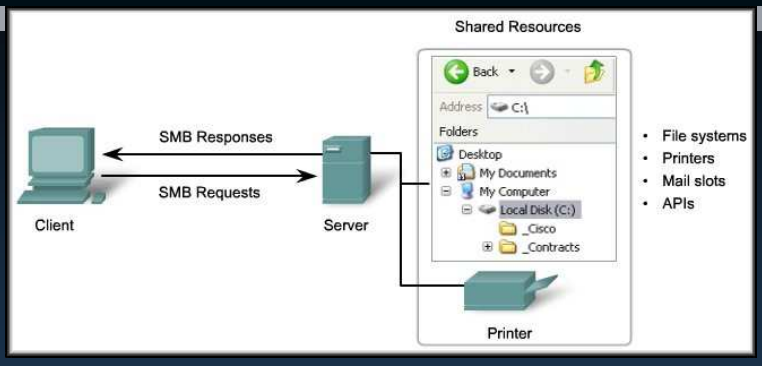
- The Server Message Block (SMB) is a client/server file sharing protocol.
- IBM in the late 1980s
- Describes the structure of shared network resources
  - Directories, files, printers, and serial ports.

Server Message Block Protocol (SMB)



- Request / Response protocol.
- Unlike FTP, clients establish a long term connection.
- Clients can access resources on the server as if the resource is local to the client.
- Linux / Unix have a similar protocol - SAMBA

Server Message Block Protocol (SMB)



- SMB messages can:
  - Start, authenticate, and terminate sessions.
  - Control file and printer access.
  - Allow an application to send or receive messages to or from another device.

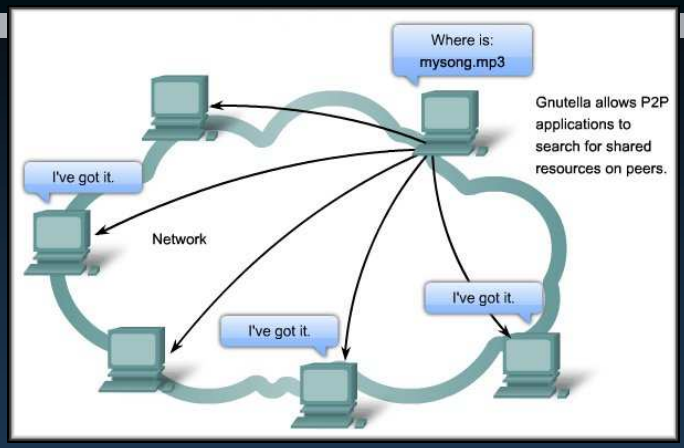
Application Layer Protocols and Services

P2P Services and
Gnutella Protocol

P2P Services and Gnutella Protocol

- "Peer-to-peer applications account for between 50 percent and 90 percent of overall Internet traffic, according to a survey this year by Ipoque GmbH, a German vendor of traffic-management equipment."
- Peter Svensson, The Associated Press Oct. 19, 2007

P2P Services and Gnutella Protocol



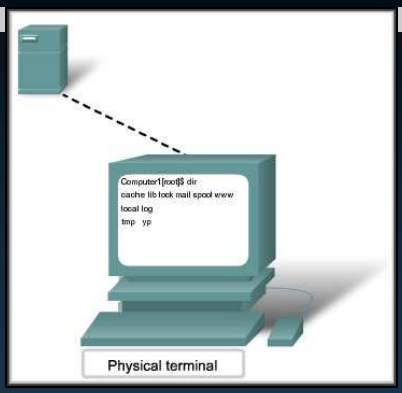
- Peers (hosts) act as both clients and servers
- No centralized file server.
- HTTP GET and responses are commonly used.

Application Layer Protocols and Services

Telnet

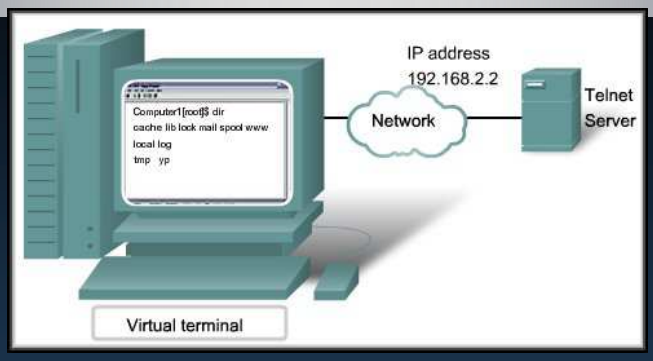
Telnet Services and Protocol

Telnet



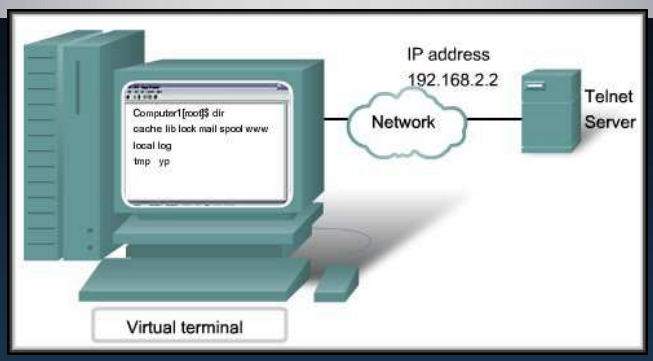
- Dates back to the 1970's.
  - People used directly connected text-based terminals to access systems.
  - Needed a means to remotely access these systems in the same way.

Telnet Services and Protocol



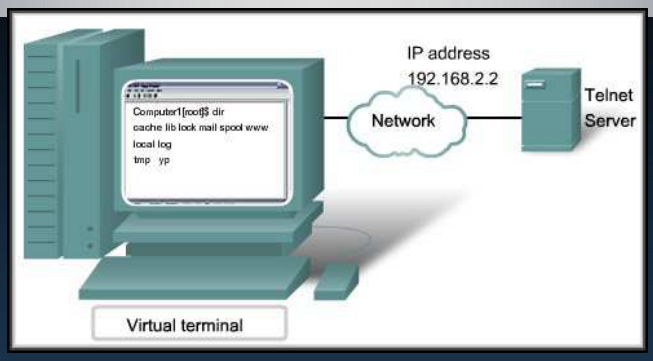
- Allows a user to remotely access another device (host, router, switch).
- A connection using Telnet is called a Virtual Terminal (VTY) session or connection.

Telnet Services and Protocol



- Telnet uses software to create a virtual device that offers the same features as a terminal session command line interface (CLI).
- Telnet Clients: Putty, Teraterm, HyperTerminal

Telnet Services and Protocol



- Telnet supports user authentication but does not encrypt data (clear text).
- Secure Shell (SSH) protocol offers a secure method for server access.
  - Stronger authentication, encrypts data

Feel like you've been run over by a truck?