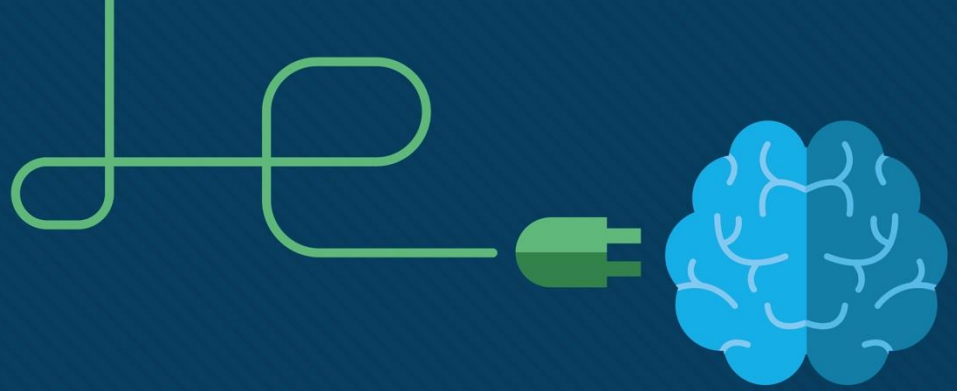


Module 10: Network Services

CyberOps Associate v1.0

Module Objectives

Module Title: Network Services

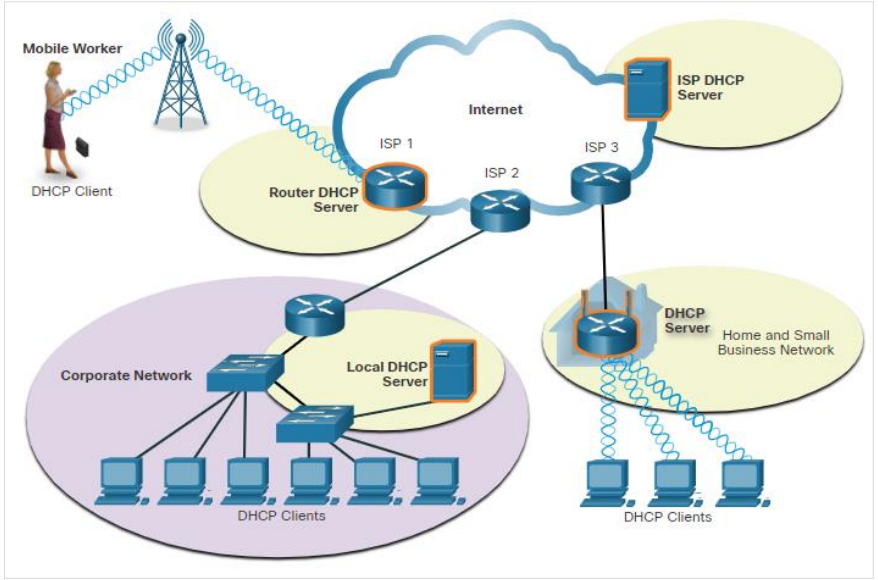
Module Objective: Explain how network services enable network functionality.

Topic Title	Topic Objective
DHCP	Explain how DHCP services enable network functionality.
DNS	Explain how DNS services enable network functionality.
NAT	Explain how NAT services enable network functionality.
File Transfer and Sharing Services	Explain how file transfer services enable network functionality.
Email	Explain how email services enable network functionality.
HTTP	Explain how HTTP services enable network functionality.

10.1 DHCP

Dynamic Host Configuration Protocol

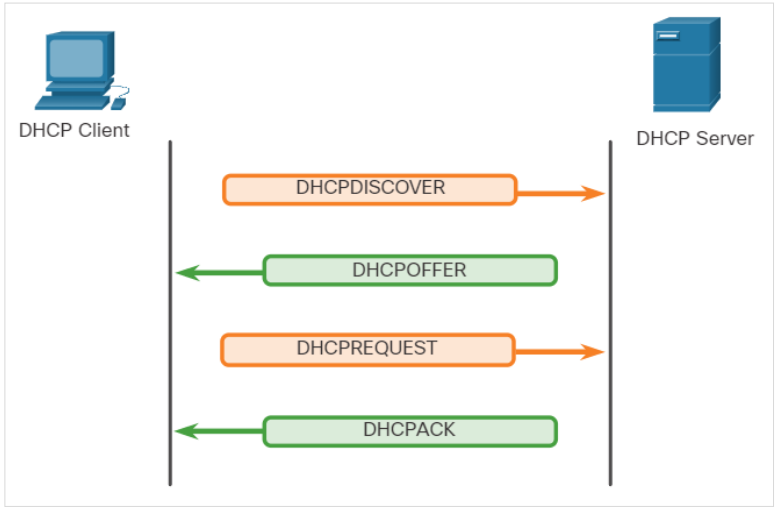
- Two types of addressing:
  - **Dynamic** – Dynamic Host Configuration Protocol (DHCP) for IPv4 service automates the assignment of IPv4 addresses, subnet masks, gateways, and other IPv4 networking parameters.
  - **Static** – The network administrator manually enters IP address information on hosts.
- When a host connects to the network, the DHCP server chooses an address from a configured range of addresses called a pool and assigns it to the host.
- DHCP can allocate IP addresses for a configurable period of time, called a lease period.



Medium-to-large networks – DHCP server is a local PC-based server
Home network – DHCP server is on the local router connecting the home network to the ISP.

DHCP Operation

- DHCP operation includes: DHCPDISCOVER, DHCPOFFER, DHCPREQUEST, DHCPACK, and DHCPNAK.
- When DHCP-configured device connects to the network, the client broadcasts a **DHCPDISCOVER** message to identify any available DHCP servers on the network.
- A DHCP server replies with a **DHCPOFFER** message, which offers a lease to the client.
- The client sends a **DHCPREQUEST** message that identifies the explicit server and lease offer that the client is accepting.



- If the IPv4 address requested by the client, or offered by the server, is still available, the server returns the **DHCPACK** message. If the offer is no longer valid, then the selected server responds with a **DHCPNAK** message. If a **DHCPNAK** message is returned, then the selection process begins again with a new **DHCPDISCOVER** message being transmitted.

DHCP Message Format

- The DHCPv4 message format is used for all DHCPv4 transactions.
- The DHCPv4 messages are encapsulated within the UDP transport protocol.
- The below table lists the fields covered in the structure of the DHCPv4 message.

Fields in the structure of DHCPv4 Message		
Operation (OP) Code	Seconds	Gateway IP Address
Hardware Type	Flags	Client Hardware Address .
Hardware Address Length	Client IP Address	Server Name
Hops	Your IP Address	Boot Filename
Transaction Identifier	Server IP Address	DHCP Options

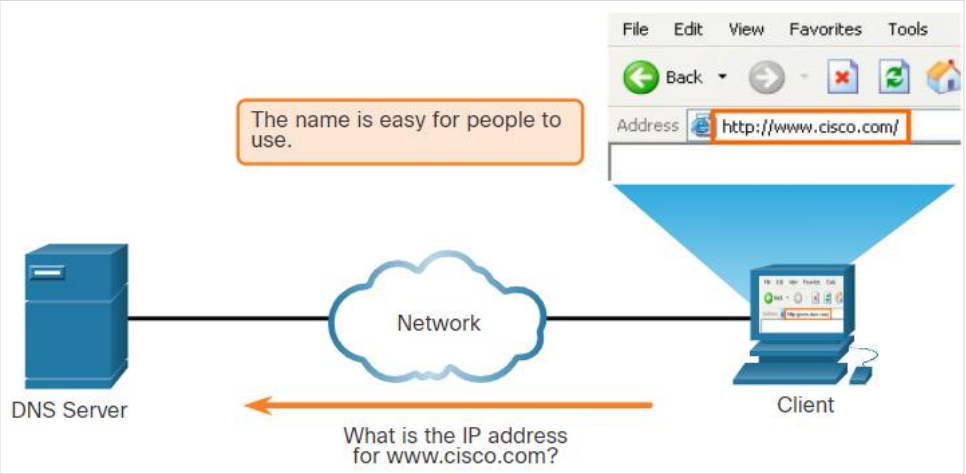
DHCP PACKET

8 OP Code (1)	16 Hardware Type (1)	24 Hardware Address Length (1)	32 Hops (1)
Transaction Identifier			
Seconds – 2 bytes		Flags – 2 bytes	
Client IP Address (CIADDR) – 4 bytes			
Your IP Address (YIADDR) – 4 bytes			
Server IP Address (SIADDR) – 4 bytes			
Gateway IP Address (GIADDR) – 4 bytes			
Client Hardware Address (CHADDR) – 16 bytes			
Server Name (SNAME) – 64 bytes			
Boot Filename – 128 bytes			
DHCP Options – variable			

10.2 DNS

DNS Overview

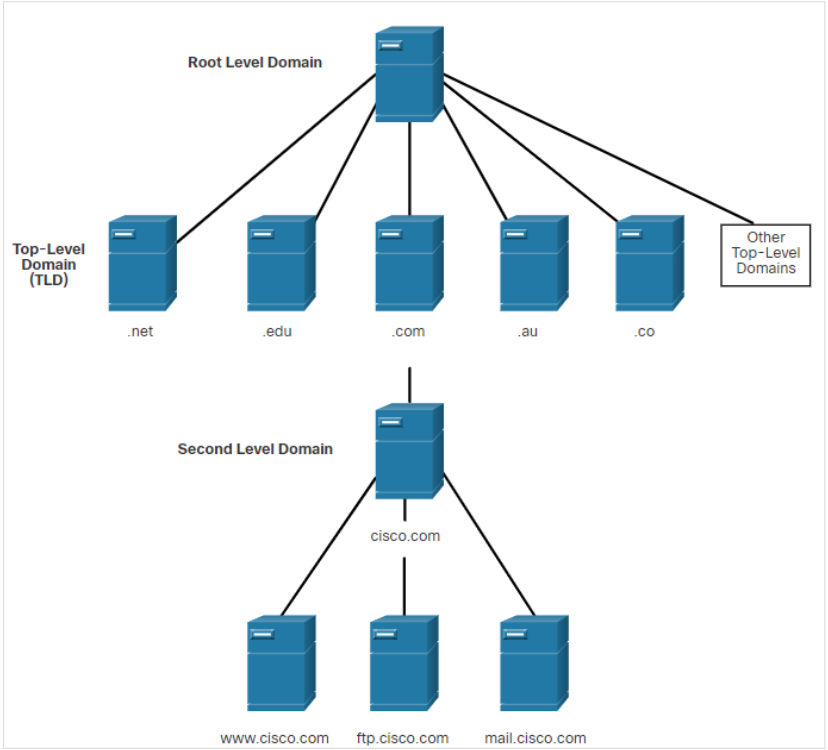
- Domain Name System (DNS) provides domain names and their associated IP addresses.
- The DNS system consists of a global hierarchy of distributed servers that contain databases of name to IP address mappings.
- The client computer in the figure will send a request to the DNS server to get the IP address for www.cisco.com so that it can address packets to that server.
- Malicious DNS traffic can be detected through protocol analysis and the inspection of DNS monitoring information.



DNS Resolves Names to IP Addresses

The DNS Domain Hierarchy

- DNS consists of a hierarchy of generic top-level domains and numerous country-level domains.
- The second-level domains are represented by a domain name that is followed by a top-level domain.
- Subdomains are found at the next level of the DNS hierarchy and represent some division of the second-level domain.
- Fourth level domain can represent a host in a subdomain.
- Top-level domains represent either the type of organization or country of origin. Examples: (**.org)** - a non-profit organization, **(.au)** – Australia.



DNS Hierarchy

root-servers.org FAQ

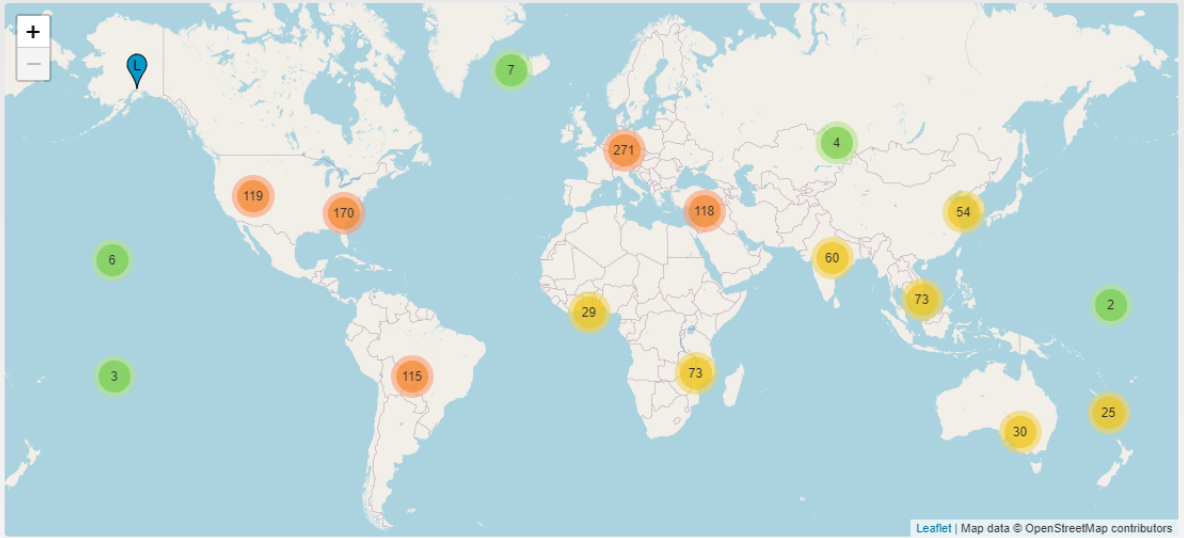
Verisign USC-ISI Cogent UMD NASA Ames ISC DISA DoD NIC ARL Netnod RIPE NCC ICANN WIDE

News and publications show all

2021-03-30	**Statement on DNS Encryption**
2019-08-14	**Threat Mitigation For the Root Server System**
2019-03-28	**Operational Statement on the final step in the KSK Rollover**

Meeting agendas show all

2021-03-08	**IETF 110/Virtual (PDF)**
2020-11-19	**IETF 109/Virtual (PDF)**
2020-07-27	**IETF 108/Virtual (PDF)**



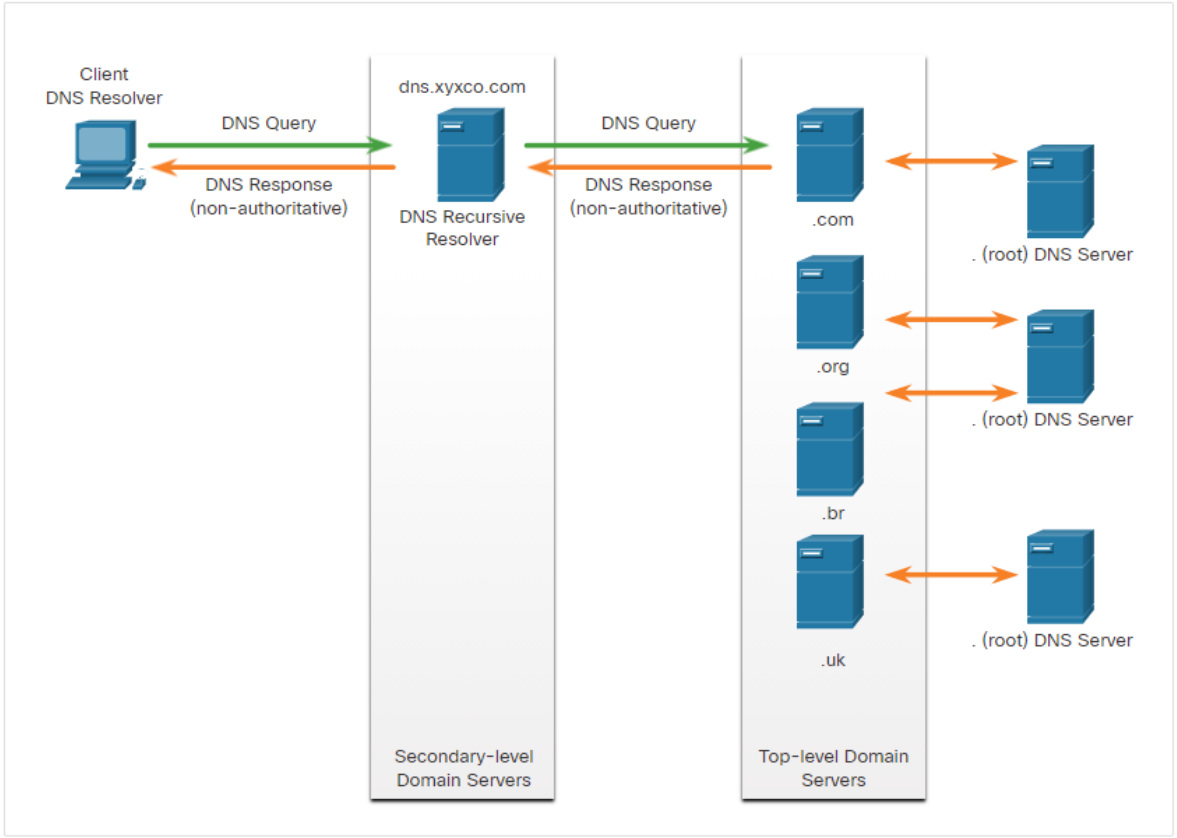
As of 05/10/2021 7:27 p.m., the root server system consists of 1378 instances operated by the 12 independent root server operators.

EK

To understand DNS, cybersecurity analysts should be familiar with the following terms:

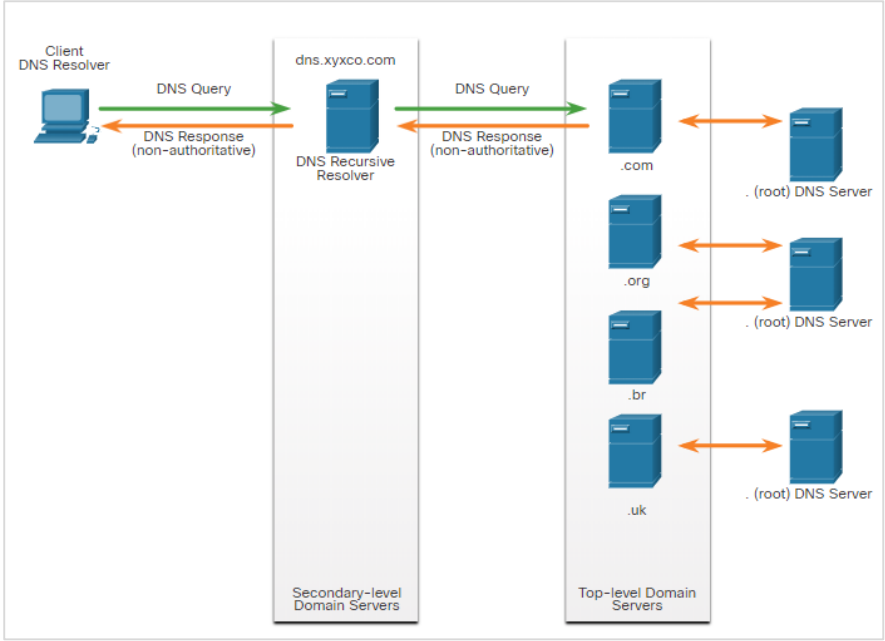
- **Resolver** – A DNS client that sends DNS messages to obtain information about the requested domain name space.
- **Recursion** – The action taken when a DNS server is asked to query on behalf of a DNS resolver.
- **Authoritative Server** – A DNS server that responds to query messages with information stored in Resource Records (RRs) for a domain name space stored on the server.
- **Recursive Resolver** – A DNS server that recursively queries for the information asked in the DNS query.
- **FQDN** – A Fully Qualified Domain Name is the absolute name of a device within the distributed DNS database.
- **RR** – A Resource Record is a format used in DNS messages that is composed of the following fields: NAME, TYPE, CLASS, TTL, RDLENGTH, and RDATA.
- **Zone** – A database that contains information about the domain name space stored on an authoritative server.

EK



The DNS Lookup Process

- To resolve a name to an IP address, the resolver, will first check its local DNS cache. If the mapping is not found, a query will be issued to the DNS server .
- If the mapping is not found there, the DNS server will query other higher-level DNS servers that are authoritative for the top-level domain in order to find the mapping. These are known as **recursive queries**.
- The caching DNS servers can resolve recursive queries without forwarding the queries to higher level servers.

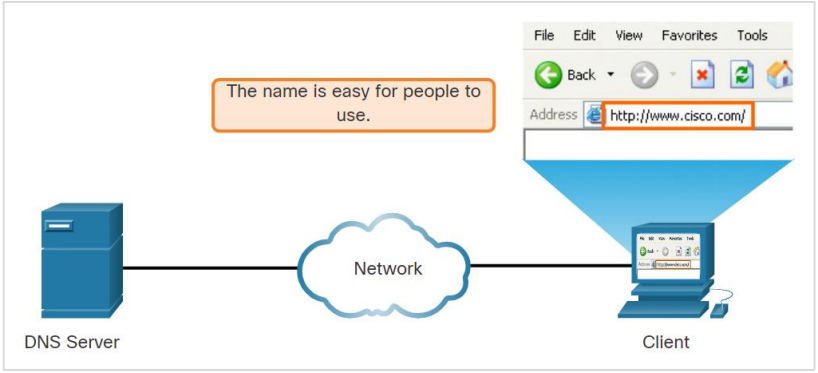


- If a server requires data for a zone, it will request a transfer of that data from an authoritative server for that zone. The process of transferring DNS data between servers is known as zone transfer.

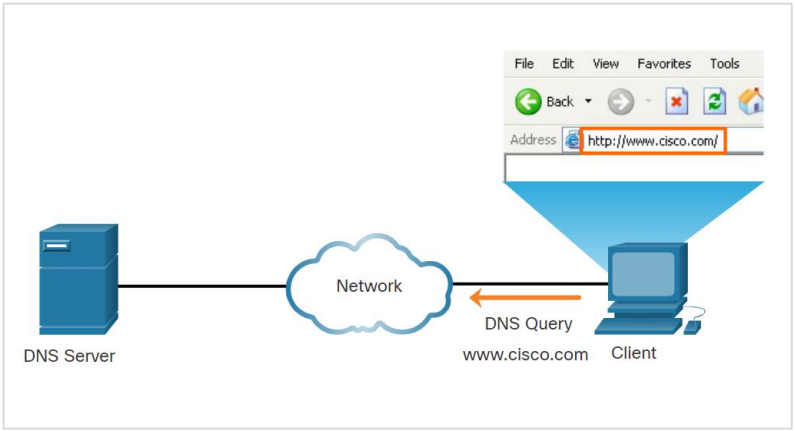
The DNS Lookup Process(Contd.)

Steps involved in DNS resolution:

Step 1 - The user types an FQDN into a browser application Address field.



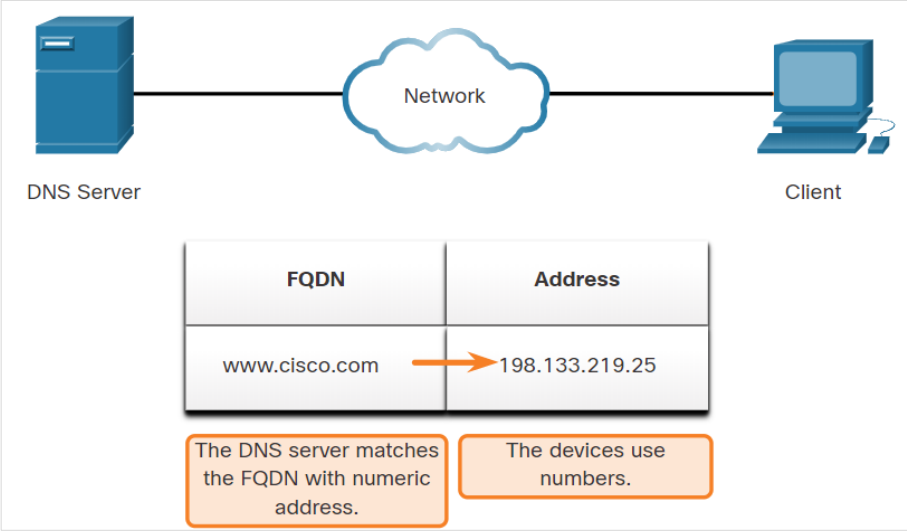
Step 2 - A DNS query is sent to the designated DNS server for the client computer.



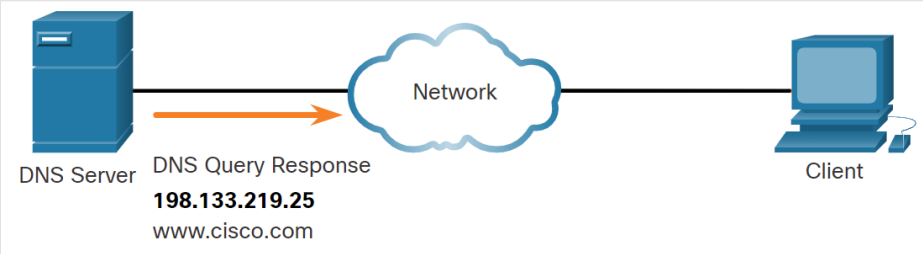
The DNS Lookup Process(Contd.)

Steps involved in DNS resolution:

Step 3 - The DNS server matches the FQDN with its IP address.



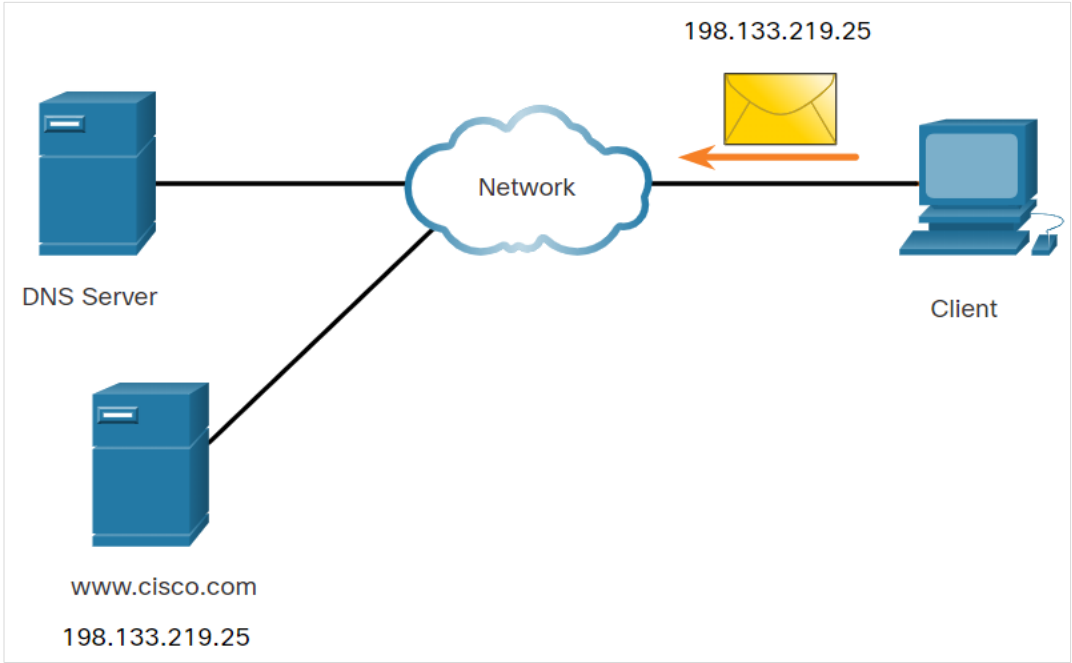
Step 4 - The DNS query response is sent back to the client with the IP address for the FQDN.



The DNS Lookup Process(Contd.)

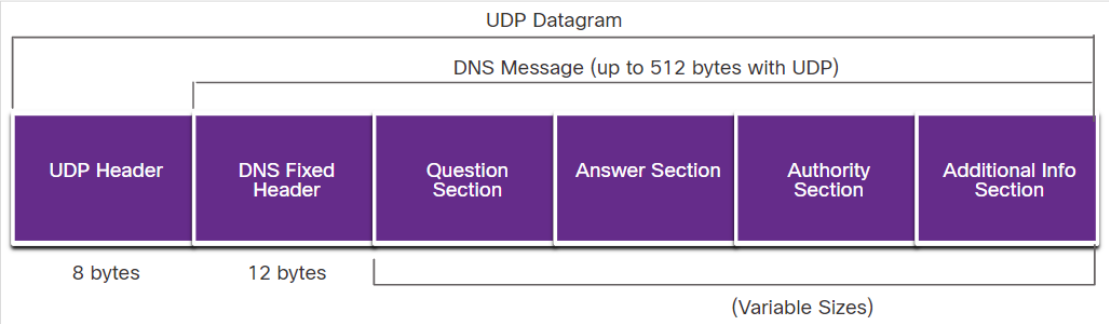
Steps involved in DNS resolution:

Step 5 - The DNS server matches the FQDN with its IP address.



DNS Message Format

- DNS uses UDP port 53 for DNS queries and responses.
- If a DNS response exceeds 512 bytes, Dynamic DNS (DDNS) is used.
- The DNS protocol communications use a single format called a **message**.
- DNS uses the same message format for all types of client queries and server responses, error messages, and transfer of resource record information.



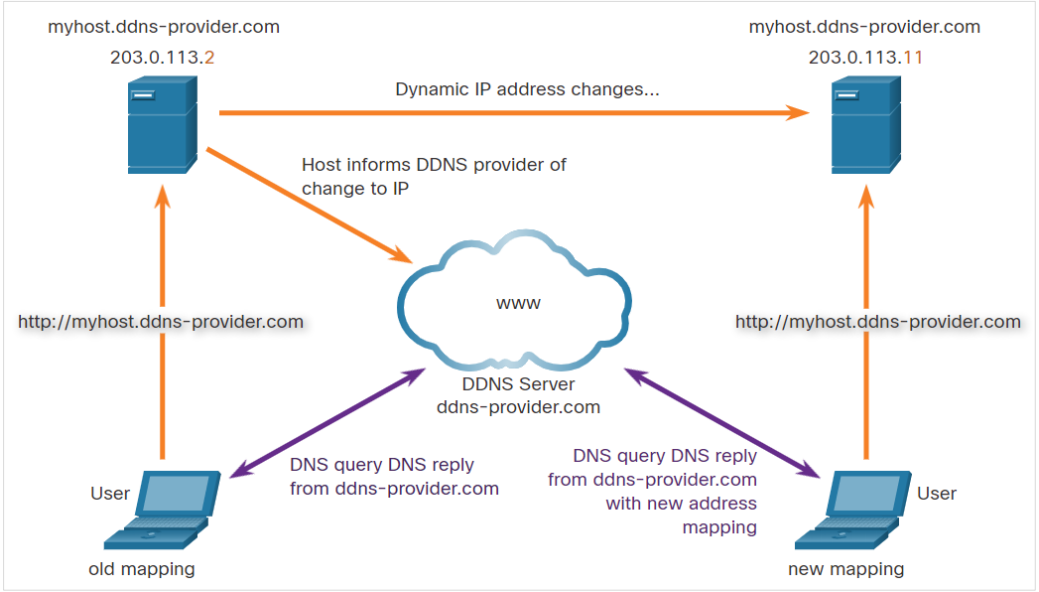
DNS Message Format (Contd.)

Sections of DNS message format :

DNS message section	Description
Question	The question for the server. It contains the domain name to be resolved, the class of domain, and the query type.
Answer	The DNS resource record, or RR, for the query including the resolved IP address depending on the RR type.
Authority	Contains the RRs for the domain authority.
Additional	Relevant to query responses only. Consists of RRs that hold additional information that will make query resolution more efficient

Dynamic DNS

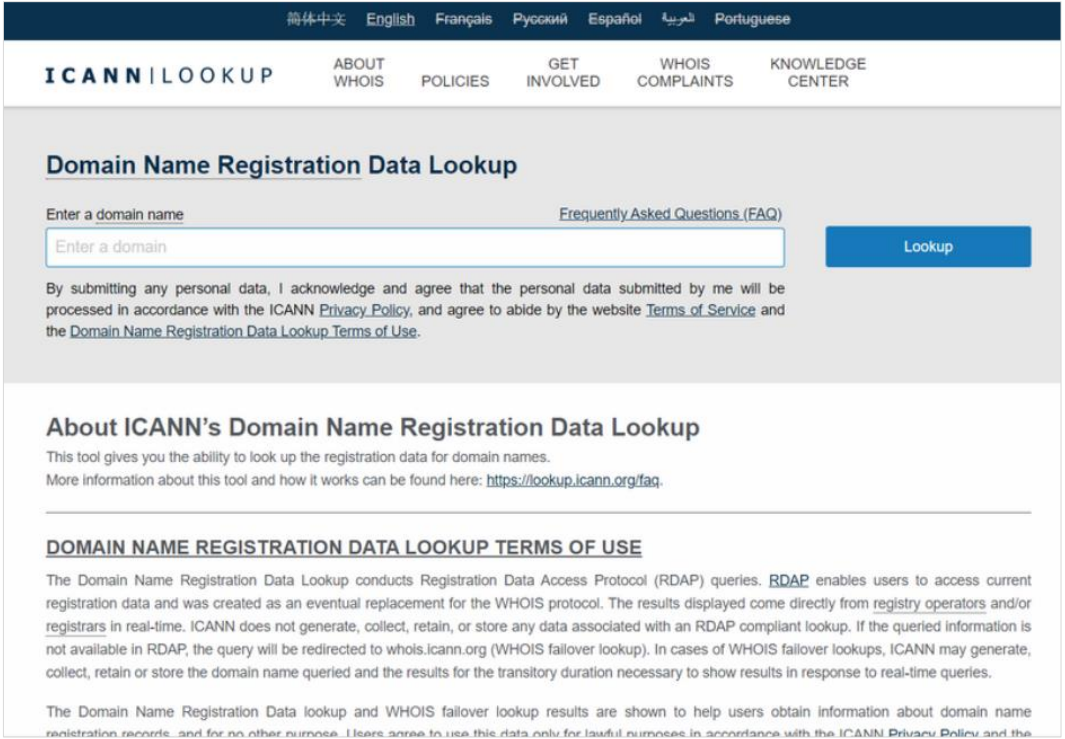
- Dynamic DNS (DDNS) allows a user or organization to register an IP address with a domain name as in DNS.
- The subdomain is mapped to the IP address of the user's server, or home router connection to the internet.
- When a change is detected, the DDNS provider is immediately informed of the change and the mapping between the user's subdomain and the internet IP address is immediately updated.



- The DDNS provider service supplies that IP address to the resolver's second level DNS server. This DNS server, either at the organization or ISP, provides the DDNS IP address to the resolver.

The WHOIS Protocol

- WHOIS is a TCP-based protocol that is used to identify the owners of internet domains through the DNS system.
- The WHOIS application uses a query, in the form of a FQDN.
- WHOIS is a starting point for identifying potentially dangerous internet locations that may have been reached through the network.
- ICANN Lookup, an internet-based WHOIS tool, is used to obtain the registration record a URL.



Lab - Using Wireshark to Examine a UDP DNS Capture

- In this lab, you will complete the following objectives:
  - Communicate with a DNS server by sending a DNS query using the UDP transport protocol.
  - Use Wireshark to examine the DNS query and response exchanges with the same server.

10.3 NAT

IPv4 Private Address Space

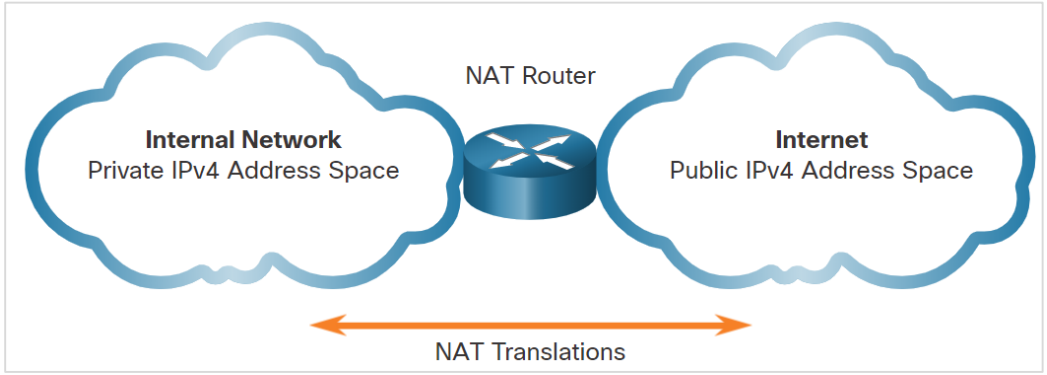
- As you know, there are not enough public IPv4 addresses to assign a unique address to each device connected to the internet. Networks are commonly implemented using private IPv4 addresses, as defined in RFC 1918. The range of addresses included in RFC 1918 are included in the following table. It is very likely that the computer that you use to view this course is assigned a private address.

Class	RFC 1918 Internal Address Range	Prefix
A	10.0.0.0 – 10.255.255.255	10.0.0.0/8
B	172.16.0.0 – 172.31.255.255	172.16.0.0/12
C	192.168.0.0 – 192.168.255.255	192.168.0.0/16

IPv4 Private Address Space

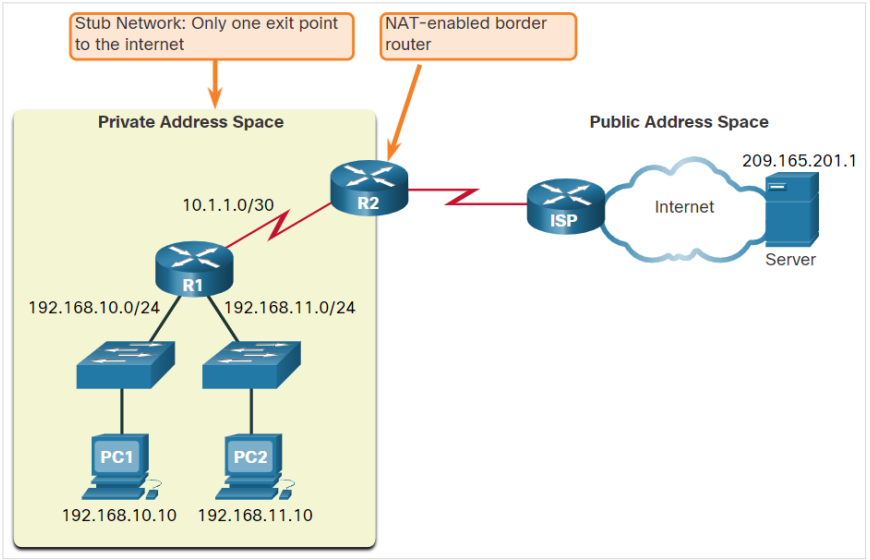
- To allow a device with a private IPv4 address to access devices and resources outside the local network, the private address must be translated to a public address.

- NAT provides the translation of private addresses to public addresses.
- A single, public IPv4 address can be shared by thousands of devices, each configured with a unique private IPv4 address.
- The solution to the exhaustion of IPv4 address space and the limitations of NAT is the eventual transition to IPv6.



What is NAT?

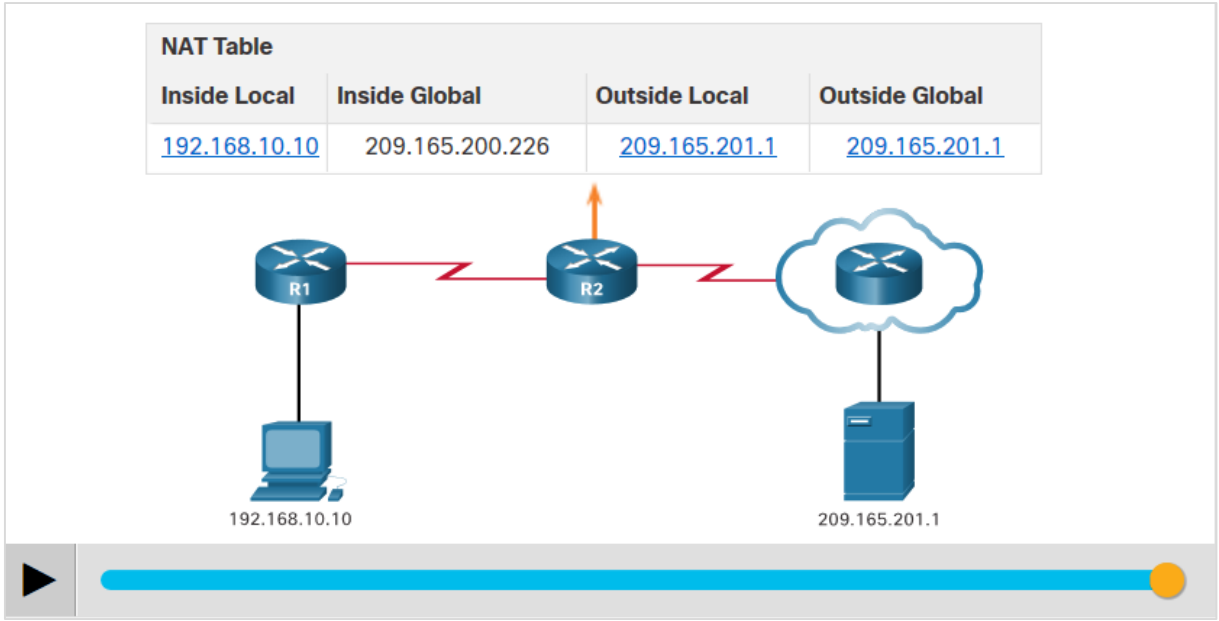
- NAT is used to conserve public IPv4 addresses.
- NAT-enabled routers can be configured with one or more valid public IPv4 addresses which are known as the **NAT pool**.
- A NAT router typically operates at the border of a stub network.
- When a device inside the stub network wants to communicate with a device outside its network, the packet is forwarded to the border router and the router performs the NAT process.



***Note**: The connection to the ISP may use a private address or a public address that is shared among customers. For the purposes of this module, a public address is shown.*

How NAT works?

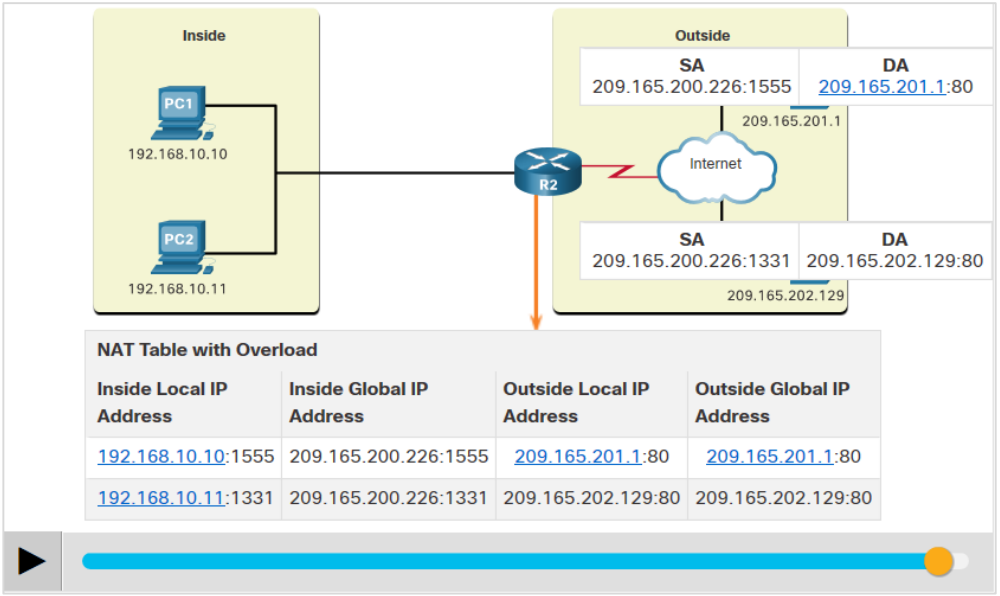
- In this example, PC1 with private address 192.168.10.10 wants to communicate with an outside web server with public address 209.165.201.1.
- Click the Play button in the figure to view the animation.



Port Address Translation

- Port Address Translation (PAT), also known as NAT overload, maps multiple private IPv4 addresses to a single public IPv4 address or a few addresses.
- When a device initiates a TCP/IP session, it generates a TCP or UDP source port value, or a specially assigned query ID for ICMP, to uniquely identify the session.
- PAT ensures that devices use a different TCP port number for each session with a server on the internet.
- PAT adds unique source port numbers to the inside global address to distinguish between translations.

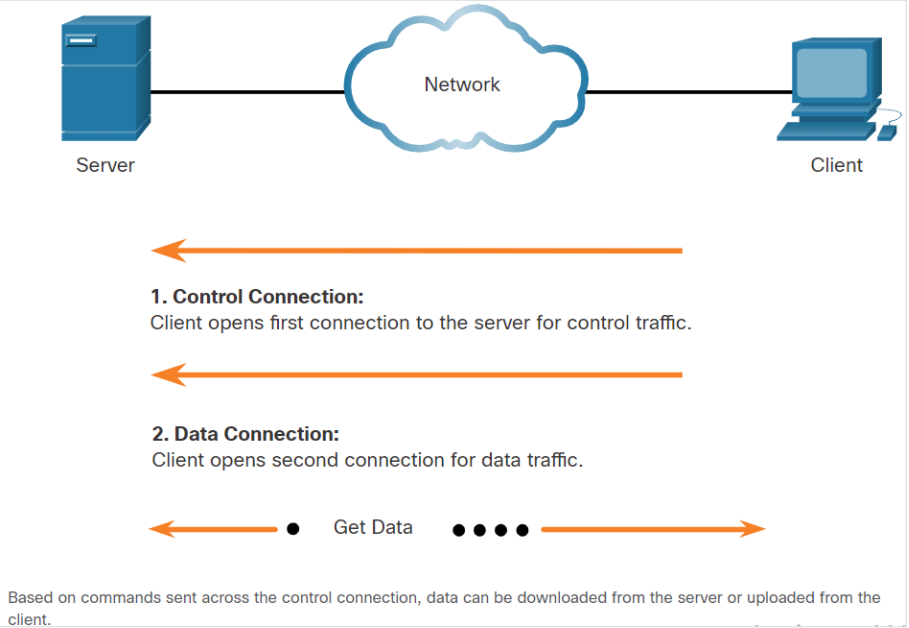
Click Play in the figure to view an animation of the PAT process.



10.4 File Transfer and Sharing Services

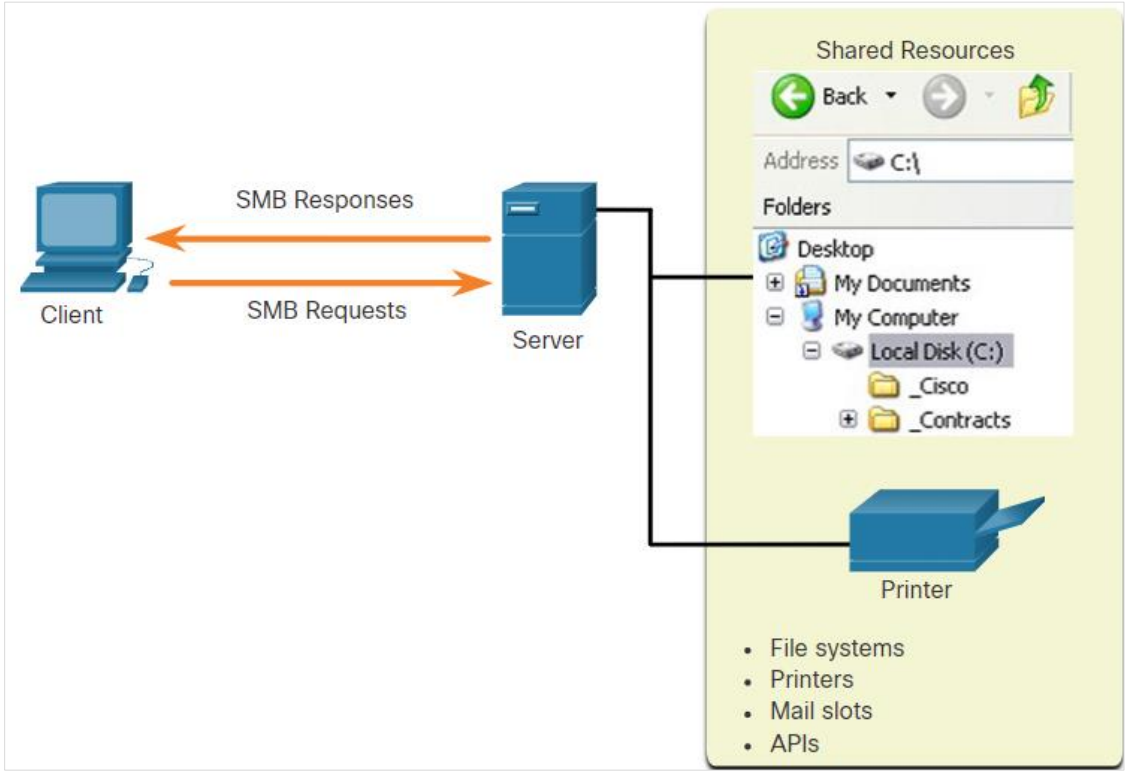
FTP and TFTP

- FTP allows data transfers between a client and a server.
- An FTP client runs on a computer and is used to push and pull data from an FTP server.
- FTP connections between the client and server:
  - **Control Connection**: The client opens the first connection to the server for control traffic.
  - **Data Connection**: The client opens the second connection to the server for data traffic.
- Trivial File Transfer Protocol (TFTP) is a simplified file transfer protocol that uses well-known UDP port number 69.



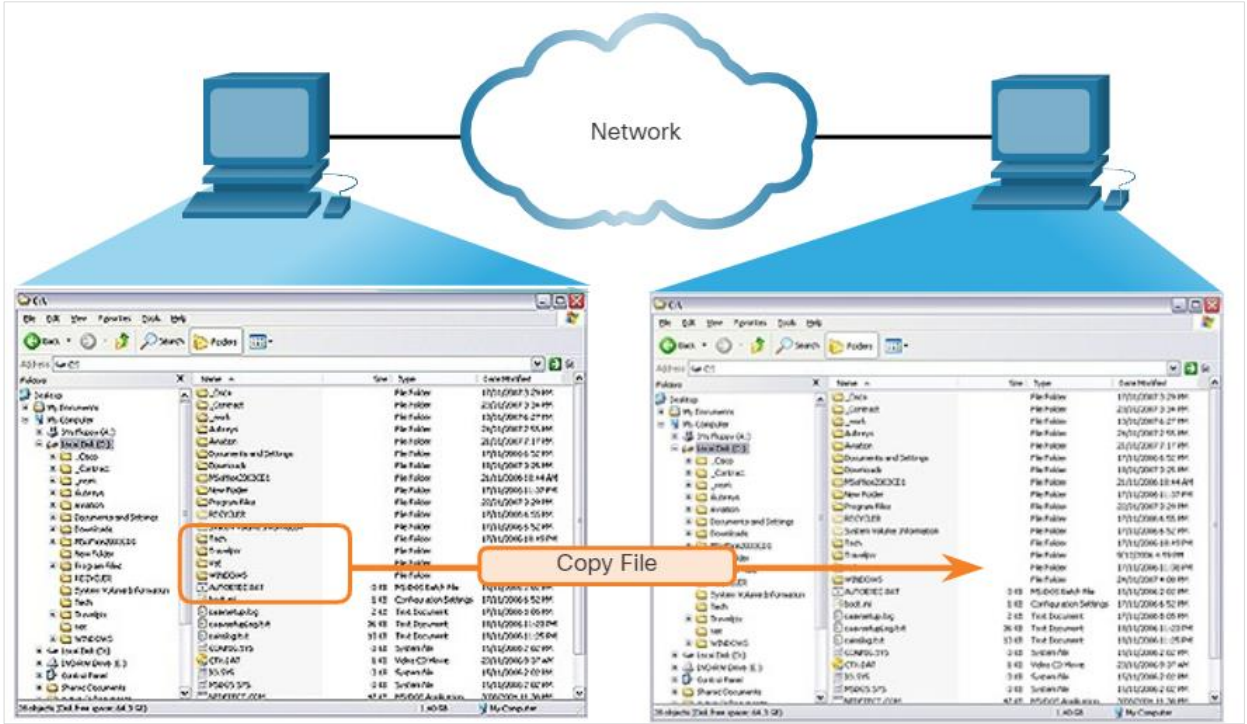
SMB

- The Server Message Block (SMB) is a client/server file sharing protocol that describes the structure of shared network resources.
- SMB is a client/server, request-response protocol.
- Servers can make their own resources available to clients on the network.



SMB (Contd.)

- SMB messages can start, authenticate, and terminate sessions, control file and printer access, and allow an application to send or receive messages to or from another device.
- SMB file sharing and print services have become the mainstay of Microsoft networking.
- A file may be copied from PC to PC with Windows Explorer using the SMB protocol.



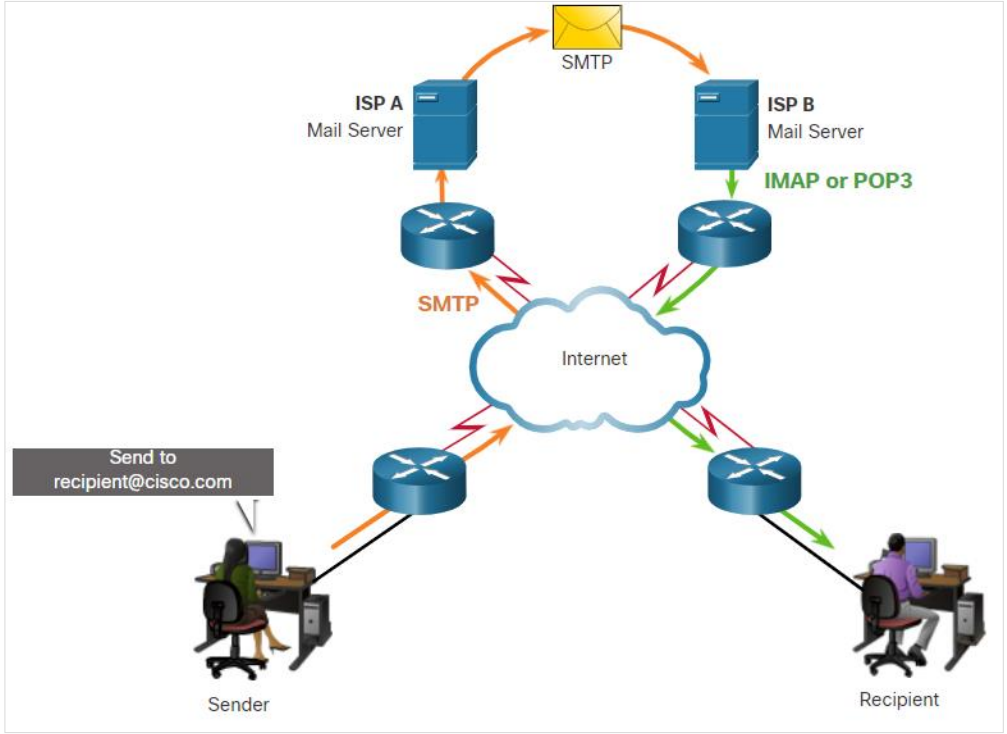
Lab - Using Wireshark to Examine TCP and UDP Captures

- In this lab, you will complete the following objectives:
  - Identify TCP Header Fields and Operation Using a Wireshark FTP Session Capture
  - Identify UDP Header Fields and Operation Using a Wireshark TFTP Session Capture

10.5 Email

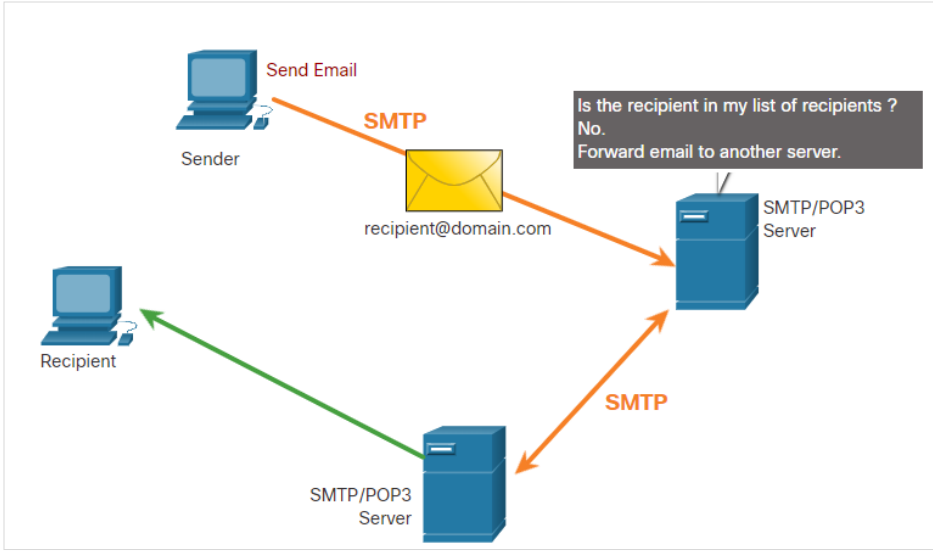
Email protocols

- Email is a store-and-forward method of sending, storing, and retrieving electronic messages across a network.
- Email clients communicate with mail servers to send and receive email.
- Email supports three separate protocols for operation: Simple Mail Transfer Protocol (SMTP), Post Office Protocol (POP), and IMAP.
- A client retrieves email using one of the two application layer protocols: POP or IMAP.



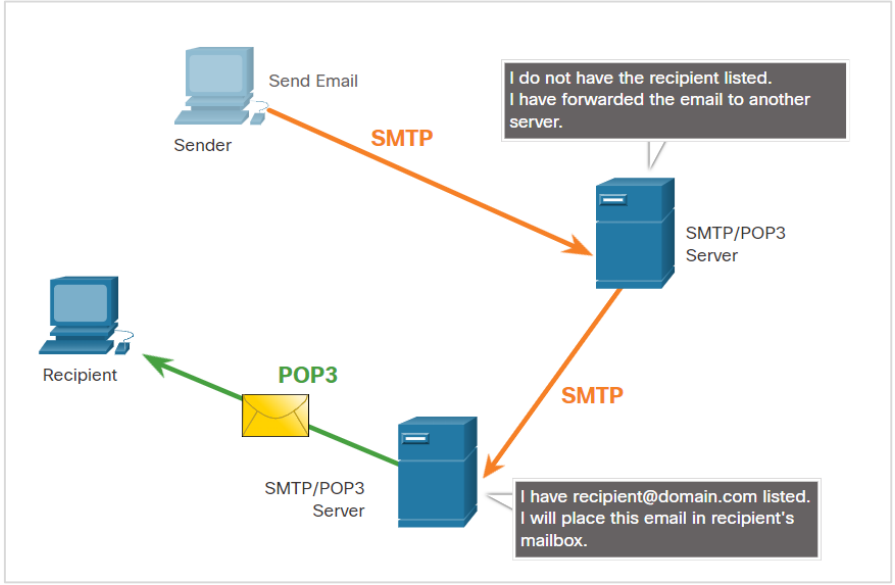
SMTP

- SMTP message formats require a message header and a message body.
- When a client sends an email, the client SMTP process connects with a server SMTP process on a well-known port 25.
- When the server receives the message, it either places the message in a local account, if the recipient is local, or forwards the message to another mail server for delivery.
- Periodically, the server checks the queue for messages and attempts to send them again. If the message is still not delivered after a predetermined expiration time, it is returned to the sender as undeliverable.



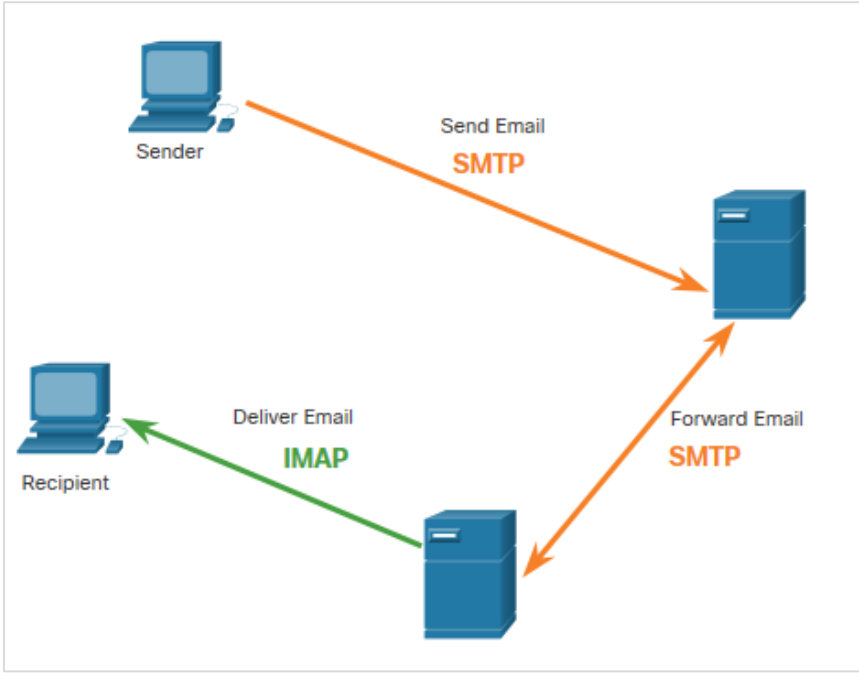
POP3

- POP3 is used by an application to retrieve a mail from a mail server.
- With POP3, email messages are downloaded to the client and removed from the server.
- The server starts the POP3 service by passively listening on TCP port 110 for client connection requests.
- The client sends a request to establish a TCP connection with the server.
- Once the connection is established, the POP3 server sends a greeting. The client and POP3 server then exchange commands and responses until the connection is closed or aborted.



IMAP

- IMAP is the protocol that describes a method to retrieve email messages.
- When the user connects to an IMAP-capable server, copies of the messages are downloaded to the client application. The original messages are kept on the server until manually deleted.
- Users view copies of the messages in their email client software.
- Users can create a file hierarchy on the server to organize and store mail.
- When a user decides to delete a message, the server synchronizes that action and deletes the message from the server.



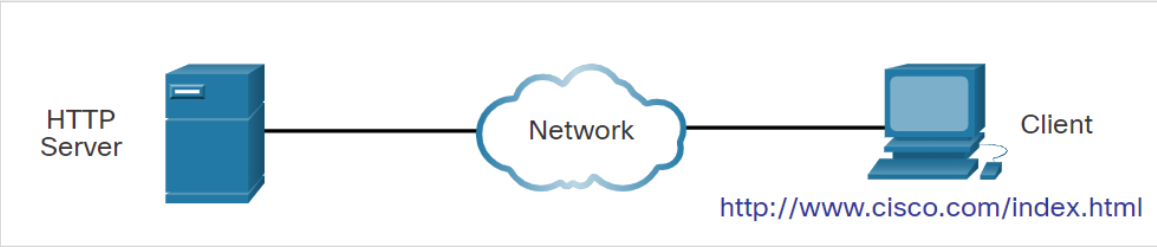
10.6 HTTP

Hypertext Transfer Protocol and Hypertext Markup Language

- When a web address or Uniform Resource Locator (URL) is typed into a web browser, the web browser establishes a connection with the web service that is using the HTTP protocol.
- Lets take a look on how a web page is opened in a browser.
  Example: http://www.cisco.com/index.html

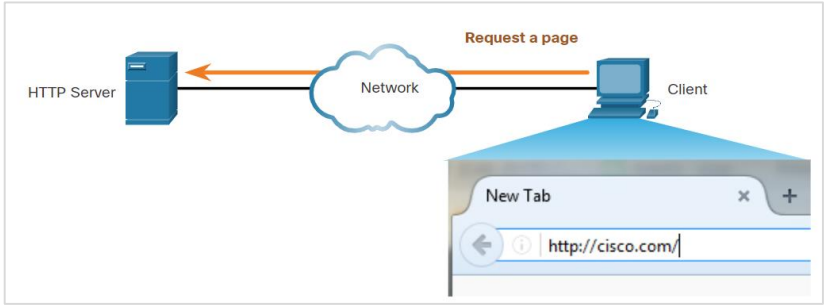
Step 1: The browser interprets the three parts of the URL:

- http (the protocol or scheme)
- www.cisco.com (the server name)
- index.html (the specific filename requested)

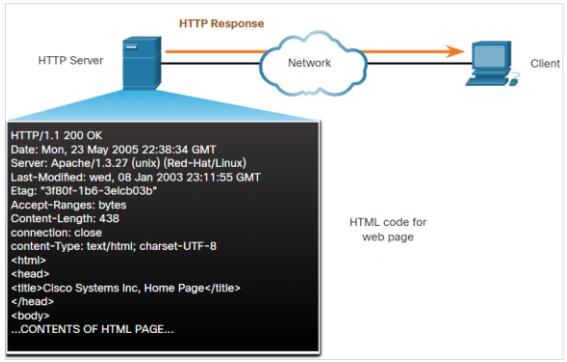


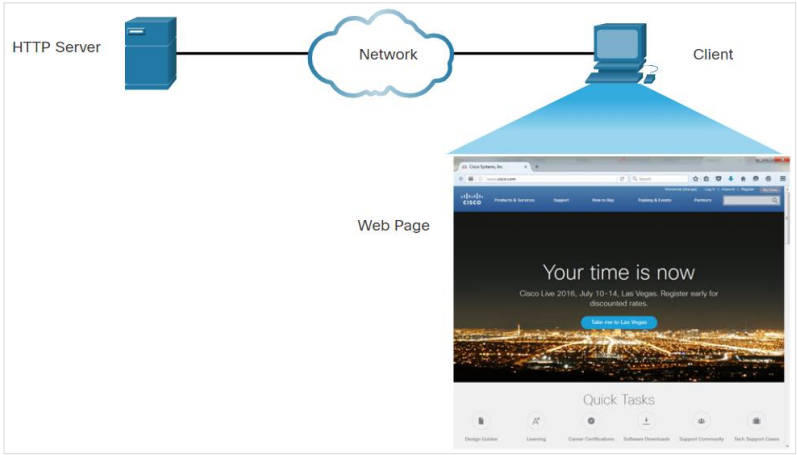
Hypertext Transfer Protocol and Hypertext Markup Language (Contd.)

- **Step 2:** The client initiates an HTTP request to a server by sending a GET request to the server and asks for the index.html file.



- **Step 3:** In response to the request, the server sends the HTML code for this web page to the browser.

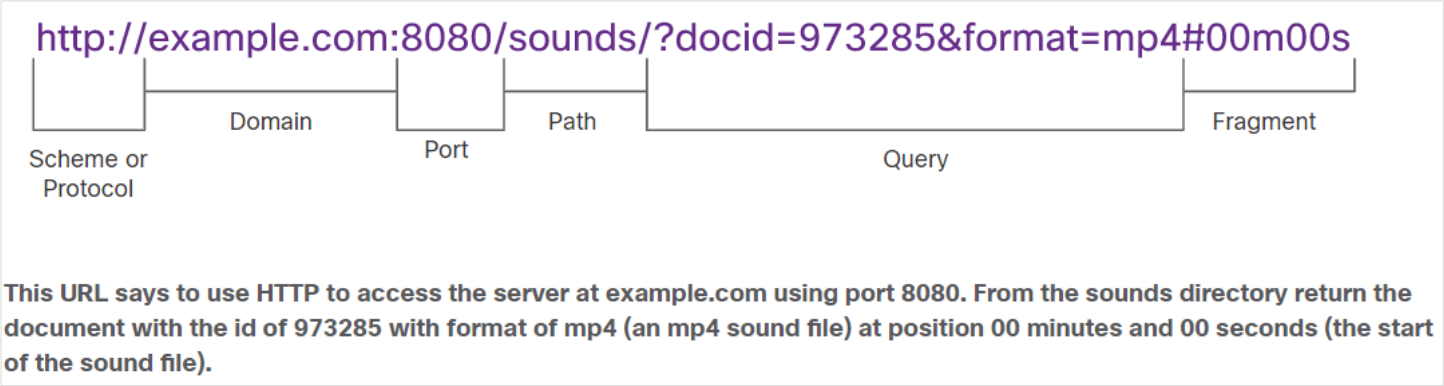




- **Step 4:** The browser deciphers the HTML code and formats the page for the browser window.

The HTTP URL

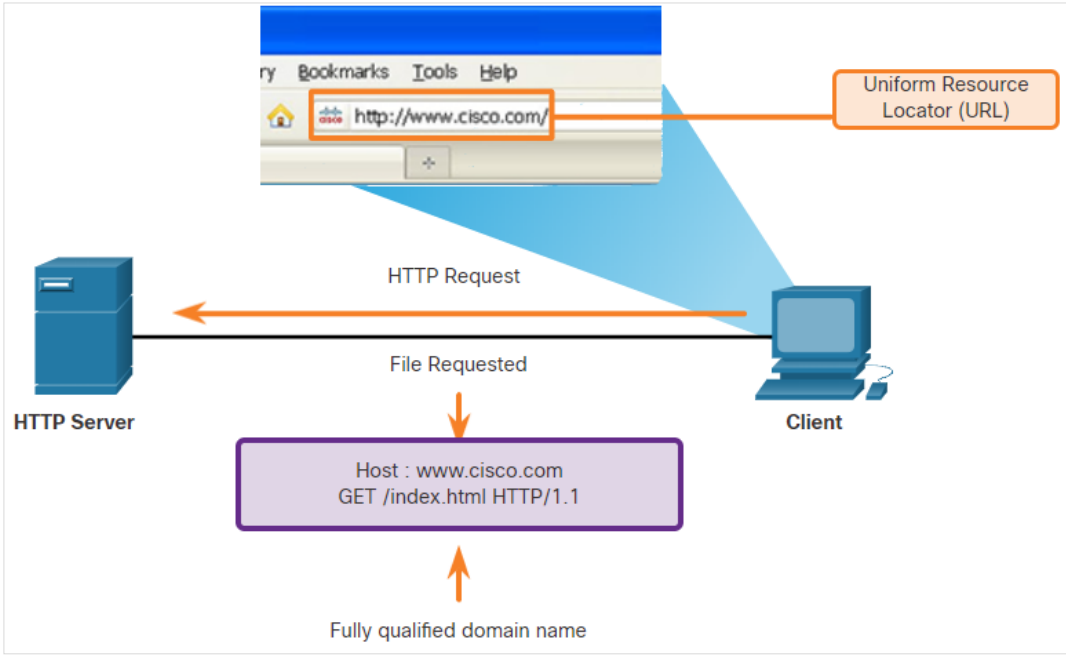
- HTTP URLs can specify the port on the server that should handle the HTTP methods.
- It can specify a query string and fragment.
- Query strings are preceded by a “?” character and typically consist of a series of name and value pairs.
- A fragment is preceded by a “#” character. It refers to a subordinate part of the resource that is requested in the URL.
- The parts of an HTTP URL are shown in the below figure:



This URL says to use HTTP to access the server at example.com using port 8080. From the sounds directory return the document with the id of 973285 with format of mp4 (an mp4 sound file) at position 00 minutes and 00 seconds (the start of the sound file).

HTTP Operation

- HTTP is a request/response protocol that uses TCP port 80.It is flexible but not a secure protocol.
- When a client sends a request to a web server, it will use one of the six methods specified by HTTP:
  - GET
  - POST
  - PUT
  - DELETE
  - OPTIONS
  - CONNECT



HTTP Status Codes

- The HTTP Status codes are numeric, with the first number in the code indicating the type of message.
- The five status code groups are **1xx** - Informational, **2xx** - Success, **3xx** - Redirection , **4xx** - Client Error and **5xx** - Server Error
- The below table explains some common status codes:

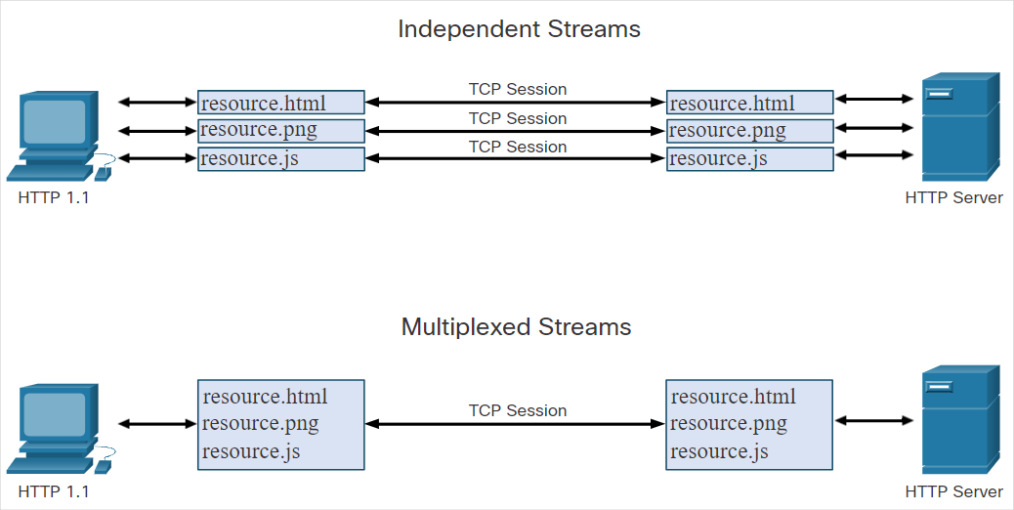
Code	Status	Meaning
1xx - Informational		
100	Continue	The client should continue with the request. The Server has verified that the request can be fulfilled.
2xx - Success		
200	OK	The request completed successfully.
202	Accepted	The request has been accepted for processing, but processing is not completed.

HTTP Status Codes (Contd.)

Code	Status	Meaning
4xx – Client Error		
403	Forbidden	The request is understood by the server, but the resource will not be fulfilled. This is possibly because the requester is not authorized to view the resource.
404	Not Found	The server could not find the requested resource. This can be caused by an out-of-date or incorrect URL.

HTTP/2

- The purpose of HTTP/2 is to improve HTTP performance by addressing latency issues that existed in the HTTP 1.1 version of the protocol.
- HTTP/2 uses the same header format as HTTP 1.1 and uses the same status codes.
- Few important features of HTTP/2 that a cybersecurity analyst must be aware of:
  - Multiplexing
  - Server PUSH
  - A binary protocol
  - Header compression



Securing HTTP – HTTPS

- For secure communication across the internet, the HTTP Secure (HTTPS) protocol is used.
- HTTPS uses authentication and encryption to secure data as it travels between the client and the server.
- HTTPS uses the same client request-server response process as HTTP, but the data stream is encrypted with Secure Socket Layer (SSL), or Transport Layer Security (TLS), before being transported across the network.
- HTTPS/2 is specified to use HTTPS over TLS with the Application-Layer Protocol Negotiation (ALPN) extension for TLS 1.2 or newer.
- Confidential information is transmitted over the Internet using HTTPS.

Lab - Using Wireshark to Examine HTTP and HTTPS Traffic

- In this lab, you will complete the following objectives:
  - Capture and view HTTP traffic
  - Capture and view HTTPS traffic

10.7 Network Services Summary

What Did I Learn in this Module?

- Dynamic Host Configuration Protocol (DHCP) for IPv4 automates the assignment of IPv4 addresses. This is referred to as dynamic addressing and is the alternative to static addressing.
- DHCP operation includes: DHCPDISCOVER, DHCPOFFER, DHCPREQUEST, DHCPACK, and DHCPNAK.
- DNS resolves names to IP addresses. There are five steps involved in DNS resolution.
- NAT provides the translation of private addresses to public addresses. A NAT router typically operates at the border of a stub network.
- Port Address Translation (PAT), also known as NAT overload, maps multiple private IPv4 addresses to a single public IPv4 address or a few addresses.
- FTP was developed to allow for file transfers between a client and a server. Trivial File Transfer Protocol (TFTP) is a simplified file transfer protocol that uses UDP port number 69.

What Did I Learn in this Module? (Contd.)

- Email clients communicate with mail servers to send and receive email.
- Email supports three separate protocols for operation: SMTP, POP, and IMAP.
- Web browsers and web servers interact using the four steps.
- HTTP is a request/response protocol that uses TCP port 80.
- When a client sends a request to a web server, it will use one of six methods that are specified by the HTTP protocol: GET, POST, PUT, DELETE, OPTIONS, and CONNECT.
- HTTP status codes: 1xx, 2xx, 3xx, 4xx, and 5xx.
- For secure communication across the internet, HTTP Secure (HTTPS) is used.
- HTTPS uses authentication and encryption to secure data as it travels between the client and the server.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