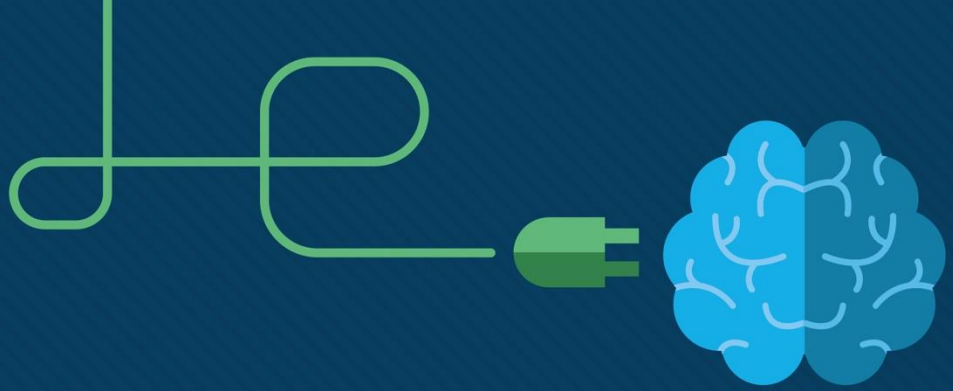


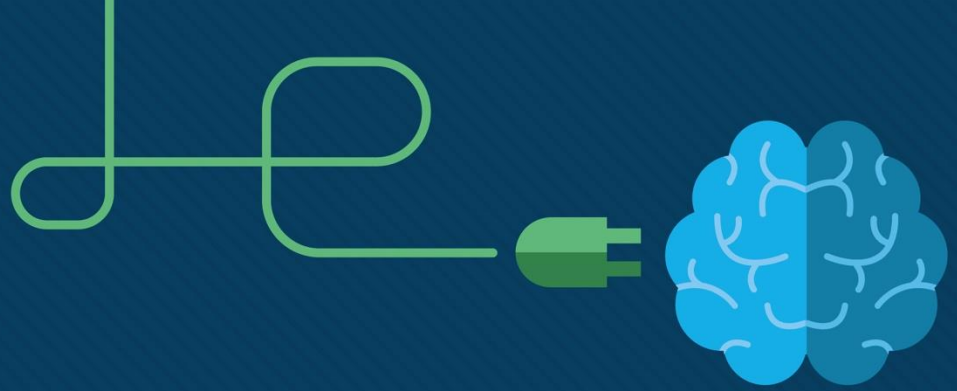
# Chapter 4: Network Protocols and Services

## Instructor Materials

CCNA Cybersecurity Operations v1.0

# Chapter 4: Network Protocols and Services

## CCNA Cybersecurity Operations v1.1 Planning Guide



# Chapter 4: Network Protocols and Services

CCNA Cybersecurity Operations v1.1

# Chapter 4 - Sections & Objectives

- 4.1 Network Protocols
  - Explain how protocols enable network operations.
    - Explain the basic operation of data networked communications.
    - Explain how protocols enable network operations.
- 4.2 Ethernet and Internet Protocol (IP)
  - Explain how Ethernet and IP protocols support network communication.
    - Explain how Ethernet supports network communication.
    - Explain how the IPv4 protocol supports network communications.
    - Explain how IP addresses enable network communication.
    - Explain the type of IPv4 addresses that enable network communication.
    - Explain how the default gateway enables network communication.
    - Explain how the IPv6 protocol supports network communications.

# Chapter 4 - Sections & Objectives (Cont.)

- 4.3 Connectivity Verification
  - Use common testing utilities to verify and test network connectivity.
    - Explain how ICMP is used to test network connectivity.
    - Use ping and traceroute utilities to test network connectivity.
- 4.4 Address Resolution Protocol
  - Explain how the address resolution protocol enables communication on a network.
    - Compare the roles of the MAC address and the IP address.
    - Describe the purpose of ARP.
    - Explain how ARP requests impact network and host performance.

# Chapter 4 - Sections & Objectives (Cont.)

- 4.5 The Transport Layer
  - Explain how transport layer protocols support network functionality.
    - Explain how transport layer protocols support network communication.
    - Explain how transport layer protocols operate..
- 4.6 Network Services
  - Explain how network services enable network functionality.
    - Explain how DHCP services enable network functionality.
    - Explain how DNS services enable network functionality.
    - Explain how NAT services enable network functionality.
    - Explain how file transfer services enable network functionality.
    - Explain how email services enable network functionality.
    - Explain how HTTP services enable network functionality.

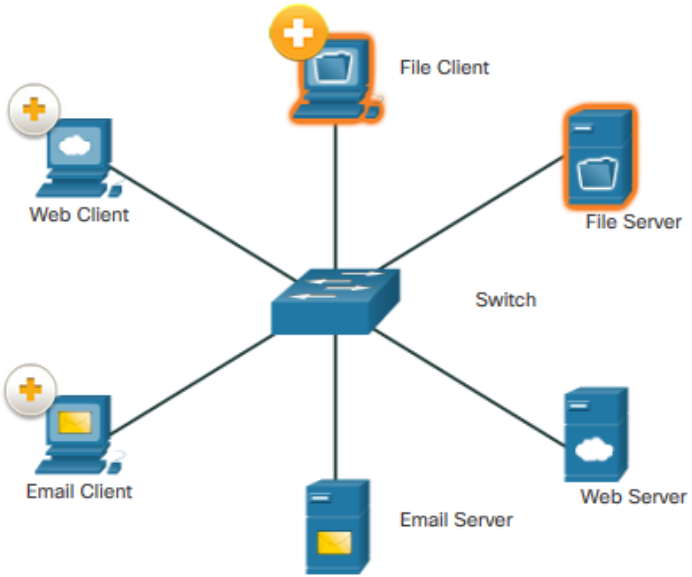
# 4.1 Network Protocols

# Views of the Network

- Views of the network
  - Small home network
  - SOHO (Small Office/Home Office)
  - Medium to large networks
  - World-wide networks

# Client-Server Communications

- File Client and Server communications
  - Server stores corporate and user files.
  - Client devices access these files or services with client software.
- Web Client Server
  - Web Server runs web server software and client uses browser software.
- Email Client-Server communications
  - Email Server runs email server software.

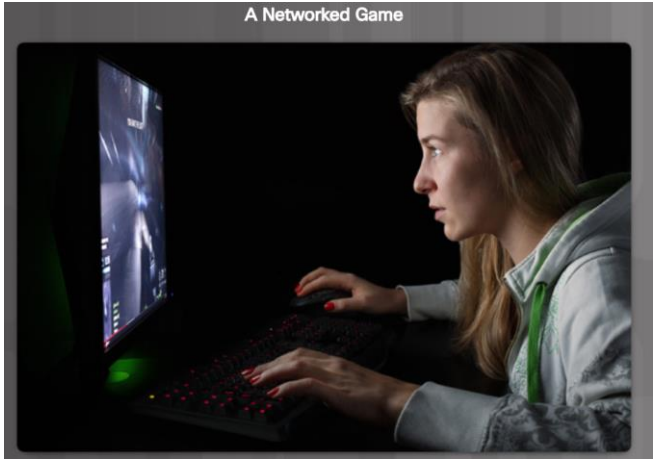


# A Typical Session: Student

- A Typical Session: Student
  - Determine the origin of the traffic enter the network.
  - For example, Terry's data flows with the data of thousands of other users along a fiber-optic network that connects Terry's ISP with the several other ISPs, including the ISP that is used by the search engine company. Eventually, Terry's search string enters the search engine company's website and is processed by its powerful servers. The results are then encoded and addressed to Terry's school and her device.

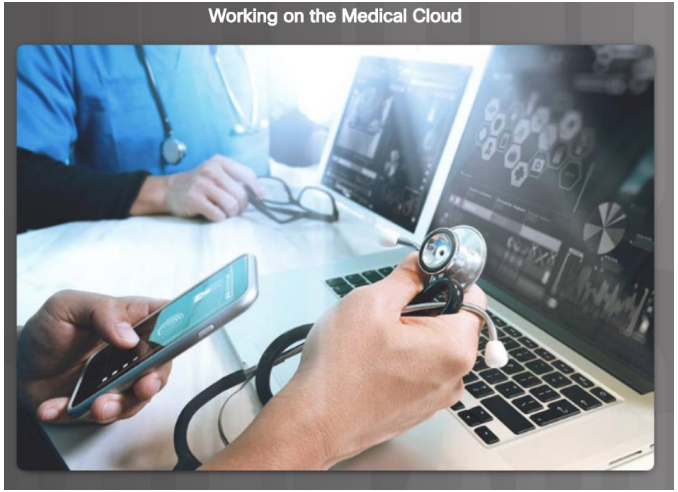
# A Typical Session: Gamer

- A Typical Session: Gamer
  - Determine the origin of the traffic enter the network.
  - Michelle's network, like many home networks, connects to an ISP using a router and modem. These devices allow Michelle's home network to connect to a cable TV network that belongs to Michelle's ISP. The cable wires for Michelle's neighborhood all connect to a central point on a telephone pole and then connect to a fiber-optic network. This fiber-optic network connects many neighborhoods that are served by Michelle's ISP.



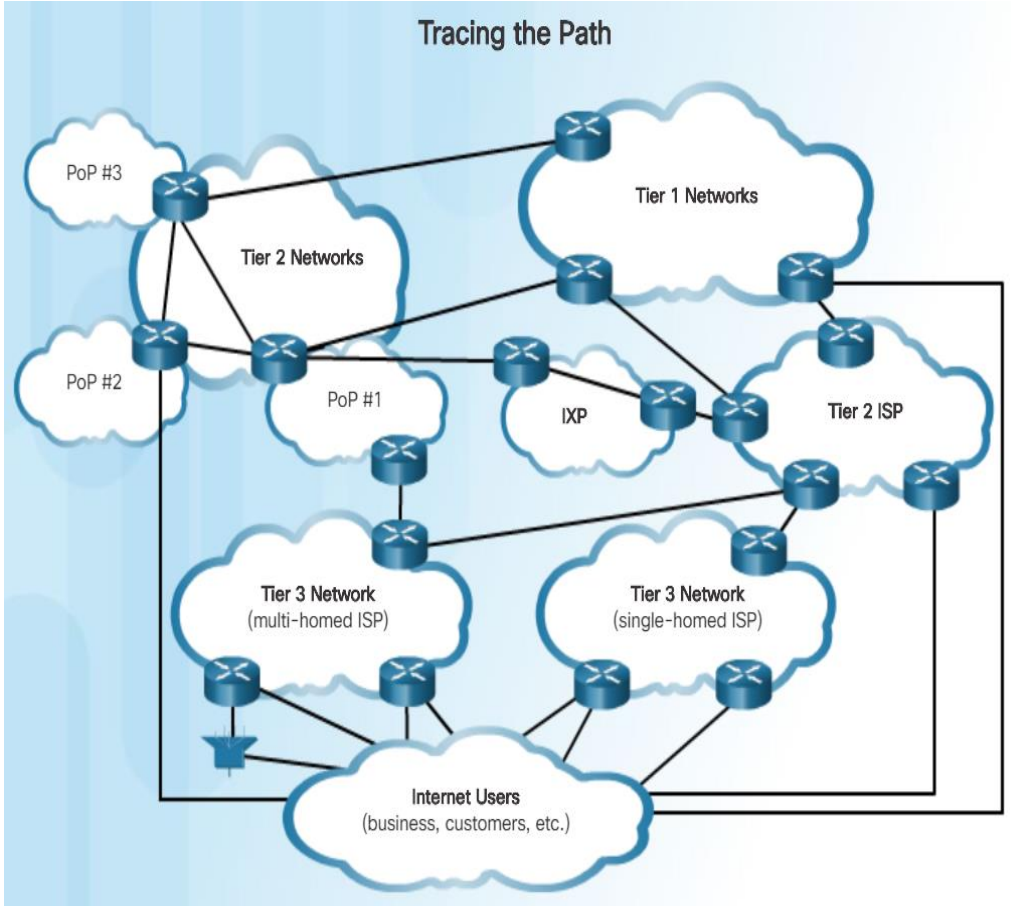
# A Typical Session: Surgeon

- A Typical Session: Surgeon
  - Determine the origin of the traffic enter the network
  - Dr. Ismael Awad is an oncologist who performs surgery on cancer patients. He frequently needs to consult with radiologists and other specialists on patient cases. The hospital that Dr. Awad works for subscribes to a special service called a cloud. The cloud allows medical data, including patient x-rays and MRIs to be stored in a central location that is accessed over the Internet.

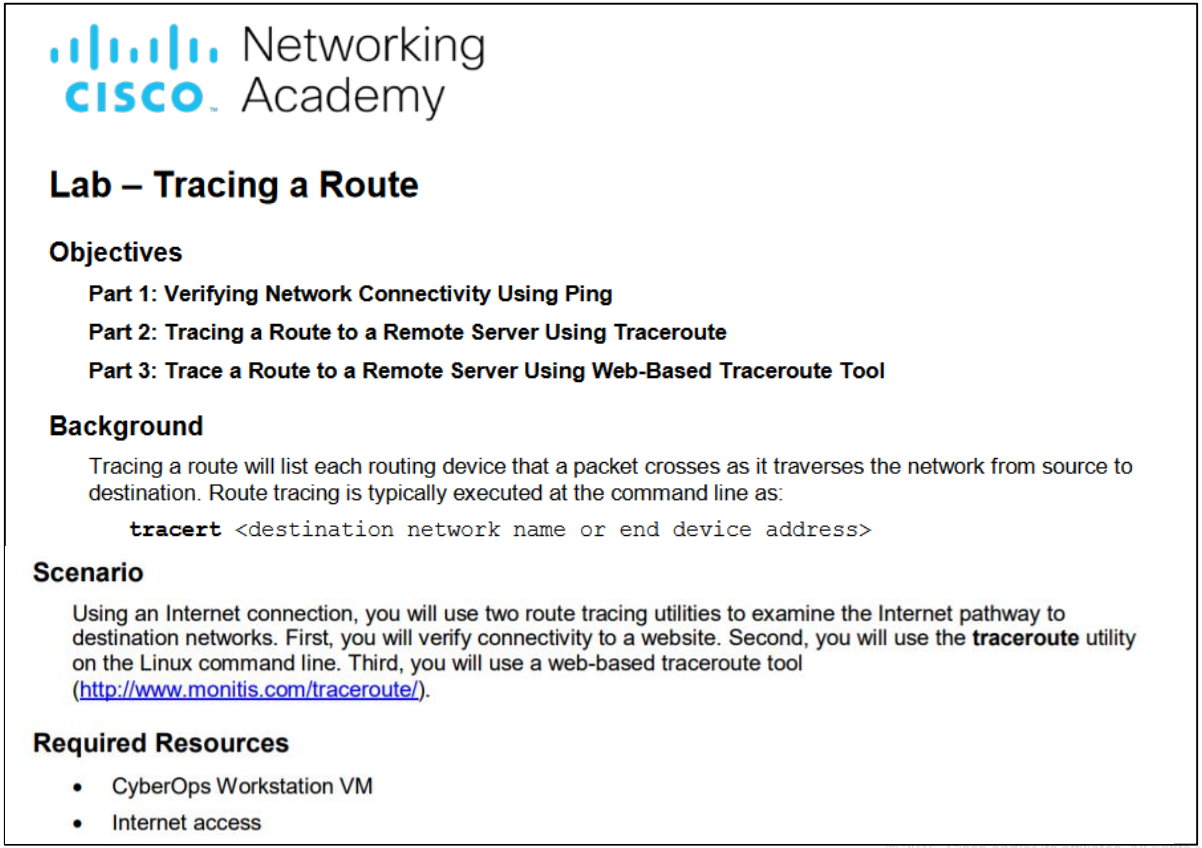


# Tracing the Path

- Cybersecurity analysts must be able to determine the origin of traffic that enters the network, and the destination of traffic that leaves it. Understanding the path that network traffic takes is essential to this.
- Tier 1 Network and Tier 2 networks usually connect through an Internet Exchange Point (IXP).
- Larger networks connect to Tier 2 networks, usually through a Point of Presence (POP).
- Tier 3 ISPs connect homes and businesses to the Internet.



# Lab – Tracing a Route



Networking Academy

## Lab – Tracing a Route

### Objectives

**Part 1: Verifying Network Connectivity Using Ping**

**Part 2: Tracing a Route to a Remote Server Using Traceroute**

**Part 3: Trace a Route to a Remote Server Using Web-Based Traceroute Tool**

### Background

Tracing a route will list each routing device that a packet crosses as it traverses the network from source to destination. Route tracing is typically executed at the command line as:

```
tracert <destination network name or end device address>
```

### Scenario

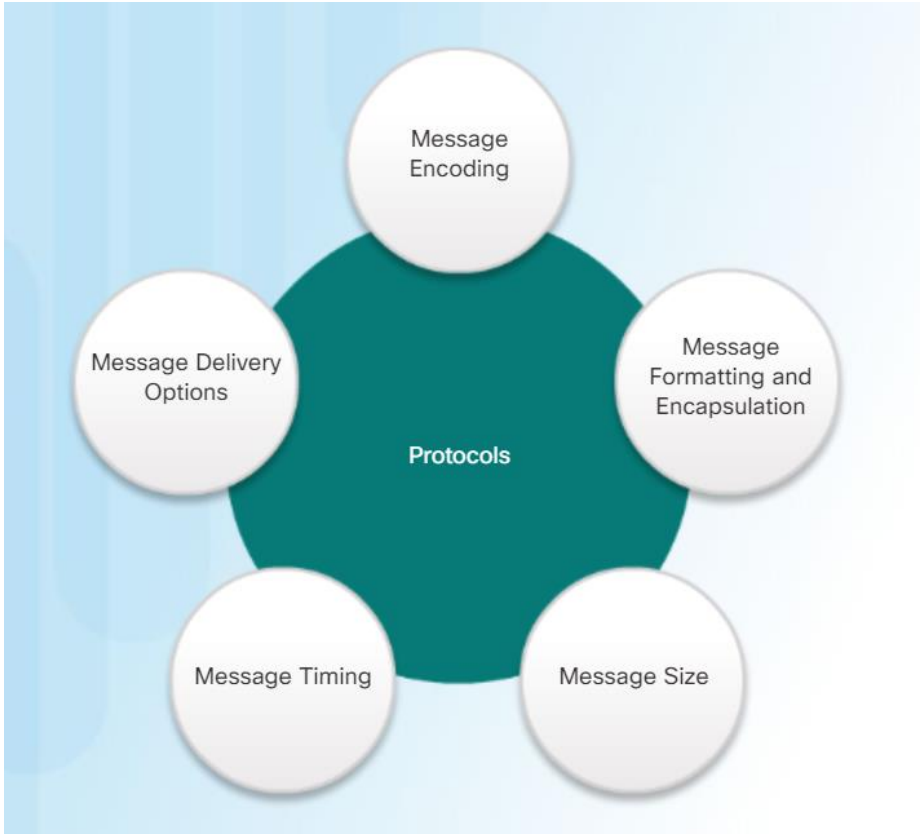
Using an Internet connection, you will use two route tracing utilities to examine the Internet pathway to destination networks. First, you will verify connectivity to a website. Second, you will use the **traceroute** utility on the Linux command line. Third, you will use a web-based traceroute tool (http://www.monitis.com/traceroute/).

### Required Resources

- CyberOps Workstation VM
- Internet access

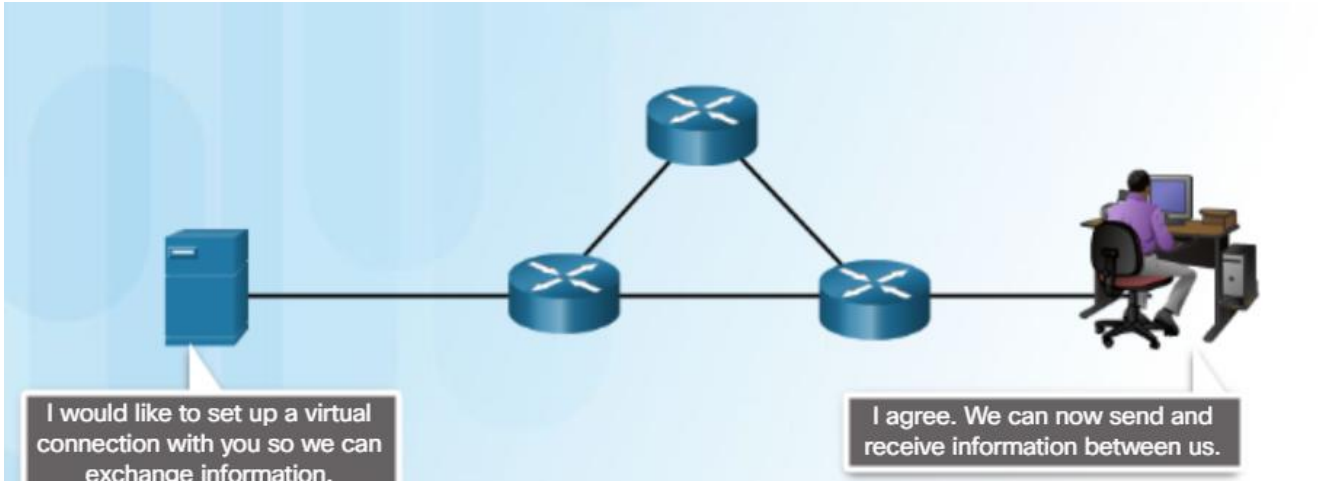
# What are Protocols?

- Protocol – The rules of communications
  - Network protocols provide the means for computers to communicate on networks.
  - Network protocols dictate the message encoding, formatting, encapsulation, size, timing, and delivery options.



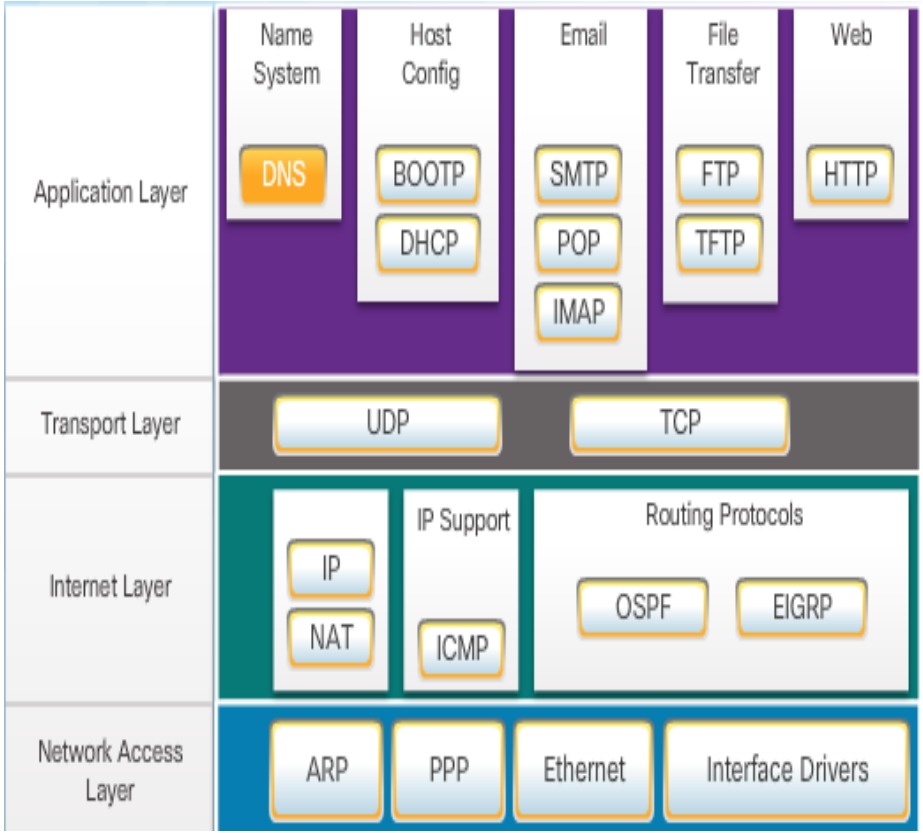
# Network Protocol Suites

- Describe precise requirements and interactions.
- Define a common format and set of rules for exchanging messages between devices.
- Some common networking protocols are Hypertext Transfer Protocol (HTTP), Transmission Control Protocol (TCP), and Internet Protocol (IP).



# TCP/IP Protocol Suite

- TCP/IP has standardized the way the computers communicate.
- TCP/IP protocols are specific to the application, transport, Internet, and network access layers.
- TCP/IP protocol suite is implemented on both the sending and receiving hosts to provide end-to-end delivery of messages over a network.



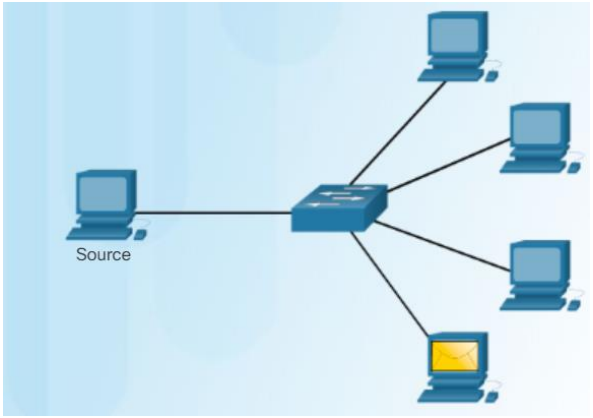
# Format, Size, and Timing

- **Format**
  - **Encapsulation** - process of placing one message format inside another message format.
  - **Decapsulation** - the reverse process of encapsulation.
- **Size** – Message is broken up into many frames when sent, and reconstructed into the original message when received.
- **Timing** – includes the access method, flow control, and response timeout.

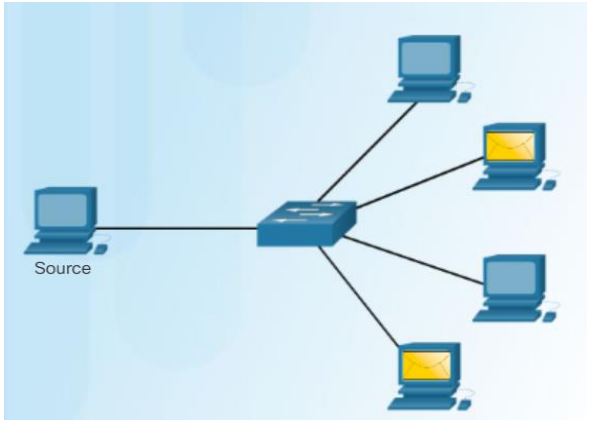
The email message and attachment are broken up into many frames and then sent on the network.

# Unicast, Multicast, and Broadcast

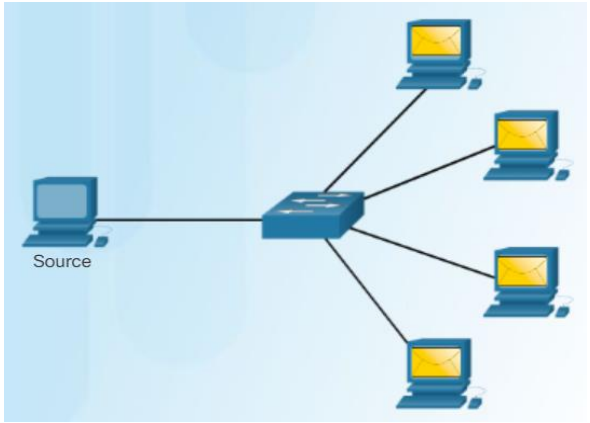
**Unicast** – one-to-one



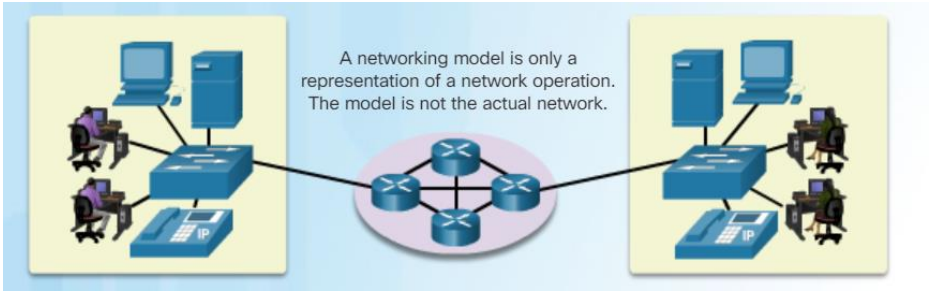

**Multicast** – one-to-many




**Broadcast** – one-to-all



# Reference Models

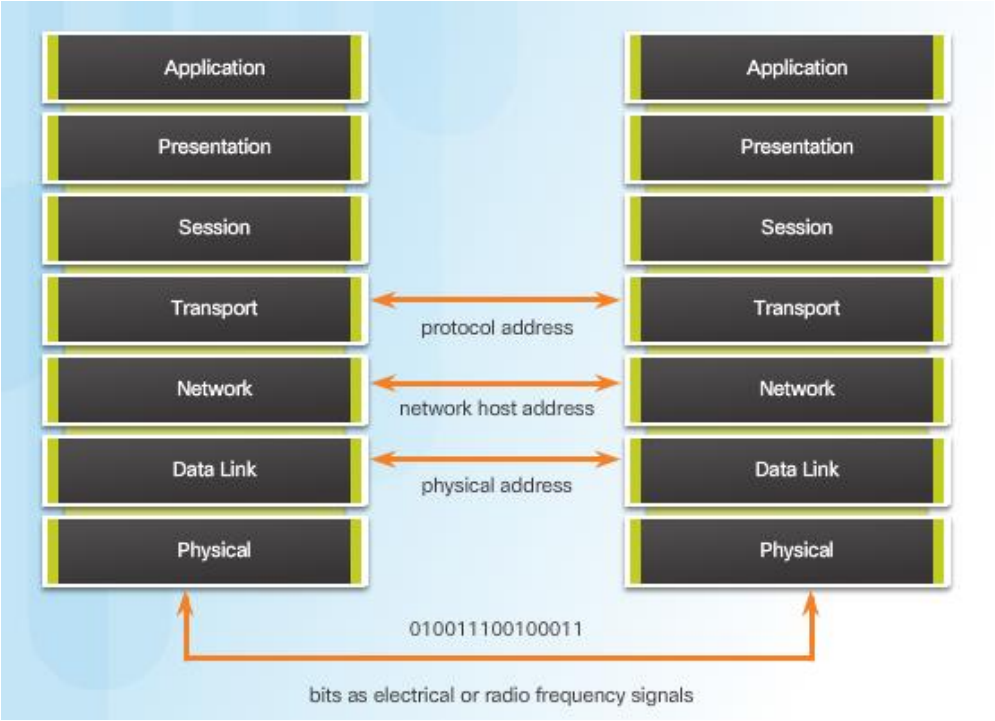



| OSI Model | | TCP/IP Protocol Suite | TCP/IP Model |
|---|---|---|---|
| 7 | Application | HTTP, DNS, DHCP, FTP | Application |
| 6 | Presentation | | |
| 5 | Session | | |
| 4 | Transport | TCP, UDP | Transport |
| 3 | Network | IPv4, IPv6, ICMPv4, ICMPv6 | Internet |
| 2 | Data Link | PPP, Frame Relay, Ethernet | Network Access |
| 1 | Physical | | |

# Three Addresses

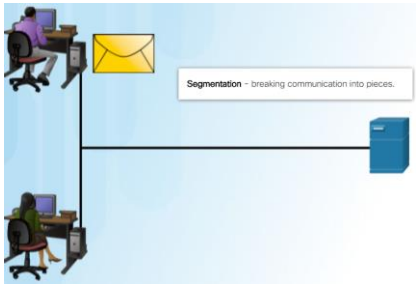
- Three important addresses:
  - Protocol address
  - Network host address
  - Physical address

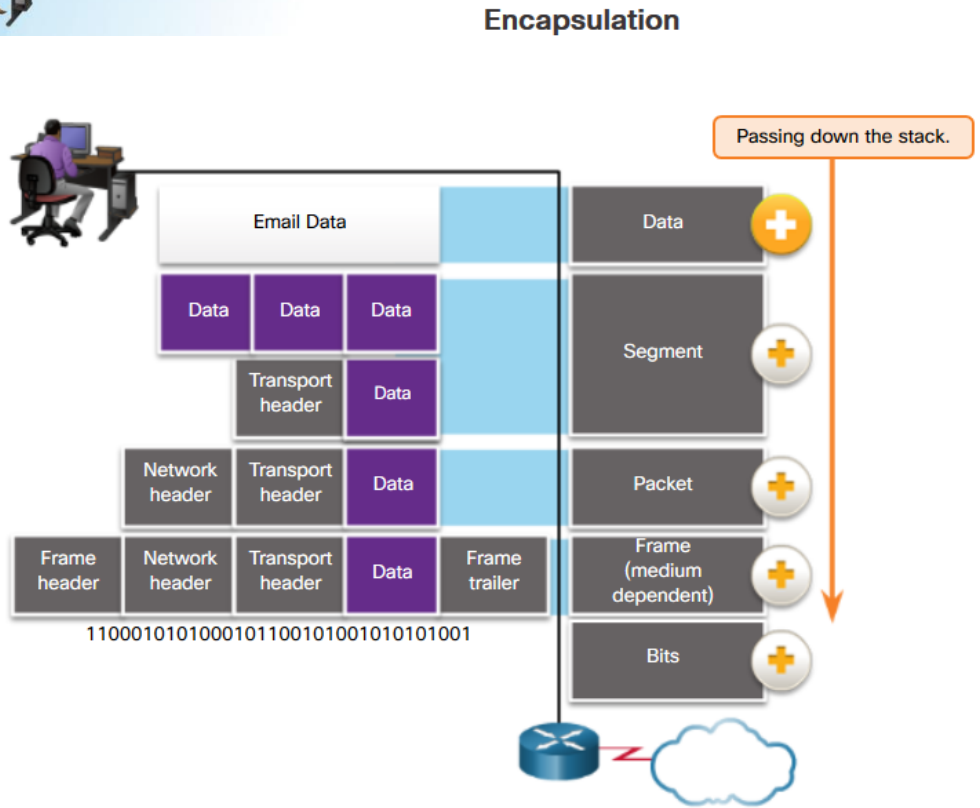
Addressing is used by the client to send requests and other data to a server. The server uses the client's address to return the requested data to the client that requested it.



# Encapsulation

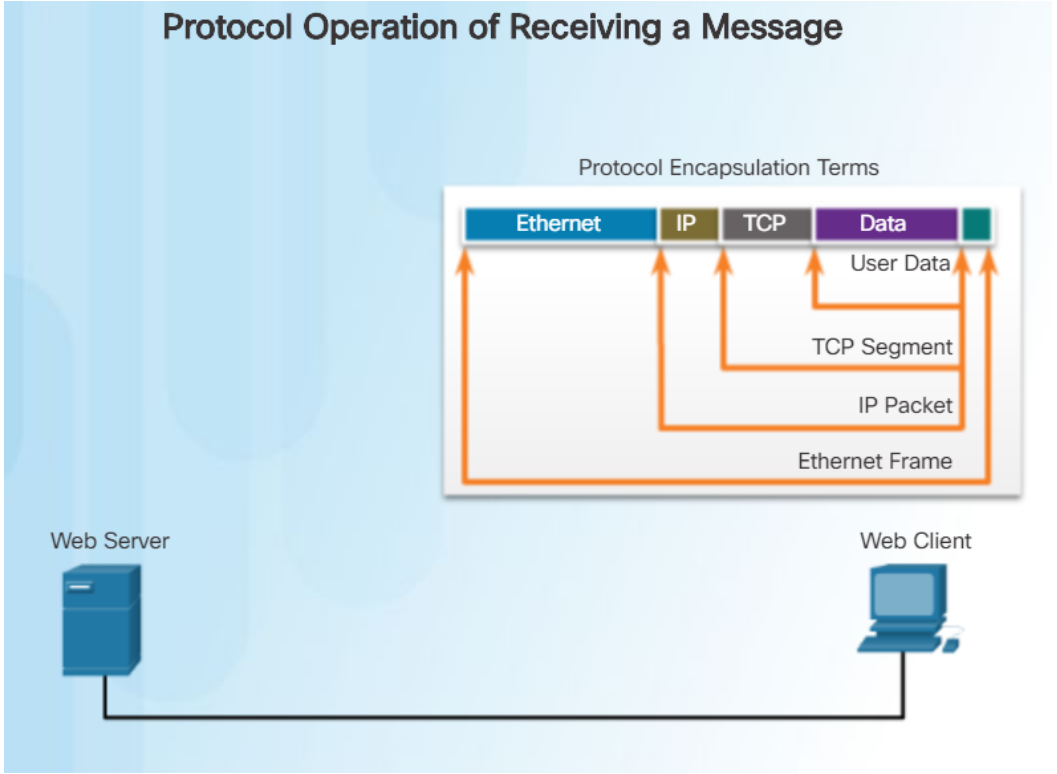
- This division of data into smaller pieces is called segmentation. Segmenting messages has two primary benefits:
  - **Segmentation**
  - **Multiplexing**
- The application data is encapsulated with various protocol information as it is passed down the protocol stack.
- The form that an encapsulated piece of data takes at any layer is called a protocol data unit (PDU).



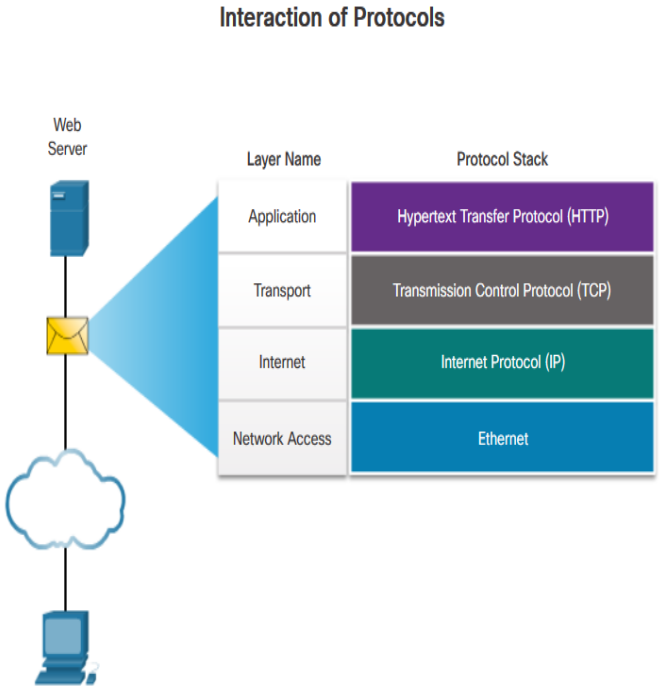
# Encapsulation (Cont.)

- This process is reversed at the receiving host, and is known as de-encapsulation. The data is de-encapsulated as it moves up the stack toward the end-user application.



# Scenario: Sending and Receiving a Web Page

- **HTTP** – This application protocol governs the way a web server and a web client interact.
- **TCP** – This transport protocol manages individual conversations. TCP divides the HTTP messages into smaller pieces, called segments. TCP is also responsible for controlling the size and rate at which messages are exchanged between the server and the client.
- **IP** – This is responsible for taking the formatted segments from TCP, encapsulating them into packets, assigning them the appropriate addresses, and delivering them to the destination host.
- **Ethernet** – This network access protocol is responsible for taking the packets from IP and formatting them to be transmitted over the media.

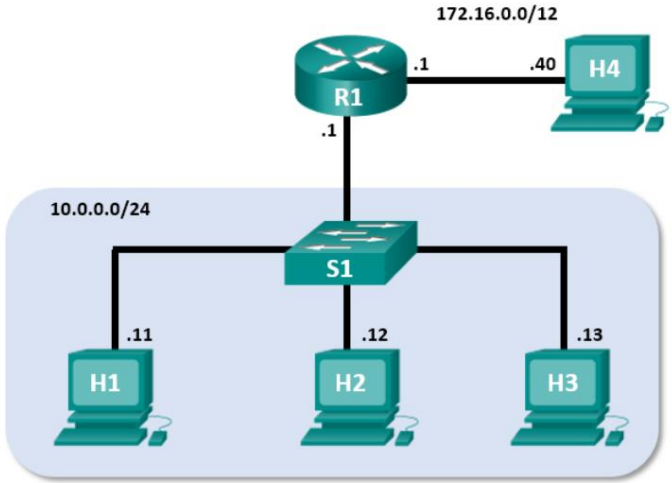


# Lab – Introduction to Wireshark

Networking Academy

**Lab – Introduction to Wireshark**

**Mininet Topology**




**Objectives**

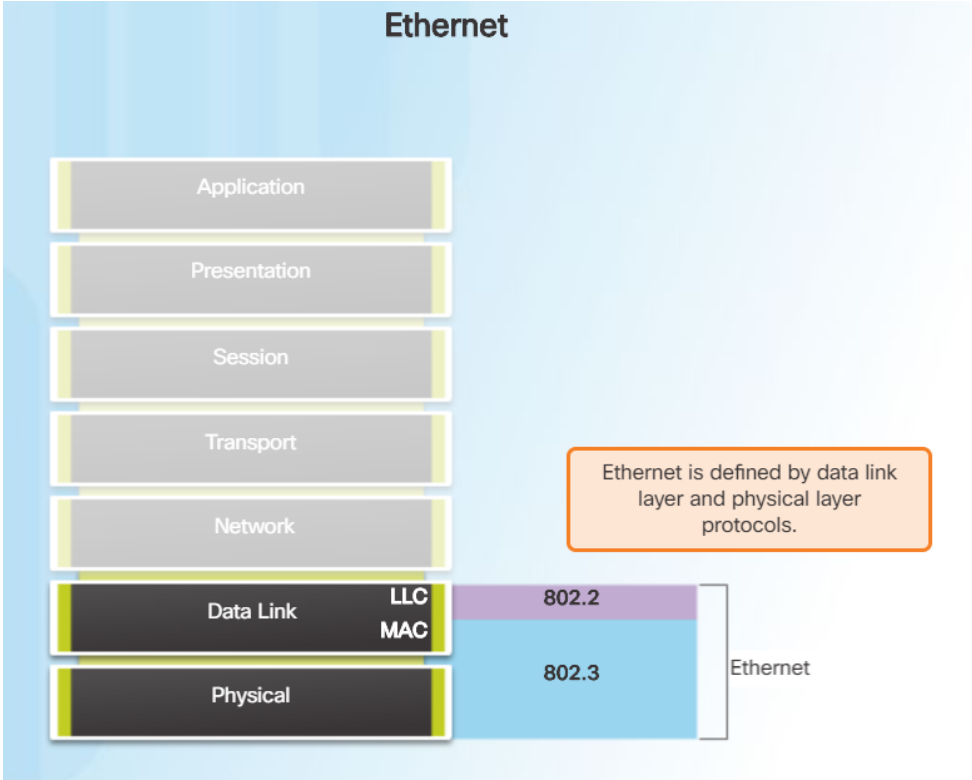
**Part 1: Install and Verify the Mininet Topology**

**Part 2: Capture and Analyze ICMP Data in Wireshark**

# 4.2 Ethernet and Internet Protocol (IP)

# The Ethernet Protocol

- Operates at Layer 1 and 2
  - Defined by the IEEE 802.2 and 802.3 standards
  - Ethernet Sublayers
    - Logical Link Layer (LLC)
    - Media Access Control Layer (MAC)
- Ethernet responsibilities
  - Data encapsulation
  - Media access control

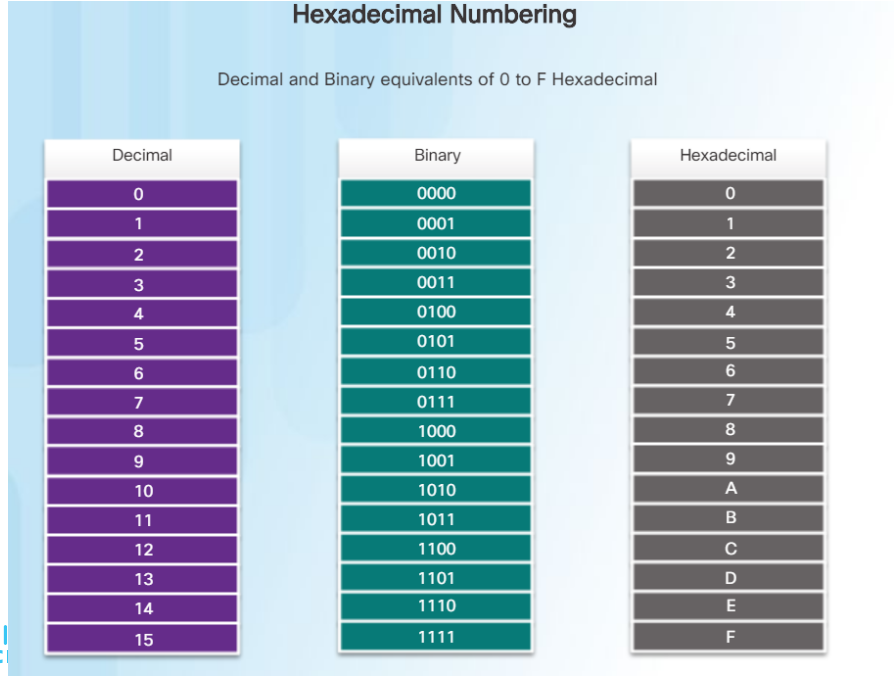


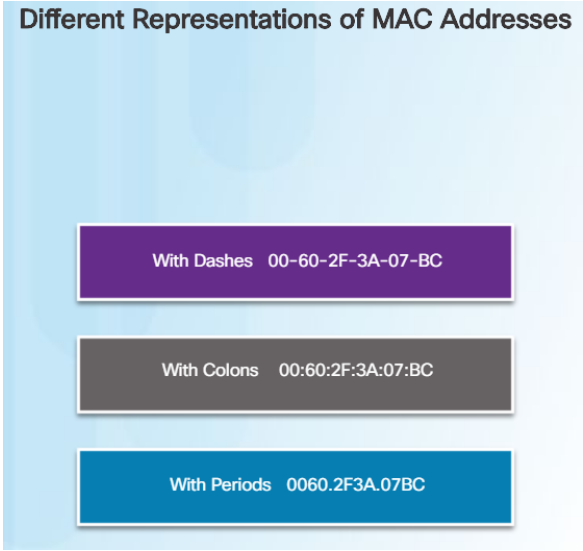
# The Ethernet Frame

- Minimum Ethernet frame size 64 bytes
- Maximum Ethernet frame size 1518 bytes
- Two key identifiers
  - Destination MAC address
  - Source MAC address
- Uses hexadecimal

# MAC Address Format

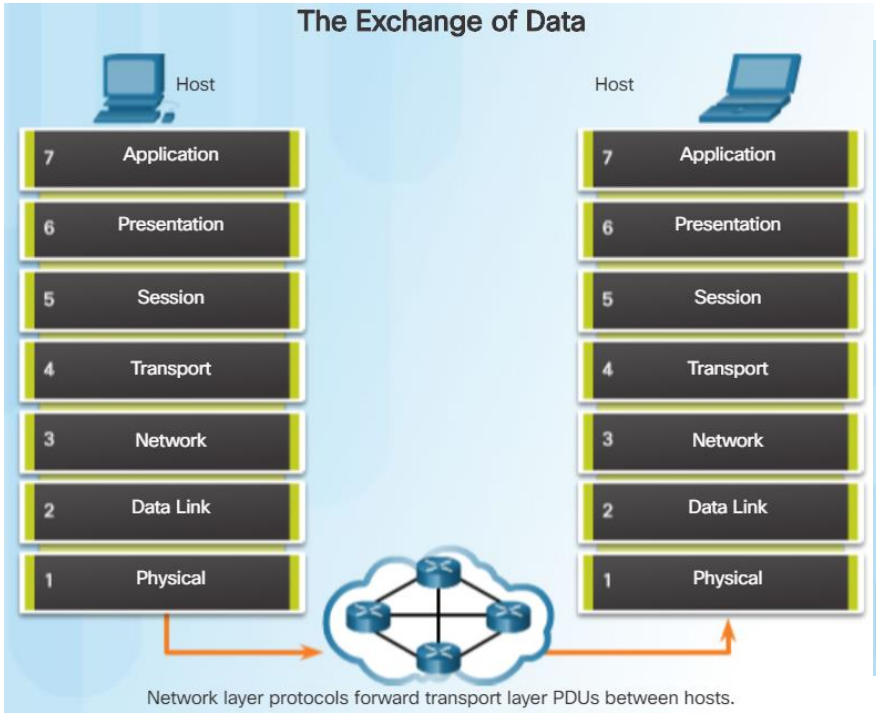
- Ethernet MAC address is 48-bit binary expressed as 12 hexadecimal digits.
  - Uses numbers 0 to 9 and letters A to F.
  - All data that travels on the network is encapsulated in Ethernet frames.

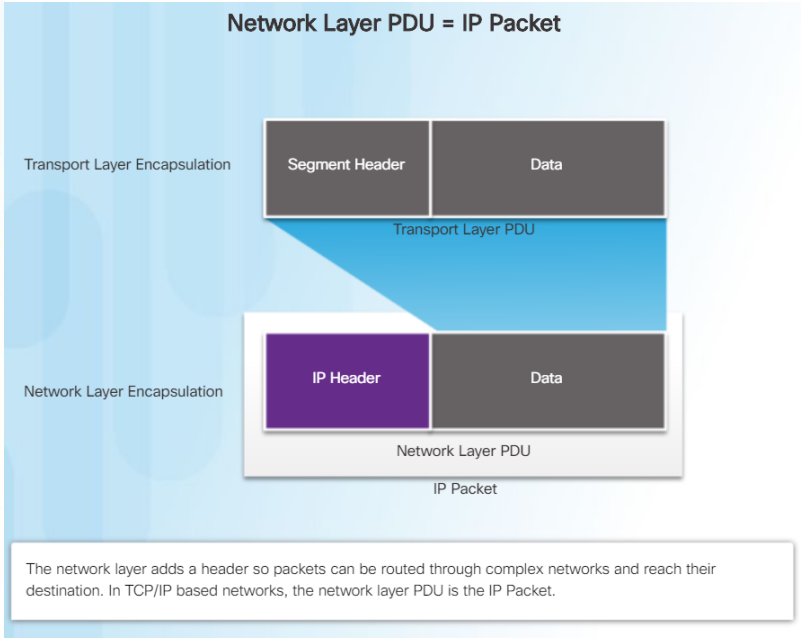


# IPv4 Encapsulation

- IP encapsulates the transport layer segment by adding an IP header.

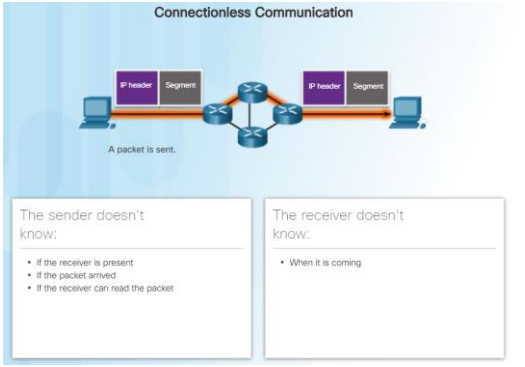


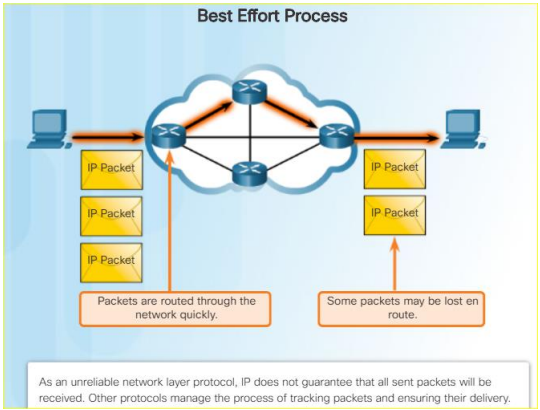



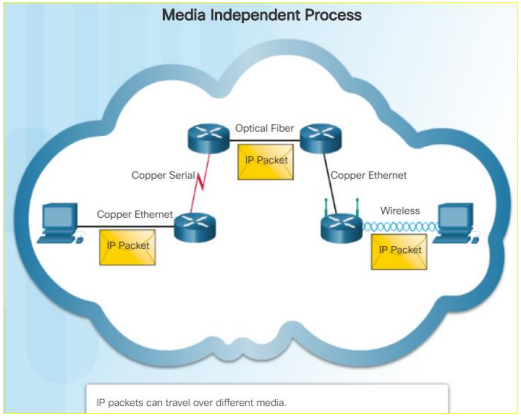
# IPv4 Characteristics

## IPv4 Characteristics

- **Connectionless** – no dedicated end-to-end connection is created before data is sent.
- **Unreliable (Best Effort)** - IP protocol does not guarantee that all packets that are delivered are, in fact, received.
- **Media Independent** - IP operates independently of the media that carry the data at lower layers of the protocol stack.

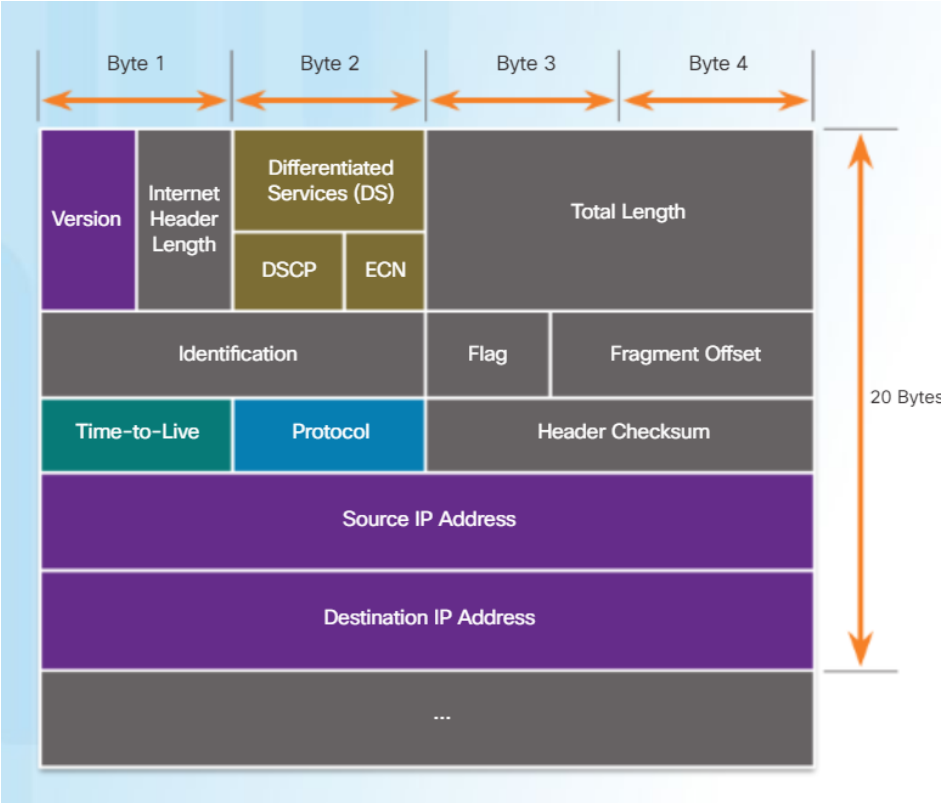


# IPv4 Packet

- Packet header consists of fields containing important information about the packet.
- Fields contain binary numbers examined by the Layer 3 process.
- The binary values of each field identify various settings of the IP packet.
- Two most commonly referenced fields are the source and destination IP addresses.

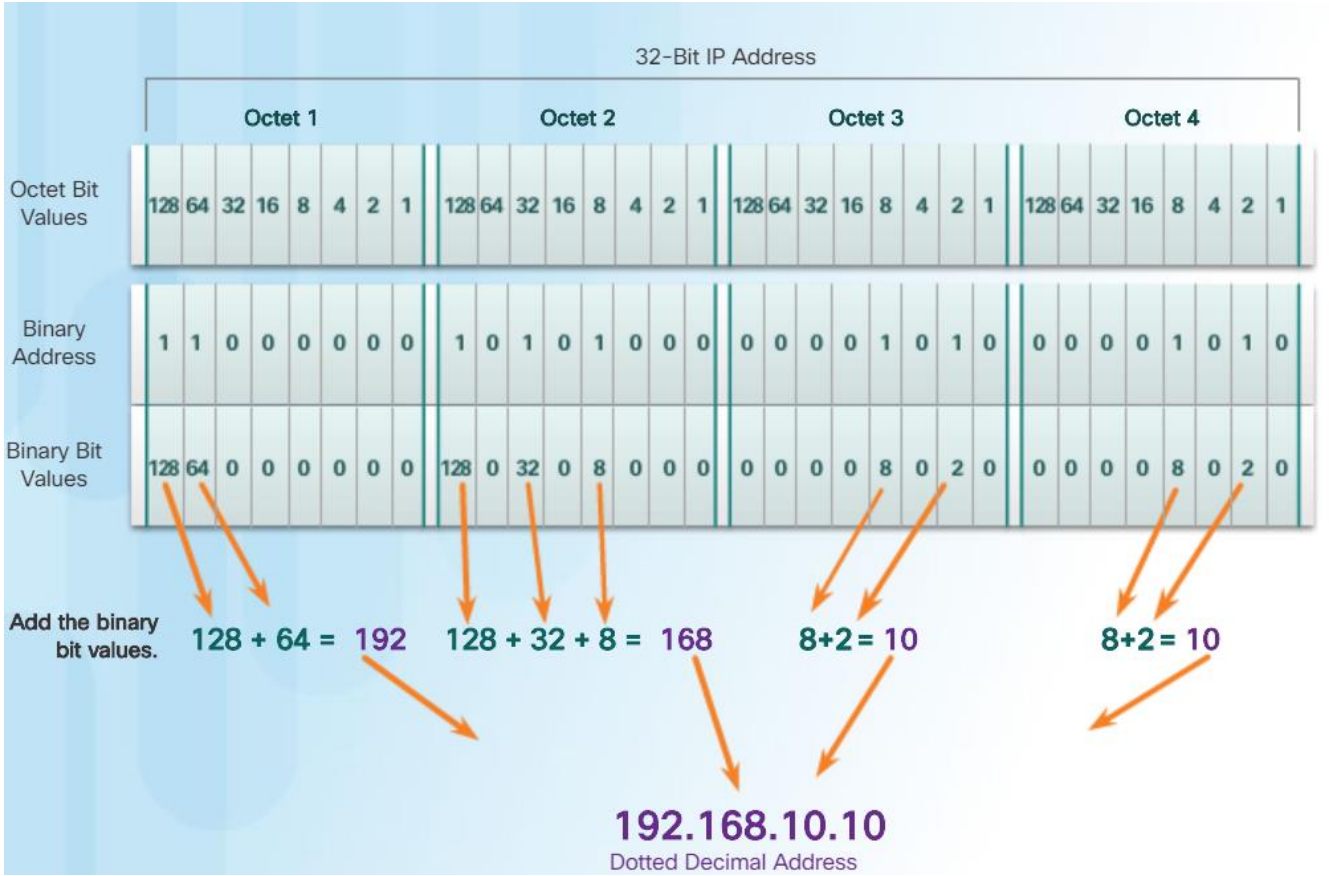


# Video Demonstration – Sample IPv4 Headers in Wireshark

- Network layer information can be seen and analyzed in Wireshark packet captures.

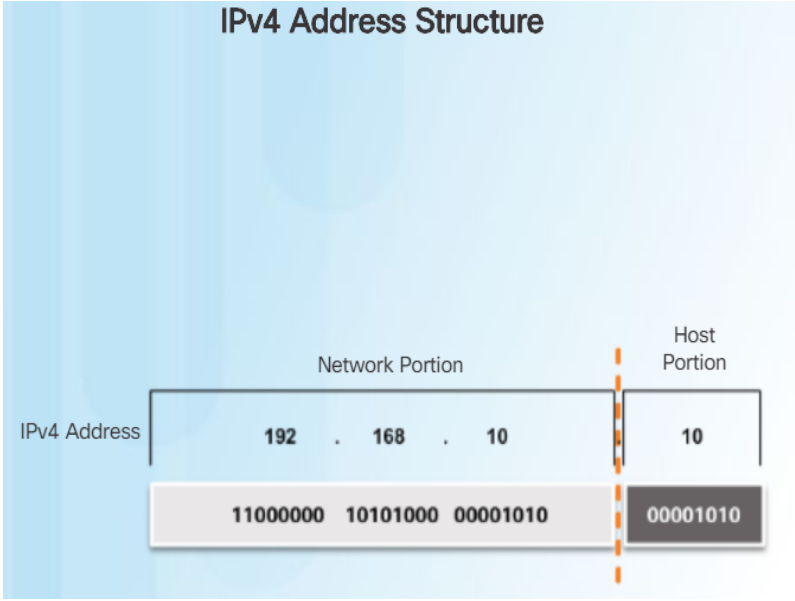
# IPv4 Address Notation

- IP address is a series of 32 binary bits (ones and zeros).
- When a host is configured with an IPv4 address, it is entered as a dotted decimal number such as 192.168.10.10.
- The equivalent address in binary is 11000000.10101000.00001010.00001010



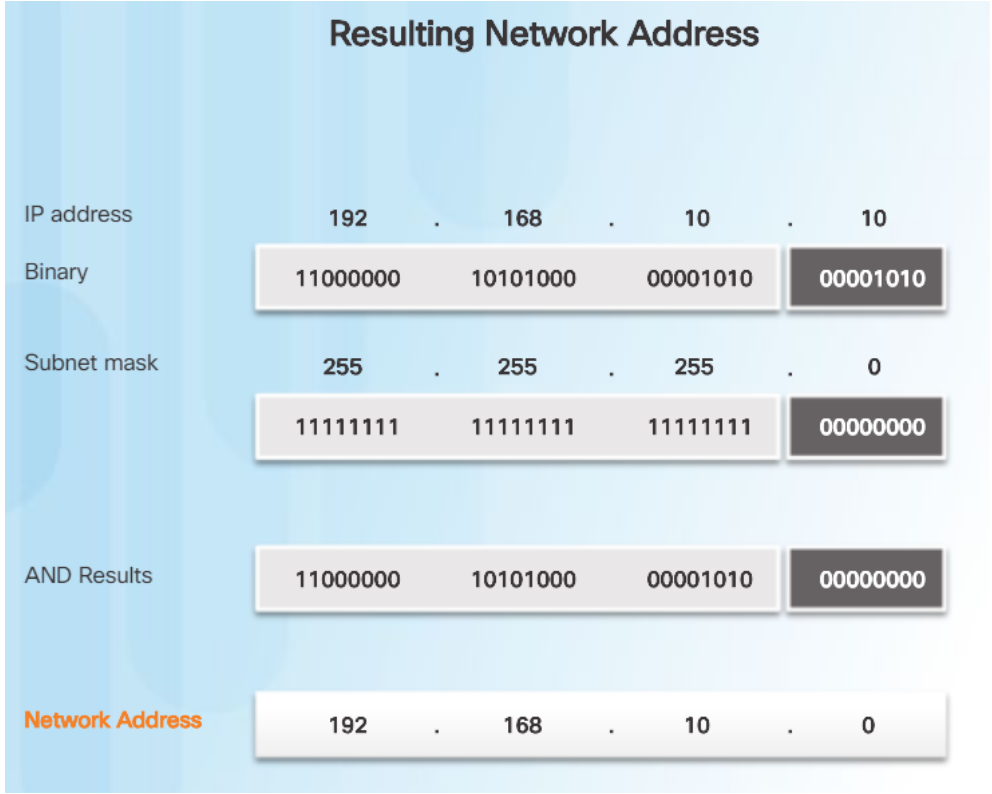
# IPv4 Host Address Structure

- IPv4 address is a hierarchical address that is made up of a network portion and a host portion.
- The network portion of the address must be identical for all devices that reside in the same network.
- The bits within the host portion of the address must be unique to identify a specific host within a network.



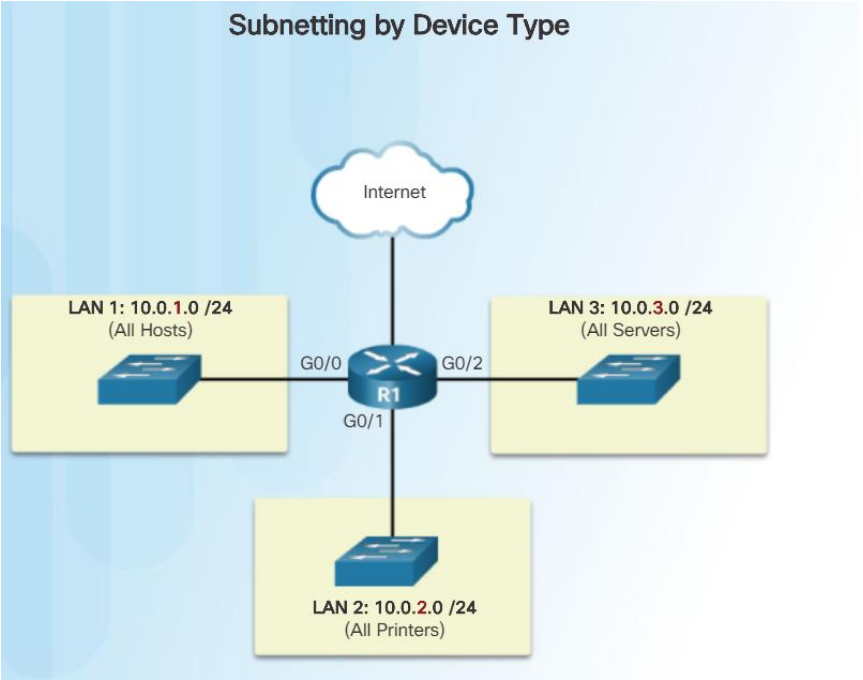
# IPv4 Subnet Mask and Network Address

- Subnetting takes a network space and divides it into smaller spaces called subnets.
- Identifying network address of an IPv4host:
  - IP address is logically ANDed, bit by bit with subnet mask.
  - ANDing between the address and the subnet mask yields the network address.



# Subnetting Broadcast Domains

- Subnetting takes a network space and divides it into smaller spaces called subnets.
- Identifying network address of an IPv4 host:
  - IP address is logically ANDed, bit by bit with subnet mask.
  - ANDing between the address and the subnet mask yields the network address.



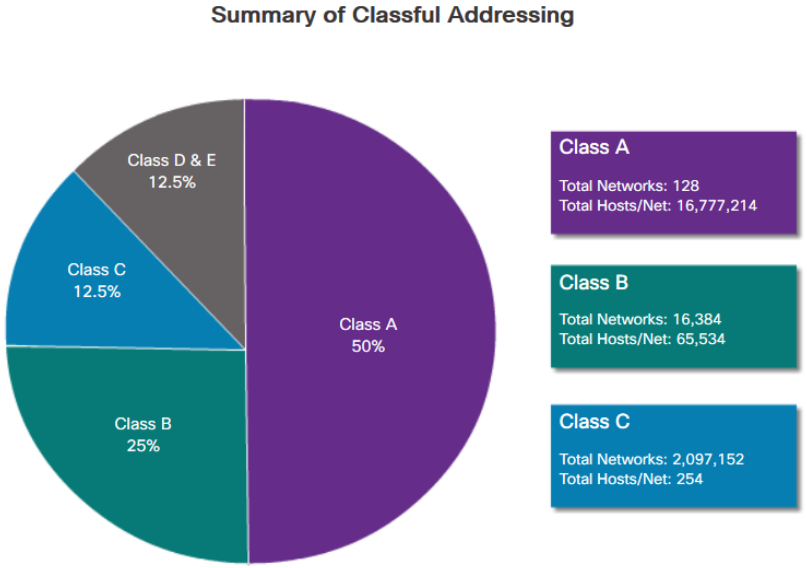
# Video Demonstration – Network, Host, and Broadcast Addresses

- **Network Address** - the first address in the network.
- **Host Address** – the first usable host address is after the network address and last useable host address is the address prior to the broadcast address.
- **Broadcast Address** - the last address in the network.
- The logical AND determines if an address is in the same network.

# IPv4 Address Classes and Default Subnet Masks

Assigned Classes – A, B, C, D, and E

- **Class A** - Designed to support extremely large networks.
- **Class B** – Designed to support moderate to large networks.
- **Class C-** Designed to support small networks.
- **Class D -** Multicast block.
- **Class E -** Experimental address block.

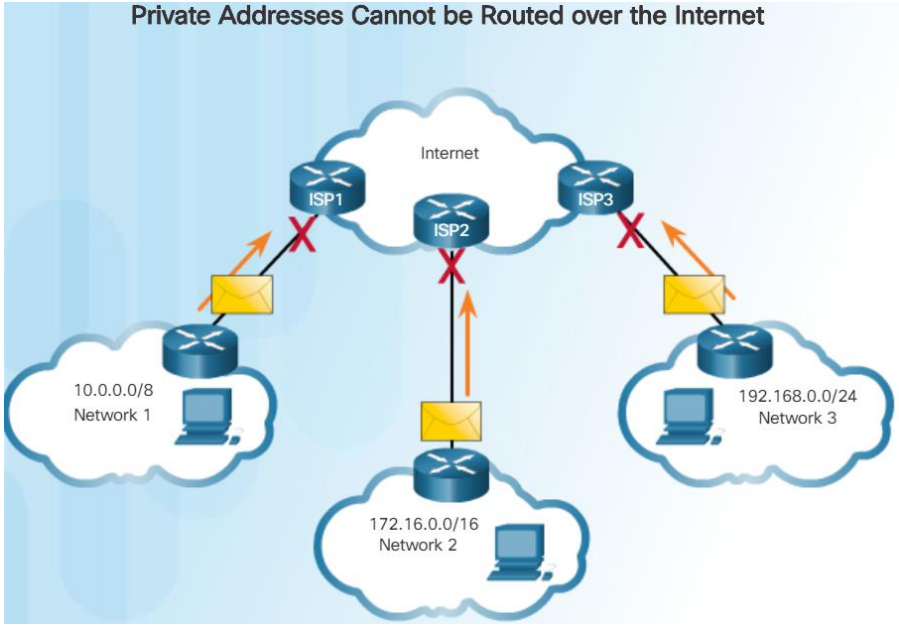



**Private Internet Addresses are Defined in RFC 1918**

| Class | RFC 1918 Internal Address Range |
|---|---|
| A | 10.0.0.0 - 10.255.255.255 |
| B | 172.16.0.0 - 172.31.255.255 |
| C | 192.168.0.0 - 192.168.255.255 |

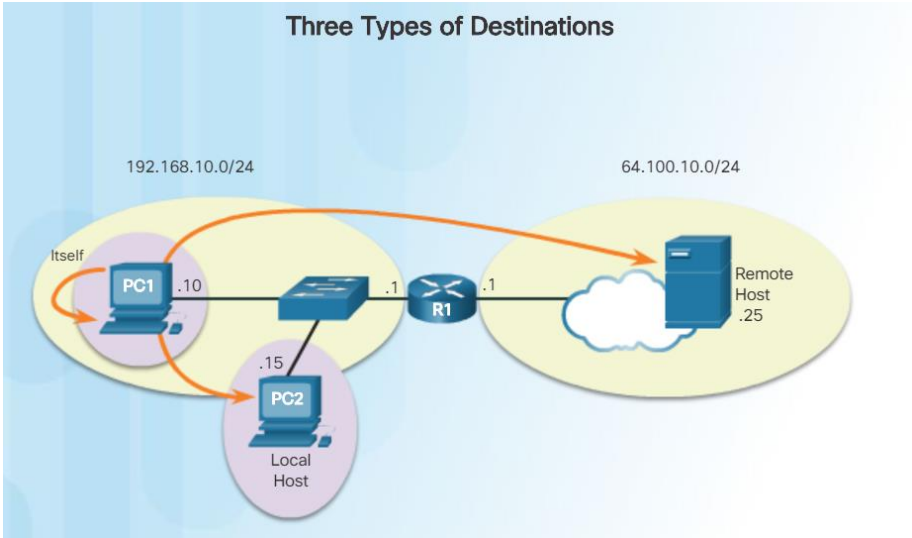
# Reserved Private Addresses

- Blocks of addresses mostly used by organizations to assign IPv4 addresses to internal hosts.
- Not unique to any network.
- Not allowed on Internet and are filtered by internal router.
- Router usually connects the internal network to the ISP network.



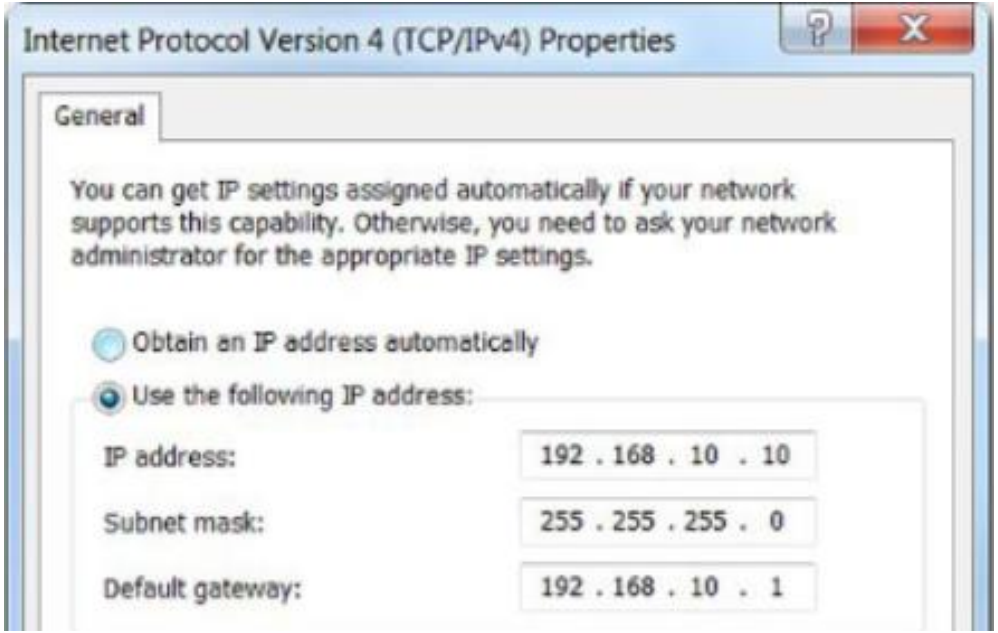
# Host Forwarding Decision

- A host can send a packet to three types of destinations:
  - **Itself** - A host can ping itself by sending a packet to a special IPv4 address of 127.0.0.1. Pinging the loopback interface tests the TCP/IP protocol stack.
  - **Local host** - This is a host on the same local network.
  - **Remote host** - This is a host on a remote network. The hosts do not share the same network address.



# Default Gateway

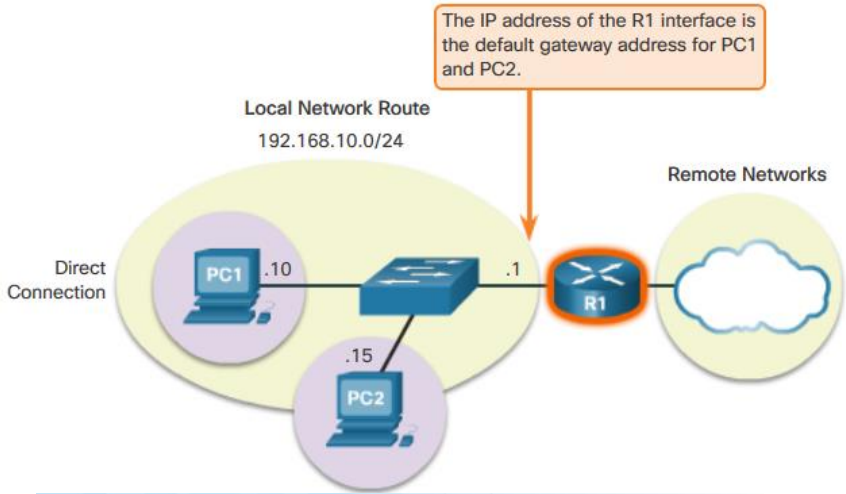
- Three dotted decimal IPv4 addresses must be configured when assigning an IPv4 configuration to host:
  - **IPv4 address** – Unique IPv4 address of the host.
  - **Subnet mask** - Used to identify the network/host portion of the IPv4 address.
  - **Default gateway** – Identifies the local gateway (i.e. local router interface IPv4 address) to reach remote networks.
- The default gateway is the network device that can route traffic to other networks. It is the router that can route traffic out of the local network.

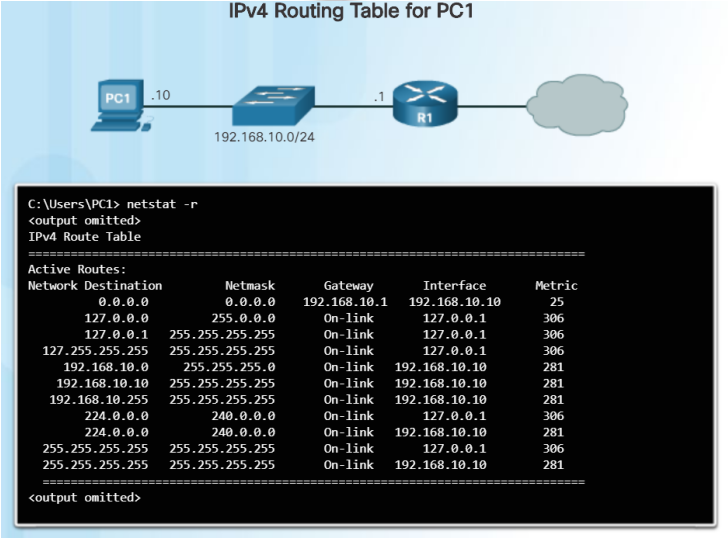


# Using the Default Gateway

A host's routing table will typically include a default gateway.

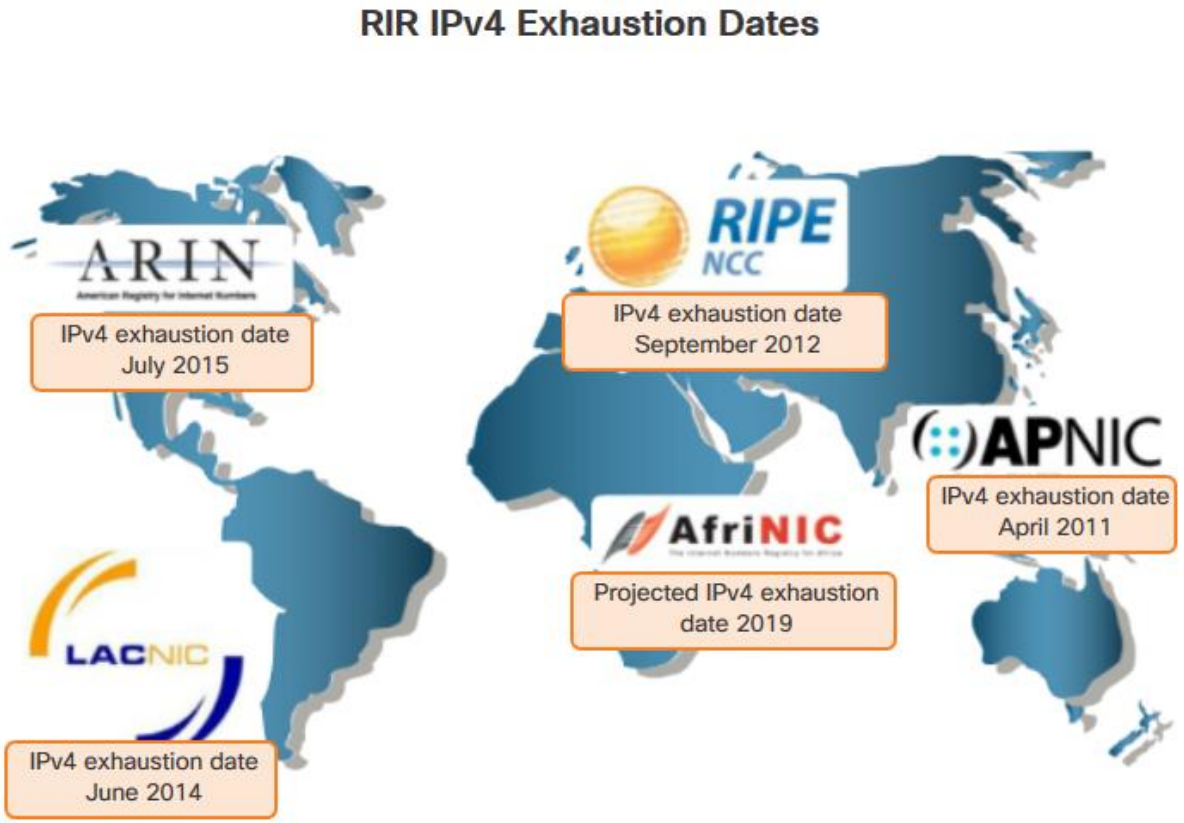
- The host receives the IPv4 address of the default gateway.
- IP addressing information:
  - Configured manually.
  - Obtained automatically/dynamically using Dynamic Host Configuration Protocol (DHCP).
  - Placed in computer's routing table.



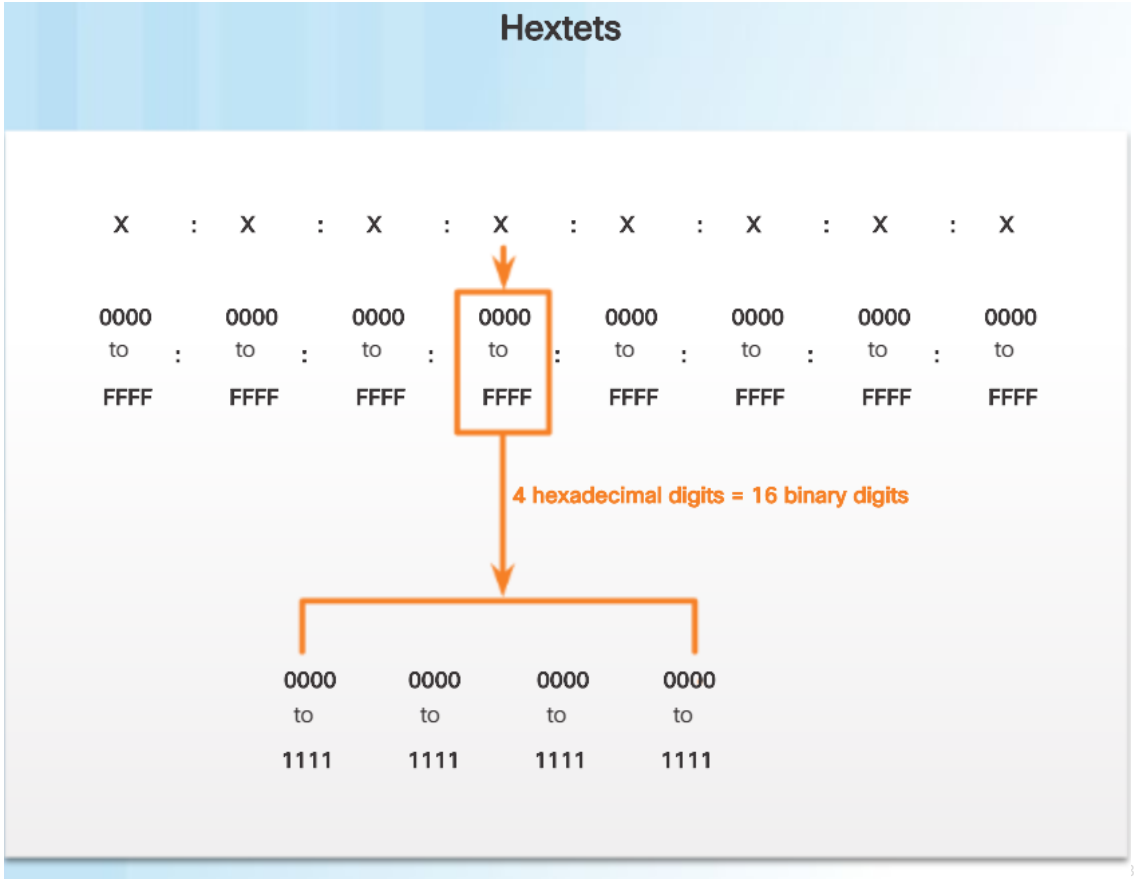
# Need for IPv6

- The depletion of IPv4 address space has been the motivating factor for moving to IPv6.128-bit address space.
- Four out of the five Regional Internet Registries (RIRs) have run out of IPv4 addresses.



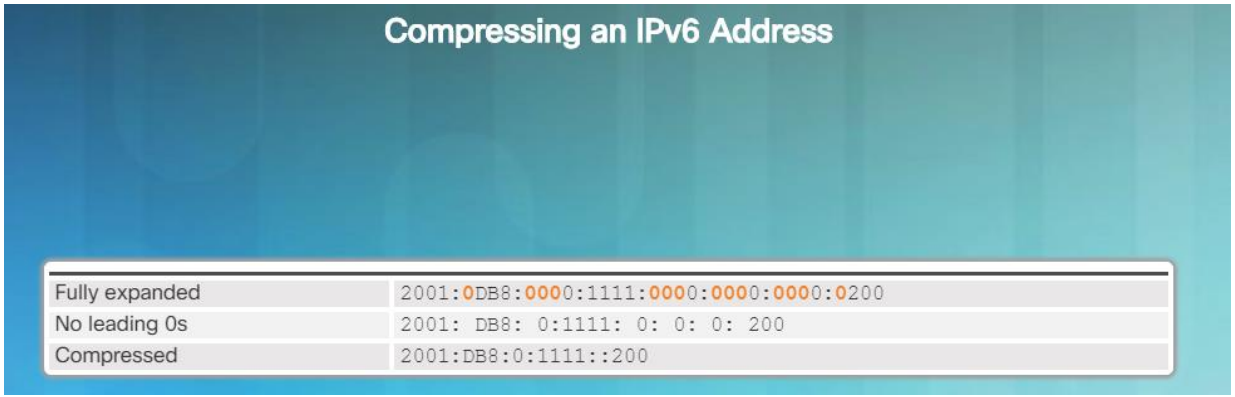
# IPv6 Size and Representation

- 128-bit address space.
  - String of 32 hexadecimal values.
  - Every 4 bits represented by one hexadecimal digit.
  - Hextet is 16 bits or 4 hexadecimal digits.



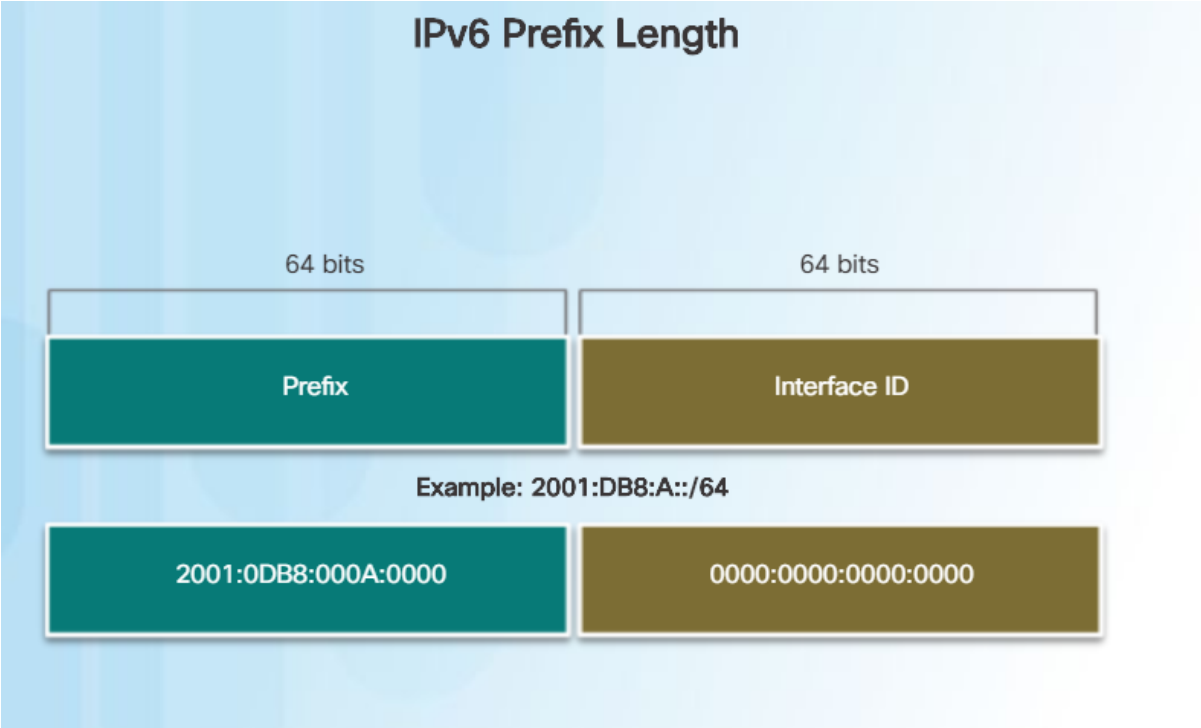
# IPv6 Address Formatting

- IPv6 Addresses:
  - 128 bit address space.
  - Can remove leading zeros.
  - Can leave out 1 “all zeros” segment.
  - Two sections: Prefix and Interface ID.



# IPv6 Prefix Length

- IPv6 Prefix length does not use the dotted decimal subnet mask notation.
- The prefix length can range from 0 to 128.



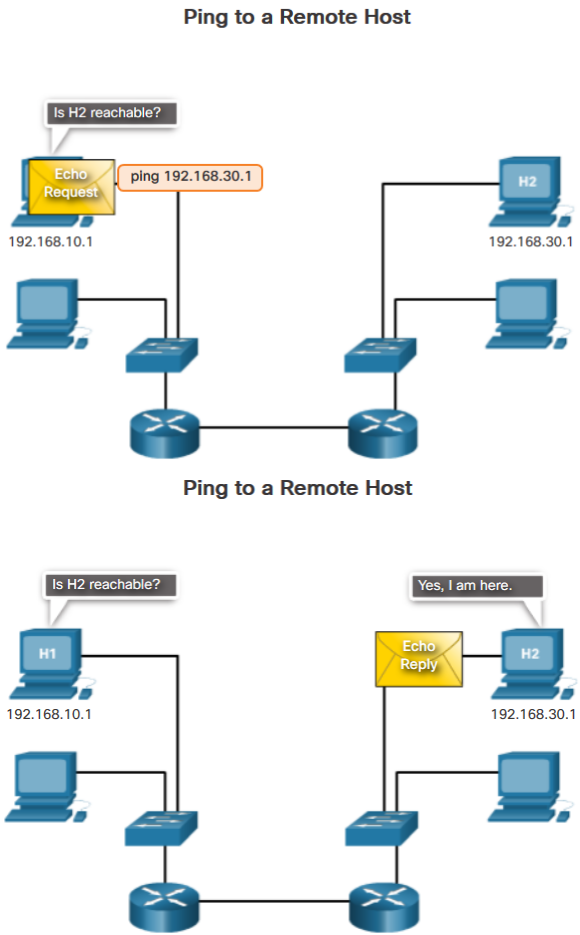
# Video Tutorial – Layer 2 and Layer 3 Addressing

- Layer 3 Address – IPv4 or IPv6 address
  - Logical address assigned by the administrator.
- Layer 2 Address – MAC address
  - Physical address or burned in address from the manufacturer of the network adapter.

# 4.3 Connectivity Verification

# ICMPv4 Messages

- Used to provide feedback and troubleshoot network problems.
- **Message types:**
  - **Host confirmation** – echo request and echo reply with the ping utility.
  - **Destination or service unreachable codes:**
    - **0** – net unreachable
    - **1** – host unreachable
    - **2** – protocol unreachable
    - **3** – port unreachable
  - **Time exceeded** – used by a router to indicate that a packet cannot be sent onward:
    - IPv4 is due to the time to live (TTL) field having a value of 0.
    - IPv6 does not have a TTL field, but has a hop limit field instead.



# ICMPv6 RS and RA Messages

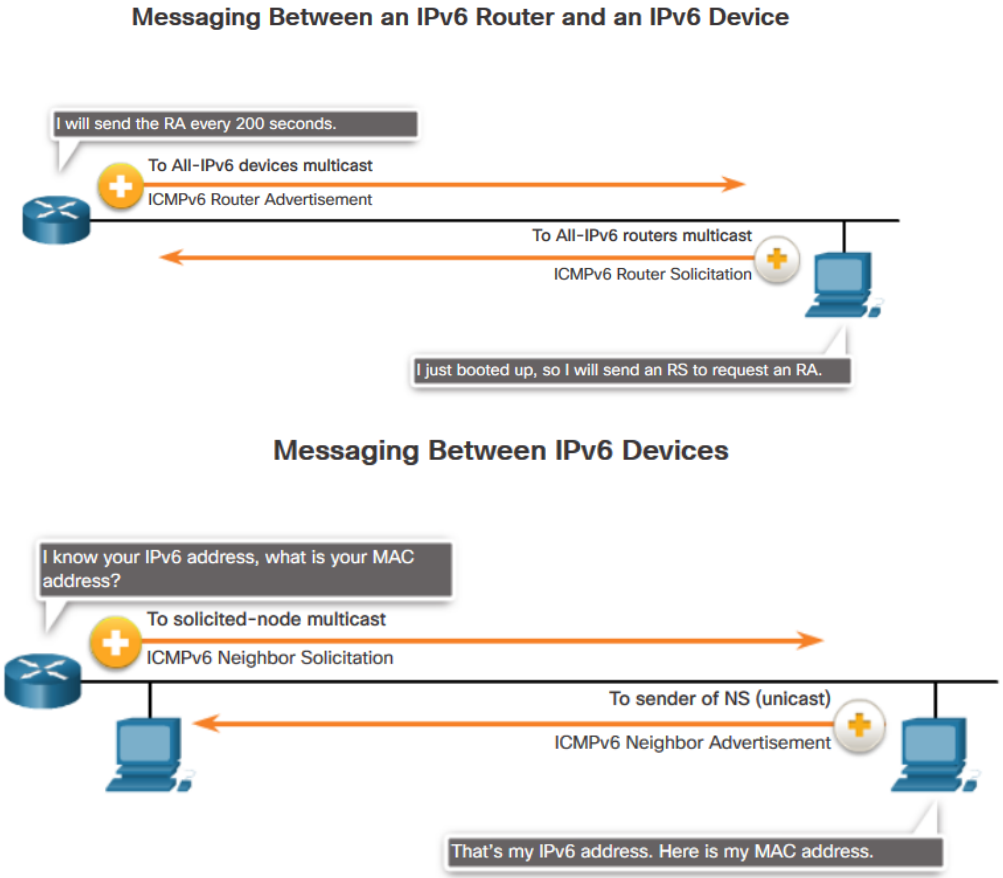
4 new protocols as part of the Neighbor Discovery Protocol (ND or NDP):

Messaging between IPv6 router and IPv6 device:

- **Router Solicitation (RS)** – used between an IPv6 device and a router.
- **Router Advertisement (RA)** – used between an IPv6 router and a device to provide addressing info using Stateless Address Autoconfiguration (SLAAC).

Messaging between IPv6 devices:

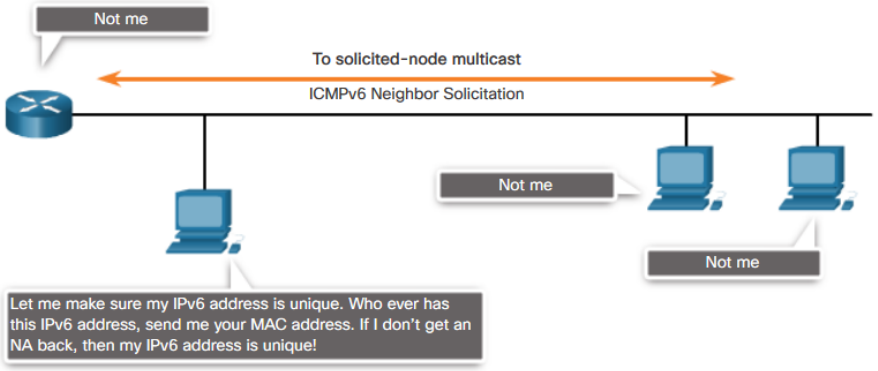
- **Neighbor Solicitation (NS) message**
- **Neighbor Advertisement (NA) message**



# ICMPv6 and RA Messages (Cont.)

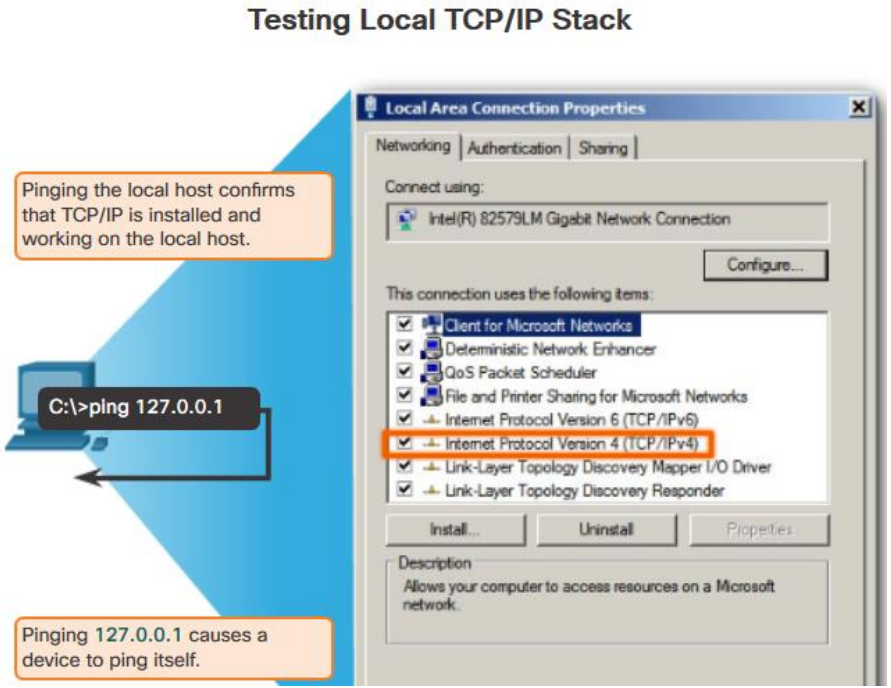
- IPv6 Duplicate Address Detection (DAD)
  - Not required, but recommended.
  - If another device on the network has the same global unicast or link-local unicast address, the device will respond with an NA message.

**Duplicate Address Detection (DAD)**



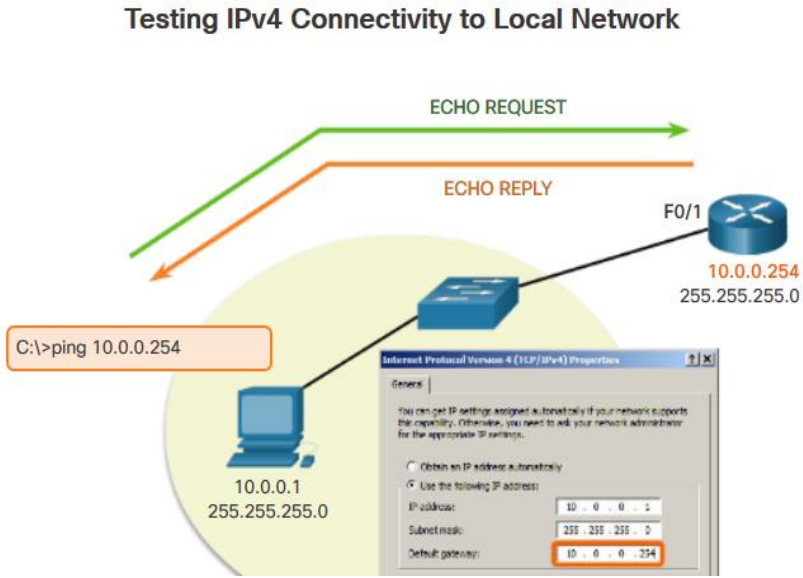
# Ping – Testing and Local Stack

- Ping is a testing utility that uses ICMP echo request and echo reply messages to test connectivity between hosts.
- To test connectivity to another host on a network, an echo request is sent to the host address using the ping command.
- If the host at the specified address receives the echo request, it responds with an echo reply.



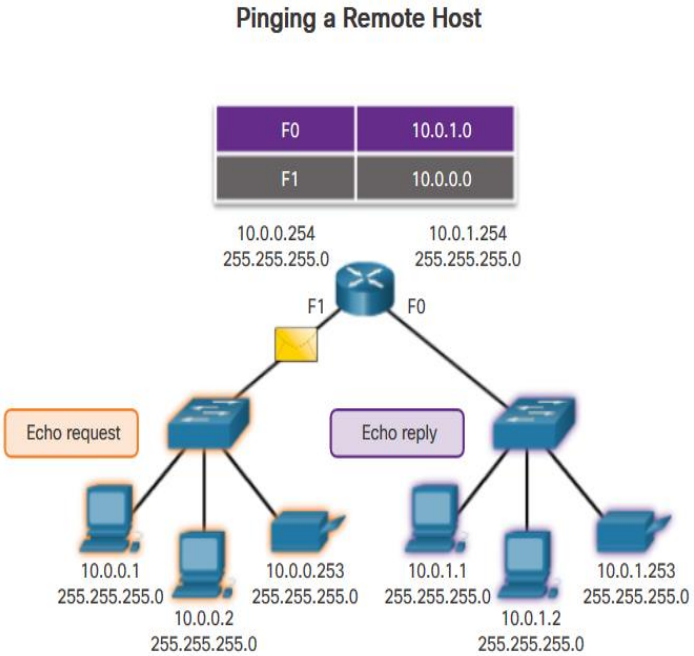
# Ping – Testing Connectivity to Local LAN

- You can also use ping to test the ability of a host to communicate on the local network. This is generally done by pinging the IP address of the gateway of the host.
- A successful ping to the gateway indicates that the host and the router interface serving as the gateway are both operational on the local network.
- For this test, the gateway address is most often used because the router is normally always operational.



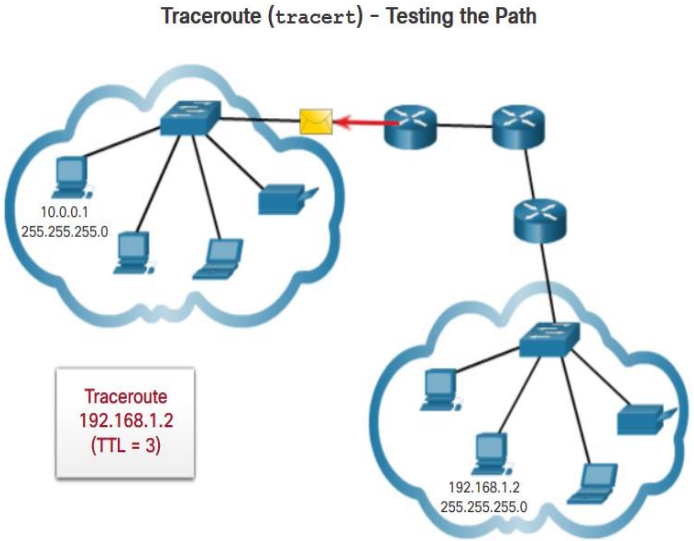
# Ping – Testing Connectivity to Remote Host

- Ping can also be used to test the ability of a local host to communicate across an internetwork.
- Successful ping across the internetwork confirms communication on the local network.
- It also confirms the operation of the router serving as the gateway, and the operation of all other routers that might be in the path between the local network and the network of the remote host.



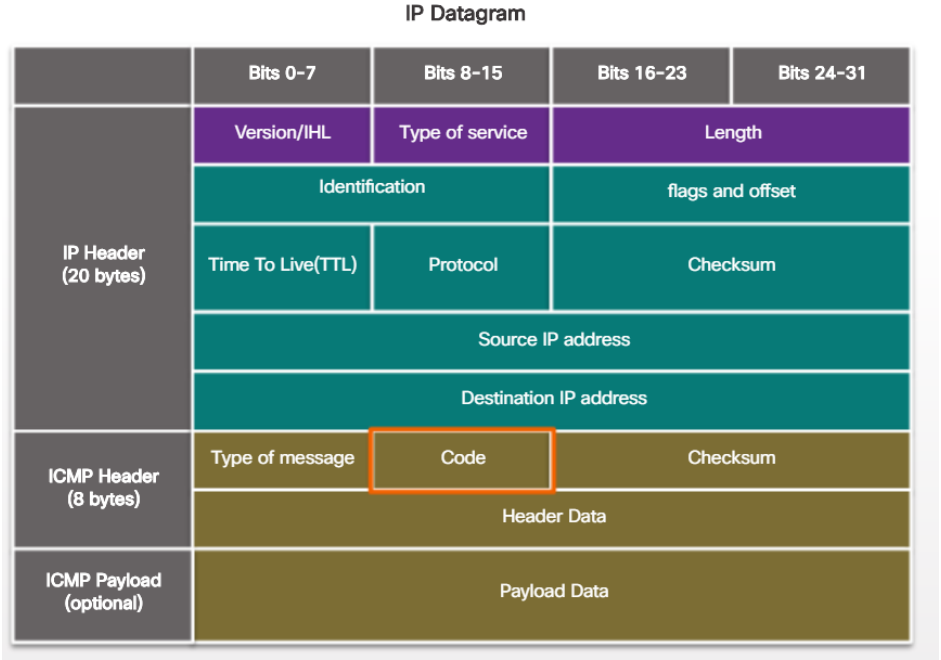
# Traceroute- Testing the Path

- Traceroute provides information about the details of devices between the hosts.
- Generates a list of hops that were successfully reached along the path:
  - **Round trip Time (RTT)** – time for each hop along path.
  - **IPv4 TTL and IPv6 Hop Limit** - Traceroute makes use of a function of the TTL field in IPv4 and the Hop Limit field in IPv6 in the Layer 3 headers, along with the ICMP time exceeded message.
- After the final destination is reached, the host responds with either an ICMP port unreachable message or an ICMP echo reply message instead of the ICMP time exceeded message.



# ICMP Packet Format

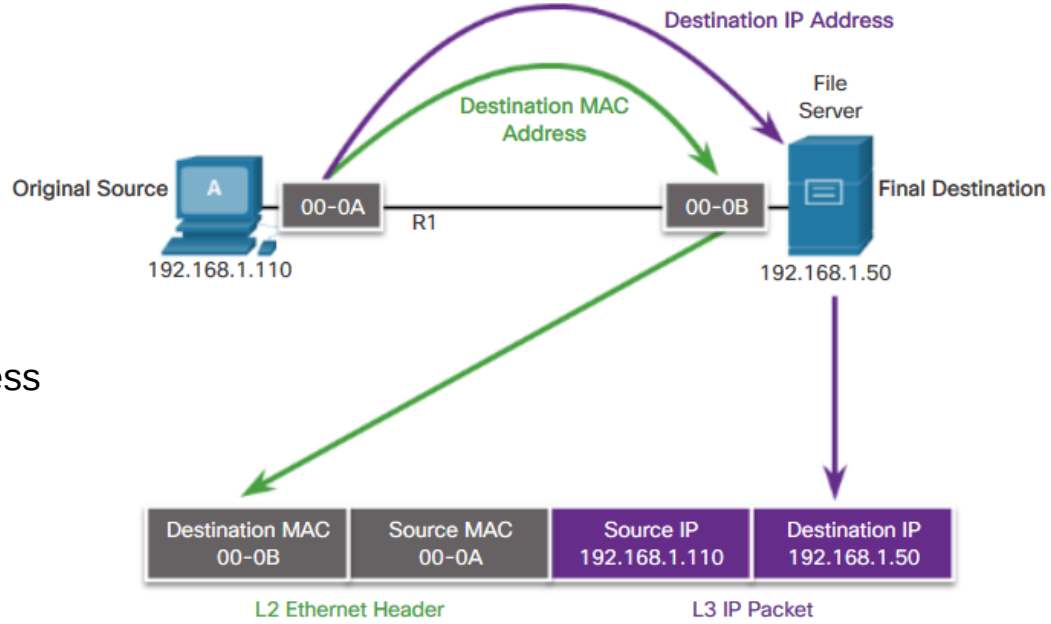
- ICPM is considered to be a Layer 3 protocol.
- ICMP acts as a data payload within the IP packet.
- It has a special header data field.
- These are some common message codes:
  - **0** – Echo reply (response to a ping)
  - **3** – Destination Unreachable
  - **5** – Redirect (use another route to your destination)
  - **8** – Echo request (for ping)
  - **11** – Time Exceeded (TTL became 0)



# 4.4 Address Resolution Protocol

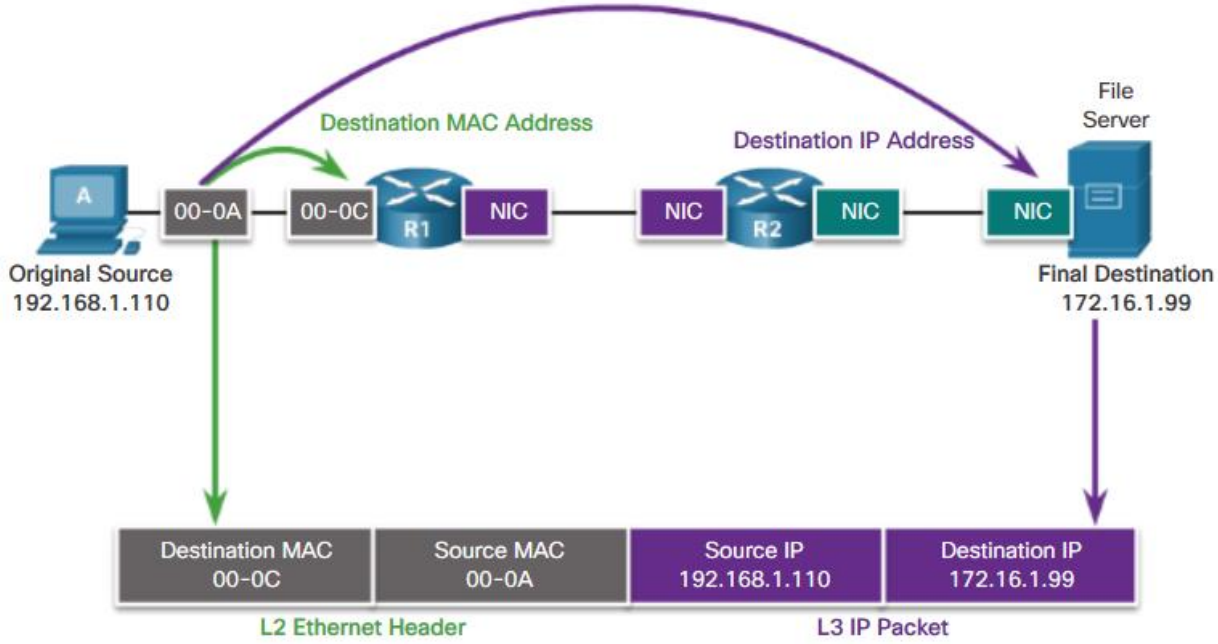
# Destination on Same Network

- Two addresses assigned to an Ethernet device:
  - **MAC address** (Layer 2 physical address)
  - **IP address** (Layer 3 logical address)
- A device must have both addresses to communicate with another TCP/IP-based device:
  - Uses the source and destination MAC address
  - Uses the source and destination IP address



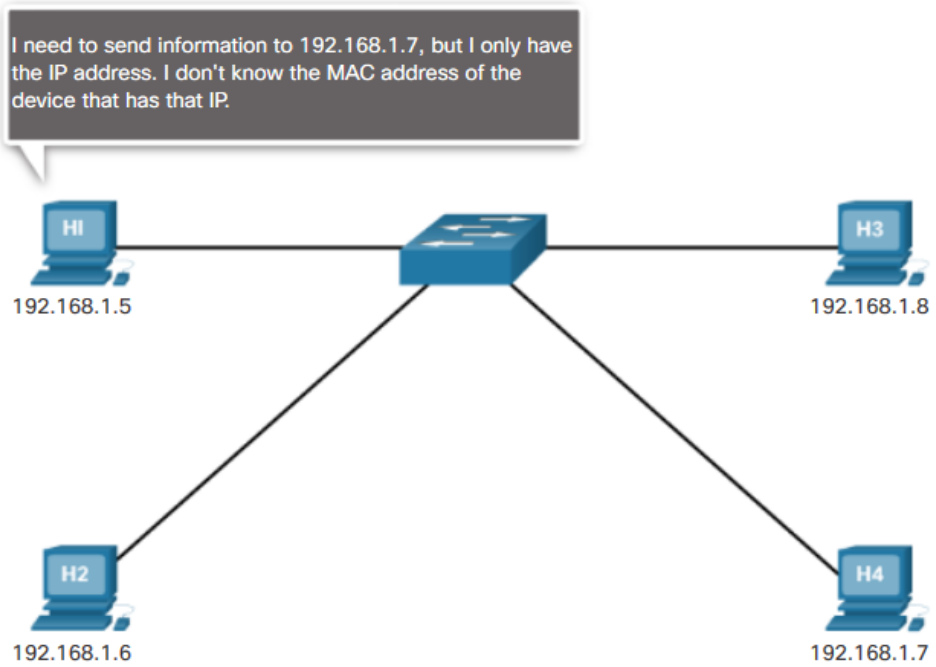
# Destination on Remote Network

- When communicating with a device on a remote network, the destination MAC address is the MAC address of the Layer 3 device interface on the same network as the device originating the packet.



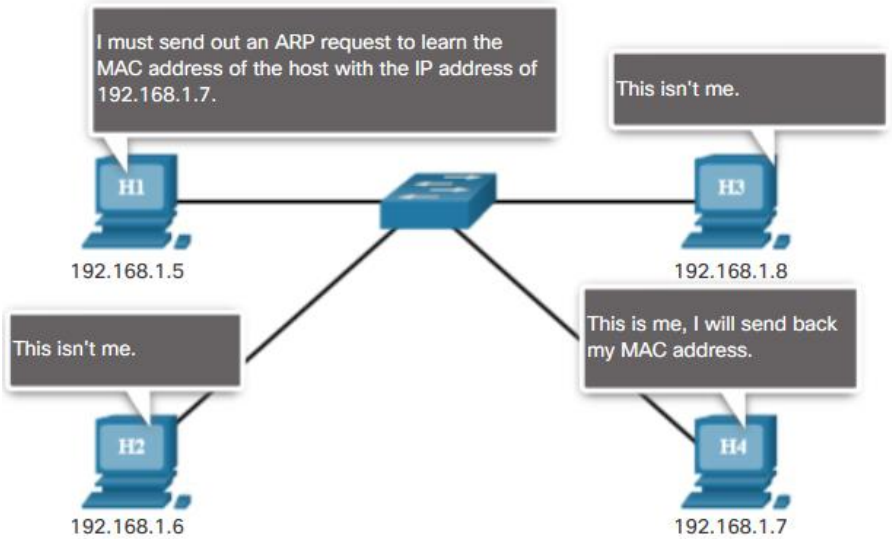
# Introduction to ARP

- When a device sends an Ethernet frame, it contains these two addresses:
  - **Destination MAC address** - The MAC address of the Ethernet NIC, which will be either the MAC address of the final destination device or the router.
  - **Source MAC address** - The MAC address of the sender's Ethernet NIC.
- To determine the destination MAC address, the device uses ARP. ARP resolves IPv4 addresses to MAC addresses, and maintains a table of mappings.



# ARP Functions

- Used to resolve IPv4 addresses to MAC addresses.
- IPv4 and MAC address mappings kept in an ARP table.



# Video - ARP Operation - ARP Request

- An ARP request is sent when a device needs a MAC address associated with an IPv4 address, and it does not have an entry for the IPv4 address in its ARP table.
- ARP messages are encapsulated directly within an Ethernet frame:
  - No IPv4 header
  - Target IPv4 address
  - Target MAC address
- ARP Header includes:
  - Destination MAC address
  - Source MAC address
  - Type

# Video - ARP Operation - ARP Reply

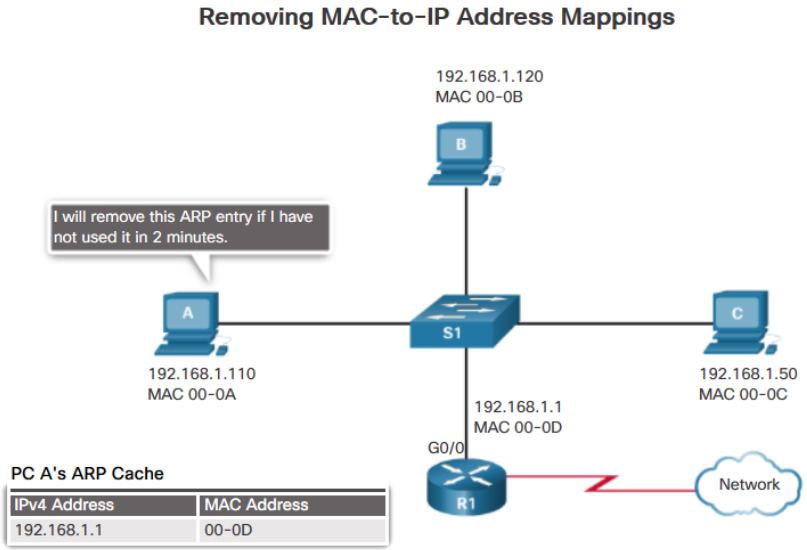
- Only the device with an IPv4 address associated with the target IPv4 address in the ARP request will respond with an ARP reply.
- ARP messages include:
  - Sender's IPv4 address
  - Senders' MAC address
- The ARP reply is encapsulated in an Ethernet frame using the following header information:
  - Destination MAC address
  - Source MAC address
  - Type

# Video - ARP Role in Remote Communication

- When the destination IPv4 address is not on the same network as the source IPv4 address, the source device needs to send the frame to its default gateway.
- Whenever a source device has a packet with an IPv4 address on another network, it will encapsulate that packet in a frame using the destination MAC address of the router.

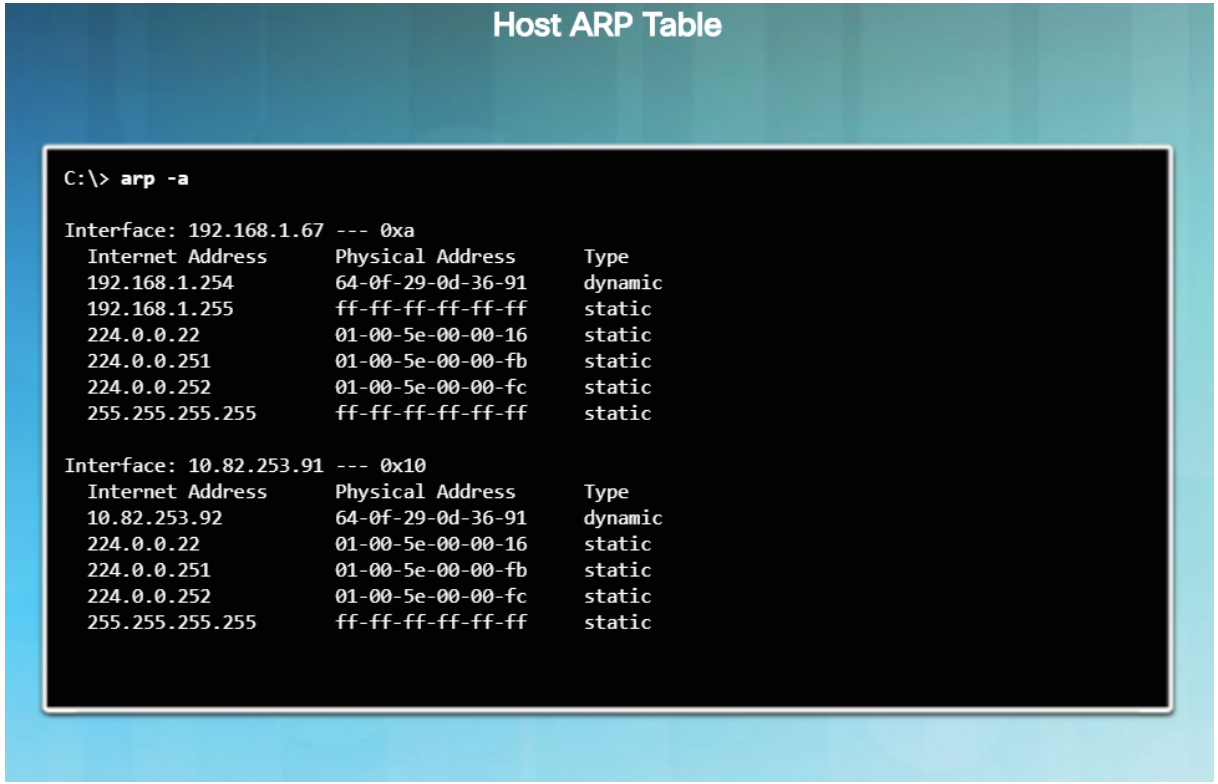
# Removing Entries from an ARP Table

- For each device, an ARP cache timer removes ARP entries that have not been used for a specified period of time.
- Commands may also be used to manually remove all or some of the entries in the ARP table.
- Network hosts and routers keep ARP tables.



# ARP Tables on Networking Devices

- Network hosts and routers keep ARP tables.
- Held in memory called ARP cache.
- Age out and removed from table.



# Lab - Using Wireshark to Examine Ethernet Frames

Networking Academy

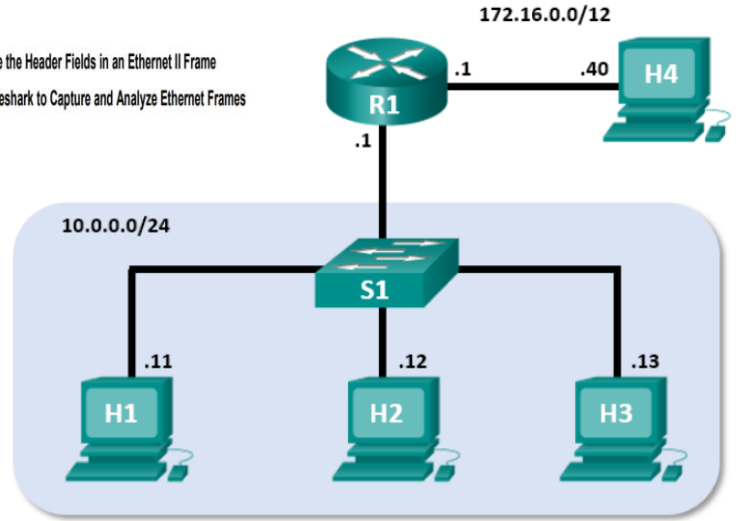
**Lab – Using Wireshark to Examine Ethernet Frames**

**Mininet Topology**

Objectives

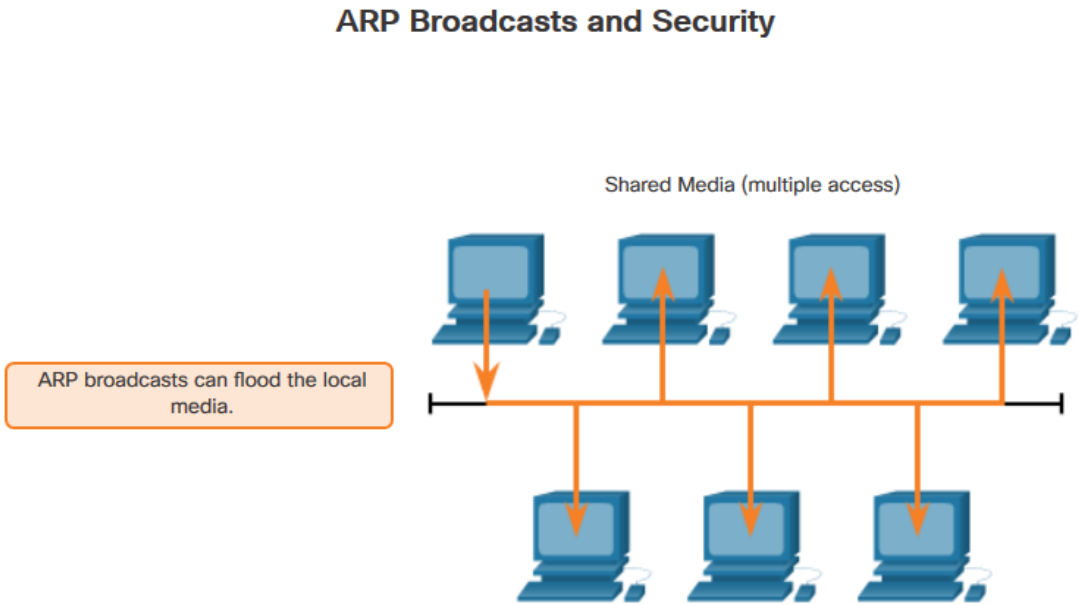
Part 1: Examine the Header Fields in an Ethernet II Frame

Part 2: Use Wireshark to Capture and Analyze Ethernet Frames



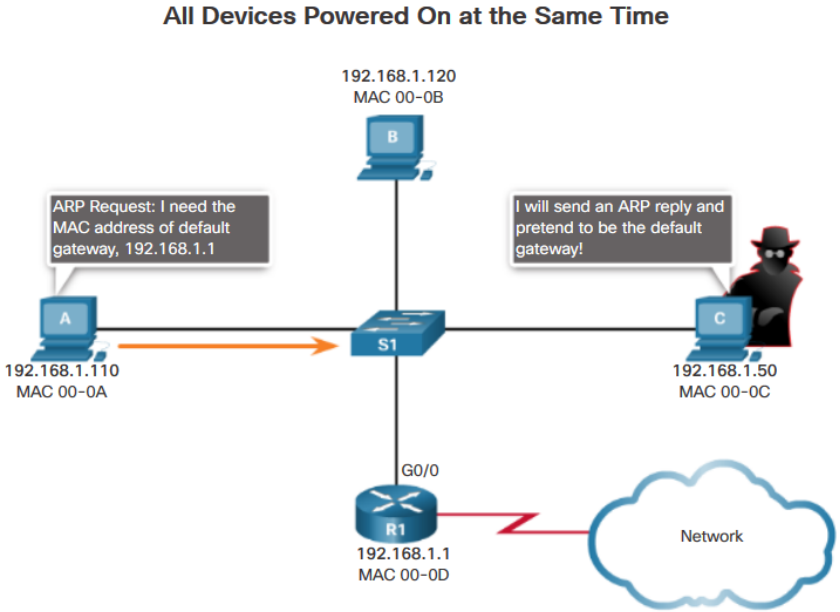
# ARP Broadcasts

- ARP Broadcasts – could impact large networks.



# ARP Spoofing

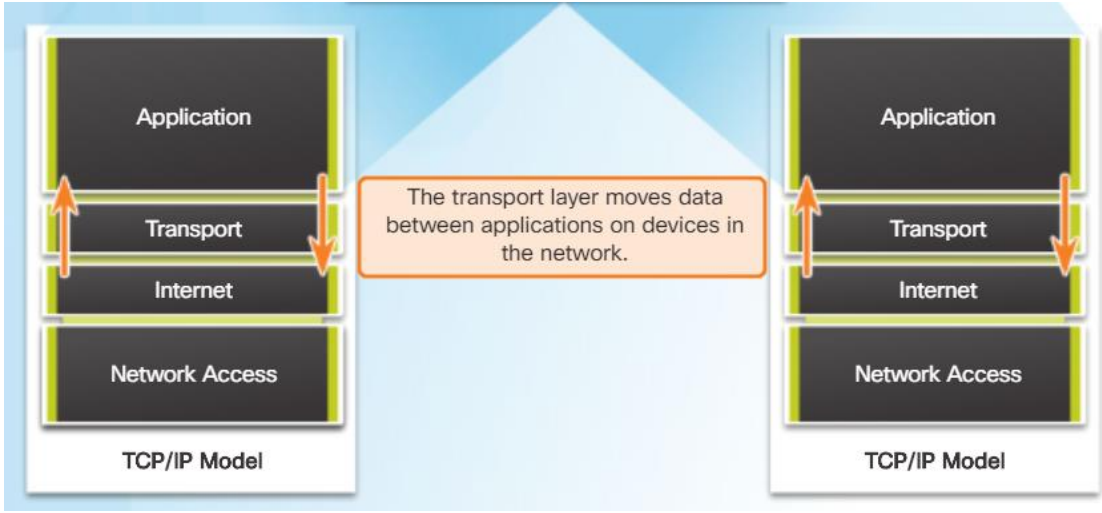
- ARP Spoofing (ARP poisoning) – security risk
  - This is a technique used by an attacker to reply to an ARP request for an IPv4 address belonging to another device, such as the default gateway.

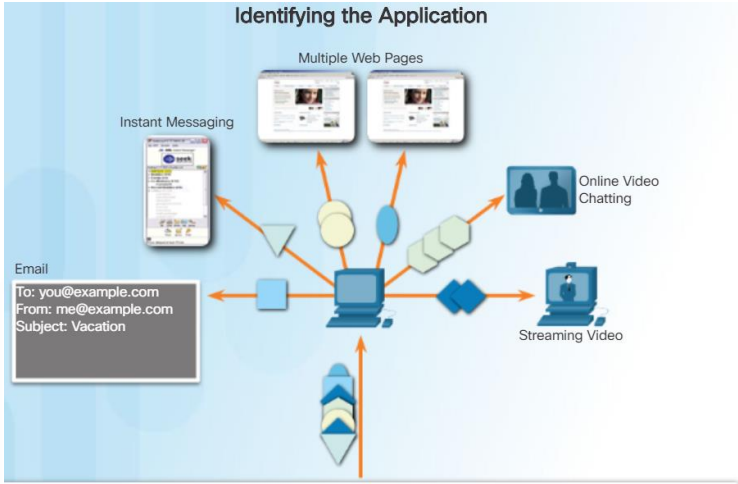


# 4.5 The Transport Layer

# Transport Layer Protocol Role in Network Communication

- Tracks individual conversations.
- Moves data between applications on network devices.
- Segments data and reassembles segments.
- Identifies applications using a port number.

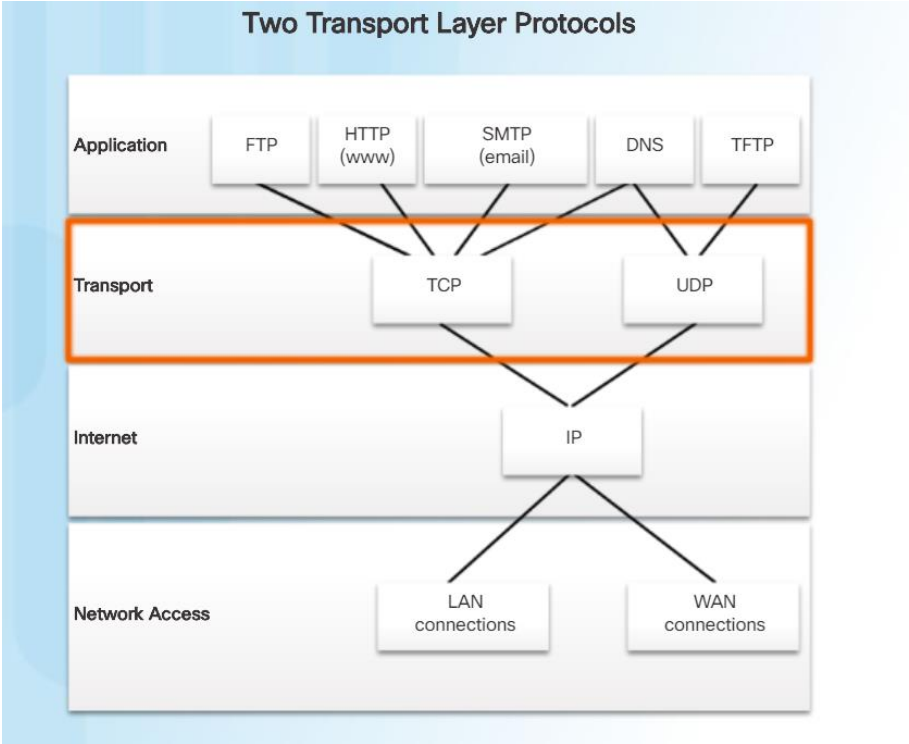



The transport layer ensures that even with multiple applications running on a device, all applications receive the correct data.

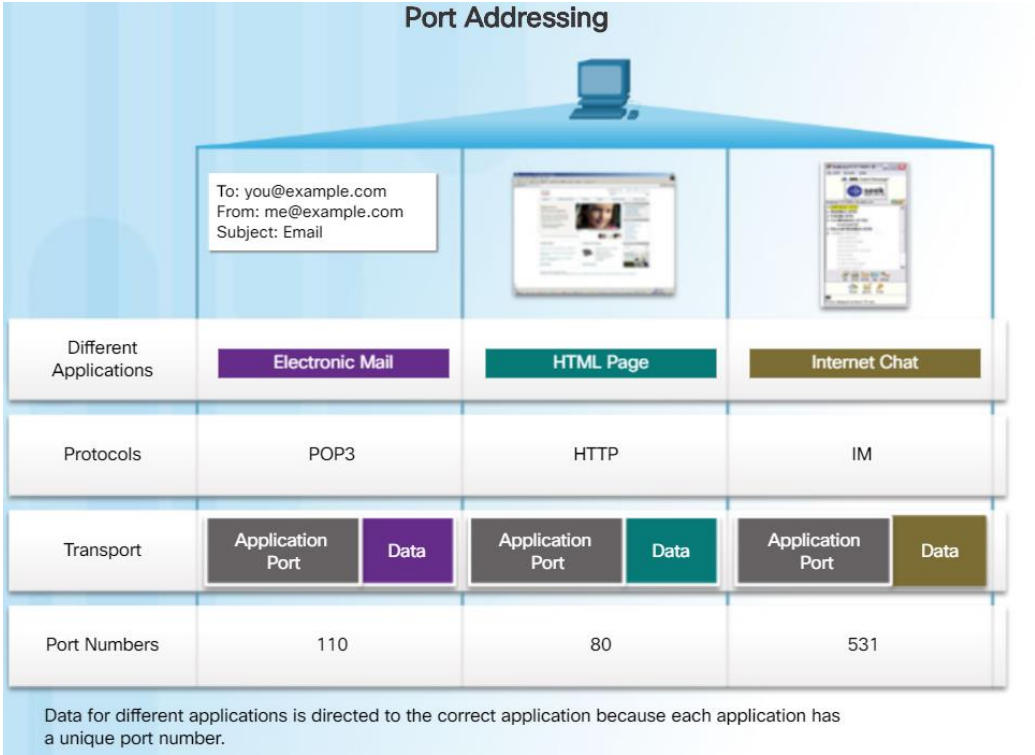
# Transport Layer Mechanisms

- Segmenting the data into smaller chunks enables many different communications, from many different users, to be interleaved (multiplexed) on the same network.
- The transport layer is also responsible for managing reliability requirements of a conversation.
- TCP/IP provides two transport layer protocols:
  - **Transmission Control Protocol (TCP)**
  - **User Datagram Protocol (UDP)**



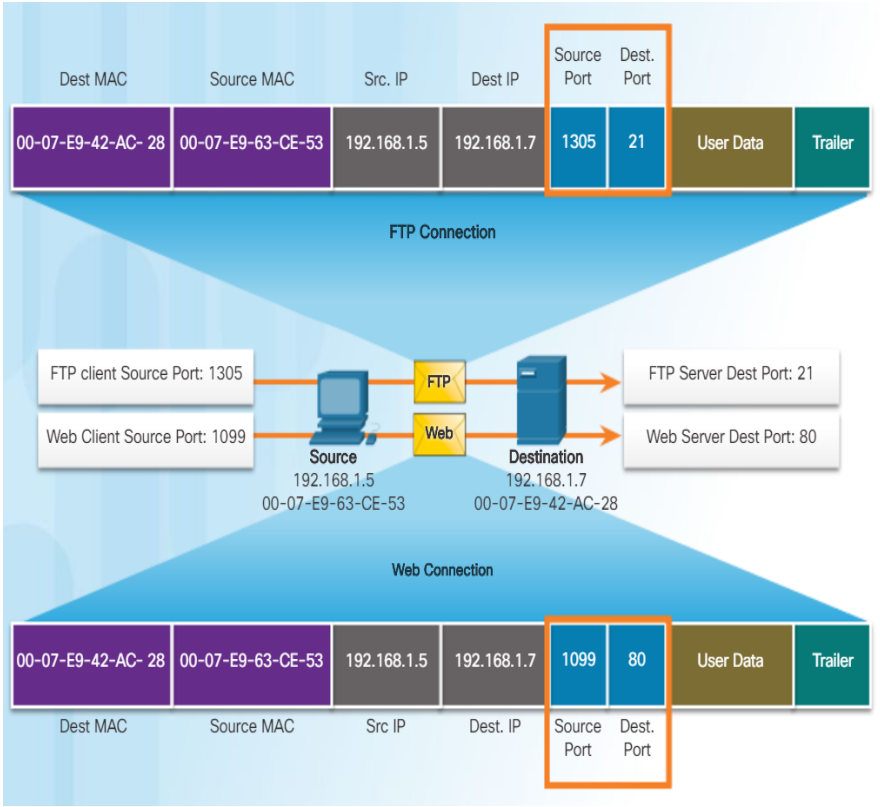
# TCP Local and Remote Ports

- TCP and UDP manage these multiple simultaneous conversations by using header fields that can uniquely identify these applications. These unique identifiers are the port numbers:
  - The **source port number** is associated with the originating application on the local host.
  - The **destination port number** is associated with the destination application on the remote host.



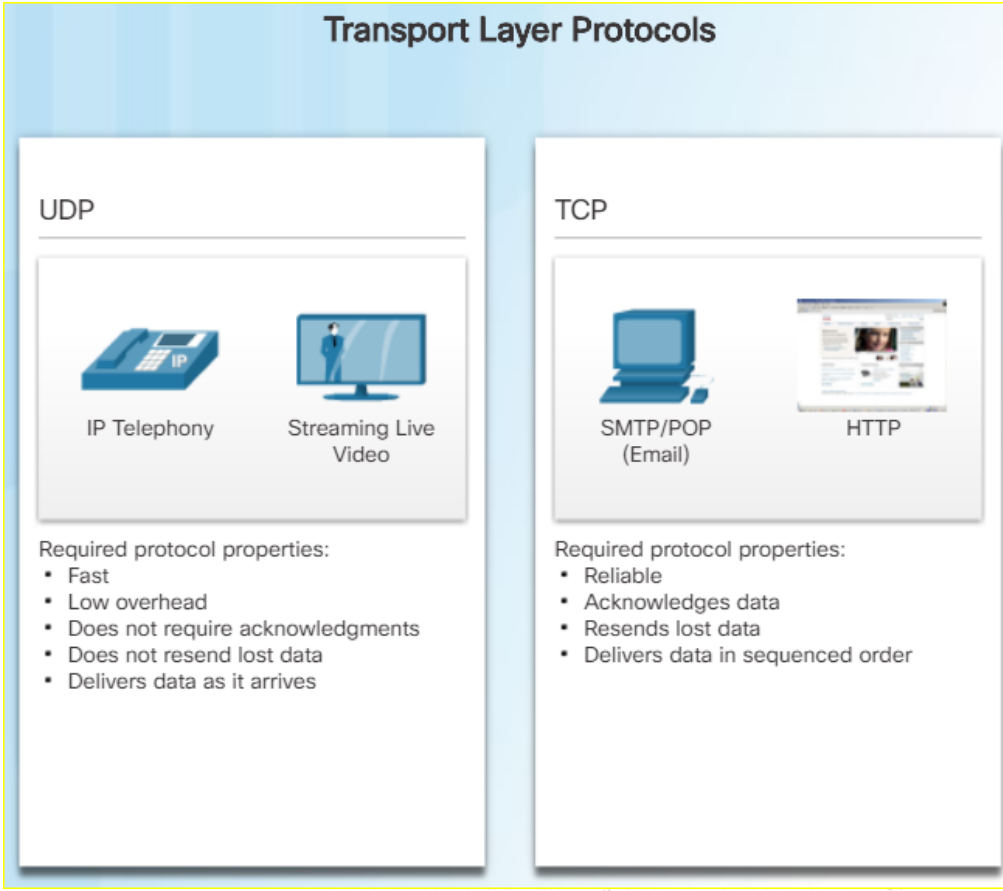
# Socket Pairs

- The combination of the source IP address and source port number, or the destination IP address and destination port number is known as a **socket**.
- The socket is used to identify the server and service being requested by the client.
- Sockets enable multiple processes, running on a client, to distinguish themselves from each other, and multiple connections to a server process to be distinguished from each other.



# TCP versus UDP

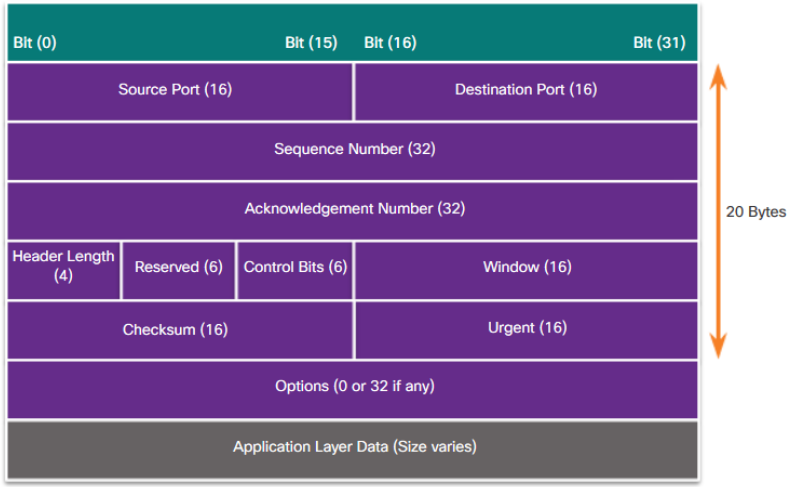
- TCP
  - Used for majority of the major TCP/IP protocols.
  - Reliable, acknowledges data, resends lost data, delivers data in sequenced order.
    - Examples: email, HTTP
- UDP
  - Fast, low overhead, does not require acknowledgments, does not resend lost data, delivers data as it arrives.
    - Examples: VoIP, streaming live videos



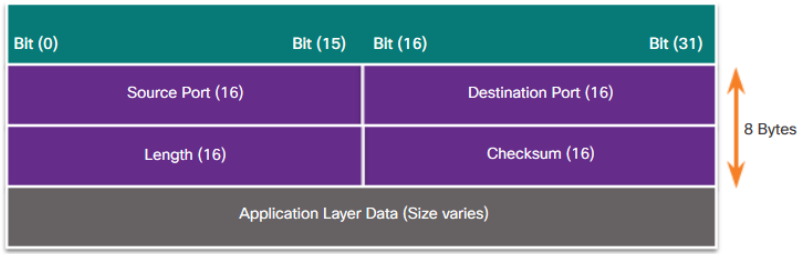
# TCP and UDP Headers

- TCP
  - TCP is a stateful protocol. A stateful protocol is a protocol that keeps track of the state of the communication session.
  - To track the state of a session, TCP records which information it has sent and which information has been acknowledged.
  - The stateful session begins with the session establishment and ends when closed with the session termination.
- UDP
  - UDP is a stateless protocol, meaning neither the client, nor the server, is obligated to keep track of the state of the communication session.
  - If reliability is required when using UDP as the transport protocol, it must be handled by the application.

TCP Segment

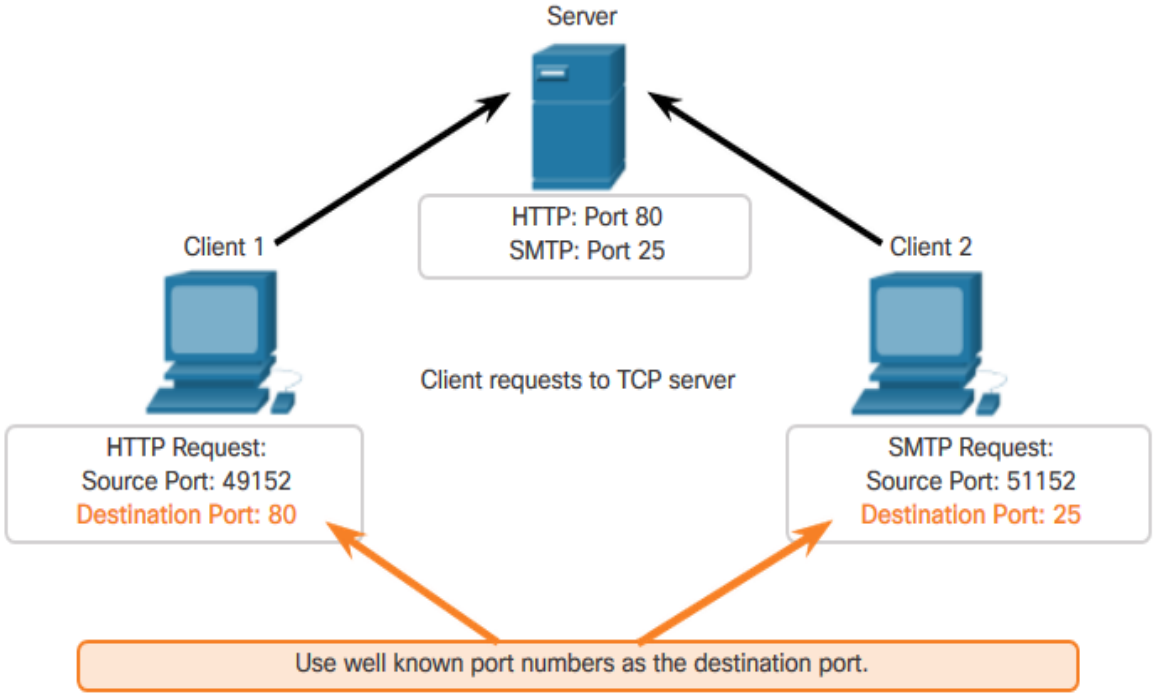



UDP Datagram



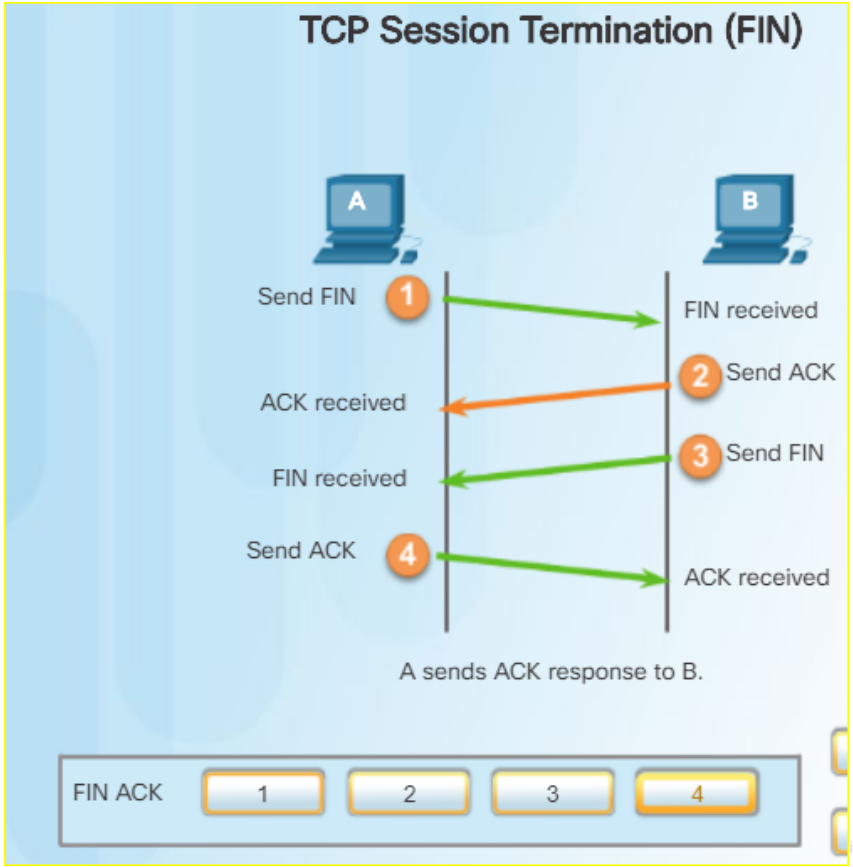
# TCP Port Allocation

- Destination port numbers:
  - Uses well-known port numbers.
- Source port numbers:
  - Uses dynamic port numbers.
  - When establishing a connection with a server, the transport layer on the client establishes a source port to keep track of data sent from the server.
  - Just as a server can have many ports open for server processes, clients can have many ports open for connections to multiple sockets.



# A TCP Session Part 1: Connection Establishment and Termination

- A TCP connection is established in three steps:
  1. The initiating client requests a client-to-server communication session with the server.
  2. The server acknowledges the client-to-server communication session and requests a server-to-client communication session.
  3. The initiating client acknowledges the server-to-client communication session.



# Video Demonstration – TCP 3-Way Handshake

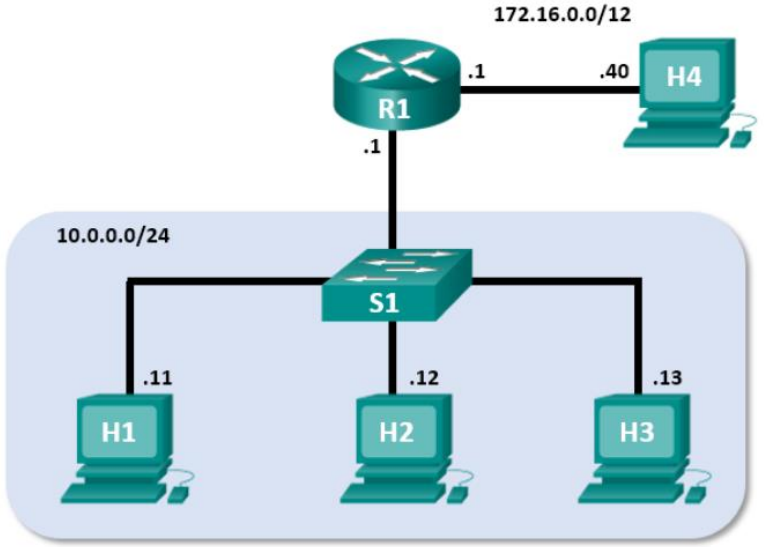
- TCP is a connection-oriented protocol, meaning an end-to-end connection needs to be established first before data can be sent or received.
- A TCP 3-Way Handshake involves three steps, a [SYN], a [SYN, ACK], and an [ACK].

# Lab - Using Wireshark to Observe the TCP 3-Way Handshake

Networking Academy

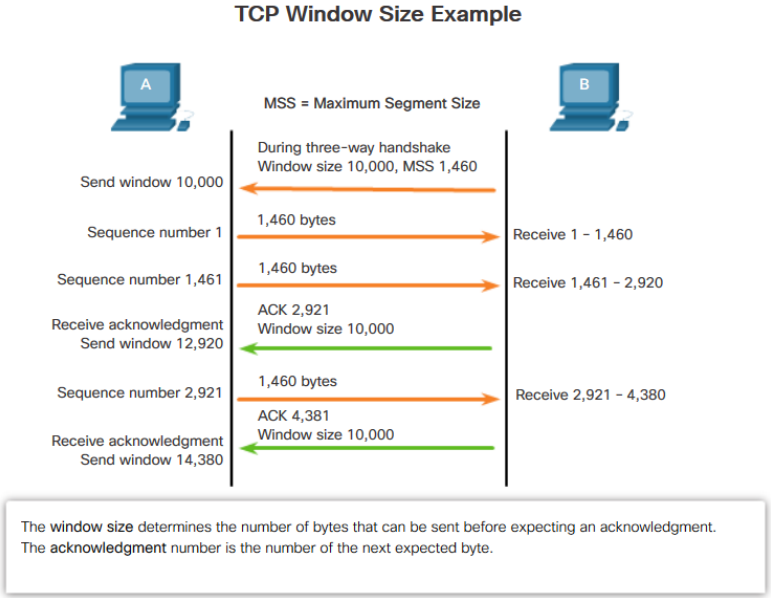
**Lab - Using Wireshark to Observe the TCP 3-Way Handshake**

**Mininet Topology**



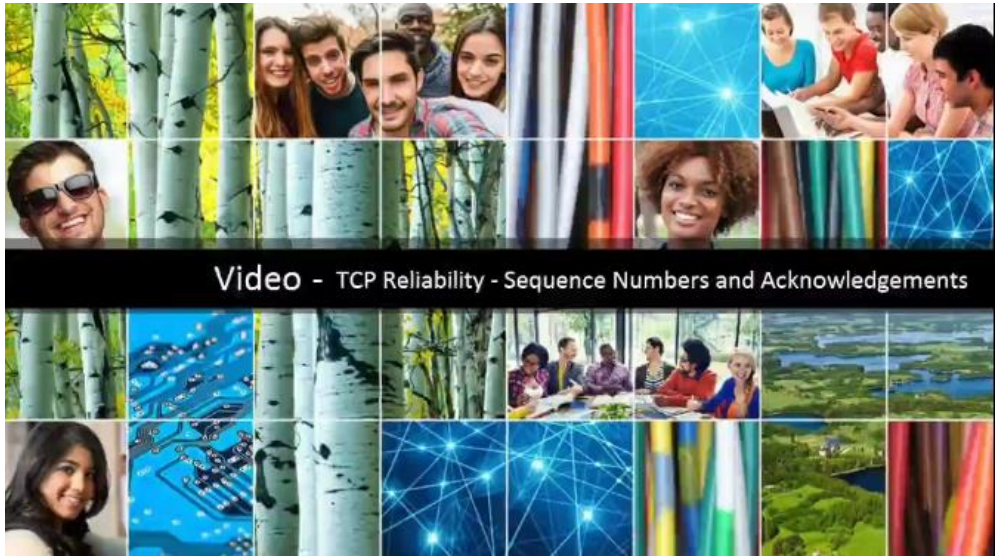
# A TCP Session Part 2: Data Transfer

- **TCP Order Delivery:**
  - Segment sequence numbers indicate how to reassemble and reorder received segments.
  - The receiving TCP process places the data into a receiving buffer.
  - Out of order segments are held for later processing.
  - When the segments with the missing bytes arrive, these segments are processed in order.
- **Flow Control:**
  - Controls the amount of data that the destination can receive and process reliably by adjusting the rate of data flow.



# Video Demonstration – Sequence Numbers and Acknowledgments

- Two things that make TCP reliable are sequence numbers and acknowledgments.
- Every TCP segment that is sent in a TCP conversation gets a sequence number.
- Every byte of data is numbered basically in a sequential list.

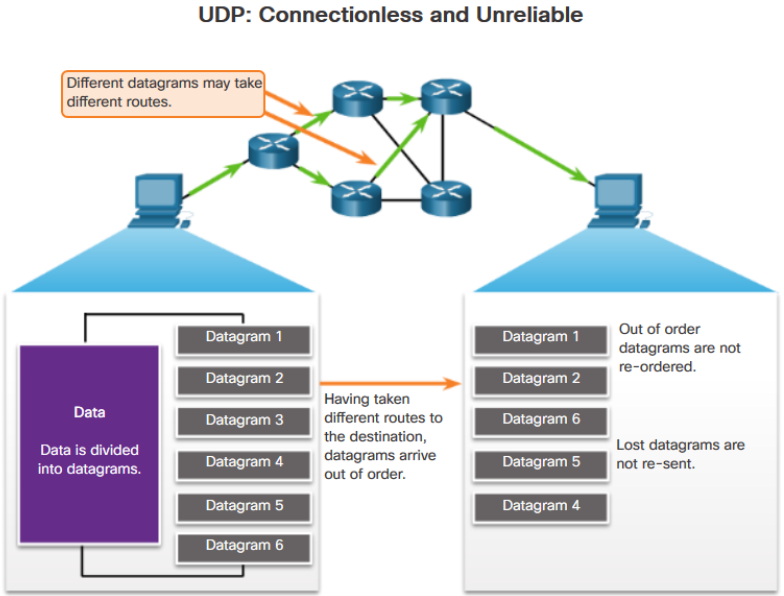


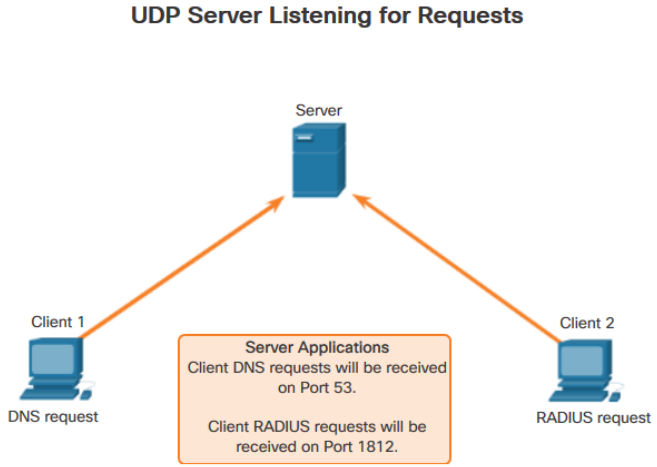
# Video Demonstration – Data Loss and Retransmission

- TCP provides a mechanism to retransmit segments for unacknowledged data.

# UDP Session

- UDP Session:
  - Resembles the data in the order it was received.
  - Assigned well-known or registered port numbers.



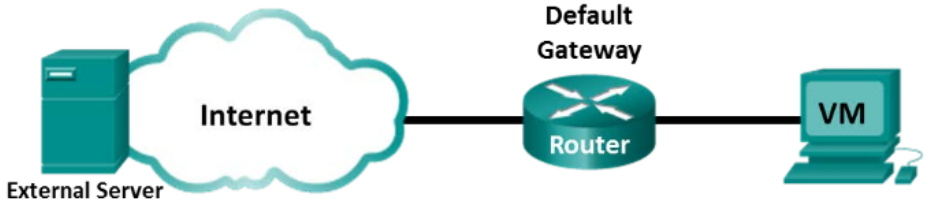

Client requests to servers have well-known port numbers as the destination port.

# Lab – Exploring Nmap

Networking Academy

## Lab - Exploring Nmap

### Topology




### Objectives

**Part 1: Exploring Nmap**

**Part 2: Scanning for Open Ports**

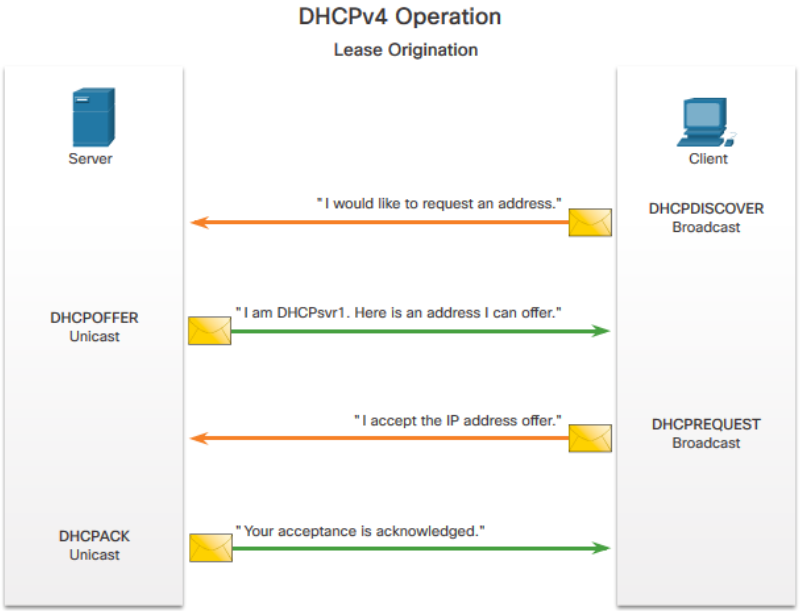
### Background / Scenario

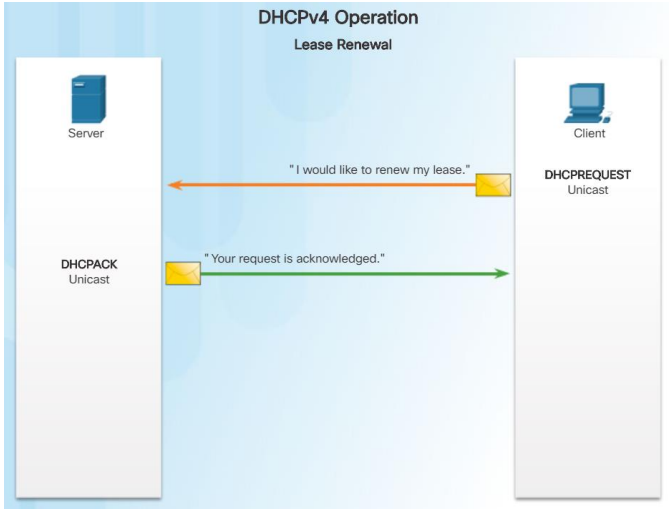
Port scanning is usually part of a reconnaissance attack. There are a variety of port scanning methods that can be used. We will explore how to use the Nmap utility. Nmap is a powerful network utility that is used for network discovery and security auditing.

# 4.6 Network Services

# DHCP Overview

- Dynamic Host Configuration Protocol (DHCP)
  - Provides IP addressing information such as IP address, subnet mask, default gateway, DNS server IP address and domain name.
  - Messages
    - Discover
    - Offer
    - Request
    - Ack(nowledge)

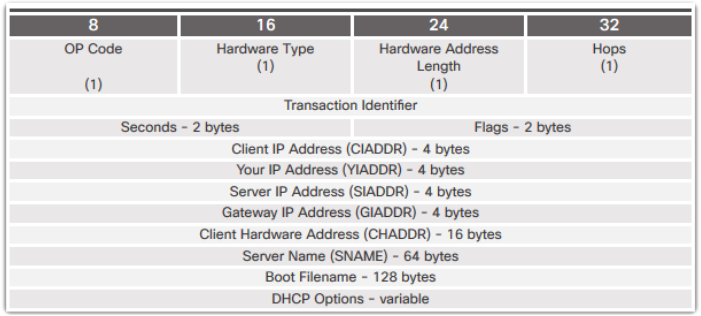


# DHCPv4 Message Format

A DHCP message contains the following fields:

- **Operation (OP) Code** - Specifies the general type of message.
- **Hardware Type** - Identifies the type of hardware used in the network.
- **Hardware Address Length** - Specifies the length of the address.
- **Hops** - Controls the forwarding of messages.
- **Transaction Identifier** - Used by the client to match the request with replies received from DHCPv4 servers.
- **Seconds** - Identifies the number of seconds elapsed since a client began attempting to acquire or renew a lease.
- **Flags** - Used by a client that does not know its IPv4 address when it sends a request.



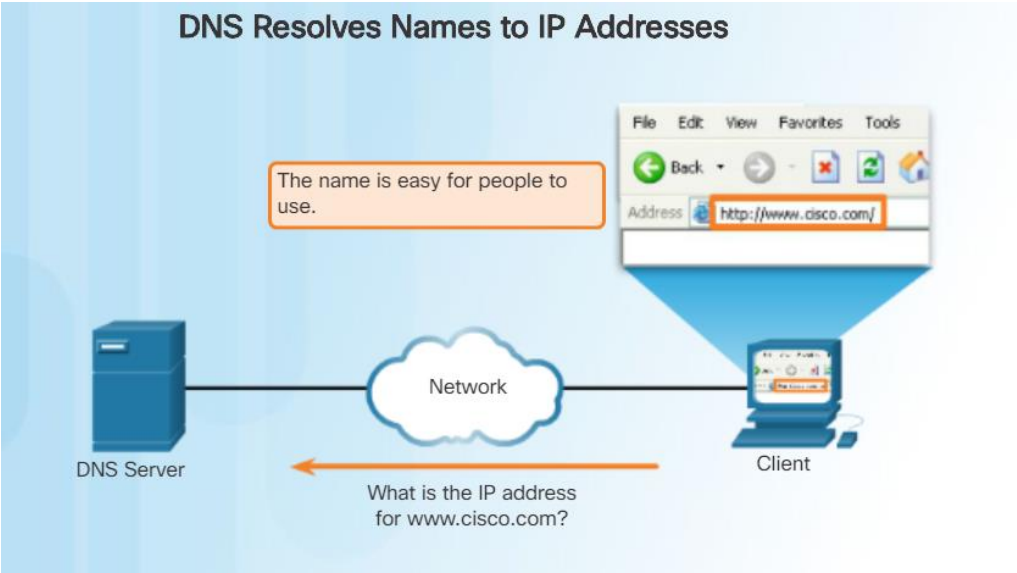
# DHCPv4 Message Format (Cont.)

A DHCP message contains the following fields:

- **Client IP Address** - Used by a client during lease renewal when the address of the client is valid and usable, not during the process of acquiring an address.
- **Your IP Address** - Used by the server to assign an IPv4 address to the client.
- **Server IP Address** - Used by the server to identify the address of the server that the client should use for the next step in the bootstrap process.
- **Gateway IP Address** - Routes DHCPv4 messages when DHCPv4 relay agents are involved.
- **Client Hardware Address** - Specifies the physical layer of the client.
- **Server Name** - Used by the server sending a DHCPOFFER or DHCPACK message.
- **Boot Filename** - Optionally used by a client to request a particular type of boot file in a DHCPDISCOVER message.
- **DHCP Options** - Holds DHCP options, including several parameters required for basic DHCP operation.

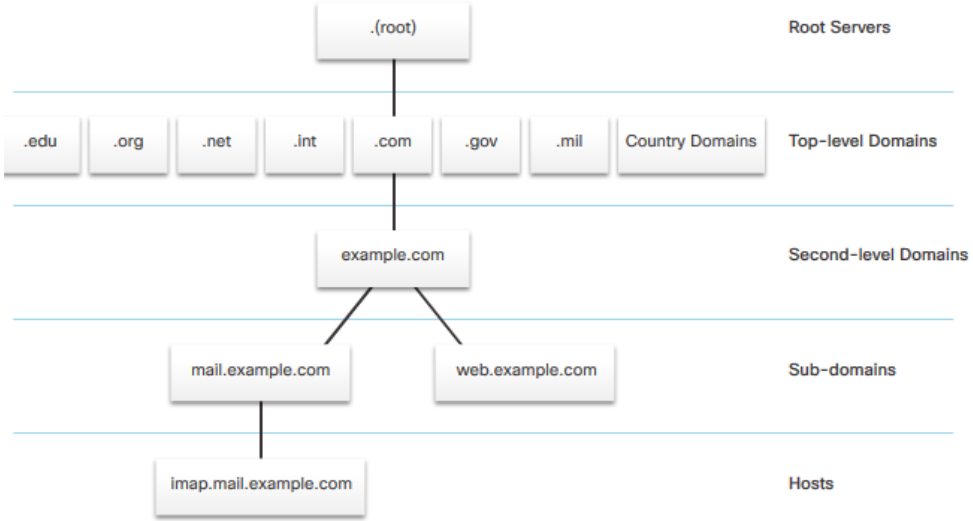
# DNS Overview

- Dynamic Name System (DNS)
  - Manages and provides domain names and associated IP addresses.
  - Hierarchy of servers.
  - 90% of malicious software used to attack networks uses DNS to carry out attack campaigns.



# DNS Domain Hierarchy

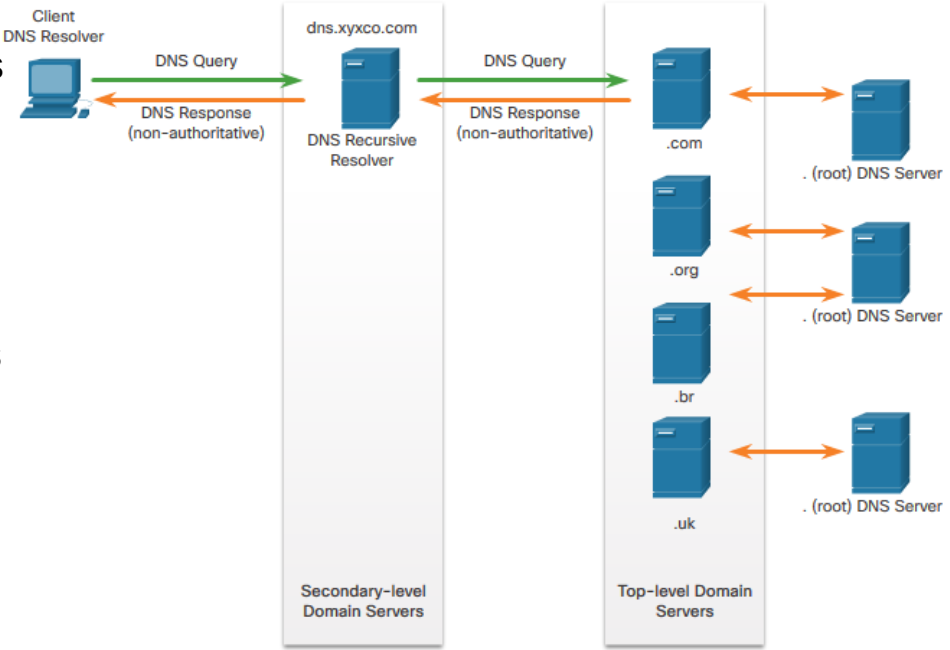
- Dynamic Name System (DNS)
  - The DNS consists of a hierarchy of generic top level domains (gTLD) which consist of .com, .net, .org, .gov, .edu, and numerous country-level domains, such as .br (Brazil), .es (Spain),.uk (United Kingdom).
  - Second-level domains are represented by a domain name that 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.
  - Finally, a fourth level can represent a host in a subdomain.



# DNS Lookup Process

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.



# DNS Lookup Process (Cont.)

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

- **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.

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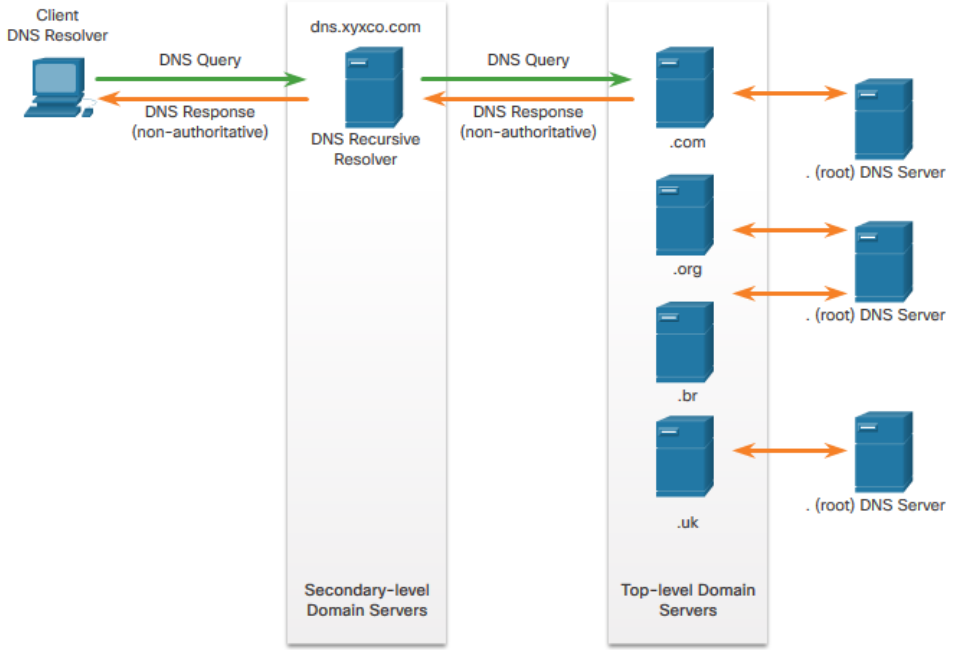
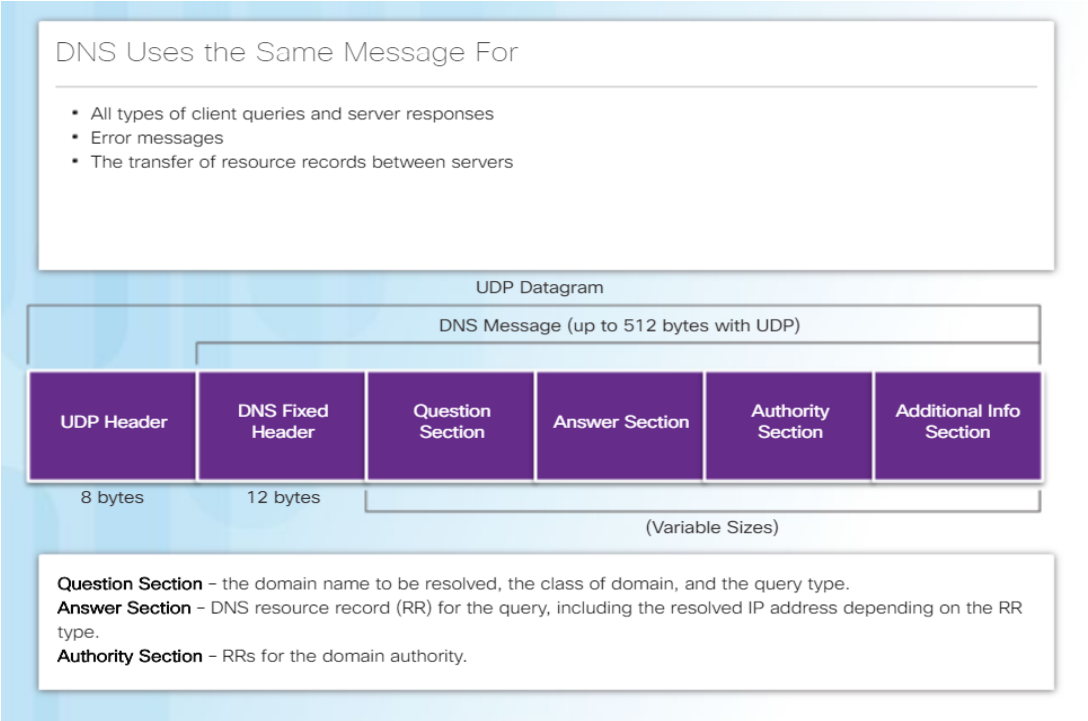


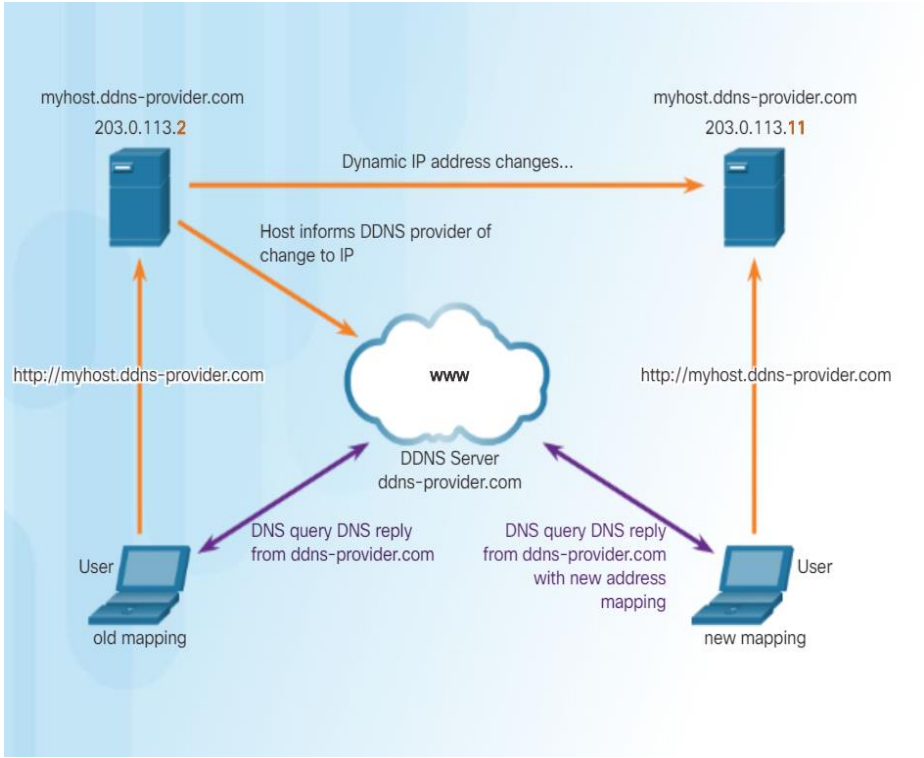

 

# DNS Message Format




- DNS uses UDP port 53 for DNS queries and responses.
- DNS queries originate at a client and responses are issued from DNS servers.
- If a DNS response exceeds 512 bytes such as when Dynamic DNS (DDNS) is used, TCP port 53 is used to handle the message.
- DNS Record Types:
  - **A** - An end device IPv4 address
  - **NS** - An authoritative name server
  - **AAAA** - An end device IPv6 address
  - **MX** - A mail exchange record

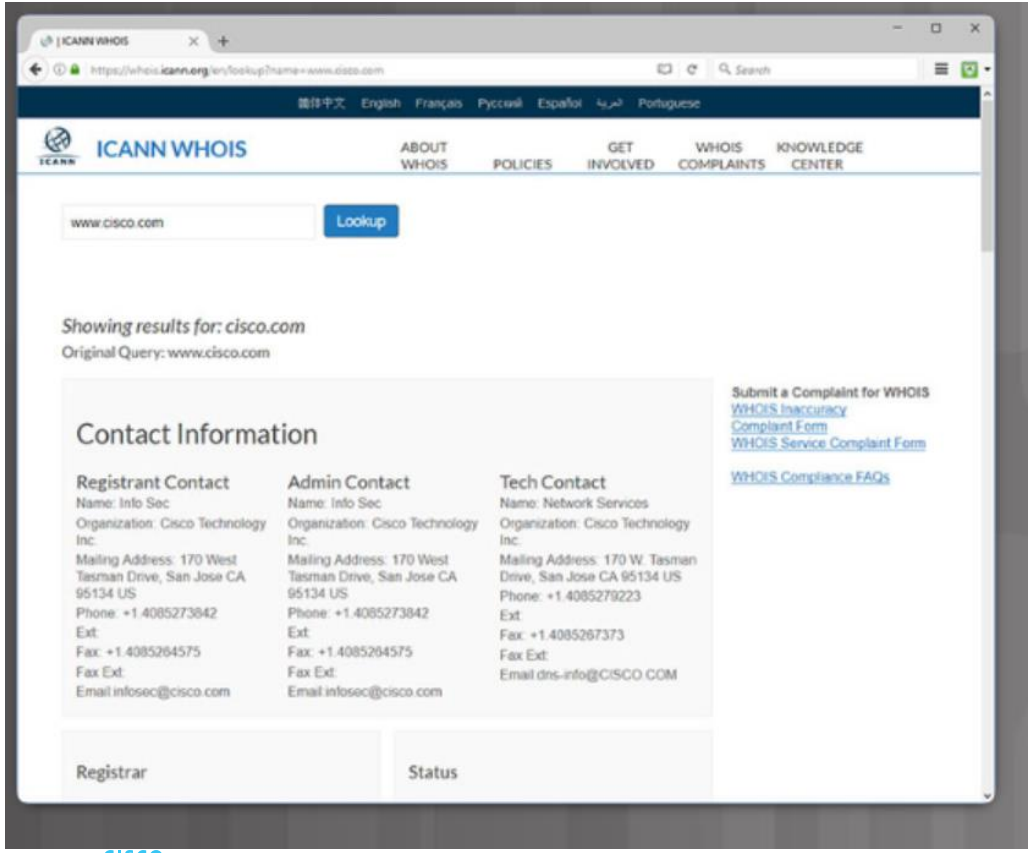
# Dynamic DNS




## Dynamic DNS (DDNS)

- Allows a user or organization to register an IP address with a domain name as in DNS.
- When the IP address of the mapping changes, the new mapping can be propagated through the DNS almost instantaneously.

# The WHOIS Protocol




WHOIS Protocol:

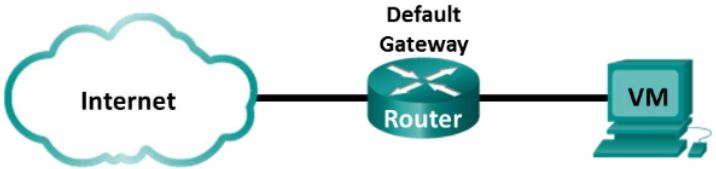
- WHOIS is a TCP-based protocol that is used to identify the owners of Internet domains through the DNS system.

# Lab – Using Wireshark to Examine a UDP DNS Capture

Networking Academy

## Lab - Using Wireshark to Examine a UDP DNS Capture

### Topology




### Objectives

**Part 1: Record a PC's IP Configuration Information**

**Part 2: Use Wireshark to Capture DNS Queries and Responses**

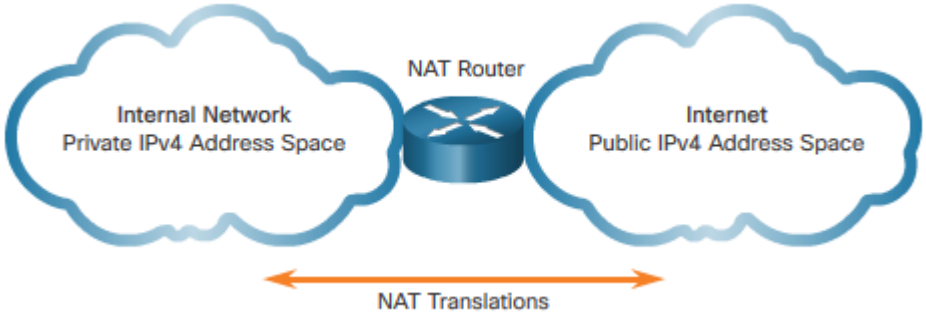
**Part 3: Analyze Captured DNS or UDP Packets**

### Background / Scenario

When you use the Internet, you use the Domain Name System (DNS). DNS is a distributed network of servers that translates user-friendly domain names like www.google.com to an IP address. When you type a website URL into your browser, your PC performs a DNS query to the DNS server's IP address. Your PC's DNS query and the DNS server's response make use of the User Datagram Protocol (UDP) as the transport layer protocol. UDP is connectionless and does not require a session setup as does TCP. DNS queries and responses are very small and do not require the overhead of TCP.

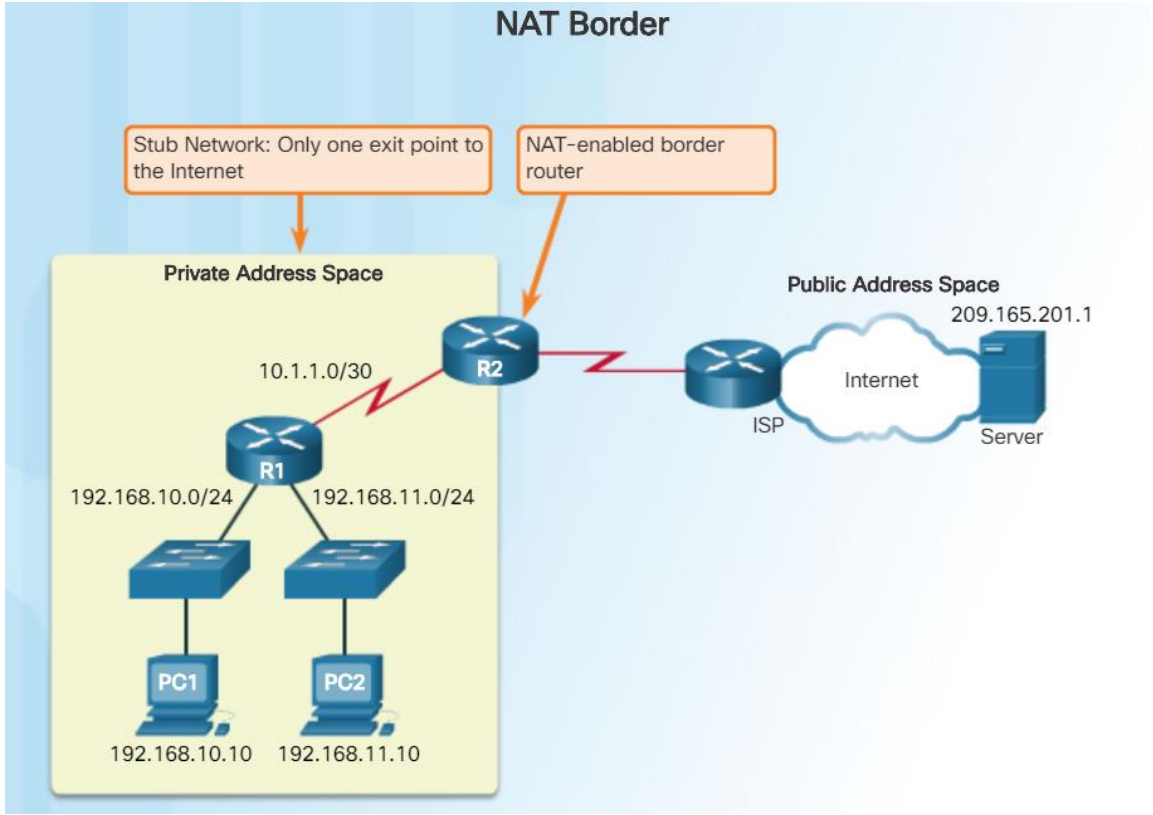
# NAT – Overview

- Network Address Translation (NAT)
  - Not enough public IPv4 addresses to assign a unique address to each device connected to the Internet.
  - Private IPv4 addresses are used within an organization or site to allow devices to communicate locally.
  - Private IPv4 addresses cannot be routed over the Internet.
  - Used on border devices.



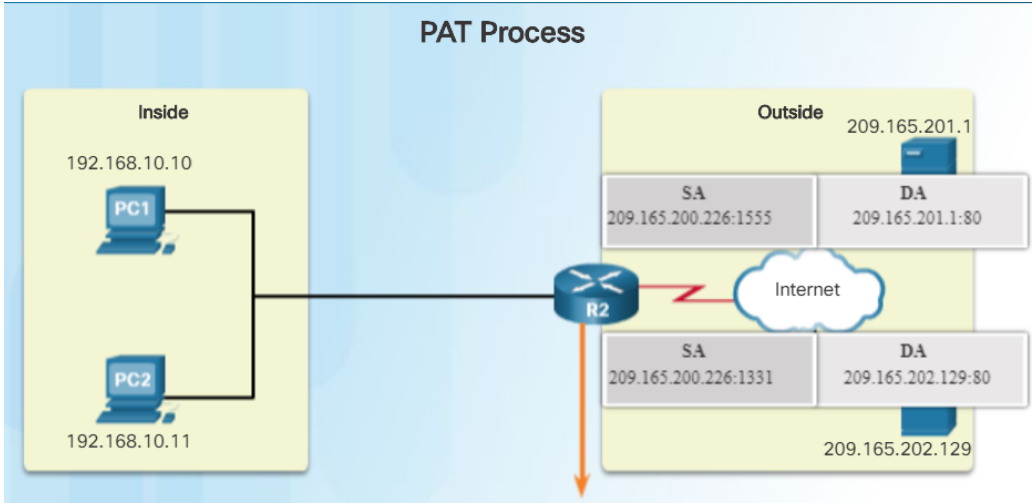
# NAT – Enabled Routers

- Network Address Translation (NAT)
  - When an internal device sends traffic out of the network, the NAT-enabled router translates the internal IPv4 address of the device to a public address from the NAT pool.
  - To outside devices, all traffic entering and exiting the network appears to have a public IPv4 address from the provided pool of addresses.
  - A NAT router typically operates at the border of a stub network.



# Port Address Translation

- Port Address Translation (PAT)
  - One-to-many – Many internal address translations to one or more public IP addresses

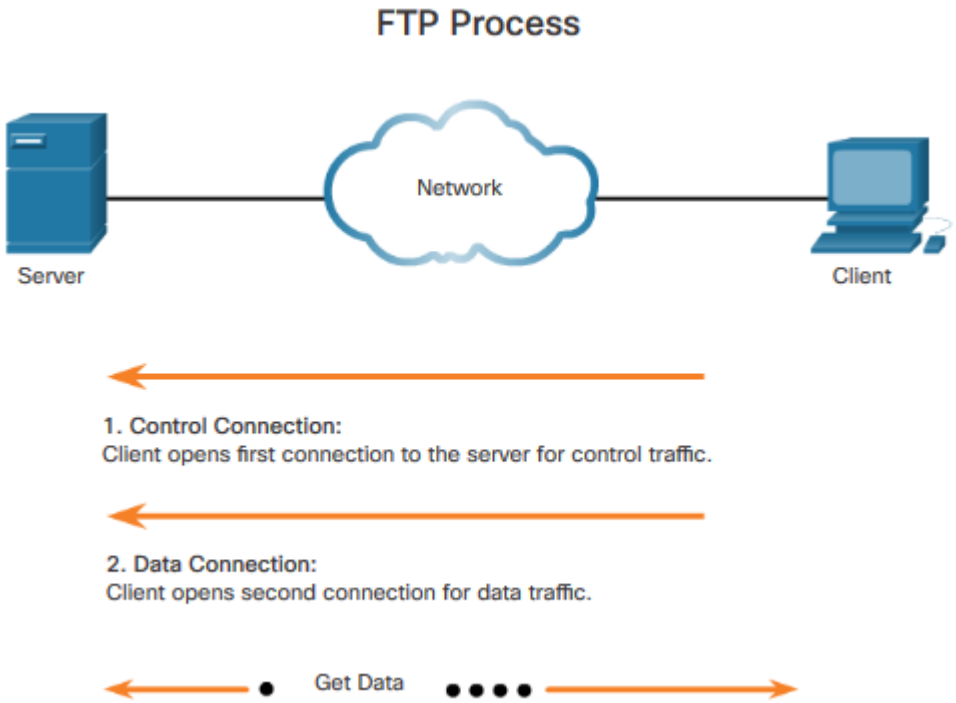



**NAT Table with Overload**

| Inside Global IP Address | Inside Local IP Address | Outside Local IP Address | Outside Global IP Address |
|---|---|---|---|
| 209.165.200.226:1555 | 192.168.10.10:1555 | 209.165.201.1:80 | 209.165.201.1:80 |
| 209.165.200.226:1331 | 192.168.10.11:1331 | 209.165.202.129:80 | 209.165.202.129:80 |

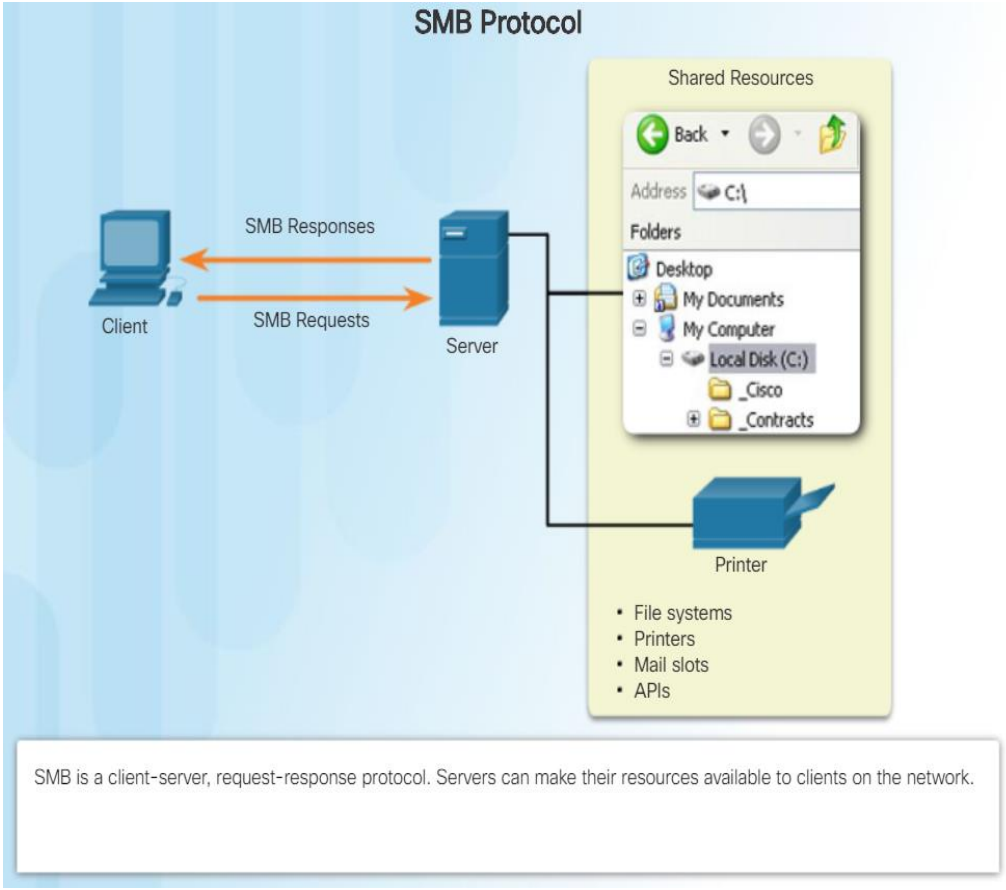
# FTP and TFTP

- File Transfer Protocol (FTP)
  - TCP-based.
  - Used to push and pull data from a server.
- Trivial File Transfer Protocol (TFTP)
  - UDP-based.
  - Fast, but unreliable.
- Server Message Block (SMB)
  - Client/server-based file sharing protocol.



# SMB

- Server Message Block (SMB)
  - Client/server-based file sharing protocol.
  - This format uses a fixed-sized header, followed by a variable-sized parameter and data component.
  - 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.

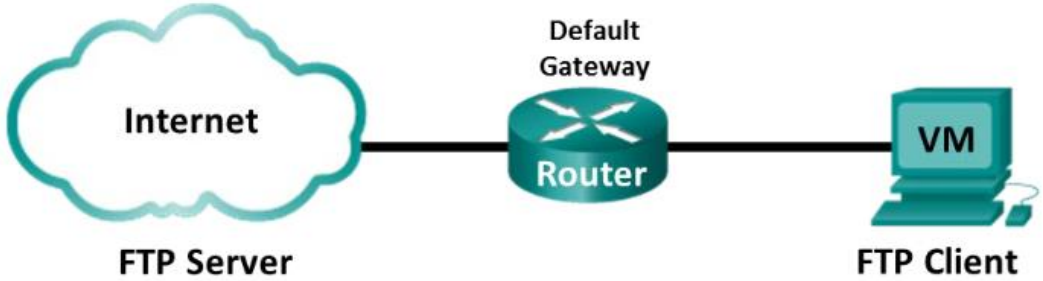


# Lab – Using Wireshark to Examine TCP and UDP Captures

Networking Academy

## Lab - Using Wireshark to Examine TCP and UDP Captures

### Topology – Part 1 (FTP)




Part 1 will highlight a TCP capture of an FTP session. This topology consists of the CyberOps Workstation VM with Internet access.

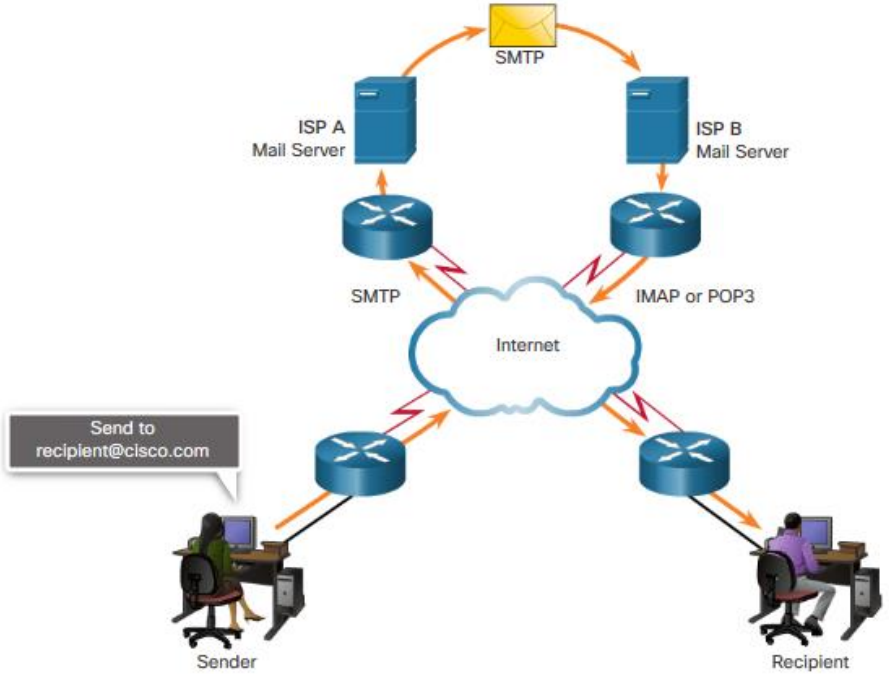
### Mininet Topology – Part 2 (TFTP)

Part 2 will highlight a UDP capture of a TFTP session using the hosts in Mininet.

# Email Overview

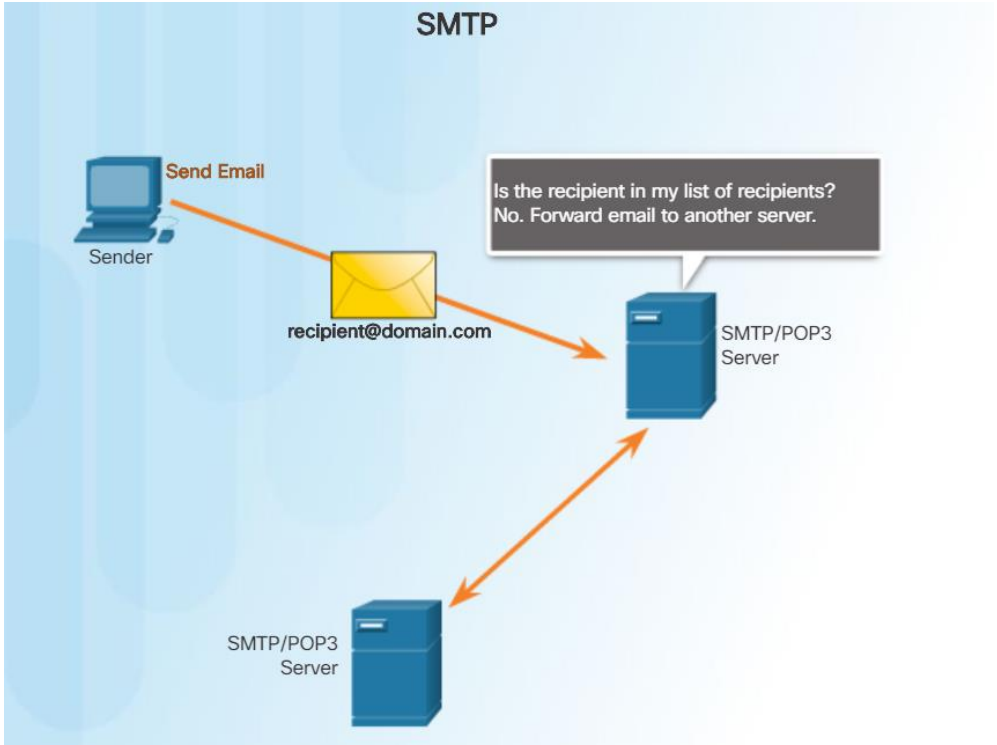
- Email supports three separate protocols for operation:
  - Simple Mail Transfer Protocol (SMTP)
  - Post Office Protocol version 3 (POP3)
  - IMAP

The application layer process that sends mail uses SMTP. A client retrieves email using one of the two application layer protocols: POP3 or IMAP.



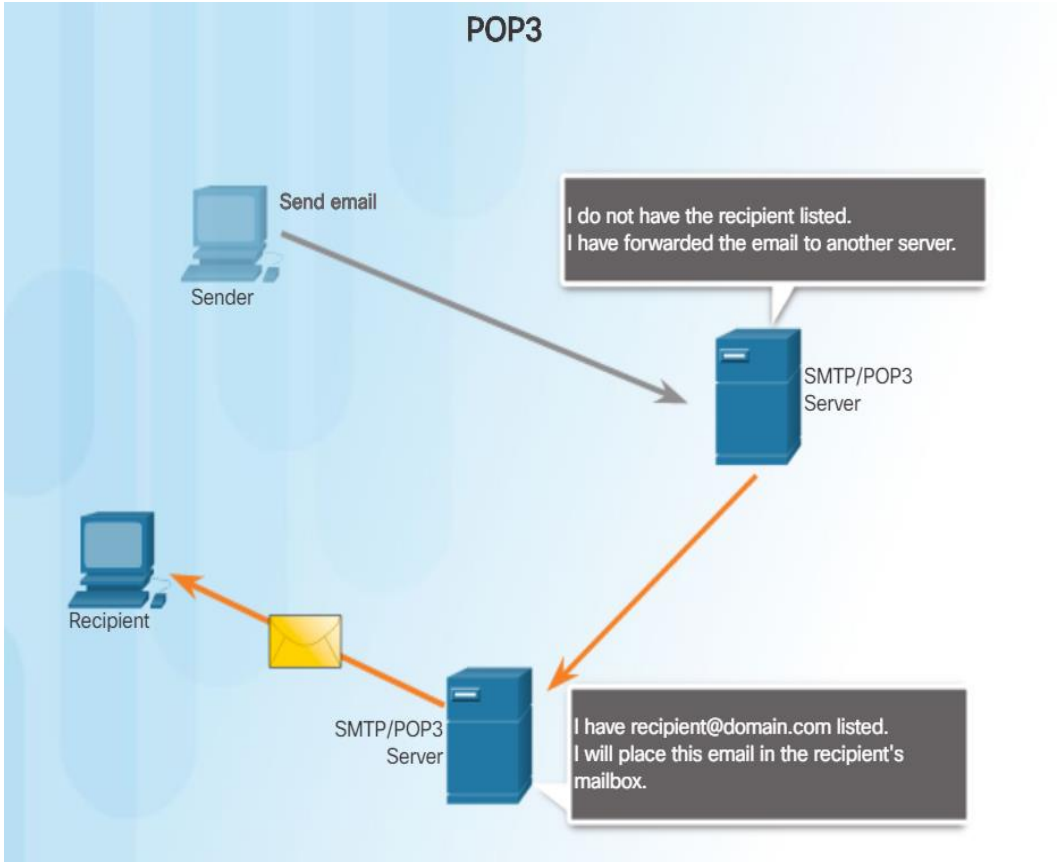
# SMTP

- SMTP
  - Simple Mail Transfer Protocol (SMTP) – Port 25.
- After the connection is made, the client attempts to send the email to the server across the connection.
- 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.



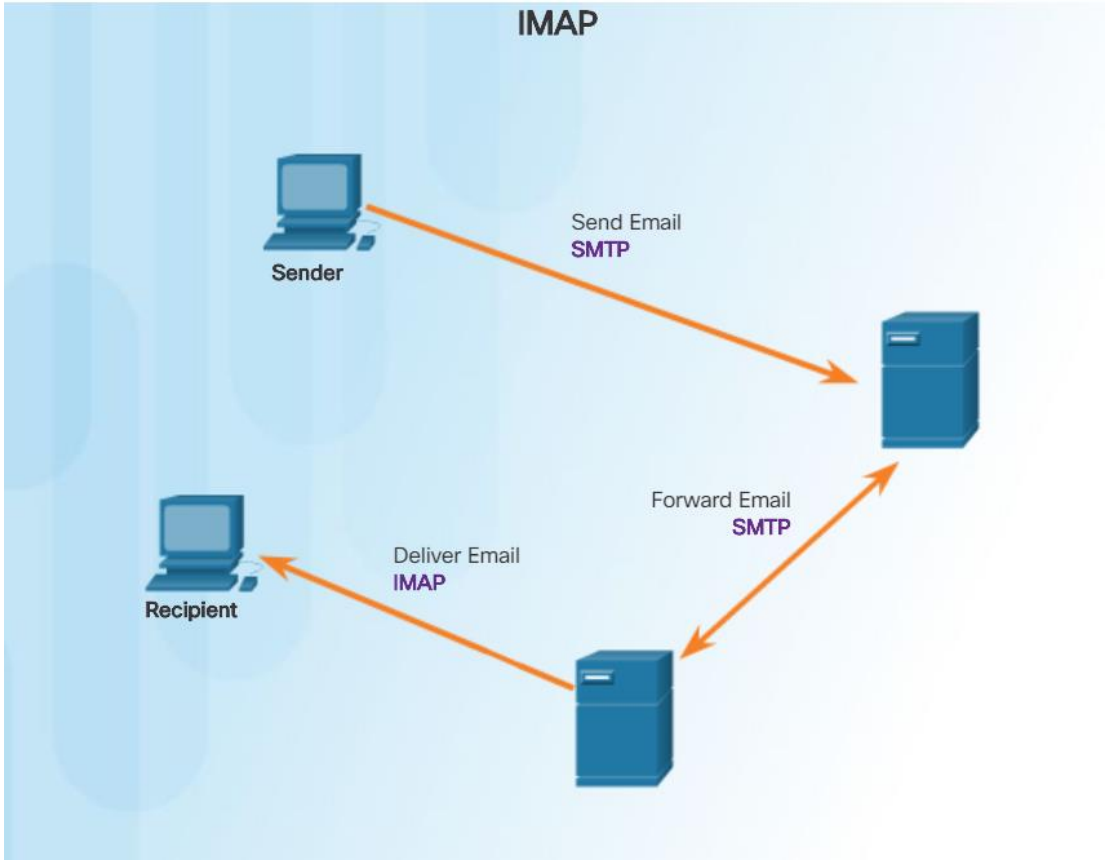
# POP3

- With POP3, mail is downloaded from the server to the client and then deleted on the server.
- With POP3, email messages are downloaded to the client and removed from the server, so there is no centralized location where email messages are kept.



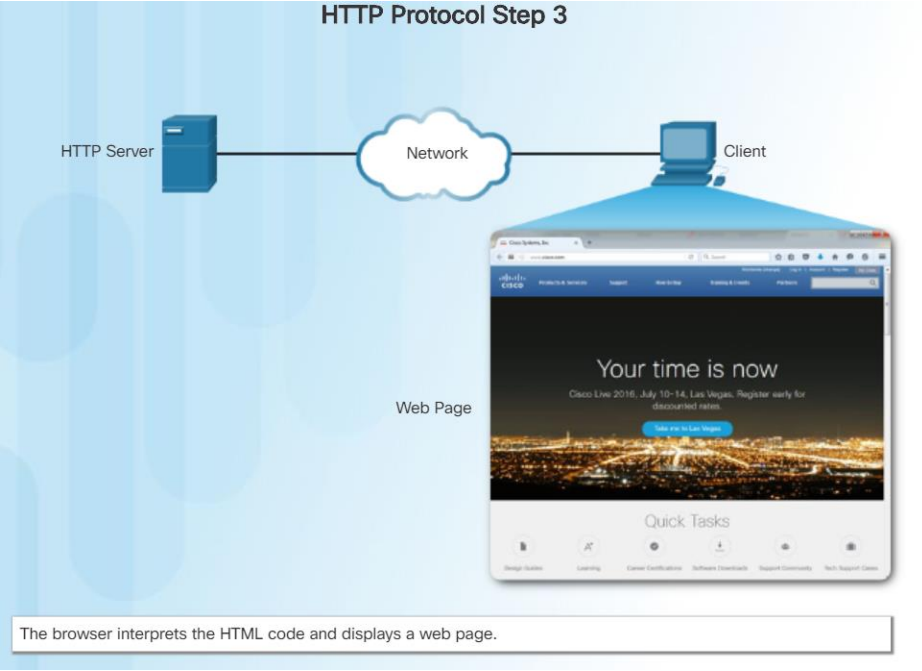
# IMAP

- When a user connects to an IMAP-capable server, copies of the messages are downloaded to the client application.
- When a user decides to delete a message, the server synchronizes that action and deletes the message from the server.



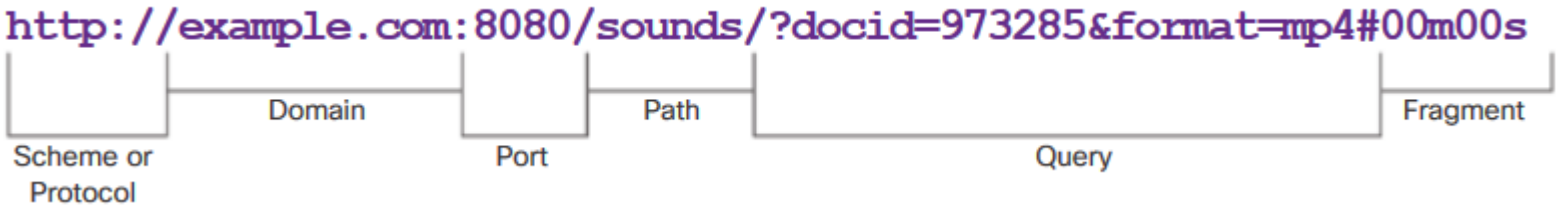
# HTTP Overview

- Hypertext Transfer Protocol (HTTP) :
  - Port 80
  - Governs the way a web server and client interact.
  - TCP-based
  - Has specific server responses.
- Steps:
  1. Client initiates HTTP request to server.
  2. HTTP returns code for a webpage.
  3. Browser interprets HTML code and displays on webpage.



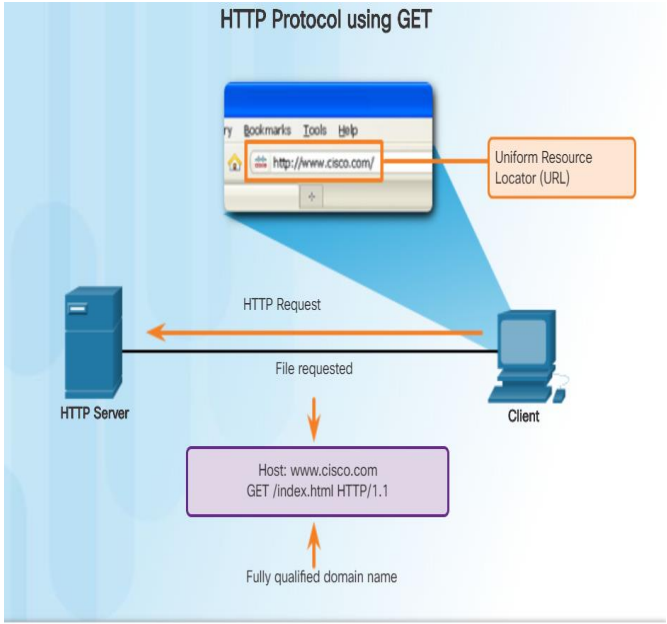
# The HTTP URL

- HTTP URLs can also specify the port on the server that should handle the HTTP methods.
- In addition, it can specify a query string and fragment.
- Query string typically contains information that is not handled by the HTTP server process itself, but is instead handled by another process that is running on the server.



# The HTTP Protocol

- HTTP is a request/response protocol that uses TCP port 80.
- When a client, typically a web browser, sends a request to a web server, it will use one of six methods that are specified by the HTTP protocol.
  - **GET** - A client request for data. A client (web browser) sends the GET message to the web server to request HTML pages.
  - **POST** - Submits data to be processed by a resource.
  - **PUT** - Uploads resources or content to the web server.
  - **DELETE** - Deletes the resource specified.
  - **OPTIONS** - Returns the HTTP methods that the server supports.
  - **CONNECT** - Requests that an HTTP proxy server forwards the HTTP TCP session to the desired destination.




Entering 'http://www.cisco.com' in the address bar of a web browser generates the HTTP 'GET' message.

# HTTP Status Code

- The HTTP server responses are identified with various status codes that inform the host application of the outcome of client requests to the server. The codes are organized into five groups.
  - **1xx** - Informational
  - **2xx** - Success
  - **3xx** - Redirection
  - **4xx** - Client Error
  - **5xx** - Server Error

| Code | Status | Meaning |
|---|---|---|
| 1xx - Informational | | |
| 100 | Continue | The client should continue with request. Server has verified that 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. |
| 4xx - Client Error | | |
| 403 | Forbidden | The request is understood by the server, but the resource will not be fulfilled, possibly because the requester is not authorized to view the resource. |
| 404 | Not Found | The server cannot find the requested resource. |

# Lab – Using Wireshark to Examine HTTP and HTTPS Traffic

Networking Academy

## Lab – Using Wireshark to Examine HTTP and HTTPS

### Objectives

**Part 1: Capture and view HTTP traffic**

**Part 2: Capture and view HTTPS traffic**

### Background / Scenario

HyperText Transfer Protocol (HTTP) is an application layer protocol that presents data via a web browser. With HTTP, there is no safeguard for the exchanged data between two communicating devices.

With HTTPS, encryption is used via a mathematical algorithm. This algorithm hides the true meaning of the data that is being exchanged. This is done through the use of certificates that can be viewed later in this lab.

Regardless of HTTP or HTTPS, it is only recommended to exchange data with websites that you trust. Just because a site uses HTTPS does not mean it is a trustworthy site. Threat actors commonly use HTTPS to hide their activities.

In this lab, you will explore and capture HTTP and HTTPS traffic using Wireshark.

# 4.7 Chapter Summary

# Summary

- Views of the network: Small home network, SOHO (Small Office/Home Office), Medium to large networks, World-wide networks.
- Client-Server communications: Server stores corporate and user files, Client devices access these files or services with client software.
- Web Client Server runs web server software and client uses browser software.
- Email Client Server runs email server software.
- Cybersecurity analysts must be able to determine the origin of traffic that enters the network, and the destination of traffic that leaves it. Understanding the path that network traffic takes is essential to this.
- Protocol are the rules of communications. Network protocols provide the means for computers to communicate on networks.
- TCP/IP protocol model (four layers): Application, Transport, Internet, and Network Access Layers.

# Summary (Cont.)

- OSI model (seven layer model): Physical, Data Link, Network, Transport, Session, Presentation, Application.
- Three important addresses are: Protocol address, Network host address and the physical address.
- Encapsulation includes Segmentation and Multiplexing.
- Ethernet Protocol operates at Layer 1 and 2 (Physical and Data) and is responsible for data encapsulation, media access control and puts bits on the medium.
- The Ethernet frame has 2 unique identifiers: Destination MAC address and Source MAC address.
- IPv4 characteristics include: connectionless, unreliable (best effort) and media independent.
- IPv4 addresses are 32-bit and commonly subnetted.
- Subnetting takes a network space and divides it into smaller spaces called subnets.
- The IPv4 Packet consists of fields containing important information about the packet, including binary numbers examined by the Layer 3 process.

# Summary (Cont.)

- IP address is logically ANDed, bit by bit with subnet mask.
- IPv4 Address Classes are: Class A, Class B, Class C, Class D, Class E.
- Private addresses are reserved and mostly used by organizations to assign IPv4 to internal hosts.
- Host forwarding decision allows packet to be sent to 3 types of destinations: Itself, Local Host and Remote Host.
- Three dotted decimal IPv4 addresses must be configured when assigning an IPv4 configuration to host: IPv4 address (unique IPv4 address of the host), subnet mask (used to identify the network/host portion of the IPv4 address) and default gateway (Identifies the local gateway to reach remote networks).
- IP Addressing can be configured manually or obtained automatically (DHCP).
- Depletion of IPv4 addresses has been a motivating factor to move to the IPv6 address (128 bit space).
- ICMPv4 messages are used to provide feedback and troubleshoot network problems.
- 4 new protocols as part of the Neighbor Discovery Protocol (ND or NDP) are : RS, RA, NS and NA.

# Summary (Cont.)

- Ping is a testing utility that uses ICMP echo request and echo reply messages to test connectivity between hosts to a LAN or to a remote host.
- Traceroute provides information about the details of devices between the hosts and generates a list of hops that were successfully reached along the path.
- Two addresses assigned to an Ethernet device: MAC address (Layer 2 physical address) and an IP address (Layer 3 logical address).
- When a device sends an Ethernet frame, it contains these two addresses: destination MAC address and the source MAC address.
- ARP function is used to resolve IPv4 addresses to MAC addresses.
- ARP messages are encapsulated within an Ethernet frame.
- Network hosts keep ARP tables that are held in memory called ARP cache and age out of the table or are manually removed.

# Summary (Cont.)

- ARP Spoofing is a security risk, as it is a technique used by a hacker to reply to an ARP request for an IPv4 address belonging to another device.
- The Transport Layer Protocol role in network communications is to track individual conversations, move data between applications on the network devices, segment and reassemble data, and identify applications using a port number.
- Socket Pairs are a combination of the source IP address and source port number ***or*** combination of the destination IP address and destination port number.
- TCP/IP provides two transport layer protocols: Transmission Control Protocol (TCP) and User Datagram Protocol (UDP).
- TCP and UDP manage multiple simultaneous conversations by using header fields that can uniquely identify these applications. These unique identifiers are the port numbers.
- The combination of the source IP address and source port number, or the destination IP address and destination port number is known as a socket.

# Summary (Cont.)

- TCP connections are established using three steps.
- UDP session reassembles the data in the order it was received and is assigned a well-known port number.
- Dynamic Host Configuration Protocol (DHCP) provides IP addressing information such as IP address, subnet mask, default gateway, DNS IP address and domain name.
- Dynamic Name System (DNS) manages and provides domain names and associated IP addresses.
- The DNS consists of a hierarchy of generic top level domains (gTLD) which consist of .com, .net, .org, .gov, .edu, and numerous country-level domains, such as .br (Brazil), .es (Spain),.uk (United Kingdom)
- When the IP address of the mapping changes, the new mapping can be propagated through the DNS almost instantaneously using Dynamic DNS.
- WHOIS is a TCP-based protocol that is used to identify the owners of Internet domains through the DNS system.
- Network Address Translation (NAT) is used within an organization or site and allows the devices to communicate locally but needs to be translated by a NAT-Enabled router to route to the Internet.

# Summary (Cont.)

- File Transfer Protocol (FTP) is TCP-based and is more reliable than TFTP.
- Trivial File Transfer Protocol (TFTP) is UDP-based and is fast but unreliable.
- Server Message Block (SMB) 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.
- Email supports three separate protocols for operation: Simple Mail Transfer Protocol (SMTP), Post Office Protocol version 3 (POP3) and IMAP.
- Hypertext Transfer Protocol (HTTP) involves 3 steps: Client initiates HTTP request to server, HTTP returns code for a webpage, and the browser interprets HTML code and displays on webpage.
- HTTP URLs can also specify the port on the server that should handle the HTTP methods.
- When a client, typically a web browser, 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.

# New Terms

- Address Resolution Protocol (ARP)
- Application layer
- ARP spoofing
- Authoritative Server
- Bootstrap Protocol (BOOTP)
- broadcast
- connectionless
- Data Link layer
- default gateway
- destination port
- DNS Zone
- Domain Name System (DNS)
- dotted-decimal
- Duplicate Address Detection (DAD)
- Dynamic DNS (DDNS)
- Dynamic Host Configuration Protocol (DHCP)
- Enhanced Interior Gateway Routing Protocol (EIGRP)
- Ethernet
- File Transfer Protocol (FTP)
- flow control
- Fully Qualified Domain Name (FQDN)

# New Terms

- hextet
- Hypertext Transfer Protocol (HTTP)
- Internet Control Message Protocol (ICMP)
- Internet Message Access Protocol (IMAP)
- Internet Protocol (IP)
- Logical Link Control (LLC) sublayer
- maximum transmission unit (MTU)
- Media Access Control (MAC) sublayer
- multicast
- Multiplexing
- Neighbor Advertisement (NA)
- Neighbor Discovery Protocol (ND or NDP)
- Neighbor Solicitation (NS)
- Network Address Translation (NAT)
- Network layer
- network protocol
- octet
- Open Shortest Path First (OSPF)
- Open Systems Interconnection (OSI) model

# New Terms

- Physical layer
- ping
- Point-to-Point Protocol (PPP)
- Port Address Translation (PAT)
- Post Office Protocol version 3 (POP3)
- Presentation layer
- private IPv4 address
- protocol data unit
- protocol suite
- public IPv4 address
- Recursion
- Recursive Resolver
- Resolver
- Resource Record (RR)
- Round Trip Time (RTT)
- Router Advertisement (RA)
- Router Solicitation (RS) multicast
- Segmentation
- Server Message Block (SMB)
- Session layer
- Simple Mail Transfer Protocol (SMTP)
- socket
- source port
- Stateless Address Autoconfiguration (SLAAC)

# New Terms

- subnet mask
- subnetting
- TCP/IP protocol suite
- Time to Live (TTL)
- traceroute
- Transmission Control Protocol (TCP)
- Transport layer
- Trivial File Transfer Protocol (TFTP)
- unicast
- unreliable
- User Datagram Protocol (UDP)
- WHOIS
- window size

# Cybersecurity Operations Certification

This chapter covers the following areas in the Cybersecurity Operations Certification:

From 210-250 SECFND - Understanding Cisco Cybersecurity Fundamentals:

- **Domain 1: Network Concepts**
  - 1.1 Describe the function of the network layers as specified by the OSI and the TCP/IP network models
  - 1.2 Describe the operation of the following protocols: IP TCP UDP ICMP
  - 1.3 Describe the operation of the following network services: ARP DNS DHCP
  - 1.6 Describe IP subnets and communication within an IP subnet and between IP subnets

  - **Domain 1: Network Concepts**
  - 5.3 Describe the following concepts as they relate to security monitoring: Access Control List, NAT/PAT, Tunneling, TOR Encryption, P2P, Encapsulation, Load Balancing

# Cybersecurity Operations Certification

This chapter covers the following areas in the Cybersecurity Operations Certification:

From 210-250 SECOPS - Understanding Cisco Cybersecurity Fundamentals:

- **Domain 2: Network Intrusion Analysis**
  - 2.2 Describe the fields in the following protocol headers as they relate to intrusion analysis: IPv4, IPv6, UDP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