Module 8: The Internet Protocol

Networking Essentials (NETESS)

Module Objectives

Module Title: The Internet Protocol
Module Objective: Explain the features of an IP address

Topic Title	Topic Objective
Purpose of an IPv4 Address	Explain the purpose of an IPv4 address.
Binary Conversion of an IPv4 Address	Calculate numbers between decimal and binary systems.
The IPv4 Address Structure	Explain how IPv4 addresses and subnets are used together.
Classful IPv4 Addressing	Describe the different IPv4 address classes.
Public and Private IPv4 Addresses	Describe the public and private IPv4 address ranges.
Unicast, Broadcast, and Multicast Addresses	Compare unicast, multicast, and broadcast addresses.

8.1 Purpose of the IPv4 Address

The IPv4 Address

The IPv4 address is a logical network address that identifies a particular host.

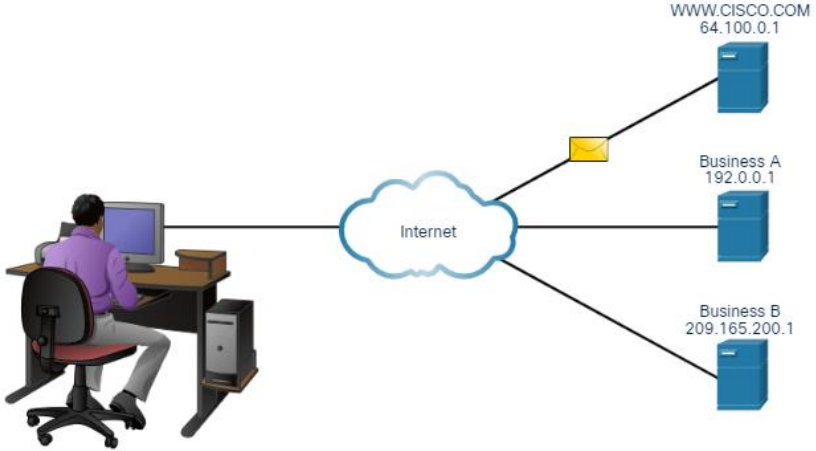
- Must be properly configured and unique within the LAN and world

An IPv4 address is assigned to the network interface connection for a host such as workstations, servers, network printers, and IP phones.

Router interfaces that provide connections to an IP network will also have an IPv4 address.

Every packet sent across the internet has a source and destination IPv4 address.

- Required by networking devices to ensure the information gets to the destination and any replies are returned to the source



Packet Tracer – Connect to a Web Server

In this activity, you will observe how packets are sent across the internet using IP addresses.

8.2 Binary Conversion of an IPv4 Address

IPv4 Addressing

An IPv4 address is a series of 32 binary bits (ones and zeros).

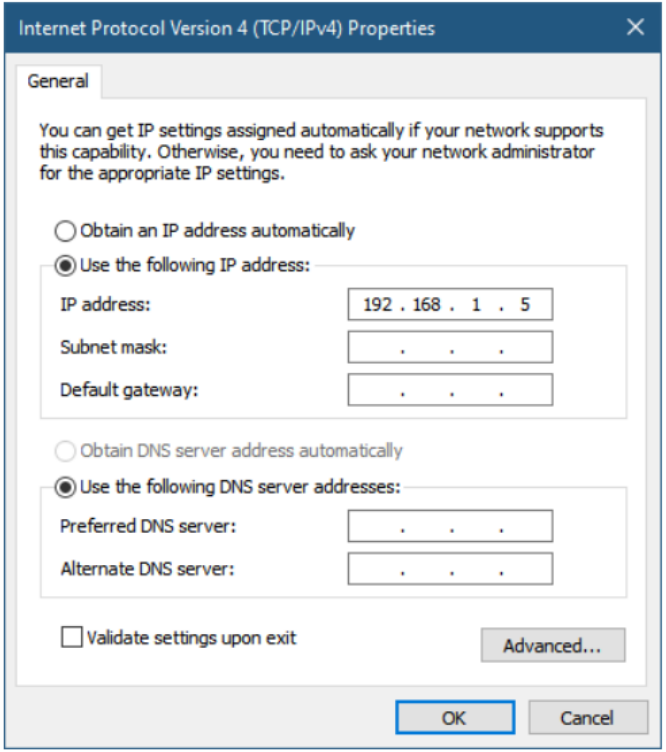
- The 32 bits are grouped into four 8-bit bytes called octets.

An IPv4 address written in binary is hard for humans to read, write, and remember.

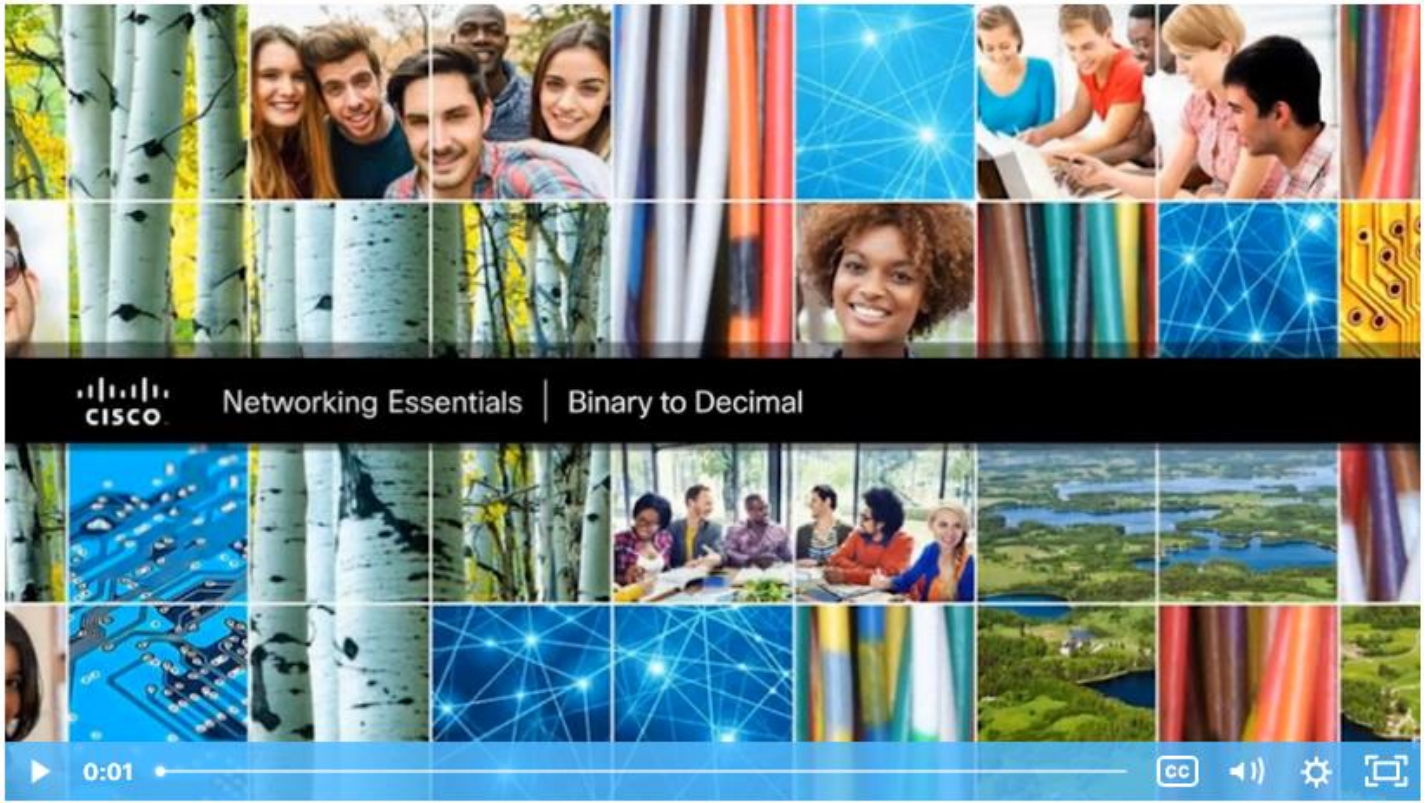
- To make the IPv4 address easier to understand, each octet is presented as its decimal value, separated by a decimal point or period.
  - This is referred to as dotted-decimal notation.

When a host is configured with an IPv4 address, it is entered as a dotted decimal number such as 192.168.1.5.

- The 32-bit binary equivalent is: 11000000101010000000000100000101.



Video - Binary to Decimal Conversion



Binary to Decimal

When a host receives an IPv4 address, it looks at all 32 bits as they are received by the NIC. Humans convert those 32 bits into their four-octet decimal equivalent.

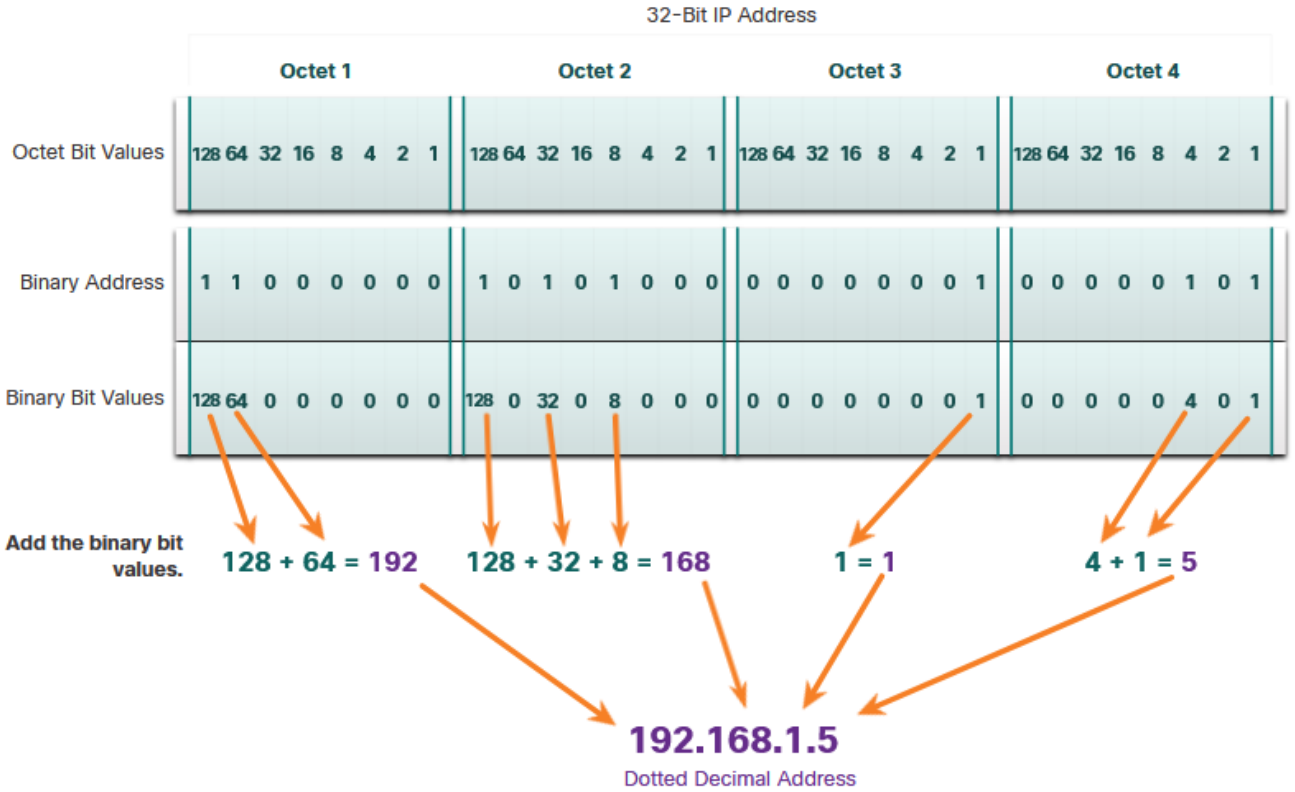
Each octet is made up of 8 bits and each bit has a value.

- The rightmost bit in an octet has a value of 1 and the values of the remaining bits, from right to left, are 2, 4, 8, 16, 32, 64, and 128.

You can determine the value of the octet by adding the values of positions wherever there is a binary 1 present:

- If there is a 0 in a position, do not add the value.
- If all 8 bits are 0s, 00000000 the value of the octet is 0.
- If all 8 bits are 1s, 11111111 the value of the octet is 255 (128+64+32+16+8+4+2+1).
- If the 8 bits are mixed, such as the example 00100111, the value of the octet is 39 (32+4+2+1).

Binary to Decimal (Cont.)



Activity - Binary to Decimal Conversions

This page includes a binary to decimal conversion activity that allows you to practice 8-bit binary to decimal conversion.

Instructions

This activity allows you to practice 8-bit binary to decimal conversion as much as necessary. We recommend that you work with this tool until you are able to do the conversion without error. Convery the binary number shown in the octet to its decimal value.

Enter decimal answer below.

Decimal Value								
Base	2	2	2	2	2	2	2	2
Exponent	7	6	5	4	3	2	1	0
Position	128	64	32	16	8	4	2	1
Bit	**1**	**1**	**1**	**1**	**0**	**1**	**1**	**0**

Binary number.

Check | New Number | Show Me | Reset

Activity - Decimal to Binary Conversions

This page includes a decimal to binary conversion activity that allows you to practice decimal to 8-bit binary conversion.

Instructions

This activity allows you to practice decimal conversions to 8-bit binary values. We recommend that you work with this tool until you are able to do the conversion without error. Convert the decimal number shown in the Decimal Value row to its binary bits.

Decimal Value	90							
Base	2	2	2	2	2	2	2	2
Exponent	7	6	5	4	3	2	1	0
Position	128	64	32	16	8	4	2	1
Bit								

Check | New Number | Show Me | Reset

Activity - Binary Game

The Binary Game presents problems which you must solve in order to gain points. This is a fun way to learn binary numbers for networking

Lab - Use a Calculator for Binary Conversions

In this lab, you will complete the following objectives:

- Switch between Windows Calculator modes.
- Use Windows Calculator to convert between decimal and binary.
- Use Windows Calculator to determine the number of hosts in a network with powers of 2.

8.3 The IPv4 Address Structure

Video - The IPv4 Address Structure

Networks and Hosts

The logical 32-bit IPv4 address is hierarchical and is made up of two parts, the network and the host. Both parts are required in an IPv4 address.

As an example, there is a host with an IPv4 address 192.168.5.11 with a subnet mask of 255.255.255.0.

- The first three octets, (192.168.5), identify the network portion of the address, and the last octet, (11) identifies the host.

This is known as hierarchical addressing because the network portion indicates the network on which each unique host address is located.

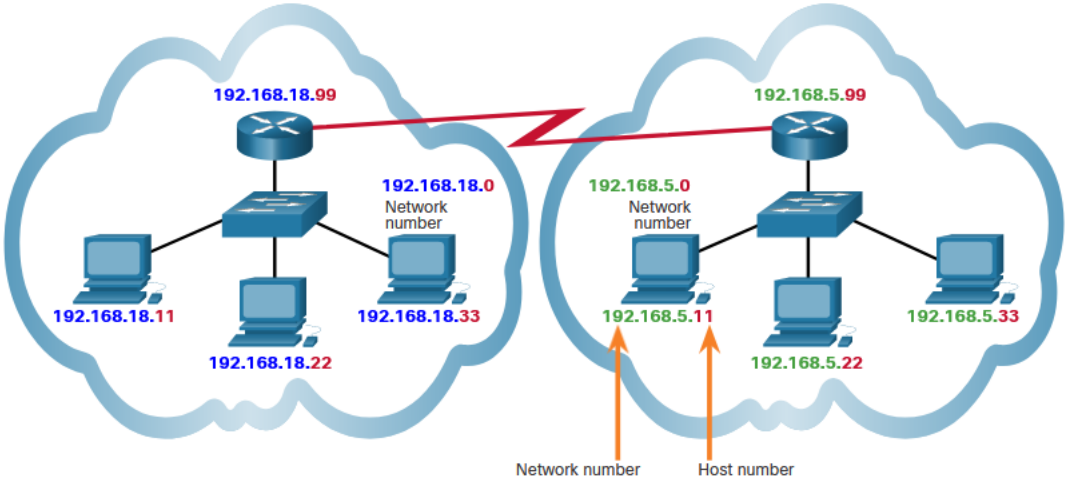
- Routers only need to know how to reach each network, rather than needing to know the location of each individual host.

Networks and Hosts (Cont.)

With IPv4 addressing, multiple logical networks can exist on one physical network, if the network portion of the logical network host addresses is different.

- The hosts with the same network number in their IPv4 addresses will be able to communicate with each other, but will not be able to communicate with the other hosts without the use of routing.

In this example, there is one physical network and two logical IPv4 networks.



Video - Local or Remote Network - Part 1

Video - Local or Remote Network - Part 2

Logical AND

A logical AND is one of three basic binary operations used in digital logic and is used in determining the network address.

Logical AND is the comparison of two bits that produce the results shown in the following. Note how only a 1 AND 1 produce a 1.

- 1 AND 1 = 1
- 0 AND 1 = 0
- 1 AND 0 = 0
- 0 AND 0 = 0

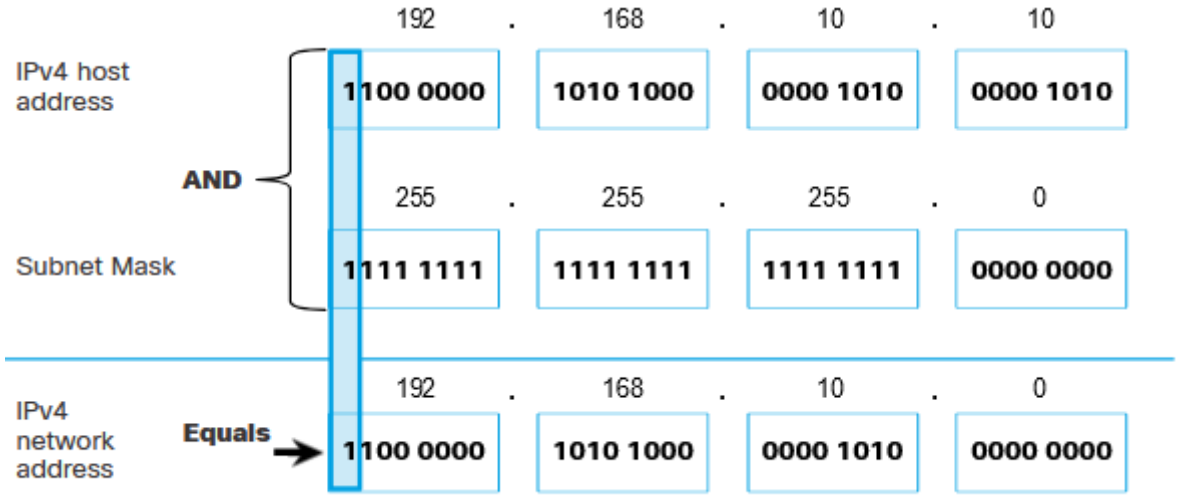
To identify the network address of an IPv4 host, the IPv4 address is logically ANDed, bit by bit, with the subnet mask.

- ANDing between the address and the subnet mask yields the network address.

Logical AND (Cont.)

To illustrate how AND is used to discover a network address, consider a host with IPv4 address 192.168.10.10 and subnet mask of 255.255.255.0.

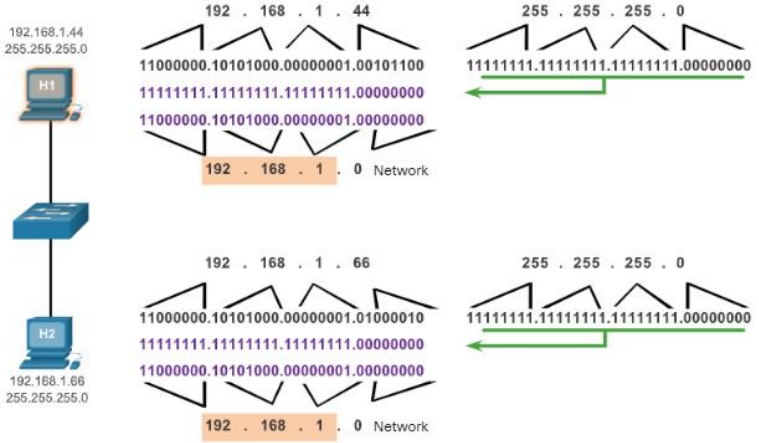
The figure displays the host IPv4 address and converted binary address. The host subnet mask binary address is ANDed.



Calculate Whether the Destination is Local or Remote

How do hosts know which portion of an IPv4 address is the network and which is the host? Answer – The subnet mask

- The subnet mask signifies which part of the IPv4 address is network and which part is host.
- The subnet mask is compared to the IPv4 address from left to right, bit for bit.
  - The 1s in the subnet mask represent the network portion; the 0s represent the host portion.
  - When a host sends a packet, it compares its subnet mask to its own IPv4 address and the destination IPv4 address.
    - If the network bits match, both the source and destination host are on the same network and the packet can be delivered locally.
    - If the network bits do not match, the sending host forwards the packet to the local router interface to be sent on to the other network.



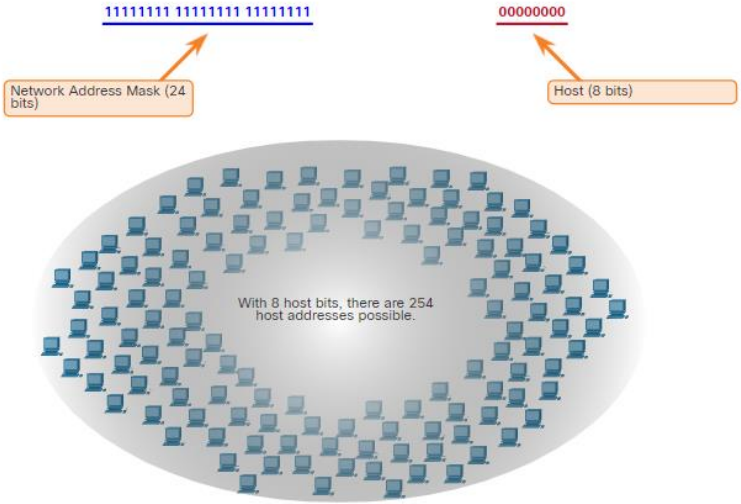
Calculate the Number of Hosts

The subnet masks most often used with networking are:

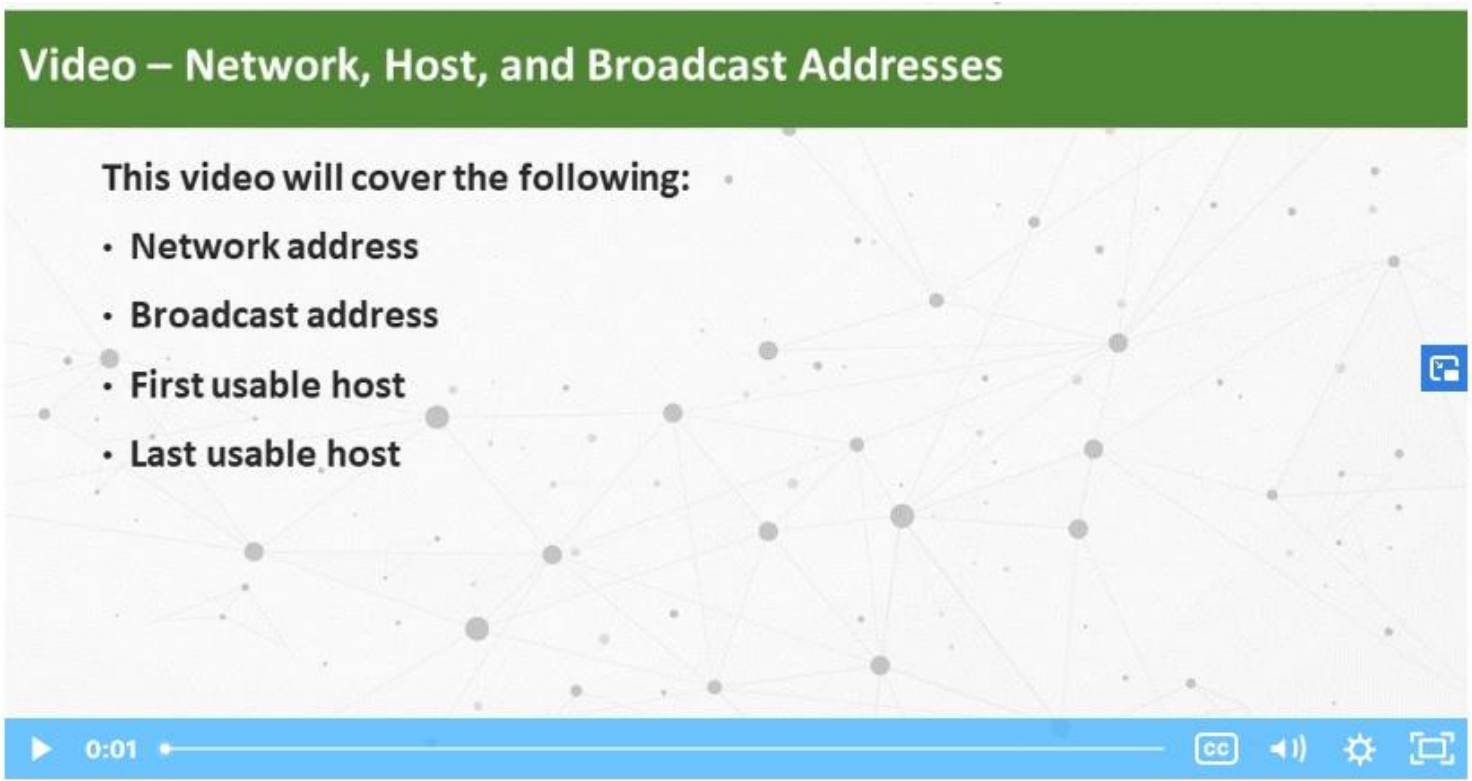
- 255.0.0.0 (8-bits)
- 255.255.0.0 (16 bits)
- 255.255.255.0 (24 bits)

A subnet mask of 255.255.255.0 (decimal) or 11111111.11111111.1111111.00000000 (binary) uses 24 network bits and 8 host bits.

- To determine how many hosts can be on that network, take the number 2 to the power of the number of host bits ($2^8 = 256$).
- Subtract 2 (256-2) for numbers that cannot be used
  - Broadcast address of all 1s in the host portion
  - Network ID of all 0s
- Another method - Add all values of the available host bits (128+64+32+16+8+4+2+1 = 255).
  - Subtract 1 (255-1 = 254), because the host bits cannot be all 1s.



Video - Network, Host, and Broadcast Addresses



Activity - ANDing to Determine the Network Address

This page includes an activity to practice the ANDing process to determine the network address (in binary and decimal formats).

Instructions:

Use the ANDing process to determine the network address (in binary and decimal formats).

Host Address	172	21	238	195
Subnet Mask	255	255	255	240
Host Address in binary	10101100	00010101	11101110	11000011
Subnet Mask in binary	11111111	11111111	11111111	11110000
Network Address in binary				
Network Address in decimal				

Check | New Problem | Show Me | Reset

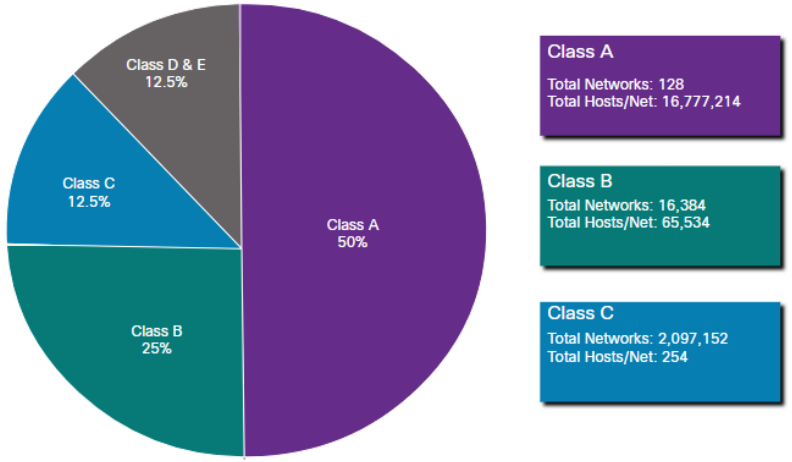
8.4 Classful IPv4 Addressing

Classful and Classless Addressing

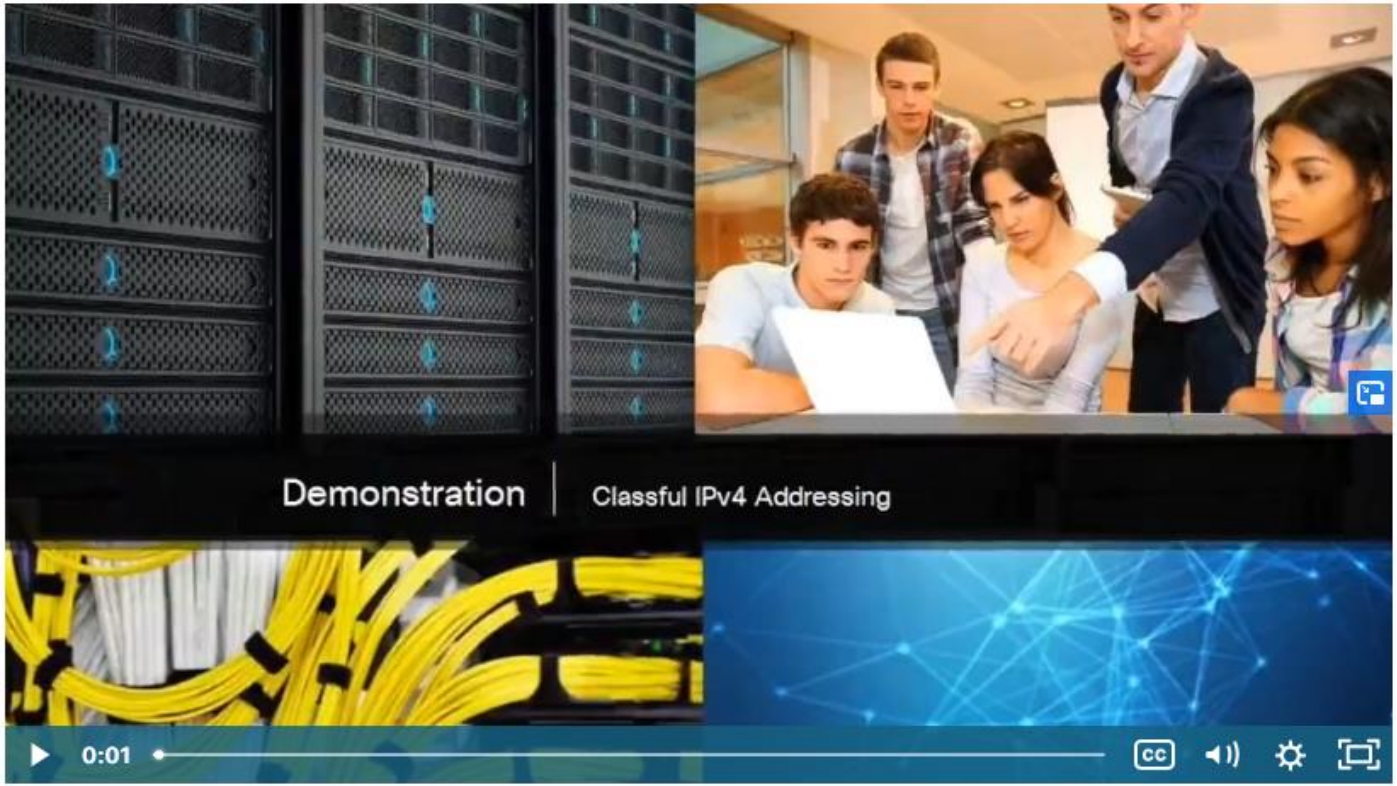
IPv4 addresses are divided into the following ranges or classes:

- **Class A (0.0.0.0/8 to 127.0.0.0/8)** - Designed to support extremely large networks with more than 16 million host addresses. It used a fixed /8 prefix (255.0.0.0).
- **Class B (128.0.0.0 /16 - 191.255.0.0 /16)** - Designed to support the needs of moderate to large size networks with up to approximately 65,000 host addresses. It used a fixed /16 prefix (255.255.0.0).
- **Class C (192.0.0.0 /24 - 223.255.255.0 /24)** - Designed to support small networks with a maximum of 254 hosts. It used a fixed /24 prefix (255.255.255.0).

Note: There is also a Class D multicast block consisting of 224.0.0.0 to 239.0.0.0 and a Class E experimental address block consisting of 240.0.0.0 - 255.0.0.0.



Video - Classful IPv4 Addressing



8.5 Public and Private IPv4 Addresses

Private IPv4 Addressing

Public IPv4 addresses are addresses which are globally routed between ISP (internet service provider) routers.

Private IPv4 addresses were introduced because of the depletion of IPv4 address space.

Private IPv4 addresses are not unique and can be used by an internal network.

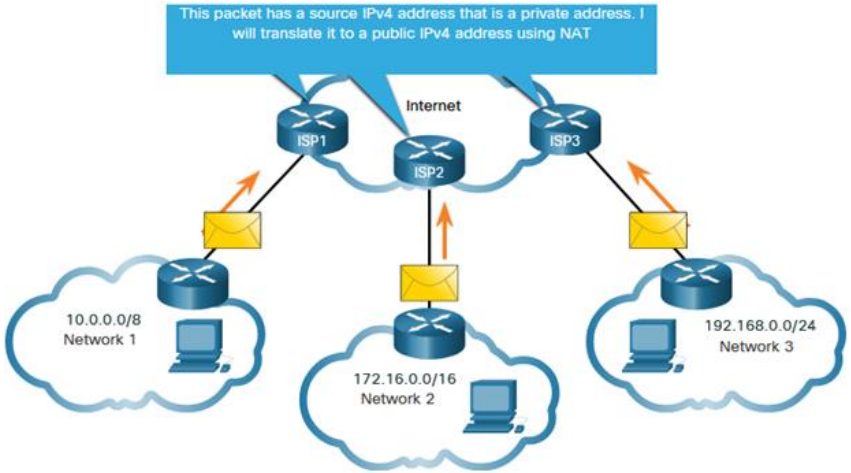
- Specifically, the private address blocks are:
  - **10.0.0.0 /8** or **10.0.0.0** to **10.255.255.255**
  - **172.16.0.0 /12** or **172.16.0.0 to 172.31.255.255**
  - **192.168.0.0 /16** or **192.168.0.0 to 192.168.255.255**

- **Note**: Private addresses are defined in RFC 1918.

Private IPv4 Addressing (Cont.)

Most organizations use private IPv4 addresses for their internal hosts. However, these RFC 1918 addresses are not routable in the internet and must be translated to a public IPv4 address.

- Network Address Translation (NAT) is used to translate between private IPv4 and public IPv4 addresses.
  - This is usually done on the router that connects the internal network to the ISP's network.
  - Home routers provide the same capability.



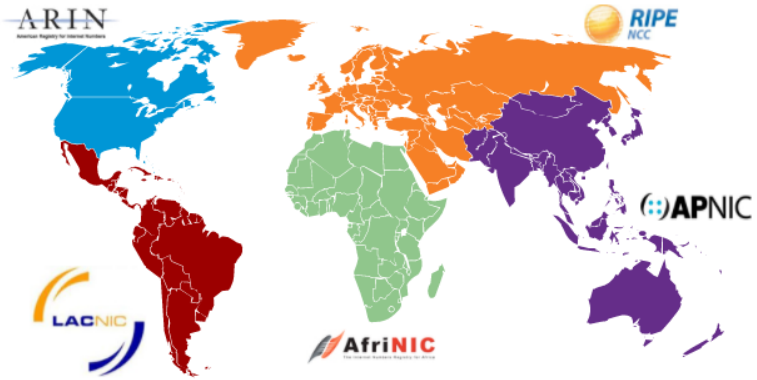
Assignment of IPv4 Addresses

For a company or organization to support network hosts that are accessible from the internet, such as web servers, that organization must have a block of public addresses assigned.

Public IPv4 and IPv6 addresses are regulated and allocated to each organization separately. These public addresses must be unique and not repeated in their use across the world.

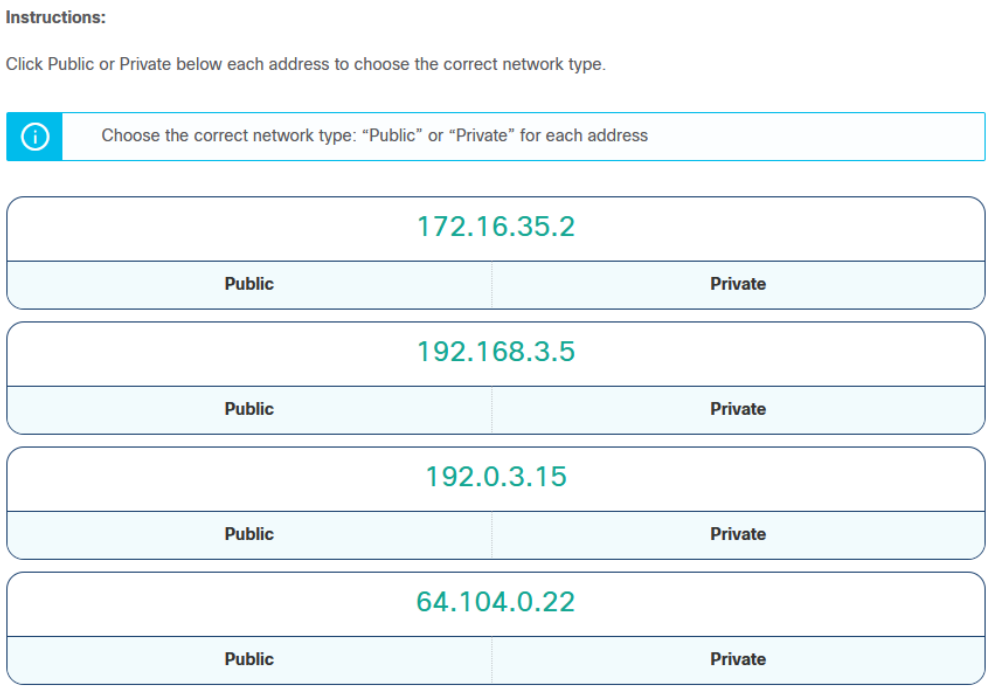
Both IPv4 and IPv6 addresses are managed by the Internet Assigned Numbers Authority (IANA).

- The IANA manages and allocates blocks of IP addresses to the Regional Internet Registries (RIRs).
  - RIRs are responsible for allocating IP addresses to ISPs, who in turn provide IPv4 address blocks to organizations and smaller ISPs.
    - Organizations can get their addresses directly from an RIR subject to the policies of that RIR.



Activity - Public or Private IPv4 Address

This page includes an activity to assist you in practicing the identification of a public or private IPv4 address.



8.6 Unicast, Broadcast and Multicast Addresses

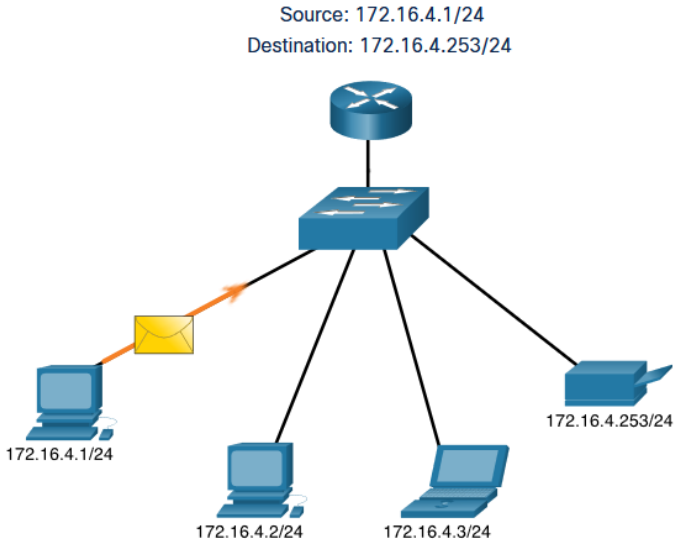
Video - IPv4 Unicast

Unicast Transmission

Unicast communication is used for normal host-to-host communication in both a client/server and a peer-to-peer network.

Unicast packets use the address of the destination device as the destination address and can be routed through an internetwork.

- During the encapsulation process, the source host uses its IPv4 address as the source address and the IPv4 address of the destination host as the destination address.
- Regardless of whether the destination specified a packet as a unicast, broadcast or multicast; the source address of any packet is always the unicast address of the originating host.



Video - IPv4 Broadcast

Broadcast Transmission

Broadcast packets are sent to all hosts in the network using a broadca address.

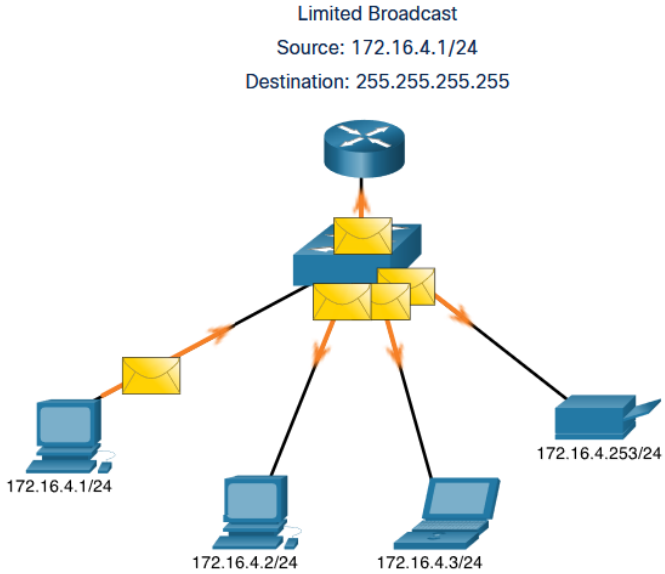
- A broadcast packet contains a destination IPv4 address with all on (1s) in the host portion.
  - All hosts on that local network (broadcast domain) will receiv and look at the packet.
  - When a host receives a broadcast packet, the host processe the packet as it would a packet addressed to its unicast address.

Broadcast may be directed or limited.

- A directed broadcast is sent to all hosts on a specific network.
- A limited broadcast is sent to 255.255.255.255.

By default, routers do not forward broadcasts.

- Routers can eliminate excessive broadcast traffic by subdividing networks into separate broadcast domains.



Video - IPv4 Multicast

Multicast Transmission

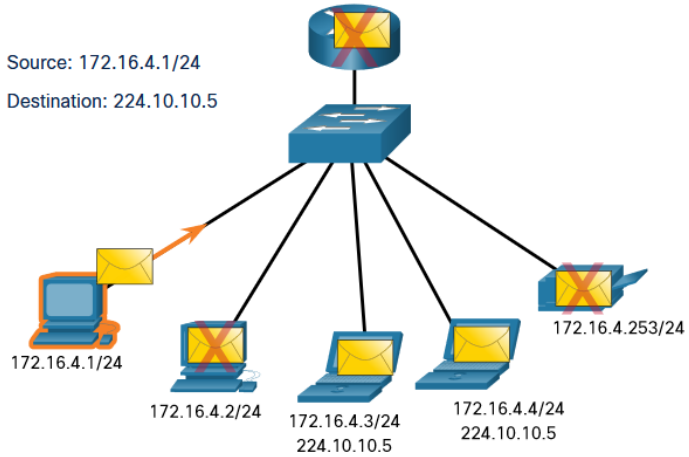
Multicast transmission reduces traffic by allowing a host to send a single packet to a selected set of hosts that subscribe to a multicast group.

IPv4 has reserved the 224.0.0.0 to 239.255.255.255 addresses as a multicast range.

- The IPv4 multicast addresses 224.0.0.0 to 224.0.0.255 are reserved for multicasting on the local network only.
  - A router connected to the local network will not forward them further.

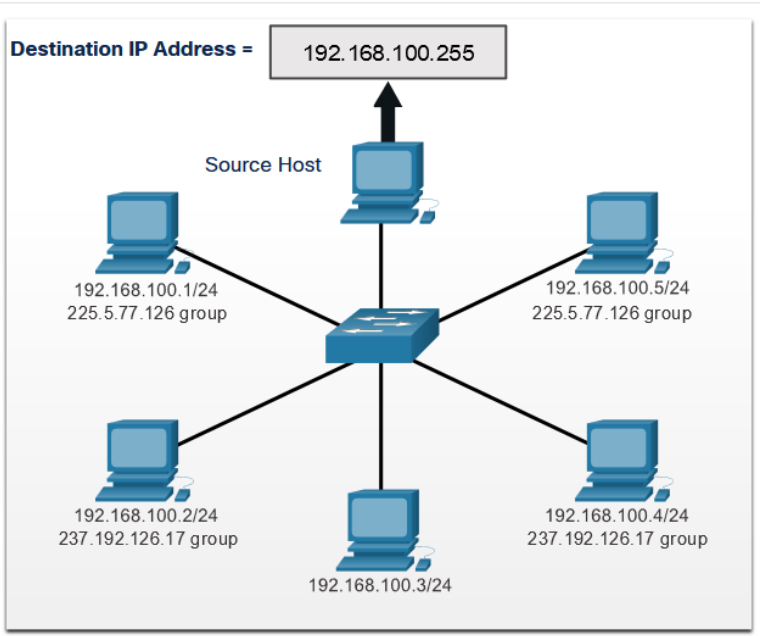
Hosts that receive multicast data are called multicast clients.

- The multicast clients use services requested by a client program to subscribe to the multicast group.
- Each multicast group is represented by a single IPv4 multicast destination address.



Activity - Unicast, Broadcast, or Multicast

This page includes an activity to assist you in practicing the identification of a unicast, multicast, or broadcast IPv4 address.



8.7 The Internet Protocol Summary

What Did I Learn in this Module?

- A host needs an IPv4 address to participate on the internet and almost all LANs today.
  - Every packet sent across the internet has a source and destination IPv4 address.
  - This information is required by networking devices to ensure the information gets to the destination and any replies are returned to the source.

- An IPv4 address is simply a series of 32 binary bits (ones and zeros). There are over 4 billion possible IPv4 addresses using a 32-bit addressing scheme.
  - The 32 bits are grouped into four 8-bit bytes called octets.
  - To make IPv4 addresses easier to understand, each octet is presented as its decimal value, separated by a decimal point or period. This is referred to as dotted-decimal notation.

- When a host receives an IPv4 address, it looks at all 32 bits as they are received by the NIC.
  - Practice 8-bit binary to decimal conversion values.
  - Practice decimal conversions to 8-bit binary values.

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

- The logical 32-bit IPv4 address is hierarchical and is made up of two parts, the network and the host.
  - Both parts are required in an IPv4 address.
  - Routers only need to know how to reach each network, rather than needing to know the location of each individual host.

- The hosts with the same network number in their IPv4 addresses will be able to communicate with each other, but will not be able to communicate with the other hosts without the use of routing.

- A logical AND is one of three basic binary operations used in digital logic and is used in determining the network address.

- The subnet mask signifies which part of the IPv4 address is network and which part is host.

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

Internet IPv4 addresses were assigned using classful addressing:

- Class A (0.0.0.0/8 to 127.0.0.0/8)
- Class B (128.0.0.0 /16 - 191.255.0.0 /16)
- Class C (192.0.0.0 /24 - 223.255.255.0 /24

Public IPv4 addresses are addresses which are globally routed between ISP (internet service provider) routers.

Private IPv4 addresses are not unique and can be used by an internal network:

- 10.0.0.0 /8 or 10.0.0.0 to 10.255.255.255
- 172.16.0.0 /12 or 172.16.0.0 to 172.31.255.255
- 192.168.0.0 /16 or 192.168.0.0 to 192.168.255.255
    - Private addresses are defined in RFC 1918.

- Unicast communication is used for normal host-to-host communication.
- Broadcast packets are sent to all hosts in the network using a broadcast address.
- Multicast transmission allows a host to send a single packet to a selected set of hosts

Module 8 – New Terms and Commands

- IPv4 address
- binary
- octet
- decimal
- dotted decimal
- subnet mask
- ANDing
- classful addressing
- classless addressing
- private IPv4 addressing
- RFC 1918
- NAT
- public IPv4 addressing
- unicast
- broadcast
- multicast


CISCO