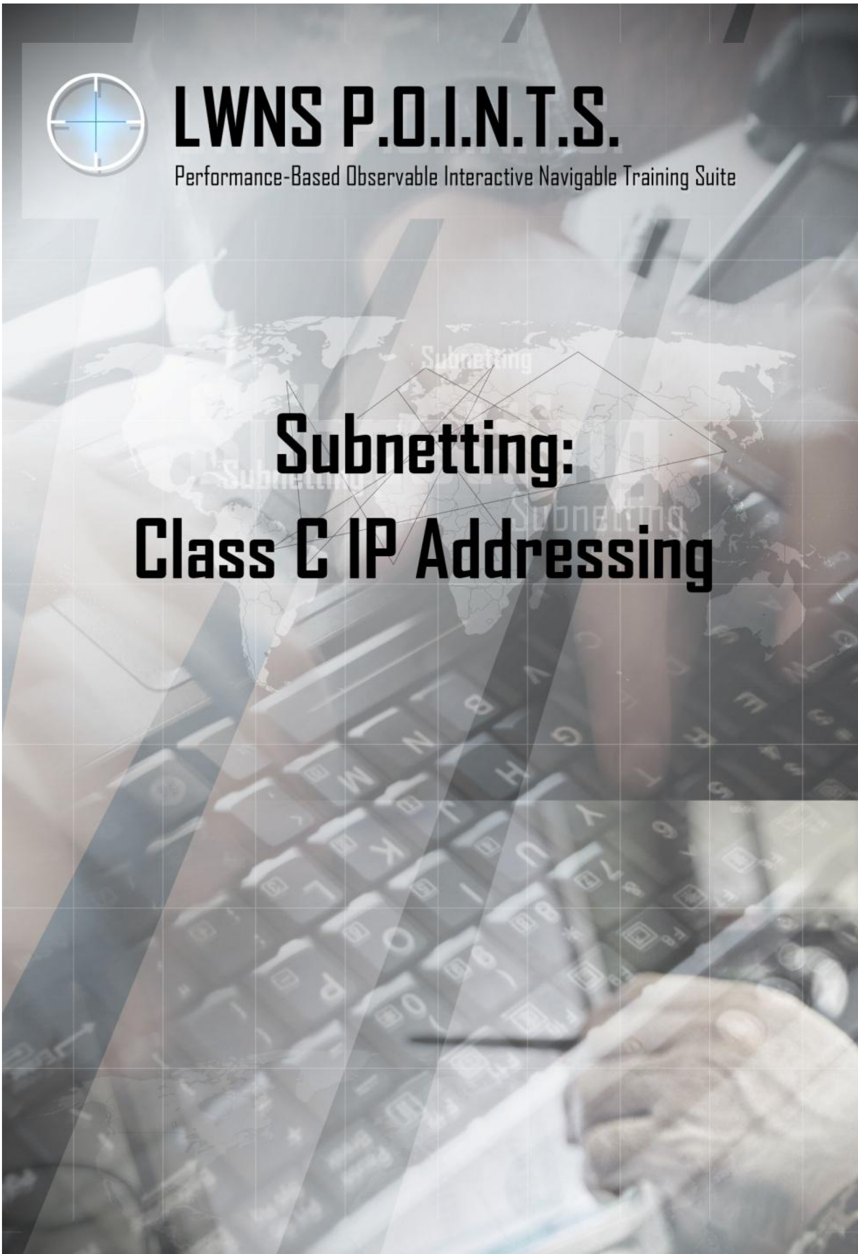

LWNS P.O.I.N.T.S.

Performance-Based Observable Interactive Navigable Training Suite

Subnetting: Class C IP Addressing

Table of Contents

Introduction

Imagine that your Commanding Officer has asked you to figure out a range of Internet Protocol (IP) addresses for a sub-network. Can you do it? Welcome to the IP Addressing lesson where you will learn how to accomplish this task without having any previous experience with IPs.

During this lesson you will learn about the basics of IPv4, including IPv4 terminology and IPv4 addresses. You will then learn about classful and classless networks and how network and subnetwork masks work. You will also learn how IPv4 addresses are used in these types of networks. Finally, you will have an opportunity to apply your knowledge by assigning IPv4 addresses to network components on both classless and classful networks.

Once this lesson is complete, you will take a test which measures whether the desired learning has occurred and if you can perform tasks to standard. The test will inform you of your results, and recommend remediation if necessary.

Even though you will use this courseware to learn about these topics for the first time, you can also review it at any time to refresh your memory.

IP Addressing

Internet Protocol (IP) is a set of rules for communicating on a network. IPv4, the fourth set of these rules, is the one used by the United States Army. While the latest internet protocol version is six (IPv6), it is currently not widely adopted.

IPv4 dictates how information is passed from one network component to another. One IPv4 rule is that all networked devices require a unique IP address.

An IP address is a unique numeric value given to each device on a network. This number represents the location of a device on the internet. IP packets (data that is moved along the network) have IP addresses within them so routers know where to send the packet.

Terminology

Before going further in this lesson let’s review some terminology that may be new to you.

IP Address - A unique number of four parts each eight bits in length that is assigned to one host or interface in a network.

Broadcast IP - Last IP address in a network that represents all the devices in the network but it cannot be used to identify a single host.

Classes - The five groups of IP addresses used in classful networks.

Host Identifier - The portion of an IP address that represents a networked device.

Interface - A connection between two network components.

Octets - An eight bit section of an IP address.

Packets - Data traveling through a network.

Network IP - First IP address in a network and cannot be used to represent a single host.

Routers - Device that moves packets between Local Area Networks to the correct network IP address.

Multicast - Transmission of information from one host to several but not all hosts.

Subnet - Portion of a subdivided class A, B, or C network.

Subnet Mask - A 32 bit number that describes the format of an IP address by representing the combined network and subnet bits with 1s and host bits with 0s.

IP Address Format

The IP address can be written in binary or decimal. If written in binary, there are always 32 characters, and the values used for each bit are either zero (0) or one (1).

When written in binary, the 32 digits are broken up into 8 bit segments, known as octets, which are separated by a period. From left to right, they are titled first, second, third, and fourth octet.

An IP address looks like this 11000011.11100001.001010.00000111 to a computer. Notice that if I count the digits, there are 32 of them. Each one of these digits is called a bit. So there are 32 bits in a IPv4 address (I will now call this an "IP"). Notice that there are 4 sets of these bits. Each one of these sets is called a byte. There are 8 bits in a byte. Since there are 8 bits in a byte we can also call the byte an octet. "Oct "means 8 in Latin, so that makes sense. Now we can say that the IPv4 address is made of 4 octets. We need to know that because we are going to play with these octets a lot in subnetting.

An example IPv4 address in binary is shown below.

11000011	.	1100001	.	00001010	.	11100111
1st Octet		2nd Octet		3rd Octet		4th Octet

Decimal Value of Binary Numbers

Each position in an octet has a corresponding decimal value, which increases from right to left. The rightmost bit has a value of 2^0, the bit to the immediate left of it has a value of 2^1, and so on.

See the table for a breakdown of each position's value.

Position in Octet	8	7	6	5	4	3	2	1
Equation	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Decimal Value	128	64	32	16	8	4	2	1

Positions within an octet that have a value of one (1) are considered turned on, while positions in an octet with a value of zero (0) are considered turned off. For each bit in an octet that has a binary value of one, you add the corresponding decimal values to determine the octets decimal value. For example, let's examine the first octet of the IP Address we used earlier:

11000011.11100001.00001010.11100111

Since we are human and do not speak in 1 and 0, we need a way to express what each of these octets numerically represents. For instance, the IP I wrote above in a computer language called binary, would be seen as 195.225.10.7 in a language called humans call decimal. You need to know this because we are going to switch between the two languages a lot.

In the table below, every place the first octet has a value of one (1) is highlighted. It also highlights the corresponding decimal value of the positions that are turned on.

To determine the decimal value of this octet, we add the decimal values for each position with a one (1). In this case, the values are 128, 64, 2, and 1. Adding these values equals 195.

Decimal Value	128	64	32	16	8	4	2	1
Example Octet	1	1	0	0	0	0	1	1
Decimal Value of Octet	**128 + 64 + 2 + 1 = 195**							

Octet Range

Minimum Decimal Value of an Octet
If all of the values in an octet were 0, then the decimal value of the octet would be zero.

Decimal Value	128	64	32	16	8	4	2	1
Binary Value in Example Octet	0	0	0	0	0	0	0	0
Decimal Value of Octet	0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 = 0							

Maximum Decimal Value of an Octet
If all of the values in an octet were 1 (all positions turned on), then decimal value of the octet would be 255 (128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255).

Decimal Value	128	64	32	16	8	4	2	1
Binary Value in Example Octet	1	1	1	1	1	1	1	1
Decimal Value of Octet	128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255							

Therefore, an octet can have a decimal value in the range of 0 to 255.

Classful Networks

A classful network is a network addressing architecture that was created in 1981. In classful networks, IP addresses were categorized into five classes, classes A, B, C, D, and E. A, B, and C were widely used, while the use of classes D and E was reserved.

All classes were assigned a range of unique IP addresses. See the table for how IP addresses were allocated for Classes A, B, and C.

Class	Start IP Address	End IP Address
A	1.0.0.0	127.255.255.255
B	128.0.0.0	191.255.255.255
C	192.0.0.0	223.255.255.255

Network Masks

For Classful networks, an IP Address is broken into two sections, a Network ID portion and a Host ID portion. A network mask is a number which specifies what portion of an IP address belongs to the network and what portion belongs to the host.

A network mask can be written in binary for computers or decimal for humans using the same format as an IP address.

Expressing the network mask in binary shows you what portion of the IP address belong to the Network ID, and what portion belongs to the Host ID.

The portion of the network mask with a value of a one is for the Network ID, while the portion with values of zeros belongs to the Host ID. There is a different network mask for classes A, B, and C.

Class A

Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
Network Mask	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Type	Network ID								Host ID																							

This table shows how the IP address is broken up for Class A networks.

This decimal value in the first octet of the IP address is used to identify the network ID, decimal values in the remaining octets are for the host IDs. When you add the decimal values for all positions that are turned on it shows that the network mask for Class A networks is 255.0.0.0.

There are 128 Class A networks.

Class B

Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
Network Mask	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Type				Network ID															Host ID													

This table shows how the IP address is broken up for Class B networks. In Class B, the first two octets identify the network ID and the last two identify the Host ID.

When you add the decimal values for all positions that are turned on it shows that the network mask for Class B networks is 255.255.0.0.

There are 16, 384 Class B networks with 65,534 host IDs per network.

Class C

Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
Network Mask	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Type				Network ID															Host ID													

This table shows how the IP address is broken up for Class C networks. In Class C, the first three octets identify the network ID and the last octet identifies the Host ID.

When you add the decimal values for all positions that are turned on it shows that the network mask for Class C networks is 255.255.255.0.

There are 2,097,152 Class C networks and there are 256 host IDs available per network.

Let’s return to our example IP address 195.255.10.231, which is a Class C network. Recall the network mask for Class C is 255.255.255.0. Writing the network mask in binary and stacking them shows how the Network and Host IDs are allocated.

To find the network ID, the total of the values in the IP address that match a one in the network mask are used for the Network ID. The value of zero in the network mask corresponds to the portion of the IP address that represents the Host ID.

So in this example, the first three octets identify the Network ID, resulting in a Network ID of 195.255.10.0, and the final octet identifies the Host ID of 231 so that the IP address of the Host is 195.255.10.231.

Classic C Network Mask

	Octet 1								Octet 2								Octet 3								Octet 4							
Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
IP Address	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	1	0	1	0	1	1	1	0	0	1	1	1
Network Mask	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
Type	Network ID																								Host ID							

Example Network ID & Host ID

IP Address	195	225	10	231
Type	Network ID			Host ID

Classless Networks

While classful networks use one or more complete octets to assign the network ID, a classless network uses portions of an octet to create a sub-divided network (or subnet).

With classless networks, when someone gives you a new IP address, it consists of the IP address and the subnet mask. The subnet mask is used to allocate a portion of a Host ID's octet to create a sub-network ID.

Network ID - The Network ID portion of the IP address consists of octets that match the ones in the subnet mask.

Subnet ID - The octet that contains the values of both ones and zeros identifies the subnet. The ones bits represent the subnet ID.

Host ID - The portions of the subnet mask with the value of zero correspond to the Host ID.

For example, consider the IP address from earlier that had a default Class C subnet mask of 255.255.255.0. Now let's give it a subnet mask of 255.255.255.192.

<table>
<tr><th></th><th colspan="8">Octet 1</th><th colspan="8">Octet 2</th><th colspan="8">Octet 3</th><th colspan="8">Octet 4</th></tr>
<tr><td>Decimal Value</td><td>128</td><td>64</td><td>32</td><td>16</td><td>8</td><td>4</td><td>2</td><td>1</td><td>128</td><td>64</td><td>32</td><td>16</td><td>8</td><td>4</td><td>2</td><td>1</td><td>128</td><td>64</td><td>32</td><td>16</td><td>8</td><td>4</td><td>2</td><td>1</td><td>128</td><td>64</td><td>32</td><td>16</td><td>8</td><td>4</td><td>2</td><td>1</td></tr>
<tr><td>IP Address</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td>Network Mask</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Type</td><td colspan="24">Network ID</td><td colspan="2">Subnet</td><td colspan="6">Host ID</td></tr>
</table>

Classless Inter-Domain Routing (CIDR)

The subnet is so important, and humans do not like writing much, so they created a standard way to shorten the IP and subnet mask combination - Classless Inter Domain Routing (CIDR) notation. We just count the number of 1s in the subnet mask and write that number after a "/" symbol.

CIDR is a method to shorten IP address and subnet mask.

Recall our example has an IP address of 195.225.10.231 and Subnet Mask of 255.255.255.194. The table shows our subnet mask converted to binary. To convert this to CIDR, count the number of ones in the Subnet Mask when written in binary. In our example there are 26.

To represent this as CIDR, simply write /26 at the end of the IP address, resulting in 195.225.10.231 /26.

	Octet 1								Octet 2								Octet 3								Octet 4							
Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
Subnet Mask	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
	CIDR																															

Determine the Number of Subnets

The total number of subnets is dependent upon the number of bits that were allocated to the subnet.

The formula used to determine the number of subnets is:

$\mathbf{2^x}$

In the formula, **x** is the number of bits allocated to the subnet ID.

In our example subnet mask, 2 bits were assigned to the subnet (the first two spots in the final octet- 11000000).

Replacing **x** with 2 results in 2x2 which equals 4. Therefore, there are 4 subnets in our example. To say this another way, the one Class C network IP was broken up into four different classes of subnets. Now, we can have four separate Local Area Networks.

	Octet 1								Octet 2								Octet 3								Octet 4							
Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
Subnet Mask	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Type	Network ID																								Subnet		Host ID					

The total number of hosts is dependent upon the number of zero bits that were allocated to host IDs.

The formula used to determine the number of usable hots per subnetwork is:

$\mathbf{2^y - 2}$

In the formula, y is the number of bits allocated to the Host IDs.

Also, Host IDs cannot consist of all zeros or all ones. One IP address is reserved for the network and one IP is reserved for broadcasting - that is why you must subtract 2 in the computation.

In our example, 6 bits were assigned to the Host ID. Remember the host bits are zeros. There are 6 zeros in the last octet. The highest position zero host bit has a value of 32. Now, use the formula 2y - 2. See (2 x 32) - 2 = 64 -2 = 62 usable host IPs per subnet.

	Octet 1								Octet 2								Octet 3								Octet 4							
Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
Subnet Mask	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Type	Network ID																								Subnet		Host ID					

Determine the Range of Usable Host IDs for Each Subnet

Usable Host IDs

We just showed there are 4 subnets and 62 usable Host IP addresses per subnet in our example laptop's network. Recall that our laptop has an IP address of 195.225.10.231 and Subnet Mask of 255.255.255.194.

Now let's figure out the range, or entire listing, of usable IP addresses for each subnet.

First IP Address in the First Subnet

Take a look at the following table, which shows our IP Address and Subnet Mask in binary. We set the Subnet and Host ID values to zero to identify the first possible value in the subnet. The first address in the first subnet is equal to the Network ID, 195.255.10.0.

	Octet 1								Octet 2								Octet 3								Octet 4							
Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
IP Address	1	1	0	0	0	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	1	0	1	0	1	1	1	0	0	1	1	1
Subnet Mask	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Type	Network ID																								Subnet		Host ID					

First Usable IP Address in the First Subnet
Since we can't have a Host ID that is all zeros, we turn on the digit related to the value of 1 (see the table below). This shows the first usable Host ID in the first subnet is 195.255.10.1.

	Octet 1								Octet 2								Octet 3								Octet 4							
Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
IP Address	1	1	0	0	0	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
Subnet Mask	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Type	Network ID																								Subnet		Host ID					

Last IP Address in the First Subnet
Now let’s figure out the end of the range of usable IP addresses for the first subnet.

Supplying a value of all ones in the Host ID gives us the values of 32 + 16 + 8 + 4 + 2 + 1, which equals 63. Therefore, the last IP address in the first subnet is 195.255.10.63.

	Octet 1								Octet 2								Octet 3								Octet 4							
Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
IP Address	1	1	0	0	0	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
Subnet Mask	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Type	Network ID																								Subnet		Host ID					

Last Usable IP Address in the First Subnet
Remember, an IP addresses that is all ones is not usable for a Host ID, so we turn on all of the digit except for that which is related to the value of one (see the second table). This results in the values of 32 + 16 + 8 + 4 + 2, which equals 62. This computation shows the last usable IP address in the first subnet is 195.255.10.62.

	Octet 1								Octet 2								Octet 3								Octet 4							
Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
IP Address	1	1	0	0	0	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
Subnet Mask	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Type	Network ID																								Subnet		Host ID					

Determine the Value of the Second Subset
To identify the start of the second subset, we turned on the subnet bit with the lowest value, and leave the remaining subnet and Host ID bits turned off.

For our example, the second subnet begins at 195.255.10.64. This is shown in the table below.

	Octet 1								Octet 2								Octet 3								Octet 4							
Decimal Value	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
IP Address	1	1	0	0	0	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1
Subnet Mask	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
Type	Network ID																								Subnet		Host ID					

Placing ones in all of the Host ID bits gives us 64 + 32 + 16 + 8 + 4 + 2 + 1, which equals 127. Therefore, the subnet ends at 195.255.10.127.

Excluding the Host IDs of all zeroes and all ones shows the range of usable IP addresses for the second subnet is 195.255.10.65 through 195.255.10.126.

Subnet IP Ranges for Example Network
Continuing this process will show the first and last usable IP addresses for the remaining subnets.

This table shows the IP addresses for all of the subnets in our example.

Notice that there are 4 subnetworks, each with 62 usable IP addresses, just like we calculated earlier.

First IP Address in Subnet	First Usable Host IP Address	Last Usable Host IP Address	Last Usable Host IP Address
195.255.10.0	195.255.10.1	195.255.10.62	195.255.10.63
195.255.10.64	195.255.10.65	195.255.10.126	195.255.10.127
195.255.10.128	195.255.10.129	195.255.10.190	195.255.10.191
195.255.10.192	195.255.10.193	195.255.10.254	195.255.10.255

Summary

This lesson introduced you to the fundamentals of Internet Protocol version 4. You learned about the structure of IP Addresses, how they can be represented in binary or decimal, and how to convert them from one format to the other.

You then learned about classful networks, and how an IP address on a classful network determines its network mask.

Finally, you learned about classless networks and how to identify the subnets and usable IP addresses within them.

Next you will perform a capstone exercise to see if you can apply what you have learned. After that, there will be a Lesson Test.

Syllabus

Terminal Learning Objective

ACTION: Determine IP addresses for network components

CONDITION: Without the aid of references

STANDARD: Achieve a score of no less than 80% correct on the lesson test

Enabling Learning Objectives

1. Convert IP addresses

2. Determine IP address for network components on a classful network

3. Determine IP addresses for network components on a classless network