CISCO NETWORKING ACADEMY PROGRAM

Lab 10.3.5a Basic Subnetting – Instructor Version

Objective

- How to identify reasons to use a subnet mask

- How to distinguish between a default subnet mask and a custom subnet mask

- What given requirements determine the subnet mask, number of subnets, and hosts per subnet

- What needs to be understood about useable subnets and useable numbers of hosts

- How to use the ANDing process to determine if a destination IP address is local or remote

- How to identify valid and invalid IP host addresses based on a network number and subnet mask

Background / Preparation

This lab exercise focuses on the basics of IP subnet masks and their use with TCP/IP networks. The subnet mask can be used to split up an existing network into subnetworks, or subnets. Some of the primary reasons for subnetting are the following:

- Reduce the size of the broadcast domains, which creates smaller networks with less traffic

- Allow LANs in different geographical locations to communicate through routers

- Provide improved security by separating one LAN from another

Routers separate subnets, and determine when a packet can go from one subnet to another. Each router a packet goes through is considered a hop. Subnet masks help workstations, servers, and routers in an IP network determine if the destination host for the packet they want to send is on their own network or another network. This lab reviews the default subnet mask and then focuses on custom subnet masks. Custom subnet masks use more bits than the default subnet masks by borrowing these bits from the host portion of the IP address. This creates a three-part address:

- The original network address

- The subnet address made up of the bits borrowed

- The host address made up of the bits left after borrowing some for subnets

Step 1 Review the structure of IP addresses

If an organization has a Class A IP network address, the first octet, or 8 bits, is assigned and does not change. The organization can use the remaining 24 bits to define up to 16,777,214 hosts on its network. This is a lot of hosts. It is not possible to put all of these hosts on one physical network without separating them with routers and subnets.

It is common for a workstation to be on one network or subnet and a server to be on another. When the workstation needs to retrieve a file from the server it will need to use its subnet mask to determine the network or subnet that the server is on. The purpose of a subnet mask is to help hosts and routers determine the network location where a destination host can be found. Refer to the table below to review the following information:

- The IP address classes

- The default subnet masks

- The number of networks that can be created with each class of network address

- The number of hosts that can be created with each class of network address

Address Class	1st Octet Decimal Range	1st Octet High Order Bits	Network/Host ID (N=Network, H=Host)	Default Subnet Mask	Number of Networks	Hosts per Network (Usable Addresses)
A	1 – 126 *	0	N.H.H.H	255.0.0.0	126 ($2^7 - 2$)	16,777,214 ($2^{24} - 2$)
B	128 – 191	10	N.N.H.H	255.255.0.0	16,382 ($2^{14} - 2$)	65,534 ($2^{16} - 2$)
C	192 – 223	110	N.N.N.H	255.255.255.0	2,097,150 ($2^{21} - 2$)	254 ($2^8 - 2$)
D	224 – 239	1110	Reserved for Multicasting			
E	240 – 254	11110	Experimental; used for research			

Class A address 127 cannot be used and is reserved for loopback and diagnostic functions.

Step 2 Review the ANDing process

Hosts and routers use the ANDing process to determine if a destination host is on the same network or not. The ANDing process is done each time a host wants to send a packet to another host on an IP network. In order to connect to a server, the IP address of the server or the host name, such as, http://www.cisco.com, must be known. If the host name is used a Domain Name Server (DNS) will convert it to an IP address.

First, the source host will compare, or AND, its own IP address to its own subnet mask. The result of the ANDing is to identify the network where the source host resides. It will then compare the destination IP address to its own subnet mask. The result of the 2nd ANDing will be the network that the destination host is on. If the source network address and the destination network address are the same, they can communicate directly. If the results are different, they are on different networks or subnets. If this is the case, the source host and the destination host will need to communicate through routers or might not be able to communicate at all.

ANDing depends on the subnet mask. The subnet mask always uses all ones to represent the network, or network + subnet, portion of the IP address. A default subnet mask for a Class C network is 255.255.255.0 or 11111111.11111111.11111111.00000000. This is compared to the source IP address bit for bit. The first bit of the IP address is compared to the first bit of the subnet mask, the second bit to the second, and so on. If the two bits are both ones, the ANDing result is a one. If the two bits are a zero and a one, or two zeros, the ANDing result is a zero. Basically, this means that a combination of 2 ones results in a one, anything else is a zero. The result of the ANDing process is the identification of the network or subnet number that the source or destination address is on.

Step 3 Two Class C networks using the default subnet mask

This example shows how a Class C default subnet mask can be used to determine which network a host is on. A default subnet mask does not break an address into subnets. If the default subnet mask is used, the network is not being subnetted. Host X, the source on network 200.1.1.0 has an IP address of 200.1.1.5. It wants to send a packet to Host Z, the destination on network 200.1.2.0 and has an IP address of 200.1.2.8. All hosts on each network are connected to hubs or switches and

then to a router. Remember that with a Class C network address, the first 3 octets, or 24 bits, are assigned as the network address. So, these are two different Class C networks. This leaves one octet, or 8 bits for hosts, so each Class C network could have up to 254 hosts:
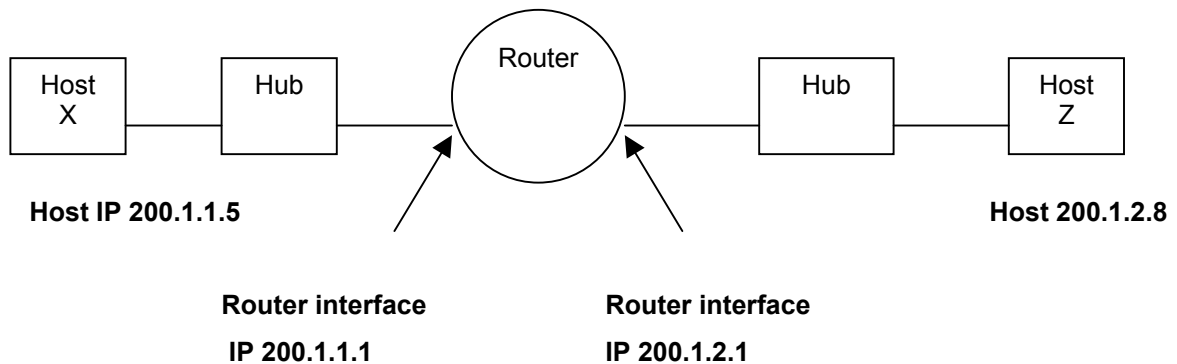
- $2^8 = 256 - 2 = 254$

Source net: 200.1.1.0	**Destination net: 200.1.2.0**
Subnet mask: 255.255.255.0	**Subnet mask: 255.255.255.0**

Host X — Hub — Router — Hub — Host Z

Host IP 200.1.1.5

Host 200.1.2.8

Router interface
IP 200.1.1.1

Router interface
IP 200.1.2.1

The ANDing process helps the packet get from Host 200.1.1.5 on network 200.1.1.0 to Host 200.1.2.8 on network 200.1.2.0 by using the following steps:

1. Host X compares its own IP address to its own subnet mask using the ANDing process.

Host X IP address 200.1.1.5	11001000.00000001.00000001.00000101
Subnet Mask 255.255.255.0	11111111.11111111.11111111.00000000
ANDing Result (200.1.1.0)	11001000.00000001.00000001.00000000

Note: The result of the ANDing process is the network address of Host X, which is 200.1.1.0.

2. Next, Host X compares the IP address of the Host Z destination to its own subnet mask using the ANDing process.

Host Z IP address 200.1.2.8	11001000.00000001.00000010.00001000
Subnet Mask 255.255.255.0	11111111.11111111.11111111.00000000
ANDing Result (200.1.2.0)	11001000.00000001.00000010.00000000

Note: The result of the ANDing process is the network address of Host Z, which is 200.1.2.0.

Host X compares the ANDing results from Step 1 and the ANDing results from Step 2, and notes they are different. Host X now knows that Host Z is not in its local-area network (LAN). Therefore, it must send the packet to its default gateway, which is the IP address of the router interface of 200.1.1.1 on network 200.1.1.0. The router then repeats the ANDing process to determine which router interface to send the packet out to.

Step 4 One Class C network with subnets using a custom subnet mask

This example uses a single Class C network address (200.1.1.0) and shows how a Class C custom subnet mask can be used to determine which subnetwork (or subnet) a host is on and to route packets from one subnetwork to another. Remember that with a Class C network address, the first 3 octets, or 24 bits are assigned as the network address. This leaves one octet, or 8 bits, for hosts. So, each Class C network could have up to 254 hosts:

- 2^8 = 256 – 2 = 254

Perhaps less than 254 hosts, workstations and servers combined, are desired on one network. This could be for security reasons or to reduce traffic. It can be done by creating two subnetworks and separating them with a router. This will create smaller independent broadcast domains and can improve network performance and increase security. This is possible because these subnetworks will be separated by one or more router. Assume at least two subnetworks will be needed and that there will be at least 50 hosts per subnetwork. Because there is only one Class C network address, only 8 bits in the fourth octet are available for a total of 254 possible hosts. Therefore, a custom subnet mask must be created. The custom subnet mask will be used to borrow bits from the host portion of the address. The following steps help accomplish this:

1. The first step to subnetting is to determine how many subnets are needed. In this case, its two subnetworks. To see how many bits should be borrowed from the host portion of the network address, add the bit values from right to left until the total is equal to or greater than the number of subnets needed. Because two subnets are needed, add the one bit and the two bit, which equals three. This is greater than the number of subnets needed. To remedy this, borrow at least two bits from the host address starting from the left side of the octet that contains the host address.

Network address: 200.1.1.0

4th octet Host address bits:	1	1	1	1	1	1	1	1
Host address bit values (from right)	128	64	32	16	8	4	**2**	**1**

Add bits starting from the right side, the 1 and the 2, until the sum is greater than the number of subnets needed.

> **Note:** An alternate way to calculate the number bits to be borrowed for subnets is to take the number of bits borrowed to the power of 2. The result must be greater than the number of subnets needed. As an example if 2 bits are borrowed the calculation is two to the second power, which equals four. Since the number of subnets needed is two this should be adequate.

2. After we know how many bits to borrow, we take them from the left side of the of the host address, the 4th octet. Every bit borrowed from the host address bit leaves fewer bits for the hosts. Even though the number of subnets is increased, the number of hosts per subnet is decreased. Because two bits need to be borrowed from the left side, that new value must be shown in the subnet mask. The existing default subnet mask was 255.255.255.0 and the new custom subnet mask is 255.255.255.192. The 192 results from adding the first two bits from the left, 128 + 64 = 192. These bits now become 1s and are part of the overall subnet mask. This leaves 6 bits for host IP addresses or 2^6 = 64 hosts per subnet.

4th Octet borrowed bits for subnet:	**1**	**1**	0	0	0	0	0	0
Subnet bit values: (from left side)	**128**	**64**	32	16	8	4	2	1

With this information, the following table can be built. The first two bits are the subnet binary value.

The last 6 bits are the host bits. By borrowing 2 bits from the 8 bits of the host address 4 subnets, 2^2, with 64 hosts each, can be created. The 4 networks created are as follows:

- The 200.1.1.0 network

- The 200.1.1.64 network

- The 200.1.1.128 network

- The 200.1.1.192 network

The 200.1.1.0 network is considered unusable, unless the networking device supports the IOS command `ip subnet-zero`, which allows using the first subnet.

Subnet No.	Subnet Bits Borrowed Binary Value	Subnet Bits Decimal Value	Host Bits Possible Binary Values (Range) (6 Bits)	Subnet/Host Decimal Range	Useable?
0 Subnet	00	0	000000–111111	0–63	No
1st Subnet	01	64	000000–111111	64–127	Yes
2nd Subnet	10	128	000000–111111	128–191	Yes
3rd Subnet	11	192	000000–111111	192–254	No

Notice that the first subnet always starts at 0 and, in this case, increases by 64, which is the number of hosts on each subnet. One way to determine the number of hosts on each subnet or the start of each subnet is to take the remaining host bits to the power of 2. Because we borrowed two of the 8 bits for subnets and have 6 bits left, the number of hosts per subnet is 2^6 or 64. Another way to figure the number of hosts per subnet or the increment from one subnet to the next is to subtract the subnet mask value in decimal, 192 in the fourth octet, from 256, which is the maximum number of possible combinations of 8 bits. This equals 64. This means start at 0 for the first network and add 64 for each additional subnetwork. For example, if the second subnet is used, the 200.1.1.64 network cannot be used for a host ID since the network ID of the 64 subnet has all zeros in the host portion.

Another common way to represent a subnet mask, is the use of the "slash/number" (/#) where the # following the slash is the number of bits used in the mask (network and subnet combined). As an example, a Class C network address such as 200.1.1.0 with a standard subnet mask (255.255.255.0) would be written as 200.1.1.0 /24, indicating that 24 bits are used for the mask. The same network, when subnetted by using two host bits for subnets, would be written as 200.1.1.0 /26. This indicates that 24 bits are used for the network and 2 bits for the subnet. This would represent a custom subnet mask of 255.255.255.192 in dotted decimal format.

A Class A network of 10.0.0.0 with a standard mask (255.0.0.0) would be written as 10.0.0.0 /8. If 8 bits (the next octet) were being used for subnets it would be written as 10.0.0.0 /16. This would represent a custom subnet mask of 255.255.0.0 in dotted decimal format. The "slash" number after the network number is an abbreviated method of indicating the subnet mask being used.

Step 5 Use the following information and the previous examples to answer the following subnet-related questions

A company has applied for and received a Class C network address of 197.15.22.0. The physical network is to be divided into 4 subnets, which will be interconnected by routers. At least 25 hosts will be needed per subnet. A Class C custom subnet mask needs to be used and a router is needed between the subnets to route packets from one subnet to another. Determine the number of bits that need to be borrowed from the host portion of the network address and the number of bits that will be left for host addresses.

Note: There will be 8 possible subnets, of which 6 can be used.

Fill in the following table and answer the following questions:

Subnet No.	Subnet Bits Borrowed Binary Value	Subnet Bits Decimal and Subnet No.	Host Bits Possible Binary Values (Range) (5 Bits)	Subnet/Host Decimal Range	Use?
0 Subnet	000	0	00000-11111	0-31	No
1st Subnet	001	32	00000-11111	32-63	Yes
2nd Subnet	010	64	00000-11111	64-95	Yes
3rd Subnet	011	96	00000-11111	96-127	Yes
4th Subnet	100	128	00000-11111	128-159	Yes
5th Subnet	101	160	00000-11111	160-191	Yes
6th Subnet	110	192	00000-11111	192-223	Yes
7th Subnet	111	224	00000-11111	224-255	No

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Use the table just developed to help answer the following questions:

1. Which octet(s) represent the network portion of a Class C IP address? First three octets

2. Which octet(s) represent the host portion of a Class C IP address? Last octet

3. What is the binary equivalent of the Class C network address in the scenario? **197.15.22.0**

    Decimal network address: 197 15 22 0

    Binary network address: 11000101 00001111 00010110 00000000

4. How many high-order bits were borrowed from the host bits in the fourth octet? 3

5. What subnet mask must be used? Show the subnet mask in decimal and binary.

    Decimal subnet mask: 255 255 255 224

    Binary subnet mask: 11111111 11111111 11111111 11100000

6. What is the maximum number of subnets that can be created with this subnet mask? 8

7. What is the maximum number of useable subnets that can be created with this mask? 6

8. How many bits were left in the fourth octet for host IDs? 5

9. How many hosts per subnet can be defined with this subnet mask? 30 usable

10. What is the maximum number of hosts that can be defined for all subnets with this scenario? Assume the lowest and highest subnet numbers and the lowest and highest host ID on each subnet cannot be used. 180 (6 usable subnets x 30 usable hosts per subnet)

11. Is 197.15.22.63 a valid host IP address with this scenario? No

12. Why or why not? It is a broadcast address.

13. Is 197.15.22.160 a valid host IP address with this scenario? No

14. Why or why not? It is a subnet ID address.

15. Host A has an IP address of 197.15.22.126. Host B has an IP address of 197.15.22.129. Are these hosts on the same subnet? No

Why? Referencing the table above, 197.15.22.126 belongs to the 3rd subnet, while 197.15.22.129 belongs to the next subnet, the 4th.