INFO 3605
Fundamentals of LAN Technologies
Week 03 IPv4 Subnetting

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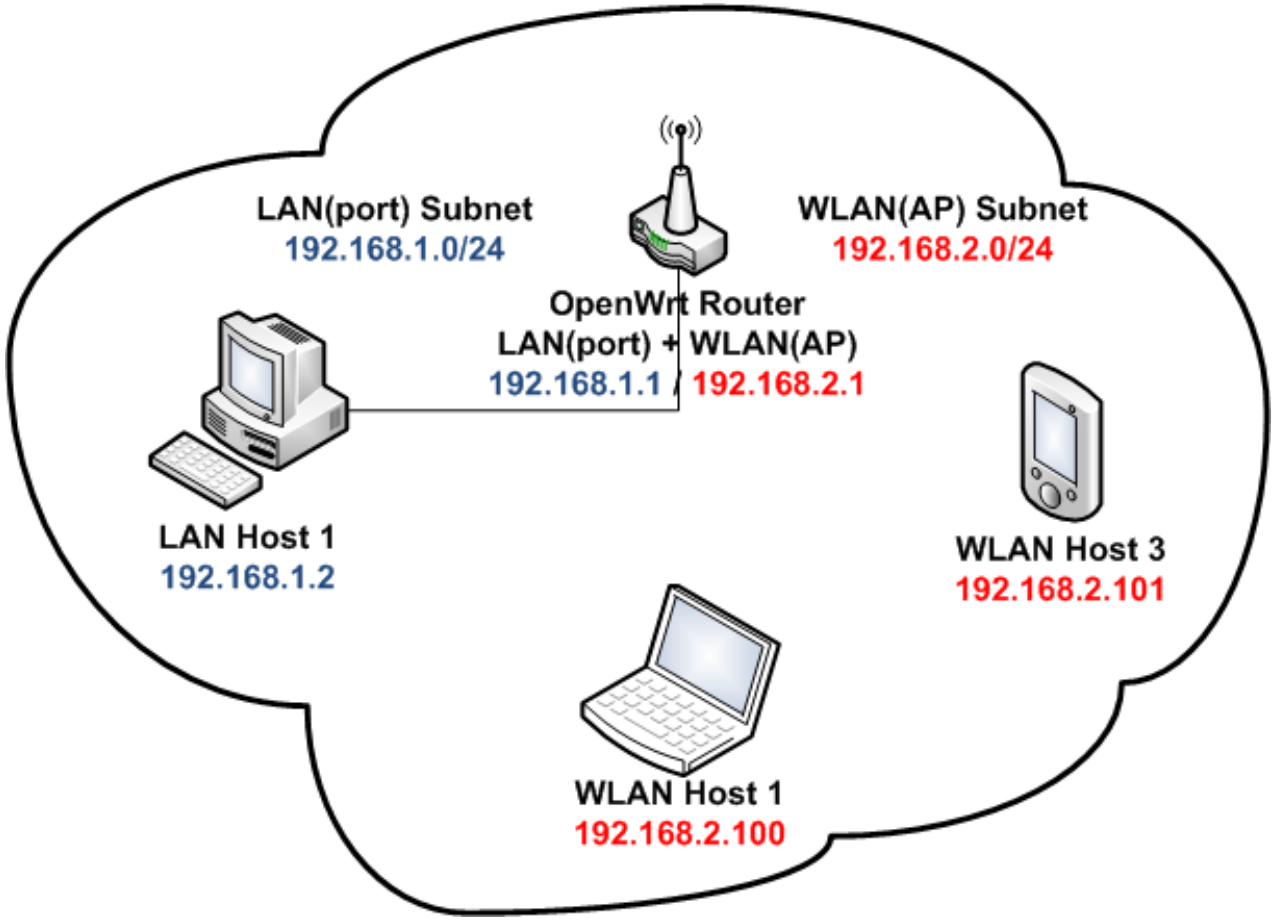
Based on Chapter 4 of Odom, Wendell. *CCENT/CCNA ICND1 100-105 official cert guide*. Indianapolis, IN: Cisco Press, 2016.

Different networks at home

- You may want to have a guest network for your visitors for Internet access only, but don't want them accessing your local computers.



Objectives

- Understand the reasons for subnetting.
- Describe the subnetting process.
- Ability to divide a network into subnetworks.

Some Review Questions

- Host A is a PC, connected to switch SW1 and assigned to VLAN 1. Which of the following are typically assigned an IP address in the same subnet as host A? (Choose two answers.)
  a. The local router's WAN interface
  b. The local router's LAN interface
  c. All other hosts attached to the same switch
  d. Other hosts attached to the same switch and also in VLAN 1

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Some Review Questions

- Why does the formula for the number of hosts per subnet ($2^H - 2$) require the subtraction of two hosts?
  - **a.** To reserve two addresses for redundant default gateways (routers)
  - **b.** To reserve the two addresses required for DHCP operation
  - **c.** To reserve addresses for the subnet ID and default gateway (router)
  - **d.** To reserve addresses for the subnet broadcast address and subnet ID

Some Review Questions

- Why does the formula for the number of hosts per subnet ($2^H - 2$) require the subtraction of two hosts?
  a. To reserve two addresses for redundant default gateways (routers)
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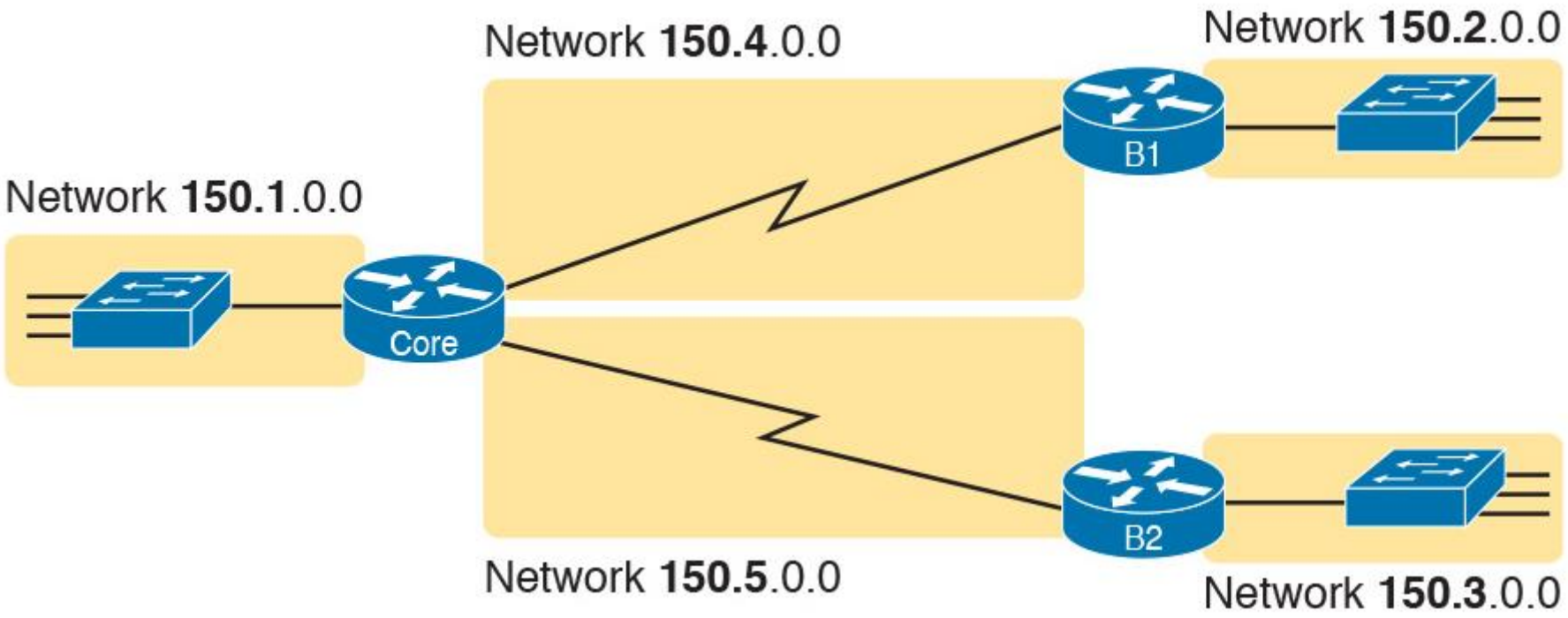
  c. To reserve addresses for the subnet ID and default gateway (router)
  d. To reserve addresses for the subnet broadcast address and subnet ID

IP Subnetting

- Subnetting defines methods of further subdividing the IPv4 address space into groups that are smaller than a single IP network.
- IP subnetting is a flexible way to take a single Class A, B or C IP network and further subdivide it into smaller groups of IP addresses.
  - subnet is just shorthand for subdivided network.
- Subnetting allows you to use fewer IP addresses.

IP Subnetting

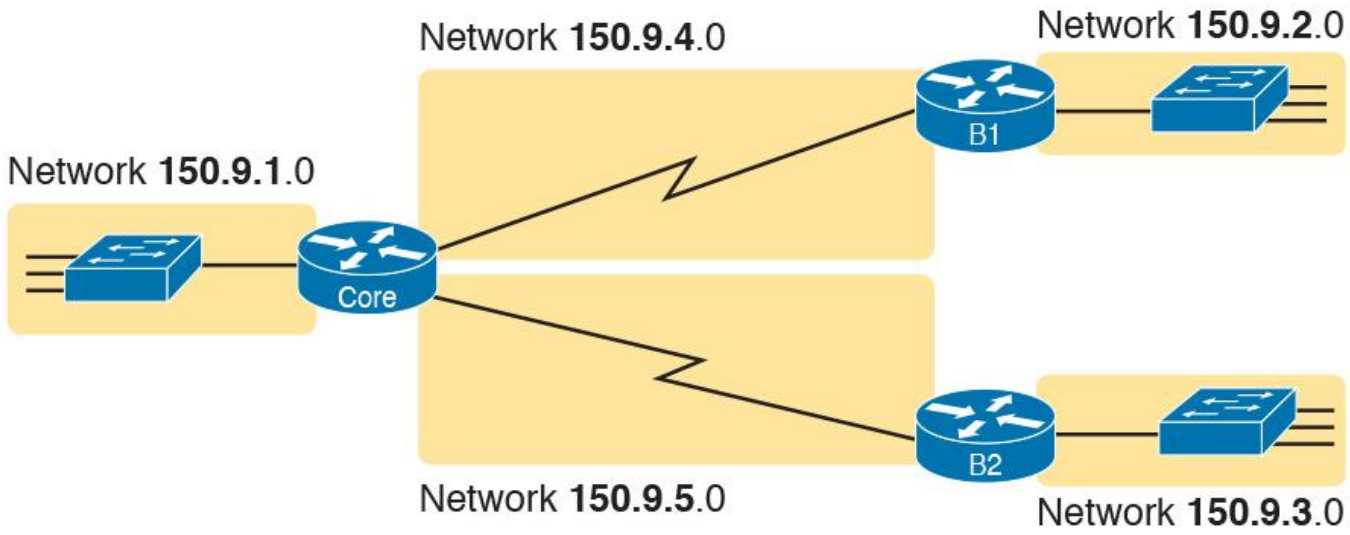
- Example That Uses Five Class B Networks



IP Subnetting – Splitting up a Classful network

- In this case, take a classful B subnet of 150.9.Y.X and split it into 5 separate networks
- Each network will be 254 addresses in size

- We will initially have them listed as:
  - 150.9.1.X
  - 150.9.2.X
  - 150.9.3.X
  - 150.9.4.X
  - 150.9.5.X



Why we cannot use these IP addresses on their own?

- Entering 150.9.1.1 on a device alone,
  - we [the computer] cannot determine which part is the network portion
    - (same value for all hosts on the same network)
  - Or the host portion
    - (different values to ensure each host has a unique IP address)

How do we solve the issue?

- The use of subnet masks

- Together with the IP address, the subnet mask can then tell the computer
  - which portion should be the same → hosts on the same network
  - Which portion should be unique → individual hosts

- They take the form of a group of contiguous 1's, then the remainder of contiguous 0's
  - E.g. 11111111.11111111.11111111.00000000
  - and its decimal equivalent is 255.255.255.0

So we have a mask, what next?

- Apply this mask by performing a bitwise **AND** operation to the IP address in bits.
- E.g. 150.9.1.1 → 10010110.00001001.00000001.00000001
- Mask of 255.255.255.0 → 11111111.11111111.11111111.00000000

10010110.00001001.00000001.0000000**1**

AND

11111111.11111111.11111111.00000000

10010110.00001001.00000001.0000000**0** **← Result**

So we have a mask, what next?

- Convert our result (10010110.00001001.00000001.00000000) back to decimal = 150.9.1.0
- 150.9.1.0 is our **Network** address.
- Any IP address that's ANDed with 255.255.255.0 and results in 150.9.1.0 means they are on the same network.

- → which means you can communicate with that device directly
  - via ARP request, get the MAC address, send data to that MAC address, etc.

AND operation with another IP address

- What if we want to communicate with another IP address,
- E.g. Host is 150.9.2.1 → 10010110.00001001.00000010.00000001
- Still use our mask of 255.255.255.0 → 11111111.11111111.11111111.00000000

10010110.00001001.00000010.00000001

AND

11111111.11111111.11111111.00000000

10010110.00001001.00000010.00000000 **← Result**

Is it the same as our network address?

- TLDR; No

- 10010110.00001001.00000001.00000000 ← **my host network address**
- 10010110.00001001.00000010.00000000 ← **Destination host network address**

- What do we do now?
- Wrap the packet up and send it to our default gateway.

Back to subnetting our 150.9.X.X network

- So, with our 150.9.X.X network, when we split it up, what would be the subnet mask?
- We need a mask of 255.255.255.0

- 150.9.1.X mask of 255.255.255.0.
  - A host of 150.9.1.10 trying to send to a host with IP address of 150.9.2.11 WILL need to go to the default gateway as their network address will not match.
- 150.9.2.X mask of 255.255.255.0
- 150.9.3.X mask of 255.255.255.0
- 150.9.4.X mask of 255.255.255.0
- 150.9.5.X mask of 255.255.255.0

Back to subnetting our 150.9.X.X network

- What if we used a subnet mask of 255.255.0.0 instead?
- When applied to the IP address, an IP with 150.9.X.X will be on the same network → which means no gateway → and the packet never crosses the router/gateway.

- The subnet mask defines your network address and the hosts that belong to a particular network.

Subnetting a Class C (192.168.123.X) network

- Using 192.168.123.1 to 192.168.123.254 for 150 hosts
- Can be divided into 4 subnets
- The number of networks increase but the number of hosts decrease
- The subnet mask 255.255.255.192 gives 4 networks with 62 hosts each
  - Why 62 and not 64?
  - 1 address is for the network the other is the broadcast address for that network
- 255. 255. 255. 192 is the same as 1111111.11111111.1111111.11000000

Subnetting

- The first two digits of the last octet become network addresses, so you get the additional networks
  - **00**000000 (0),
  - **01**000000 (64),
  - **10**000000 (128) and
  - **11**000000 (192).
- The last 6 binary digits can be used for host addresses
  - 2^6 = 64 hosts, actually 62 (1 for network address, 1 for broadcast address)

Subnetting

- So using a subnet mask of 255.255.255.192,
- Your 192.168.123.0 network bbecomes 4 networks:
  - 192.168.123.**0**, -> .00000000
  - 192.168.123.**64**, -> .01000000
  - 192.168.123.**128** and -> .100000000
  - 192.168.123.**192** -> .1100000000
- The corresponding host ranges are:
  - 192.168.123.1-62
  - 192.168.123.65-126
  - 192.168.123.129-190
  - 192.168.123.193-254

These are your networks

Inverse Mask

- Take Subnet Mask and apply XOR to 255.255.255.255
- 255. 255. 255. 192 is the same as 1111111.11111111.1111111.11000000

XOR

- 255. 255. 255. 255 or
- 11111111.11111111.11111111.11111111

128 64 32 16 8 4 2 1

- 00000000.00000000.00000000.00111111 or
- 0. 0. 0. 63

This is your Network Size

Subnetting

- And what is your broadcast address for these networks?
- **Network Address + Inverse Mask = Broadcast Address**
- **Host Range = Network Address + 1 to Broadcast Address -1**

Network	Host Range	Broadcast Address
192.168.123.**0**	192.168.123.1-62	192.168.123.**63**
192.168.123.**64**	192.168.123.65-126	192.168.123.**127**
192.168.123.**128**	192.168.123.129-190	192.168.123.**191**
192.168.123.**192**	192.168.123.193-254	192.168.123.**255**

Subnet Example

- Two addresses:
  - 192.168.123.71 and
  - 192.168.123.133.
- If both are using a class C subnet, will they see one another?
- If you use a subnet mask of 255.255.255.192, will they see one another?
- 192.168.123.71 belongs to which network?
- 192.168.123.133 belongs to which network?

Subnet Formula

- Number of subnets = 2^n where n is the number of bits borrowed to make the subnet mask
- Number of hosts = $2^n – 2$ where n is the number of bits in your subnet mask

Binary Mask				Prefix Length	Subnet Mask
11111111	00000000	00000000	00000000	/8	255.0.0.0
11111111	10000000	00000000	00000000	/9	255.128.0.0
11111111	11000000	00000000	00000000	/10	255.192.0.0
11111111	11100000	00000000	00000000	/11	255.224.0.0
11111111	11110000	00000000	00000000	/12	255.240.0.0
11111111	11111000	00000000	00000000	/13	255.248.0.0
11111111	11111100	00000000	00000000	/14	255.252.0.0
11111111	11111110	00000000	00000000	/15	255.254.0.0
11111111	11111111	00000000	00000000	/16	255.255.0.0
11111111	11111111	10000000	00000000	/17	255.255.128.0
11111111	11111111	11000000	00000000	/18	255.255.192.0
11111111	11111111	11100000	00000000	/19	255.255.224.0
11111111	11111111	11110000	00000000	/20	255.255.240.0
11111111	11111111	11111000	00000000	/21	255.255.248.0
11111111	11111111	11111100	00000000	/22	255.255.252.0
11111111	11111111	11111110	00000000	/23	255.255.254.0
11111111	11111111	11111111	00000000	/24	255.255.255.0
11111111	11111111	11111111	10000000	/25	255.255.255.128
11111111	11111111	11111111	11000000	/26	255.255.255.192
11111111	11111111	11111111	11100000	/27	255.255.255.224
11111111	11111111	11111111	11110000	/28	255.255.255.240
11111111	11111111	11111111	11111000	/29	255.255.255.248
11111111	11111111	11111111	11111100	/30	255.255.255.252
11111111	11111111	11111111	11111110	/31	255.255.255.254
11111111	11111111	11111111	11111111	/32	255.255.255.255

http://www.cisco.com/web/about/ac123/ac147/archived_issues/ipj_9-1/ip_addresses.html

Class A Subnet

Network Bits	Subnet Mask	Bits Borrowed	Subnets	Hosts/Subnet
8	255.0.0.0	0	1	16777214
9	255.128.0.0	1	2	8388606
10	255.192.0.0	2	4	4194302
11	255.224.0.0	3	8	2097150
12	255.240.0.0	4	16	1048574
13	255.248.0.0	5	32	524286
14	255.252.0.0	6	64	262142
15	255.254.0.0	7	128	131070
16	255.255.0.0	8	256	65534
17	255.255.128.0	9	512	32766
18	255.255.192.0	10	1024	16382
19	255.255.224.0	11	2048	8190
20	255.255.240.0	12	4096	4094
21	255.255.248.0	13	8192	2046
22	255.255.252.0	14	16384	1022
23	255.255.254.0	15	32768	510
24	255.255.255.0	16	65536	254
25	255.255.255.128	17	131072	126
26	255.255.255.192	18	262144	62
27	255.255.255.224	19	524288	30
28	255.255.255.240	20	1048576	14
29	255.255.255.248	21	2097152	6
30	255.255.255.252	22	4194304	2

http://www.tutorialspoint.com/ipv4/ipv4_subnetting.htm

Class B Subnet

Network Bits	Subnet Mask	Bits Borrowed	Subnets	Hosts/Subnet
16	255.255.0.0	0	0	65534
17	255.255.128.0	1	2	32766
18	255.255.192.0	2	4	16382
19	255.255.224.0	3	8	8190
20	255.255.240.0	4	16	4094
21	255.255.248.0	5	32	2046
22	255.255.252.0	6	64	1022
23	255.255.254.0	7	128	510
24	255.255.255.0	8	256	254
25	255.255.255.128	9	512	126
26	255.255.255.192	10	1024	62
27	255.255.255.224	11	2048	30
28	255.255.255.240	12	4096	14
29	255.255.255.248	13	8192	6
30	255.255.255.252	14	16384	2

http://www.tutorialspoint.com/ipv4/ipv4_subnetting.htm

Class C Subnet

Network Bits	Subnet Mask	Bits Borrowed	Subnets	Hosts/Subnet
24	255.255.255.0	0	1	254
25	255.255.255.128	1	2	126
26	255.255.255.192	2	4	62
27	255.255.255.224	3	8	30
28	255.255.255.240	4	16	14
29	255.255.255.248	5	32	6
30	255.255.255.252	6	64	2

http://www.tutorialspoint.com/ipv4/ipv4_subnetting.htm

IP Address Breakdown

/24 8+8+8 255.255.255.0 256 Hosts	/25 8+8+8+1 255.255.255.128 128 Hosts	/26 8+8+8+2 255.255.255.192 64 Hosts	/27 8+8+8+3 255.255.255.224 32 Hosts	/28 8+8+8+4 255.255.255.240 16 Hosts	/29 8+8+8+5 255.255.255.248 8 Hosts	/30 8+8+8+6 255.255.255.252 4 Hosts
0-127	0-127	0-63	0-31	0-15	0-7	0-3
						4-7
					8-15	8-11
						12-15
				16-31	16-23	16-19
						20-23
					24-31	24-27
						28-31
			32-63	32-47	32-39	32-35
						36-39
					40-47	40-43
						44-47
				48-63	48-55	48-51
						52-55
					56-63	56-59
						60-63
		64-127	64-95	64-79	64-71	64-67
						68-71
					72-79	72-75
						76-79
				80-95	80-87	80-83
						84-87
					88-95	88-91
						92-95
			96-127	96-111	96-103	96-99
						100-103

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/24 8+8+8 255.255.255.0 256 Hosts	/25 8+8+8+1 255.255.255.128 128 Hosts	/26 8+8+8+2 255.255.255.192 64 Hosts	/27 8+8+8+3 255.255.255.224 32 Hosts	/28 8+8+8+4 255.255.255.240 16 Hosts	/29 8+8+8+5 255.255.255.248 8 Hosts	/30 8+8+8+6 255.255.255.252 4 Hosts
0-255		64-127		80-95	80-87	80-83
						84-87
					88-95	88-91
						92-95
				96-111	96-103	96-99
						100-103
					104-111	104-107
						108-111
				112-127	112-119	112-115
						116-119
					120-127	120-123
						124-127
		128-191		128-143	128-135	128-131
						132-135
					136-143	136-139
						140-143
				144-159	144-151	144-147
						148-151
					152-159	152-155
						156-159
				160-175	16-167	160-163
						164-167
					168-175	168-171
						172-175
					176-183	176-179

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	128-255			[illegible]	168-175	168-171
						172-175
				176-191	176-183	176-179
						180-183
					184-191	184-187
						188-191
		192-255		192-207	192-199	192-195
						196-199
					200-207	200-203
						204-207
				208-223	208-215	208-211
						212-215
					216-223	216-219
						220-223
				224-239	224-231	224-227
						228-231
					232-239	232-235
						236-239
				240-255	240-247	240-243
						244-247
					248-255	248-251
						252-255

What do you know now?

- A Class B network needs to be subnetted such that it supports 100 subnets and 100 hosts/subnet. Which of the following answers list a workable combination for the number of network, subnet, and host bits? (Choose two answers.)
  a. Network = 16, subnet = 7, host = 7
  b. Network = 16, subnet = 8, host = 8
  c. Network = 16, subnet = 9, host = 7
  d. Network = 8, subnet = 7, host = 17

What do you know now?

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  b. Network = 16, subnet = 8, host = 8

  c. Network = 16, subnet = 9, host = 7

  d. Network = 8, subnet = 7, host = 17

Summary

- Key facts about subnets.
- Rules about what places in a network topology need a subnet.
- Location of the network, subnet and host parts of an IPv4 address.

End of Lecture 13.1, Further Reading, References

- Odom, Wendell. *CCENT/CCNA ICND1 100-105 official cert guide*. Indianapolis, IN: Cisco Press, 2016.
- http://www.networkworld.com/article/2260776/lan-wan/chapter-1--network-overview.html
- http://support.microsoft.com/kb/164015
- https://www.apnic.net/__data/assets/pdf_file/0020/8147/501302.pdf
- http://www.cisco.com/web/about/ac123/ac147/archived_issues/ipj_9-1/ip_addresses.html
- http://www.tutorialspoint.com/ipv4/ipv4_subnetting.htm