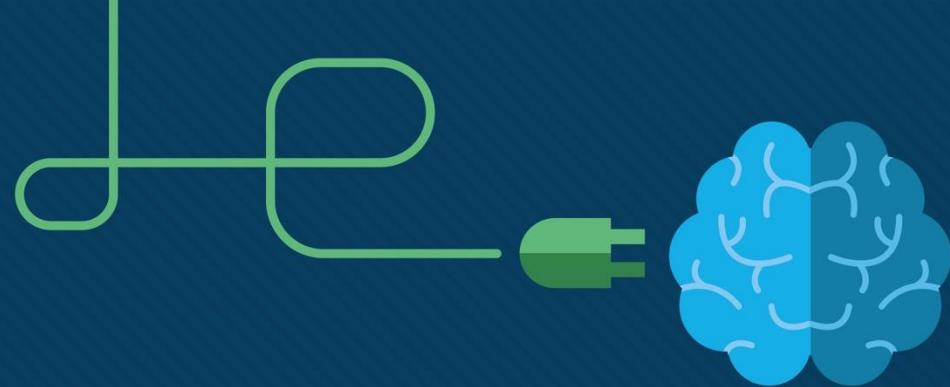


Chapter 8: Subnetting IP Networks

**Introduction to Networks 6.0 Planning
Guide**





Chapter 8:

Subnetting IP Networks

CCNA Routing and Switching
Introduction to Networks v6.0



Chapter 8 - Sections & Objectives

- 8.1 Subnetting an IPv4 Network
 - Implement an IPv4 addressing scheme to enable end-to-end connectivity in a small to medium-sized business network.
 - Explain how subnetting segments a network to enable better communication.
 - Explain how to calculate IPv4 subnets for a /24 prefix.
 - Explain how to calculate IPv4 subnets for a /16 and /8 prefix.
 - Given a set of requirements for subnetting, implement an IPv4 addressing scheme.
 - Explain how to create a flexible addressing scheme using variable length subnet masking (VLSM).
- 8.2 Addressing Schemes
 - Given a set of requirements, implement a VLSM addressing scheme to provide connectivity to end users in a small to medium-sized network.
 - Implement a VLSM addressing scheme.

Chapter 8 - Sections & Objectives (Cont.)

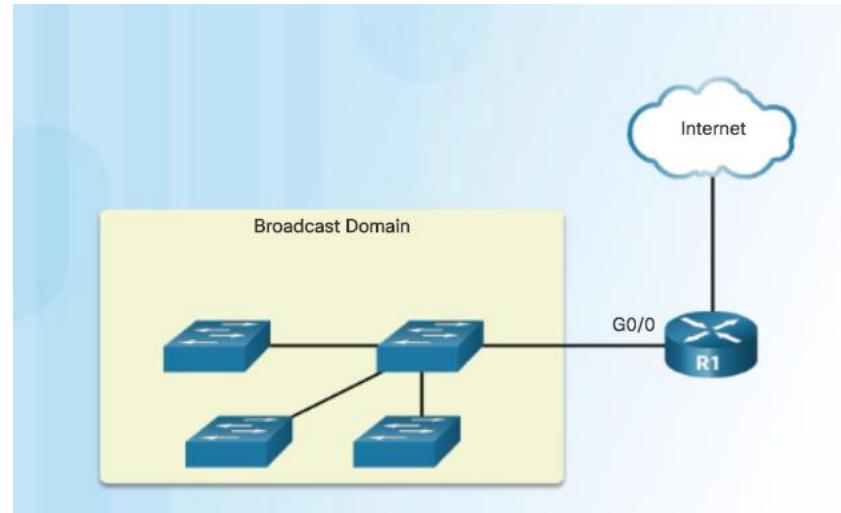
- 8.3 Address Schemes

- Explain design considerations for implementing IPv6 in a business network.
- Explain how to implement IPv6 address assignments in a business network.

8.1 Subnetting an IPv4 Network

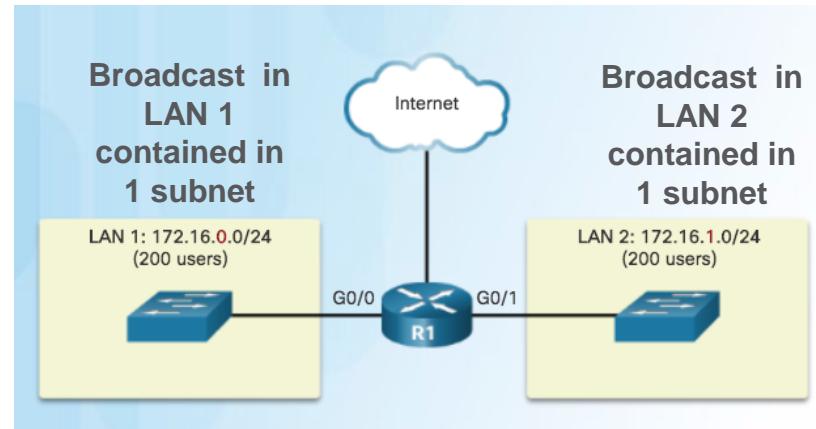
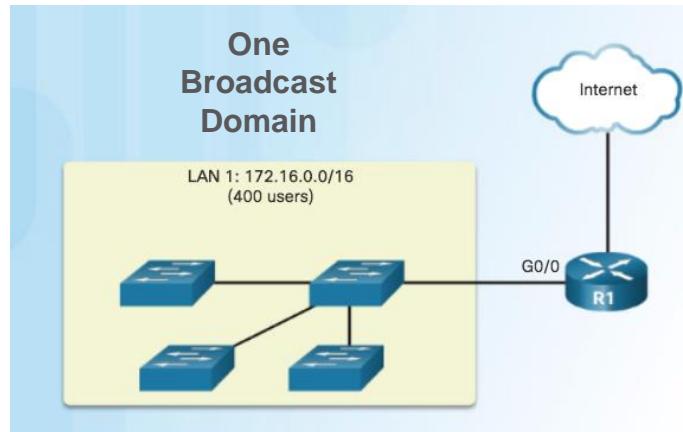
Broadcast Domains

- Devices use broadcasts in an Ethernet LAN to locate:
 - **Other devices** - Address Resolution Protocol (ARP) which sends Layer 2 broadcasts to a known IPv4 address on the local network to discover the associated MAC address.
 - **Services** – Dynamic Host Configuration Protocol (DHCP) which sends broadcasts on the local network to locate a DHCP server.
- Switches propagate broadcasts out all interfaces except the interface on which it was received.



Problems with Large Broadcast Domains

- Hosts can generate excessive broadcasts and negatively affect the network.
 - Slow network operations due to the significant amount of traffic it can cause.
 - Slow device operations because a device must accept and process each broadcast packet.
- Solution: Reduce the size of the network to create smaller broadcast domains. These smaller network spaces are called *subnets*.

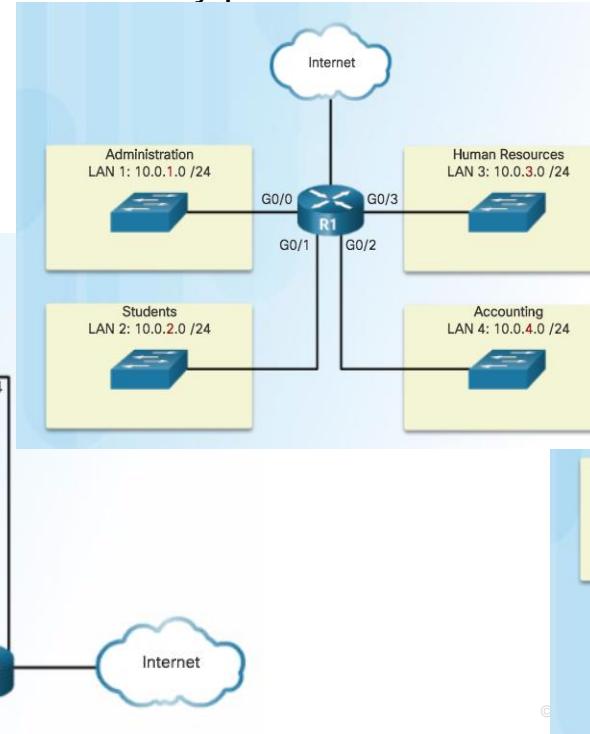
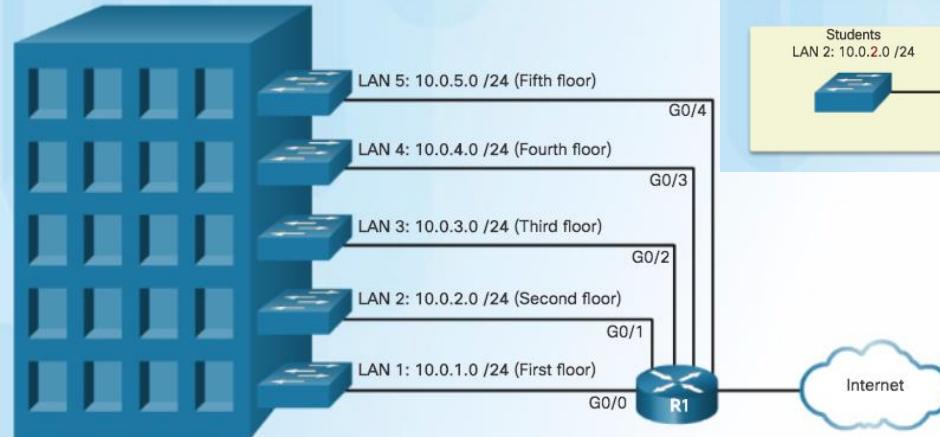


Network Segmentation

Reasons for Subnetting

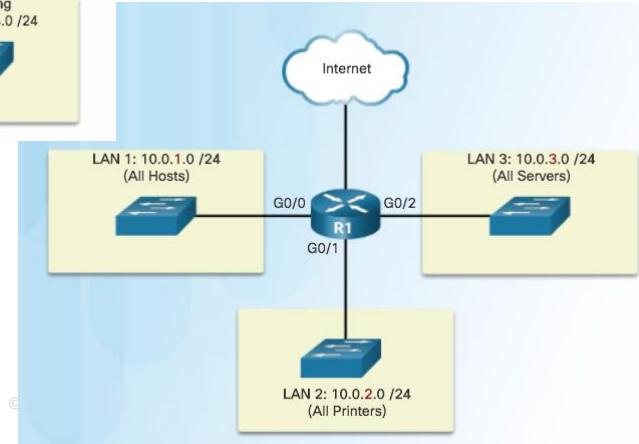
- Reduces overall network traffic and improves network performance.
- Enables an administrator to implement security policies such as which subnets are allowed or not allowed to communicate together.

Subnetting by Location



Communicating between Networks

Subnetting by Device Type



Octet Boundaries

Networks are most easily subnetted at the octet boundary of /8, /16, and /24

Prefix Length	Subnet Mask	Subnet Mask in Binary (n = network, h = host)	# of hosts
/8	255.0.0.0	<code>nnnnnnnn.hhhhhh.hhhhhh.hhhhhh 11111111.00000000.00000000.00000000</code>	16,777,214
/16	255.255.0.0	<code>nnnnnnnn.nnnnnnnn.hhhhhh.hhhhhh 11111111.11111111.00000000.00000000</code>	65,534
/24	255.255.255.0	<code>nnnnnnnn.nnnnnnnn.nnnnnnnn.hhhhhh 11111111.11111111.11111111.00000000</code>	254

- Prefix length and the subnet mask are different ways of identifying the network portion of an address.
- Subnets are created by borrowing host bits for network bits.
- More host bits borrowed, the more subnets that can be defined.

Subnetting on the Octet Boundary

Subnet Address (256 Possible Subnets)	Host Range (65,534 possible hosts per subnet)	Broadcast
<u>10.0.0.0/16</u>	<u>10.0.0.1</u> - <u>10.0.255.254</u>	<u>10.0.255.255</u>
<u>10.1.0.0/16</u>	<u>10.1.0.1</u> - <u>10.1.255.254</u>	<u>10.1.255.255</u>
<u>10.2.0.0/16</u>	<u>10.2.0.1</u> - <u>10.2.255.254</u>	<u>10.2.255.255</u>
<u>10.3.0.0/16</u>	<u>10.3.0.1</u> - <u>10.3.255.254</u>	<u>10.3.255.255</u>
<u>10.4.0.0/16</u>	<u>10.4.0.1</u> - <u>10.4.255.254</u>	<u>10.4.255.255</u>
<u>10.5.0.0/16</u>	<u>10.5.0.1</u> - <u>10.5.255.254</u>	<u>10.5.255.255</u>
<u>10.6.0.0/16</u>	<u>10.6.0.1</u> - <u>10.6.255.254</u>	<u>10.6.255.255</u>
<u>10.7.0.0/16</u>	<u>10.7.0.1</u> - <u>10.7.255.254</u>	<u>10.7.255.255</u>
...
<u>10.255.0.0/16</u>	<u>10.255.0.1</u> - <u>10.255.255.254</u>	<u>10.255.255.255</u>

- Subnetting Network 10.x.0.0/16
- Define up to 256 subnets with each subnet capable of connecting 65,534 hosts.
- First two octets identify the network portion while the last two octets are for host IP addresses.

Subnetting on the Octet Boundary (Cont.)

Subnet Address (65,536 Possible Subnets)	Host Range (254 possible hosts per subnet)	Broadcast
<u>10.0.0.0/24</u>	<u>10.0.0.1 - 10.0.0.254</u>	<u>10.0.0.255</u>
<u>10.0.1.0/24</u>	<u>10.0.1.1 - 10.0.1.254</u>	<u>10.0.1.255</u>
<u>10.0.2.0/24</u>	<u>10.0.2.1 - 10.0.2.254</u>	<u>10.0.1.255</u>
...
<u>10.0.255.0/24</u>	<u>10.0.255.1 - 10.0.255.254</u>	<u>10.0.255.255</u>
<u>10.1.0.0/24</u>	<u>10.1.0.1 - 10.1.0.254</u>	<u>10.1.0.255</u>
<u>10.1.1.0/24</u>	<u>10.1.1.1 - 10.1.1.254</u>	<u>1.1.1.0.255</u>
<u>10.1.2.0/24</u>	<u>10.1.2.1 - 10.1.2.254</u>	<u>10.1.2.0.255</u>
...
<u>10.100.0.0/24</u>	<u>10.100.0.1 - 10.100.0.254</u>	<u>10.100.0.255</u>
...
<u>10.255.255.0/24</u>	<u>10.255.255.1 - 10.255.255.254</u>	<u>10.255.255.255</u>

- Subnetting Network 10.x.x.0/24
- Define 65,536 subnets each capable of connecting 254 hosts.
- /24 boundary is very popular in subnetting because of number of hosts.

Classless Subnetting

Subnetting a /24 Network

Prefix Length	Subnet Mask	Subnet Mask in Binary (n = network, h = host)	# of subnets	# of hosts
/25	255.255.255.128	nnnnnnnn.nnnnnnnn.nnnnnnnn. n hhhhhhh 1 1111111.11111111.11111111. 1 0000000	2	126
/26	255.255.255.192	nnnnnnnn.nnnnnnnn.nnnnnnnn. nn hhhhhhh 1 1111111.11111111.11111111. 11 000000	4	62
/27	255.255.255.224	nnnnnnnn.nnnnnnnn.nnnnnnnn. nnn hhhhh 1 1111111.11111111.11111111. 111 00000	8	30
/28	255.255.255.240	nnnnnnnn.nnnnnnnn.nnnnnnnn. nnnn hhh 1 1111111.11111111.11111111. 1111 0000	16	14
/29	255.255.255.248	nnnnnnnn.nnnnnnnn.nnnnnnnn. nnnnn hh 1 1111111.11111111.11111111. 11111 000	32	6
/30	255.255.255.252	nnnnnnnn.nnnnnnnn.nnnnnnnn. nnnnnn h 1 1111111.11111111.11111111. 111111 00	64	2

Subnets can borrow bits from *any* host bit position to create other masks.

Video Demonstration – The Subnet Mask

Subnetting in Binary

- ANDING

- Convert IP address and Subnet Mask to Binary (line up vertically like an addition problem)
- Logically AND (1 and 1 = 1, all other combinations = 0)
- Result is network address for original IP address

- Classful Subnetting

- Class A /8 255.0.0.0
- Class B /16 255.255.0.0
- Class C /24 255.255.255.0



Video Demonstration – The Subnet Mask (Cont.)

Subnetting 192.168.1.0/24

192	168	1	0
255	255	255	128
11000000	10101000	00000001	00000000
11111111	11111111	11111111	10000000
N	N	N	S n H

Subnet bits = $2^1 = 2$

Host bits = $2^7 = 128 - 2 = 126$

Subnetworks = 2

Subnetting 192.168.1.0/24

192	168	1	68
255	255	255	128
11000000	10101000	00000001	01000100
11111111	11111111	11111111	10000000
11000000	10101000	00000001	00000000
192	168	1	0

192.168.1.0 /25 -----> 192.168.1.127 /25

192.168.1.128 /25 -----> 192.168.1.255 /25

Video Demonstration – Subnetting with the Magic Number

- Magic number technique used to calculate subnets
- Magic number is simply the place value of the last one in the subnet mask
- /25 11111111.11111111.11111111.**1**0000000 magic number = **128**
- /26 11111111.11111111.11111111.**11**000000 magic number = **64**
- /27 11111111.11111111.11111111.**111**00000 magic number = **32**



Video Demonstration – Subnetting with the Magic Number (Cont.)

The Magic Number is the last 1 in Binary

192	168	1	0
255	255	255	224
11000000	10101000	00000001	00000000
11111111	11111111	11111111	11100000
		SN	H

The Magic Number is? 32

192.168.1.0 /27 192.168.1.128 /27
192.168.1.32 /27 192.168.1.160 /27
192.168.1.64 /27 192.168.1.192 /27
192.168.1.96 /27 192.168.1.224 /27

Video Demonstration – Subnetting with the Magic Number (Cont.)

Subnetting 172.16.0.0/16 -->/23			
172	16	0	0
255	255	254	0
10101010	00010000	00000000	00000000
11111111	11111111	1111 1110	00000000
		SN	H
			H

What is the magic number? 2

172.16.0.0 ---- 172.16.1.255 /23

172.16.2.0 /23

172.16.4.0 /23

Subnetting an IPv4 Network

Classless Subnetting Example

192.168.1.0/25 Network

Borrow 1 bit from the host portion of the address.

Original	192.	168.	1.	0	000 0000	1 Network
Mask	255.	255.	255.	0	000 0000	

The borrowed bit value is 0 for the Net 0 address.

Net 0	192.	168.	1.	0	000 0000	2 Subnets
Net 1	192.	168.	1.	1	000 0000	

The new subnets have the SAME subnet mask.

Mask	255.	255.	255.	1	000 0000
------	------	------	------	---	----------

Dotted Decimal Addresses

Borrow 1 bit from the host portion of the address.

Original	192.	168.	1.	0	000 0000	1 Network
Mask	255.	255.	255.	0	000 0000	

192. 168. 1. 0/25

Net 0	192.	168.	1.	0	000 0000	2 Subnets
Net 1	192.	168.	1.	128	000 0000	

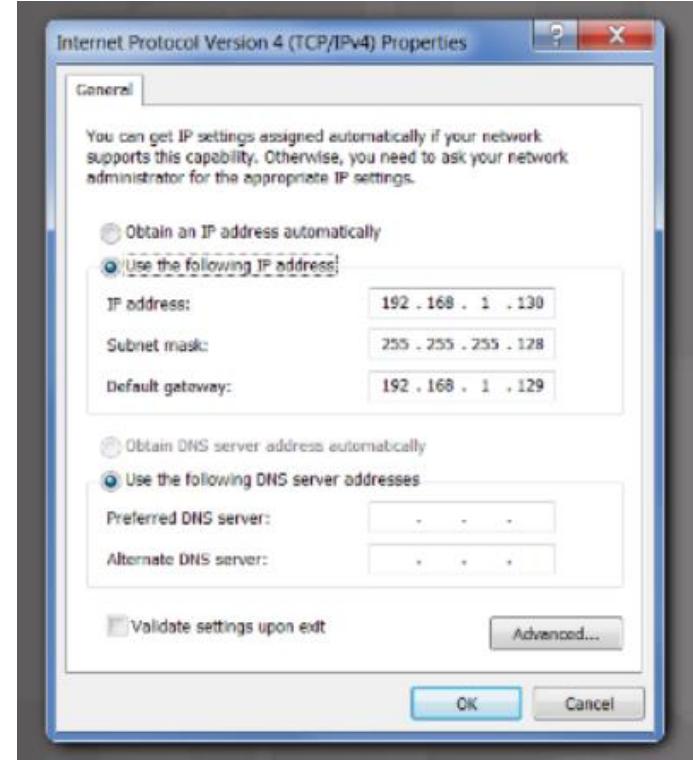
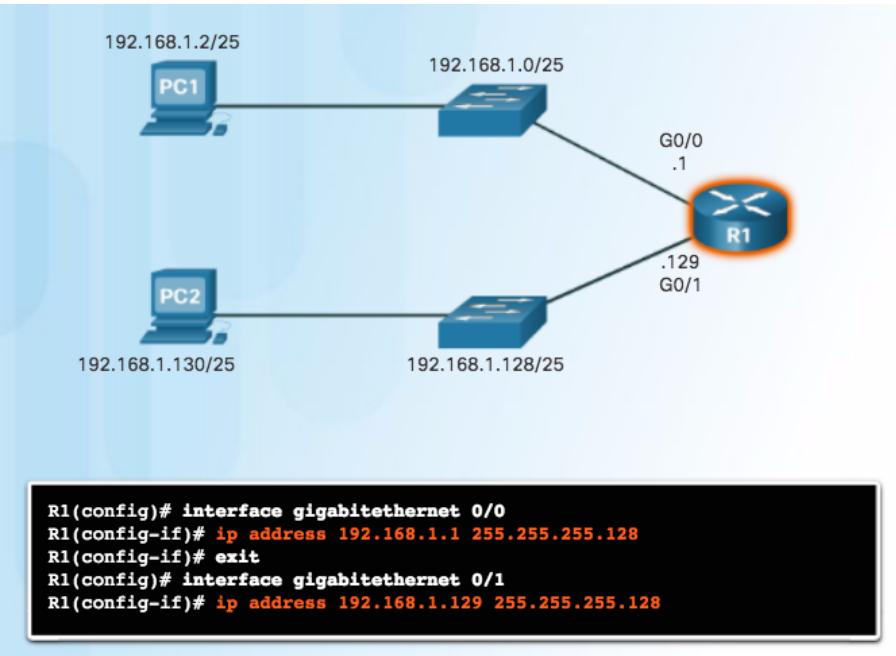
255. 255. 255. 128

Mask	255.	255.	255.	1	000 0000
------	------	------	------	---	----------

Subnetting an IPv4 Network

Creating 2 Subnets

- /25 Subnetting Topology



Subnetting an IPv4 Network

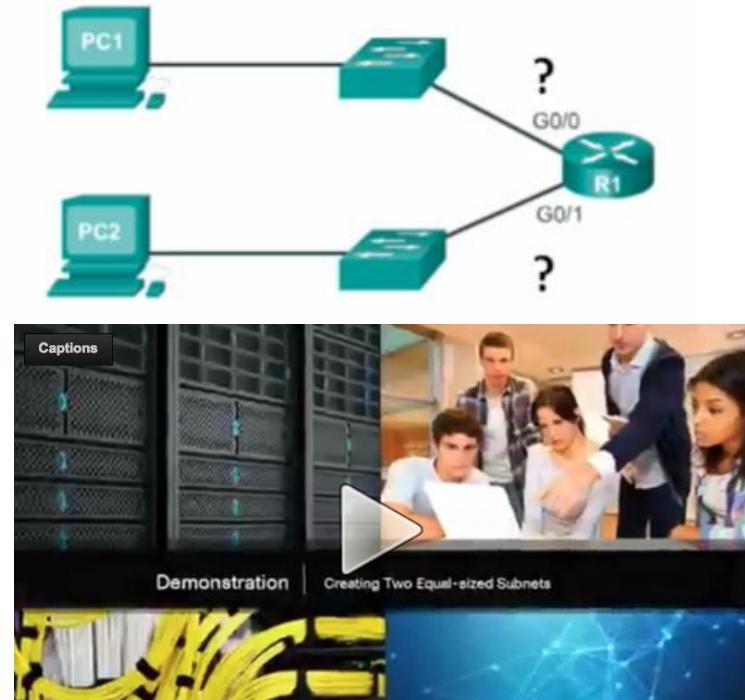
Video Demonstration – Creating Two Equal-sized Subnets (/25)

Create 2 Equal-sized Subnets from 192.168.1.0 /24

- **Subnet Mask** - 11111111.11111111.11111111.**1**0000000

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1
1	0	0	0	0	0	0	0

- Magic Number = **128**
- 192.168.1.0 /25 (**start at 0**)
- 192.168.1.128 /25 (**Add 128**)



Subnetting an IPv4 Network

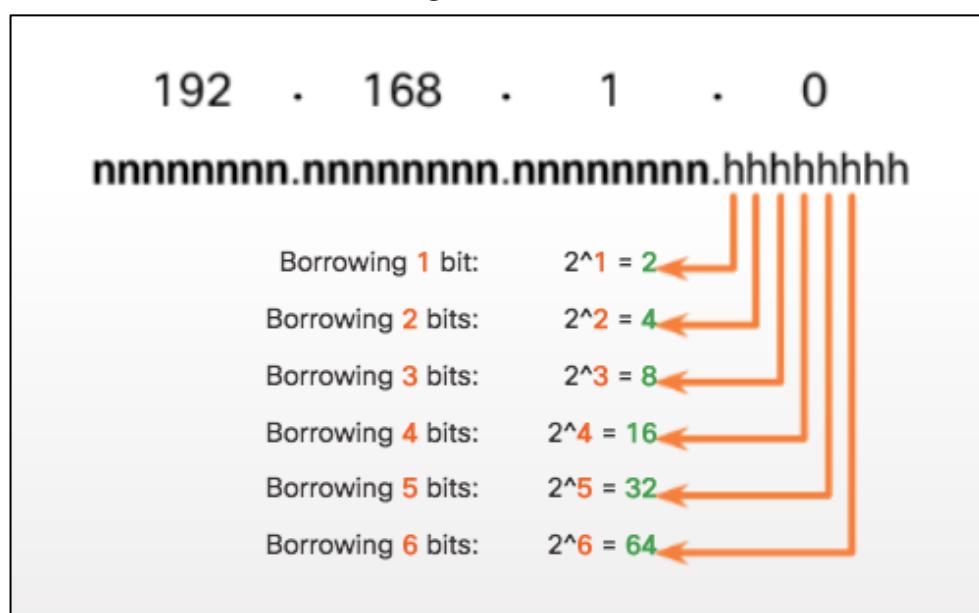
Subnetting Formulas

Calculate Number of Subnets Formula

$$2^n$$

n = bits borrowed

Subnetting a /24 Network



Subnetting an IPv4 Network

Subnetting Formulas (Cont.)

Calculate Number of Hosts Formula

$$2^n - 2$$

n

= the number of bits remaining in the host field

Calculating the Number of Hosts

192.	168.	1.	0	000	0000
------	------	----	---	-----	------

7 bits remain in host field

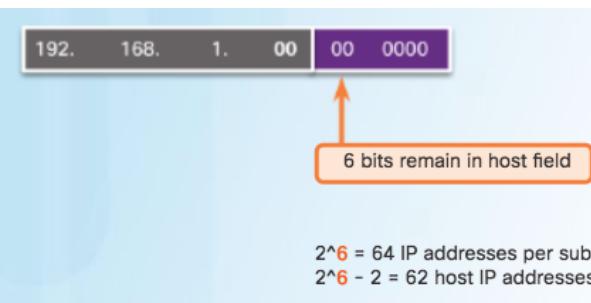
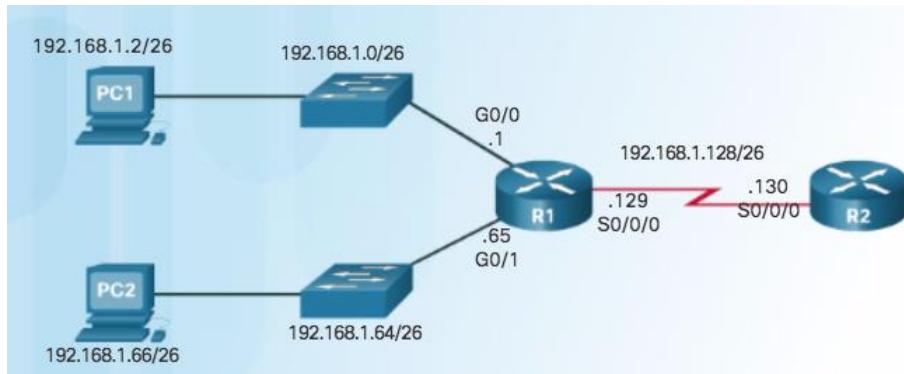
$2^7 = 128$ IP addresses per subnet

$2^7 - 2 = 126$ host IP addresses per subnet

Subnetting an IPv4 Network

Creating 4 Subnets

- /26 Subnetting Topology



All 4 subnets use the same mask:

Mask	255.	255.	255.	11	00 0000
------	------	------	------	----	---------

Mask: 255.255.255.11

Subnetting an IPv4 Network

Creating 4 Subnets (Cont.)

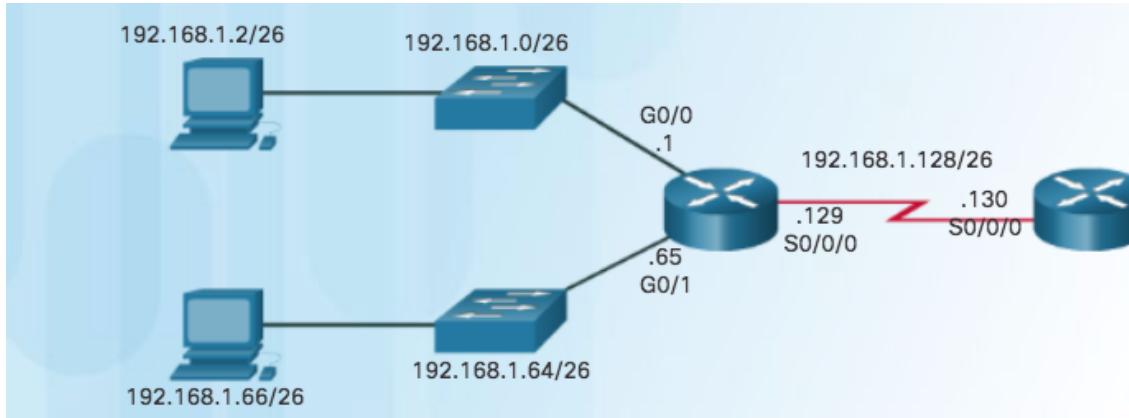
- /26 Subnetting Topology

		Network	192.	168.	1.	00	00 0000	192.168.1.0
		First	192.	168.	1.	00	00 0001	192.168.1.1
		Last	192.	168.	1.	00	11 1110	192.168.1.62
		Broadcast	192.	168.	1.	00	11 1111	192.168.1.63
		Network	192.	168.	1.	01	00 0000	192.168.1.64
		First	192.	168.	1.	01	00 0001	192.168.1.65
		Last	192.	168.	1.	01	11 1110	192.168.1.126
		Broadcast	192.	168.	1.	01	11 1111	192.168.1.127
		Network	192.	168.	1.	10	00 0000	192.168.1.128
		First	192.	168.	1.	10	00 0001	192.168.1.129
		Last	192.	168.	1.	10	11 1110	192.168.1.190
		Broadcast	192.	168.	1.	10	11 1111	192.168.1.191

Subnetting an IPv4 Network

Creating 4 Subnets (Cont.)

- /26 Subnetting Topology



```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ip address 192.168.1.1 255.255.255.192
R1(config-if)#exit
R1(config)#interface gigabitethernet 0/1
R1(config-if)#ip address 192.168.1.65 255.255.255.192
R1(config-if)#exit
R1(config)#interface serial 0/0/0
R1(config-if)#ip address 192.168.1.129 255.255.255.192
```

Video Demonstration – Creating Four Equal-sized Subnets (/26)

Create 4 Equal-sized Subnets from 192.168.1.0 /24

- Subnet Mask in Binary – 11111111.11111111.11111111.**11**000000
- $2^2 = 4$ Subnets
- Magic Number = 64
- 192.168.1.0 /26
- 192.168.1.64 /26
- 192.168.1.128 /26
- 192.168.1.192 /26



Video Demonstration – Creating Eight Equal-sized Subnets (/27)

Create 8 Equal-sized Subnets from 192.168.1.0 /24

- Borrow 3 bits – 11111111.11111111.11111111.**111**000000
- Magic Number = 32
- 192.168.1.0 /27 **(Start at 0)**
- 192.168.1.32 /27 **(Add 32 to previous network)**
- 192.168.1.64 /27 **(Add 32)**
- 192.168.1.96 /27 **(Add 32)**
- 192.168.1.128 /27 **(Add 32)**
- 192.168.1.160 /27 **(Add 32)**
- 192.168.1.192 /27 **(Add 32)**
- 192.168.1.224 /27 **(Add 32)**



Subnetting a /16 and /8 Prefix

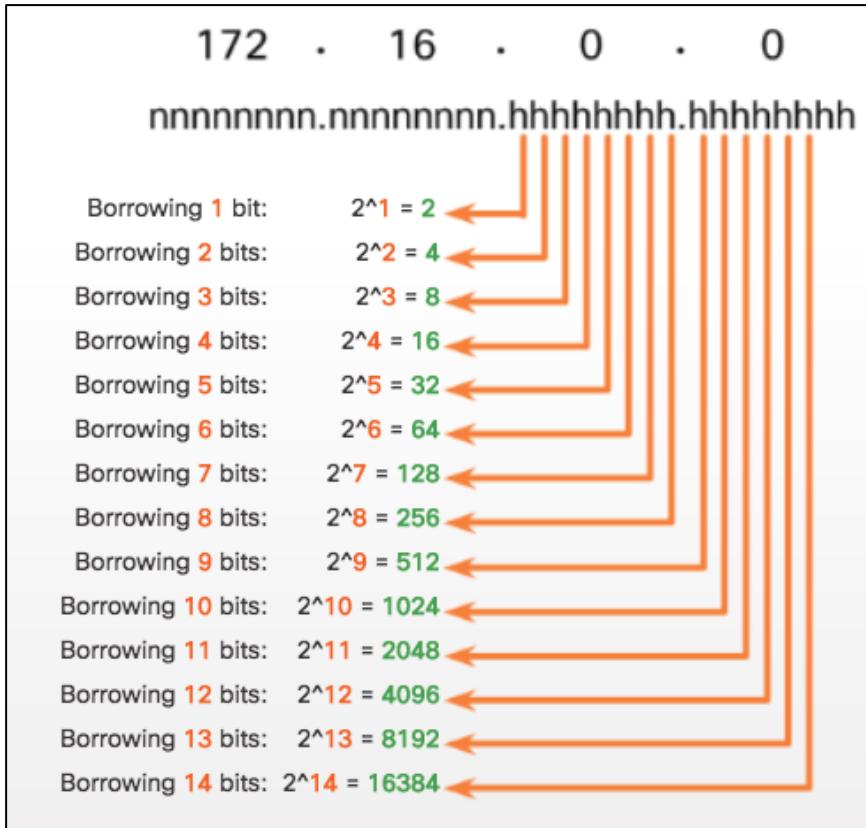
Creating Subnets with a /16 prefix

Subnetting a /16 Network

Prefix Length	Subnet Mask	Network Address (n = network, h = host)	# of subnets	# of hosts
/17	255.255.128.0	nnnnnnnn.nnnnnnnn.nhhhhhhh.hhhhhhhh 11111111.11111111.10000000.00000000	2	32766
/18	255.255.192.0	nnnnnnnn.nnnnnnnn.nnhhhhhh.hhhhhhhh 11111111.11111111.11000000.00000000	4	16382
/19	255.255.224.0	nnnnnnnn.nnnnnnnn.nnnhhhhh.hhhhhhhh 11111111.11111111.11100000.00000000	8	8190
/20	255.255.240.0	nnnnnnnn.nnnnnnnn.nnnnhhhh.hhhhhhhh 11111111.11111111.11110000.00000000	16	4094
/21	255.255.248.0	nnnnnnnn.nnnnnnnn.nnnnnhhh.hhhhhhhh 11111111.11111111.11111000.00000000	32	2046
/22	255.255.252.0	nnnnnnnn.nnnnnnnn.nnnnnnhh.hhhhhhhh 11111111.11111111.11111100.00000000	64	1022

Subnetting a /16 and /8 Prefix

Creating 100 Subnets with a /16 prefix



Subnetting a /16 and /8 Prefix

Calculating the Hosts

Hosts = 2^n
(where n = host bits remaining)

172. 16. 00 00 00 0 | 0. 0000 0000



9 bits remain in host field

$2^9 = 512$ IP addresses per subnet
 $2^9 - 2 = 510$ host IP addresses per subnet

Address Range for 172.16.0.0/23 Subnet

Network Address

172. 16. 00 00 00 0 | 0. 0000 0000 = 172.16.0.0/23

First Host Address

172. 16. 00 00 00 0 | 0. 0000 0001 = 172.16.0.1/23

Last Host Address

172. 16. 00 00 00 0 | 1. 1111 1110 = 172.16.1.254/23

Broadcast Address

172. 16. 00 00 00 0 | 1. 1111 1111 = 172.16.1.255/23

Subnetting a /16 and /8 Prefix

Video Demonstration – Creating One Hundred Equal-sized Subnets

- An enterprise network requires 100 equal-sized subnets starting from 172.16.0.0/16

- New Subnet Mask
 - 11111111.11111111.**1111111**0.00000000
- $2^7 = 128$ Subnets
- $2^9 = 512$ hosts per subnet
- Magic Number = **2**
- 172.16.**0**.0 /23
- 172.16.**2**.0 /23
- 172.16.**4**.0 /23
- 172.16.**6**.0 /23
- ...
- 172.16.**254**.0 /23



Subnetting a /16 and /8 Prefix

Creating 1000 Subnets with a /8 Network



Subnetting a /16 and /8 Prefix

Creating 1000 Subnets with a /8 Network (Cont.)

Resulting /18 Subnets

10.	0000	0000. 00	00 0000.	0000 0000
255.	1111	1111. 11	00 0000.	0000 0000

Borrowing 10 bits creates 1024 subnets

10.	0000	0000. 00	00 0000.	0000 0000	10.0.0.0/18
10.	0000	0000. 01	00 0000.	0000 0000	10.0.64.0/18
10.	0000	0000. 10	00 0000.	0000 0000	10.0.128.0/18
10.	0000	0000. 11	00 0000.	0000 0000	10.0.192.0/18
10.	0000	0001. 00	00 0000.	0000 0000	10.1.0.0/18

... to ...

10.	1111	1111. 11	00 0000.	0000 0000	10.255.192.0/18
-----	------	----------	----------	-----------	-----------------

10.	00 00 00 00.	00	00 0000.	0000 0000
-----	--------------	----	----------	-----------

14 bits remain in host field

$2^{14} = 16384$ IP addresses per subnet

$2^{14} - 2 = 16382$ host IP addresses by subnet

Network Address

10.	00 00 00 00.	00	00 0000.	0000 0000	=10.0.0.0/18
-----	--------------	----	----------	-----------	--------------

First Host Address

10.	00 00 00 00.	00	00 0000.	0000 0001	=10.0.0.1/18
-----	--------------	----	----------	-----------	--------------

Last Host Address

10.	00 00 00 00.	00	11 1111.	1111 1110	=10.0.63.254/18
-----	--------------	----	----------	-----------	-----------------

Broadcast Address

10.	00 00 00 00.	00	11 1111.	1111 1111	=10.0.63.255/18
-----	--------------	----	----------	-----------	-----------------

Subnetting a /16 and /8 Prefix

Video Demonstration – Subnetting Across Multiple Octets

The Magic Number is the last 1 in Binary			
10	0	0	0
255	0	0	0
00001010	00000000	00000000	00000000
11111111	11100000	00000000	00000000
	SN	H	H
			H
The Magic Number is? 32			

10.0.0.0/11 10.128.0.0/11
10.32.0.0/11 10.160.0.0/11
10.64.0.0/11 10.192.0.0 – 10.223.255.255/11
10.96.0.0/11 10.224.0.0/11



New Challenge Problem: Create over 300 Equal-sized Subnets of 20,000 Hosts each starting from 10.0.0.0/8

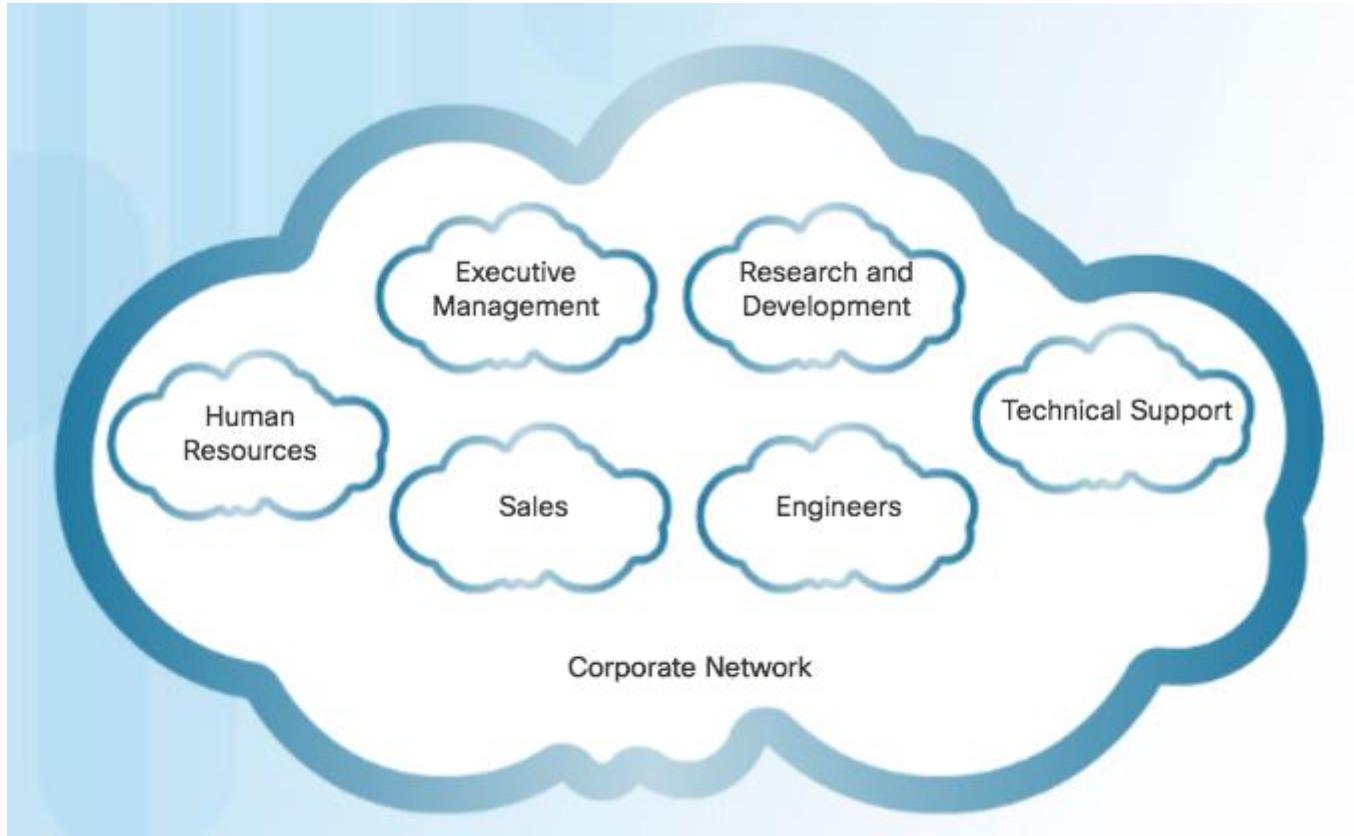
Subnetting to Meet Requirements

Subnetting Based on Host Requirements

Prefix Length	Subnet Mask	Subnet Mask in Binary (n = network, h = host)	# of subnets	# of hosts
/25	255.255.255.128	nnnnnnnn.nnnnnnnn.nnnnnnnn. n hhhhh 11111111.11111111.11111111. 1 0000000	2	126
/26	255.255.255.192	nnnnnnnn.nnnnnnnn.nnnnnnnn. nn hhhhh 11111111.11111111.11111111. 11 000000	4	62
/27	255.255.255.224	nnnnnnnn.nnnnnnnn.nnnnnnnn. nnn hhh 11111111.11111111.11111111. 111 00000	8	30
/28	255.255.255.240	nnnnnnnn.nnnnnnnn.nnnnnnnn. nnnn hh 11111111.11111111.11111111. 1111 0000	16	14

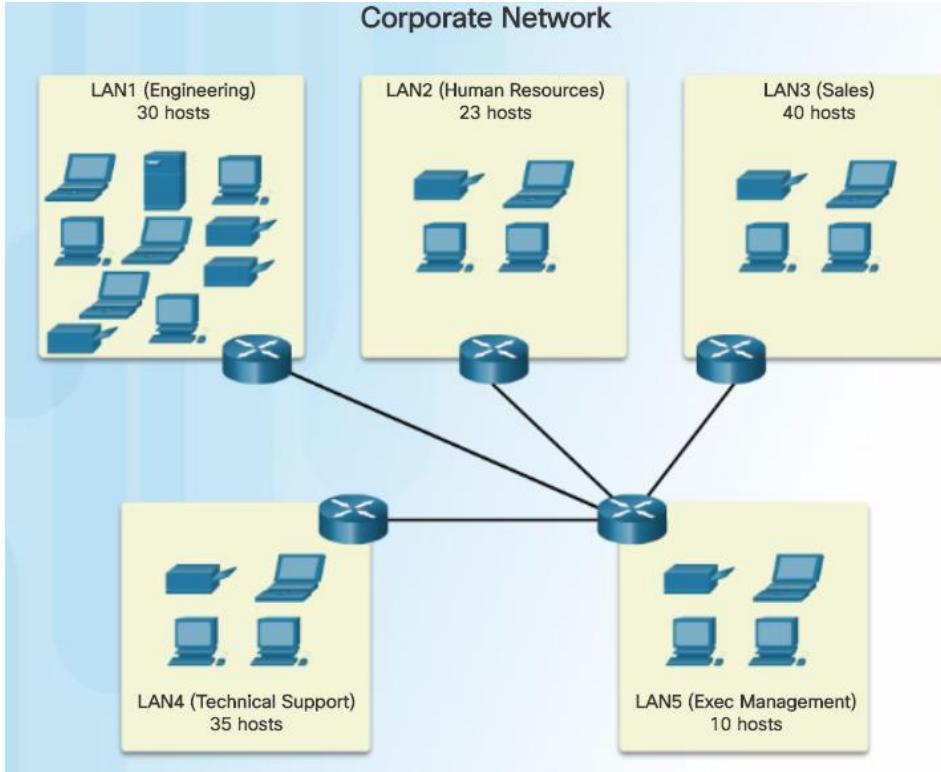
Subnetting Based On Network Requirements

Host devices used by employees in the Engineering department in one network and Management in a separate network.



Subnetting to Meet Requirements

Network Requirement Example

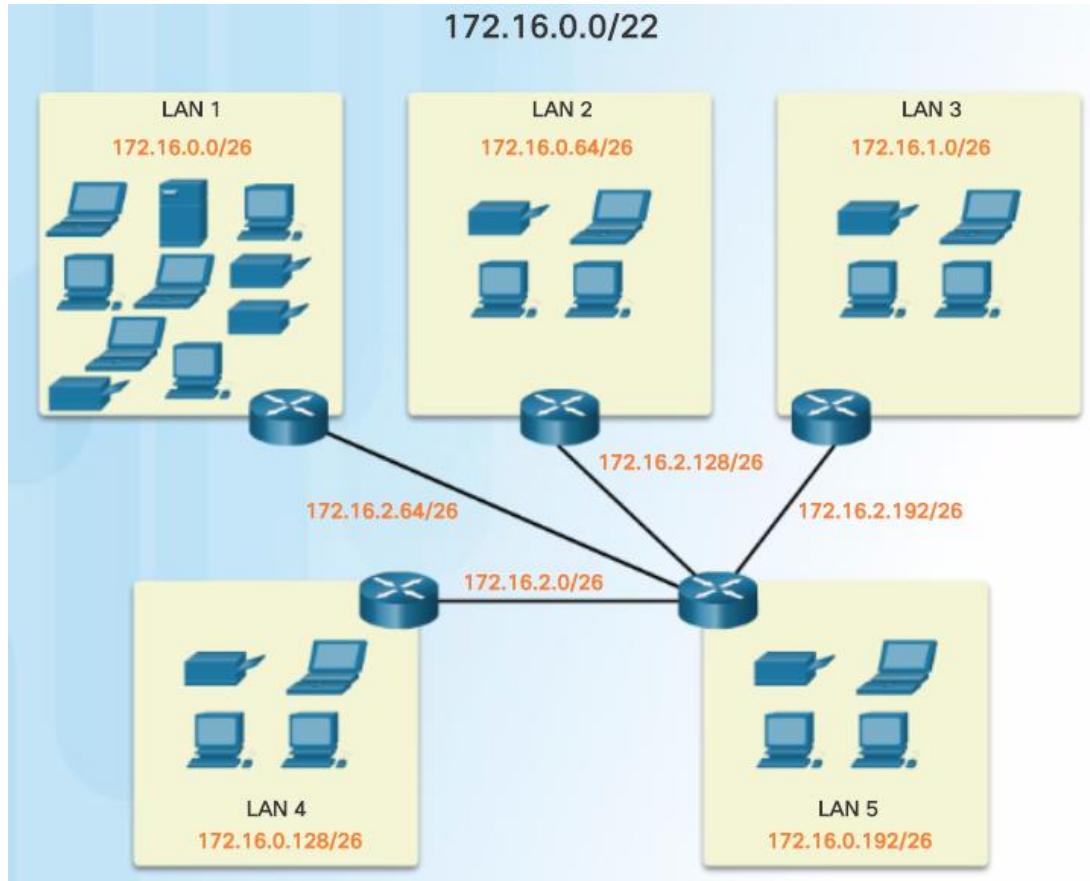


Network portion	Host portion	
10101100.00010100.000000	00.00000000	172.16.0.0/22
10 host bits		
$2^{10} - 2 = 1,022 \text{ hosts}$		

	Network Portion	Host Portion	Dotted Decimal
0	10101100.00010000.000000	00.00	172.16.0.0/22
1	10101100.00010000.000000	00.01	172.16.0.64/26
2	10101100.00010000.000000	00.10	172.16.0.128/26
3	10101100.00010000.000000	00.11	172.16.0.192/26
4	10101100.00010000.000000	01.00	172.16.1.0/26
5	10101100.00010000.000000	01.01	172.16.1.64/26
6	10101100.00010000.000000	01.10	172.16.1.128/26
Nets 7 – 13 not shown			
14	10101100.00010000.000000	11.10	172.16.3.128/26
15	10101100.00010000.000000	11.11	172.16.3.192/26
4 bits borrowed from host portion to create subnets			

Subnetting to Meet Requirements

Network Requirement Example (Cont.)



Subnetting to Meet Requirements

Lab – Calculating IPv4 Subnets



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Lab – Calculating IPv4 Subnets

Objectives

Part 1: Determine IPv4 Address Subnetting

Part 2: Calculate IPv4 Address Subnetting

Background / Scenario

The ability to work with IPv4 subnets and determine network and host information based on a given IP address and subnet mask is critical to understanding how IPv4 networks operate. The first part is designed to reinforce how to compute network IP address information from a given IP address and subnet mask. When given an IP address and subnet mask, you will be able to determine other information about the subnet.

Required Resources

- 1 PC (Windows 7 or 8 with Internet access)
- Optional: IPv4 address calculator

Part 1: Determine IPv4 Address Subnetting

In Part 1, you will determine the network and broadcast addresses, as well as the number of hosts, given an IPv4 address and subnet mask.

REVIEW: To determine the network address, perform binary ANDing on the IPv4 address using the subnet mask provided. The result will be the network address. Hint: If the subnet mask has decimal value 255 in an octet, the result will ALWAYS be the original value of that octet. If the subnet mask has decimal value 0 in an octet, the result will ALWAYS be 0 for that octet.

Example:

IP Address	192.168.10.10
Subnet Mask	255.255.255.0
	=====
Result (Network)	192.168.10.0



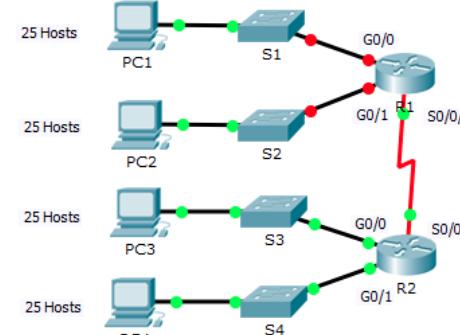
Subnetting to Meet Requirements

Packet Tracer – Subnetting Scenario

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Packet Tracer - Subnetting Scenario

Topology



The network topology consists of four hosts (PC1, PC2, PC3, PC4) connected to four switches (S1, S2, S3, S4). Each host is labeled "25 Hosts". The switches are interconnected, forming a path to a central backbone switch. The backbone switch is connected to router R1 via its G0/0 and G0/1 interfaces. Router R1 is also connected to another router, R2, via its G0/0 and G0/1 interfaces. Router R2 is connected to a final backbone switch, which has an S0/0/0 interface.

Addressing Table

Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	G0/0			
	G0/1			
	S0/0/0			

Subnetting to Meet Requirements

Lab – Designing and Implementing a Subnetted IPv4 Addressing Scheme

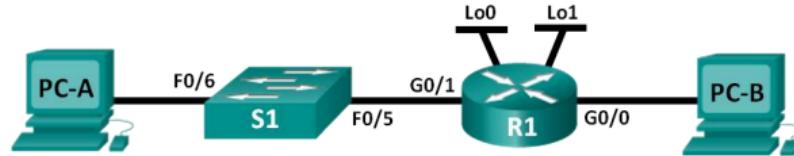


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Lab - Designing and Implementing a Subnetted IPv4 Addressing Scheme

Topology



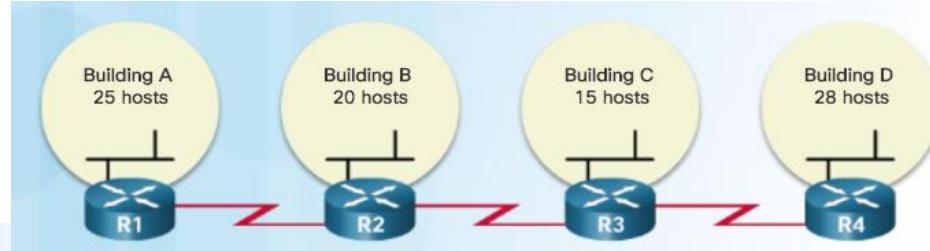
Addressing Table

Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	G0/0			N/A
	G0/1			N/A
	Lo0			N/A
	Lo1			N/A
S1	VLAN 1	N/A	N/A	N/A
PC-A	NIC			
PC-B	NIC			



Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes Addresses



	Network Portion	Host Portion	
	11000000.10101000.00010100	.000 00000	192.168.20.0/24
0	11000000.10101000.00010100	.000 00000	192.168.20.0/27
1	11000000.10101000.00010100	.001 00000	192.168.20.32/27
2	11000000.10101000.00010100	.010 00000	192.168.20.64/27
3	11000000.10101000.00010100	.011 00000	192.168.20.96/27
4	11000000.10101000.00010100	.100 00000	192.168.20.128/27
5	11000000.10101000.00010100	.101 00000	192.168.20.160/27
6	11000000.10101000.00010100	.110 00000	192.168.20.192/27
7	11000000.10101000.00010100	.111 00000	192.168.20.224/27

Annotations:

- Subnet portion: $2^3 = 8$ subnets
- Host portion: $2^5 - 2 = 30$ host IP addresses per subnet
- Building LANs A, B, C, and D: Subnets 0, 1, 2, 3 (192.168.20.0/27 to 192.168.20.64/27)
- Site to Site WANs: Subnets 4, 5, 6 (192.168.20.128/27 to 192.168.20.192/27)
- Unused / Available: Subnet 7 (192.168.20.224/27)

	Network Portion	Host Portion	Dotted Decimal
4	11000000.10101000.00010100	.100 00000	192.168.20.128/27
5	11000000.10101000.00010100	.101 00000	192.168.20.160/27
6	11000000.10101000.00010100	.110 00000	192.168.20.192/27

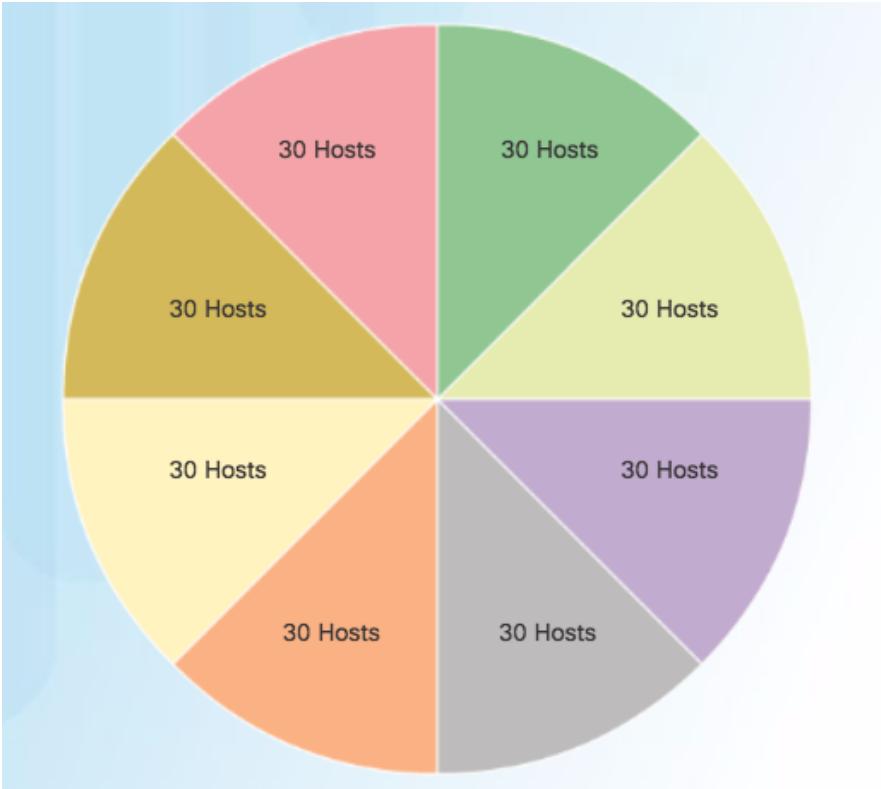
Annotations:

- Host portion: $2^5 - 2 = 30$ host IP addresses per subnet
- 30 - 2 = 28
Each WAN subnet wastes 28 addresses
- $28 \times 3 = 84$
84 addresses are unused

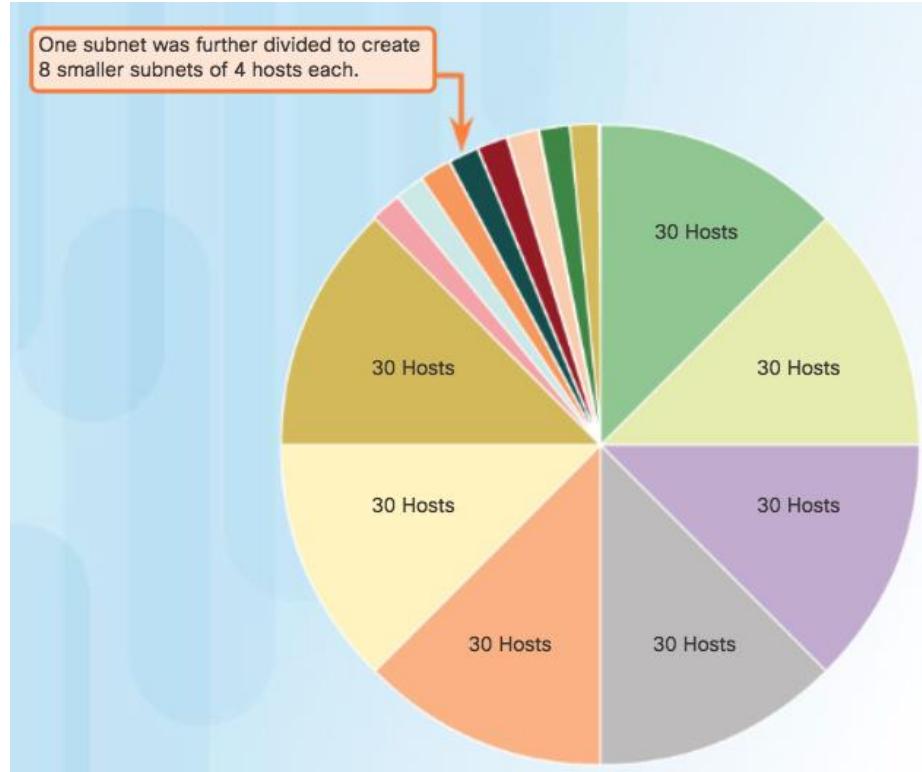
Benefits of Variable Length Subnet Masking

Variable Length Subnet Masks (VLSM)

Traditional



Subnets of Varying Sizes



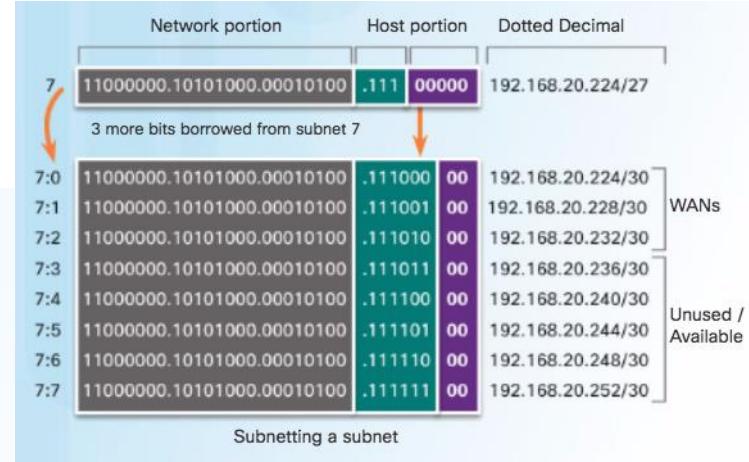
Benefits of Variable Length Subnet Masking

Basic VLSM

Basic Subnetting

	Network portion	Host portion	Dotted Decimal
	11000000.10101000.00010100	.00000000	192.168.20.0/24
0	11000000.10101000.00010100	.000	192.168.20.0/27
1	11000000.10101000.00010100	.001	192.168.20.32/27
2	11000000.10101000.00010100	.010	192.168.20.64/27
3	11000000.10101000.00010100	.011	192.168.20.96/27
4	11000000.10101000.00010100	.100	192.168.20.128/27
5	11000000.10101000.00010100	.101	192.168.20.160/27
6	11000000.10101000.00010100	.110	192.168.20.192/27
7	11000000.10101000.00010100	.111	192.168.20.224/27

Subnet 7 will be subnetted further.

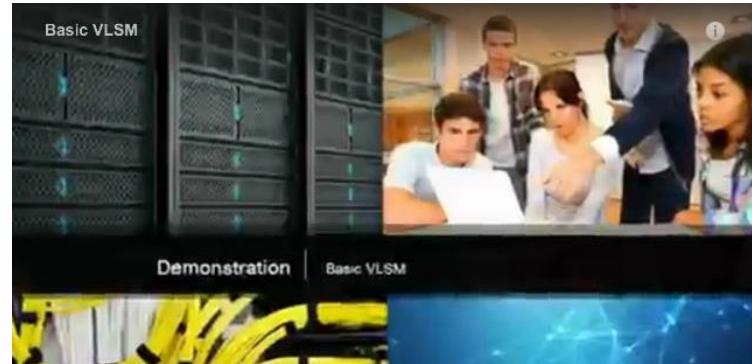
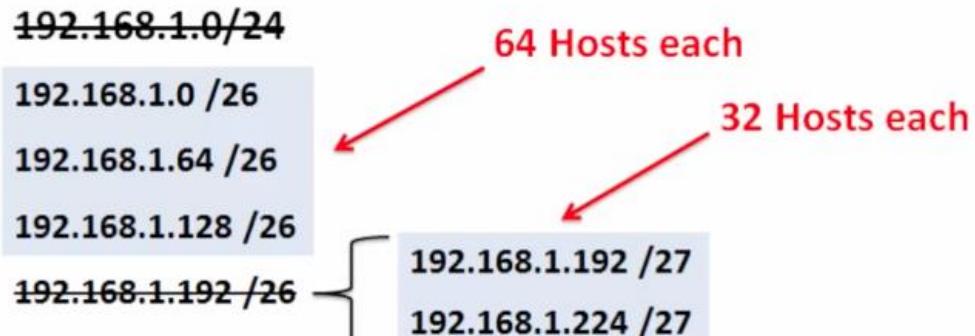


Benefits of Variable Length Subnet Masking

Video Demonstration – VLSM Basics

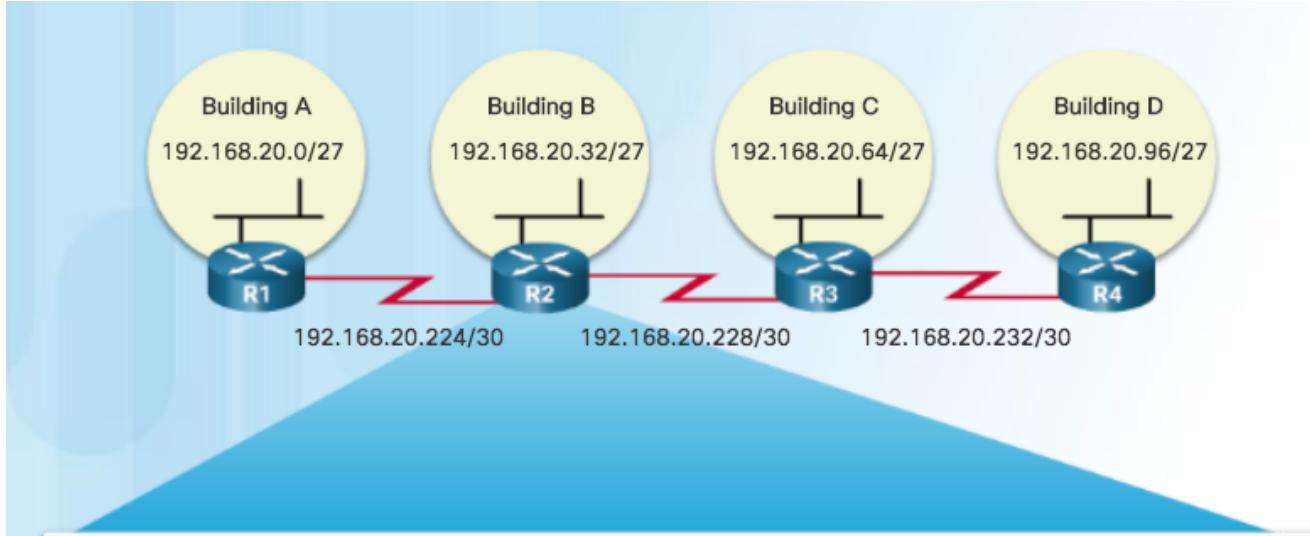
- Basic VLSM

- Subnets do not have to be equal sizes, as long as their address ranges do not overlap.
- When creating subnets it is easier to work from larger to smaller.



Benefits of Variable Length Subnet Masking

VLSM in Practice



```
R2(config)# interface gigabitethernet 0/0
R2(config-if)# ip address 192.168.20.33 255.255.255.224
R2(config-if)# exit
R2(config)# interface serial 0/0/0
R2(config-if)# ip address 192.168.20.226 255.255.255.252
R2(config-if)# exit
R2(config)# interface serial 0/0/1
R2(config)# ip address 192.168.20.229 255.255.255.252
R2(config-if)# end
R2#
```

Benefits of Variable Length Subnet Masking

VLSM Chart

VLSM Subnetting of 192.168.20.0/24

	/27 Network	Hosts
Bldg A	.0	.1 - .30
Bldg B	.32	.33 - .62
Bldg C	.64	.65 - .94
Bldg D	.96	.97 - .126
Unused	.128	.129 - .158
Unused	.160	.161 - .190
Unused	.192	.193 - .222
	.224	.225 - .254

	/30 Network	Hosts
WAN R1-R2	.224	.225 - .226
WAN R2-R3	.228	.229 - .230
WAN R3-R4	.232	.233 - .234
Unused	.236	.237 - .238
Unused	.240	.241 - .242
Unused	.244	.245 - .246
Unused	.248	.249 - .250
Unused	.252	.253 - .254

Benefits of Variable Length Subnet Masking

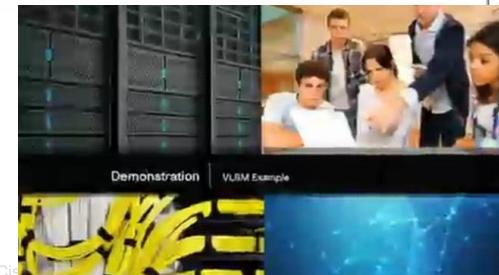
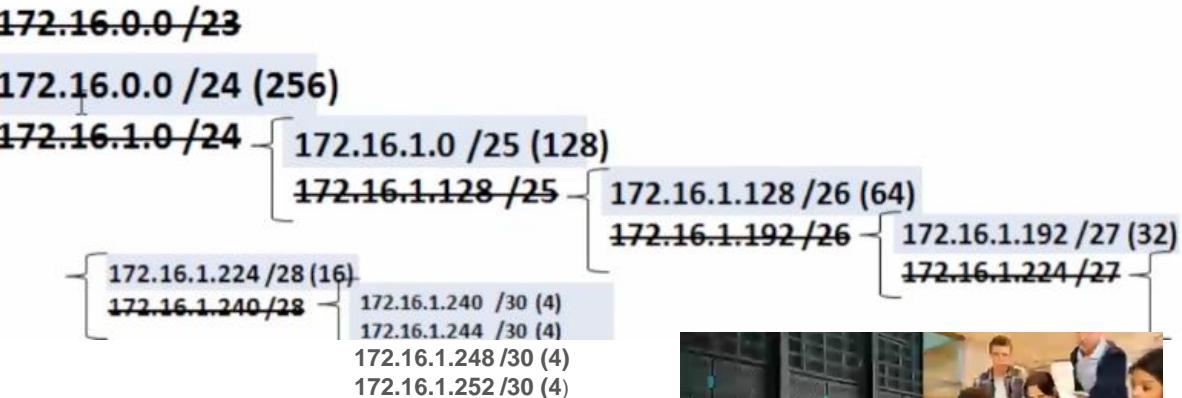
Video Demonstration – VLSM Example

- Given the network 172.16.0.0 /23 creates subnets:
 - 1 network for 200 hosts - 256
 - 1 network for 100 hosts - 128
 - 1 network for 50 hosts - 64
 - 1 network for 25 hosts - 32
 - 1 network for 10 hosts - 16
 - 4 point-to-point networks for 2 hosts each – 4x4 = 16

/23 = 2^9 hosts = 512

256+128+64+32+16+16 = 512 hosts needed

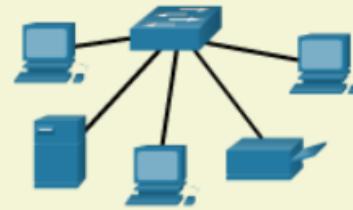
Address range 172.16.0.0 – 172.16.1.255



8.2 Addressing Schemes

Network Address Planning

Planning IP Address Assignment



Student LAN



Faculty LAN



Admin LAN

Planning requires decisions on each subnet in terms of size, the number of hosts per subnet, and how host addresses will be assigned.

Planning to Address the Network



- Each host in an internetwork must have a unique address.
- Need proper planning & documentation.
- Must provide & control access to servers from internal hosts and external hosts.
- Layer 3 STATIC address assigned to a server can be used to control access to that server.
- Monitoring security and performance of hosts means network traffic is examined for source IP addresses that are generating or receiving excessive packets.

Assigning Addresses to Devices

- Devices that require addresses:
 - **End user clients**
 - Can be set for DHCP to save time and manual errors.
 - A change in the subnetting scheme requires reconfiguration of DHCP server. IPv6 clients use DHCPv6/SLAAC.
- **Servers**
 - Configured with static addresses.
 - Private addresses translated to public addresses if accessible from the Internet.
- **Intermediary devices**
 - Set with static addresses for remote management.
- **Gateway**
 - Router interface used to exit the network.

Network: 192.168.1.0/24		
Use	First	Last
Host Devices	.1	.229
Servers	.230	.239
Printers	.240	.249
Intermediary Devices	.250	.253
Gateway (router LAN interface)	.254	

Structured Design

Packet Tracer – Designing and Implementing a VLSM Addressing Scheme

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Packet Tracer - Designing and Implementing a VLSM Addressing Scheme

Topology

You will receive one of three possible topologies.

Addressing Table

Device	Interface	IP Address	Subnet Mask	Default Gateway
	G0/0			N/A
	G0/1			N/A
	S0/0/0			N/A
	G0/0			N/A
	G0/1			N/A
	S0/0/0			N/A
VLAN 1				
NIC				

Objectives

- Part 1: Examine the Network Requirements
- Part 2: Design the VLSM Addressing Scheme
- Part 3: Assign IP Addresses to Devices and Verify Connectivity

Structured Design

Lab – Designing and Implementing a VLSM Addressing Scheme

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Lab – Designing and Implementing a VLSM Addressing Scheme

Topology

```
graph TD; HQ[G0/0] --- BR1[G0/0]; HQ[G0/1] --- BR2[G0/0]; BR1[G0/0] --- 2k[2,000 Hosts]; BR1[G0/0] --- 4k[4,000 Hosts]; BR1[G0/1] --- 8k[8,000 Hosts]; BR2[G0/0] --- 1k[1,000 Hosts]; BR2[G0/0] --- 500[500 Hosts]; BR2[G0/1] --- 16k[16,000 Hosts]; style HQ fill:#006699,color:#fff; style BR1 fill:#006699,color:#fff; style BR2 fill:#006699,color:#fff; style 2k fill:#e0e0e0; style 4k fill:#e0e0e0; style 8k fill:#e0e0e0; style 1k fill:#e0e0e0; style 500 fill:#e0e0e0; style 16k fill:#e0e0e0;
```

Objectives

- Part 1: Examine Network Requirements
- Part 2: Design the VLSM Address Scheme
- Part 3: Cable and Configure the IPv4 Network

Background / Scenario

Variable Length Subnet Mask (VLSM) was designed to avoid wasting IP addresses. With VLSM, a network is subnetted and then re-subnetted. This process can be repeated multiple times to create subnets of various sizes based on the number of hosts required in each subnet. Effective use of VLSM requires address planning.

In this lab, use the 172.16.128.0/17 network address to develop an address scheme for the network displayed in the topology diagram. VLSM is used to meet the IPv4 addressing requirements. After you have designed the VLSM address scheme, you will configure the interfaces on the routers with the appropriate IP address information.

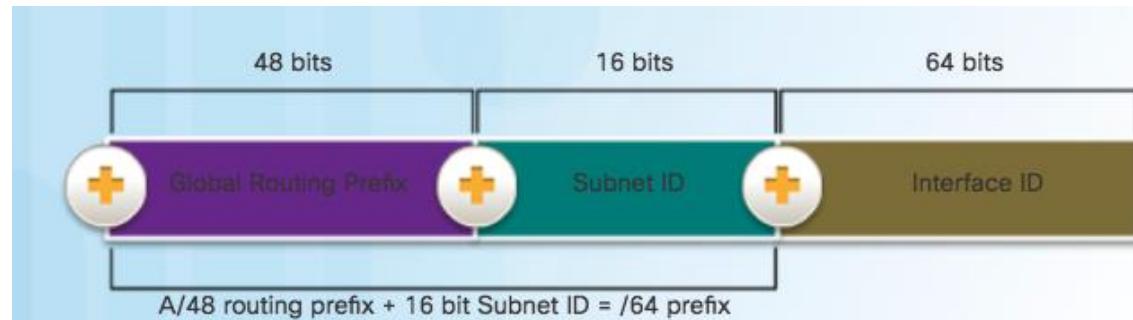
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8.3 Design Considerations for IPv6

The IPv6 Global Unicast Address

- IPv6 subnetting is not concerned with conserving address space.
- IPv6 subnetting is about building an addressing hierarchy based on the number of subnetworks needed.
- IPv6 link-local address is never subnetted.
- IPv6 global unicast address can be subnetted.
- IPv6 global unicast address normally consists of a /48 global routing prefix, a 16 bit subnet ID, and a 64 bit interface ID.

Structure



Global Routing Prefix

This is the prefix, or network, portion of the address that is assigned by the provider. Typically, Regional Internet Registries (RIRs) assign a /48 global routing prefix to ISPs and customers.

Subnetting Using the Subnet ID

Address Block: 2001:0DB8:ACAD::/48

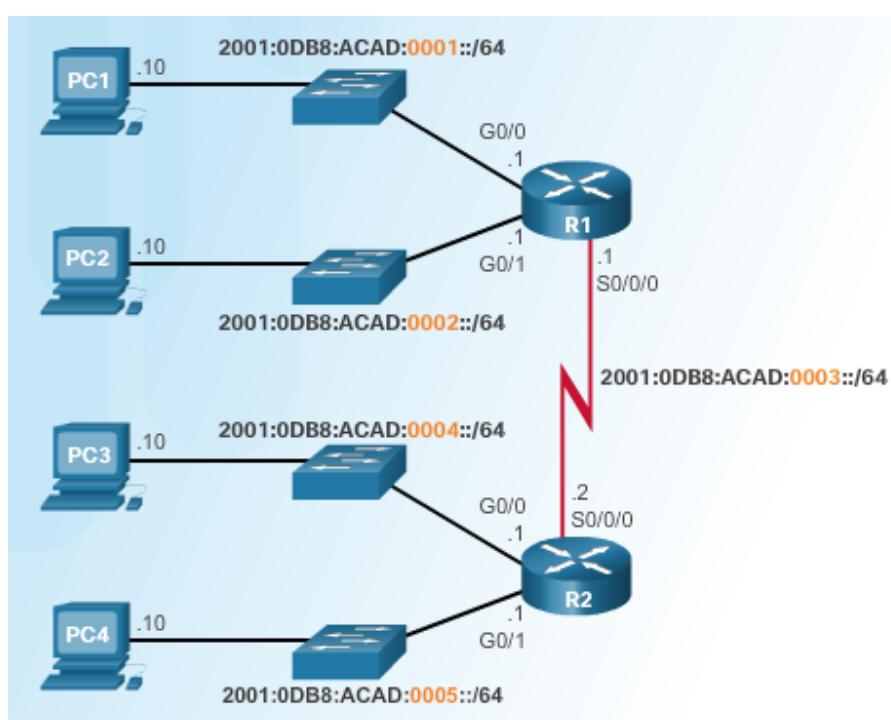
Increment subnet ID to create 65,536 subnets



2001:0DB8:ACAD:0000::/64
2001:0DB8:ACAD:0001::/64
2001:0DB8:ACAD:0002::/64
2001:0DB8:ACAD:0003::/64
2001:0DB8:ACAD:0004::/64
2001:0DB8:ACAD:0005::/64
2001:0DB8:ACAD:0006::/64
2001:0DB8:ACAD:0007::/64
2001:0DB8:ACAD:0008::/64
2001:0DB8:ACAD:0009::/64
2001:0DB8:ACAD:000A::/64
2001:0DB8:ACAD:000B::/64
2001:0DB8:ACAD:000C::/64
Subnets 13 - 65,534 not shown
2001:0DB8:ACAD:FFFF::/64

Subnetting an IPv6 Network

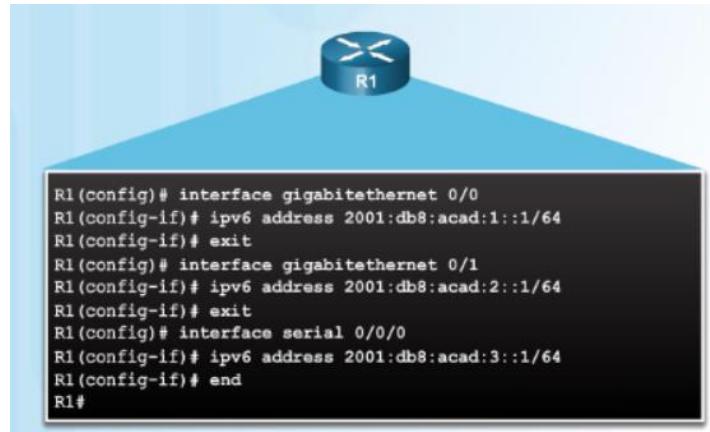
IPv6 Subnet Allocation



Address Block: 2001:0DB8:ACAD::/48

5 subnets allocated
from 65,536
available subnets

2001:0DB8:ACAD:0000::/64
2001:0DB8:ACAD:0001::/64
2001:0DB8:ACAD:0002::/64
2001:0DB8:ACAD:0003::/64
2001:0DB8:ACAD:0004::/64
2001:0DB8:ACAD:0005::/64
2001:0DB8:ACAD:0006::/64
2001:0DB8:ACAD:0007::/64
2001:0DB8:ACAD:0008::/64
2001:0DB8:ACAD:FFFF::/64



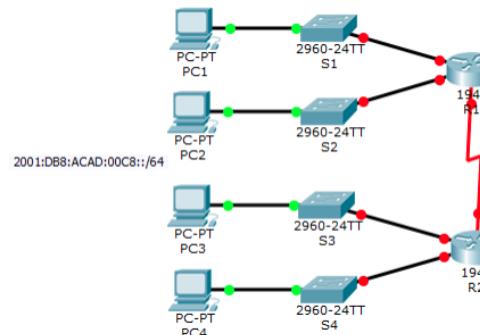
Subnetting an IPv6 Network

Packet Tracer – Implementing a Subnetted IPv6 Addressing Scheme

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Packet Tracer - Implementing a Subnetted IPv6 Addressing Scheme

Topology



The network consists of four hosts (PC1-PT, PC2-PT, PC3-PT, PC4-PT) connected to four switches (S1, S2, S3, S4). S1, S2, and S3 are connected to R1, while S4 is connected to R2. Router R1 has two interfaces: G0/0 (2001:DB8:ACAD:00C8::/64) and G0/1 (1941). Router R2 has two interfaces: G0/0 (1941) and G0/1 (1941).

Addressing Table

Device	Interface	IPv6 Address	Link-Local
R1	G0/0		FE80::1
	G0/1		FE80::1
	S0/0/0		FE80::1
R2	G0/0		FE80::2
	G0/1		FE80::2
	S0/0/0		FE80::2
PC1	NIC	Auto Config	
PC2	NIC	Auto Config	

8.4 Chapter Summary

Conclusion

Packet Tracer - Skills Integration Challenge

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Packet Tracer - Skills Integration Challenge

Topology

The network topology consists of four LAN segments:

- LAN A1: 500 Hosts, connected to PC-A1 and Sw-A1. Subnet: 172.20.16.0/23.
- LAN A2: 250 Hosts, connected to PC-A2 and Sw-A2. Subnet: 172.20.31.252/30.
- LAN B1: 250 Hosts, connected to PC-B1 and Sw-B1. Subnet: 2001:DB8:FFFF:FFFF::/64.
- LAN B2: 250 Hosts, connected to PC-B2 and Sw-B2. Subnet: 2001:DB8:FADE:00FF::/64.

Branch-A and Branch-B switches connect their respective LANs to the Central switch. The Central switch also connects to a DNS Server (central.pka) with IP 172.20.32.10 and an IPv6 address 2001:DB8:FADE:1000::10. The Central switch has an IPv6 address 2001:DB8:FFFF:FFFF::/64.

Addressing Table

Device	Interface	IPv4 Address	Subnet Mask	Default Gateway
		IPv6 Address/Prefix		
Branch-A	G0/0			N/A
	G0/1			N/A
	G0/2	172.20.31.254	255.255.255.252	N/A
	G0/3			N/A

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Chapter 8: Subnetting IP Networks

- Implement an IPv4 addressing scheme to enable end-to-end connectivity in a small to medium-sized business network.
- Given a set of requirements, implement a VLSM addressing scheme to provide connectivity to end users in a small to medium-sized network.
- Explain design considerations for implementing IPv6 in a business network.

