Cisco Networking Academy
Mind Wide Open

Chapter 8:
Subnetting IP networks

Introduction to Networks v5.1

Chapter Outline

Section 8.1: Subnetting an IPv4 Network

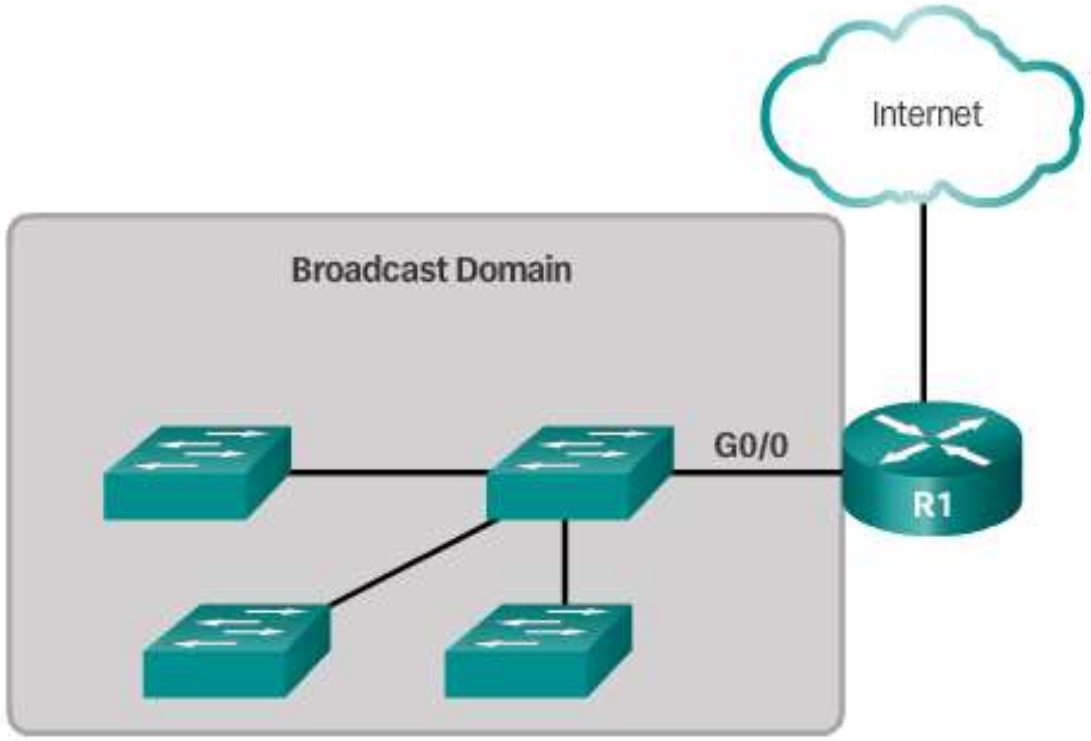
Upon completion of this section, you should be able to:

- 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).

Topic 8.1.1:
Network Segmentation

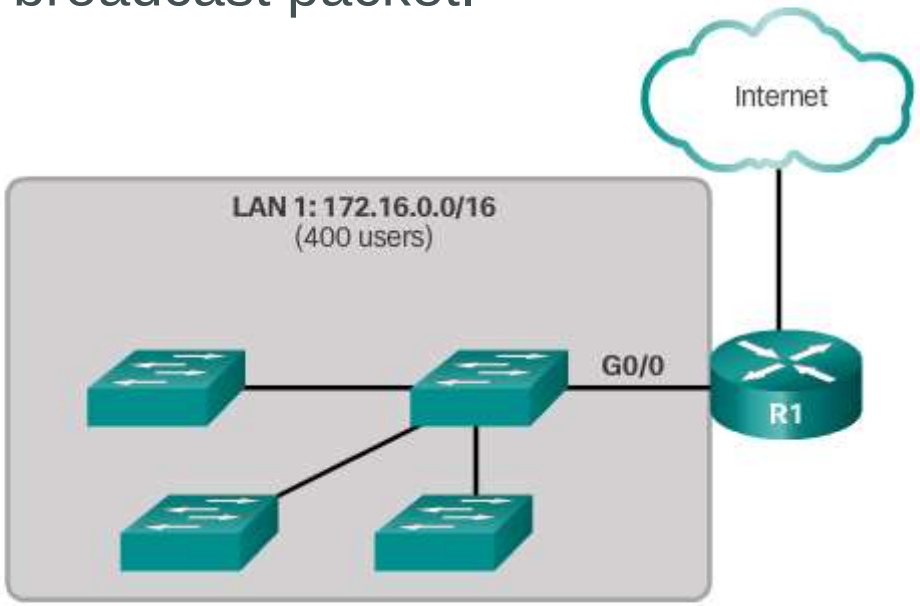
Broadcast Domains

Each router interface connects a *broadcast domain* and broadcasts are only propagated within its specific broadcast domain.



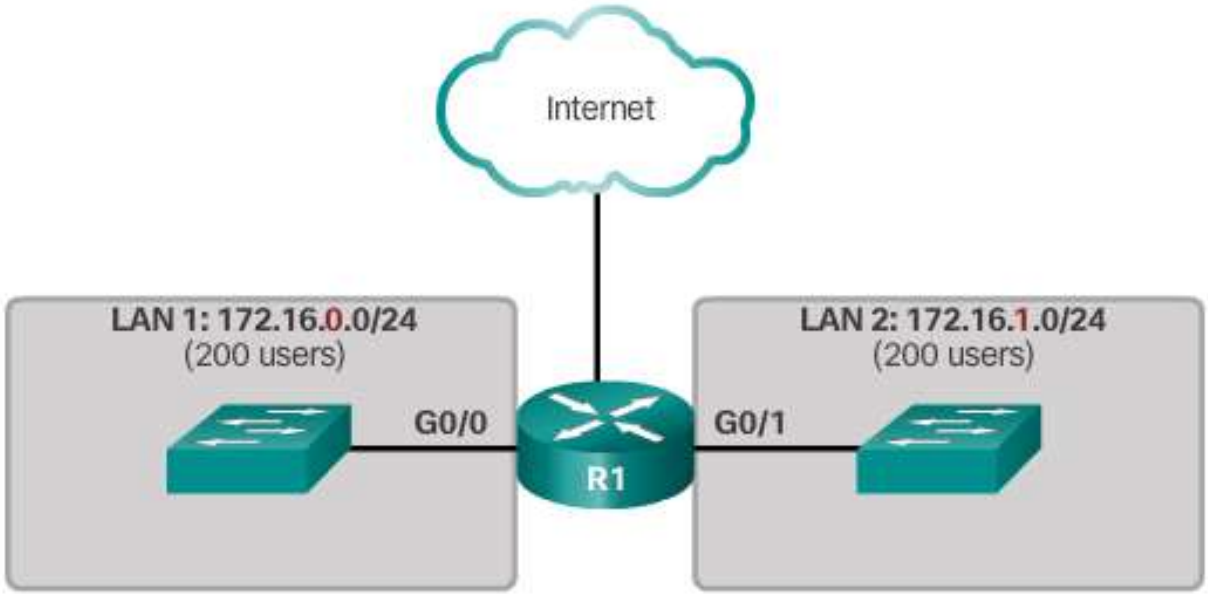
Problems with Large Broadcast Domains

- Slow network operations due to the significant amount of broadcast traffic.
- Slow device operations because a device must accept and process each broadcast packet.



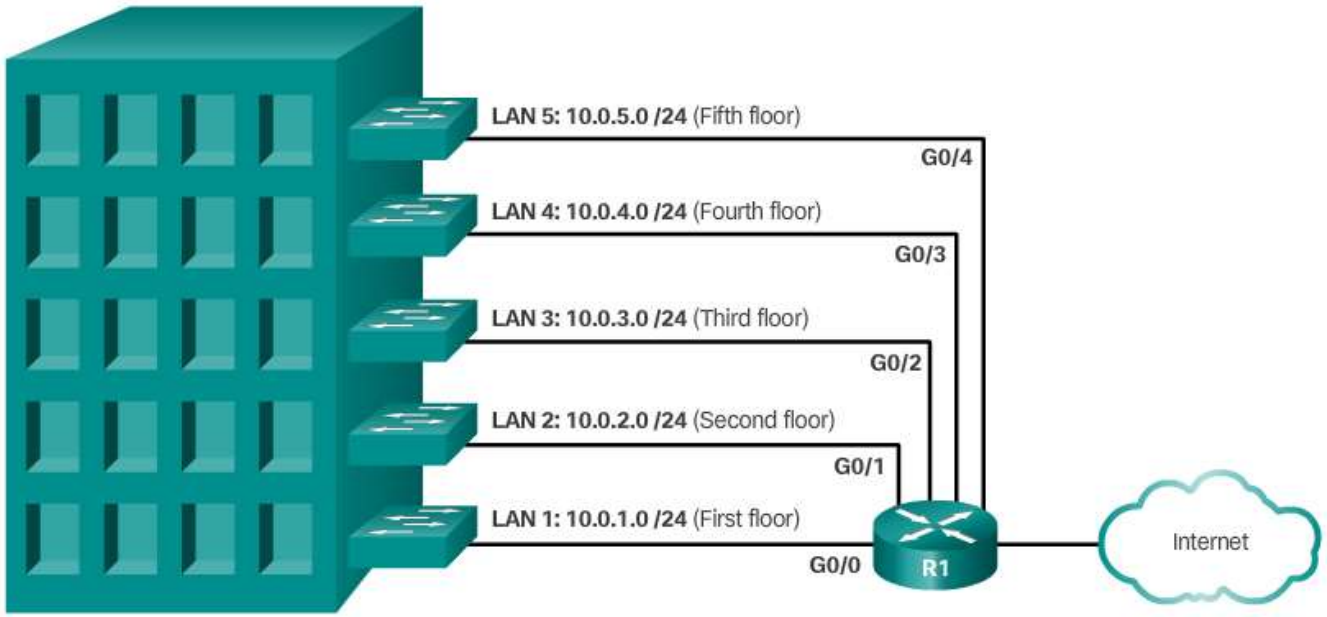
Problems with Large Broadcast Domains (cont.)

- Solution -reduce the size of the network to create smaller broadcast domains in a process called *subnetting*.
- These smaller network spaces are called *subnets*.



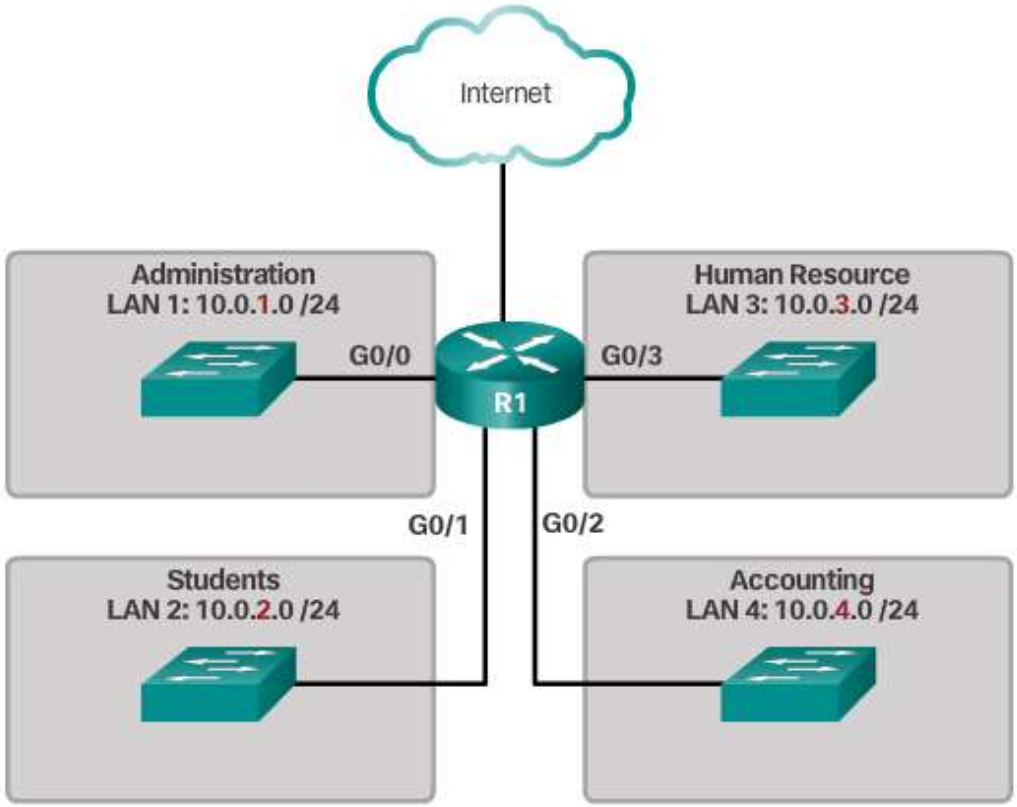
Reasons for Subnetting

Network administrators can group devices and services into subnets that are determined by: Location



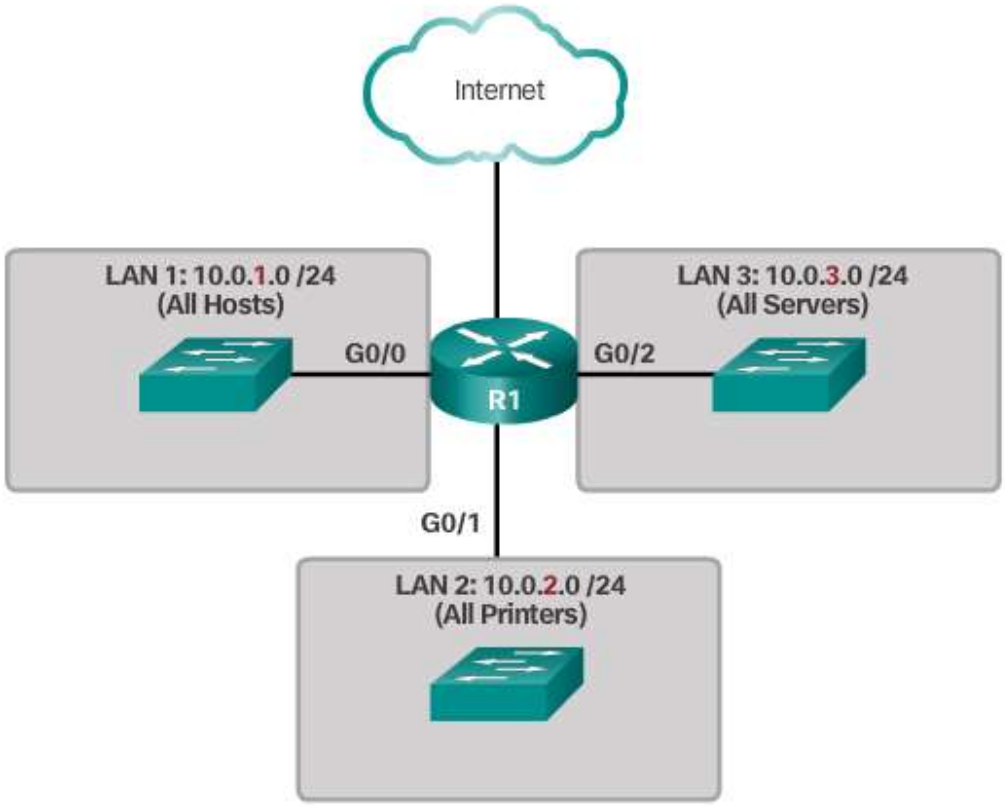
Reasons for Subnetting (cont.)

Network administrators can group devices and services into subnets that are determined by: Organizational unit.



Reasons for Subnetting (cont.)

Network administrators can group devices and services into subnets that are determined by: Device type.



Topic 8.1.2:
Subnetting an IPv4 Network

Octet Boundaries

Subnetting Networks on the Octet Boundary

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

Subnetting on the Octet Boundary

Subnetting 10.x.0.0/16

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

Subnetting 10.x.x.0/24

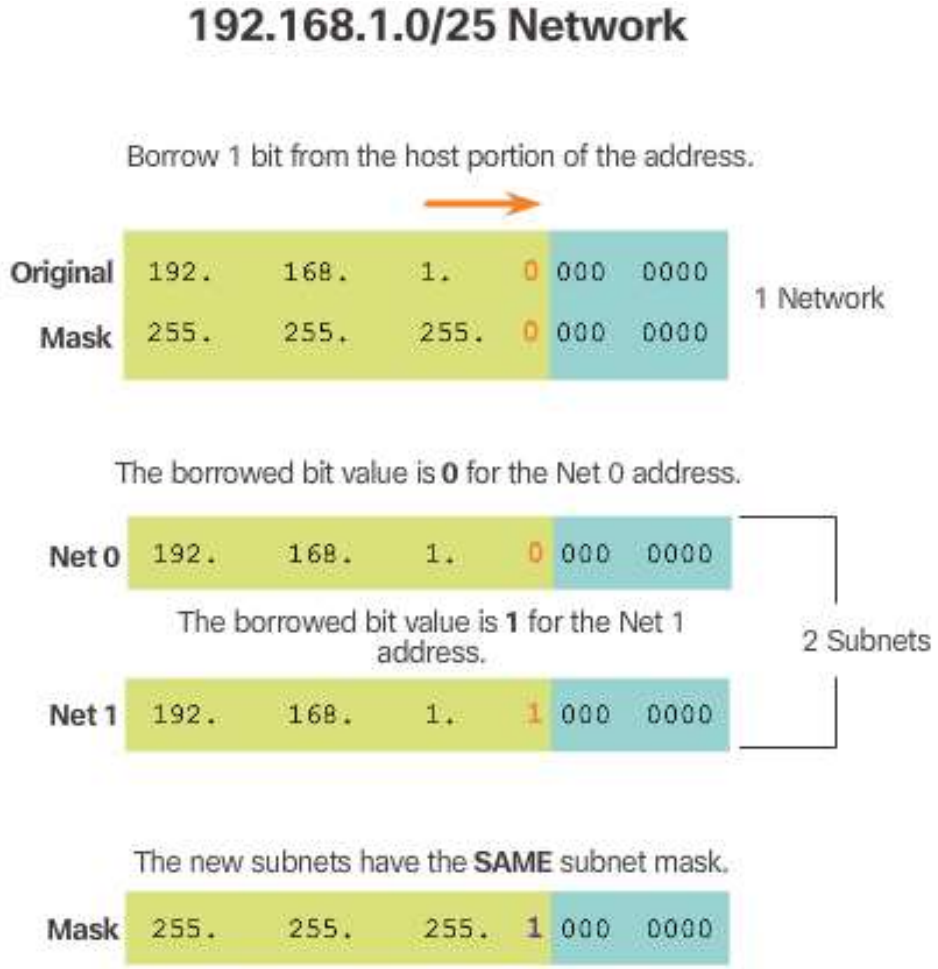
Subnet Address (65,536 Possible Subnets)	Host Range (254 possible hosts per subnet)	Broadcast
10.0.0.0/24	10.0.0.1 – 10.0.0.254	10.0.0.255
10.0.1.0/24	10.0.1.1 – 10.0.1.254	10.0.1.255
10.0.2.0/24	10.0.2.1 – 10.0.2.254	10.0.1.255
…	…	…
10.0.255.0/24	10.0.255.1 – 10.0.255.254	10.0.255.255
10.1.0.0/24	10.1.0.1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

Classless Subnetting

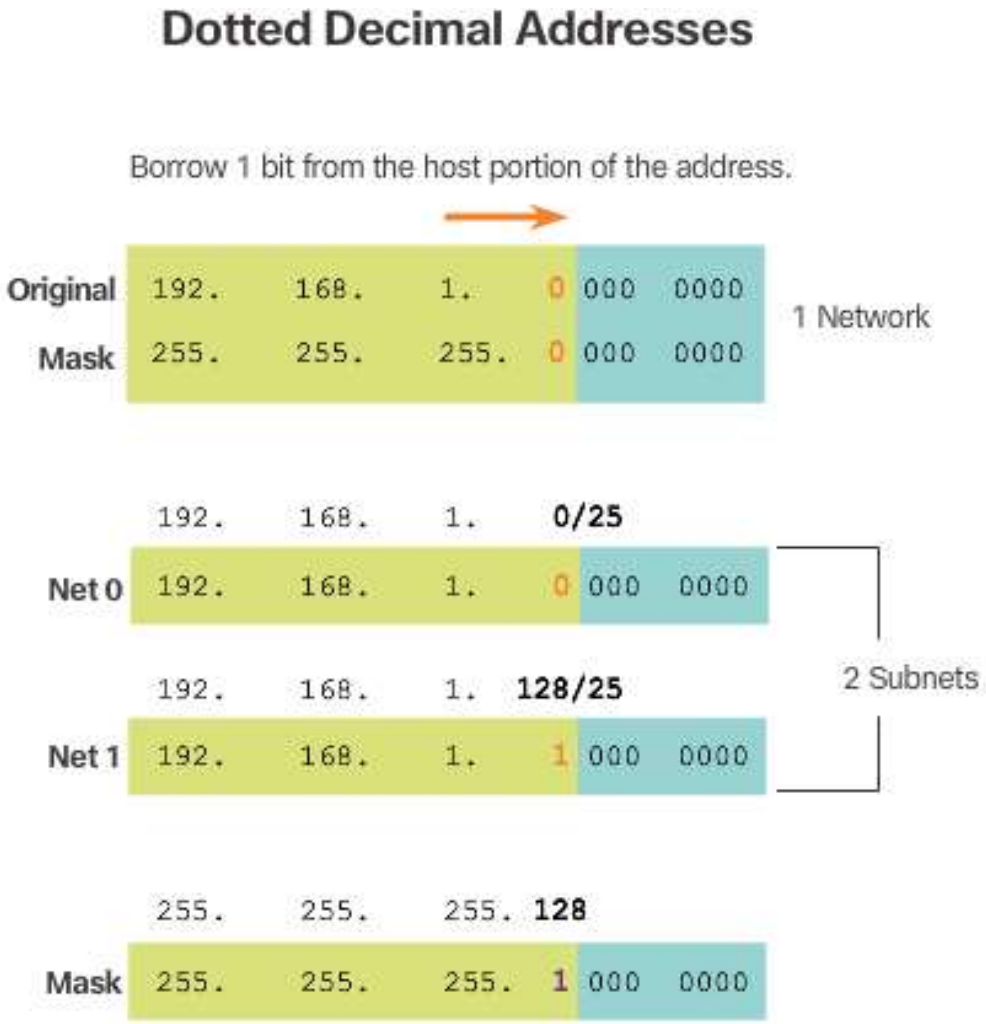
- /25 – Borrowing 1 bit from the fourth octet creates 2 subnets supporting 126 hosts each.
- /26 – Borrowing 2 bits creates 4 subnets supporting 62 hosts each.
- /27– Borrowing 3 bits creates 8 subnets supporting 30 hosts each.
- /28 – Borrowing 4 bits creates 16 subnets supporting 14 hosts each.
- /29 – Borrowing 5 bits creates 32 subnets supporting 6 hosts each.
- /30– Borrowing 6 bits creates 64 subnets supporting 2 hosts each.

Prefix Length	Subnet Mask	Subnet Mask in Binary (n = network, h = host)	# of subnets	# of hosts
/25	255.255.255.128	nnnnnnnn.nnnnnnnn.nnnnnnnn.nhhhhhhh 11111111.11111111.11111111.10000000	2	126
/26	255.255.255.192	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnhhhhhh 11111111.11111111.11111111.11000000	4	62
/27	255.255.255.224	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnnhhhhh 11111111.11111111.11111111.11100000	8	30
/28	255.255.255.240	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnnnhhhh 11111111.11111111.11111111.11110000	16	14
/29	255.255.255.248	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnnnnhhh 11111111.11111111.11111111.11111000	32	6
/30	255.255.255.252	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnnnnnhh 11111111.11111111.11111111.11111100	64	2

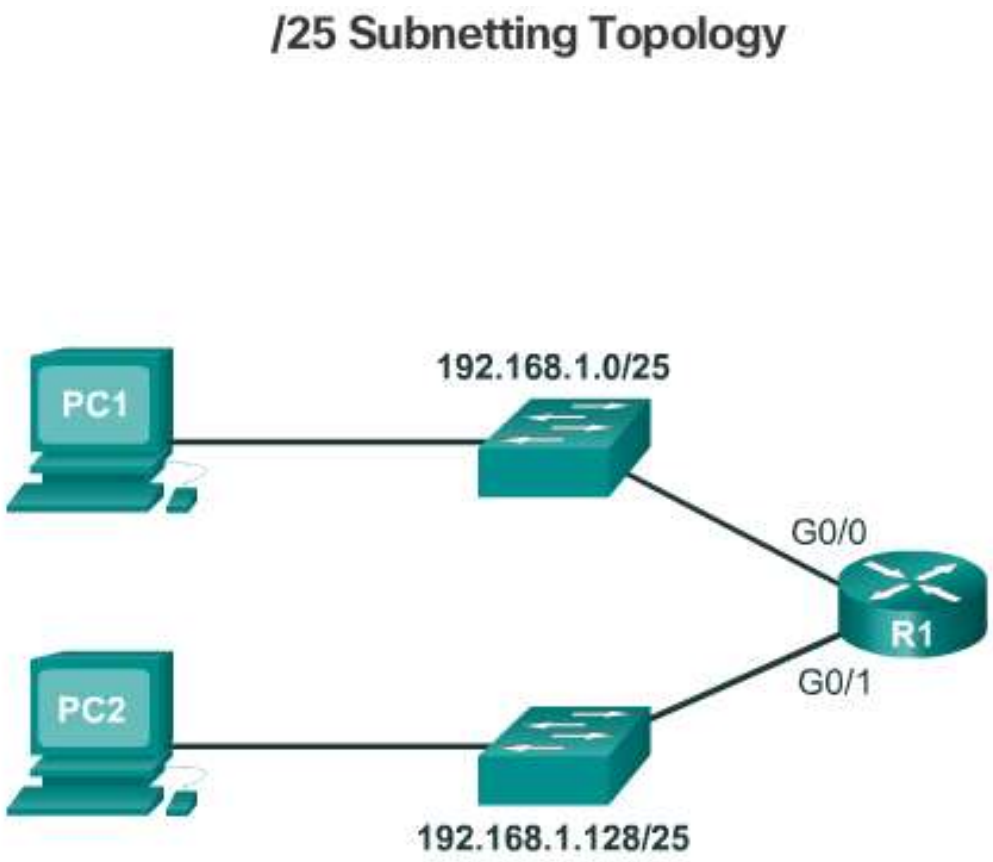
Classless Subnetting Example



Classless Subnetting Example (cont.)



Creating 2 Subnets



Creating 2 Subnets (cont.)

Address Range for 192.168.1.0/25 Subnet

Network Address

192. 168. 1. 0 000 0000 = 192.168.1.0

First Host Address

192. 168. 1. 0 000 0001 = 192.168.1.1

Last Host Address

192. 168. 1. 0 111 1110 = 192.168.1.126

Broadcast Address

192. 168. 1. 0 111 1111 = 192.168.1.127

Address Range for 192.168.1.128/25 Subnet

Network Address

192. 168. 1. 1 000 0000 = 192.168.1.128

First Host Address

192. 168. 1. 1 000 0001 = 192.168.1.129

Last Host Address

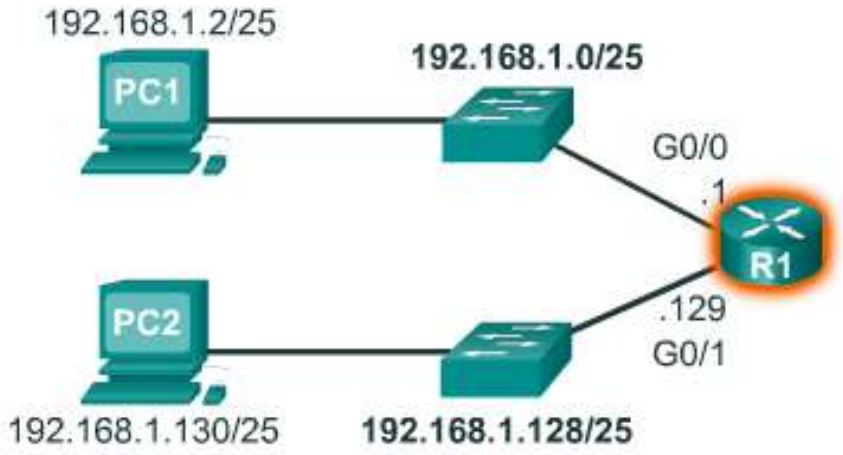
192. 168. 1. 1 111 1110 = 192.168.1.254

Broadcast Address

192. 168. 1. 1 111 1111 = 192.168.1.255

Creating 2 Subnets (cont.)

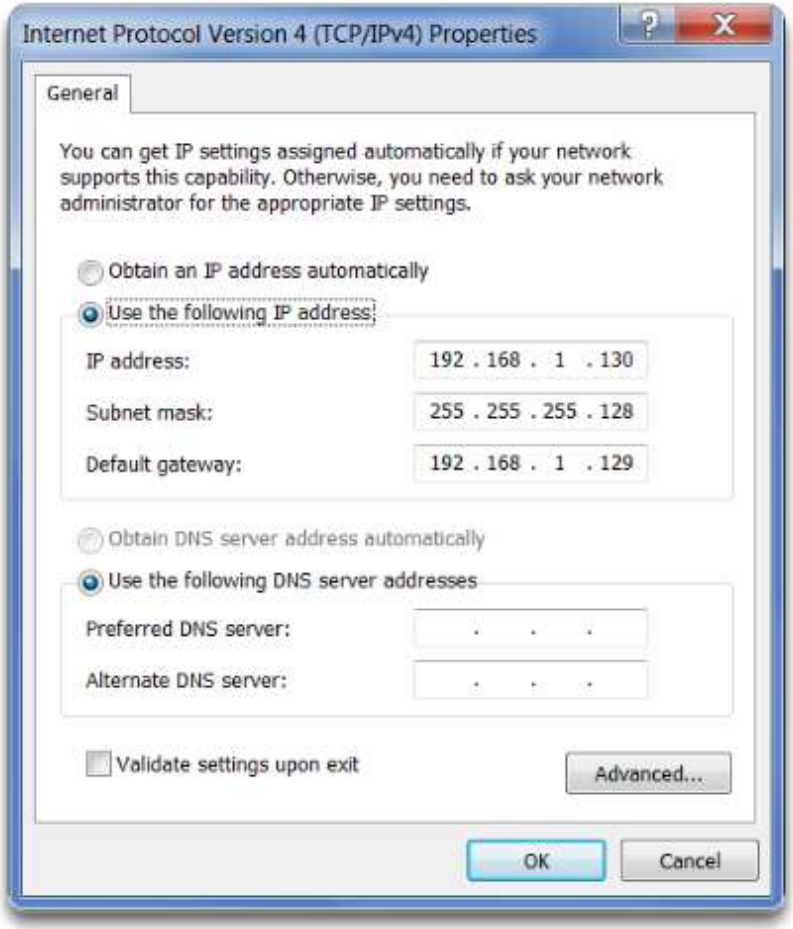
Configure R1 Gigabit Interfaces




```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ip address 192.168.1.1 255.255.255.128
R1(config-if)#exit
R1(config)#interface gigabitethernet 0/1
R1(config-if)#ip address 192.168.1.129 255.255.255.128
```

Creating 2 Subnets (cont.)

Assign a Valid Host IP Address



Subnetting Formulas

To calculate the number of subnets.

$$2^n$$

n= bits borrowed

192 . 168 . 1 . 0

nnnnnnnn . nnnnnnnn . nnnnnnnn . hhhhhhhh

Borrowing 1 bit: 2^1 = 2

Borrowing 2 bits: 2^2 = 4

Borrowing 3 bits: 2^3 = 8

Borrowing 4 bits: 2^4 = 16

Borrowing 5 bits: 2^5 = 32

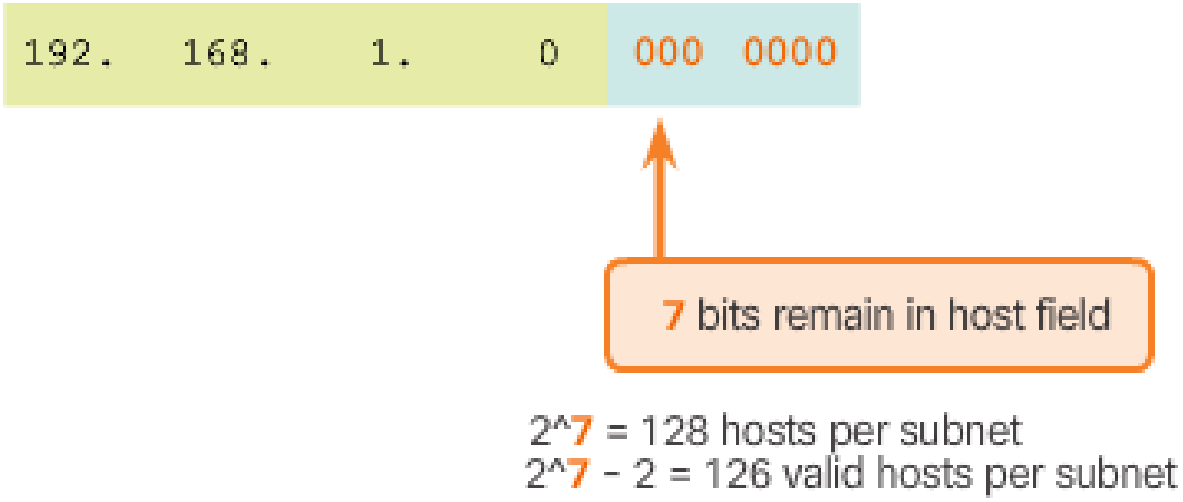
Borrowing 6 bits: 2^6 = 64

Subnetting Formulas (cont.)

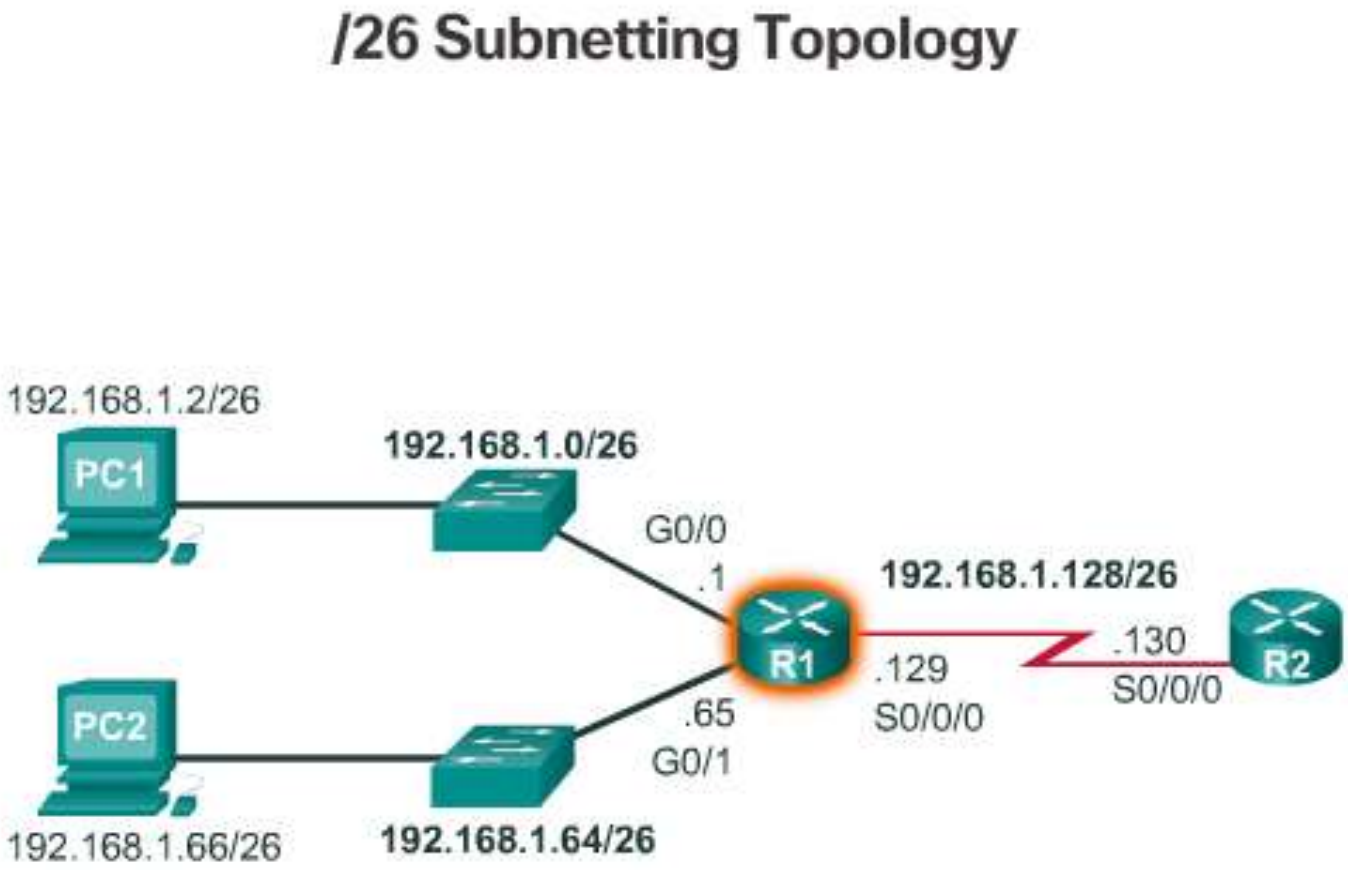
To calculate the number of hosts.

$$2^n-2$$

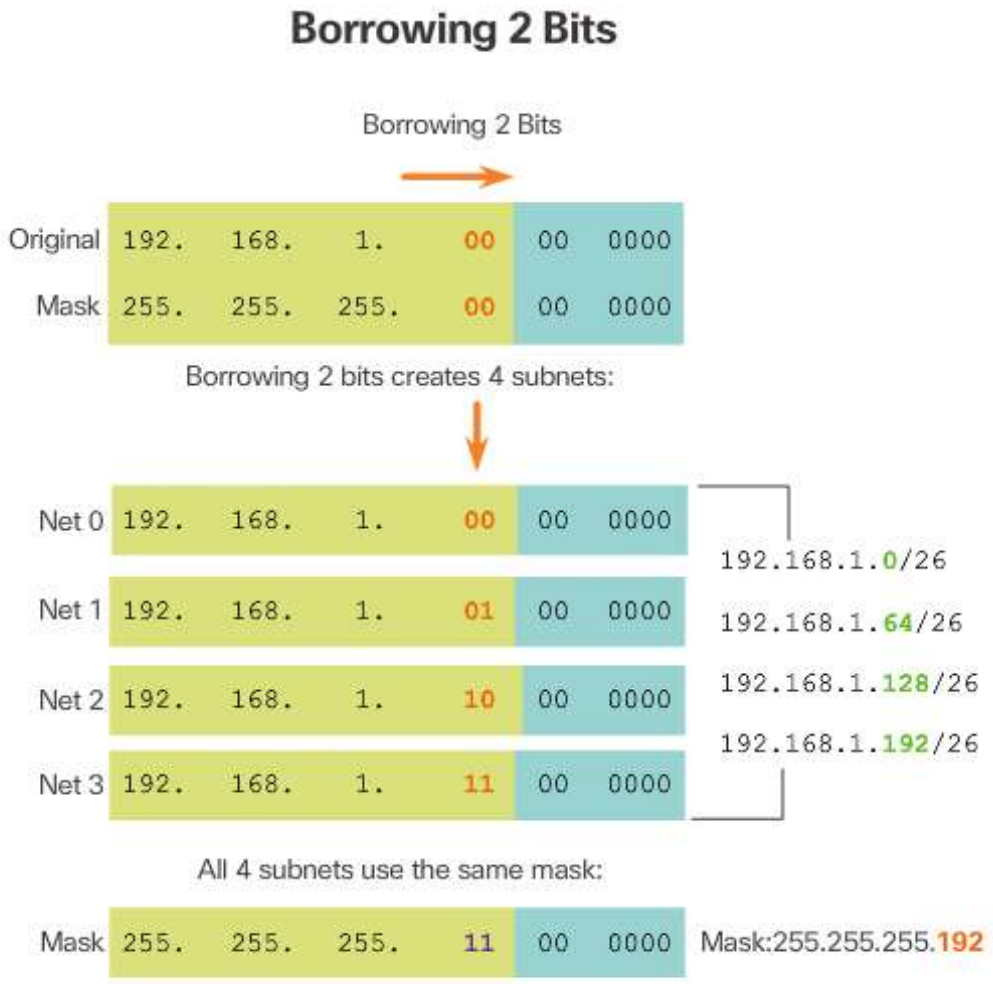
n= the number of bits remaining in the host field



Creating 4 Subnets

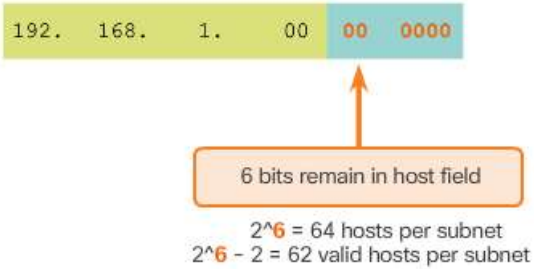


Creating 4 Subnets (cont.)



Creating 4 Subnets (cont.)

Calculate Number of Hosts



Address Range for 192.168.1.0/26 Subnet

Network Address

192. 168. 1. 00 00 0000 = 192.168.1.0

First Host Address

192. 168. 1. 00 00 0001 = 192.168.1.1

Last Host Address

192. 168. 1. 00 11 1110 = 192.168.1.62

Broadcast Address

192. 168. 1. 00 11 1111 = 192.168.1.63

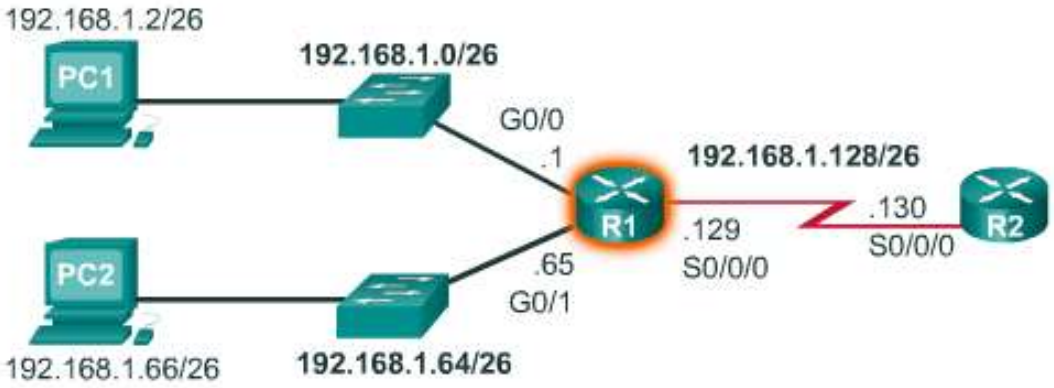
Creating 4 Subnets (cont.)

Address Ranges Nets 0 - 2

Net 0	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
Net 1	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
Net 2	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

Creating 4 Subnets (cont.)

Configuring the Interfaces with /26 Addresses



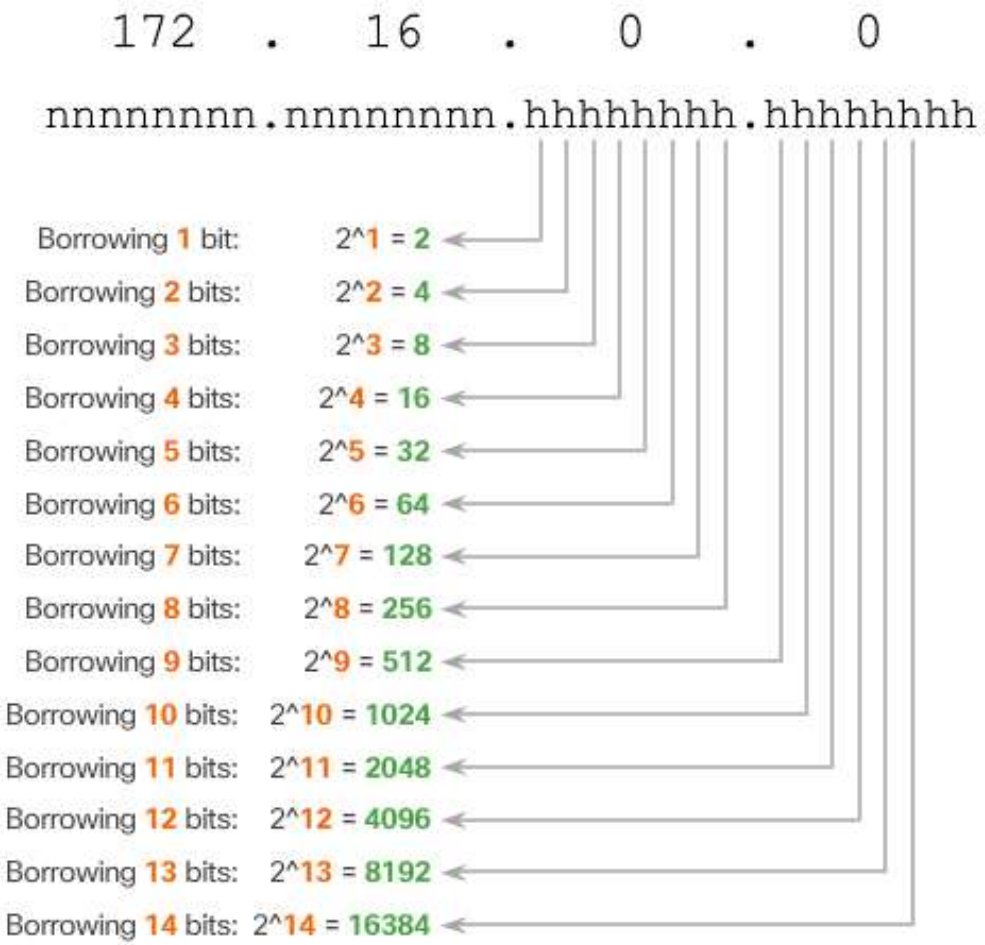

```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ip address 192.168.1.1 255.255.255.192
R1(config-if)#exit
R1(config)#interface gigabitethernet 0/1
R1(config-if)#ip address 192.168.1.65 255.255.255.192
R1(config-if)#exit
R1(config)#interface serial 0/0/0
R1(config-if)#ip address 192.168.1.129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

Topic 8.1.3:
Subnetting a /16 and a /8 Prefix

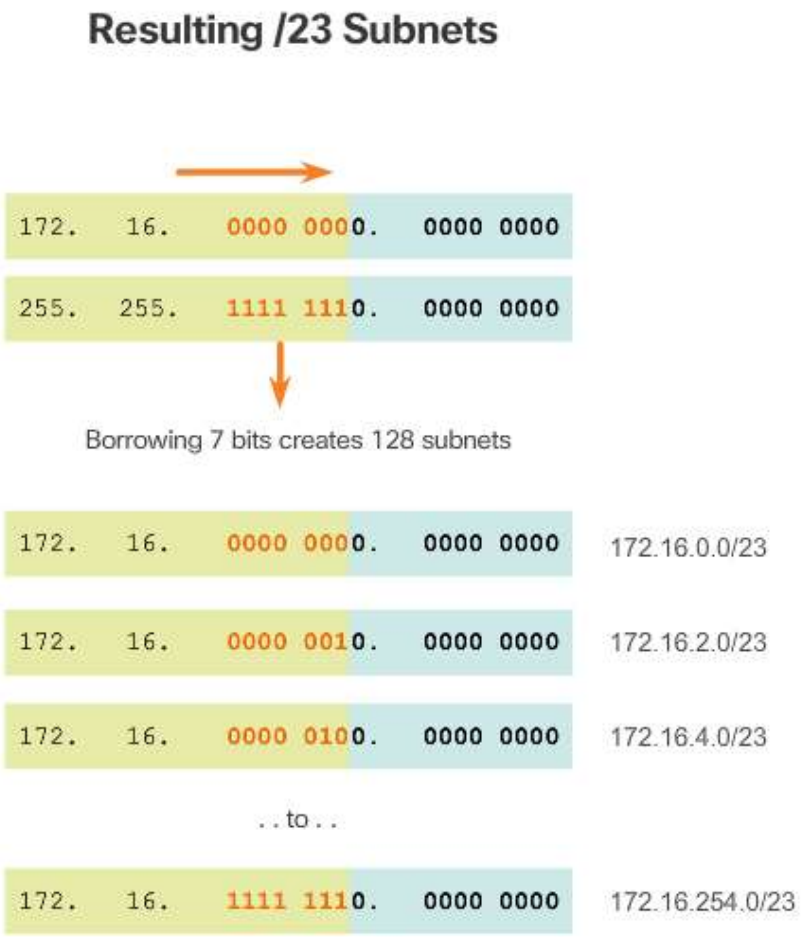
Creating Subnets with a /16 prefix

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	32564
/18	255.255.192.0	nnnnnnnn.nnnnnnnn.nnhhhhhh.hhhhhhhh 11111111.11111111.11000000.00000000	4	16282
/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
/23	255.255.254.0	nnnnnnnn.nnnnnnnn.nnnnnnnh.hhhhhhhh 11111111.11111111.11111110.00000000	128	510
/24	255.255.255.0	nnnnnnnn.nnnnnnnn.nnnnnnnn.hhhhhhhh 11111111.11111111.11111111.00000000	256	254
/25	255.255.255.128	nnnnnnnn.nnnnnnnn.nnnnnnnn.nhhhhhhh 11111111.11111111.11111111.10000000	512	126
/26	255.255.255.192	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnhhhhhh 11111111.11111111.11111111.11000000	1024	62
/27	255.255.255.224	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnnhhhhh 11111111.11111111.11111111.11100000	2048	30

Creating 100 Subnets with a /16 Network



Creating 100 Subnets with a /16 Network (cont.)



Calculating the Hosts

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

172. 16. 00 00 00 00. 0000 0000

9 bits remain in host field

2^9 = 512 hosts per subnet
2^9 - 2 = 510 valid hosts per subnet

Address Range for 172.16.0.0/23 Subnet

Network Address

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

First Host Address

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

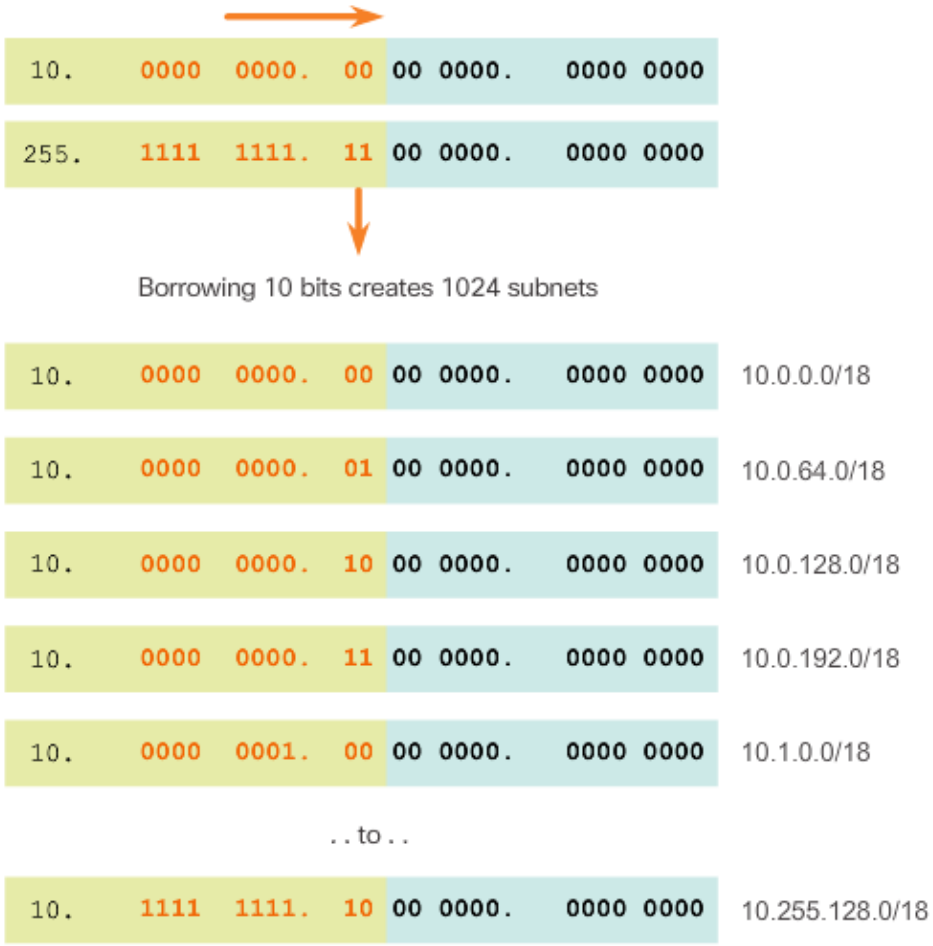
Last Host Address

172. 16. 00 00 00 01. 1111 1110 = 172.16.1.254/23

Broadcast Address

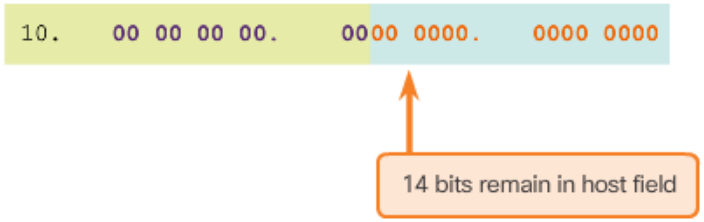
172. 16. 00 00 00 01. 1111 1111 = 172.16.1.255/23

Creating 1000 Subnets with a /8 Network



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

Calculating Hosts



2^14 = 16384 hosts per subnet
2^14 - 2 = 16382 valid hosts per subnet

Address Range for 10.0.0.0/18 Subnet

Network Address
10. 00 00 00 00. 0000 0000. 0000 0000 = 10.0.0.0/18

First Host Address
10. 00 00 00 00. 0000 0000. 0000 0001 = 10.0.0.1/18

Last Host Address
10. 00 00 00 00. 0011 1111. 1111 1110 = 10.0.63.254/18

Broadcast Address
10. 00 00 00 00. 0011 1111. 1111 1111 = 10.0.63.255/18

Topic 8.1.4:
Subnetting to Meet Requirements

Subnetting Based on Host Requirements

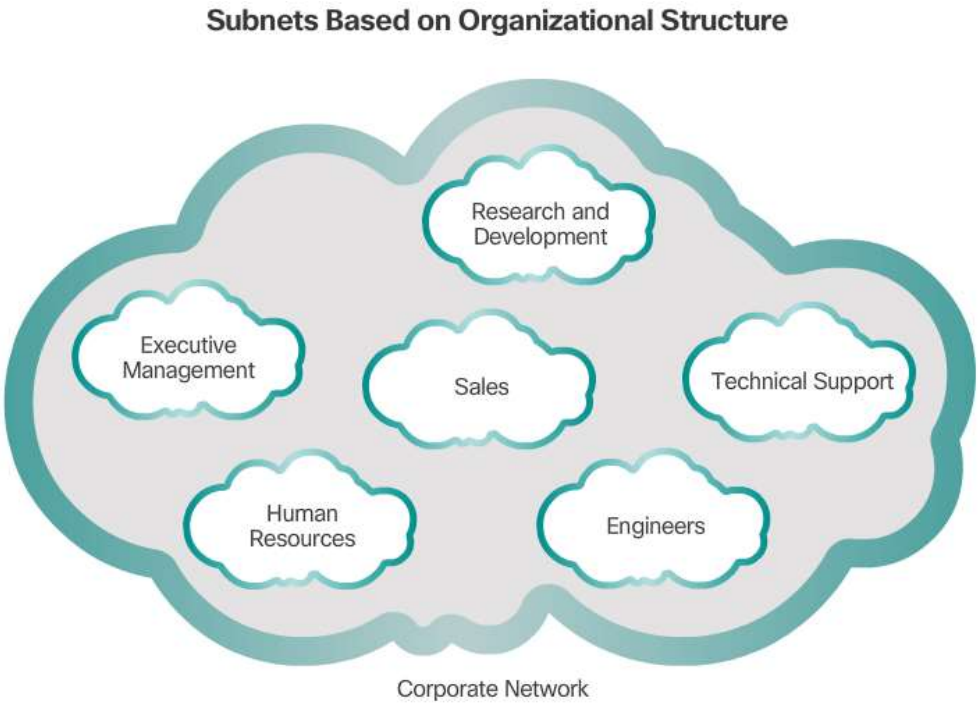
Two considerations when planning subnets:

- The number of host addresses required for each network.
- The number of individual subnets needed.

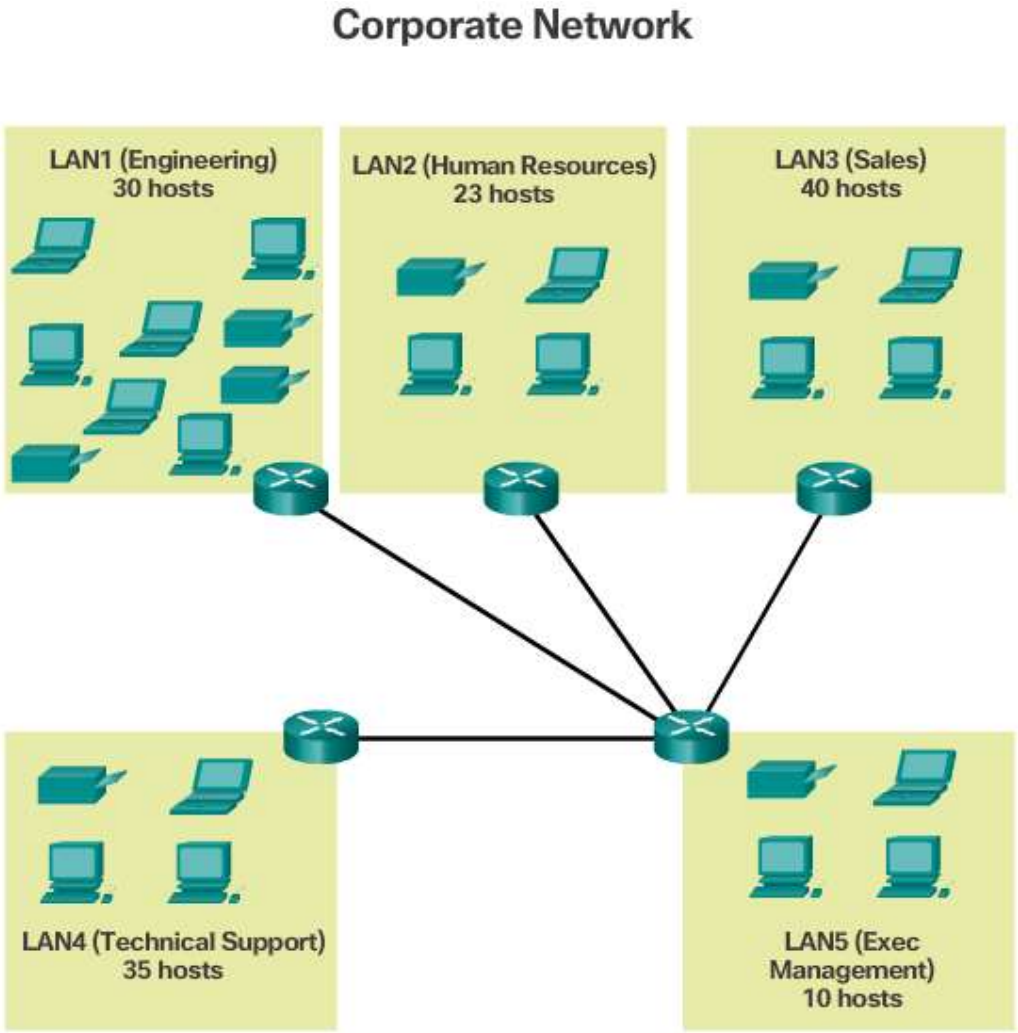
Prefix Length	Subnet Mask	Subnet Mask in Binary (n = network, h = host)	# of subnets	# of hosts
/25	255.255.255.128	nnnnnnnn.nnnnnnnn.nnnnnnnn.nhhhhhhh 11111111.11111111.11111111.10000000	2	126
/26	255.255.255.192	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnhhhhhh 11111111.11111111.11111111.11000000	4	62
/27	255.255.255.224	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnnhhhhh 11111111.11111111.11111111.11100000	8	30
/28	255.255.255.240	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnnnhhhh 11111111.11111111.11111111.11110000	16	14
/29	255.255.255.248	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnnnnhhh 11111111.11111111.11111111.11111000	32	6
/30	255.255.255.252	nnnnnnnn.nnnnnnnn.nnnnnnnn.nnnnnnhh 11111111.11111111.11111111.11111100	64	2

The more bits borrowed to create subnets, the fewer host bits available.

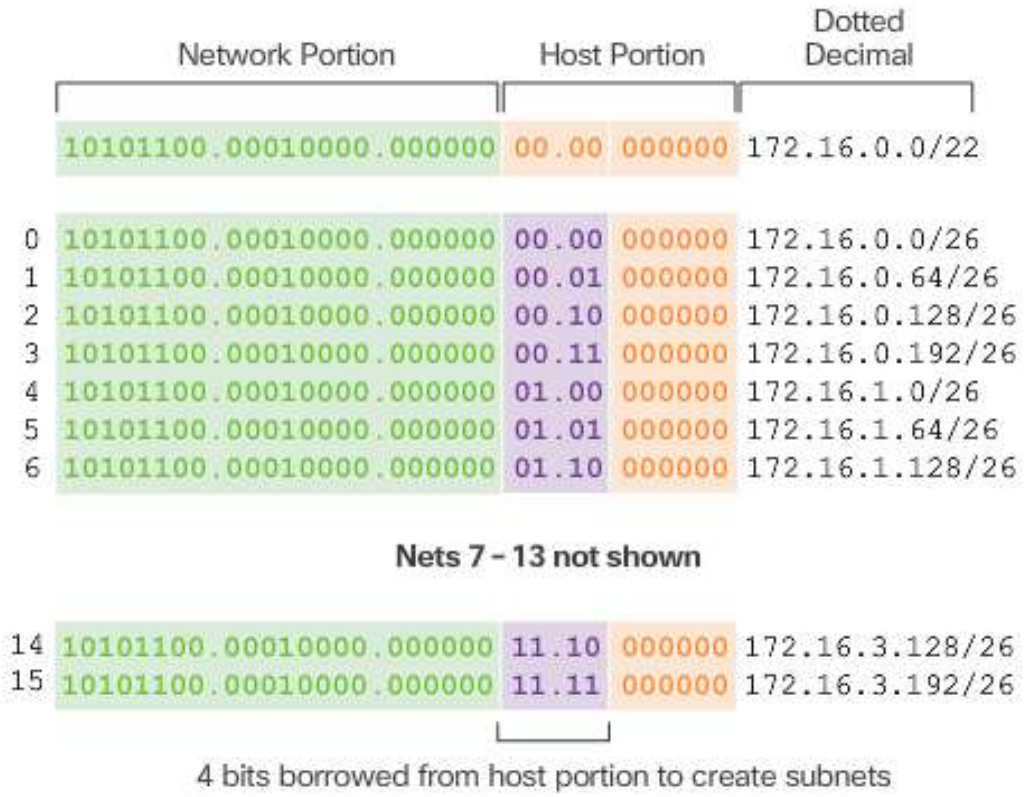
Subnetting Based on Network Requirements



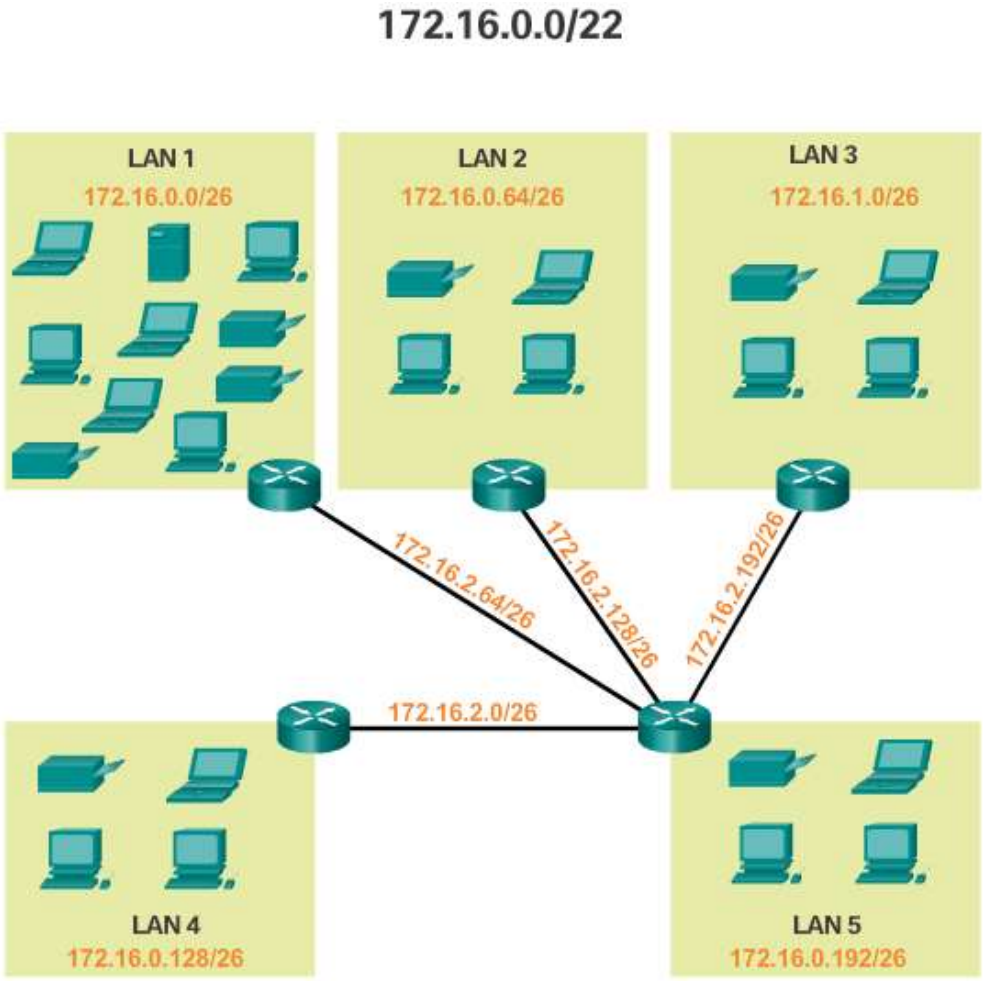
Network Requirement Example



Network Requirement Example (cont.)

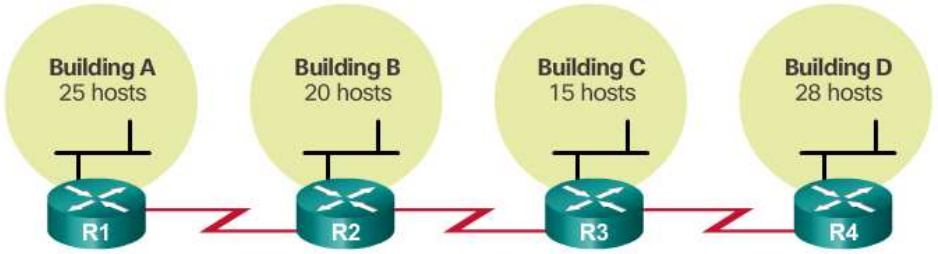


Network Requirement Example (cont.)



Topic 8.1.5:
Benefits of Variable Length Subnetting 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

Building LANs A, B, C, and D

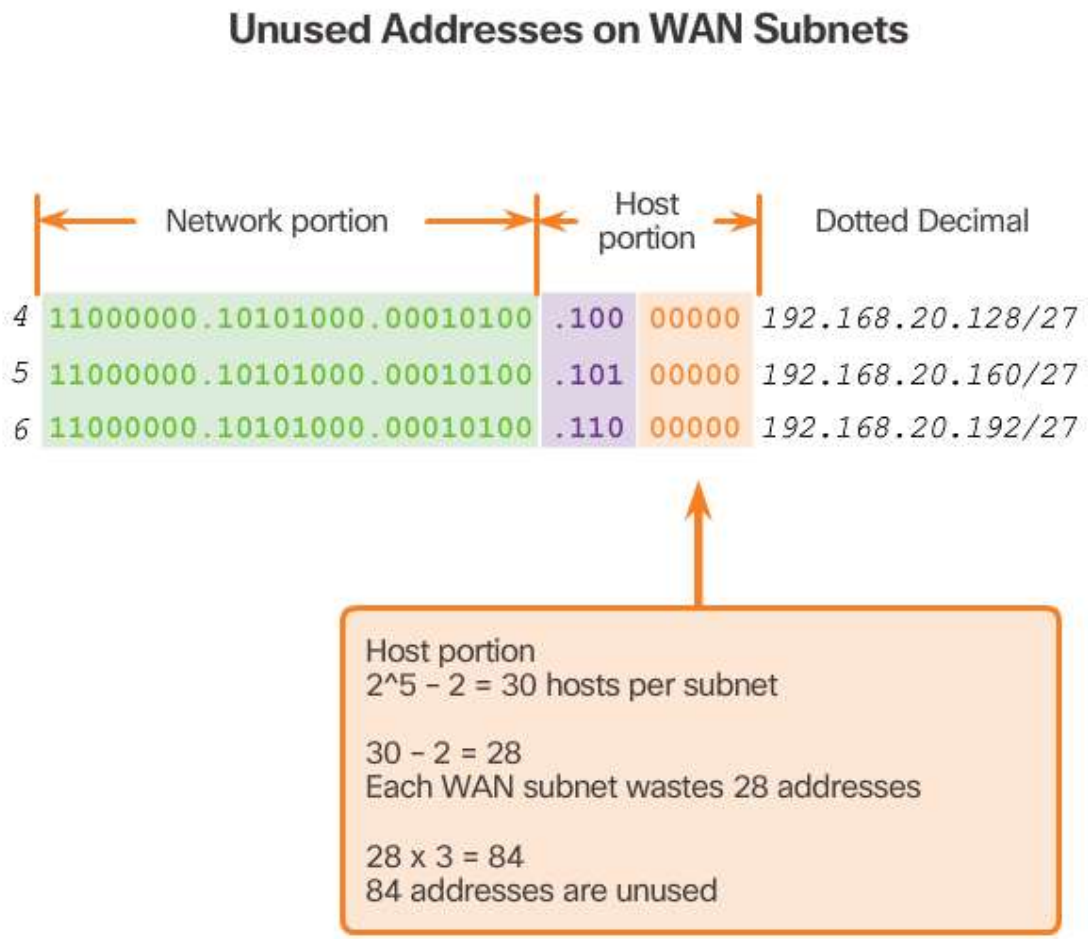
Site to Site WANs

Unused / Available

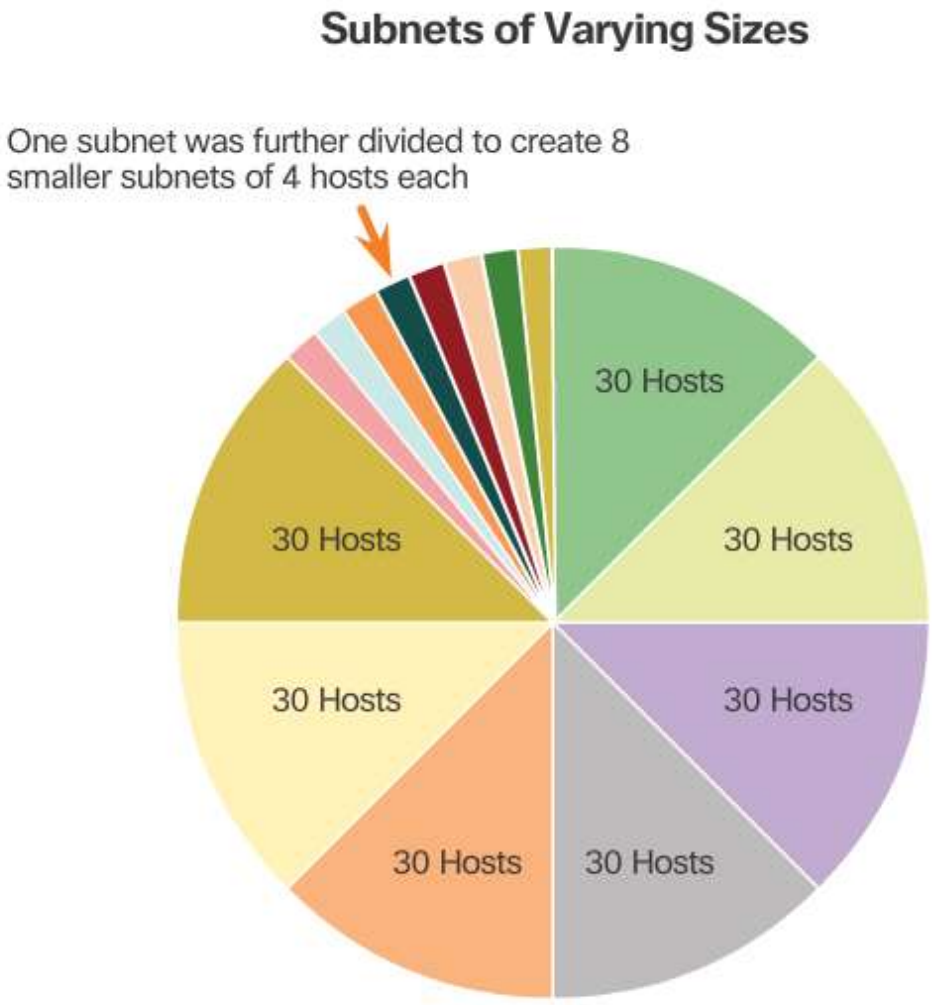
Subnet portion
2^3 = 8 subnets

Host portion
2^5 – 2 = 30 hosts per subnet

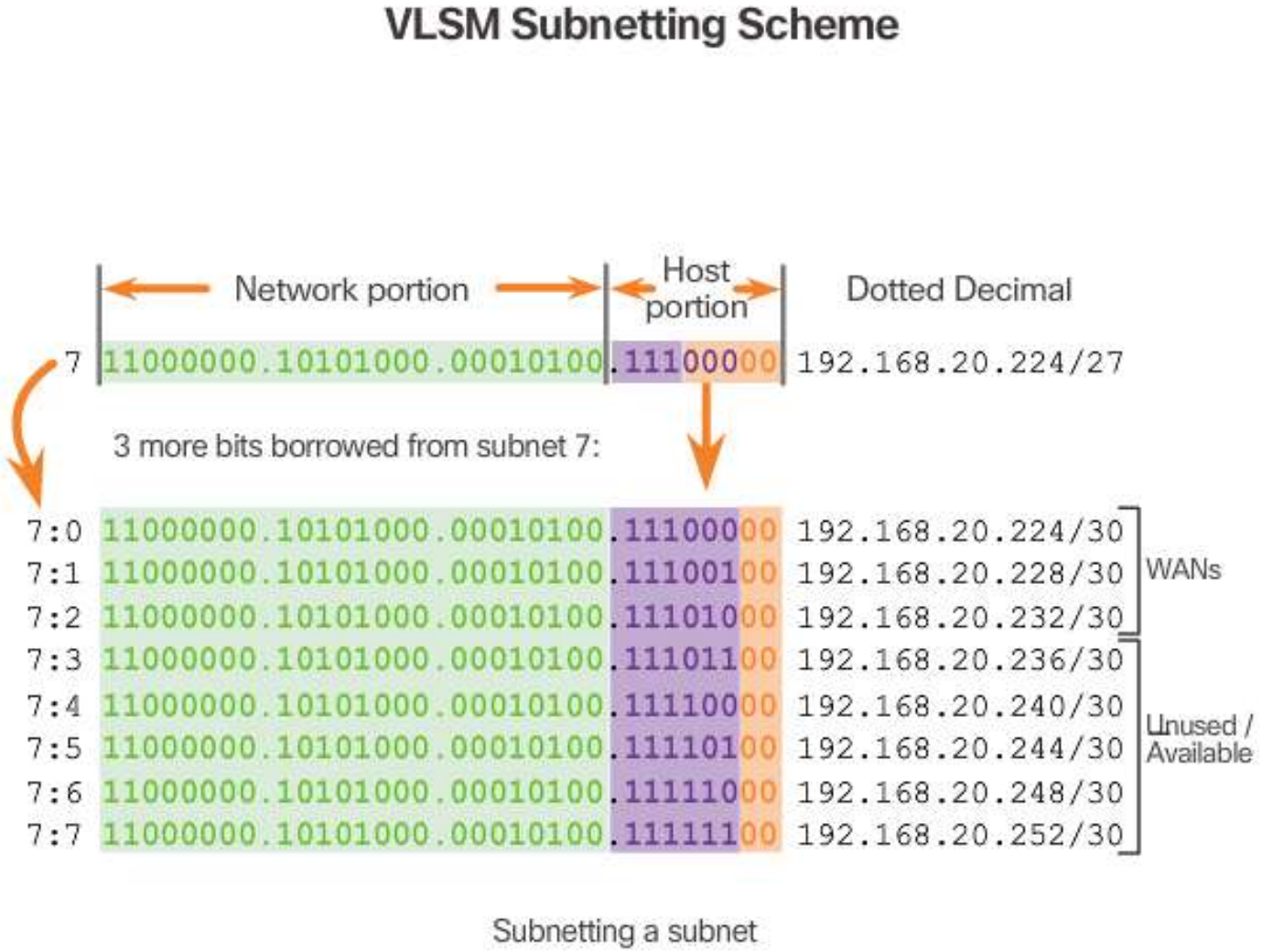
Traditional Subnetting Wastes Addresses (Cont.)



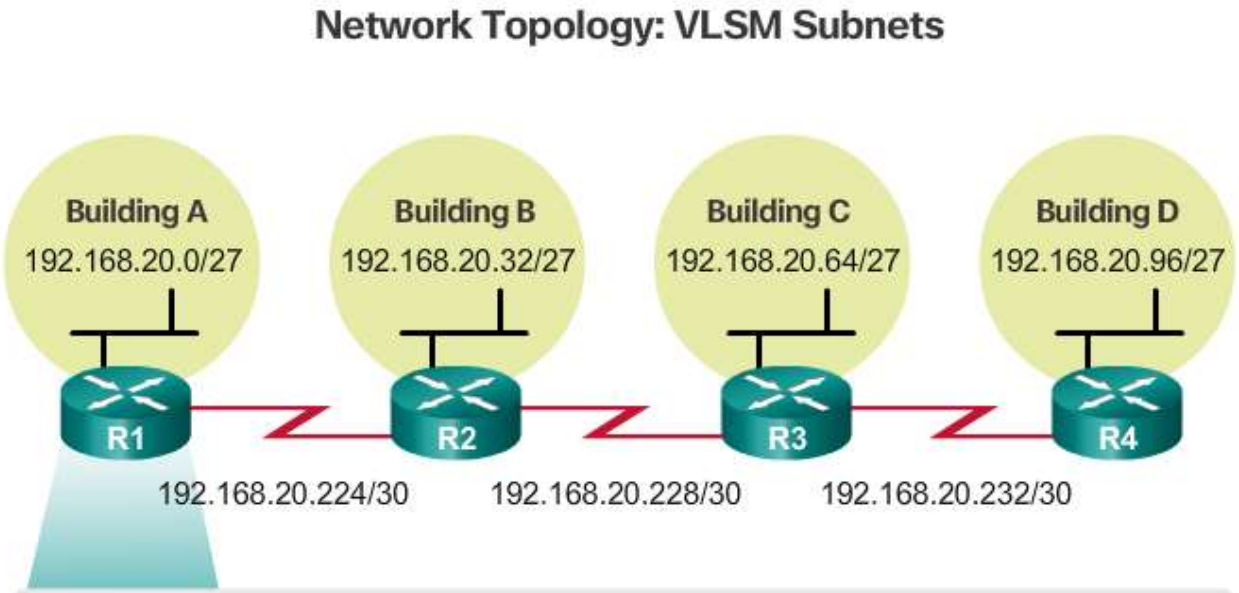
Variable Length Subnet Masks



Basic VLSM

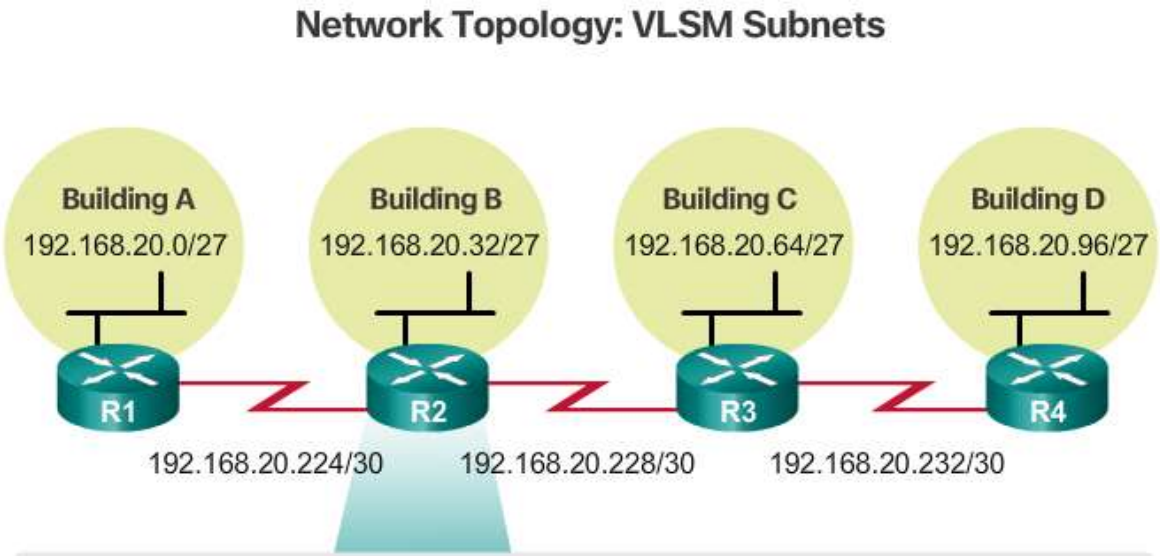


VLSM in Practice



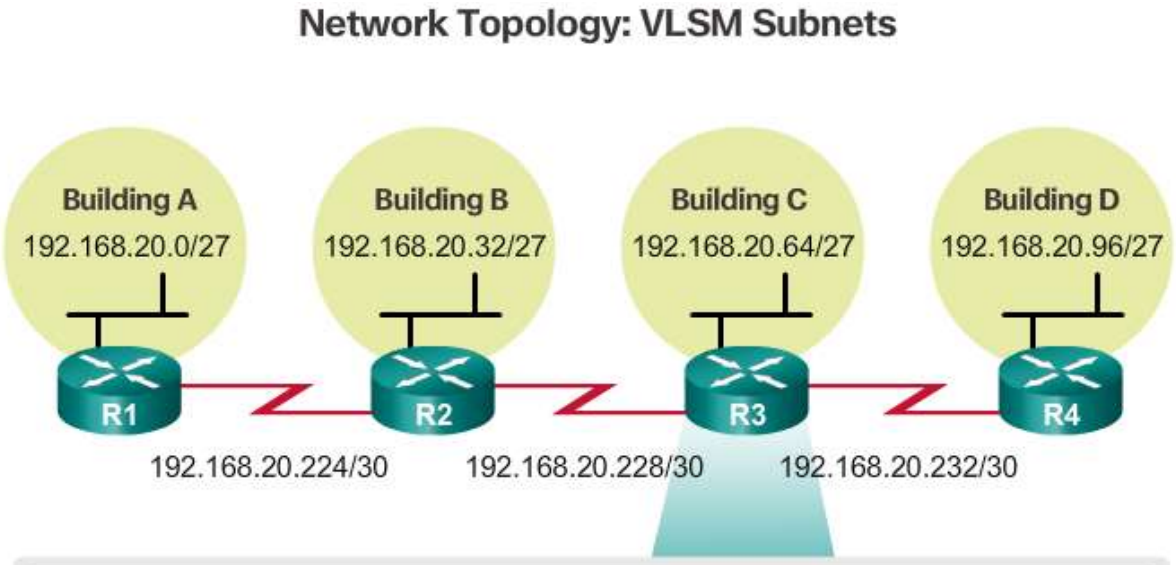

```
R1(config)# interface gigabitethernet 0/0
R1(config-if)# ip address 192.168.20.1 255.255.255.224
R1(config-if)# exit
R1(config)# interface serial 0/0/0
R1(config-if)# ip address 192.168.20.225 255.255.255.252
R1(config-if)# end
R1#
```

VLSM in Practice (cont.)



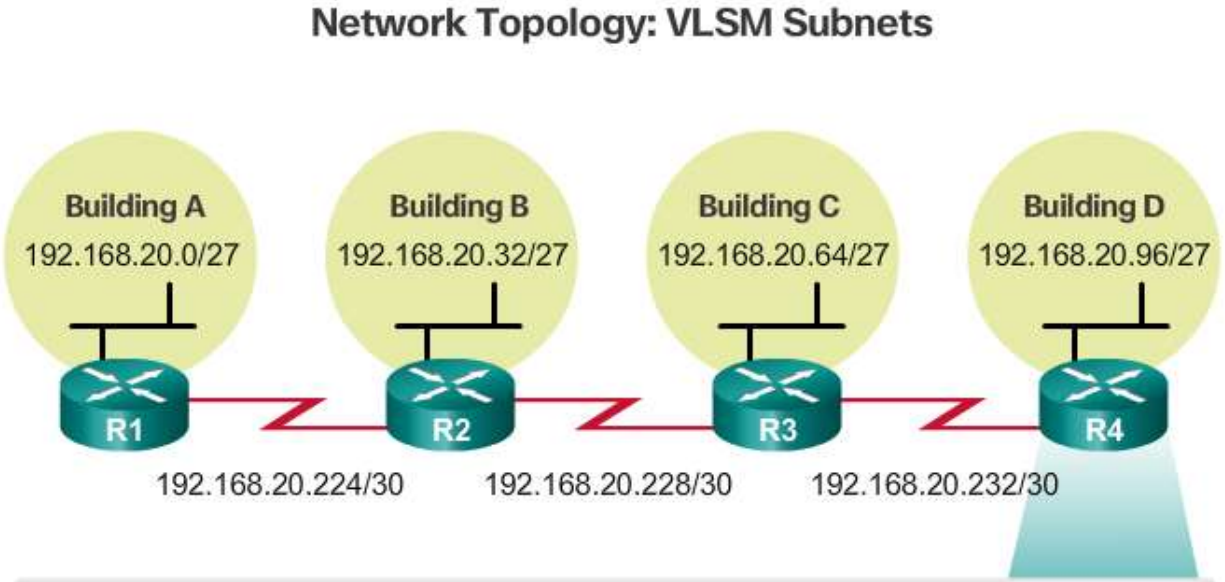

```
R2(config)# interface gigabitethernet 0/0
R2(config-if)# ip address 192.168.20.33 255.255.255.224
R2(config-if)# exit
R2(config)# interface serial 0/0/0
R2(config-if)# ip address 192.168.20.226 255.255.255.252
R2(config-if)# exit
R2(config)# interface serial 0/0/1
R2(config)# ip address 192.168.20.229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

VLSM in Practice (cont.)




```
R3(config)# interface gigabitethernet 0/0
R3(config-if)# ip address 192.168.20.65 255.255.255.224
R3(config-if)# exit
R3(config)# interface serial 0/0/0
R3(config-if)# ip address 192.168.20.230 255.255.255.252
R3(config-if)# exit
R3(config)# interface serial 0/0/1
R3(config)# ip address 192.168.20.233 255.255.255.252
R3(config-if)# end
R3#
```

VLSM in Practice (Cont.)




```
R4(config)# interface gigabitethernet 0/0
R4(config-if)# ip address 192.168.20.97 255.255.255.224
R4(config-if)# exit
R4(config)# interface serial 0/0/0
R4(config-if)# ip address 192.168.20.234 255.255.255.252
R4(config-if)# end
R4#
```

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

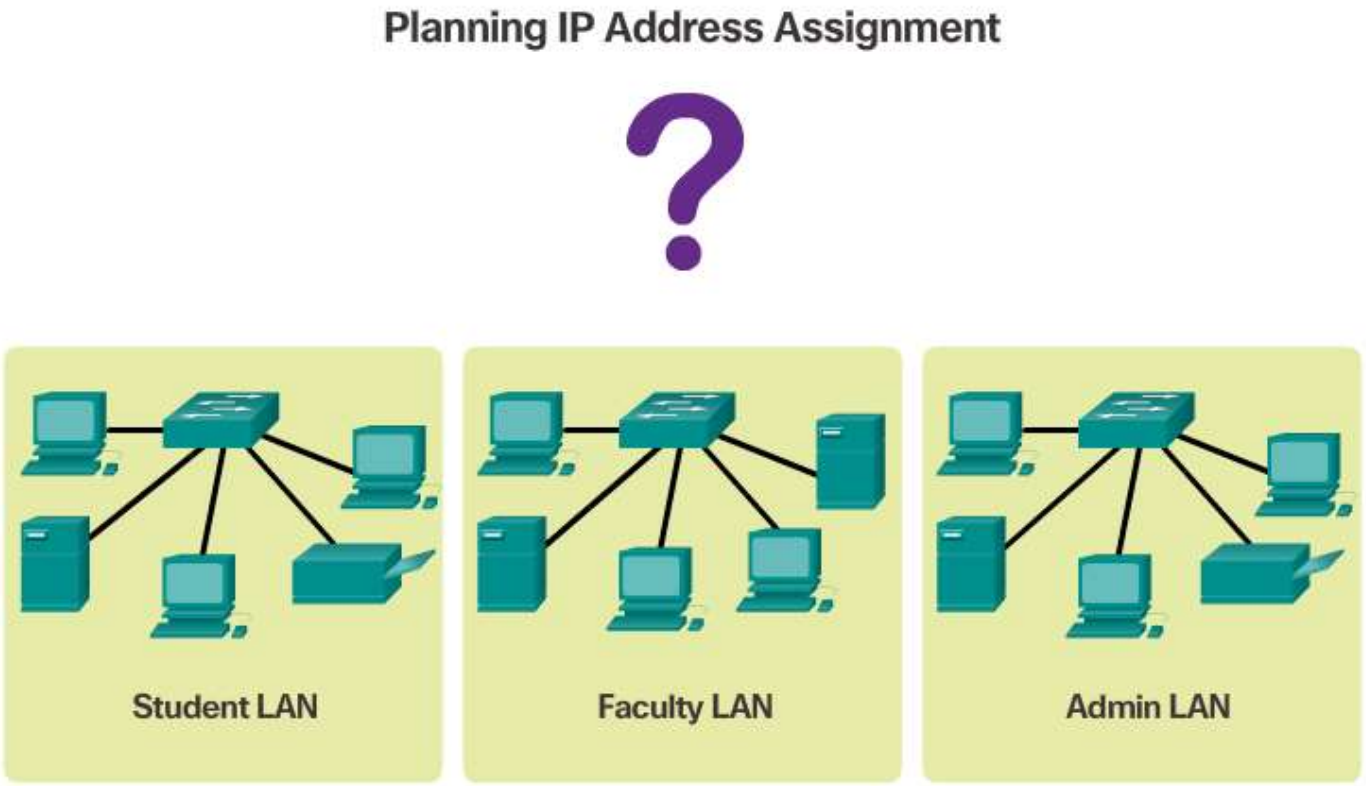
Section 8.2: Addressing Schemes

Upon completion of this section, you should be able to:

- Implement a VLSM addressing scheme.

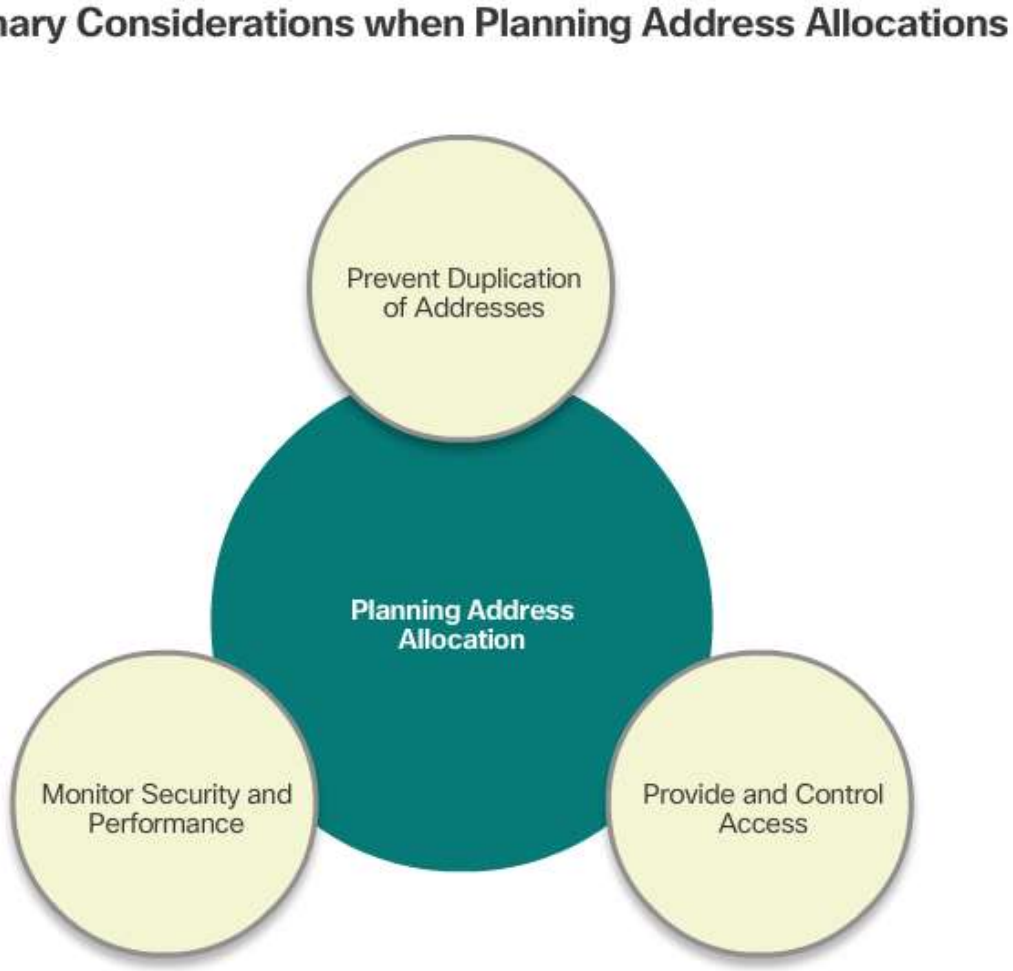
Topic 8.2.1:
Structured Design

Network Address Planning



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



Assigning Addresses to Devices

IP Address Ranges

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	

Section 8.3: Design Considerations for IPv6

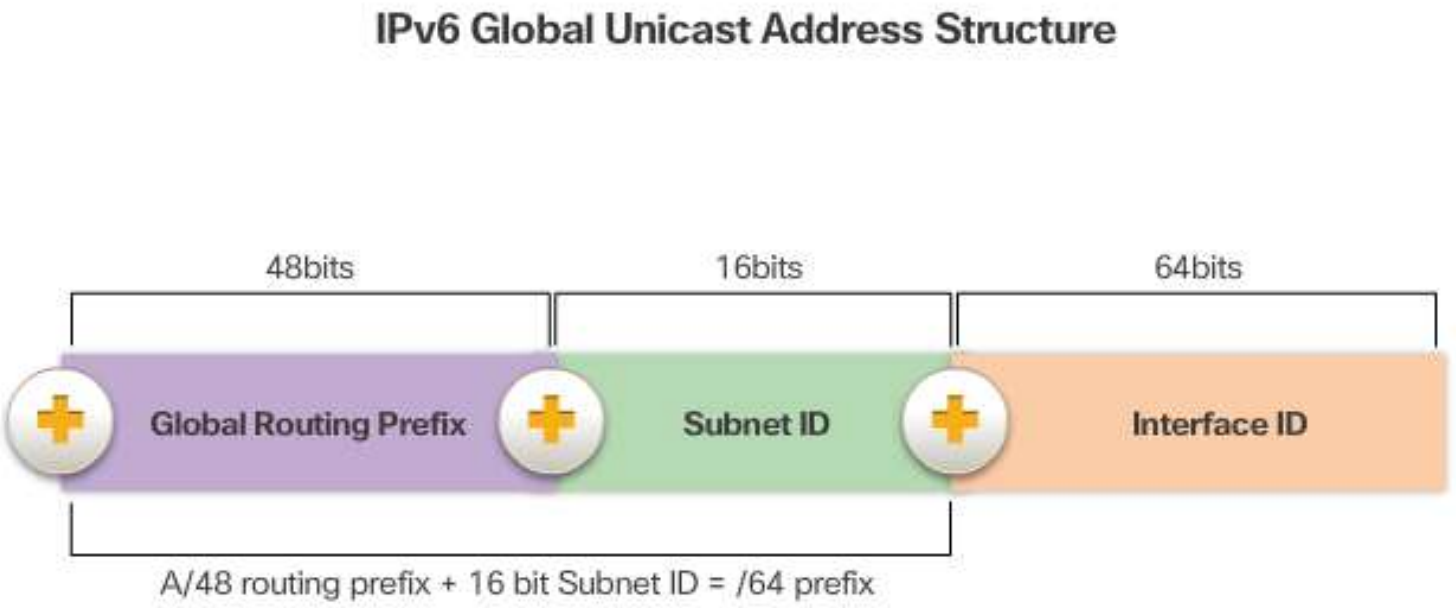
Upon completion of this section, you should be able to:

- Explain how to implement IPv6 address assignments in a business network.

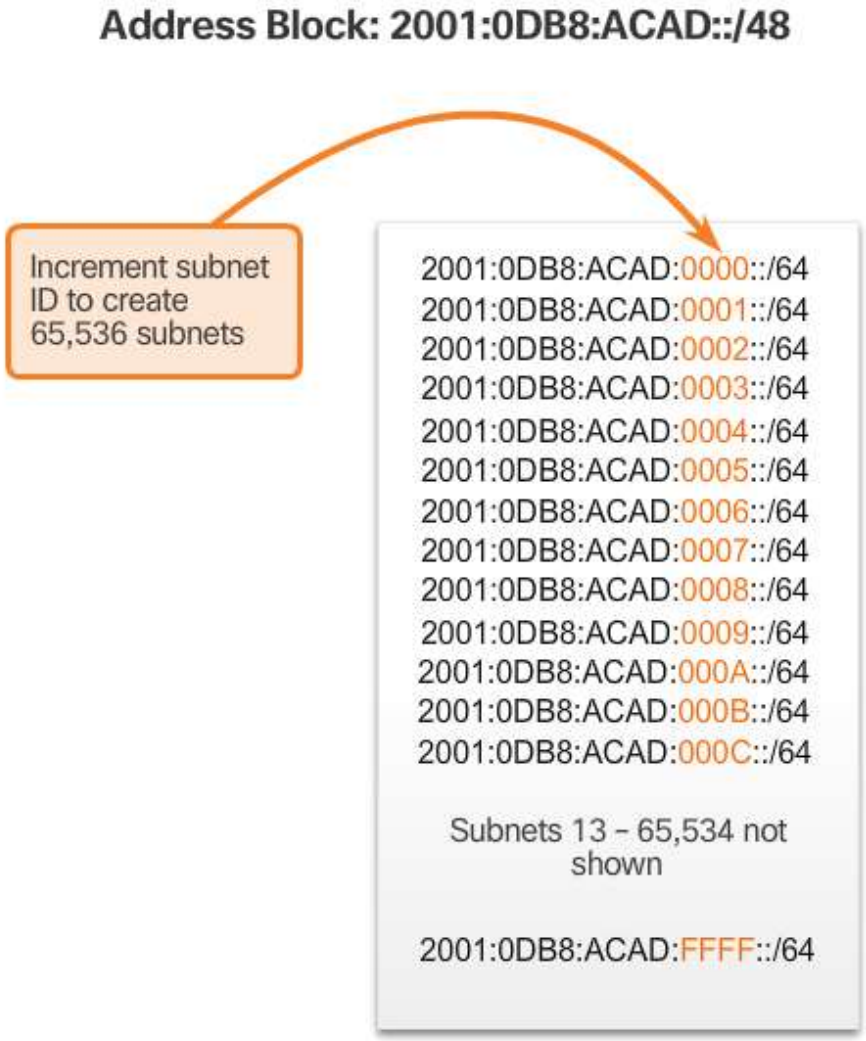
Topic 8.3.1:
Subnetting an IPv6 Network

The IPv6 Global Unicast Address

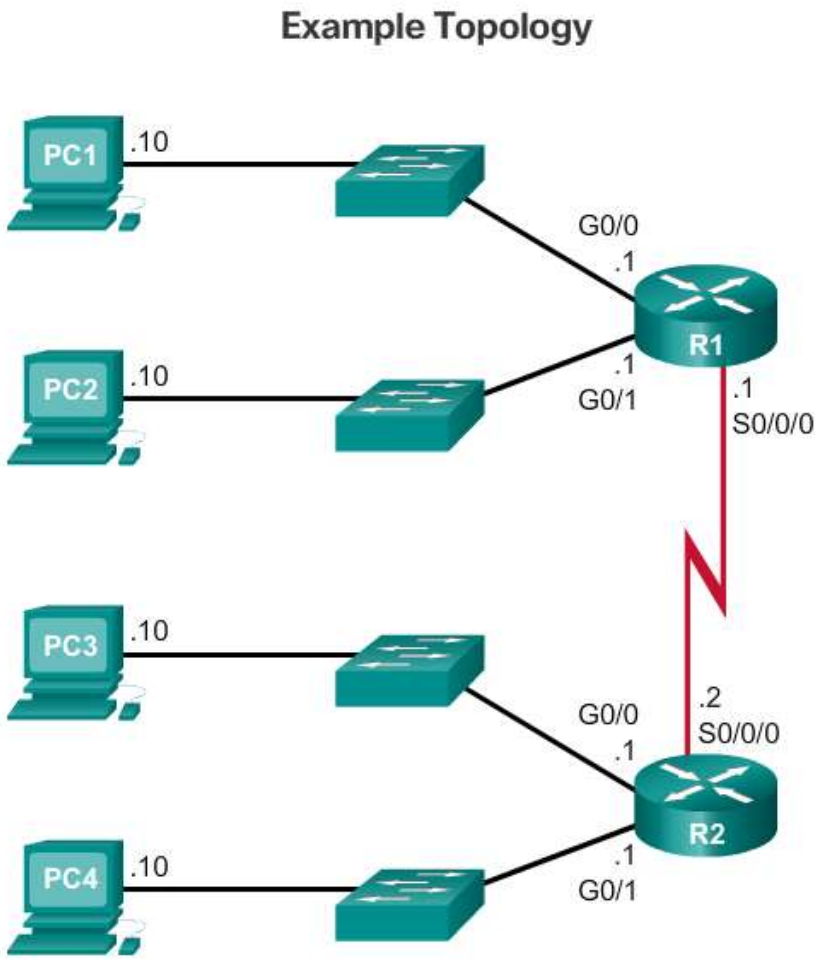
The IPv6 global unicast address normally consists of a /48 global routing prefix, a 16 bit subnet ID, and a 64 bit interface ID.



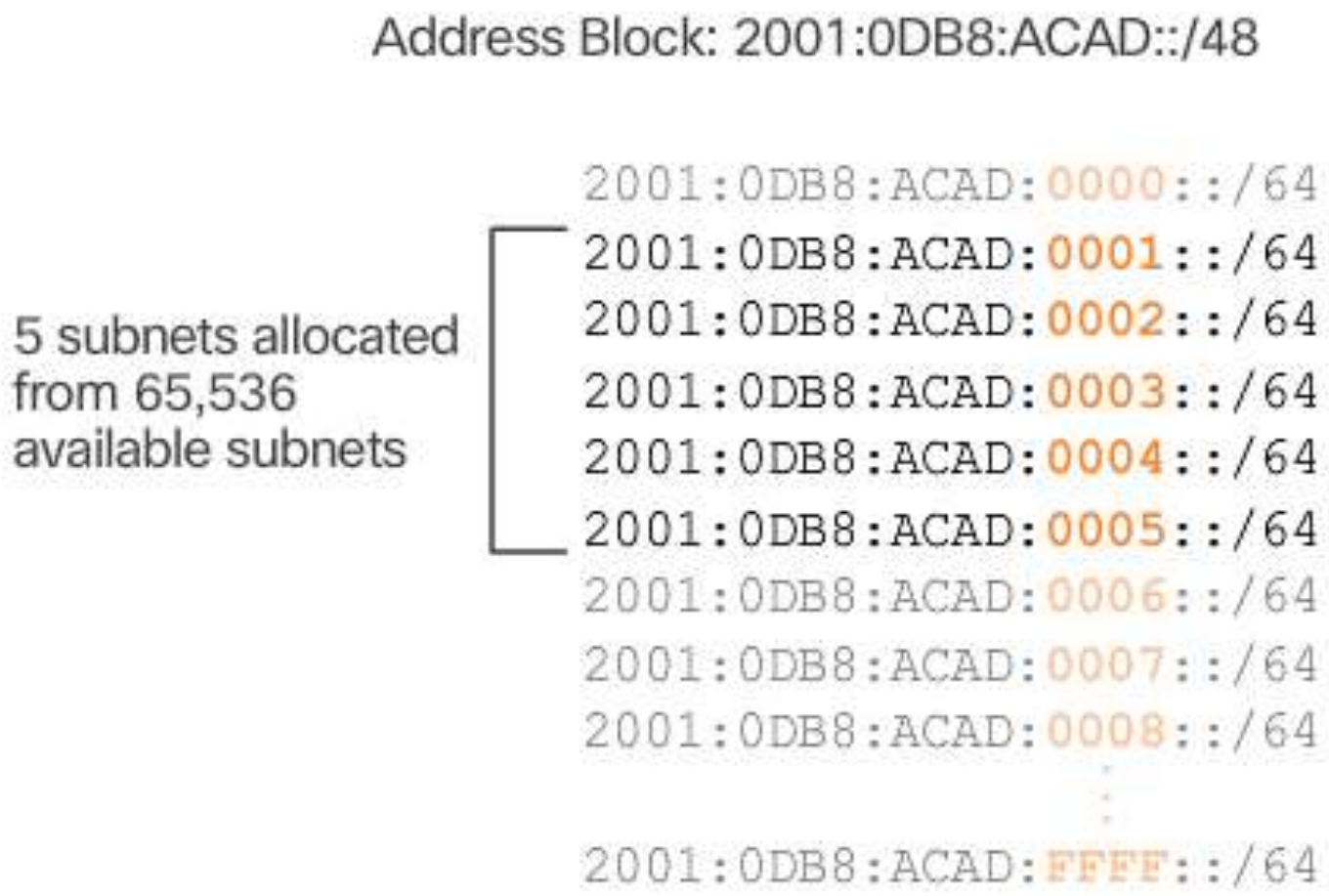
Subnetting Using the Subnet ID



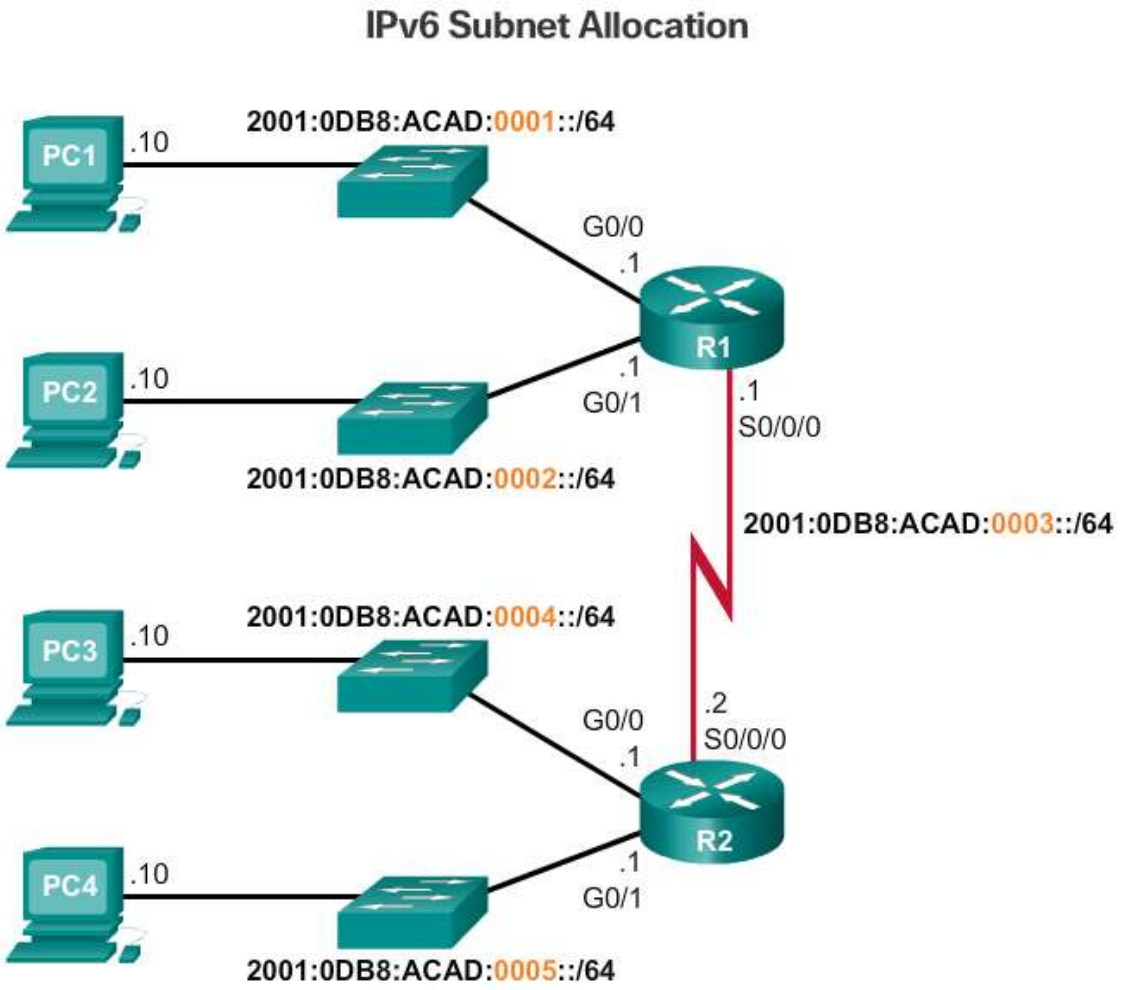
IPv6 Subnet Allocation



IPv6 Subnet Allocation (cont.)

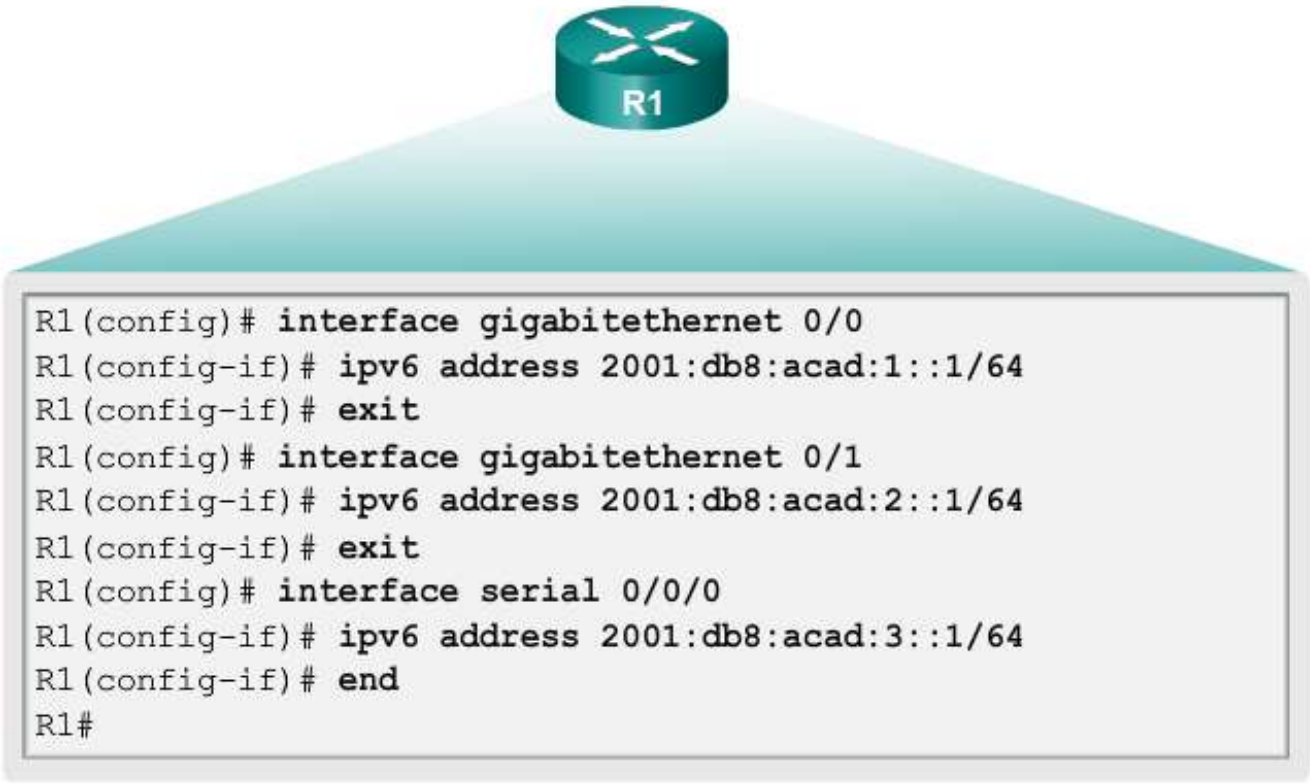


IPv6 Subnet Allocation (cont.)



IPv6 Subnet Allocation (cont.)

IPv6 Address Configuration



Section 8.4: Summary

Chapter Objectives:

- 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.

Thank you.

Cisco Networking Academy

Mind Wide Open