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.

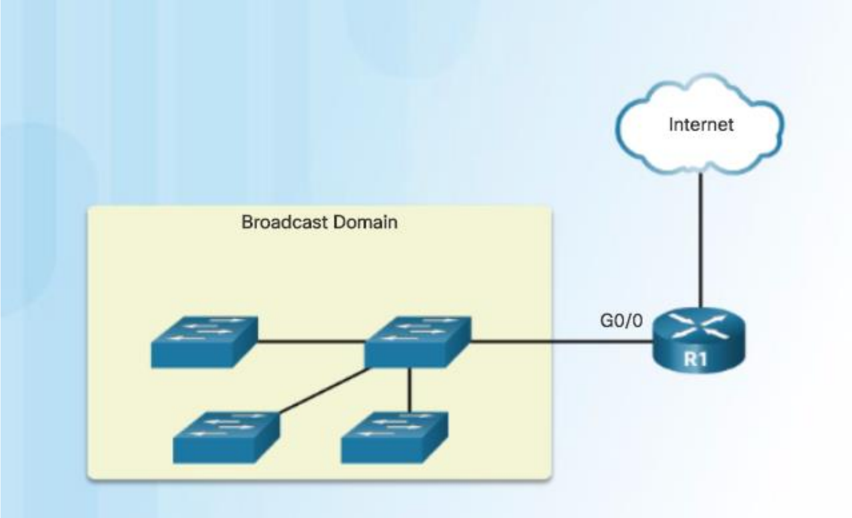
Chapter 8 - Sections & Objectives (Cont.)

- 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

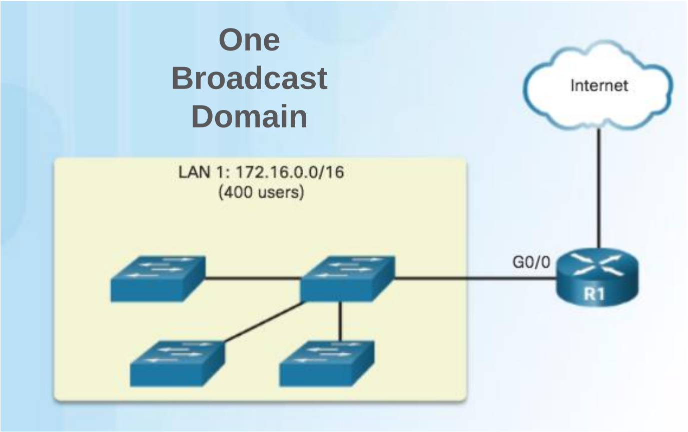
Broadcast Domains

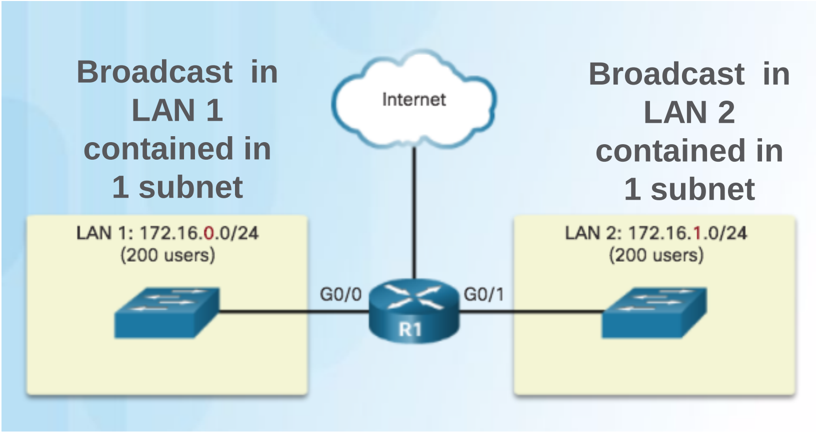
- Devices use broadcasts in an Ethernet LAN to locate:
  - **Other devices** - Address Resolution Protocol (ARP) which sends Layer 2 broadcasts to a known IPv4 address on the local network to discover the associated MAC address.
  - **Services –** Dynamic Host Configuration Protocol (DHCP) which sends 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*.

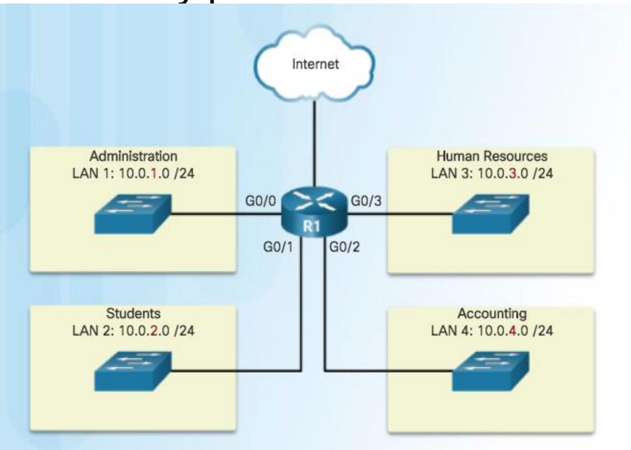




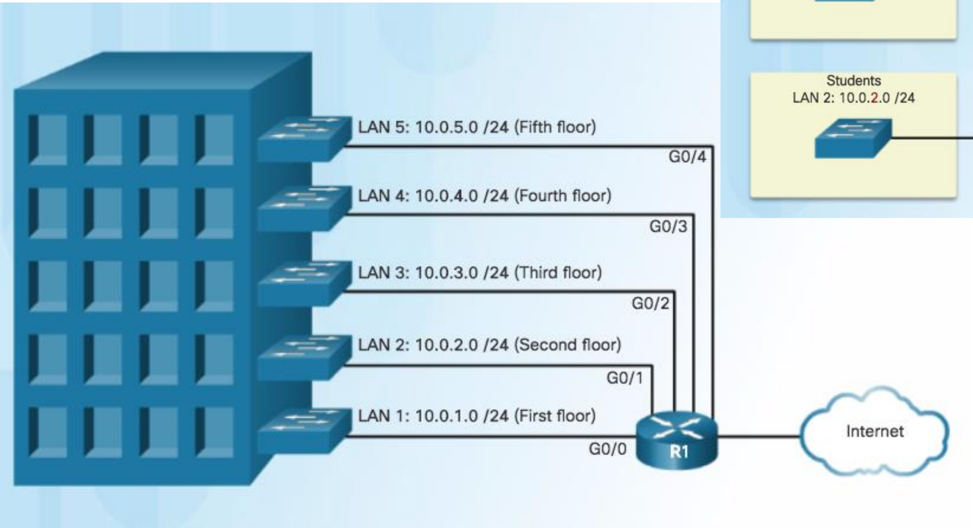
Reasons for Subnetting

- 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.

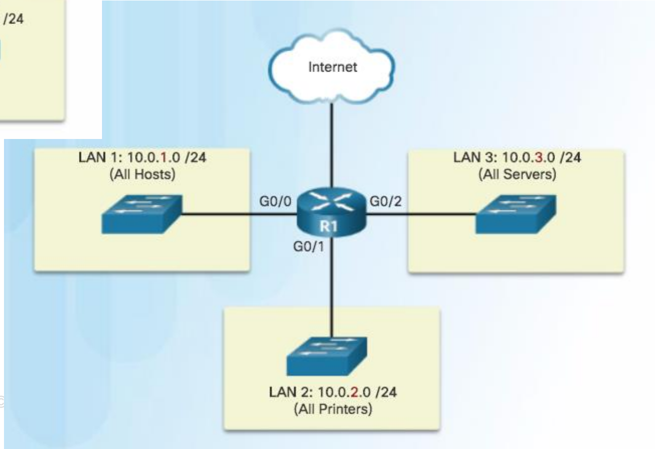
Communicating between Networks



Subnetting by Location



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	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

- 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
10.0.0.0/16	10.0.0.1 - 10.0.255.254	10.0.255.255
10.1.0.0/16	10.1.0.1 - 10.1.255.254	10.1.255.255
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 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
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

- 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.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

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	SN H

Subnet bits = 2^1 = 2
Host bits = 2^7 = 128-2 = 126
Subnetworks = 2

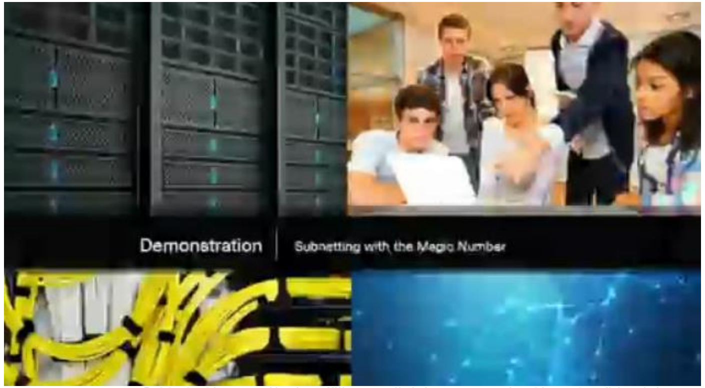
Subnetting 192.168.1.0/24

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 11111111.11111111.11111111.10000000 magic number = 128
- /26 11111111.11111111.11111111.11000000 magic number = 64
- /27 11111111.11111111.11111111.11100000 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
192.168.1.32 /27
192.168.1.64 /27
192.168.1.96 /27
192.168.1.128 /27
192.168.1.160 /27
192.168.1.192 /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

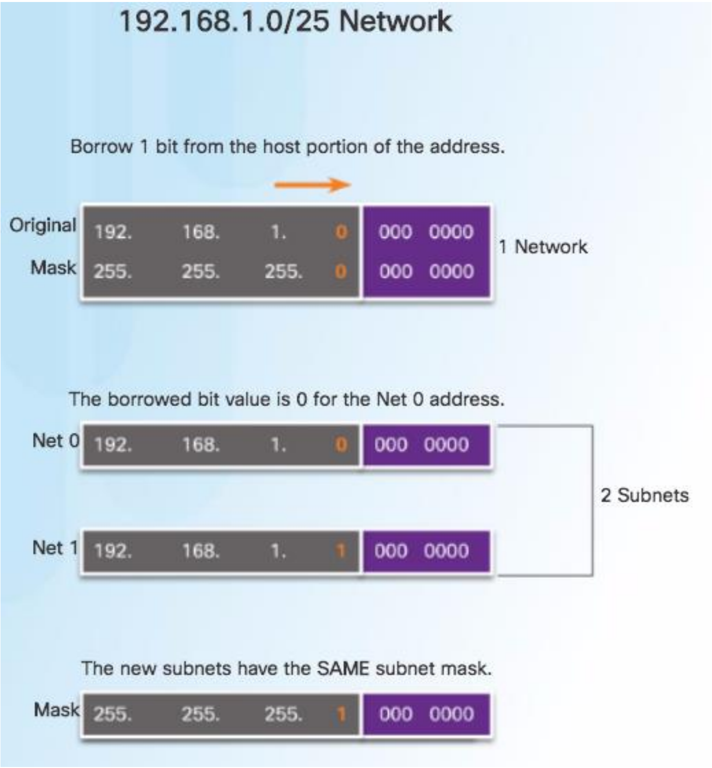
What is the magic number? 2

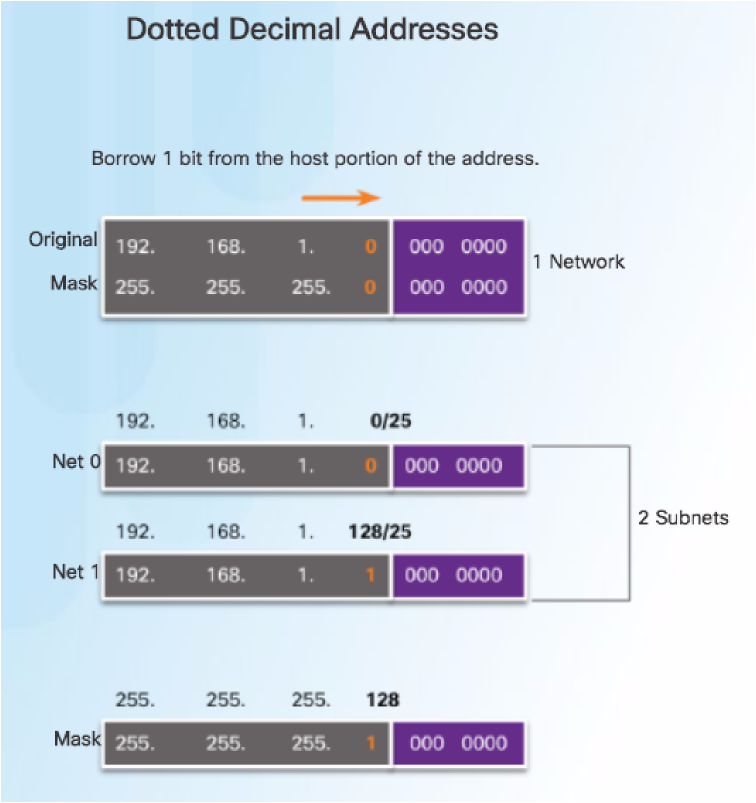
172.16.0.0 ---- 172.16.1.255 /23

172.16.2.0 /23

172.16.4.0 /23

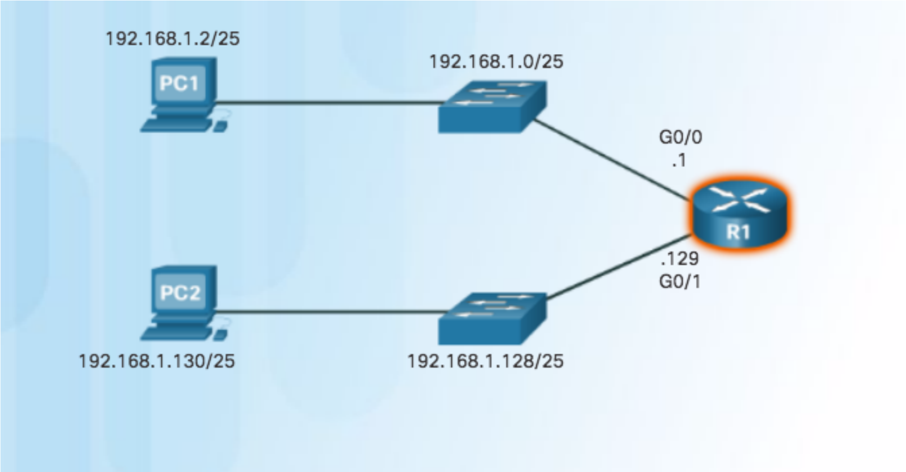
Classless Subnetting Example



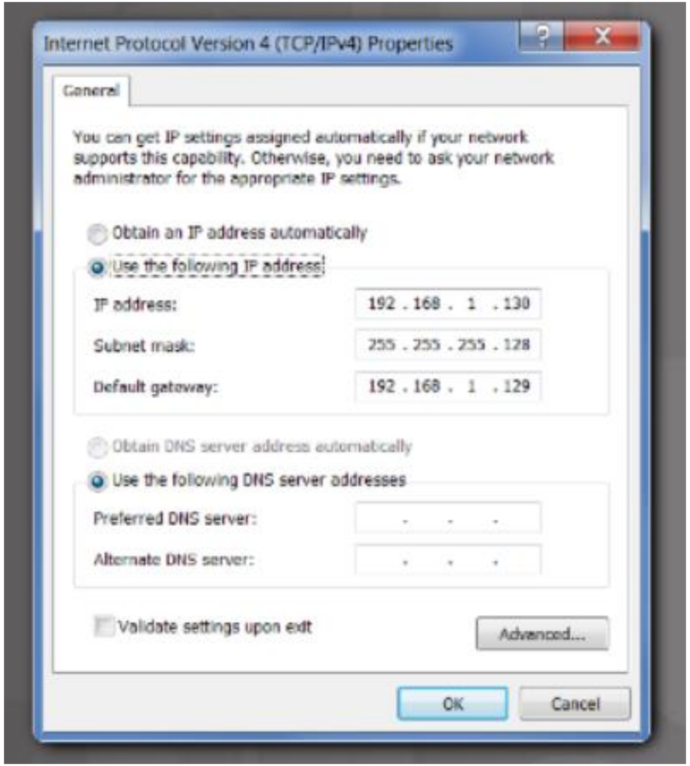


Creating 2 Subnets

- /25 Subnetting Topology




```
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
```



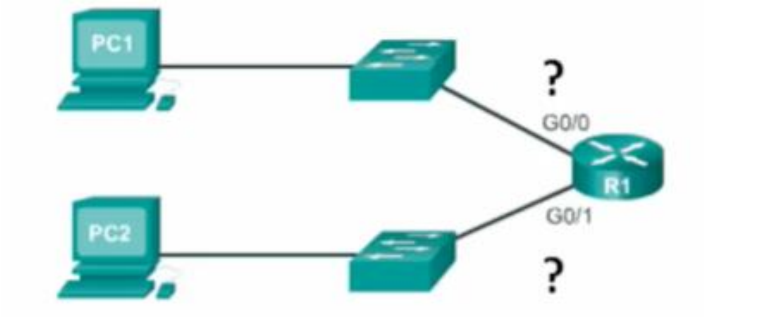
Video Demonstration – Creating Two Equal-sized Subnets (/25)

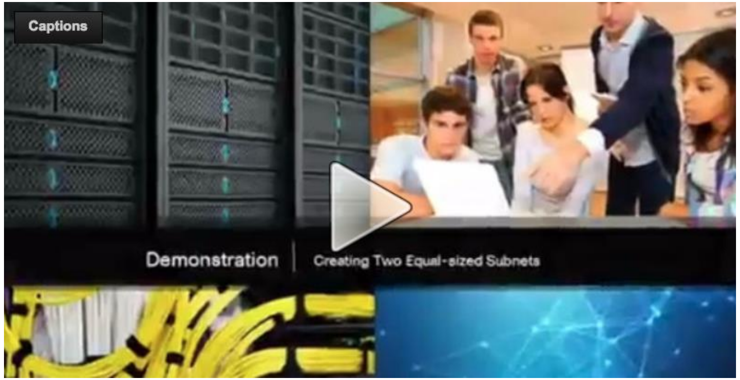
Create 2 Equal-sized Subnets from 192.168.1.0 /24

- **Subnet Mask** - 11111111.11111111.11111111.10000000

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)





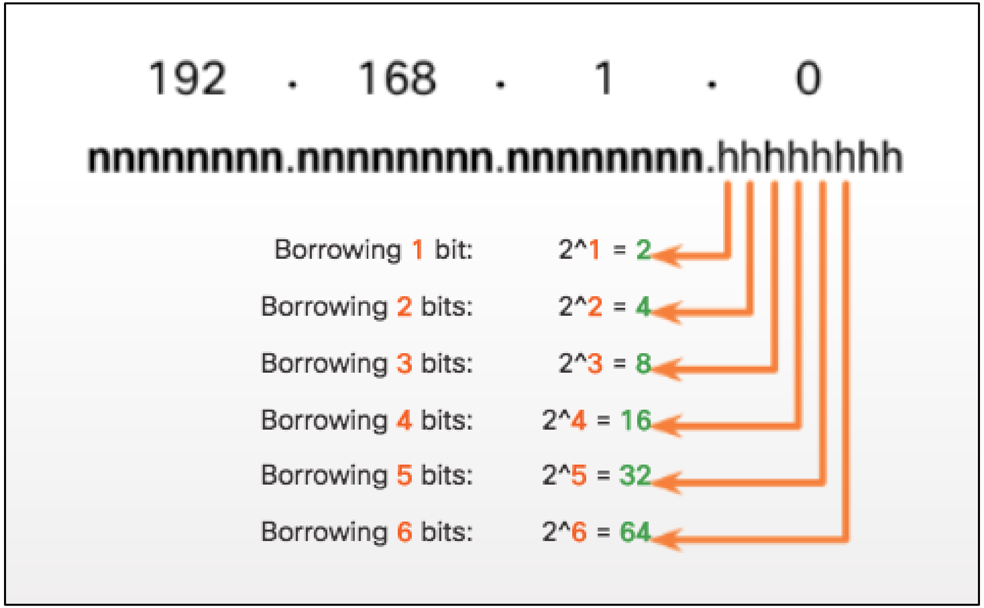
Subnetting Formulas

Calculate Number of Subnets Formula

$$2^n$$

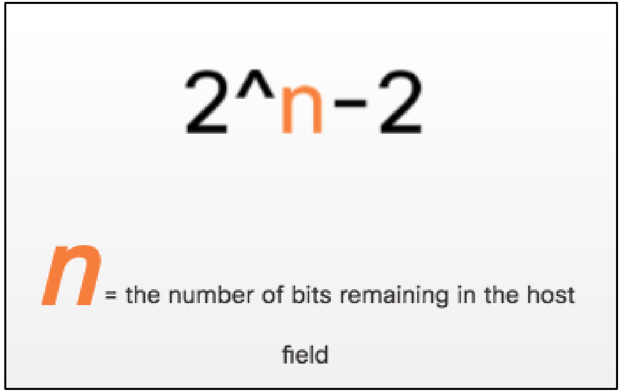
n =bits borrowed

Subnetting a /24 Network

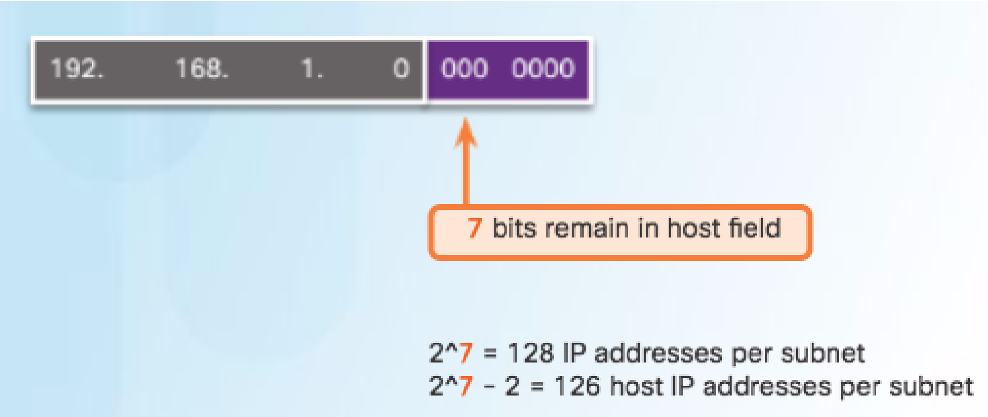


Subnetting Formulas (Cont.)

Calculate Number of Hosts Formula

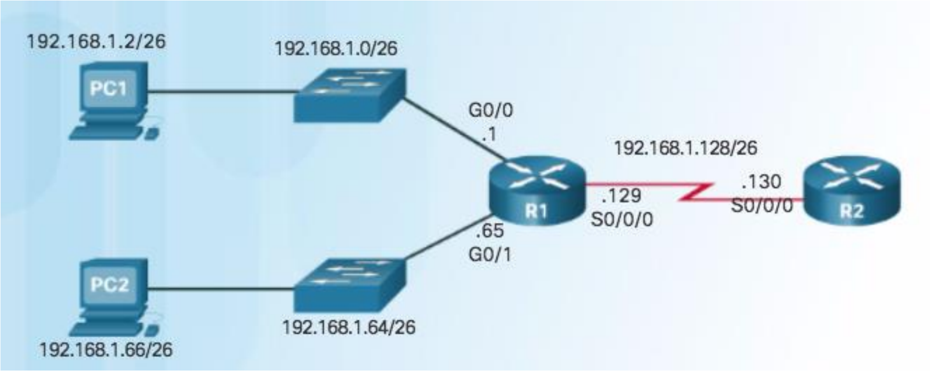


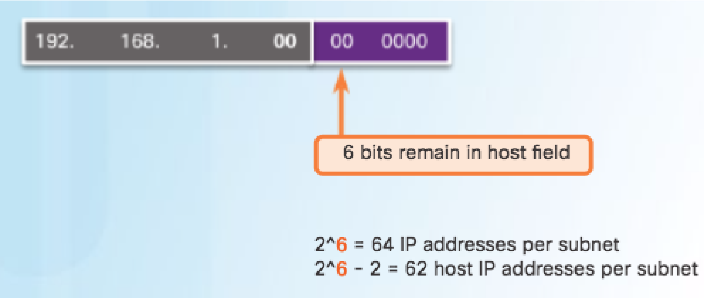
Calculating the Number of Hosts

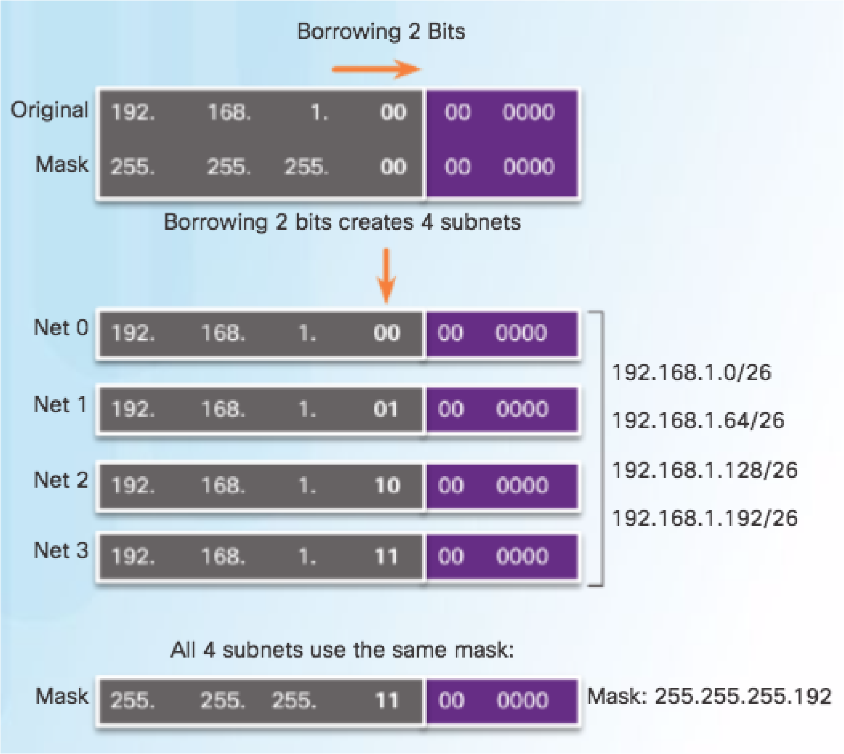


Creating 4 Subnets

- /26 Subnetting Topology







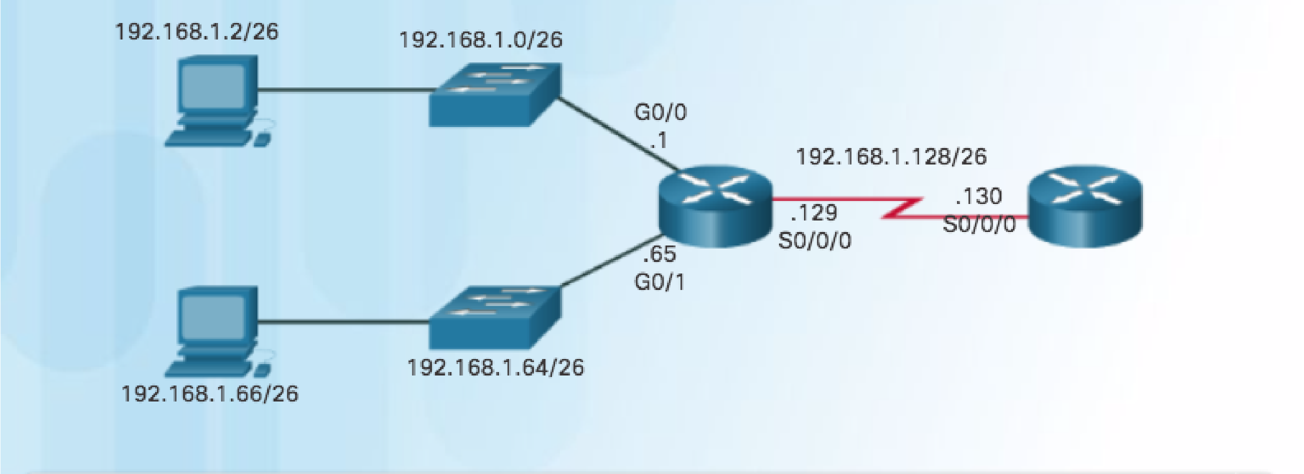
Creating 4 Subnets (Cont.)

- /26 Subnetting Topology

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.)

- /26 Subnetting Topology

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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 – 11111111.11111111.11111111.11000000
- 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

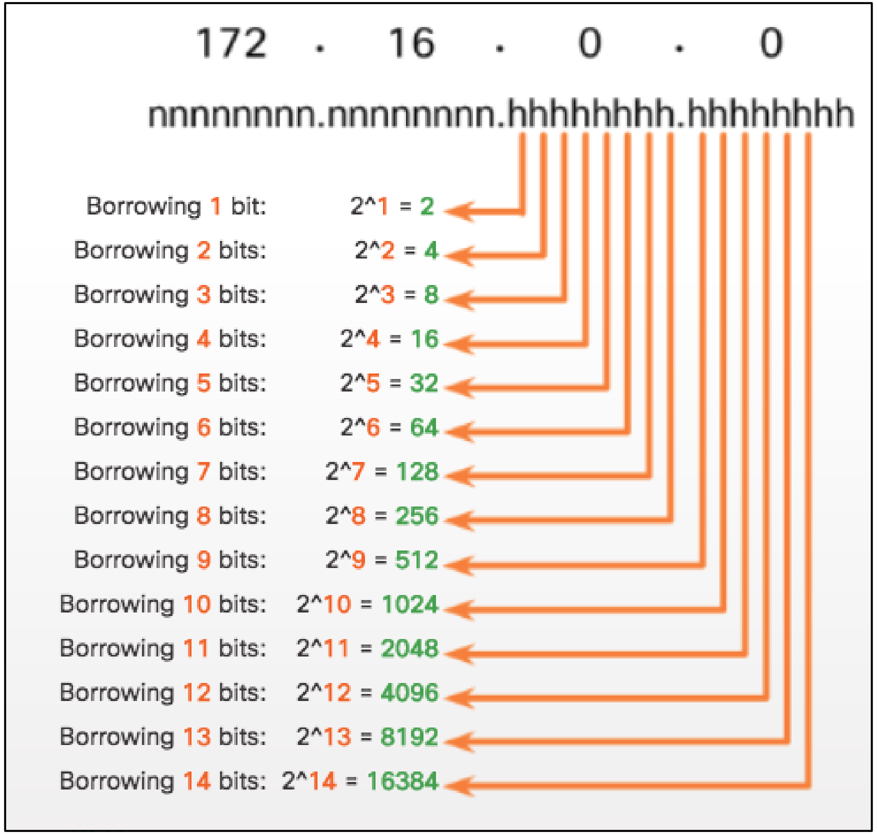
- Borrow 3 bits – 11111111.11111111.11111111.11100000
- Magic Number = 32
- 192.168.1.0 /27 (Start at 0)
- 192.168.1.32 /27 (Add 32 to previous network)
- 192.168.1.64 /27 (Add 32)
- 192.168.1.96 /27 (Add 32)
- 192.168.1.128 /27 (Add 32)
- 192.168.1.160 /27 (Add 32)
- 192.168.1.192 /27 (Add 32)
- 192.168.1.224 /27 (Add 32)

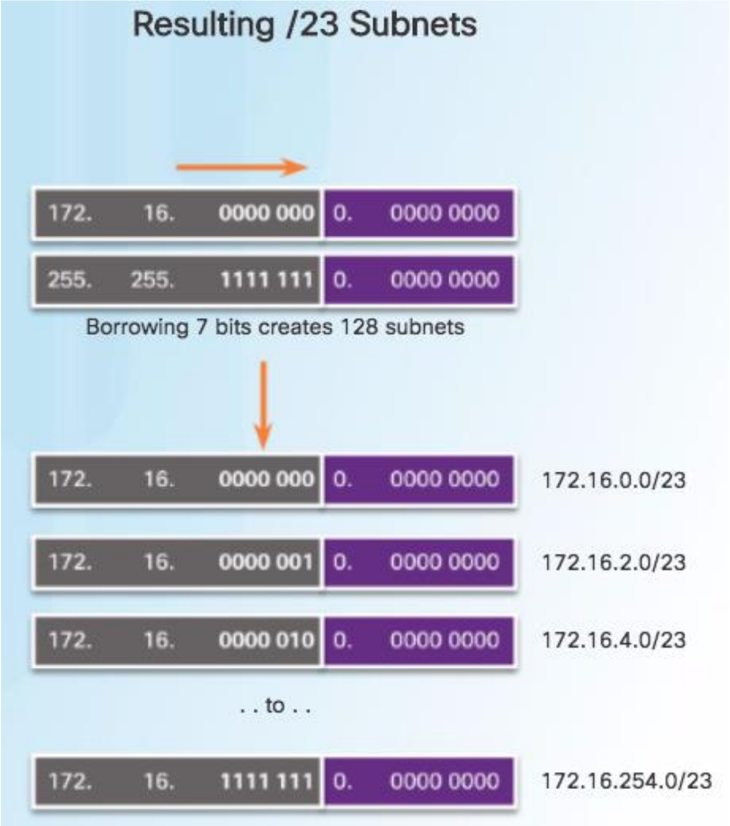
Creating Subnets with a /16 prefix

Subnetting a /16 Network

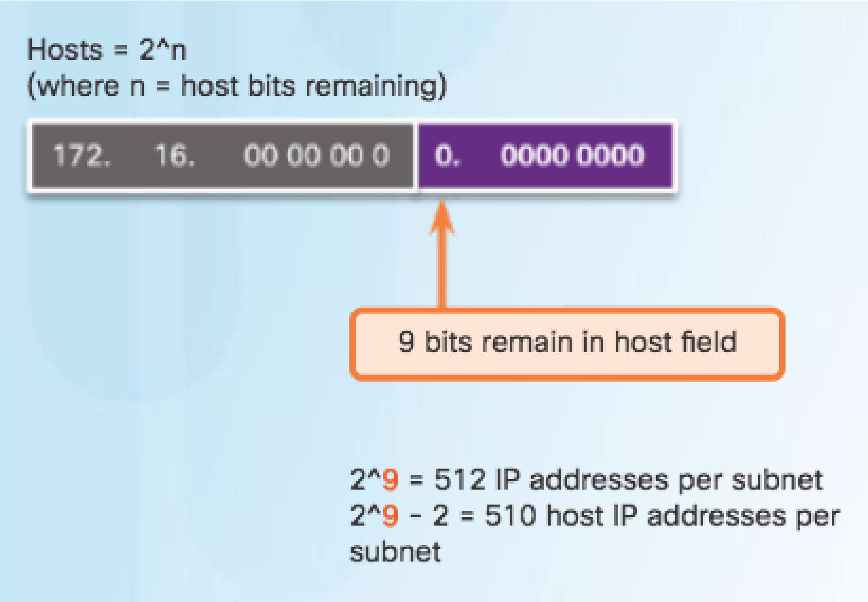
Prefix Length	Subnet Mask	Network Address (n = network, h = host)	# of subnets	# of hosts
/17	255.255.128.0	nnnnnnnn.nnnnnnnn.nhhhhhhh.hhhhhhhh 11111111.11111111.10000000.00000000	2	32766
/18	255.255.192.0	nnnnnnnn.nnnnnnnn.nnhhhhhh.hhhhhhhh 11111111.11111111.11000000.00000000	4	16382
/19	255.255.224.0	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

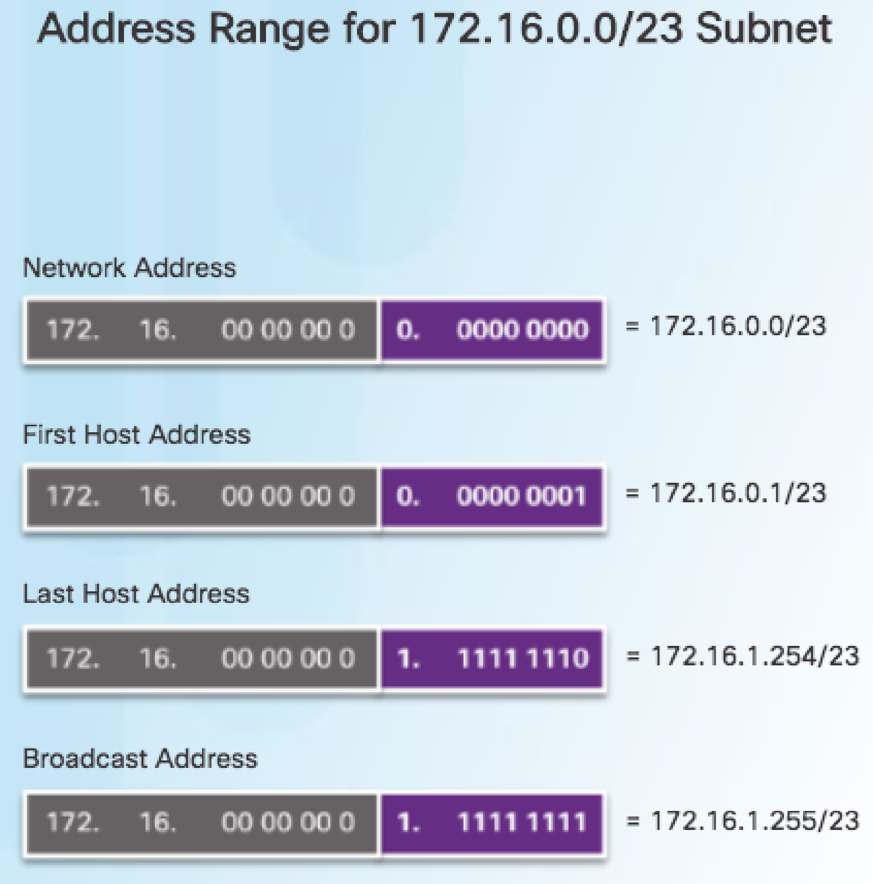
Creating 100 Subnets with a /16 prefix





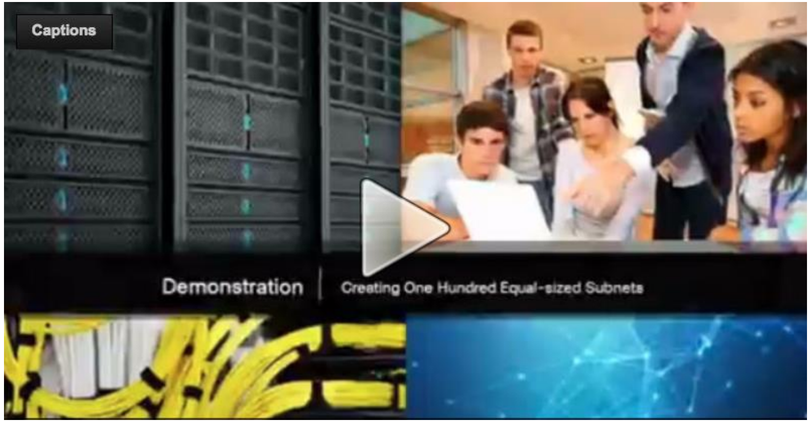
Calculating the Hosts





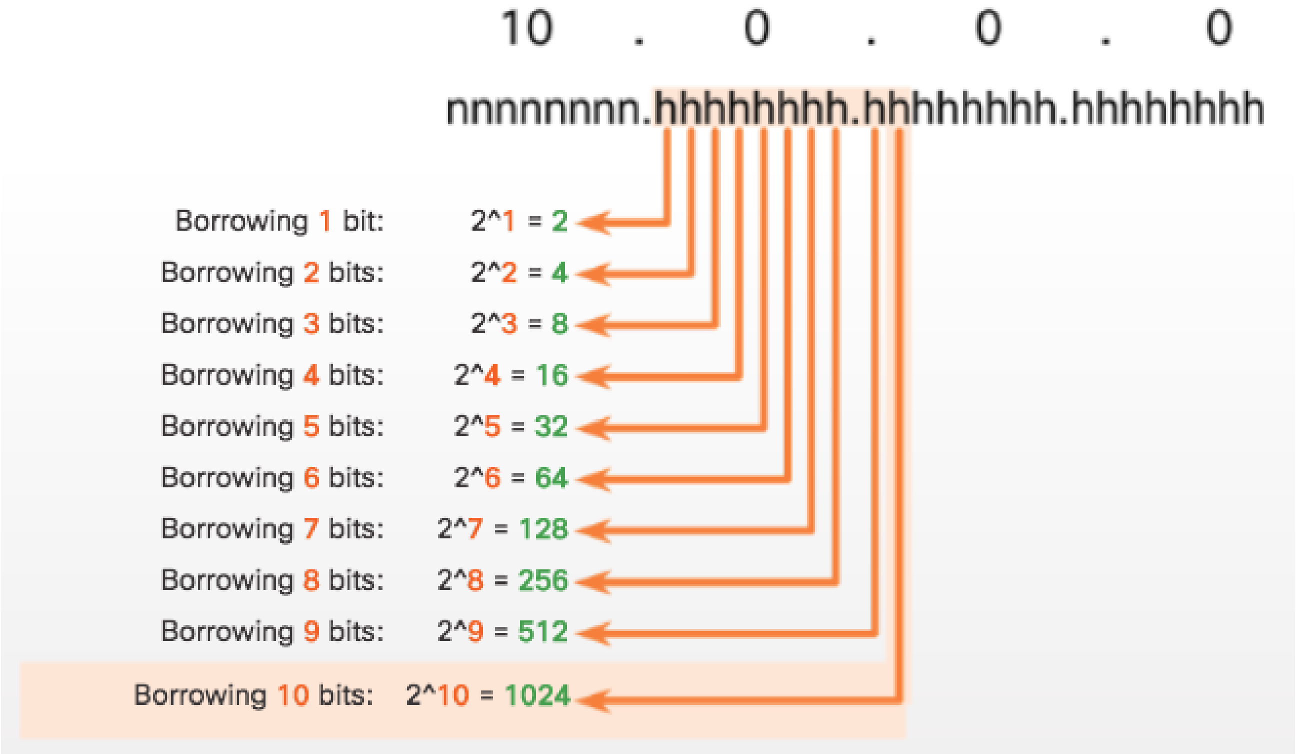
Video Demonstration – Creating One Hundred Equal-sized Subnets

- An enterprise network requires 100 equal-sized subnets starting from 172.16.0.0/16
  - New Subnet Mask
    - 11111111.11111111.11111110.00000000
  - 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

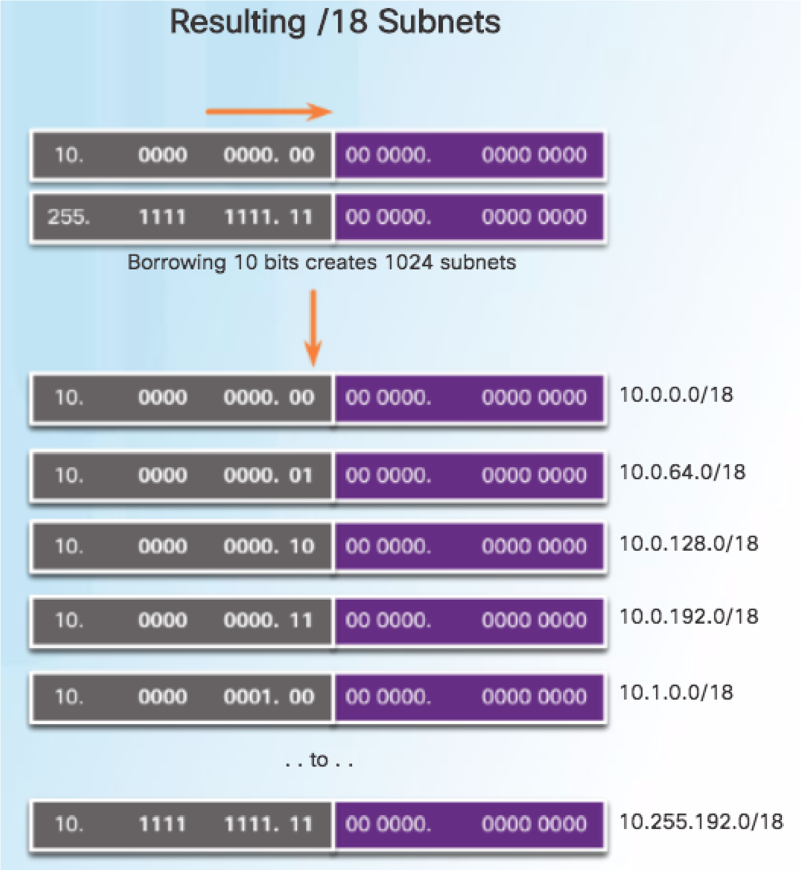


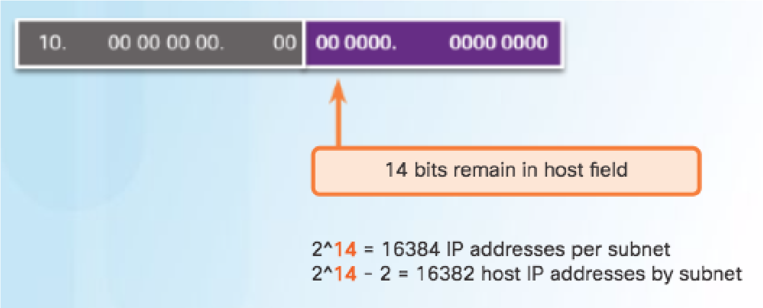
Subnetting a /16 and /8 Prefix

Creating 1000 Subnets with a /8 Network



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





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

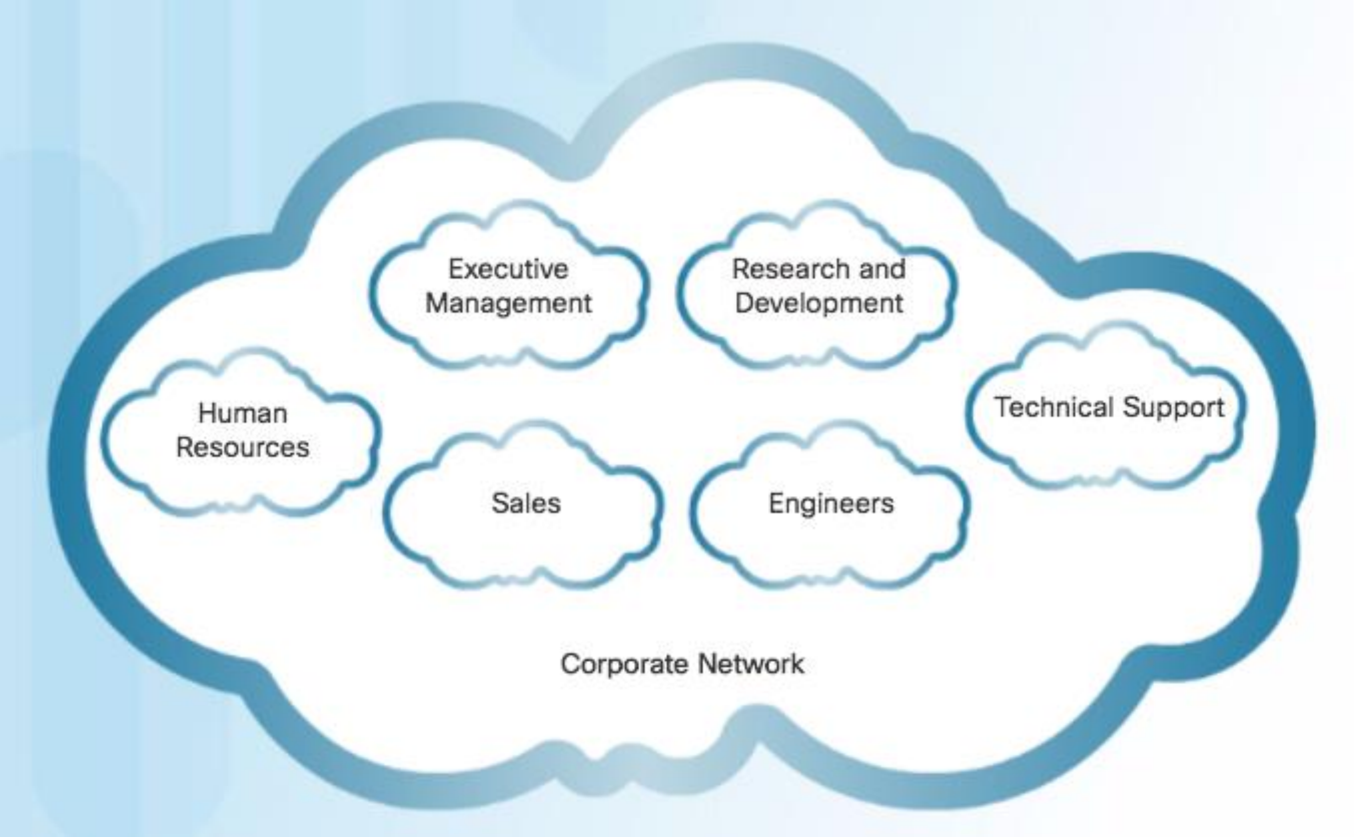
New Challenge Problem: Create over 300 Equal-sized Subnets of 20,000 Hosts each starting from 10.0.0.0/8

Subnetting 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.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

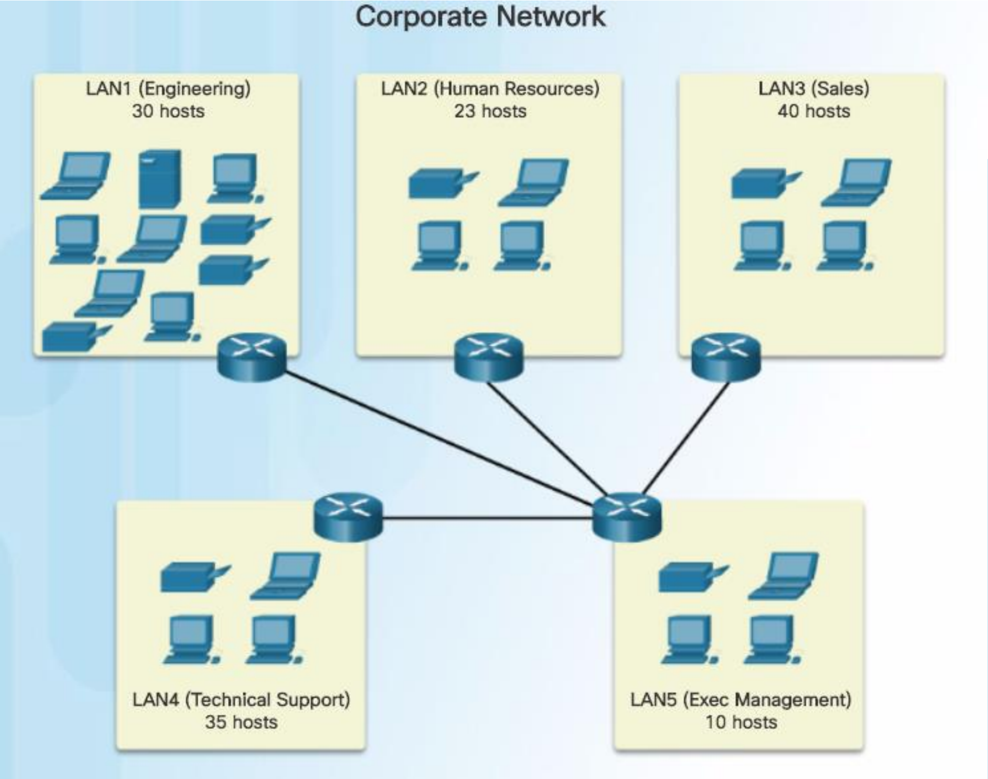
Subnetting Based On Network Requirements

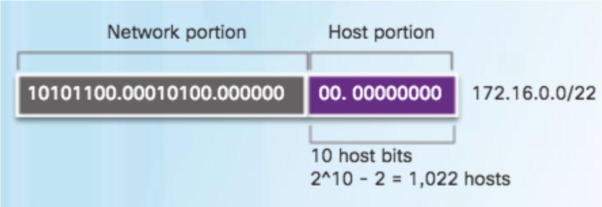
Host devices used by employees in the Engineering department in one network and Management in a separate network.



Subnetting to Meet Requirements

Network Requirement Example



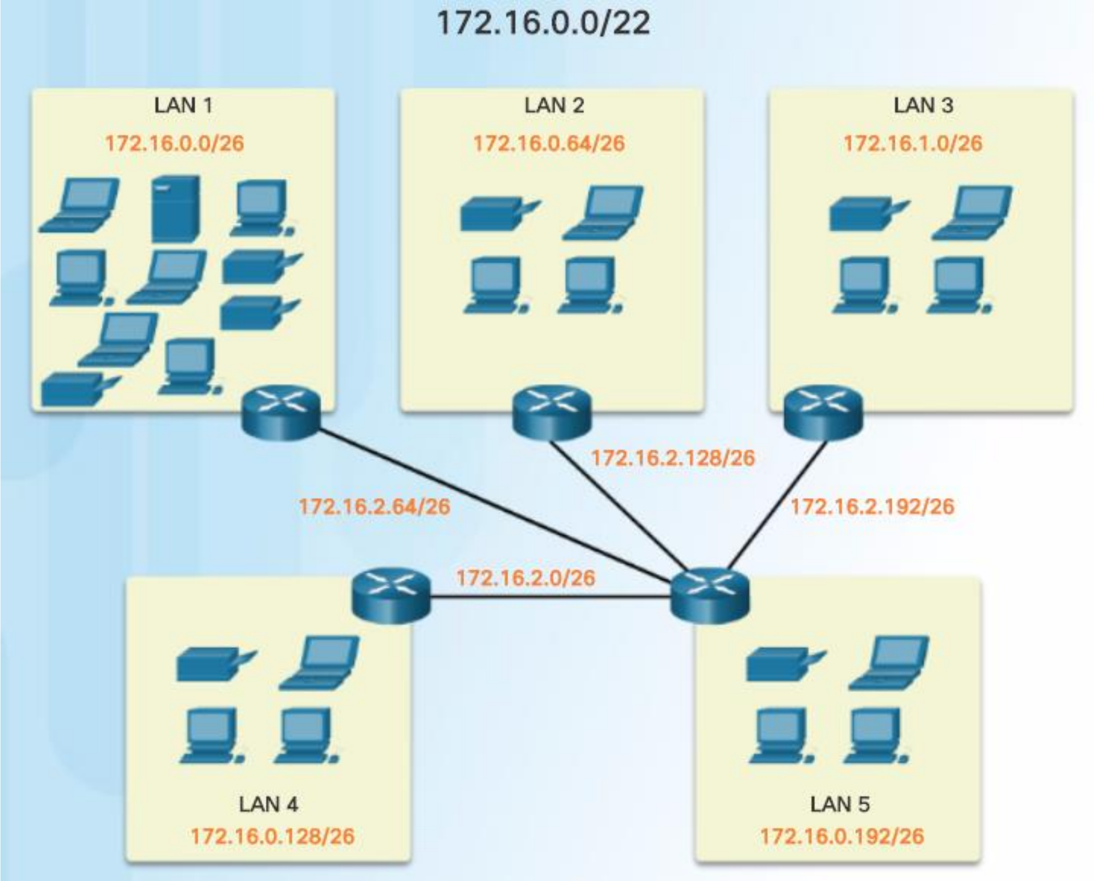


	Network Portion	Host Portion		Dotted Decimal
	10101100.00010000.000000	00.00	000000	172.16.0.0/22
0	10101100.00010000.000000	00.00	000000	172.16.0.0/26
1	10101100.00010000.000000	00.01	000000	172.16.0.64/26
2	10101100.00010000.000000	00.10	000000	172.16.0.128/26
3	10101100.00010000.000000	00.11	000000	172.16.0.192/26
4	10101100.00010000.000000	01.00	000000	172.16.1.0/26
5	10101100.00010000.000000	01.01	000000	172.16.1.64/26
6	10101100.00010000.000000	01.10	000000	172.16.1.128/26
14	10101100.00010000.000000	11.10	000000	172.16.3.128/26
15	10101100.00010000.000000	11.11	000000	172.16.3.192/26

Nets 7 – 13 not shown

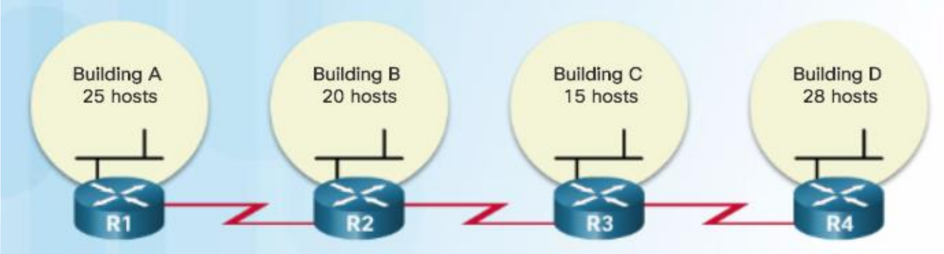
4 bits borrowed from host portion to create subnets

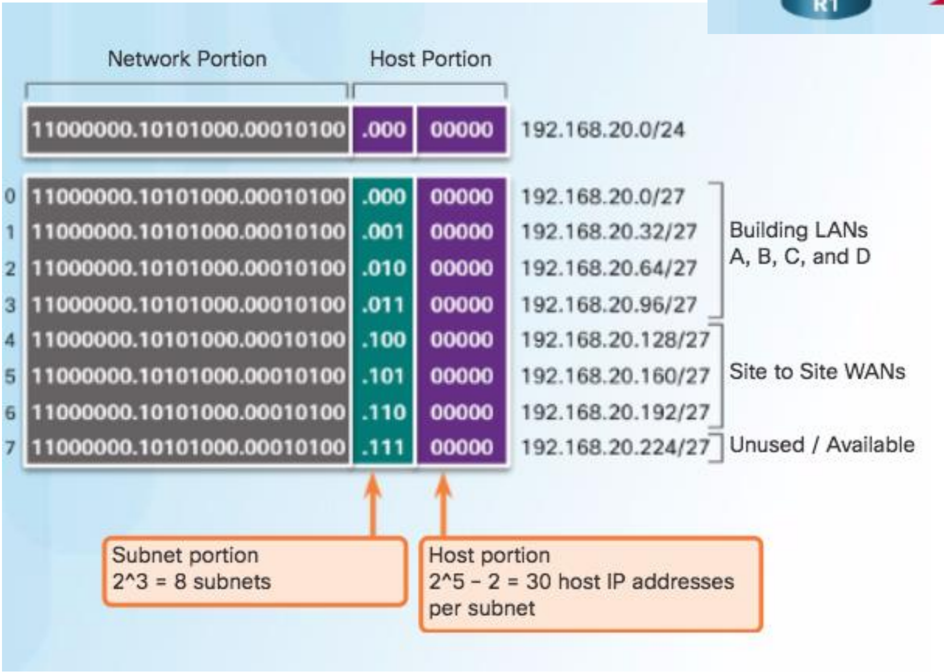
Network Requirement Example (Cont.)

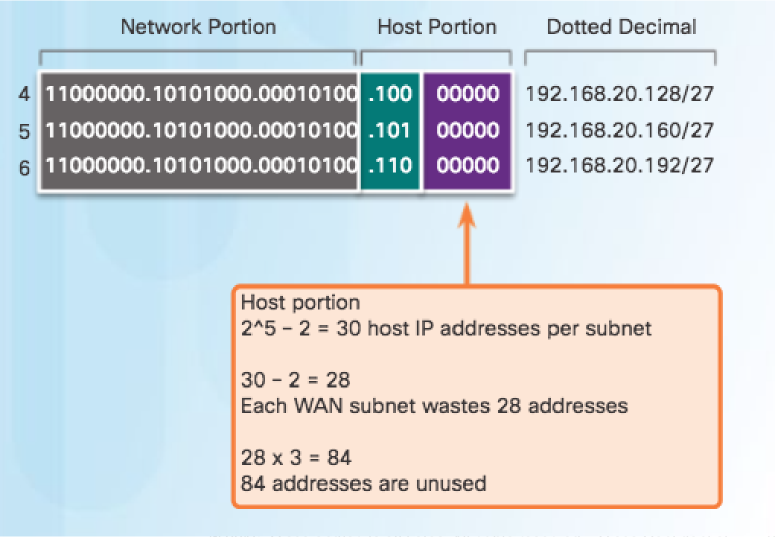


Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes Addresses

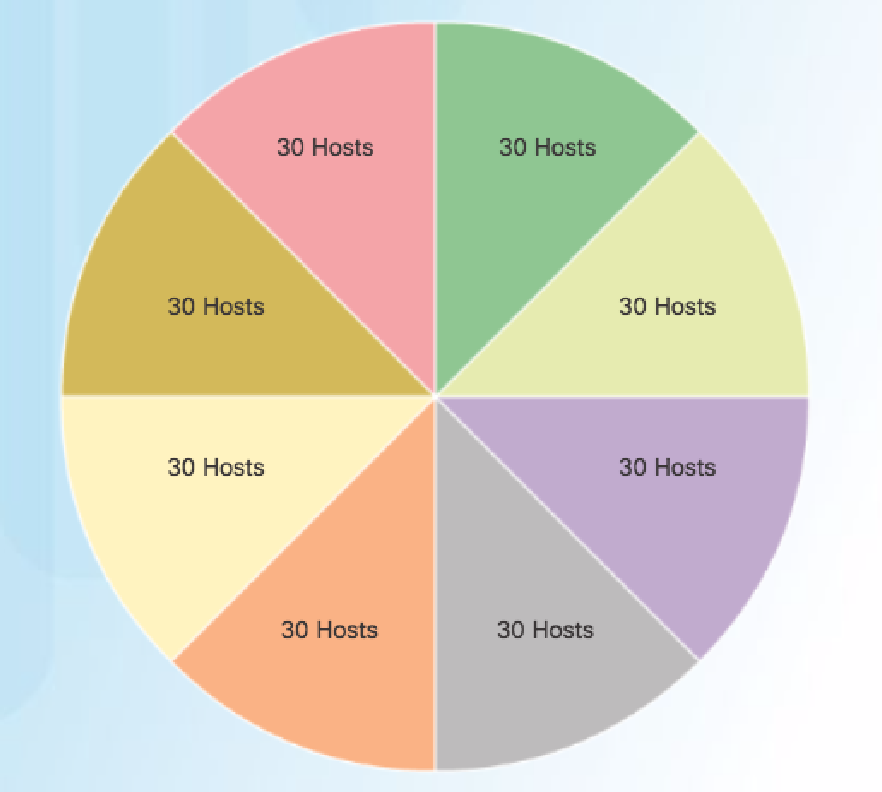




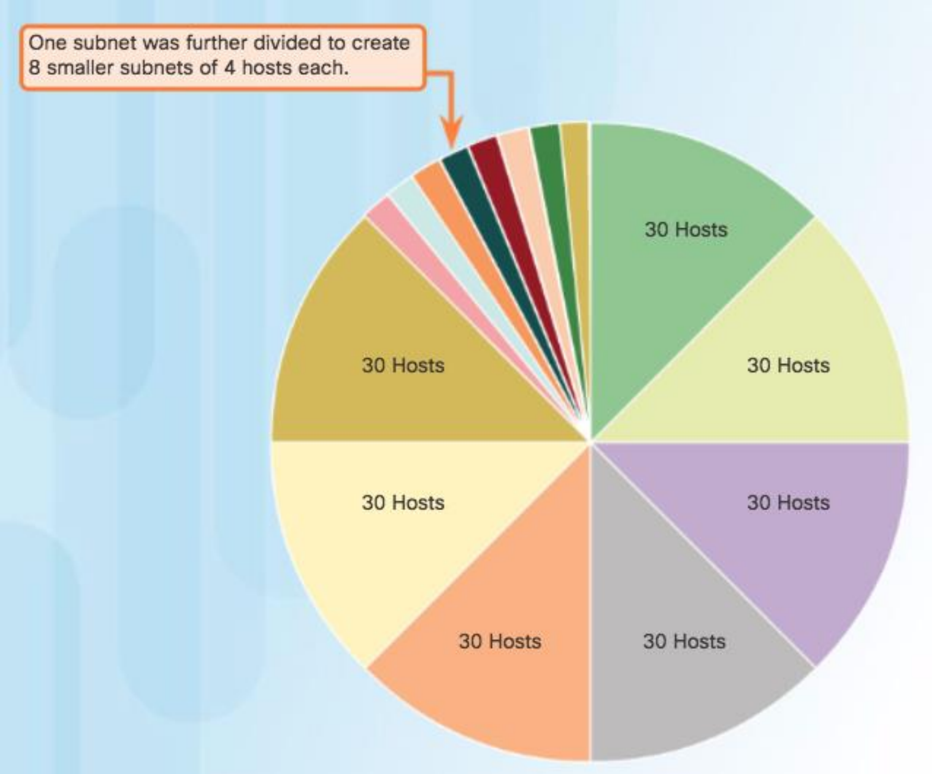


Variable Length Subnet Masks (VLSM)

Traditional

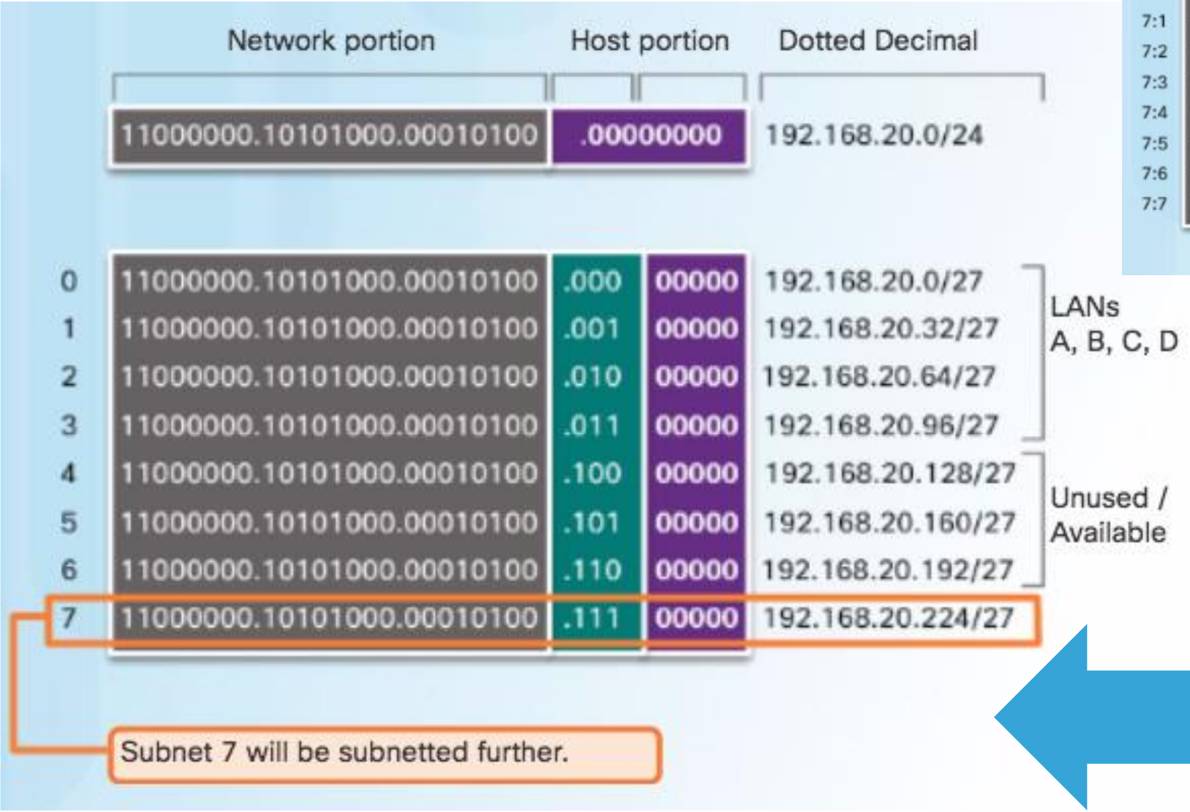


Subnets of Varying Sizes

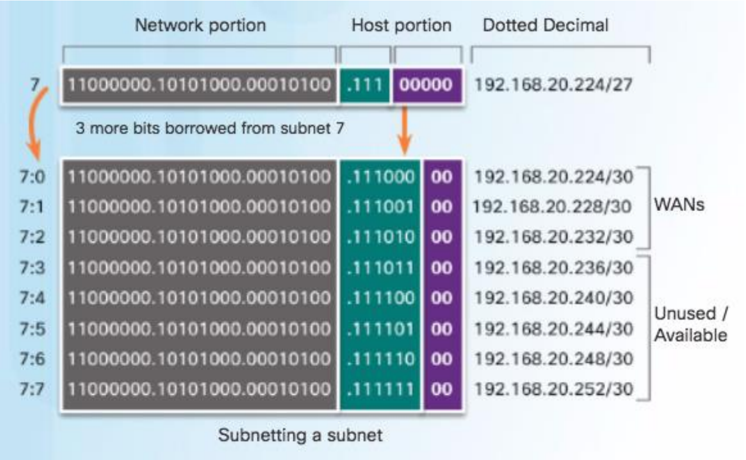


Basic VLSM

Basic Subnetting



	Network portion	Host portion		Dotted Decimal
	11000000.10101000.00010100	.00000000		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

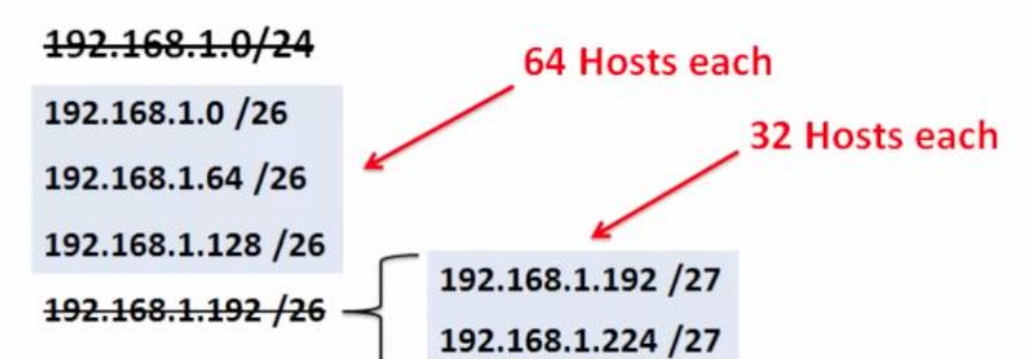


	Network portion	Host portion		Dotted Decimal
7	11000000.10101000.00010100	.111	00000	192.168.20.224/27
7:0	11000000.10101000.00010100	.111000	00	192.168.20.224/30
7:1	11000000.10101000.00010100	.111001	00	192.168.20.228/30
7:2	11000000.10101000.00010100	.111010	00	192.168.20.232/30
7:3	11000000.10101000.00010100	.111011	00	192.168.20.236/30
7:4	11000000.10101000.00010100	.111100	00	192.168.20.240/30
7:5	11000000.10101000.00010100	.111101	00	192.168.20.244/30
7:6	11000000.10101000.00010100	.111110	00	192.168.20.248/30
7:7	11000000.10101000.00010100	.111111	00	192.168.20.252/30

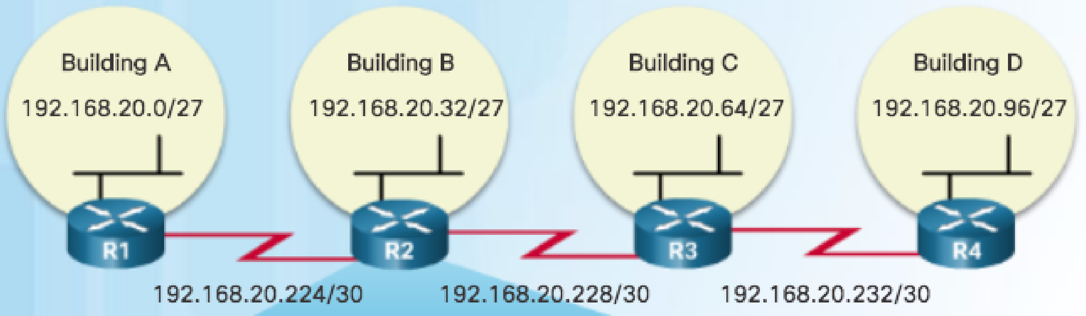
Subnetting a subnet

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.



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

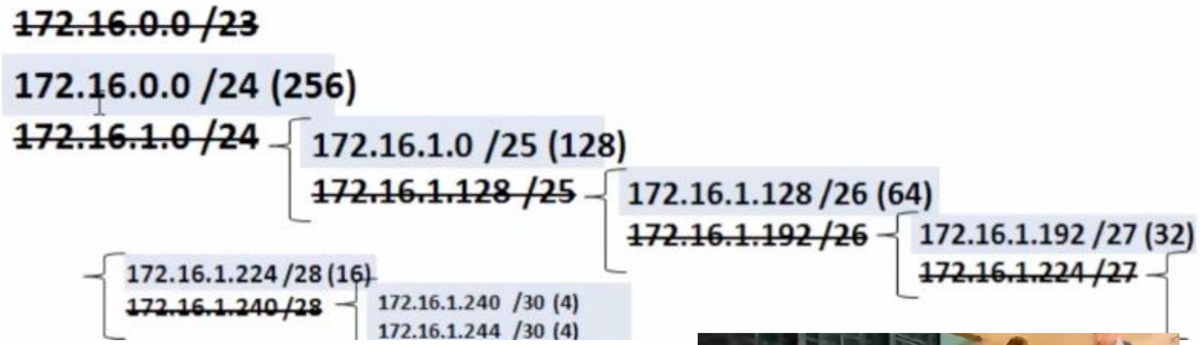
	/27 Network	Hosts
Bldg A	.0	.1 - .30
Bldg B	.32	.33 - .62
Bldg C	.64	.65 - .94
Bldg D	.96	.97 - .126
Unused	.128	.129 - .158
Unused	.160	.161 - .190
Unused	.192	.193 - .222
	.224	.225 - .254

	/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

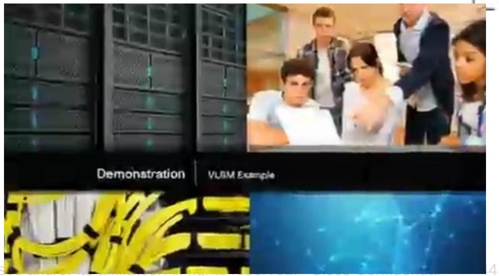
Video Demonstration – VLSM Example

- 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



172.16.1.248 /30 (4)
172.16.1.252 /30 (4)

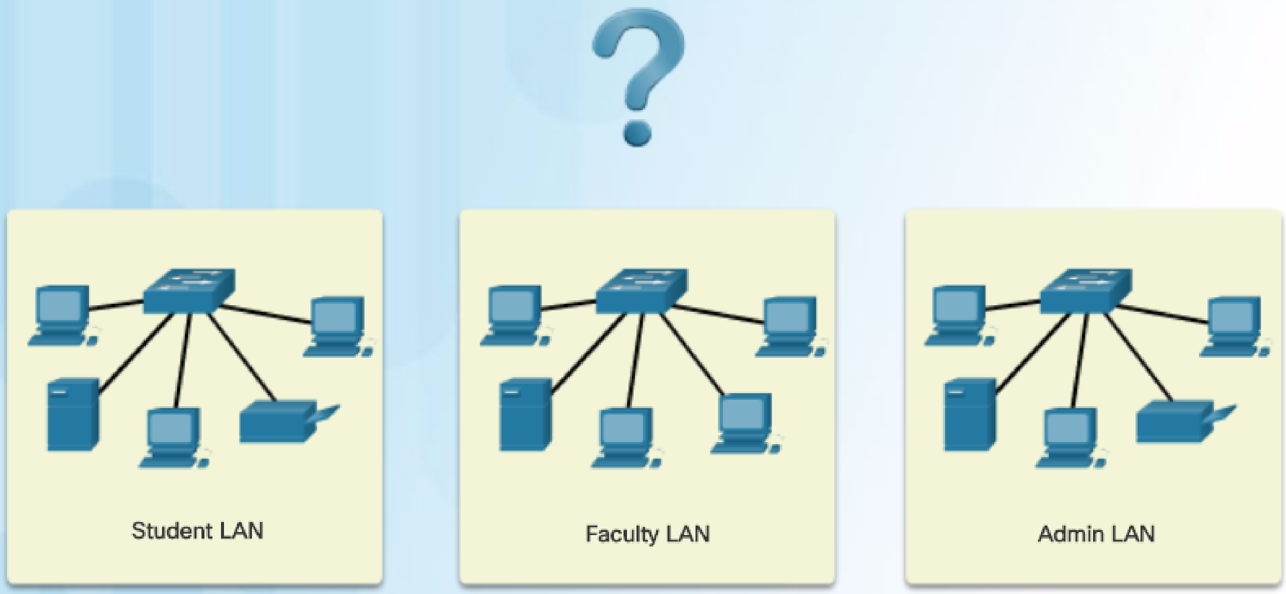


8.2 Addressing Schemes

Structured Design

Network Address Planning

Planning IP Address Assignment



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

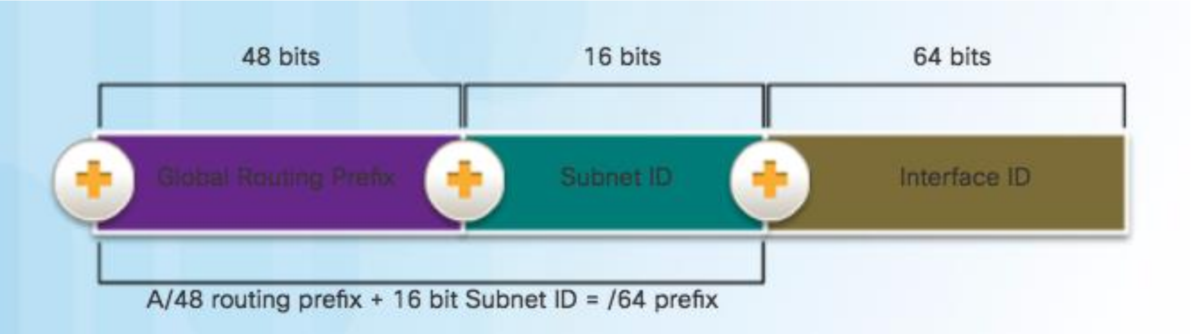
Use	First	Last
Host Devices	.1	.229
Servers	.230	.239
Printers	.240	.249
Intermediary Devices	.250	.253
Gateway (router LAN interface)	.254	

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

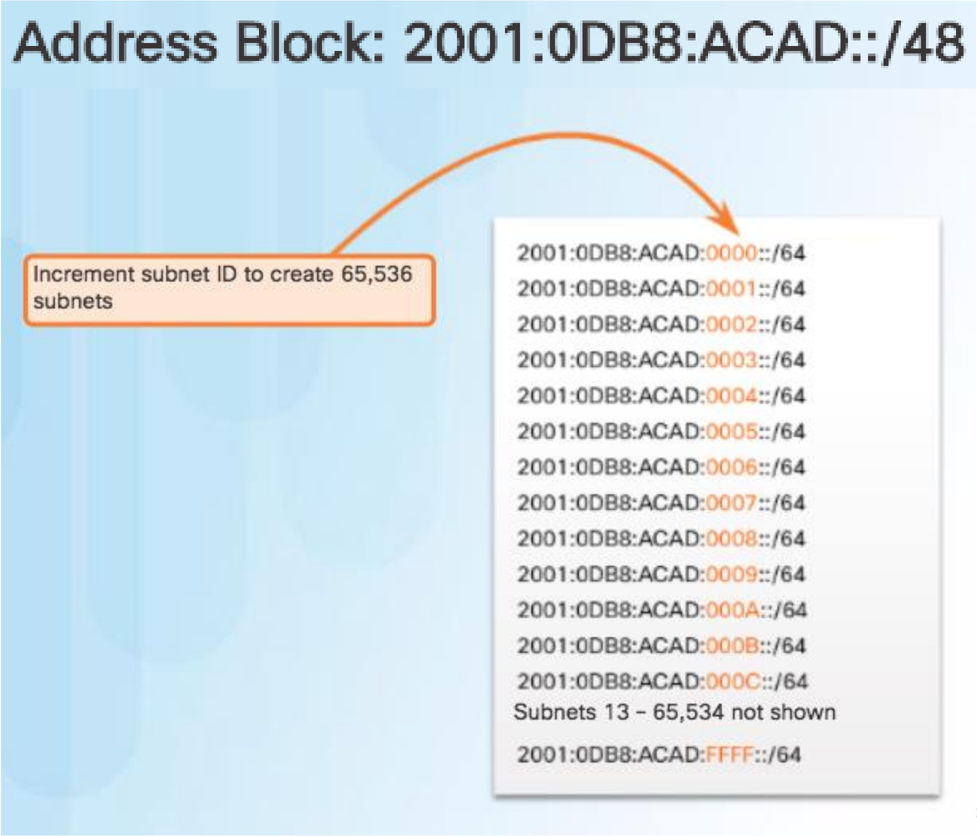


Global Routing Prefix

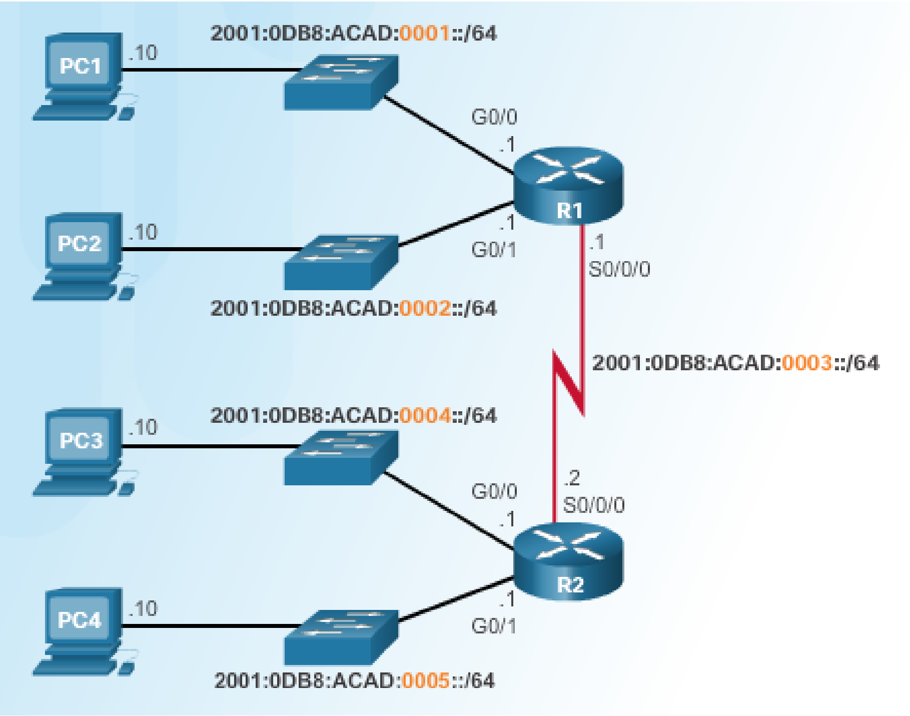
This is the prefix, or network, portion of the address that is assigned by the provider. Typically, Regional Internet Registries (RIRs) assign a /48 global routing prefix to ISPs and customers.

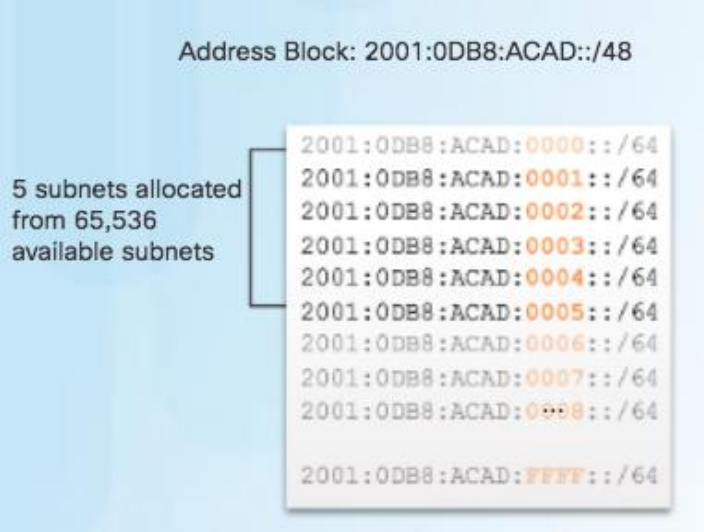
Subnetting an IPv6 Network

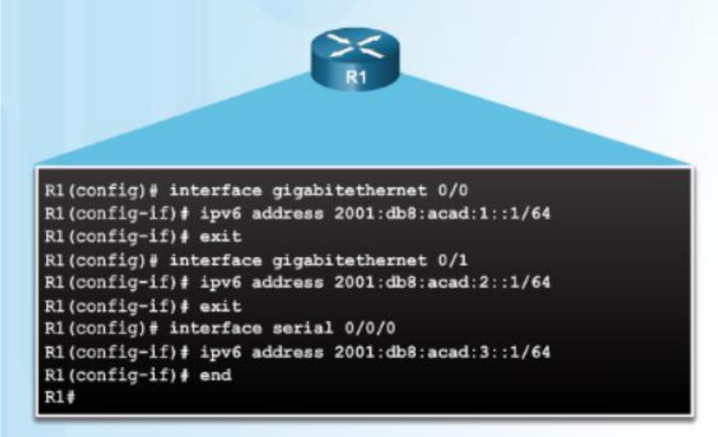
Subnetting Using the Subnet ID



IPv6 Subnet Allocation







8.4 Chapter Summary

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.

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