



CHAPTER 8: SUBNETTING IP NETWORKS



**CCENT Routing and Switching
Introduction to Networks v6.0**

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Chapter 8 - Sections & Objectives

- 8.1 Subnetting an IPv4 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
 - Implement a VLSM addressing scheme.
- 8.3 Design Considerations for IPv6
 - Explain how to implement IPv6 address assignments in a business network.

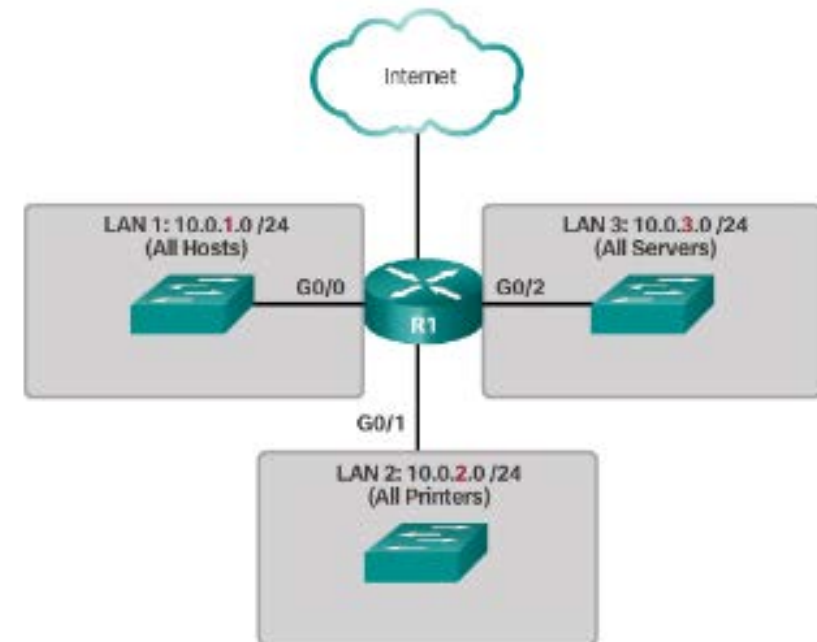


8.1 SUBNETTING AN IPV4 NETWORK

Broadcast Domains

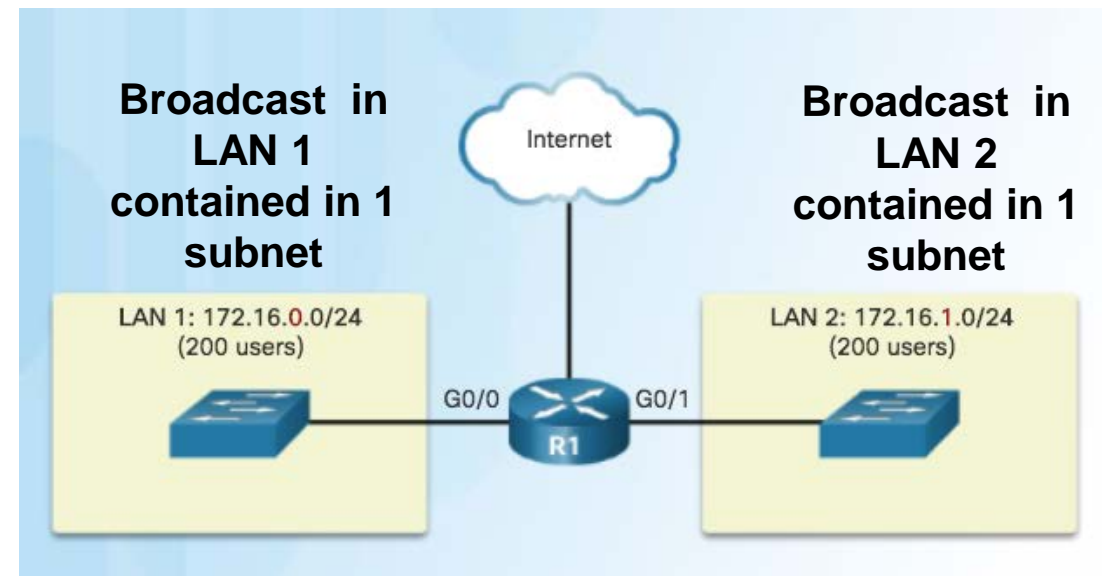
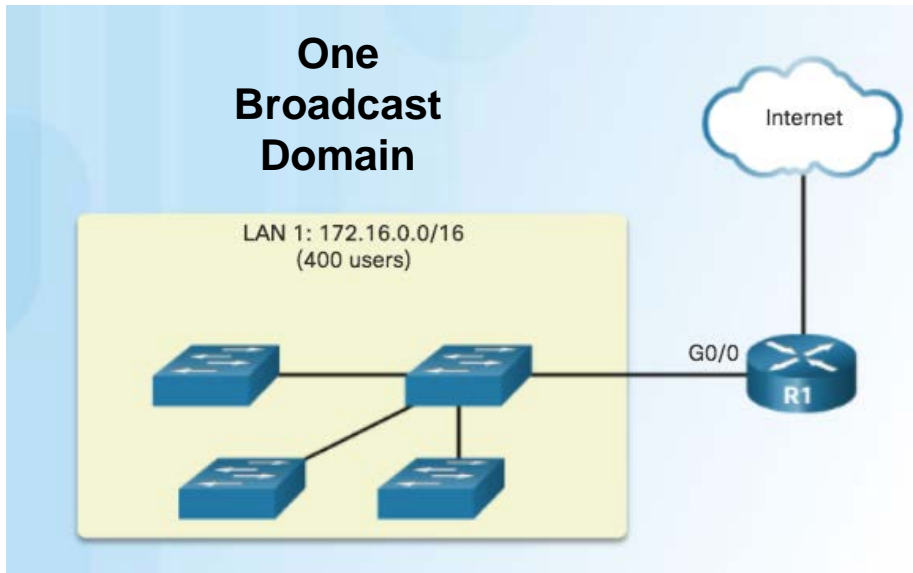
- Each router interface connects a broadcast domain
- Broadcasts are only propagated within its broadcast domain
- **Devices use broadcasts in an Ethernet LAN to locate:**
 - **Other devices** - Address Resolution Protocol (ARP) which sends Layer 2 broadcasts to a known IPv4 address on the local network 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
 - Connecting switches together increases the size of the broadcast domain
- How many broadcast domains are there if the graphic?

4



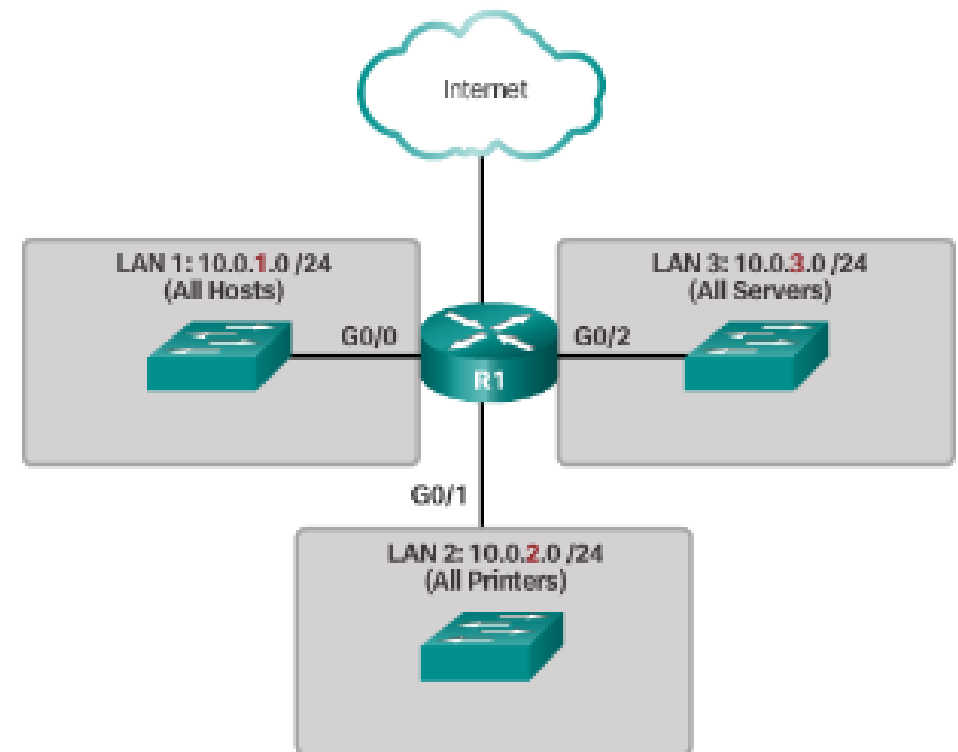
Problems with Large Broadcast Domains

- 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

- Large networks need to be segmented into smaller sub-networks, creating smaller groups of devices and services in order to:
 - Reduce the size of the network to create smaller broadcast domains
 - Control traffic by containing broadcast traffic within subnetwork
 - Reduce overall network traffic and improve network performance
 - Enables an administrator to implement security policies such as which subnets are allowed or not allowed to communicate together
- Subnetting - process of segmenting a network into multiple smaller network spaces called **subnetworks** or **subnets**

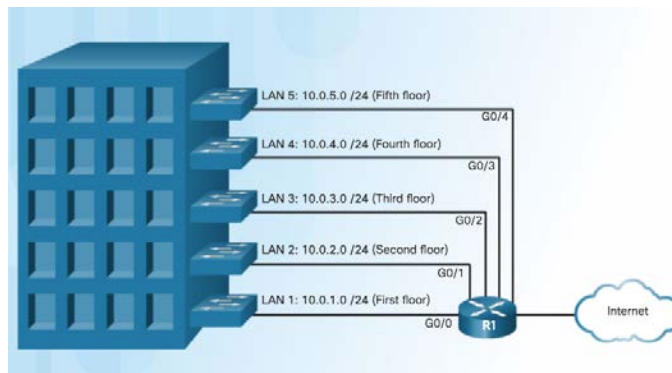




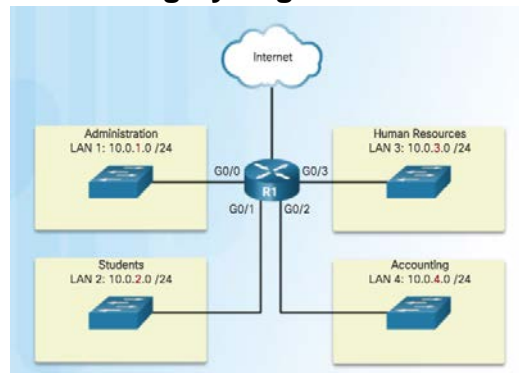
Reasons for Subnetting

- Communication Between Subnets
 - A router is necessary for devices on different networks and subnets to communicate
 - Because each broadcast domain connects to a different router interface, each domain needs its own network address space
 - Each router interface must have an IP host address that belongs to the network or subnet that the router interface is connected to
 - Devices on a network and subnet use the router interface attached to their LAN as their default gateway
 - Network administrators can group devices into subnets that are determined by location, organizational unit or device type

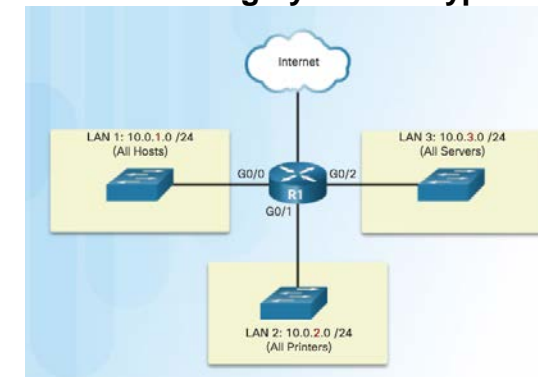
Subnetting by Location



Subnetting by Organizational Unit



Subnetting by Device Type





Octet Boundaries

- Prefix length and the subnet mask are different ways of identifying the network portion of an address
- **Subnets can be created based on octet boundaries. (/8, /16 or /24)**
- 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
 - Also known as IPv4 Classes
 - Uses the octet boundaries to separate network from hosts
- Classless Subnetting
 - Uses address bits to separate network from hosts
 - Allows for much more flexibility

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 Network 10.x.x.x/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

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 - 10.0.255.254</u>	<u>10.0.255.255</u>
<u>10.1.0.0/16</u>	<u>10.1.0.1 - 10.1.255.254</u>	<u>10.1.255.255</u>
<u>10.2.0.0/16</u>	<u>10.2.0.1 - 10.2.255.254</u>	<u>10.2.255.255</u>
<u>10.3.0.0/16</u>	<u>10.3.0.1 - 10.3.255.254</u>	<u>10.3.255.255</u>
<u>10.4.0.0/16</u>	<u>10.4.0.1 - 10.4.255.254</u>	<u>10.4.255.255</u>
<u>10.5.0.0/16</u>	<u>10.5.0.1 - 10.5.255.254</u>	<u>10.5.255.255</u>
<u>10.6.0.0/16</u>	<u>10.6.0.1 - 10.6.255.254</u>	<u>10.6.255.255</u>
<u>10.7.0.0/16</u>	<u>10.7.0.1 - 10.7.255.254</u>	<u>10.7.255.255</u>
...
<u>10.255.0.0/16</u>	<u>10.255.0.1 - 10.255.255.254</u>	<u>10.255.255.255</u>



Subnetting on the Octet Boundary

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

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>



Classless Subnetting

- Subnetting a /24 Network
- Subnets can borrow bits from any host bit position to create other masks

Prefix Length	Subnet Mask	Subnet Mask in Binary (n = network, h = host)	# of subnets	# of hosts
/25	255.255.255.128	n n n n n n n n . n n n n n n n n . n n n n n n n n . n h h h h h h h 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 0 0 0 0 0 0 0	2	126
/26	255.255.255.192	n n n n n n n n . n n n n n n n n . n n n n n n n n . n n h h h h h h h 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 0 0 0 0 0 0 0	4	62
/27	255.255.255.224	n n n n n n n n . n n n n n n n n . n n n n n n n n . n n n h h h h h h h 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 0 0 0 0 0 0 0	8	30
/28	255.255.255.240	n n n n n n n n . n n n n n n n n . n n n n n n n n . n n n n h h h h h h h 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 0 0 0 0 0 0 0	16	14
/29	255.255.255.248	n n n n n n n n . n n n n n n n n . n n n n n n n n . n n n n n h h h h h h 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 0 0 0 0 0 0 0	32	6
/30	255.255.255.252	n n n n n n n n . n n n n n n n n . n n n n n n n n . n n n n n n h h h h h 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 1 1 . 1 1 1 1 1 1 0 0 0 0 0 0 0	64	2

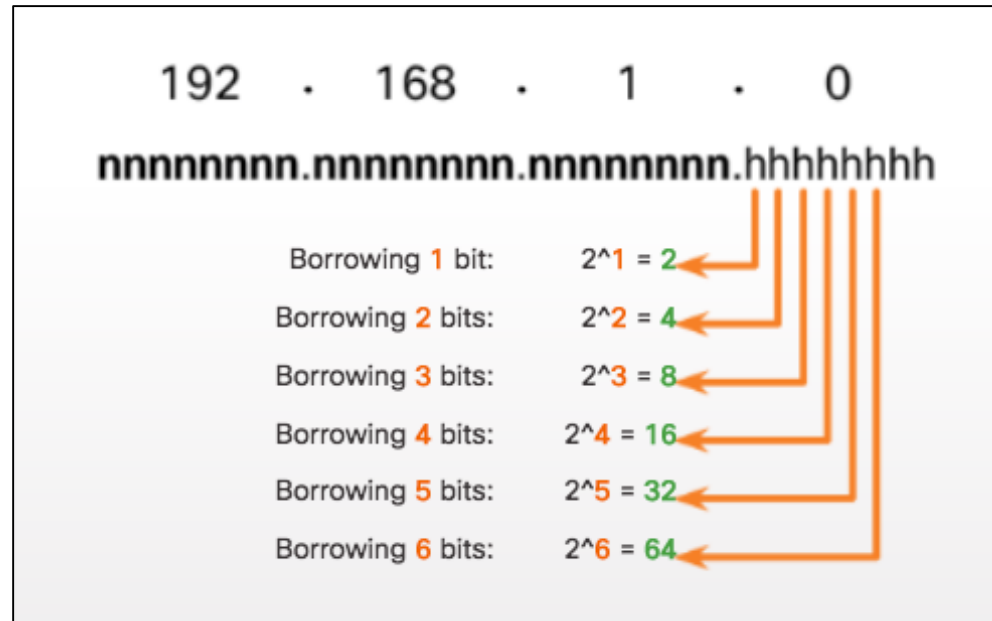


Subnetting Formulas

Calculate the
Number of Subnets

$$2^B \text{ or } 2^B$$

B = bits Borrowed
(taken from the host bits)



Calculate the
Number of Hosts

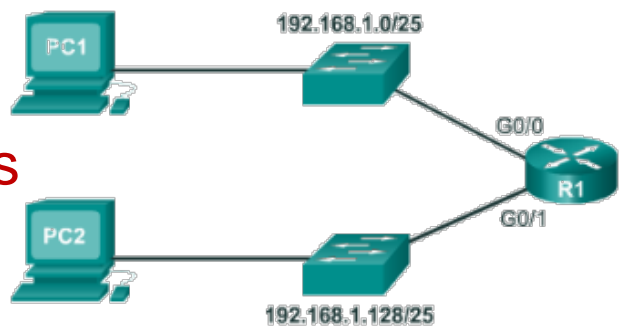
$$2^{U-2} \text{ or } 2^{U-2}$$

U = Unused bits
(number of bits remaining in the host)



Subnetting an IPv4 Network

- Creating 2 Subnets from a /24 Prefix
 - A subnet mask of /25 applied to 192.168.10.0, creates two equal subnets, each one with 126 hosts
- Subnetting Formulas
 - Use 2^B , to calculate the number of subnets
 - **B** is the number allocated to the network portion of the address
 - Use $2^U - 2$ to calculate the number of hosts
 - **U** is the number allocated to the host portion of the address
- Creating 4 Subnets from a /24 Prefix
 - A subnet mask of /26 applied to 192.168.10.0, creates four equal subnets, each one with 62 hosts
 - $B = 2$ and therefore $2^2 = 4$ Subnets
 - $U = 6$ and therefore $2^6 - 2 = 62$ Usable Hosts



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



Subnetting a /16 and /8 Prefix

- Creating Subnets from a /16 Prefix
 - A subnet mask of /16 applied to 172.16.32.0, creates a network with 65534 hosts
 - A subnet mask of /18 applied to 172.16.32.0, creates 4 networks with 16382 hosts in each network
 - A subnet mask of /22 applied to 172.16.32.0, creates 64 networks with 1022 hosts in each network
- Creating 100 Subnets from a /16 Prefix
 - A subnet mask of /23 applied to 172.16.32.0, creates 128 networks with 510 hosts in each network
- Calculating the Hosts
 - Use $2^h - 2$ to calculate the number of hosts
 - h is the number allocated to the host portion of the address
- Creating 1000 Subnets from a /8 Prefix
 - A subnet mask of /18 applied to 20.0.0.0, creates 1024 networks with 16382 hosts in each network



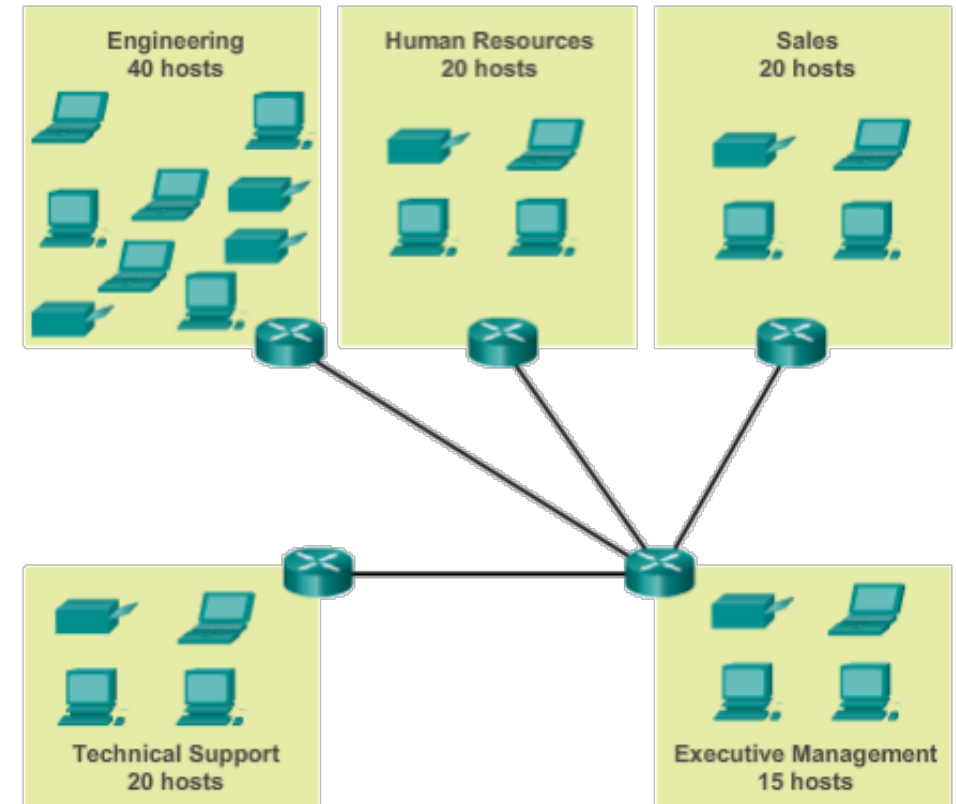
Subnetting to Meet Requirements

- 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
- Subnetting Based on Network Requirements
 - Administrators may be asked to subnet an IP range to accommodate a specific number of networks
 - Think of a company with 7 departments where each department must have its own subnetwork
 - The number of hosts per subnet, while secondary, is also important
- Network Requirement Example
 - Assume the range 200.42.98.0/24 was given to the administrator
 - 7 subnets must be created
 - Each department will have no more than 29 hosts
 - A subnet mask of /27 applied to 200.42.98.0/24, creates 8 networks with 30 hosts in each network

Subnetting To Meet Network Requirements

- It is important to balance the number of subnets needed and the number of hosts required for the largest subnet
- Design the addressing scheme to accommodate the maximum number of hosts for each subnet
- Allow for growth in each subnet
- When developing an IP addressing scheme for an enterprise network, hosts accessible from the Internet are recommended to be grouped into their own subnet or logical addressing group
- You are assigned the address block of 128.107.0.0/16. What subnet mask would provide the maximum number of equal size subnets while providing enough host addresses for each subnet in the graphic?

255.255.255.192



Traditional Subnetting Wastes Addresses

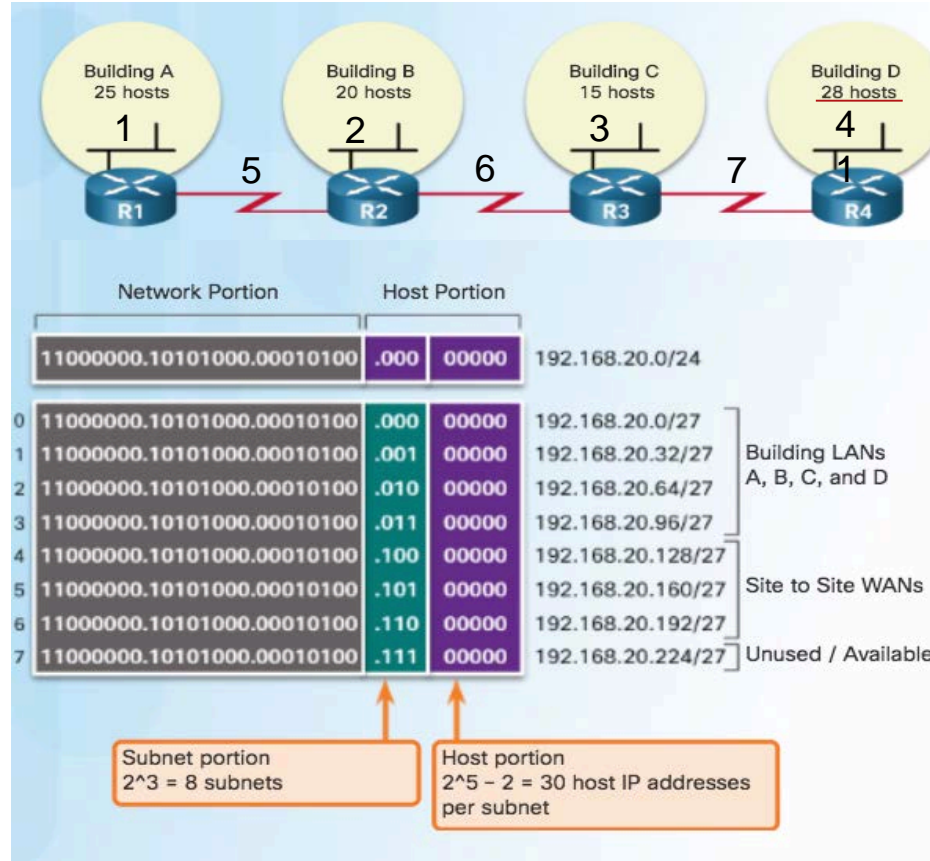
- Traditional subnetting - same number of addresses is allocated for each subnet
- Subnets that require fewer addresses have unused (wasted) addresses
 - For example, WAN links only need 2 addresses

Need 7 Subnets with 28 Hosts each

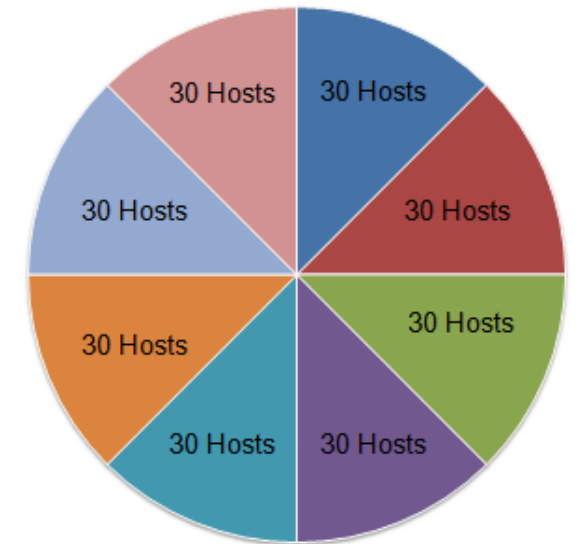
$2^3 = 8$ Subnets
 $2^5 - 2 = 30$ Usable Hosts

How many total host addresses are wasted?

144

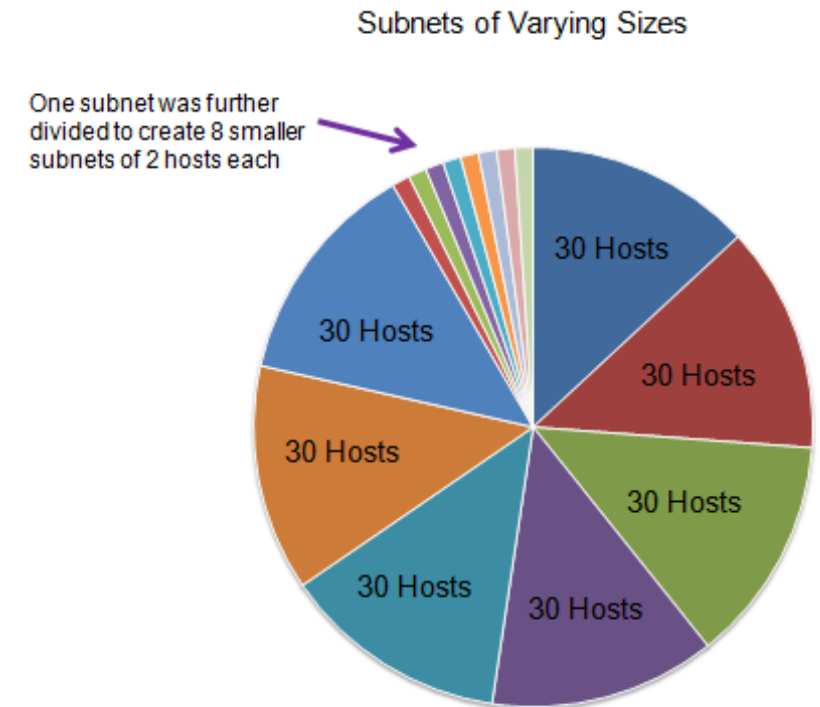


Traditional Subnetting Creates Equal Sized Subnets



Variable Length Subnet Masks (VLSM)

- **Variable Length Subnet Mask (VLSM)** or subnetting a subnet provides more efficient use of addresses
 - Allows a network space to be divided in unequal parts
 - By varying the mask, an administrator has more control
 - Less waste
 - Subnet mask will vary depending on how many bits have been borrowed for a particular subnet
 - Network is first subnetted, and then the subnets are subnetted again
 - Process repeated as necessary to create subnets of various sizes

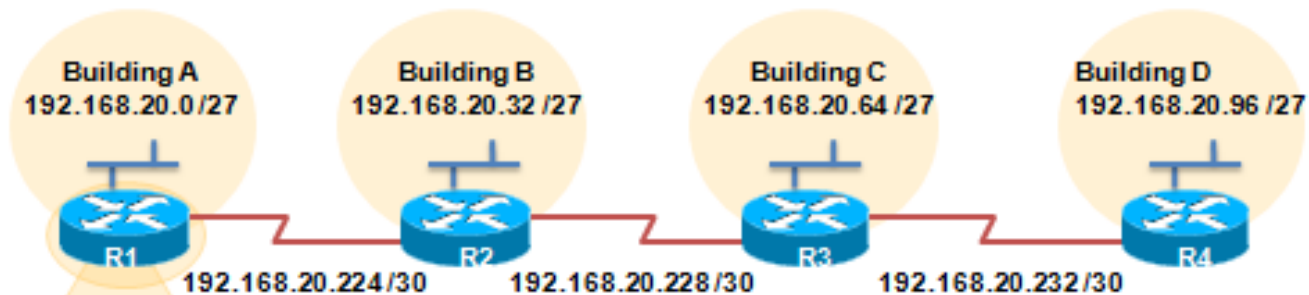




VLSM in Practice

- Using VLSM subnets, the LAN and WAN segments in example below can be addressed with minimum waste
- Each LANs will be assigned a subnet with /27 mask
- Each WAN link will be assigned a subnet with /30 mask
- /30 is a preferred match for a serial link**

Network Topology: VLSM Subnets



```

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 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

VLSM in Practice



```

R1#
interface fa0/0
ip address 192.168.1.1 255.255.255.0
interface s0/0/0
ip address 10.1.1.1 255.255.255.0
  
```

```

R2#
interface fa0/0
ip address 192.168.1.129 255.255.255.128
interface s0/0/0
ip address 10.1.1.2 255.255.255.0
  
```

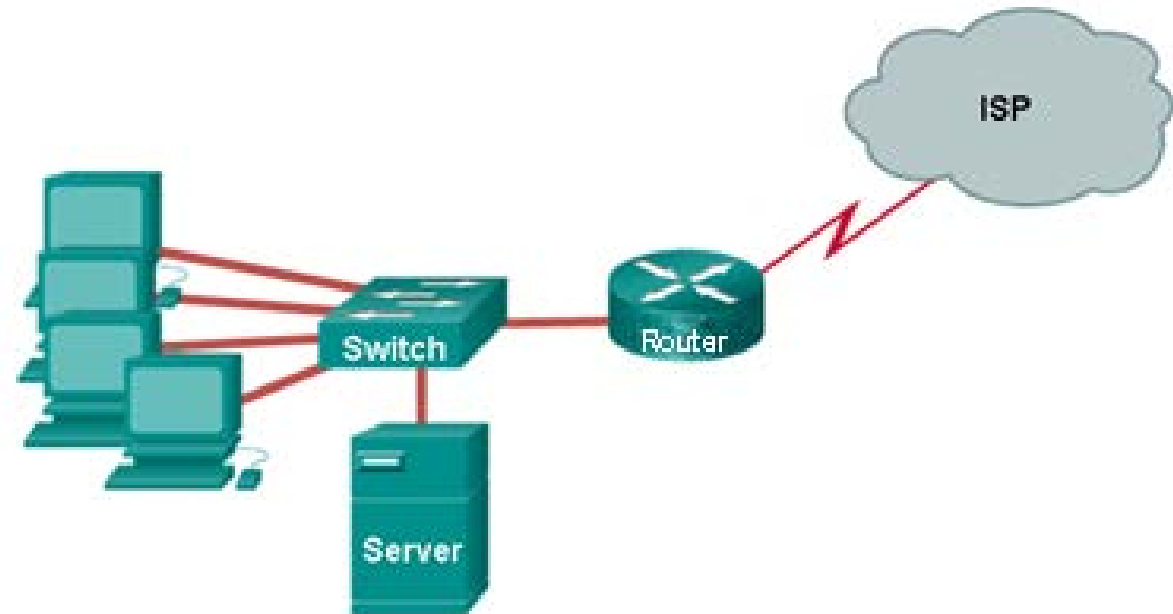
- What issue is causing Host A to be unable to communicate with Host B?

Host A and host B are on overlapping subnets

VLSM in Practice

- You have been given an address range of 192.168.10.0/29. You need to use the fifth subnet to configure the LAN. The router interface gets the first usable host address and the workgroup server is given the last usable host address. Which configuration should be entered on the server?

IP address: 192.168.10.38
Subnet mask: 255.255.255.248
Default gateway: 192.168.10.33





VLSM in Practice

- How many host addresses are available on the network 172.16.128.0 with a subnet mask of 255.255.252.0? **1022**
- Which subnet mask would be used if 5 host bits are available?
255.255.255.224
- A company has a network address of 192.168.1.64 with a subnet mask of 255.255.255.192. The company wants to create two subnetworks that would contain 10 hosts and 18 hosts respectively. Which two networks would achieve that? (Choose two.)
 - 192.168.1.16/28
 - 192.168.1.64/27 ←
 - 192.168.1.128/27
 - 192.168.1.96/28 ←
 - 192.168.1.192/28



8.2 ADDRESSING SCHEMES



Planning to Address the Network

- Allocation of network addresses should be planned and documented for the purposes of:
 - Eliminates most address configuration errors
 - Preventing duplication of addresses (Each host in an internetwork must have a unique address)
 - Providing and controlling access to servers from internal hosts and external hosts
 - It reduces the burden on network support staff
 - 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
- When a network administrator needs to monitor network traffic to and from servers in a data center, predictable static IP addresses should be applied for easier identification

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	

Sample Network Addressing Plan

Planning to Address the Network

- Clients addresses are usually dynamically assigned using Dynamic Host Configuration Protocol (DHCP)
- Preferred method of assigning IP addresses to host, especially on large networks
 - It eliminates most address configuration errors
 - It reduces the burden on network support staff

DHCP Server Commands

```
Router1>enable
Router1#config t
Router1(config)#ip dhcp pool MYP00L
Router1(dhcp-config)#network 172.16.0.0 255.255.0.0
Router1(dhcp-config)#dns-server 172.16.1.103 172.16.2.103
Router1(dhcp-config)#default-router 172.16.1.100
Router1(dhcp-config)#lease 7 8 30
Router1(dhcp-config)#exit
Router1(config)#ip dhcp excluded-address 172.16.1.100 172.16.1.103
```

Diagram annotations:

- Descriptive Name: Points to `MYP00L`
- Network Address: Points to `172.16.0.0`
- Default-Gateway: Points to `172.16.1.100`
- Lowest IP Address: Points to `172.16.1.100`
- Highest IP Address: Points to `172.16.1.103`



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	

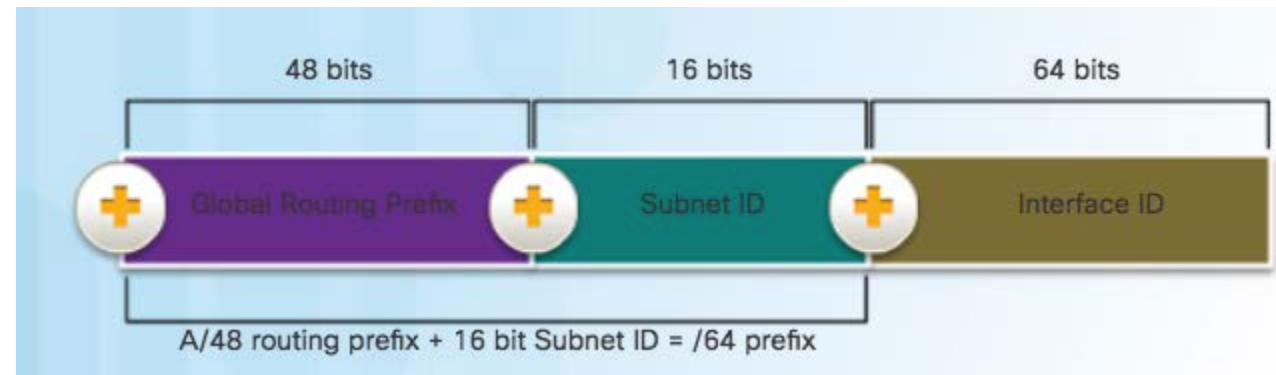


8.3 DESIGN CONSIDERATIONS FOR IPV6

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 bit global routing prefix
 - 16 bit subnet ID
 - 64 bit interface ID

Structure



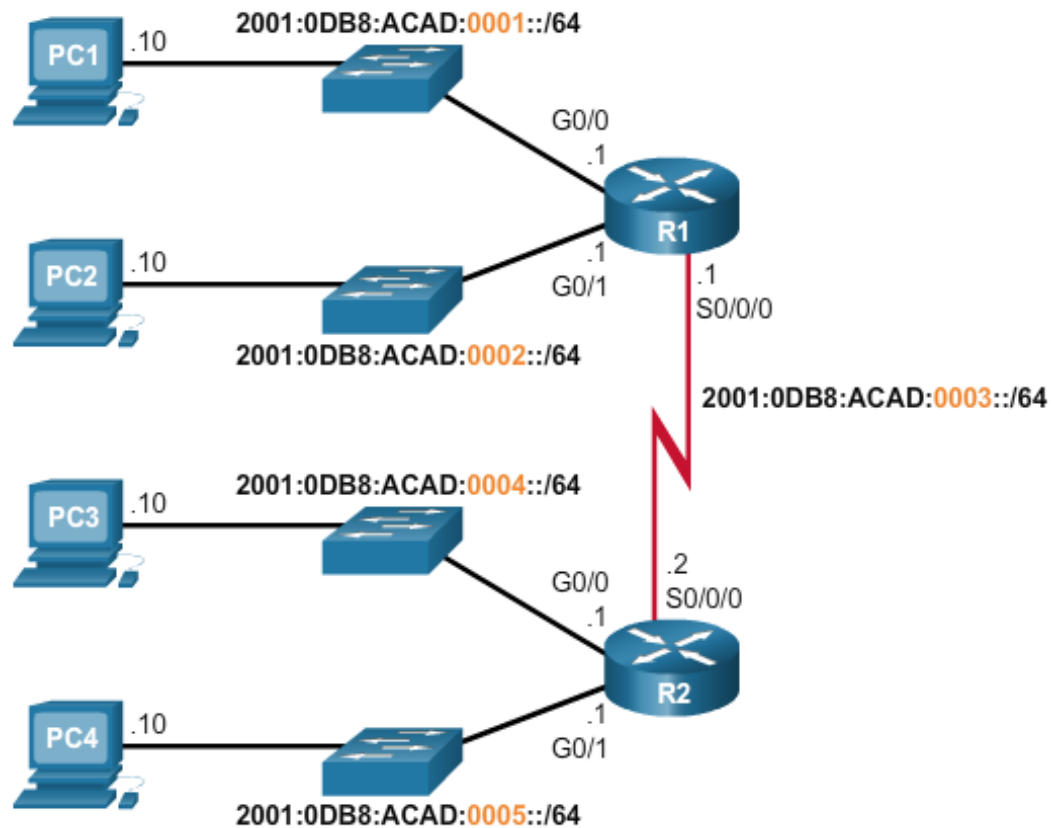
Global Routing Prefix

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.



IPv6 Structured Design

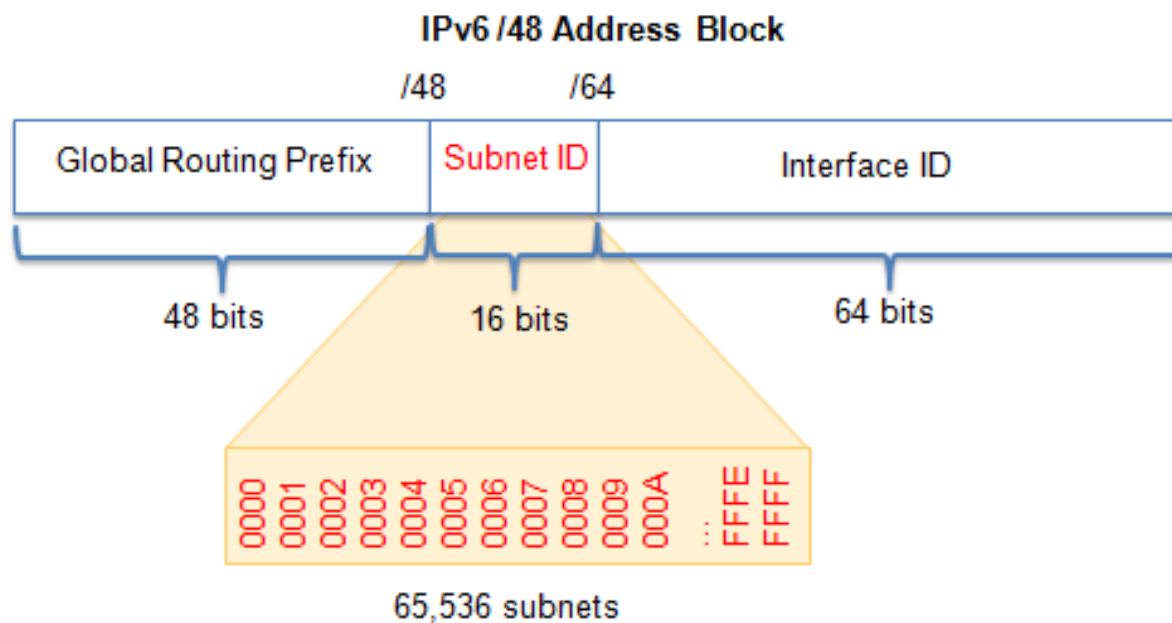
- The IPv6 global unicast address normally consists of a /48 global routing prefix, a 16 bit subnet ID, and a 64 bit interface ID





Subnetting IPv6 Using the Subnet ID

- An IPv6 Network Space is subnetted to support hierarchical, logical design of the network
- The subnet ID provides plenty subnets and host support in one subnet
- The subnet ID alone allows for creating up to 65,536 /64 subnets



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 IPv6

- Consider the following range of addresses:

2001:0DB8:BC15:00A0:0000::

2001:0DB8:BC15:00A1:0000::

2001:0DB8:BC15:00A2:0000::

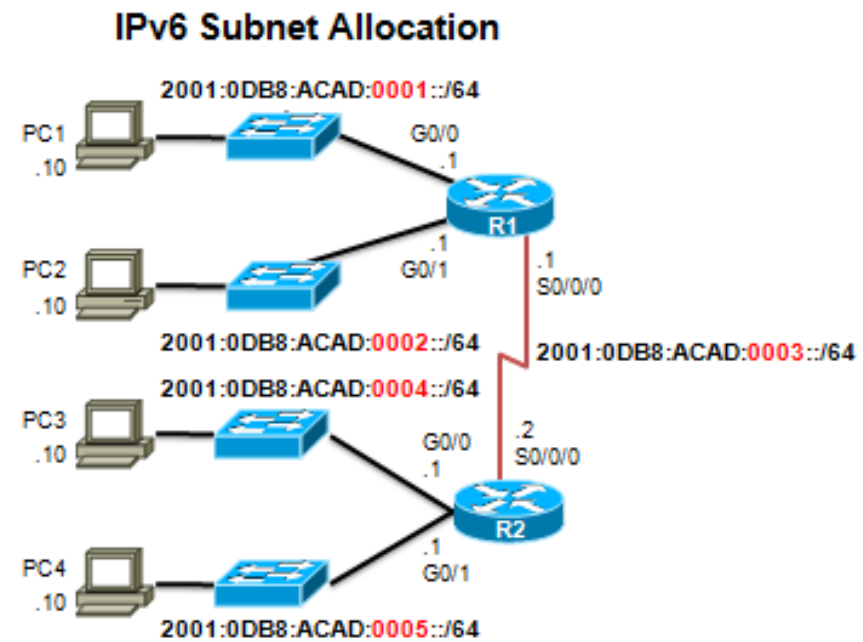
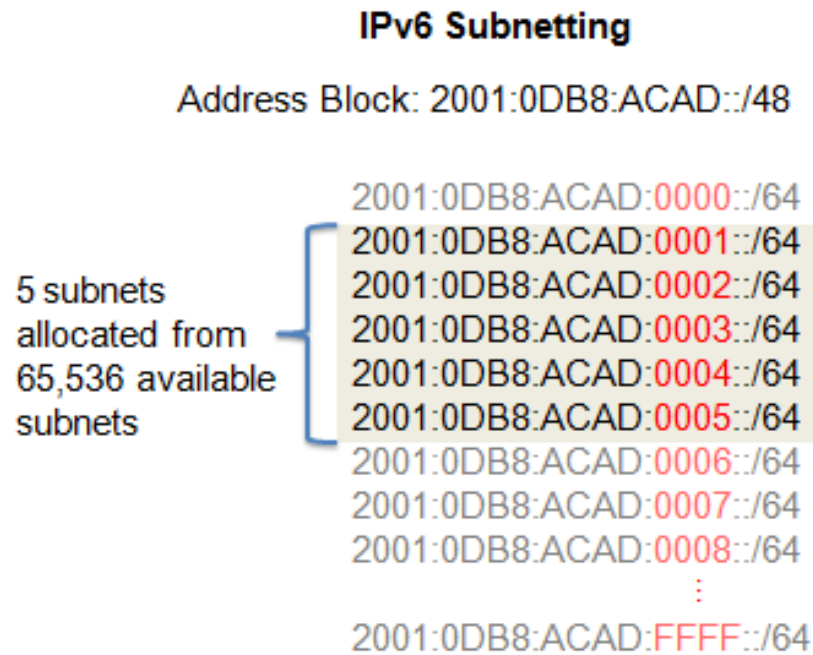
2001:0DB8:BC15:00AF:0000::

The prefix-length for the range of addresses is /60.

- What is the prefix for the host address 2001:DB8:BC15:A:12AB::1/64? **2001:DB8:BC15:A**
- Which two notations are useable nibble boundaries when subnetting in IPv6? (Choose two.)
 - /62
 - /64 ←
 - /66
 - /68 ←
 - /70

IPv6 Subnet Allocation

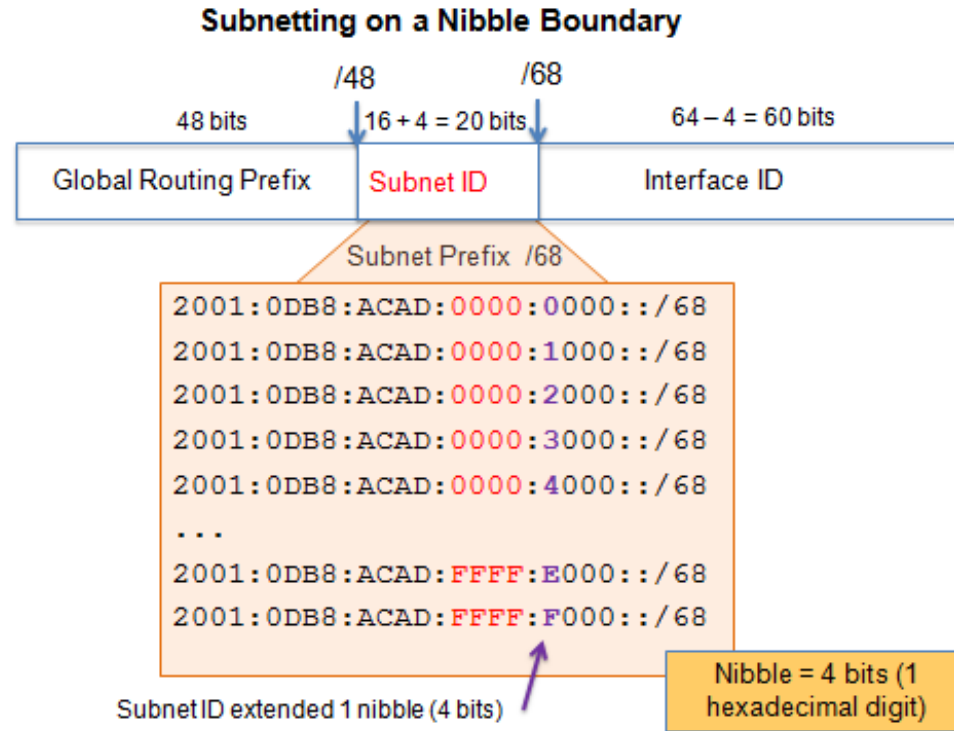
- Address waste is not a concern in IPv6
- Administrators can concentrate on designing a logical scheme to address the network



- What is the subnet address for the address 2001:DB8:BC15:A:12AB::1/64?
2001:DB8:BC15:A::0

Subnetting into the Interface ID

- IPv6 bits can be borrowed from the interface ID to create additional IPv6 subnets



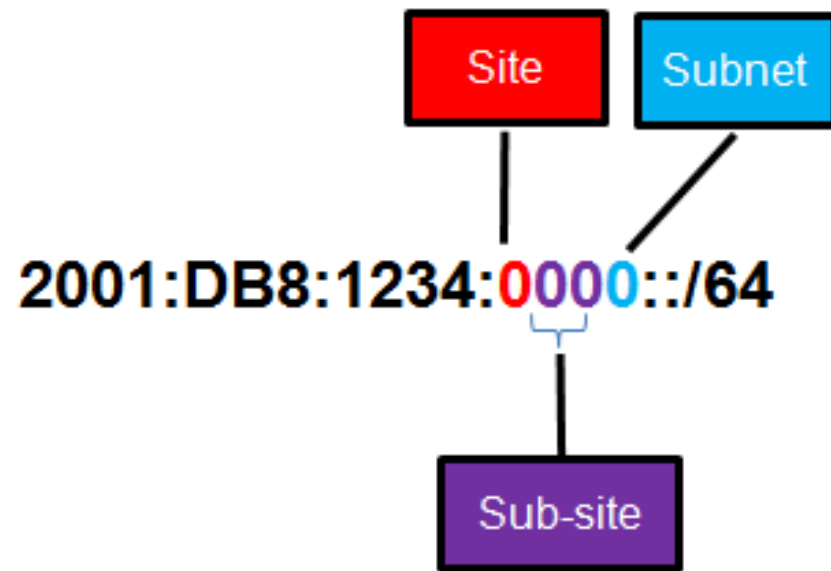
- When subnetting a /64 IPv6 network prefix, which is the preferred new prefix length?

/72

Subnetting into the Interface ID

- You are helping to deploy an IPv6 addressing scheme. The design document indicates that the **subnet** portion of the IPv6 addresses is used for the new hierarchical network design, with the **site** subsection to represent multiple geographical sites of the company, the **sub-site** section to represent multiple campuses at each site, and the **subnet** section to indicate each network segment separated by routers. With such a scheme, what is the maximum number of *subnets* achieved per *sub-site*?

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CHAPTER TERMS



Section 6.1 Terms and Commands

- Subnetting
- Classful Boundary
- Classless Subnetting
- Magic number
- Octet boundary
- Variable Length Subnet Mask (VLSM)
- Global Routing Prefix

