Chapter 9: Subnetting IP Networks

Introduction to Networks

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Chapter 9: Objectives

Upon completion of this chapter, you will be able to:

- Explain why routing is necessary for hosts on different networks to communicate.
- Describe IP as a communication protocol used to identify a single device on a network.
- Given a network and a subnet mask, calculate the number of host addresses available.
- Calculate the necessary subnet mask in order to accommodate the requirements of a network.
- Describe the benefits of variable length subnet masking (VLSM).
- Explain how IPv6 address assignments are implemented in a business network.

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9.1 Subnetting an IPv4 Network

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Re-cap on IPv4 Addressing

IP Address is made up of 32 bits.

- Expressed as 32 Binary bits or dotted decimal.
- IP address has a Network & Host portion.
  → Network portion cannot change, we can only borrow bits from the Host portion.
- The subnet mask helps to determine the Network portion.

There are 3 types IP Address:

- Network address → Host bits all are '0'.
- Broadcast address → Host bits all are '1'.
- Host / Usable addresses → Host bits has '0' and '1'.
  (Range of addresses between Network & Broadcast address)

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Reasons for Subnetting

Subnetting is the process of dividing / segmenting a network into multiple smaller network spaces called subnetworks or subnets.

- Large networks must be segmented into smaller subnets, creating smaller groups of devices and services to:
  - Control traffic by containing broadcast traffic within each subnetwork.
  - Reduce overall network traffic and improve network performance.

Communication Between Subnets

- A router is necessary for devices on different networks and subnets to communicate.
- Each router interface must have an IPv4 host address that belongs to the network or subnet that the router interface is connected.
- Devices on a network and subnet use the router interface attached to their LAN as their default gateway.

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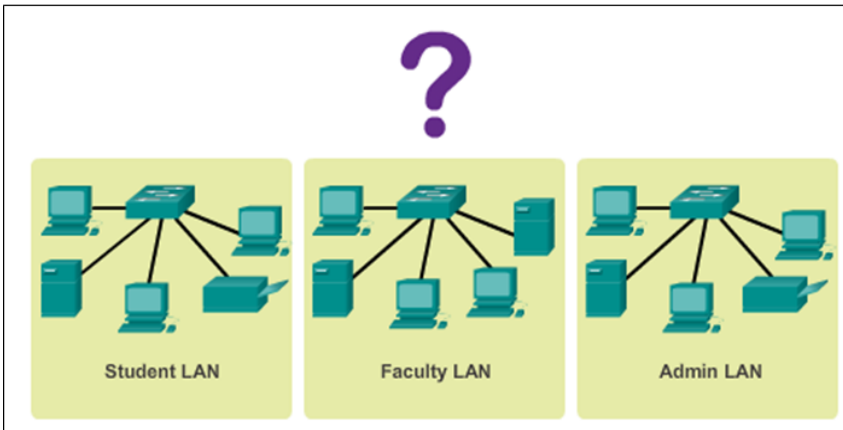
Subnetting an IPv4 Network - Planning

Planning the Network



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

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Basic Subnetting

- Borrowing Bits to Create Subnets
- Borrowing 1 bit → 2^1 = 2 subnets

Address	192	168	1	0000 0000
Mask	255	255	255	0000 0000

Network Portion | Host Portion

Original	192.	168.	1.	0 000 0000	Network 192.168.1.0/24
Mask	255.	255.	255.	0 000 0000	Mask: 255.255.255.0

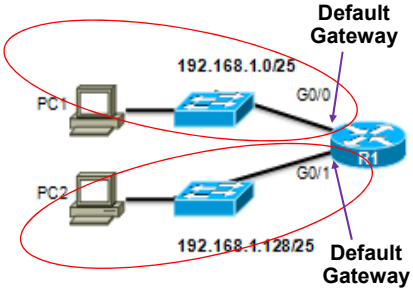
Borrowing 1 Bit from the host portion creates 2 subnets

Subnet 0
Network 192.168.1.**0-127**/**25**
Mask: 255.255.255.**128**

Subnet 1
Network 192.168.1.**128-255**/**25**
Mask: 255.255.255.**128**

Subnets in Use

Subnet 0
Network 192.168.1.**0-127** /**25**



Subnet 1
Network 192.168.1.**128-255** /**25**

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

Subnetting Formulas

Calculate number of subnets

Subnets = 2^n
(where n = bits borrowed)

192. 168. 1. 0 000 0000

1 bit was borrowed

2^1 = 2 subnets

Calculate number of hosts

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

192. 168. 1. 0 000 0000

7 bits remain in host field

2^7 = 128 addresses per subnet
2^7 - 2 = 126 valid hosts per subnet

No. of hosts = $2^H - 2$

Where H = no. of host bits

Creating 4 Subnets

Borrowing 2 bits to create 4 subnets. **2^2 = 4 subnets**

Creating 4 Subnets

Borrowing 2 Bits

Original	192.	168.	1.	00	00 0000
Mask	255.	255.	255.	00	00 0000

Borrowing 2 bits creates 4 subnets:

Net 0	192.	168.	1.	00	00 0000	192.168.1.0/26
Net 1	192.	168.	1.	01	00 0000	192.168.1.64/26
Net 2	192.	168.	1.	10	00 0000	192.168.1.128/26
Net 3	192.	168.	1.	11	00 0000	192.168.192/26

All 4 subnets use the same mask:

Mask	255.	255.	255.	11	00 0000	Mask: 255.255.255.192

Creating Eight Subnets

Borrowing 3 bits to **Create 8 Subnets**. **2^3 = 8 subnets**

Net 0	Network	192.	168.	1.	000	0 0000	192.168.1.0
	First	192.	168.	1.	000	0 0001	192.168.1.1
	Last	192.	168.	1.	000	1 1110	192.168.1.30
	Broadcast	192.	168.	1.	000	1 1111	192.168.1.31
Net 1	Network	192.	168.	1.	001	0 0000	192.168.1.32
	First	192.	168.	1.	001	0 0001	192.168.1.33
	Last	192.	168.	1.	001	1 1110	192.168.1.62
	Broadcast	192.	168.	1.	001	1 1111	192.168.1.63
Net 2	Network	192.	168.	1.	010	0 0000	192.168.1.64
	First	192.	168.	1.	010	0 0001	192.168.1.65
	Last	192.	168.	1.	010	1 1110	192.168.1.94
	Broadcast	192.	168.	1.	010	1 1111	192.168.1.95
Net 3	Network	192.	168.	1.	010	0 0000	192.168.1.96
	First	192.	168.	1.	010	0 0001	192.168.1.97
	Last	192.	168.	1.	010	1 1110	192.168.1.126
	Broadcast	192.	168.	1.	010	1 1111	192.168.1.127

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Creating Eight Subnets (Cont.)

Net 4	Network	192.	168.	1.	100	0 0000	192.168.1.128
	Fist	192.	168.	1.	100	0 0001	192.168.1.129
	Last	192.	168.	1.	100	1 1110	192.168.1.158
	Broadcast	192.	168.	1.	100	1 1111	192.168.1.159
Net 5	Network	192.	168.	1.	101	0 0000	192.168.1.160
	Fist	192.	168.	1.	101	0 0001	192.168.1.161
	Last	192.	168.	1.	101	1 1110	192.168.1.190
	Broadcast	192.	168.	1.	101	1 1111	192.168.1.191
Net 6	Network	192.	168.	1.	110	0 0000	192.168.1.192
	Fist	192.	168.	1.	110	0 0001	192.168.1.193
	Last	192.	168.	1.	110	1 1110	192.168.1.222
	Broadcast	192.	168.	1.	110	1 1111	192.168.1.223
Net 7	Network	192.	168.	1.	111	0 0000	192.168.1.224
	Fist	192.	168.	1.	111	0 0001	192.168.1.225
	Last	192.	168.	1.	111	1 1110	192.168.1.254
	Broadcast	192.	168.	1.	111	1 1111	192.168.1.255

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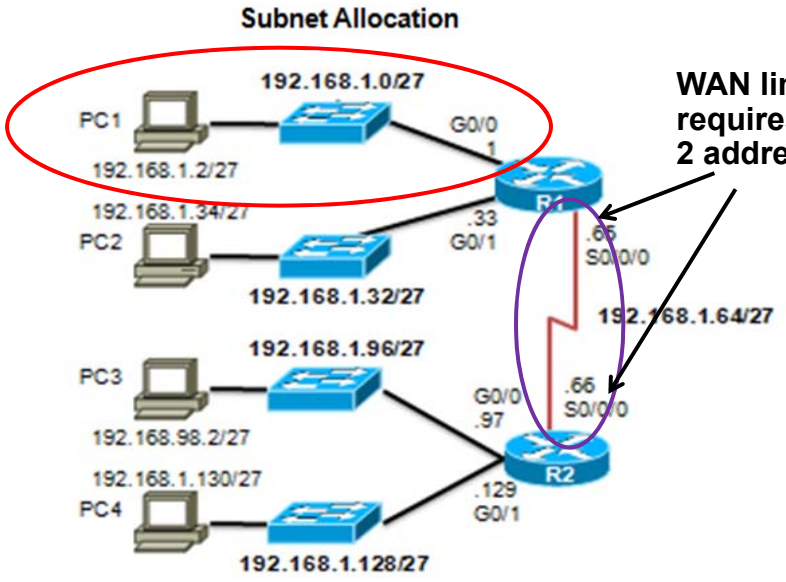
Creating Eight Subnets (Cont.)



Subnetting Based on Host Requirements

Two considerations when planning subnets:

- Number of subnets required.
- Number of host addresses required.

Formula to determine number of usable hosts: $2^H - 2$

- 2^H (where H is the number of remaining host bits) is used to calculate the number of hosts.
- **- 2** (The subnetwork address and broadcast address cannot be used on each subnet.)

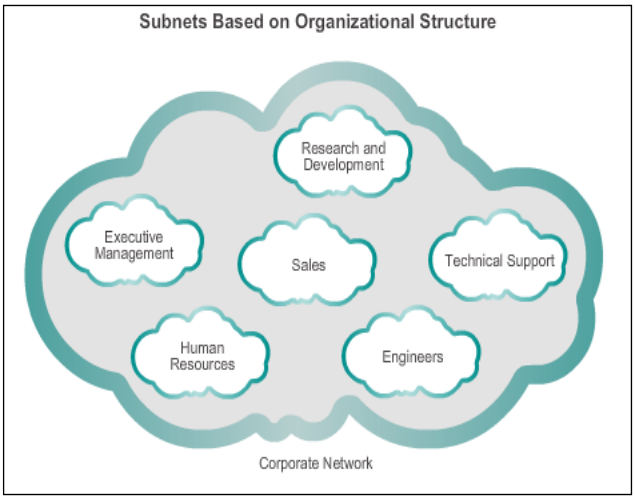
No. of usable hosts = $2^H - 2$

Where H = no. of host bits

Subnetting Network-Based Requirements

Calculate the number of subnets:

- **2^n** (where n is the number of bits borrowed)
- Subnet needed for each department.



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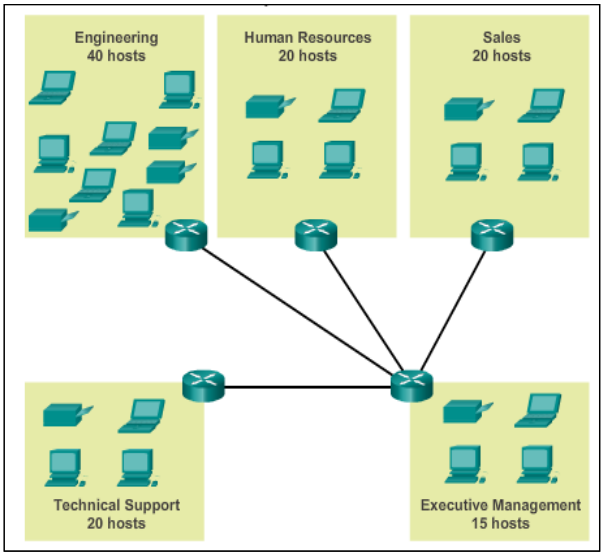
Subnetting To Meet Network Requirements

- Balance the required number of subnets and hosts for the largest subnet.
- Design the addressing scheme to accommodate the maximum number of hosts for each subnet.
- Allow for growth in each subnet.



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Determining the Subnet Mask

Subnets and Addresses

	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
	Nets 7 – 14 not shown	
15	10101100.00010000.000000**11**.**10**000000	172.16.3.128/26
16	10101100.00010000.000000**11**.**11**000000	172.16.3.192/26

2^4 = 16 subnets

2^6 – 2 = 62 Hosts per subnet

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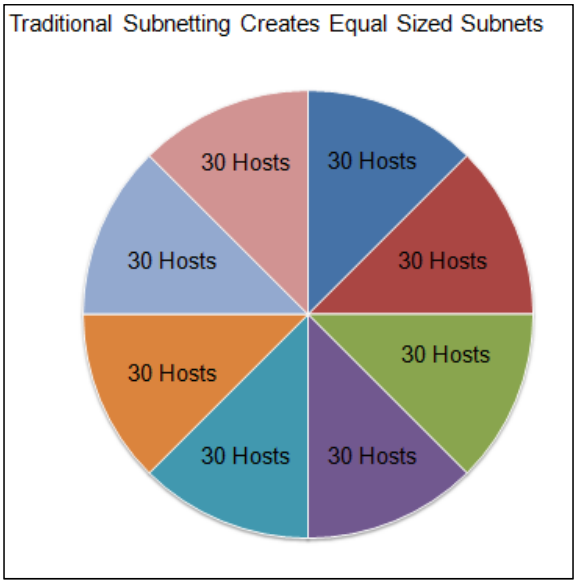
Traditional Subnetting Wastes Addresses

- Traditional subnetting – allocates the same number of addresses for each subnet.
- Subnets that require fewer addresses have unused (wasted) addresses.
- For example, WAN links only need two addresses.



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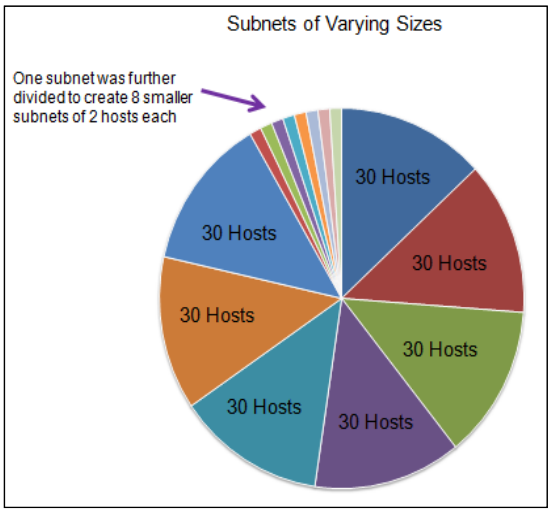
Variable Length Subnet Masks (VLSM)

- The variable-length subnet mask (VLSM) or subnetting a subnet provides more efficient use of addresses.
- VLSM allows a network space to be divided in unequal parts.
- Subnet mask varies, depending on how many bits have been borrowed for a particular subnet.
- Network is first subnetted and then the subnets are re-subnetted.



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Basic VLSM

VLSM Subnetting Scheme

	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

LANs A, B, C, D

Unused / Available

3 more bits borrowed from subnet 7:

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

WANs

Unused / Available

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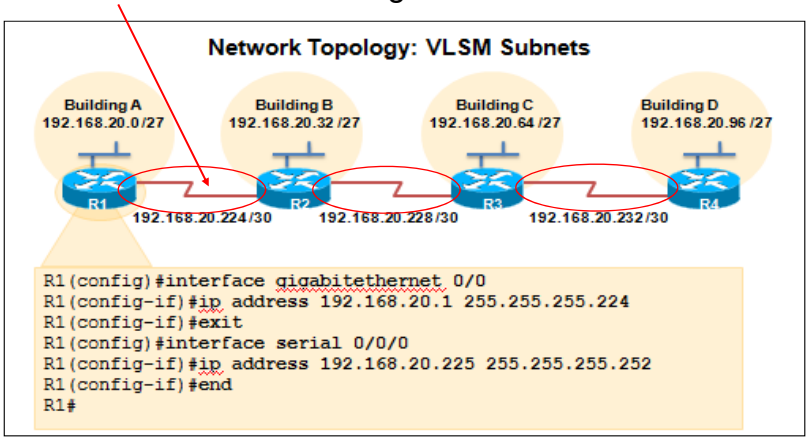
VLSM in Practice

- 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.



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

9.2 Addressing Schemes

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Planning to Address the Network

Allocation of network addresses should be planned and documented for the purposes of:

- Preventing duplication of addresses.
- Providing and controlling access.
- Monitoring security and performance.

Client addresses – Usually dynamically assigned using the Dynamic Host Configuration Protocol (DHCP).

Sample Network Addressing Plan

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	

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9.3 Design Considerations for IPv6

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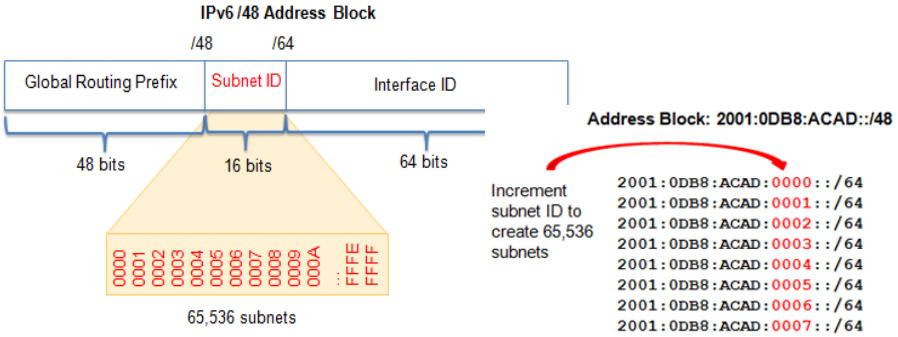
Subnetting an IPv6 Network - Subnetting Using the Subnet ID

An IPv6 Network Space is subnetted to support hierarchical, logical design of the network.



IPV6 Subnet Allocation

IPv6 Subnetting

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

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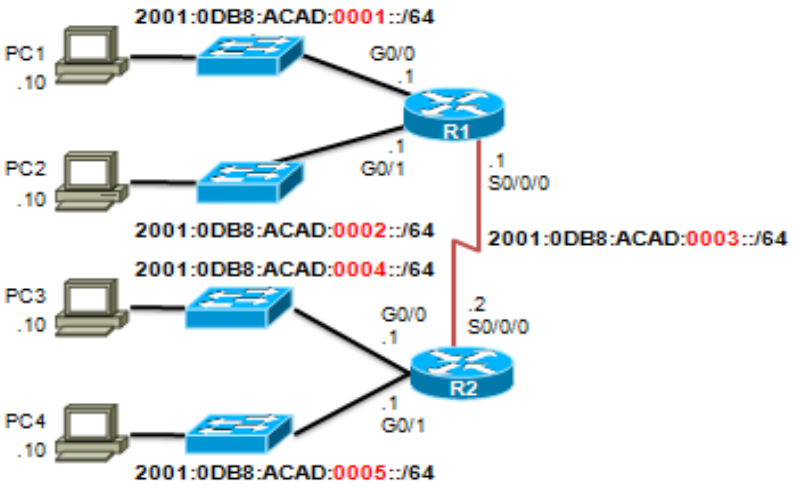
IPV6 Subnet Allocation

IPv6 Subnet Allocation



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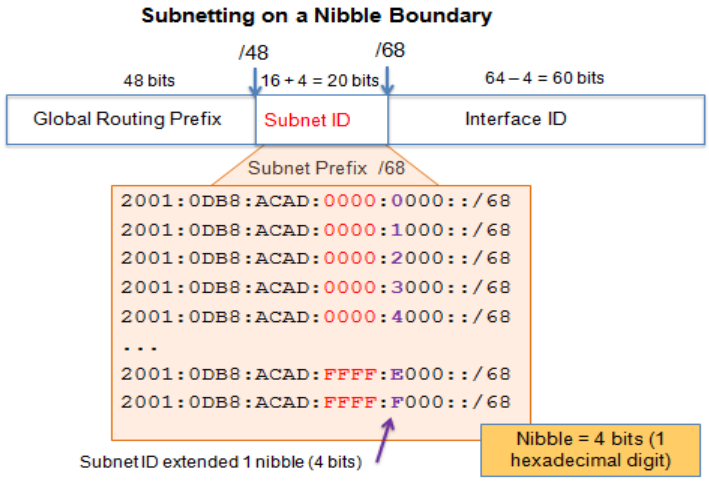
Subnetting into the Interface ID

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



Chapter 9: Summary

In this chapter, you learned that:

- Subnetting is the process of segmenting a network, by dividing it into multiple smaller network spaces.
- Subnetting a subnet, or using VLSM, was designed to avoid wasting addresses.
- IPv6 address space is subnetted to support the hierarchical, logical design of the network.
- Size, location, use, and access requirements are all considerations in the address planning process.