Subnetting IP Networks

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Chapter 9

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.

9.1 Subnetting an IPv4 Network

Reasons for Subnetting

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

- Large networks must be segmented into smaller subnetworks, 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.

The Plan

Planning the Network

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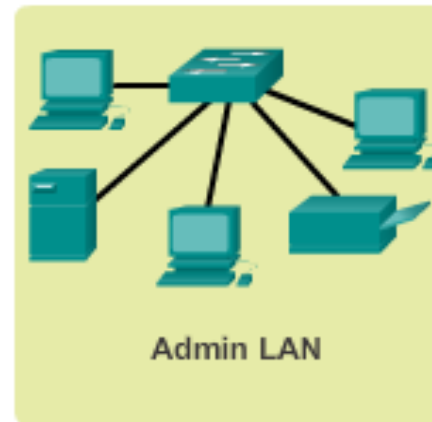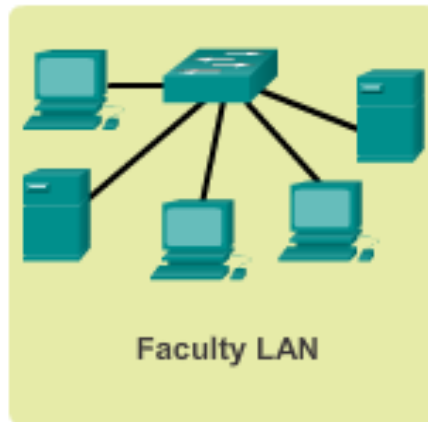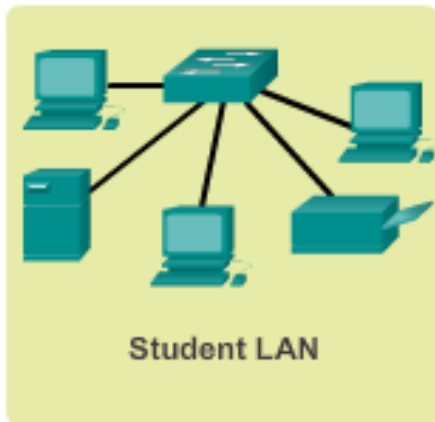
Planning requires decisions on each subnet in terms of size, the number of hosts per subnet, and how host addresses will be assigned.

Basic Subnetting

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

Borrowing 1 Bit from the host portion creates 2 subnets with the same subnet mask

Subnet 0	Subnet 1
Network 192.168.1.**0-127**/**25**	Network 192.168.1.**128-255**/**25**
Mask: 255.255.255.**128**	Mask: 255.255.255.**128**

Subnets in Use

Subnets in Use

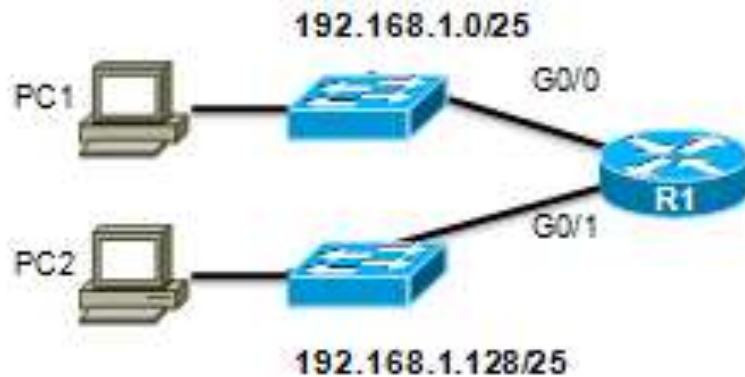Address Range for 192.168.1.0/25 Subnet

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 |

Subnet 0

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

192.168.1.0/25

PC1 — G0/0 — R1

PC2 — G0/1

192.168.1.128/25

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 |

Subnet 1

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

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
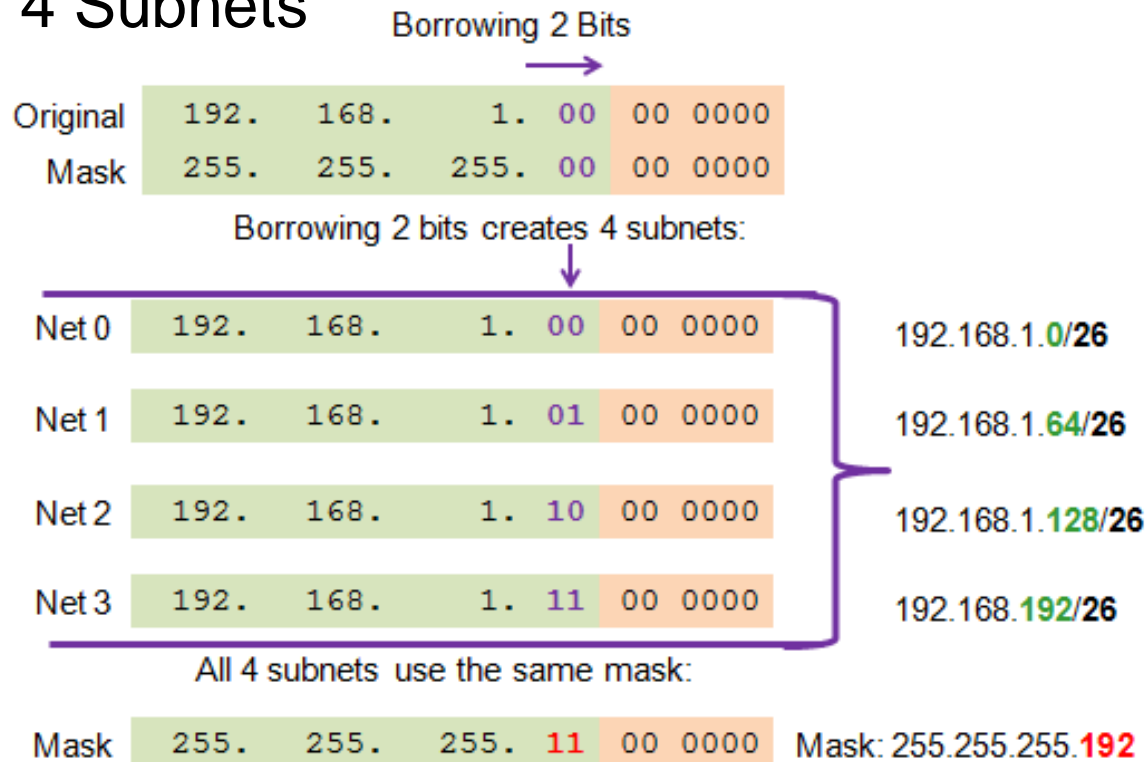2^**7** - 2 = 126 valid hosts per subnet

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

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

Creating Eight Subnets (Cont.)

Subnet Allocation
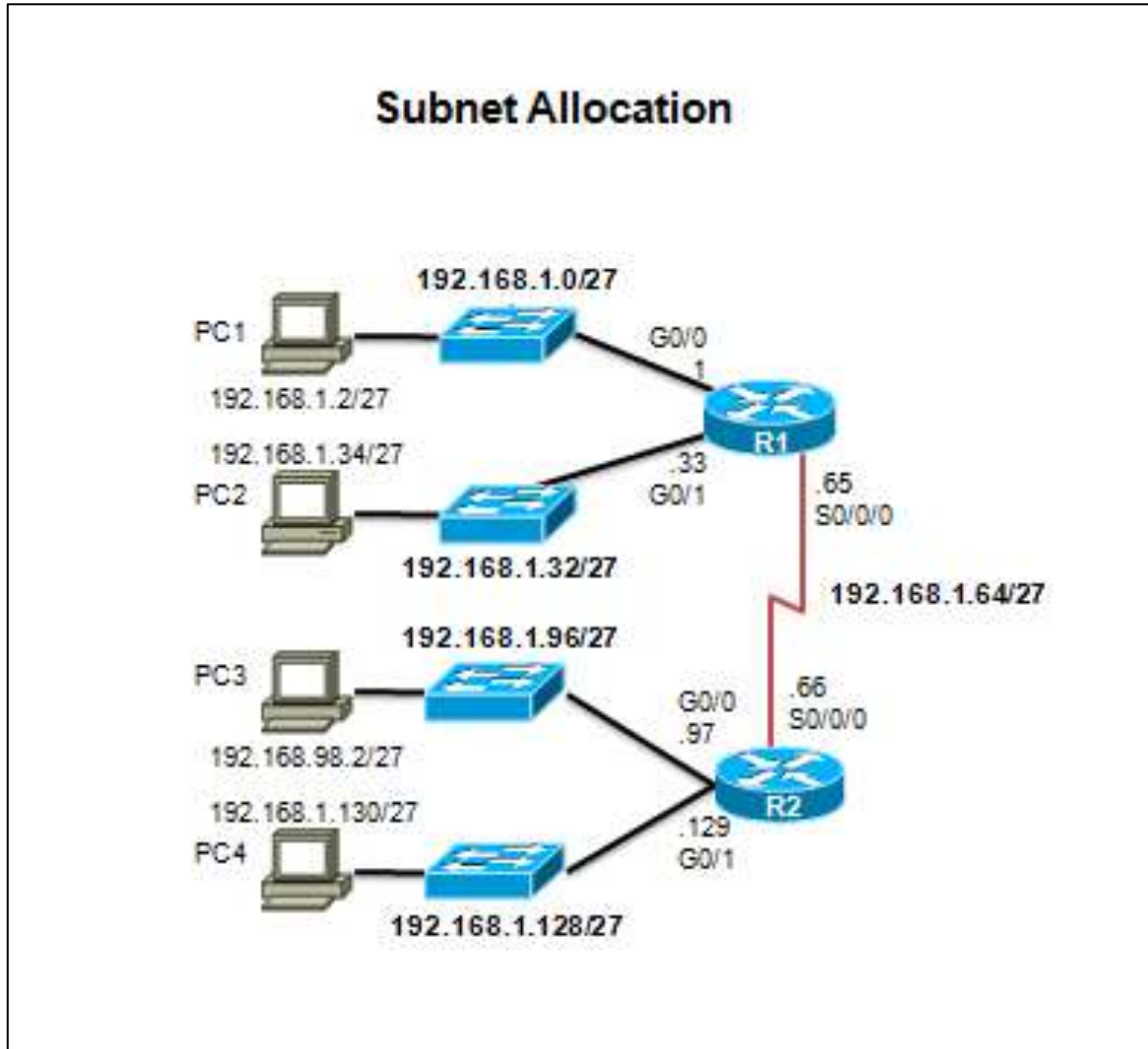
Subnetting Based on Host Requirements

Two considerations when planning subnets:

- Number of subnets required

- Number of host addresses required

Formula to determine number of usable hosts: 2^n-2

- 2^n (where *n* is the number of remaining host bits) is used to calculate the number of hosts.

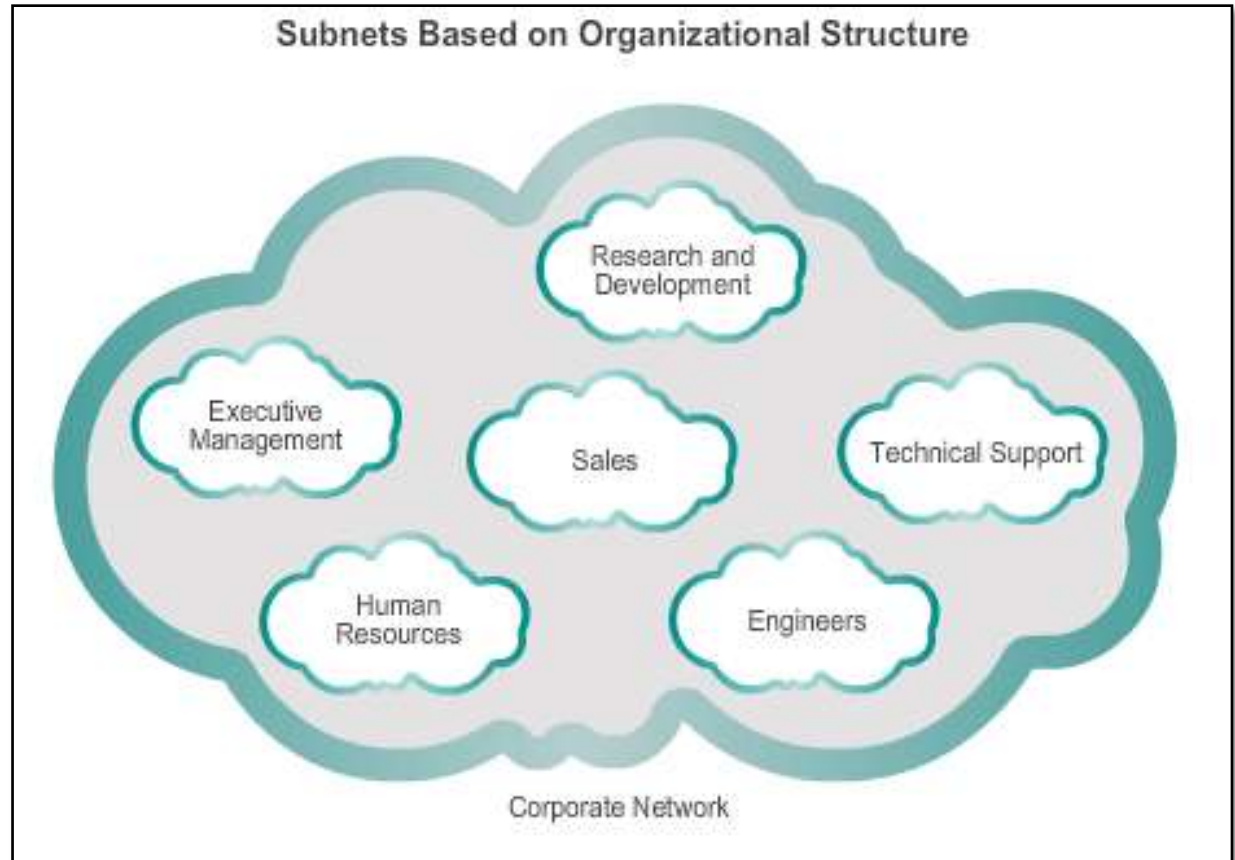- -2 (The subnetwork ID and broadcast address cannot be used on each subnet.)

Subnetting Network-Based Requirements

Calculate the number of subnets:

- **2^n** (where n is the number of bits borrowed)

- Subnet needed for each department.

Subnets Based on Organizational Structure

Research and Development

Executive Management

Sales

Technical Support

Human Resources

Engineers

Corporate Network

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.
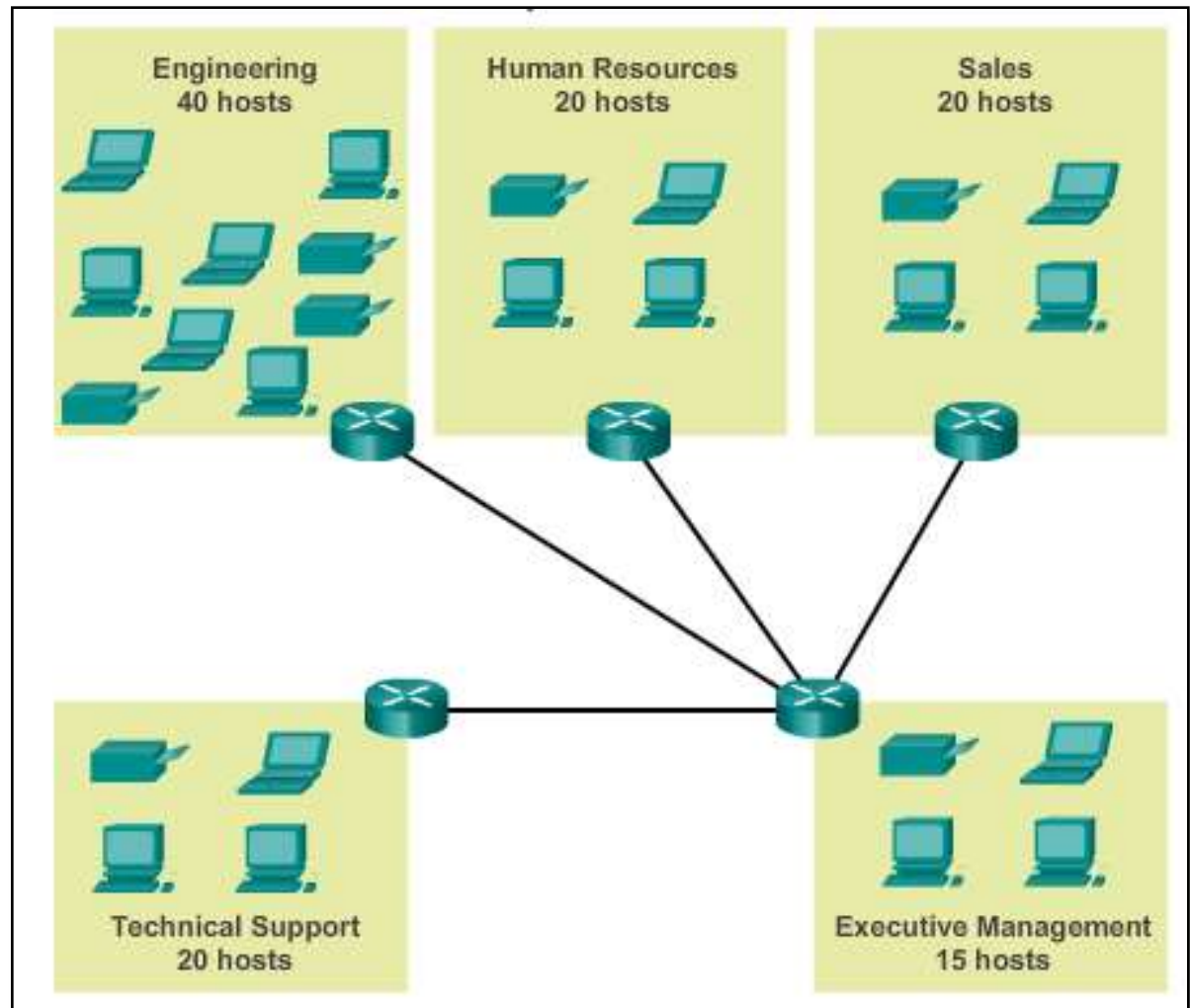
Subnetting To Meet Network Requirements

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

Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes Addresses

- Traditional subnetting – Uses the same number of addresses is allocated for each subnet.

- Subnets that require fewer addresses have unused (wasted) addresses; for example, WAN links only need two addresses.
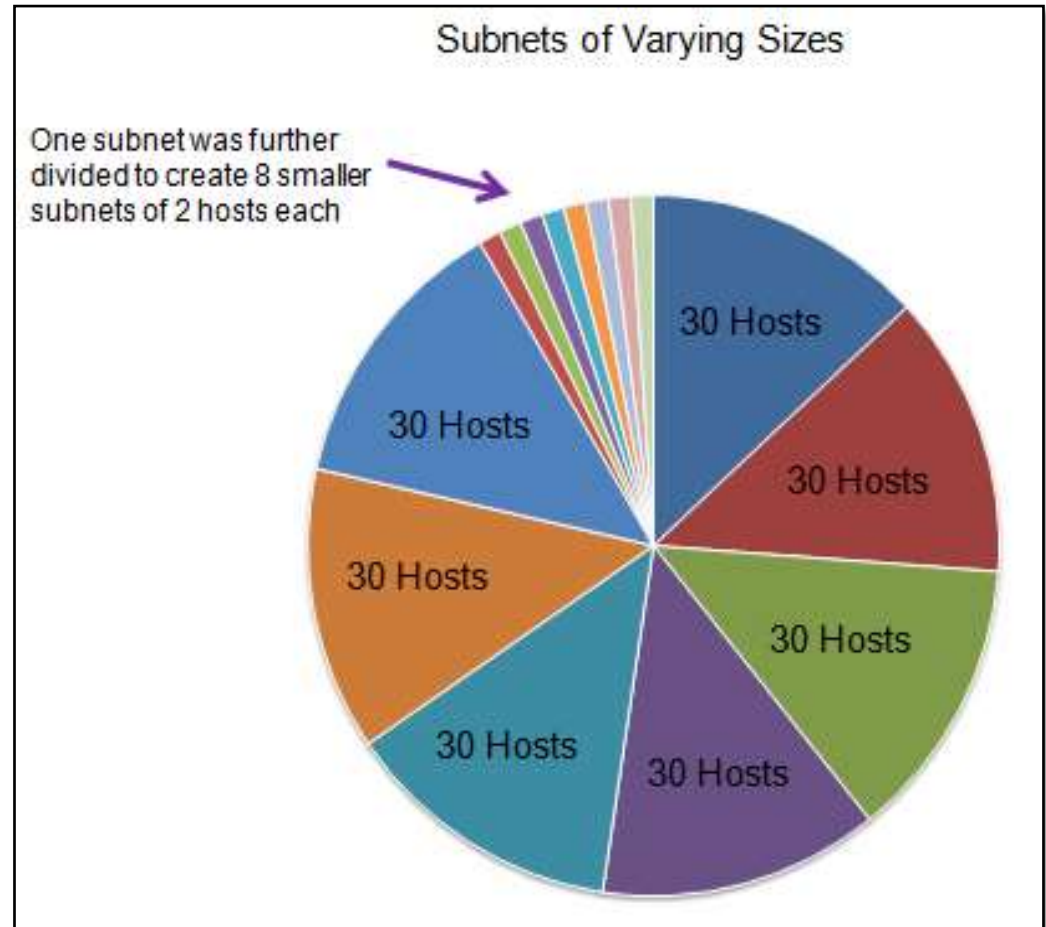

Traditional Subnetting Creates Equal Sized Subnets

30 Hosts (×8)
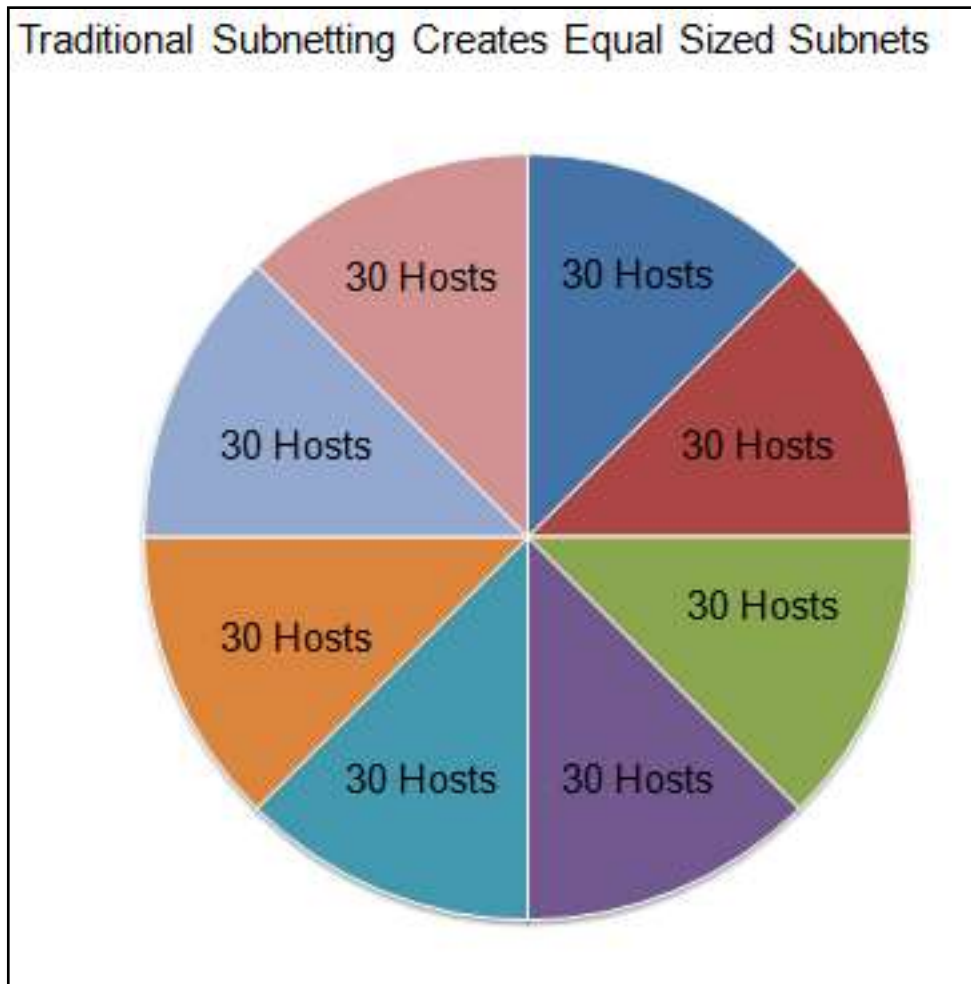
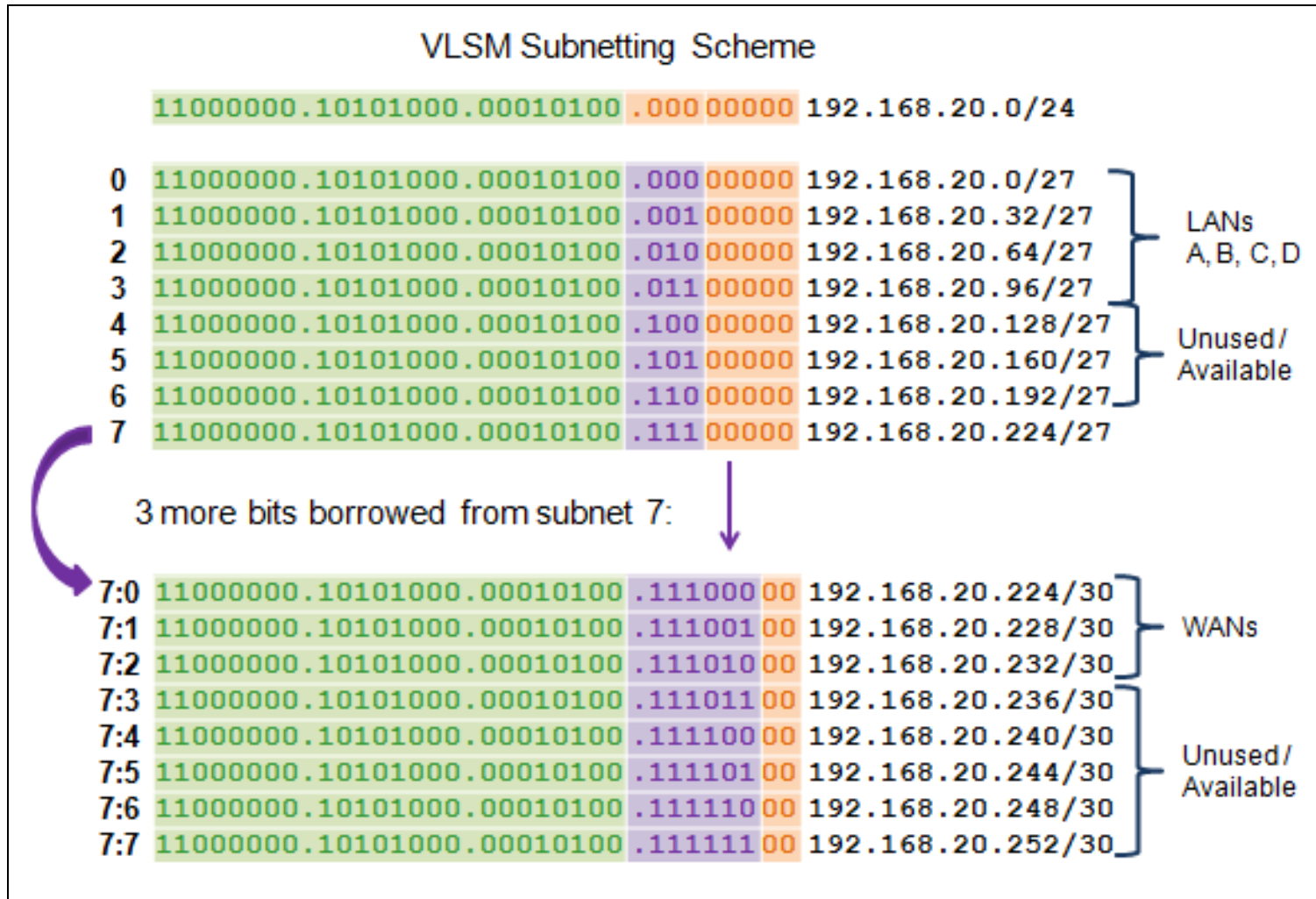# Variable Length Subnet Masks (VLSM)

- 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 resubnetted.
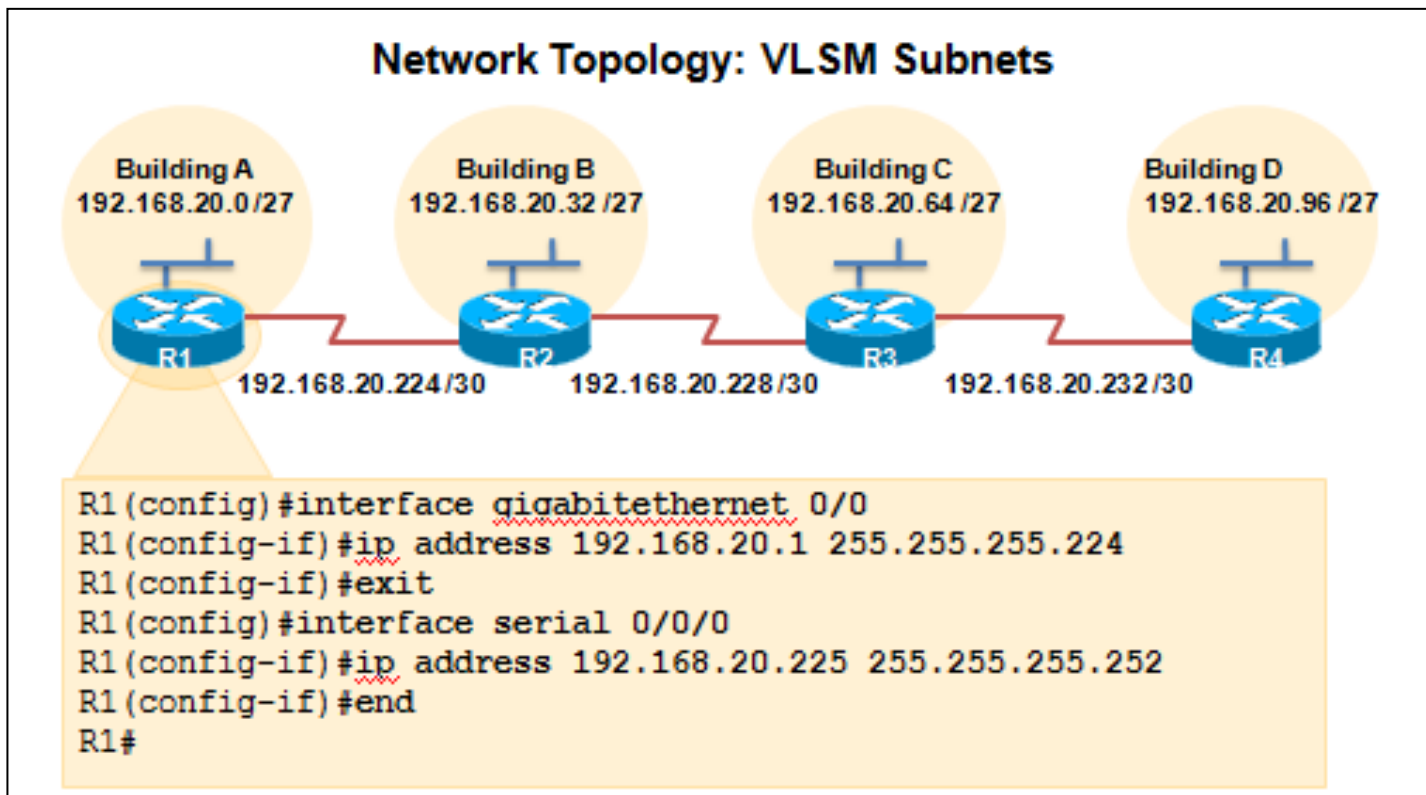
Subnets of Varying Sizes

One subnet was further divided to create 8 smaller subnets of 2 hosts each

30 Hosts
30 Hosts
30 Hosts
30 Hosts
30 Hosts
30 Hosts
30 Hosts

Basic VLSM

VLSM Subnetting Scheme

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.

Network Topology: VLSM Subnets

Building A
192.168.20.0 /27

Building B
192.168.20.32 /27

Building C
192.168.20.64 /27

Building D
192.168.20.96 /27

R1   192.168.20.224/30   R2   192.168.20.228/30   R3   192.168.20.232/30   R4

```
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 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

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	

9.3 Design Considerations for IPv6

Subnetting Using the Subnet ID

An IPv6 Network Space is subnetted to support hierarchical, logical design of the network
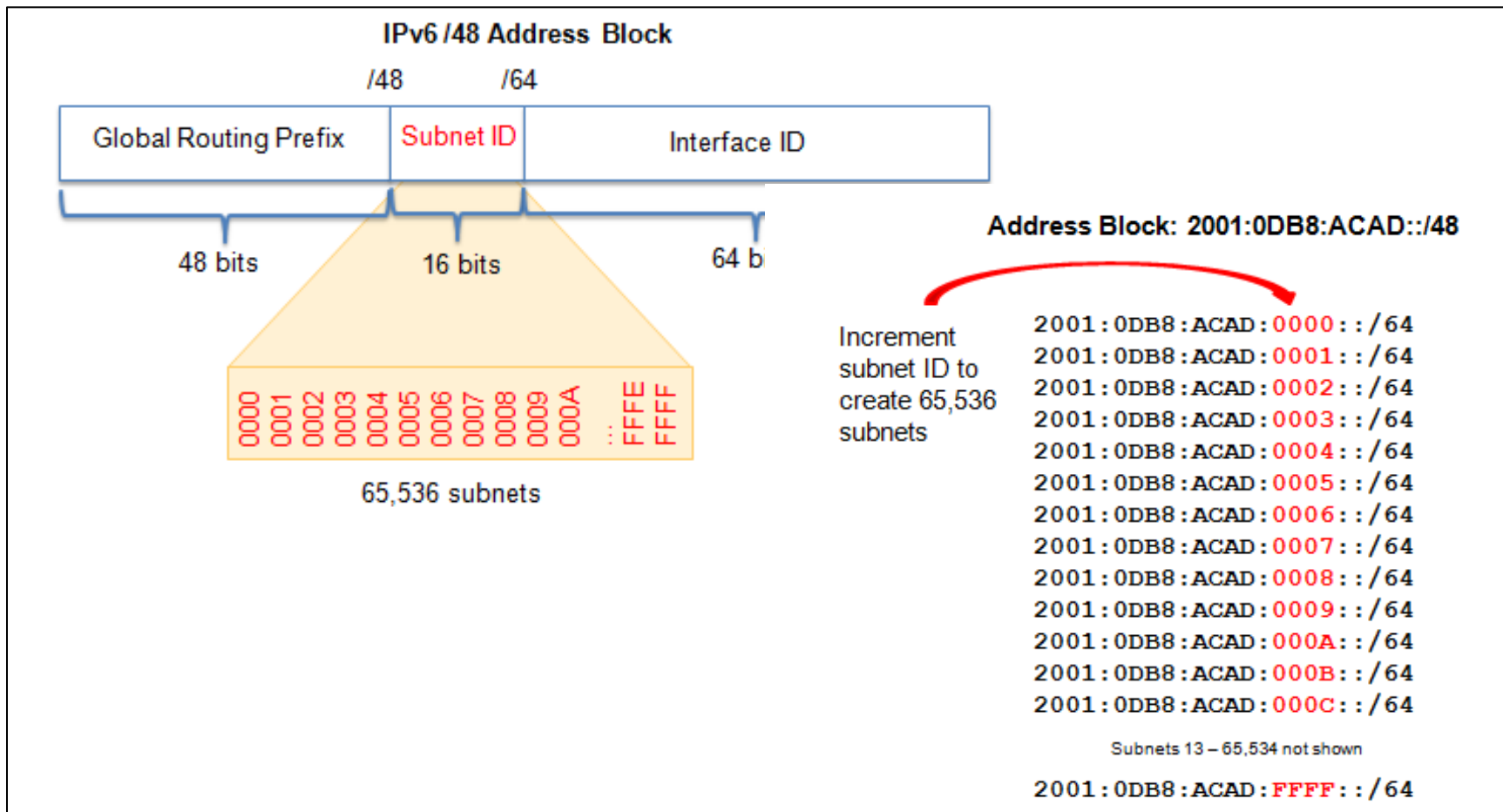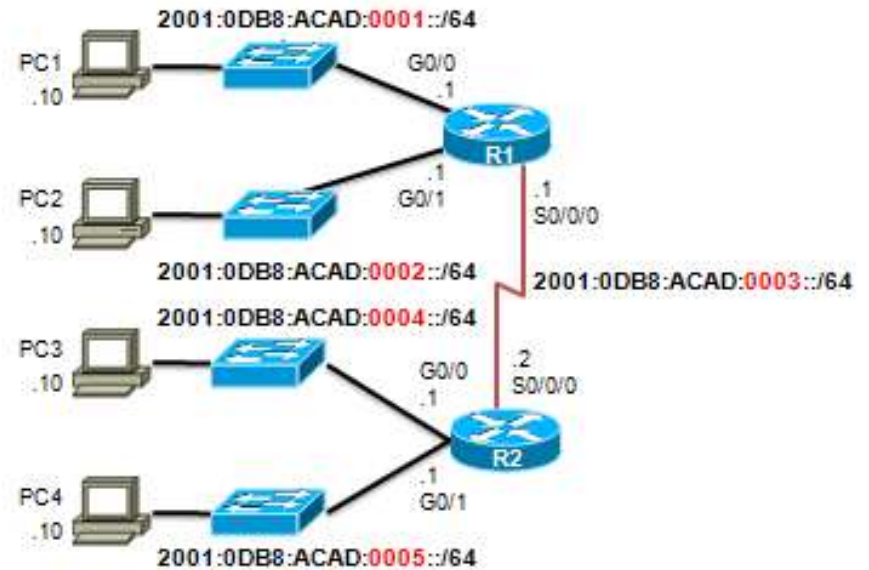
IPV6 Subnet Allocation

Subnetting into the Interface ID

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