



## Chapter 9: Subnetting IP Networks



## Introduction to Networking

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# Chapter 9

9.1 Subnetting an IPv4 Network

9.2 Addressing Schemes

9.3 Design Considerations for IPv6

9.4 Summary



# Chapter 9: Objectives

- 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.



## Network Segmentation

# Reasons for Subnetting

**Large networks need to be segmented into smaller sub-networks, creating smaller groups of devices and services in order to:**

- Control traffic by containing broadcast traffic within subnetwork
- Reduce overall network traffic and improve network performance

**Subnetting** - process of segmenting a network into multiple smaller network spaces called subnetworks or **Subnets**.

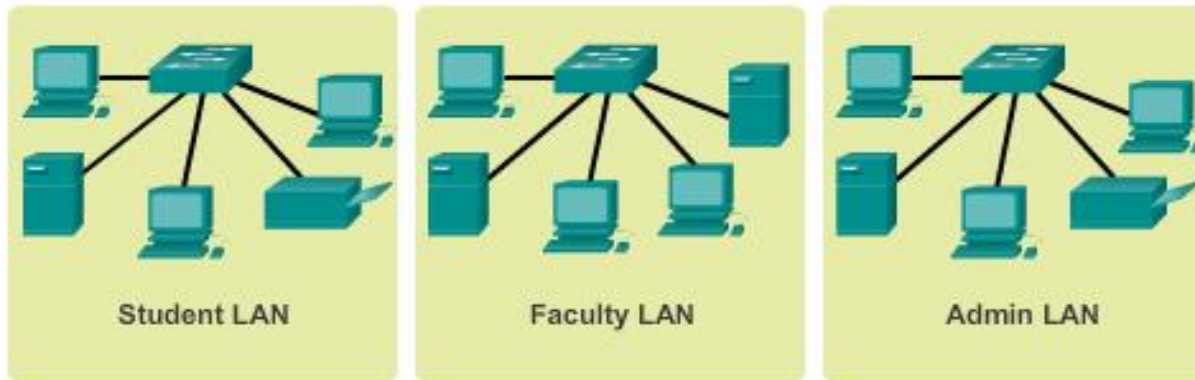
## Communication Between Subnets

- 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 to.
- Devices on a network and subnet use the router interface attached to their LAN as their default gateway.



## Subnetting an IPv4 Network

# IP Subnetting is FUNdamental



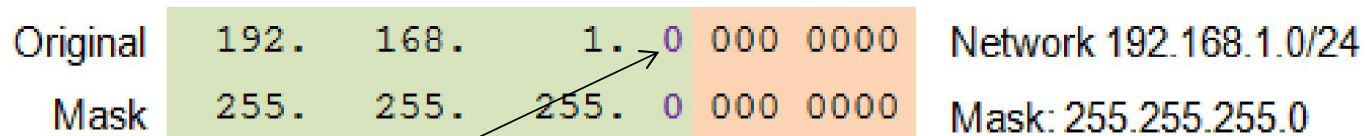
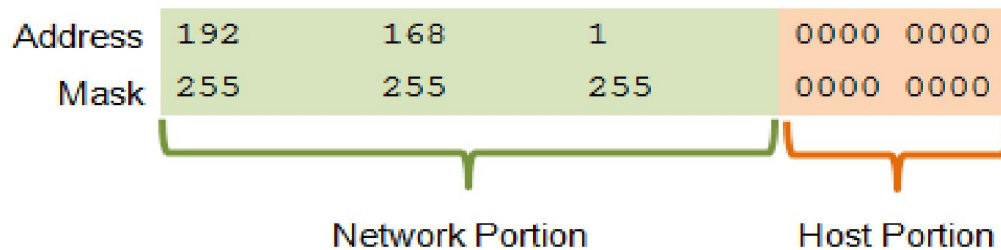
Planning requires decisions on each subnet in terms of size, the number of hosts per subnet, and how host addresses will be assigned.



# Subnetting an IPv4 Network

## 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

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

Mask: 255.255.255.**128**

Subnet 1

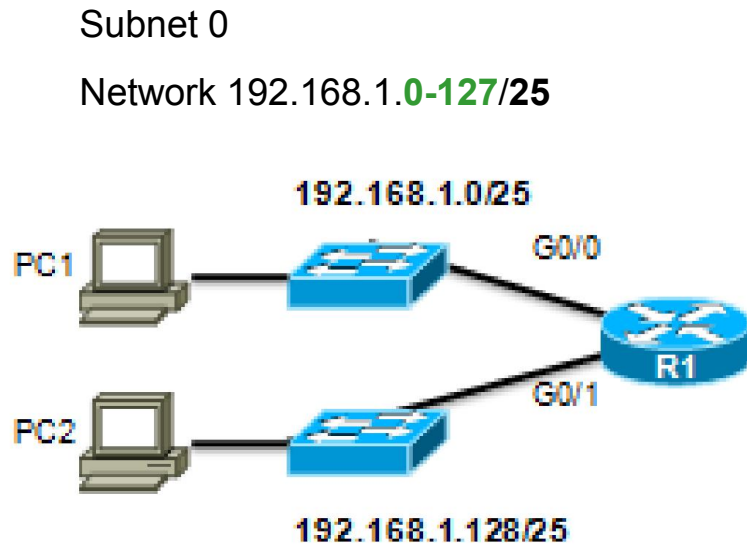
Network 192.168.1.**128-255**/25

Mask: 255.255.255.**128**



# Subnetting an IPv4 Network

## Subnets in Use



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



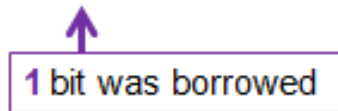
# Subnetting an IPv4 Network

## Subnetting Formulas

### ■ Calculate Number of Subnets

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

192. 168. 1. 0 000 0000



$2^1 = 2$  subnets

### ■ Calculate Number of Hosts

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

192. 168. 1. 0 000 0000



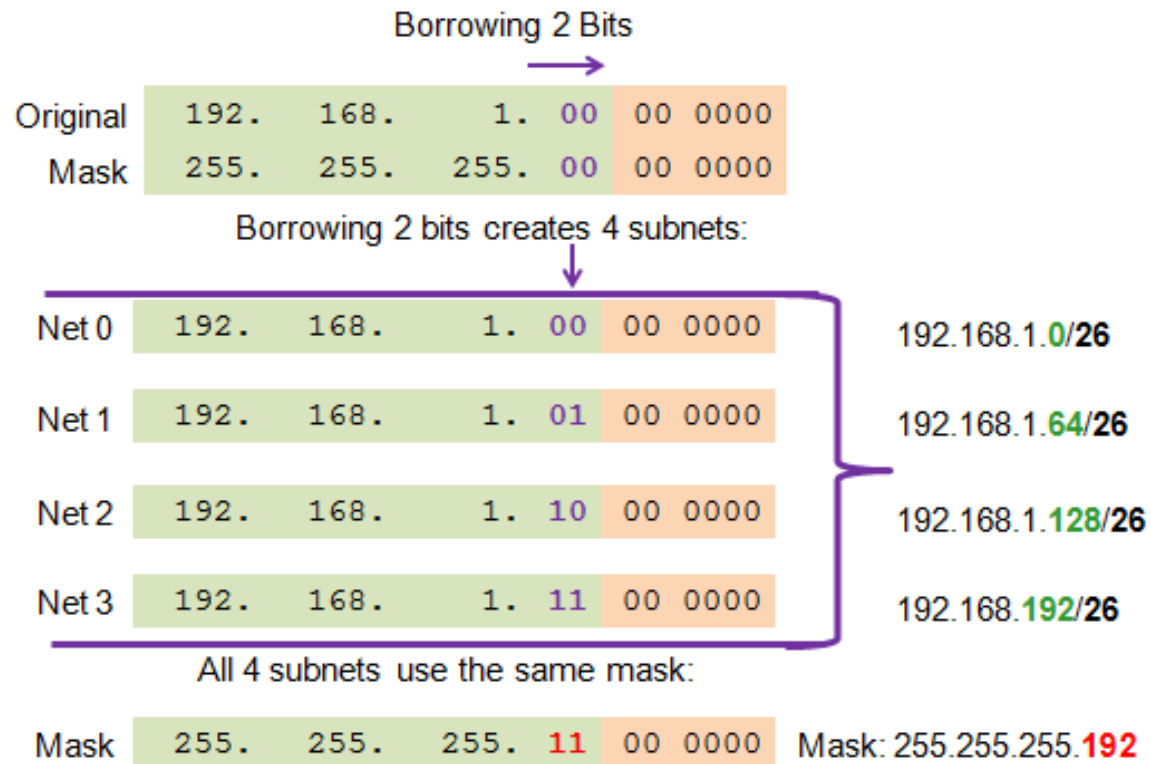




# Subnetting an IPv4 Network

## Creating 4 Subnets

- Borrowing 2 bits to create 4 subnets.  $2^2 = 4$  subnets





# Subnetting an IPv4 Network

## Creating 8 Subnets

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

Net 0	Network	192.	168.	1.	000	0 0000	192.168.1.1
	Fist	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
	Fist	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
	Fist	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
	Fist	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

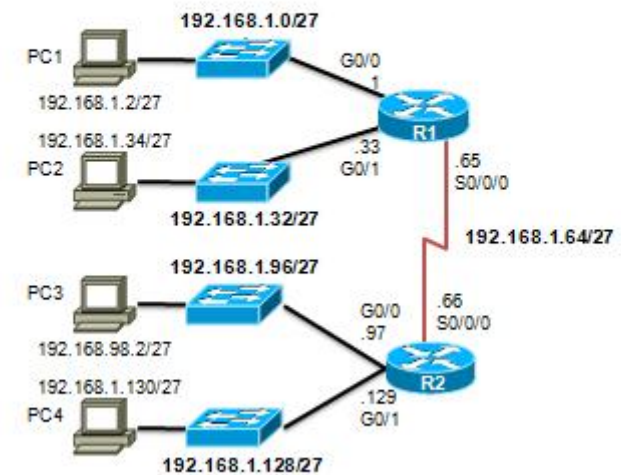


# Subnetting an IPv4 Network

## Creating 8 Subnets(continued)

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

**Subnet Allocation**





## Determining the Subnet Mask

# Subnetting Based on Host Requirements

**There are two considerations when planning subnets:**

- Number of Subnets required
- Number of Host addresses required
- Formula to determine number of useable hosts

$$2^n - 2$$

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

**-2** Subnetwork ID and broadcast address cannot be used on each subnet

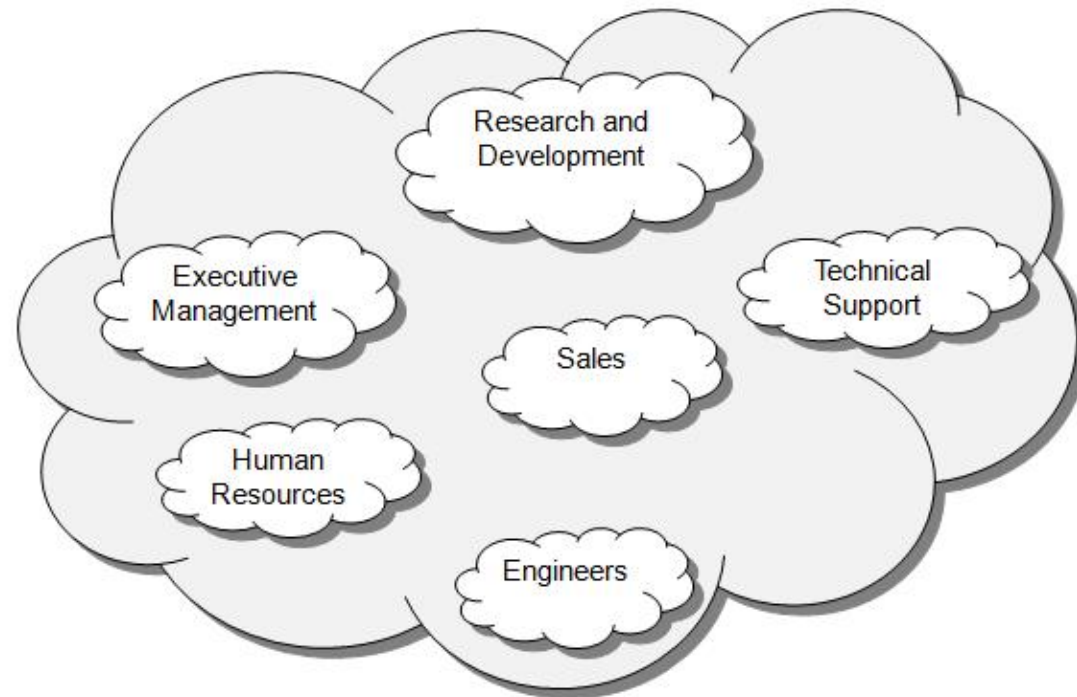


## Determining the Subnet Mask

# Subnetting Network-Based Requirements

Calculate number of subnets

- Formula  $2^n$  (where  $n$  is the number of bits borrowed)
- Subnet needed for each department in graphic

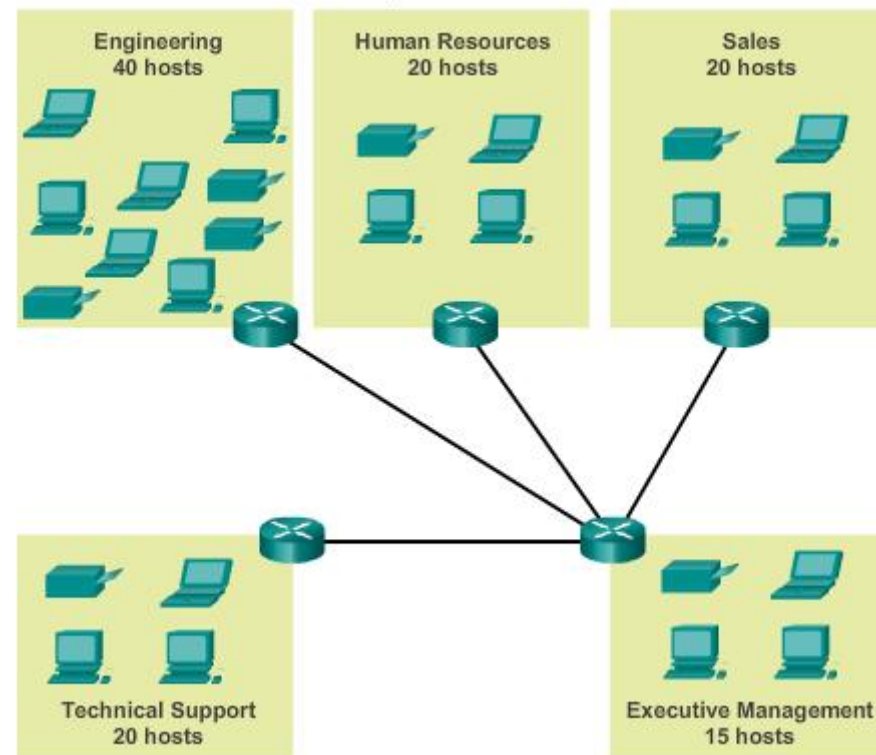




## Determining the Subnet Mask

# 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.





# Determining the Subnet Mask

## Subnetting To Meet Network Requirements (cont)

### Subnets and Addresses

	10101100.00010000.00000000.00000000	00.00	00000000	172.16.0.0/22
0	10101100.00010000.00000000.00000000	00.00	00000000	172.16.0.0/26
1	10101100.00010000.00000000.00000000	00.01	00000000	172.16.0.64/26
2	10101100.00010000.00000000.00000000	00.10	00000000	172.16.0.128/26
3	10101100.00010000.00000000.00000000	00.11	00000000	172.16.0.192/26
4	10101100.00010000.00000000.00000000	01.00	00000000	172.16.1.0/26
5	10101100.00010000.00000000.00000000	01.01	00000000	172.16.1.64/26
6	10101100.00010000.00000000.00000000	01.10	00000000	172.16.1.128/26

Nets 7 – 14 not shown

15	10101100.00010000.00000000.00000000	11.10	00000000	172.16.3.128/26
16	10101100.00010000.00000000.00000000	11.11	00000000	172.16.3.192/26

  $2^4 = 16$  subnets  
  $2^6 - 2 = 62$  Hosts per subnet

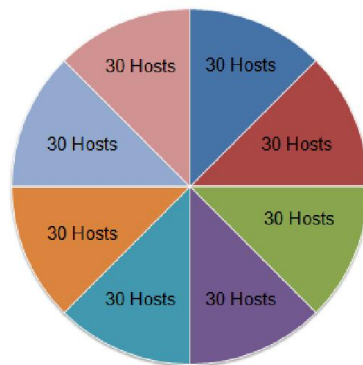


## Benefits of Variable Length Subnet Masking

# Traditional Subnetting Wastes Addresses

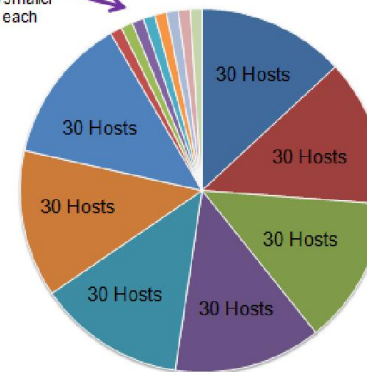
- Traditional subnetting - same number of addresses is allocated for each subnet.
- Subnets that require fewer addresses have unused (wasted) addresses. For example, WAN links only need 2 addresses.
- Variable Length Subnet Mask (VLSM) or subnetting a subnet provides more efficient use of addresses.

Traditional Subnetting Creates Equal Sized Subnets



Subnets of Varying Sizes

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







## Benefits of Variable Length Subnet Masking

# Variable Length Subnet Masks (VLSM)

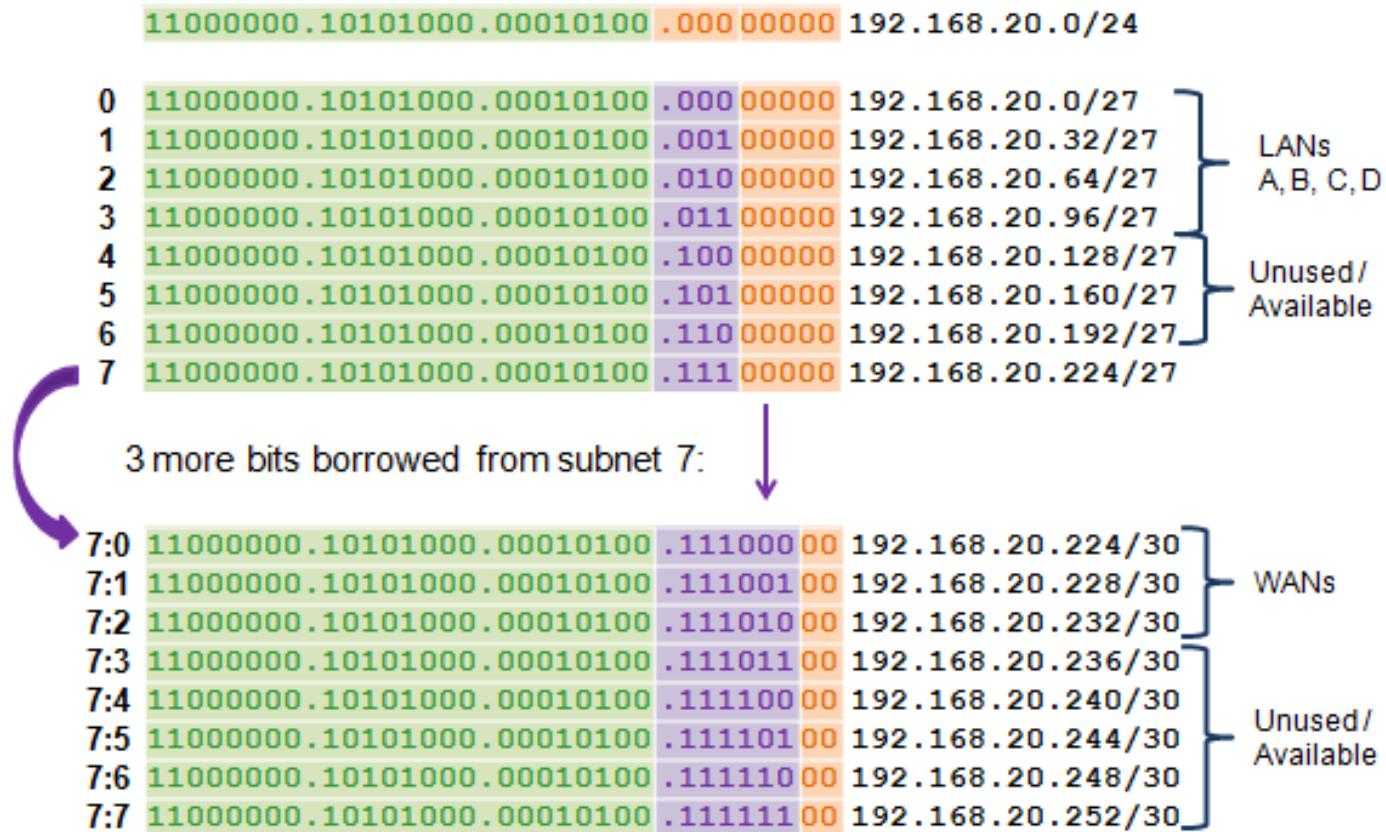
- VLSM allows a network space to be divided in unequal parts.
- Subnet mask will vary depending on how many bits have been borrowed for a particular subnet.
- Network is first subnetted, and then the subnets are subnetted again.
- Process repeated as necessary to create subnets of various sizes.



# Benefits of Variable Length Subnet Masking

## Basic VLSM

VLSM Subnetting Scheme

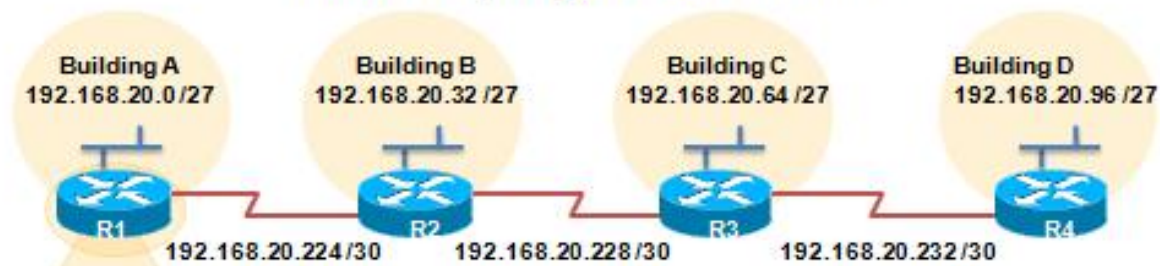




## Benefits of Variable Length Subnet Masking VLSM in Practice

- 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



```
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#
```



# 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



## Structured Design

# 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

Addresses for Clients - usually dynamically assigned using Dynamic Host Configuration Protocol (DHCP)

Network: 192.168.1.0/24

Sample Network Addressing Plan

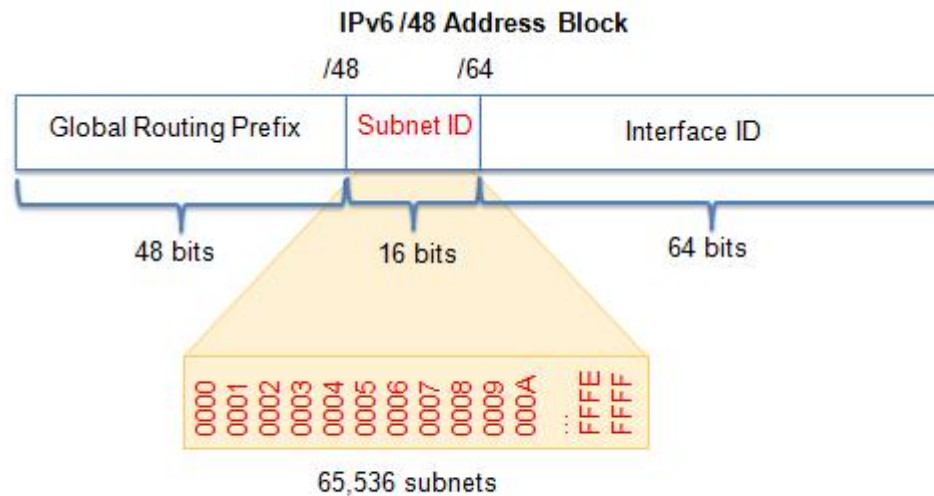
Use	First	Last
Host Devices	.1	.229
Servers	.230	.239
Printers	.240	.249
Intermediary Devices	.250	.253
Gateway (router LAN interface)	.254	



# Subnetting an IPv6 Network

## Subnetting Using the Subnet ID

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



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 an IPv6 Network

## IPv6 Subnet Allocation

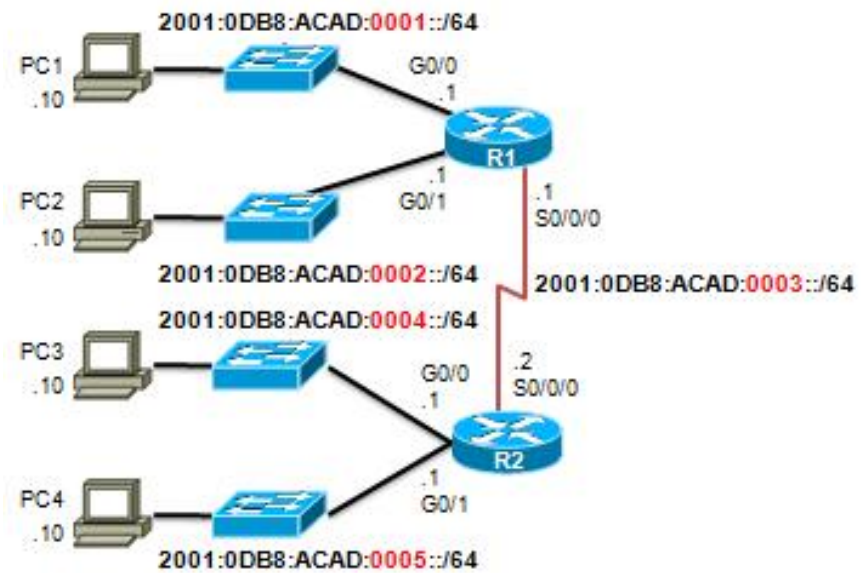
### IPv6 Subnetting

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

### IPv6 Subnet Allocation

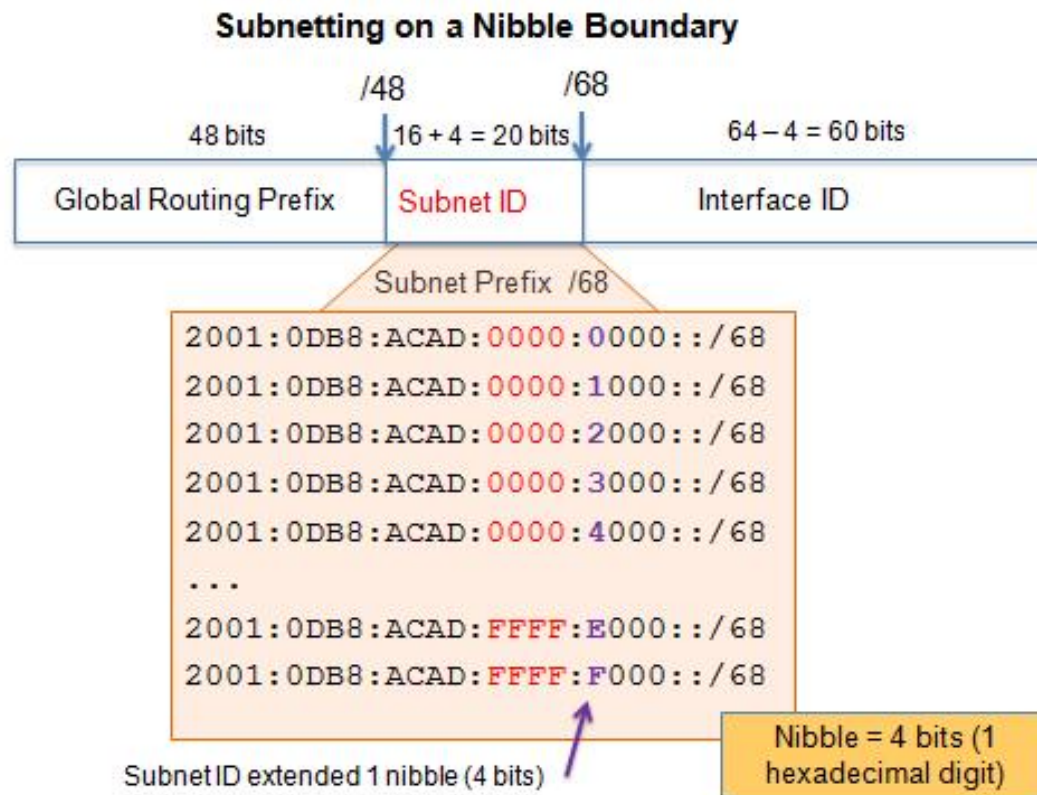




# Subnetting an IPv6 Network

## Subnetting into the Interface ID

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







## Chapter 9: Summary

- Process of segmenting a network, by dividing it into to multiple smaller network spaces, is called subnetting.
- Subnetting a subnet, or using Variable Length Subnet Mask (VLSM) was designed to avoid wasting addresses.
- IPv6 address space is a huge address space so it is subnetted to support the hierarchical, logical design of the network not to conserve addresses.
- Size, location, use, and access requirements are all considerations in the address planning process.
- IP networks need to be tested to verify connectivity and operational performance.

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