Fundamentals of Telecommunications Networks

ECP 602

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Subnetting IP Networks

Lecture Objectives

Upon completion of this lecture, 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.

Lecture Overview

Introduction
Subnetting an IPv4 Network
Addressing Schemes
Design Considerations for IPv6
Summary

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.

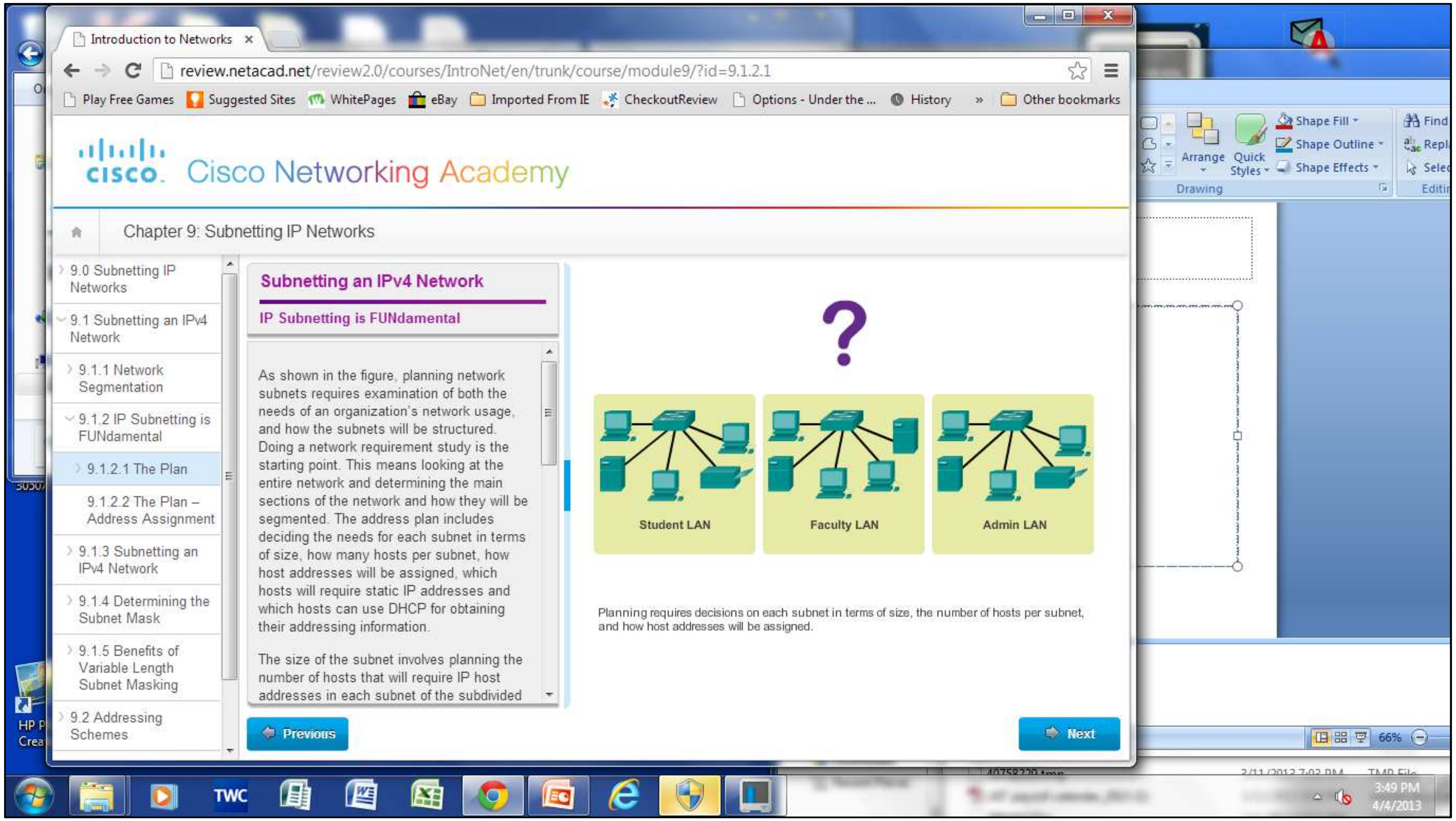
Communication Between Subnets

- 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.

IP Subnetting is FUNdamental

The Plan

Planning the Network



Subnetting an IPv4 Network

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
Mask	255.	255.	255. 0	000 0000

Network 192.168.1.0/24

Mask: 255.255.255.0

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**

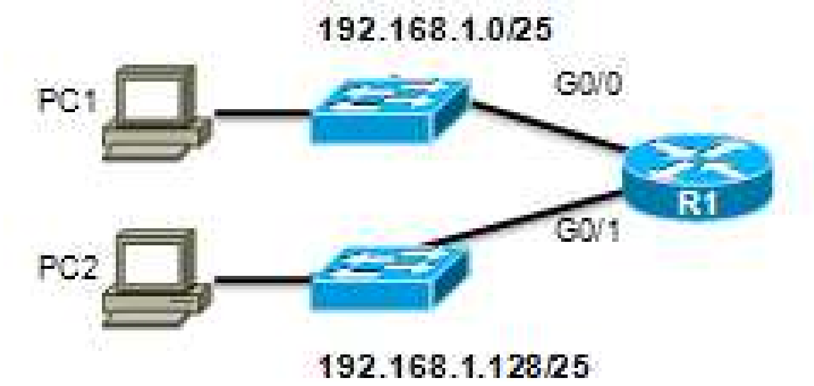
Subnetting an IPv4 Network

Subnets in Use

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

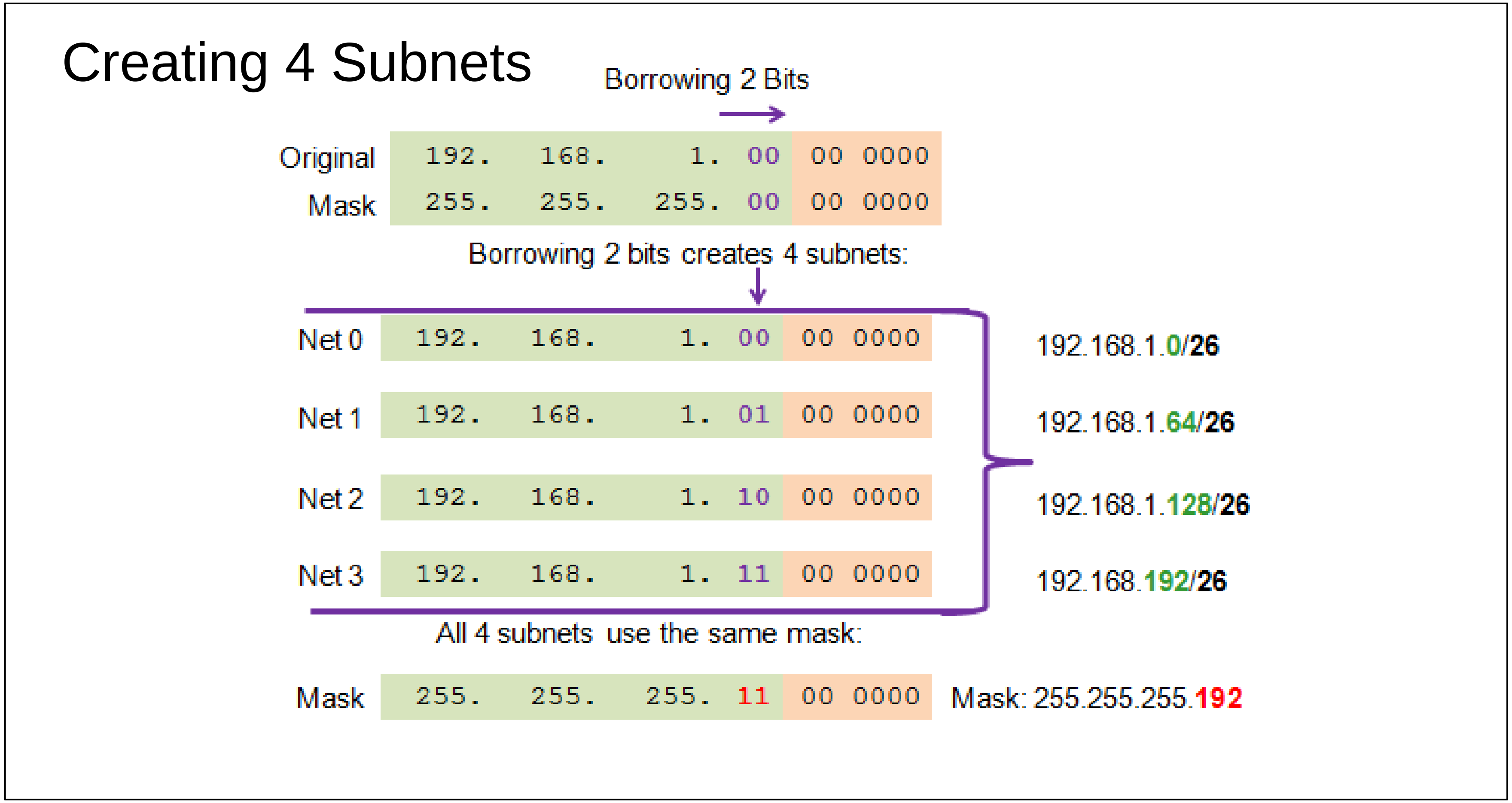
Network Address	192. 168. 1. 1 000 0000	= 192.168.1.128
First Host Address	192. 168. 1. 1 000 0001	= 192.168.1.129
Last Host Address	192. 168. 1. 1 111 1110	= 192.168.1.254
Broadcast Address	192. 168. 1. 1 111 1111	= 192.168.1.255

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

Creating 4 Subnets

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



Subnetting an IPv4 Network

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

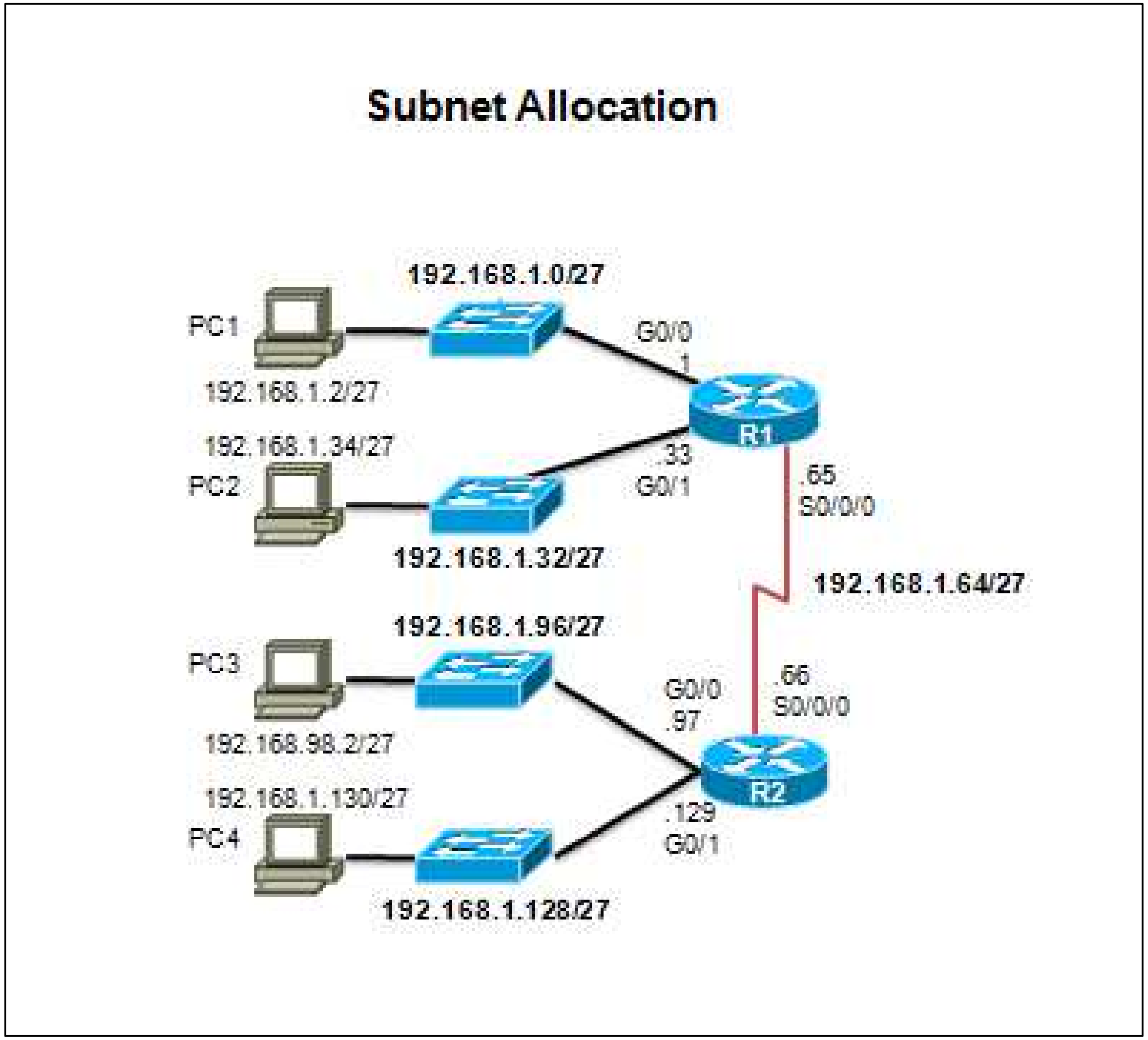
Subnetting an IPv4 Network

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

Subnetting an IPv4 Network

Creating Eight Subnets (Cont.)



Determining the Subnet Mask

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

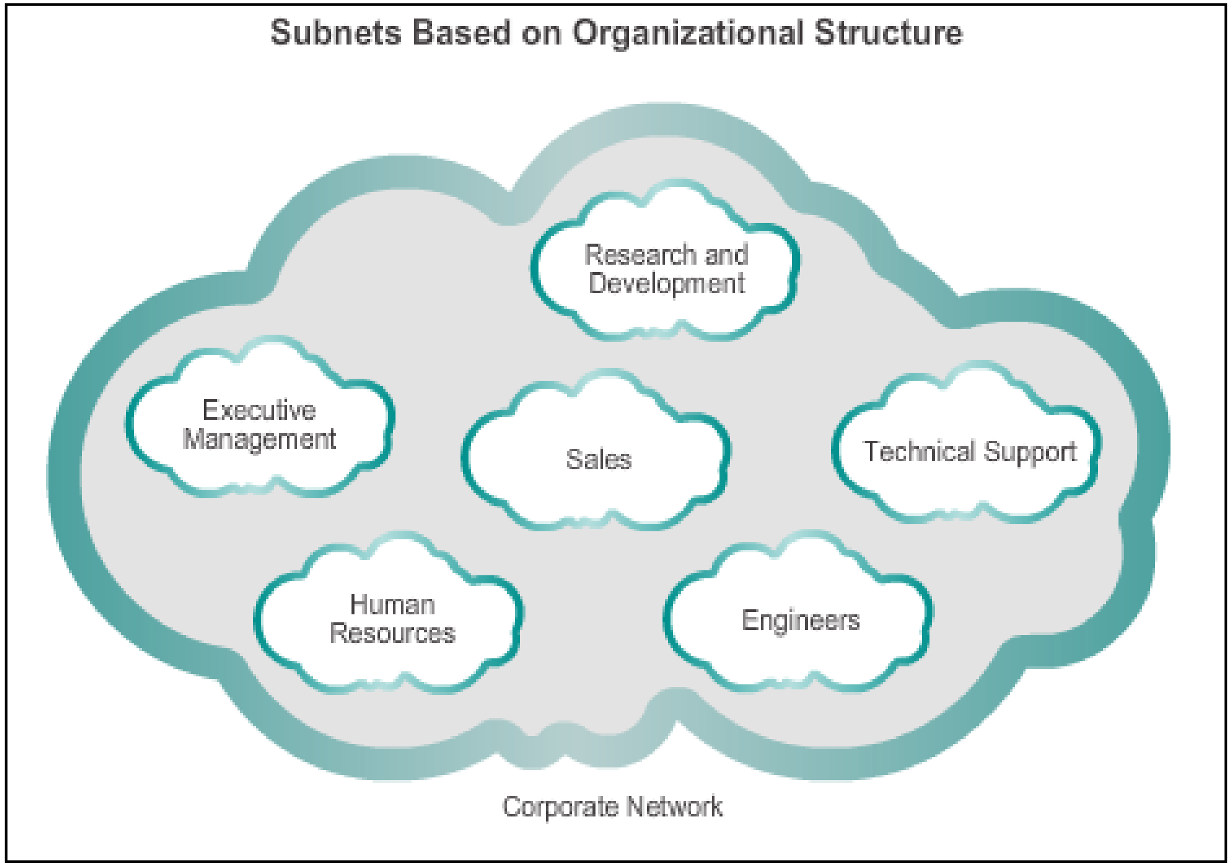
- 2^*n* (where *n* is the number of remaining host bits) is used to calculate the number of hosts.
- -2 (The subnetwork ID and broadcast address cannot be used on each subnet.)

Determining the Subnet Mask

Subnetting Network-Based Requirements

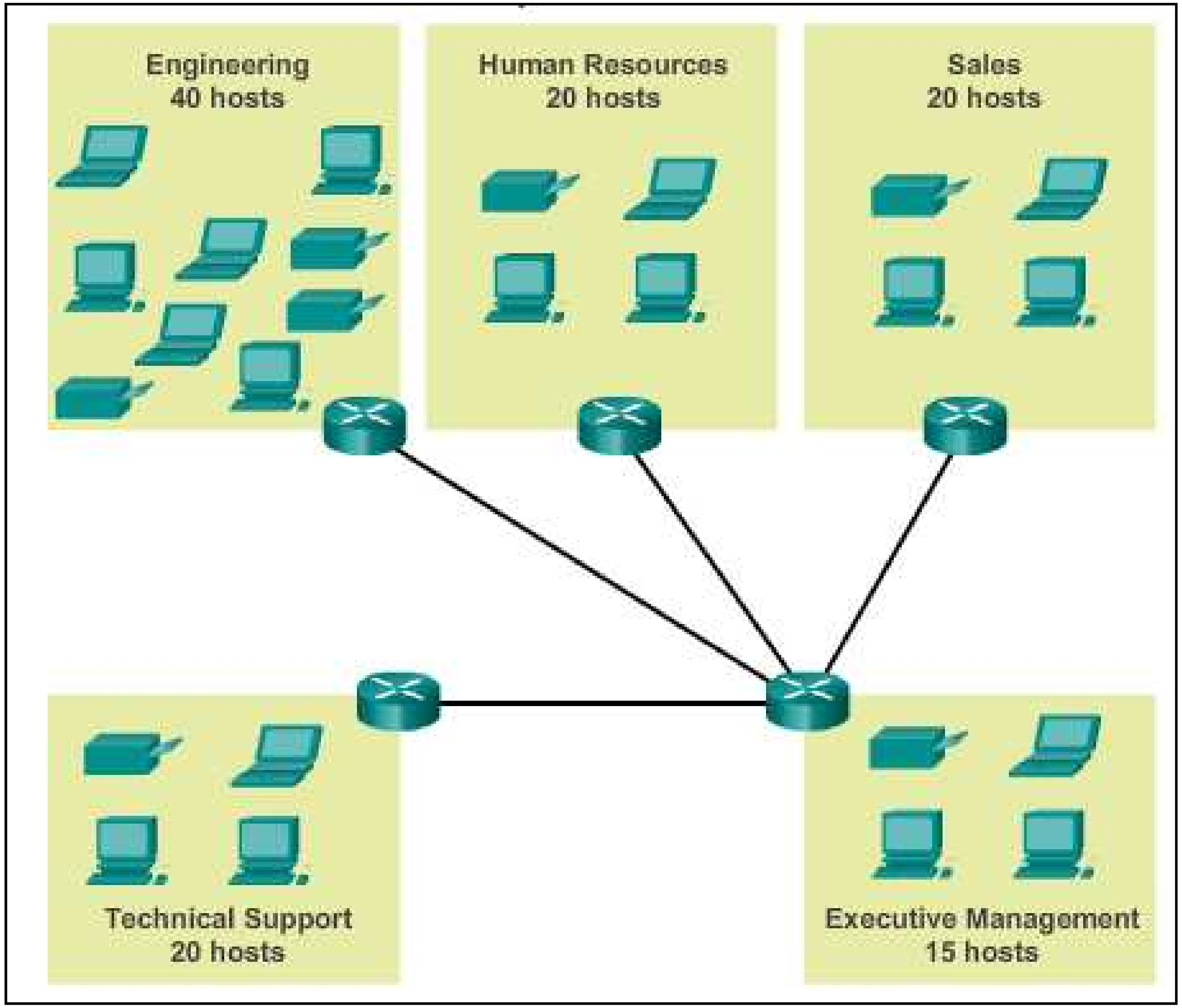
Calculate the number of subnets:

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



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.



Determining the Subnet Mask

Subnetting To Meet Network Requirements

Subnets and Addresses

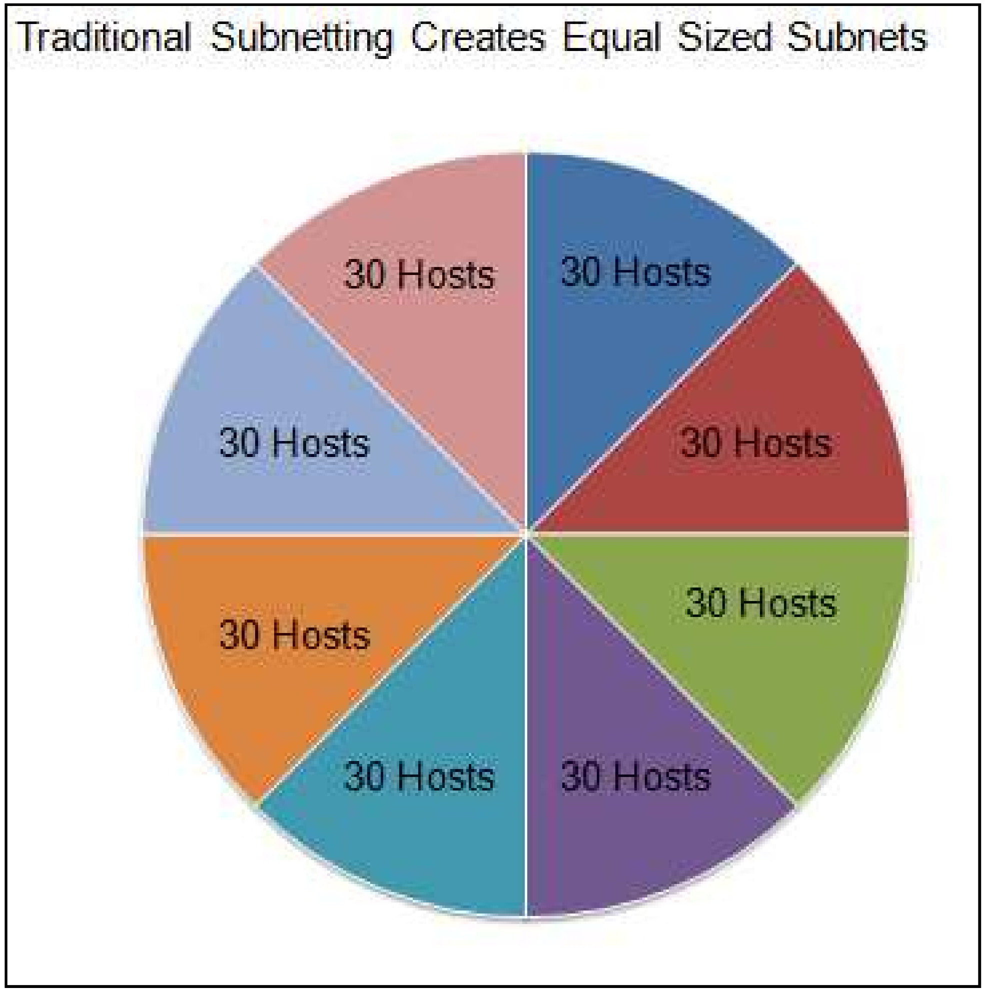
	10101100.00010000.00000000.00000000	172.16.0.0/22
0	10101100.00010000.00000000.00000000	172.16.0.0/26
1	10101100.00010000.00000000.01000000	172.16.0.64/26
2	10101100.00010000.00000000.10000000	172.16.0.128/26
3	10101100.00010000.00000000.11000000	172.16.0.192/26
4	10101100.00010000.00000001.00000000	172.16.1.0/26
5	10101100.00010000.00000001.01000000	172.16.1.64/26
6	10101100.00010000.00000001.10000000	172.16.1.128/26
	Nets 7 – 14 not shown	
15	10101100.00010000.00000011.10000000	172.16.3.128/26
16	10101100.00010000.00000011.11000000	172.16.3.192/26

2^4 = 16 subnets

2^6 – 2 = 62 Hosts per subnet

Traditional Subnetting Wastes Addresses

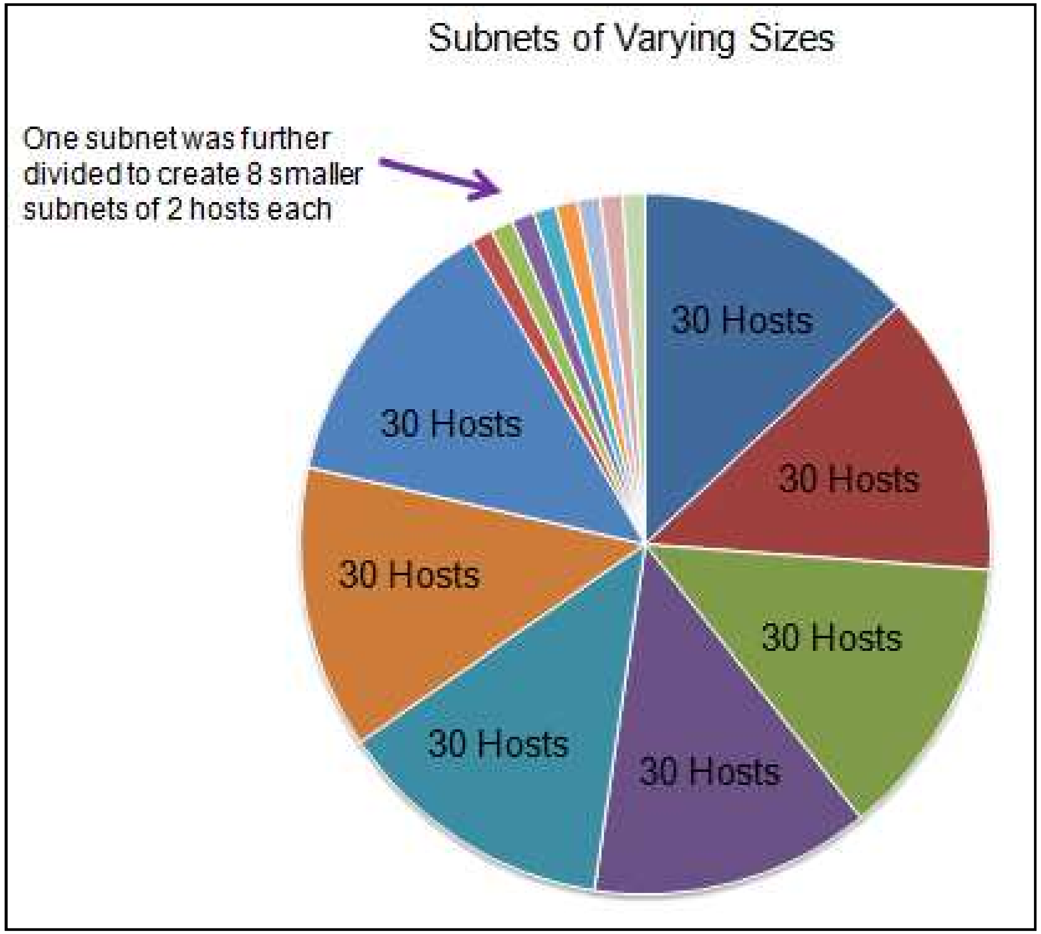
- Traditional subnetting – Uses the same number of addresses is allocated for each subnet.
- Subnets that require fewer addresses have unused (wasted) addresses; for example, WAN links only need two addresses.



Benefits of Variable Length Subnet Masking

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.



Benefits of Variable Length Subnet Masking

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	LANs A, B, C, D
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	Unused / Available
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	

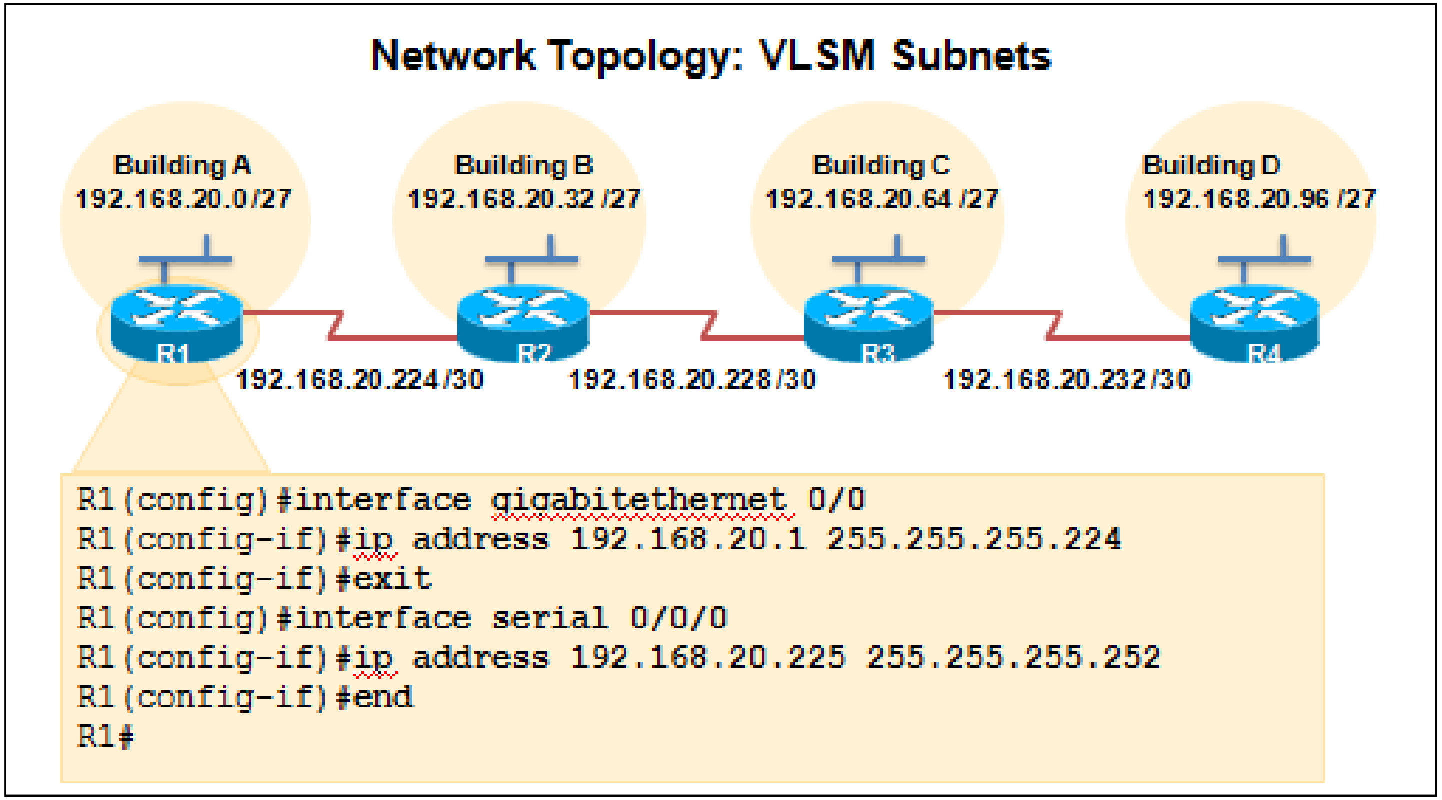
3 more bits borrowed from subnet 7:

7:0	11000000.10101000.00010100	.111000	00	192.168.20.224/30	WANs
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	Unused / Available
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	

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.



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

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

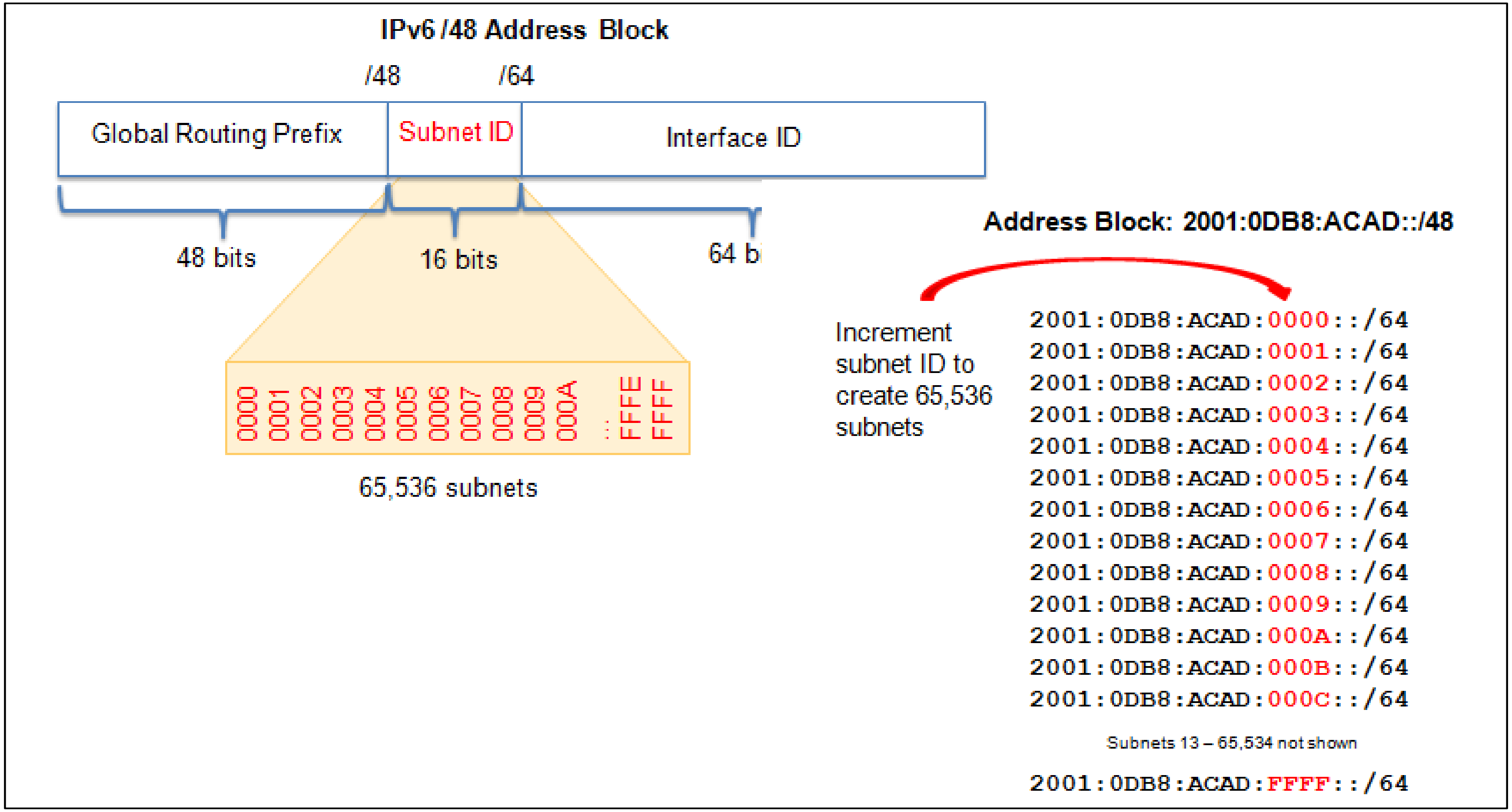
Use	First	Last
Host Devices	.1	.229
Servers	.230	.239
Printers	.240	.249
Intermediary Devices	.250	.253
Gateway (router LAN interface)	.254	

Design Considerations for IPv6

Subnetting an IPv6 Network

Subnetting Using the Subnet ID

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



<u>Subnetting an IPv6 Network</u>

IPV6 Subnet Allocation

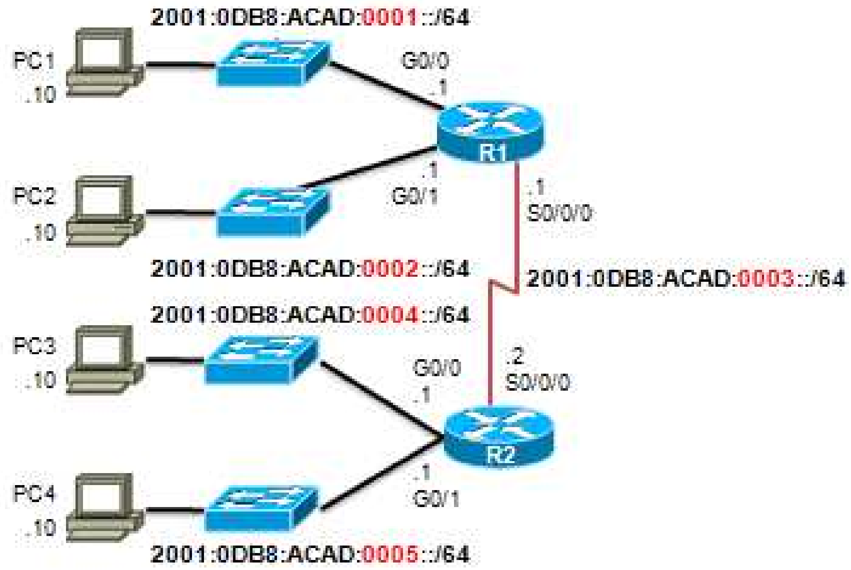
IPv6 Subnetting

Address Block: 2001:0DB8:ACAD::/48

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

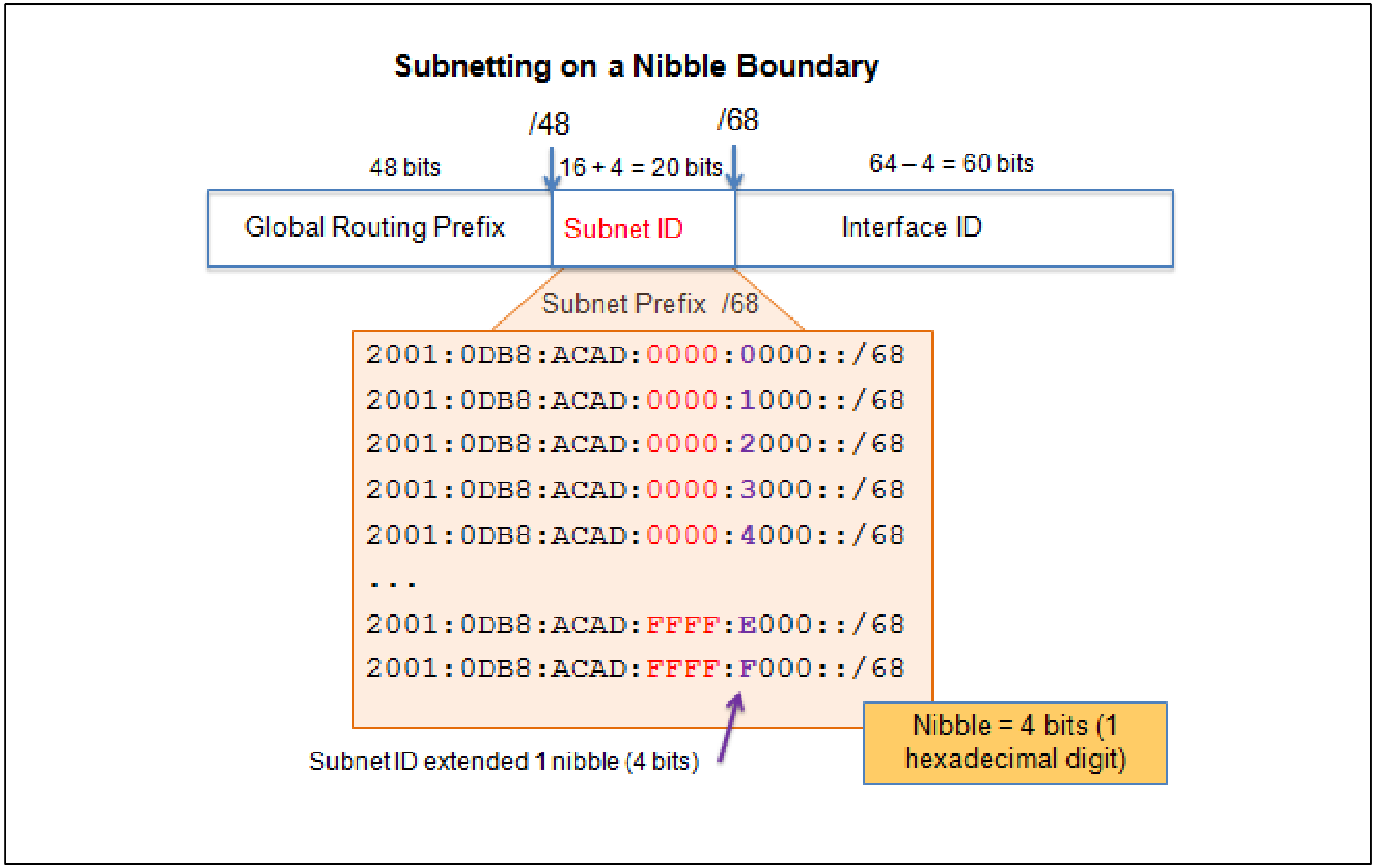
5 subnets allocated from 65,536 available subnets

IPv6 Subnet Allocation



Subnetting into the Interface ID

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



Summary

Summary

In this lecture, 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.
- IP networks must be tested to verify connectivity and operational performance.