Chapter 9: Subnetting IP Networks

Introduction to Networks

Cisco | Networking Academy®
Mind Wide Open™

Chapter 9

9.1 Subnetting an IPv4 Network

Cisco | Networking Academy®
Mind Wide Open™

Network Segmentation

Subnetting

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

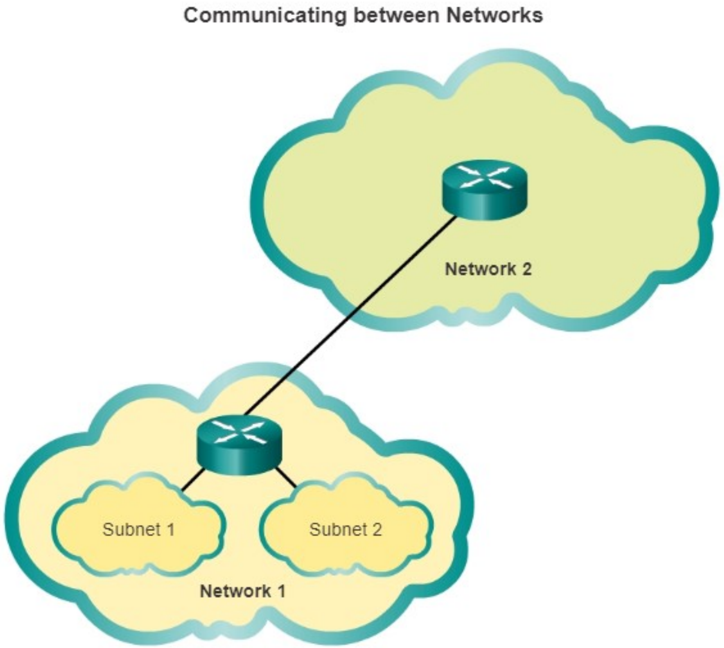
Reasons for Subnetting:

- 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.

Network Segmentation
Subnetting

Communication Between Subnets

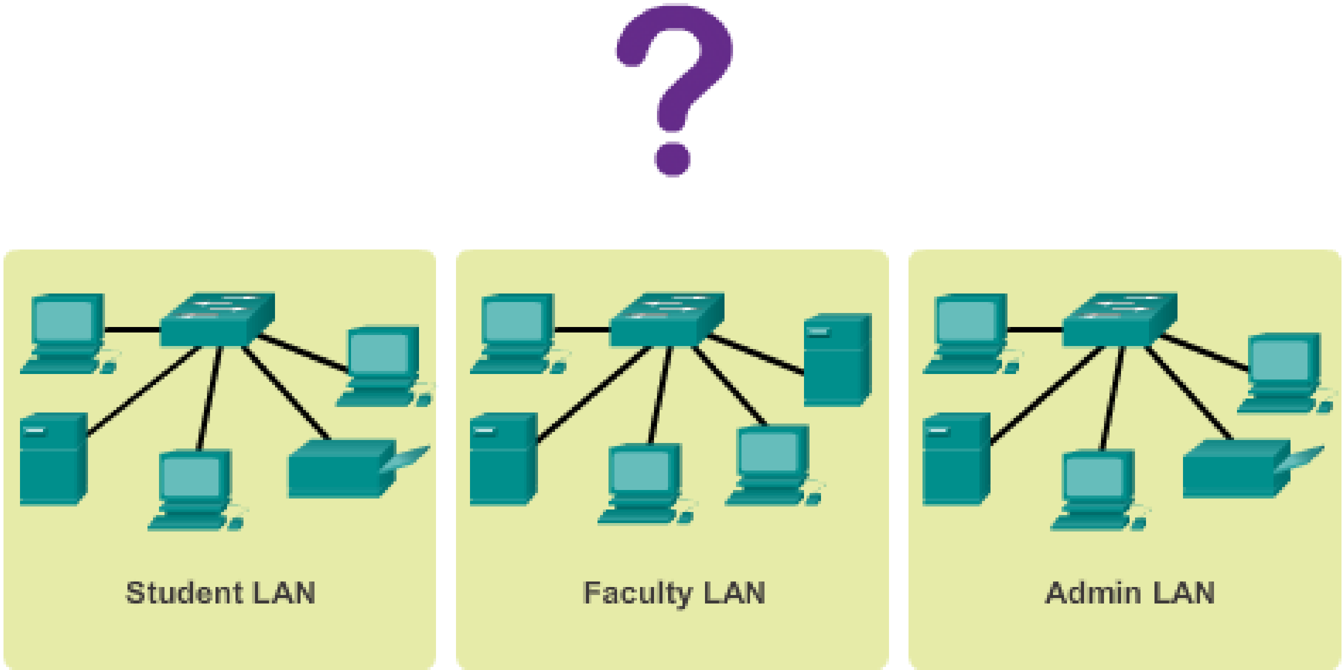
- A router is necessary for devices on different networks and subnets to communicate.
- Each router interface must have an IPv4 host address that belongs to the network or subnet that the router interface is connected.
- Devices on a network and subnet use the router interface attached to their LAN as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



IP Subnetting is FUNdamental

The Plan

Planning the Network



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

- Subnets are created by using one or more of the host bits as network bits.
- This is done by borrowing some of the bits from the host portion of the address.
- The more host bits borrowed, the more subnets can be created.
- For each bit borrowed, the number of subnetworks available is doubled.
- For example, if 1 bit is borrowed, 2 subnets can be created. If 2 bits, 4 subnets are created, if 3 bits are borrowed, 8 subnets are created, and so on (2^n; where n is the number of borrowed bits).
- However, with each bit borrowed, fewer host addresses are available per subnet.

Let’s examine the example in Section 9.1.3.1.

Subnetting an IPv4 Network

Basic Subnetting

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

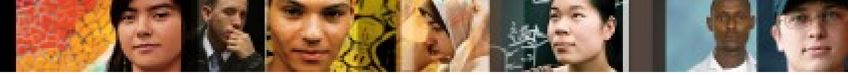
Network 192.168.1.**0-127**/**25**

Mask: 255.255.255.**128**

Subnet 1

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

Mask: 255.255.255.**128**



Subnetting 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 bit remaining)

`192. 168. 1. 0 000 0000`

7 bits remain in host field

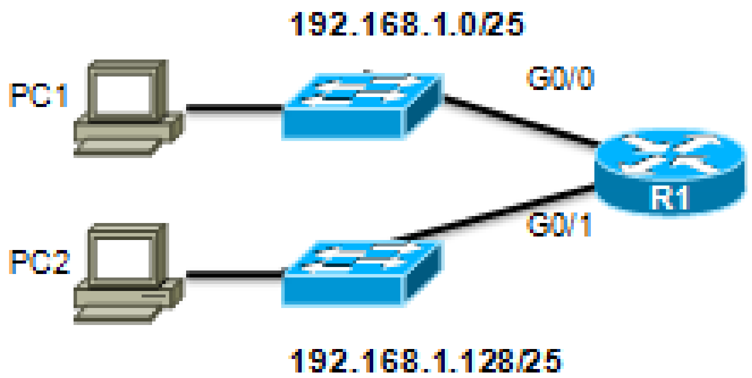
2^7 = 128 addresses per subnet
$2^7 - 2$ = 126 valid host addresses per subnet

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 an IPv4 Network

Creating 4 Subnets

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

Creating 4 Subnets

Borrowing 2 Bits

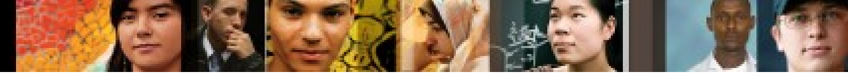
Original	192.	168.	1.	00	00 0000
Mask	255.	255.	255.	00	00 0000

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



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

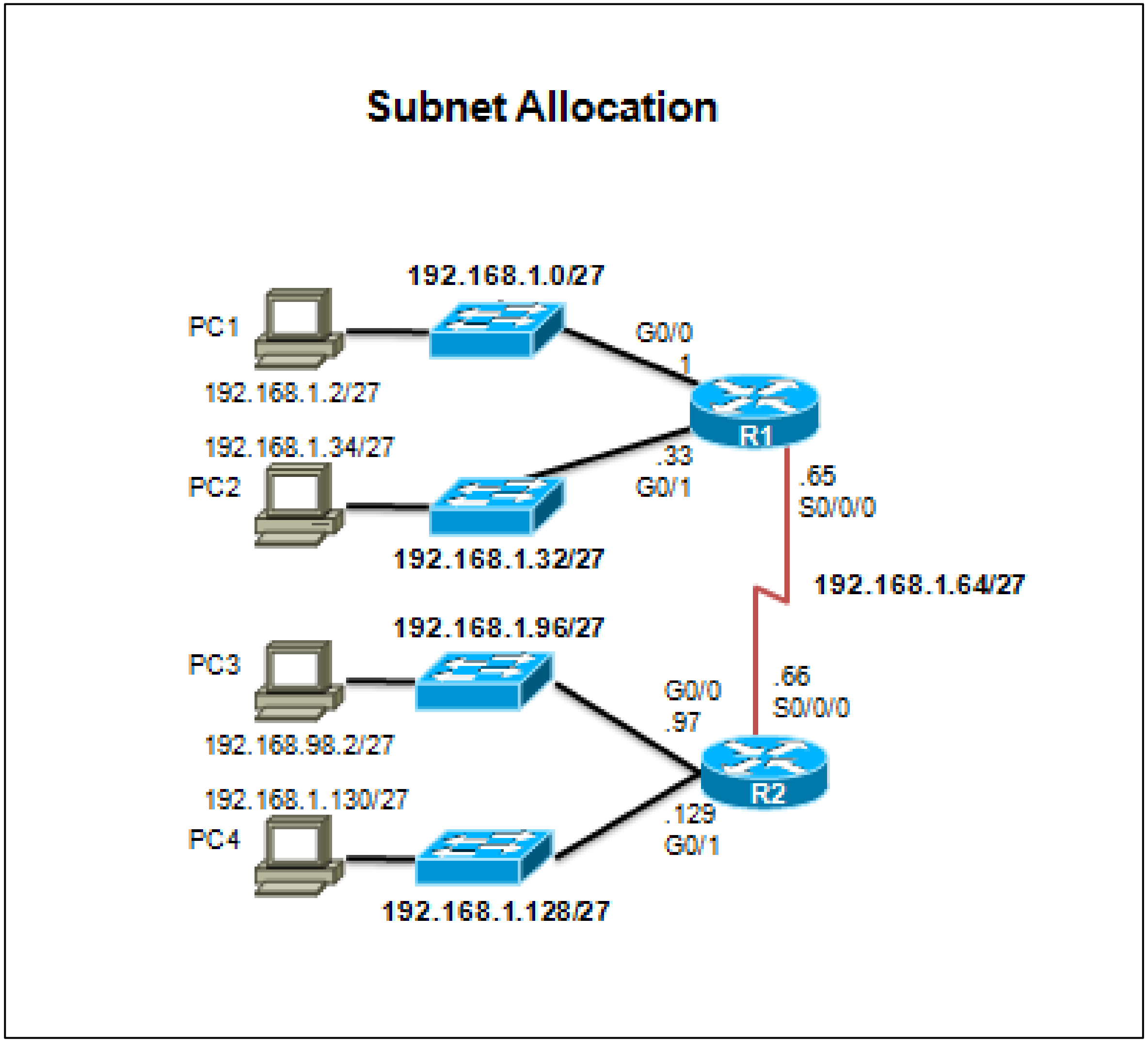
Subnetting an IPv4 Network

Creating Eight Subnets (Cont.)

Net 4	Network	192.	168.	1.	100	0 0000	192.168.1.128
	First	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
	First	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
	First	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
	First	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 address and broadcast address cannot be used on each subnet.)

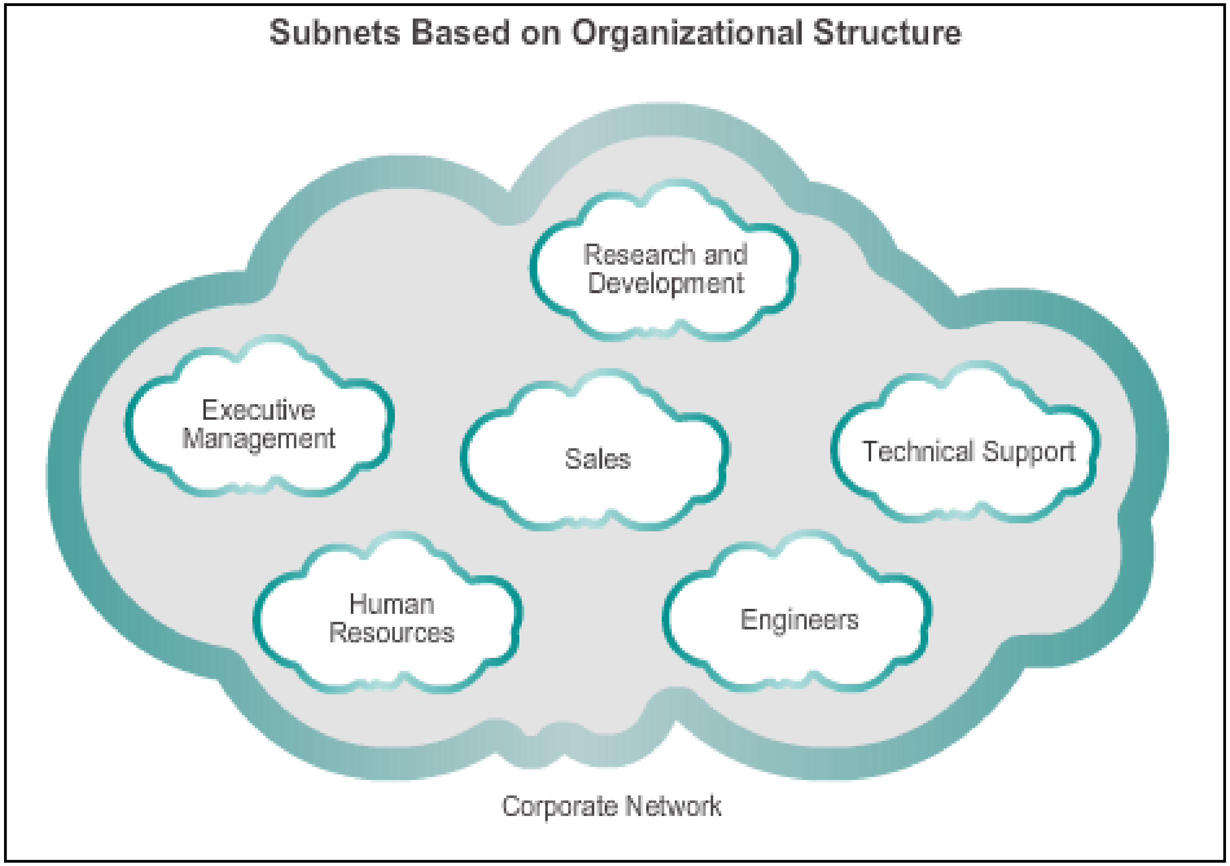
Calculate the number of subnets:

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

Let’s examine the animation in 9.1.4.1

Determining the Subnet Mask

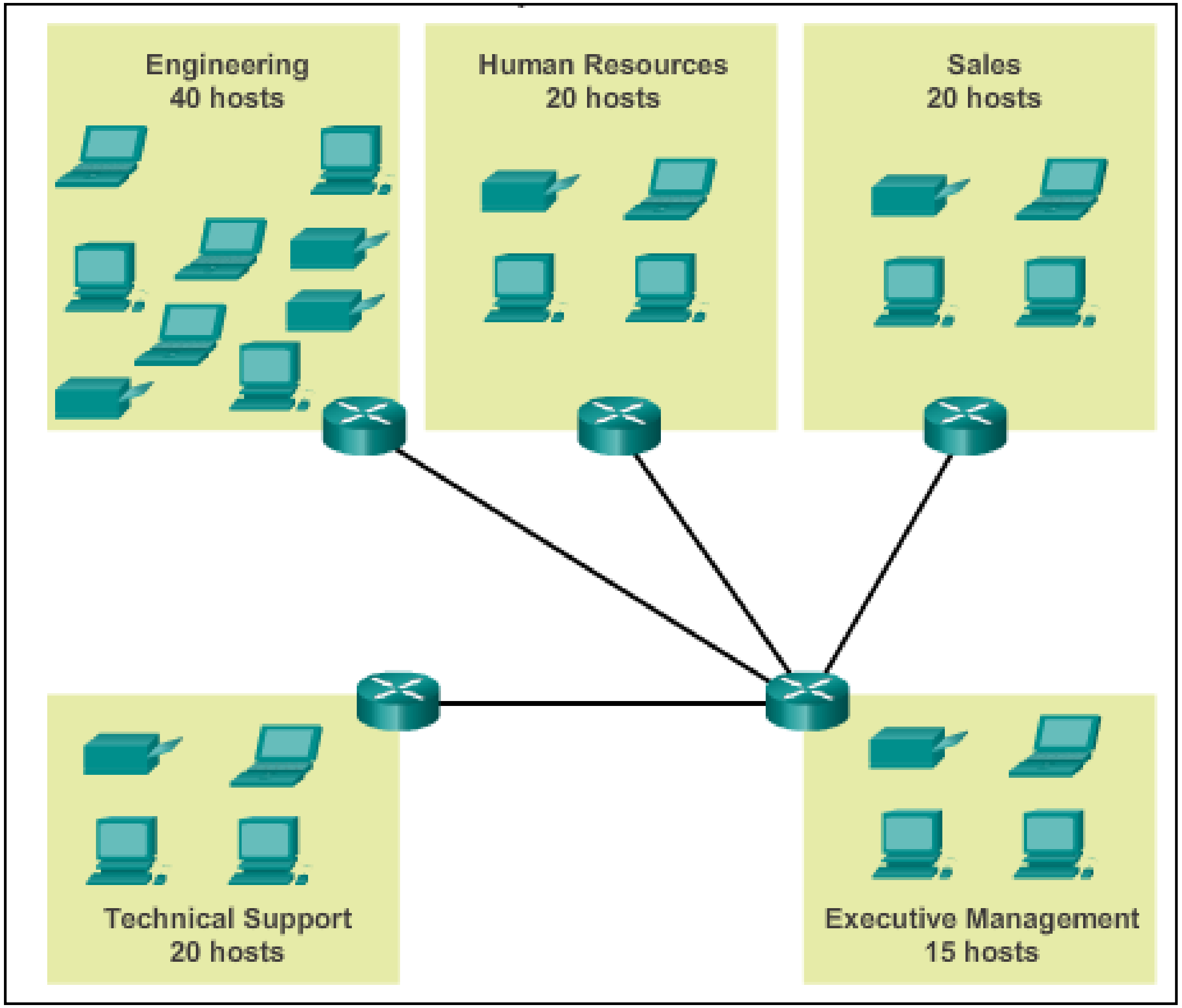
Subnetting Network-Based Requirements



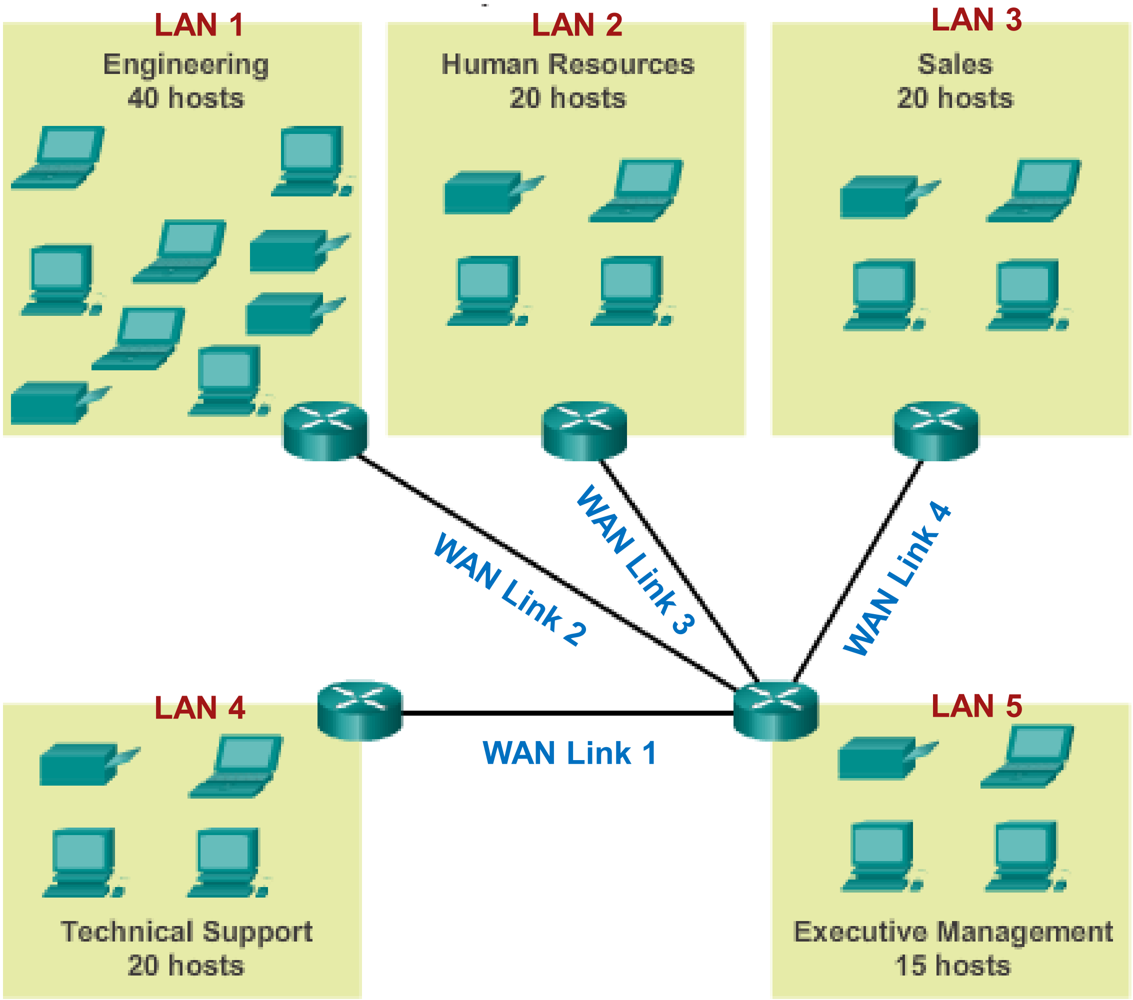
Determining the Subnet Mask

Subnetting To Meet Network Requirements

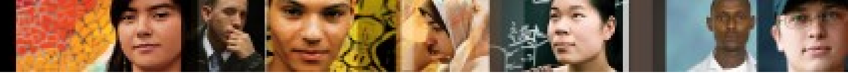
- Balance the required number of subnets and hosts for the largest subnet.
- Design the addressing scheme to accommodate the maximum number of hosts for each subnet.
- Allow for growth in each subnet.



Determine the Number and Size of the Networks



- Given, Network Address 172.16.0.0/22.
- Available host bits: 10.
- The largest subnet requires 40 hosts, a minimum of 6 host bits are needed to provide addressing for 40 hosts ($2^6 - 2 = 62$ hosts).
- The first 4 host bits can be used to allocate subnets ($2^4 = 16$).
- Because the example internetwork requires 9 subnets this will meet the requirement and allow for some additional growth.



Determining the Subnet Mask

Subnetting To Meet Network Requirements

Subnets and Addresses

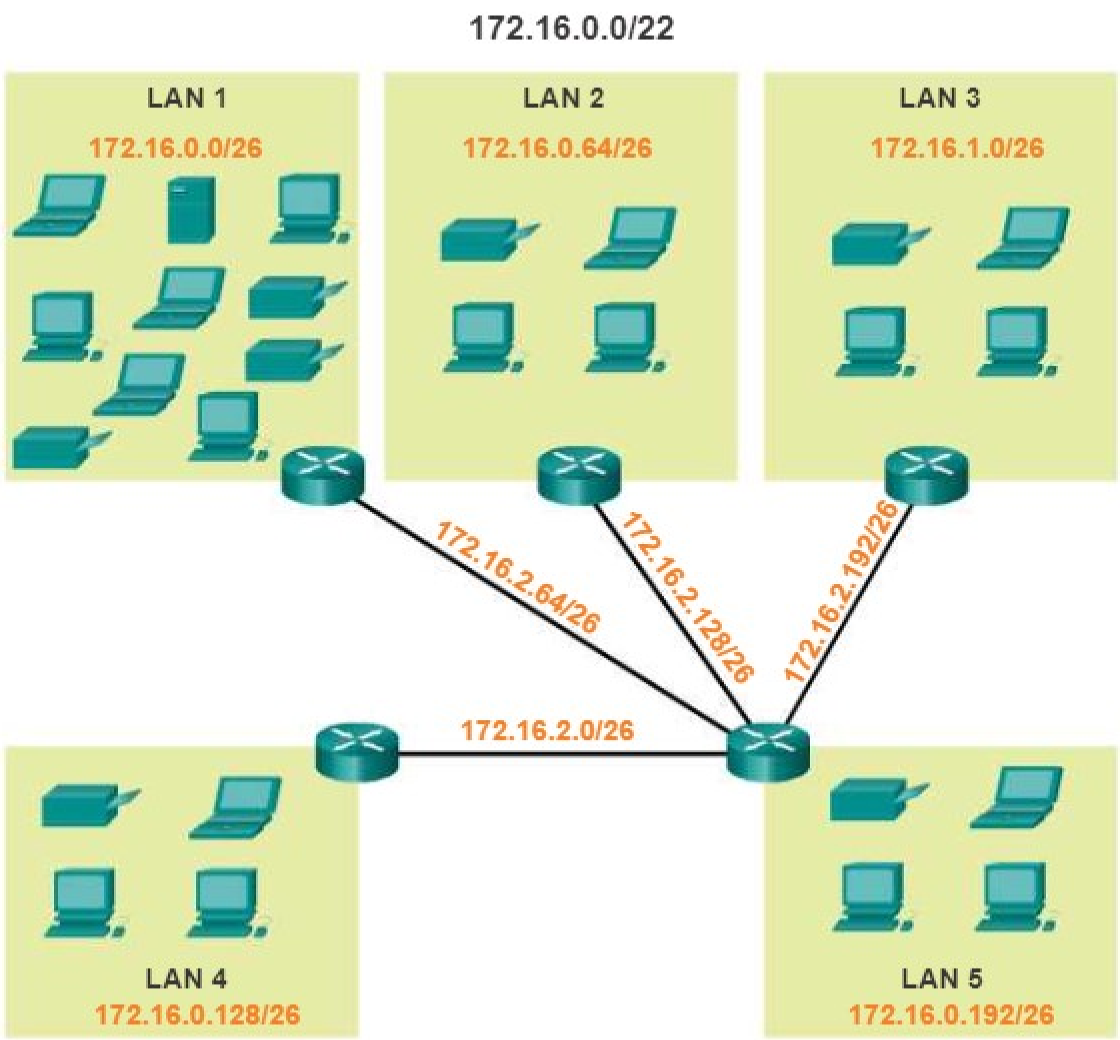
	10101100.00010000.00000000.00000000	172.16.0.0/22
0	10101100.00010000.00000000.00000000	172.16.0.0/26
1	10101100.00010000.00000000.01000000	172.16.0.64/26
2	10101100.00010000.00000000.10000000	172.16.0.128/26
3	10101100.00010000.00000000.11000000	172.16.0.192/26
4	10101100.00010000.00000001.00000000	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

Determining the Subnet Mask

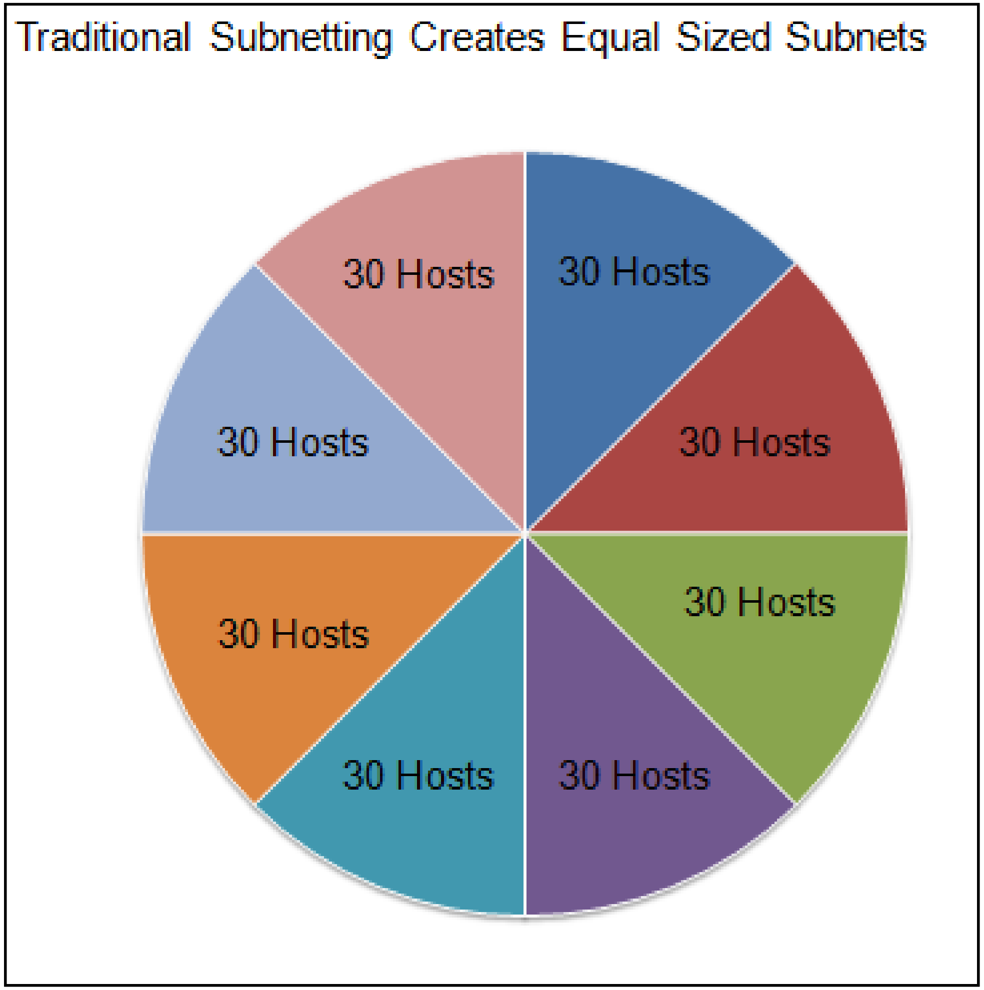
Subnetting To Meet Network Requirements

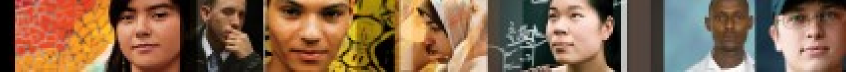


Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes Addresses

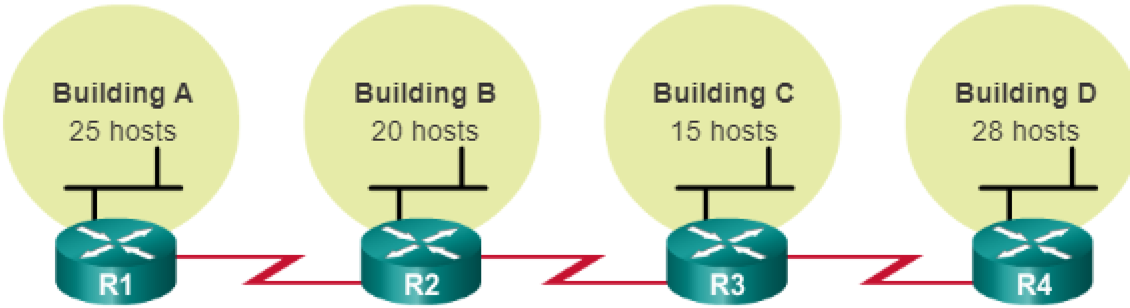
- Traditional subnetting – Uses the same number of addresses is allocated for each subnet.
- Subnets that require fewer addresses have unused (wasted) addresses; for example, WAN links only need two addresses.





Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes Addresses



	Network portion	Host portion			
	11000000.10101000.00010100	.000	00000	192.168.20.0/24	
0	11000000.10101000.00010100	.000	00000	192.168.20.0/27	Building LANs A, B, C, and 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	Site to Site WANs
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	Unused / Available

Subnet portion
2^3 = 8 subnets

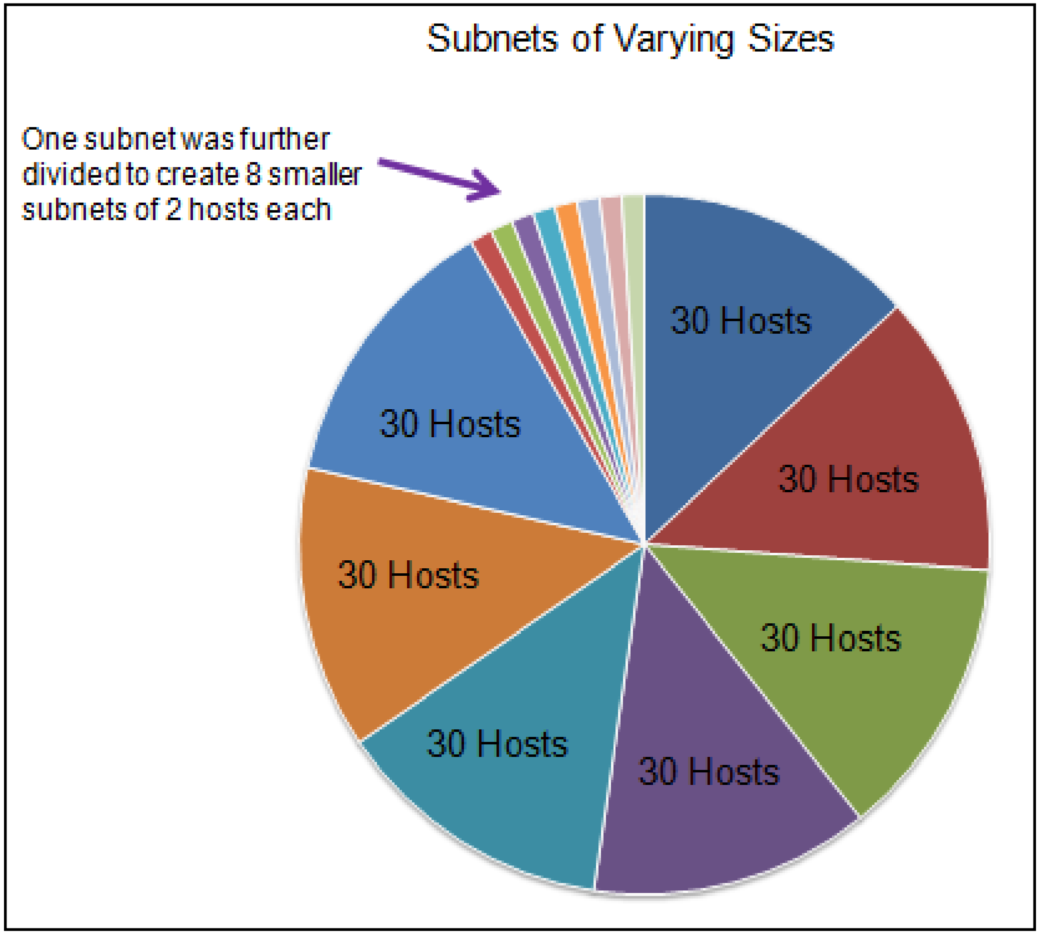
Host portion
2^5 – 2 = 30 hosts per subnet

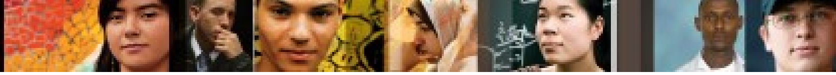
→ Host portion: 2^5-2=30 hosts per subnet
→ 30-2=28 Each WAN subnet wastes 28 addresses
→ 28 x 3 = 84 addresses are unused and wasted

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 re-subnetted.





Benefits of Variable Length Subnet Masking

Basic VLSM

VLSM Subnetting Scheme

	Binary	Subnet	
	11000000.10101000.00010100.00000000	192.168.20.0/24	
0	11000000.10101000.00010100.00000000	192.168.20.0/27	LANs A, B, C, D
1	11000000.10101000.00010100.00100000	192.168.20.32/27	
2	11000000.10101000.00010100.01000000	192.168.20.64/27	
3	11000000.10101000.00010100.01100000	192.168.20.96/27	
4	11000000.10101000.00010100.10000000	192.168.20.128/27	Unused / Available
5	11000000.10101000.00010100.10100000	192.168.20.160/27	
6	11000000.10101000.00010100.11000000	192.168.20.192/27	
7	11000000.10101000.00010100.11100000	192.168.20.224/27	

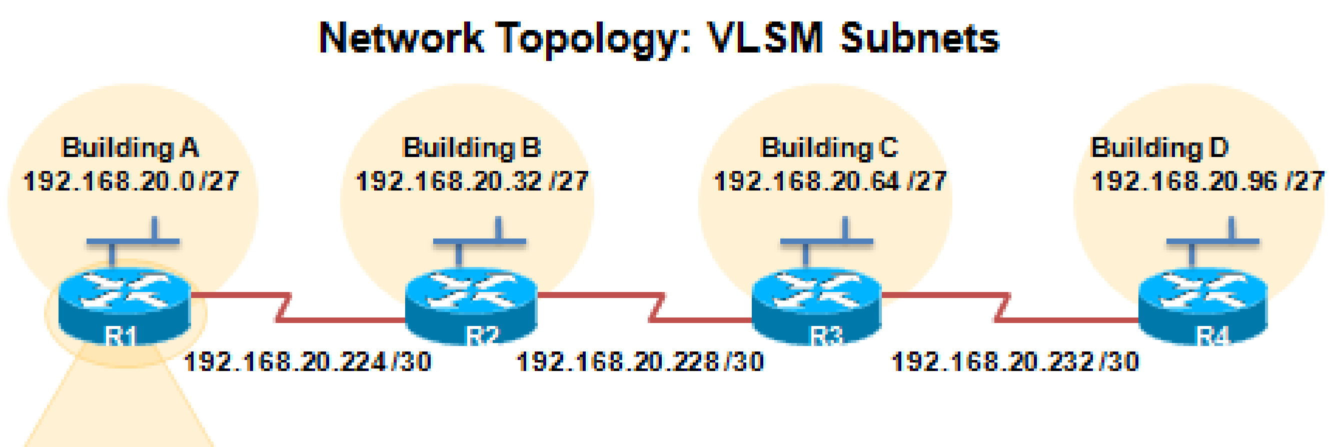
3 more bits borrowed from subnet 7:

	Binary	Subnet	
7:0	11000000.10101000.00010100.11100000	192.168.20.224/30	WANs
7:1	11000000.10101000.00010100.11100100	192.168.20.228/30	
7:2	11000000.10101000.00010100.11101000	192.168.20.232/30	
7:3	11000000.10101000.00010100.11101100	192.168.20.236/30	Unused / Available
7:4	11000000.10101000.00010100.11110000	192.168.20.240/30	
7:5	11000000.10101000.00010100.11110100	192.168.20.244/30	
7:6	11000000.10101000.00010100.11111000	192.168.20.248/30	
7:7	11000000.10101000.00010100.11111100	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.




```
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

Basic Subnetting of 192.168.20.0/24

	/27 Network	Hosts
Building A	.0	.1 - .30
Building B	.32	.33 - .62
Building C	.64	.65 - .94
Building D	.96	.97 - .126
WAN R1 – R2	.128	.129 - .158
WAN R2 – R3	.160	.161 - .190
WAN R3 – R4	.192	.193 - .222
Unused	.224	.225 - .254

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

Cisco | Networking Academy®
Mind Wide Open™

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

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	