



Chapter 9: Subnetting IP Networks



Introduction to Networks

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Chapter 9

9.0 Introduction

9.1 Subnetting an IPv4 Network

9.2 Addressing Schemes



9.1 Subnetting an IPv4 Network



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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.

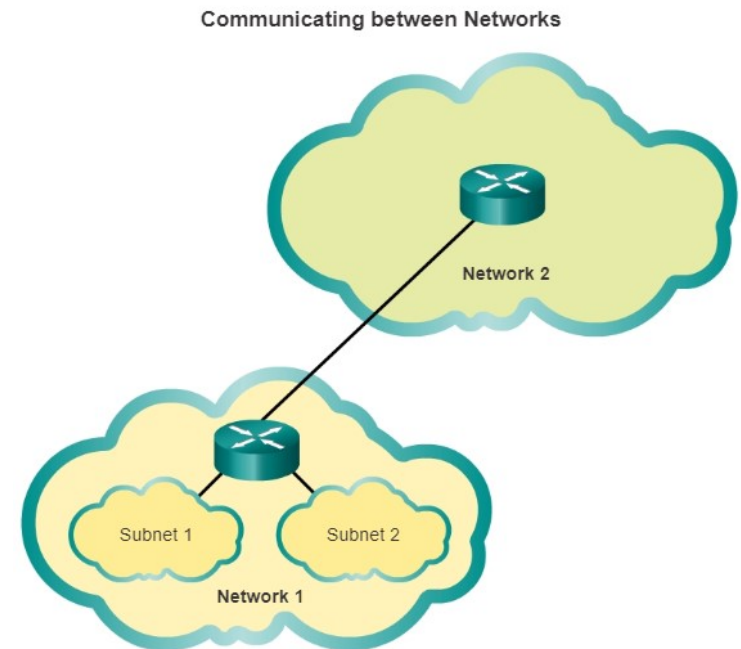


Network Segmentation

Subnetting

Communication Between Subnets

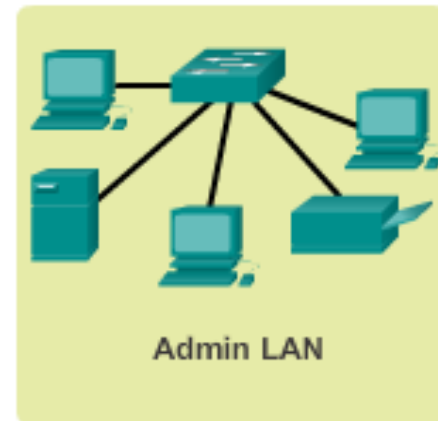
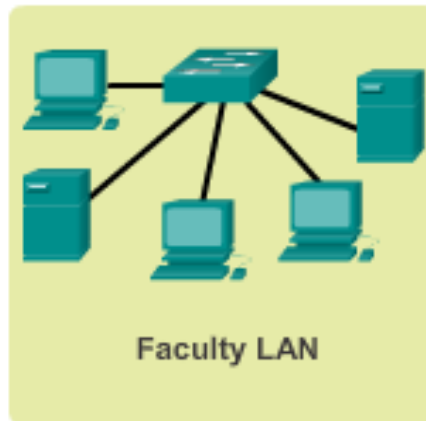
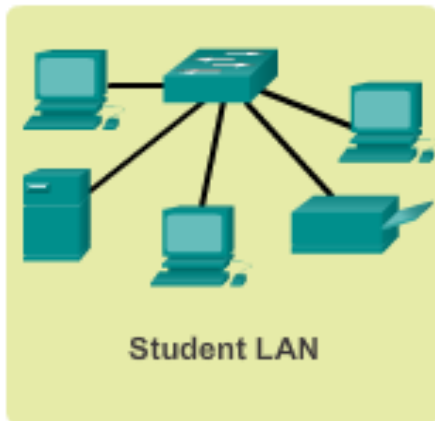
- A router is necessary for devices on different networks and subnets to communicate.
- Each router interface must have an IPv4 host address that belongs to the network or subnet that the router interface is connected.
- Devices on a network and subnet use the router interface attached to their LAN as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

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



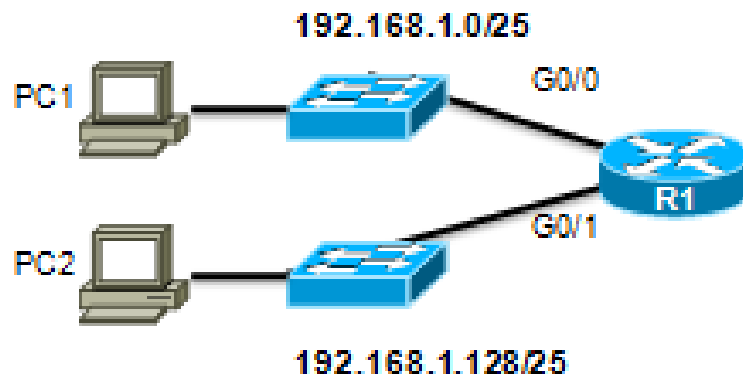
Subnetting an IPv4 Network

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

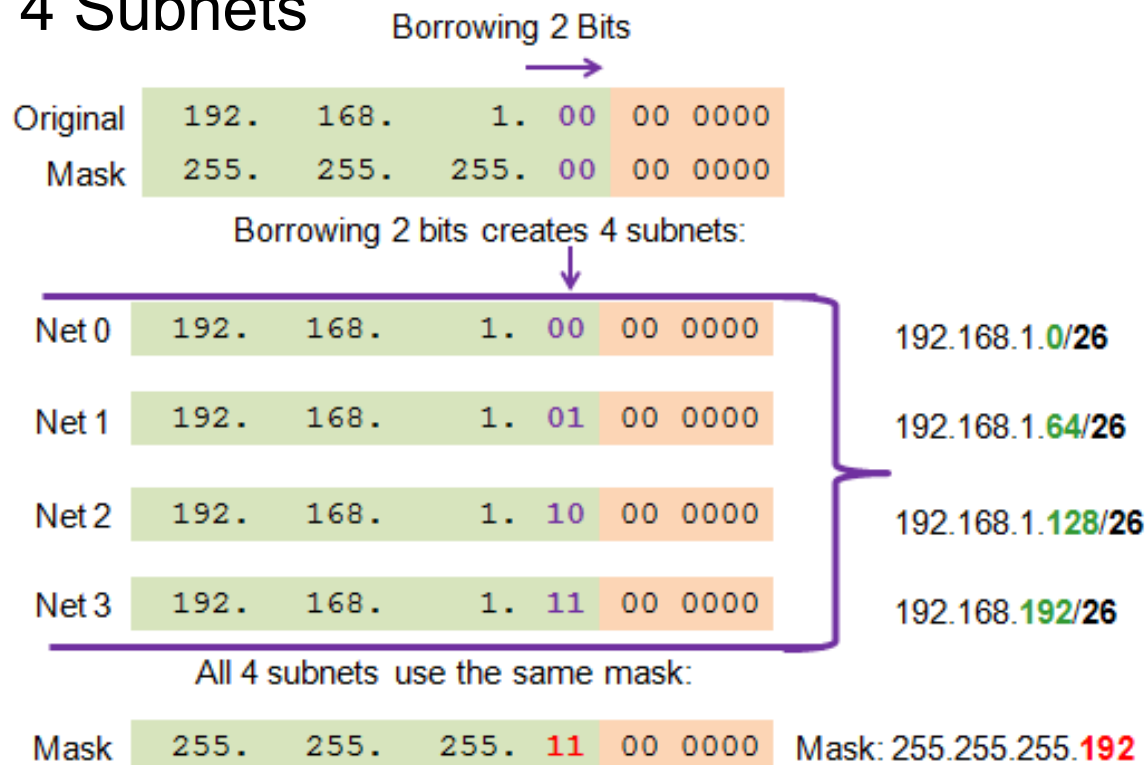


Subnetting an IPv4 Network

Creating 4 Subnets

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

Creating 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

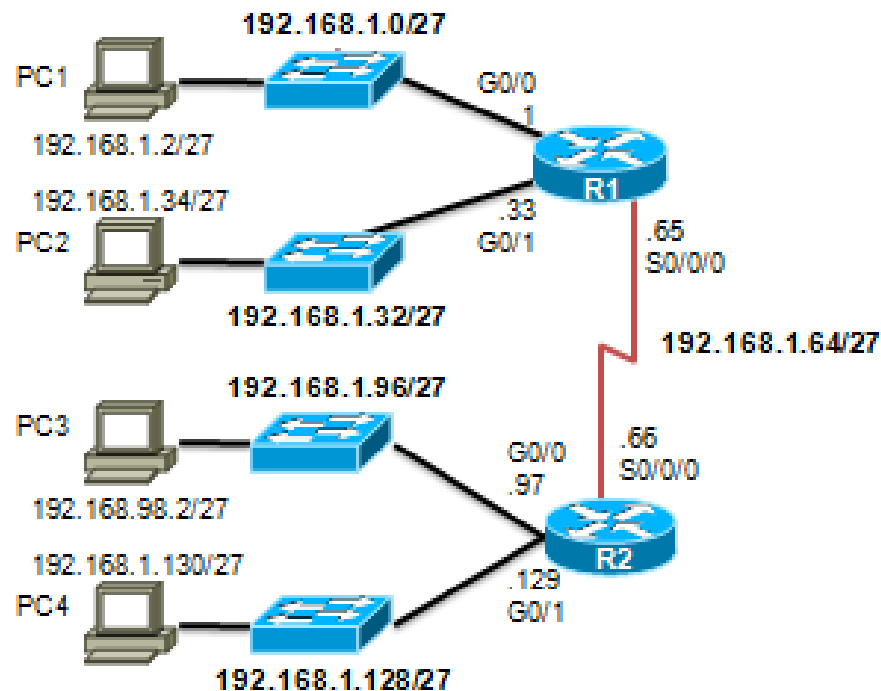
Creating Eight Subnets (Cont.)

Net 4	Network	192.	168.	1.	100	0 0000	192.168.1.128
	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.)

Subnet Allocation





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:

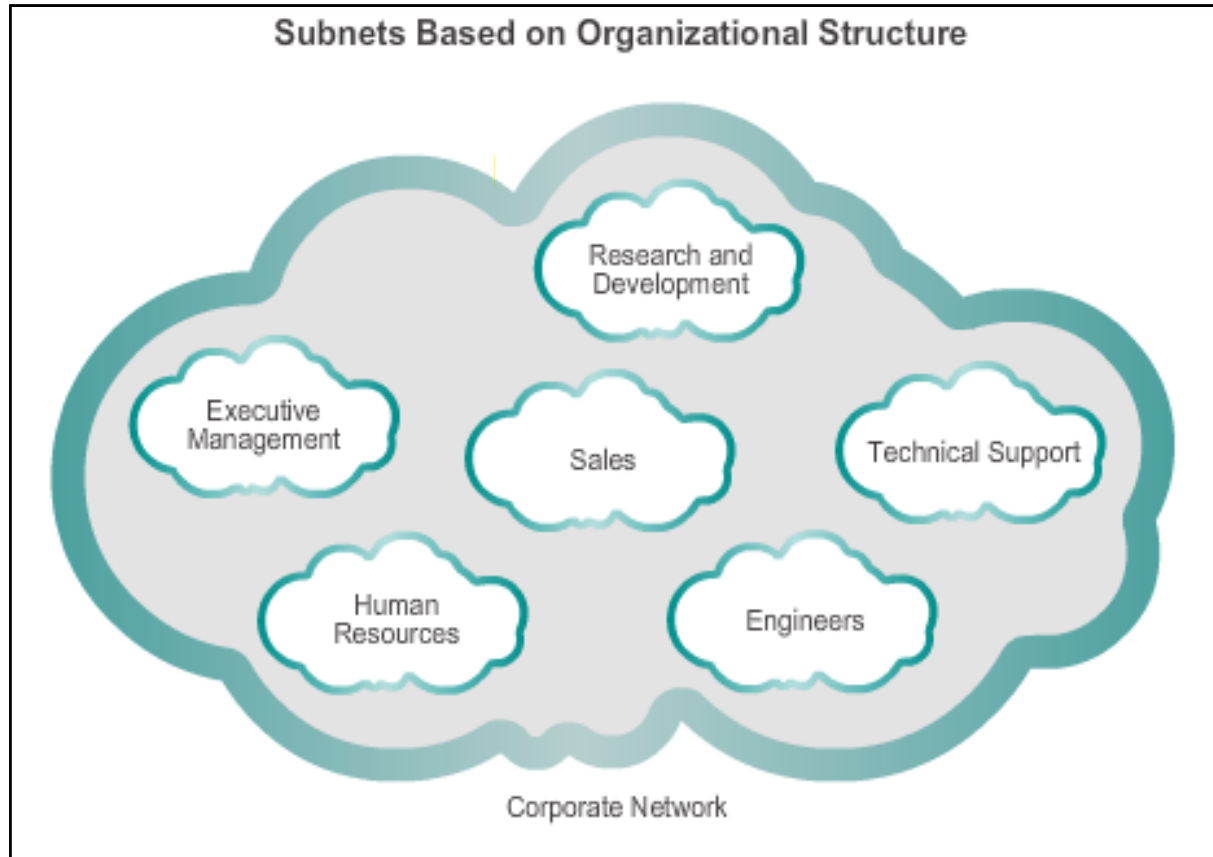
- 2^n (where n is the number of bits borrowed)
- Subnet needed for each department.

Let's examine the animation in 9.1.4.1



Determining the Subnet Mask

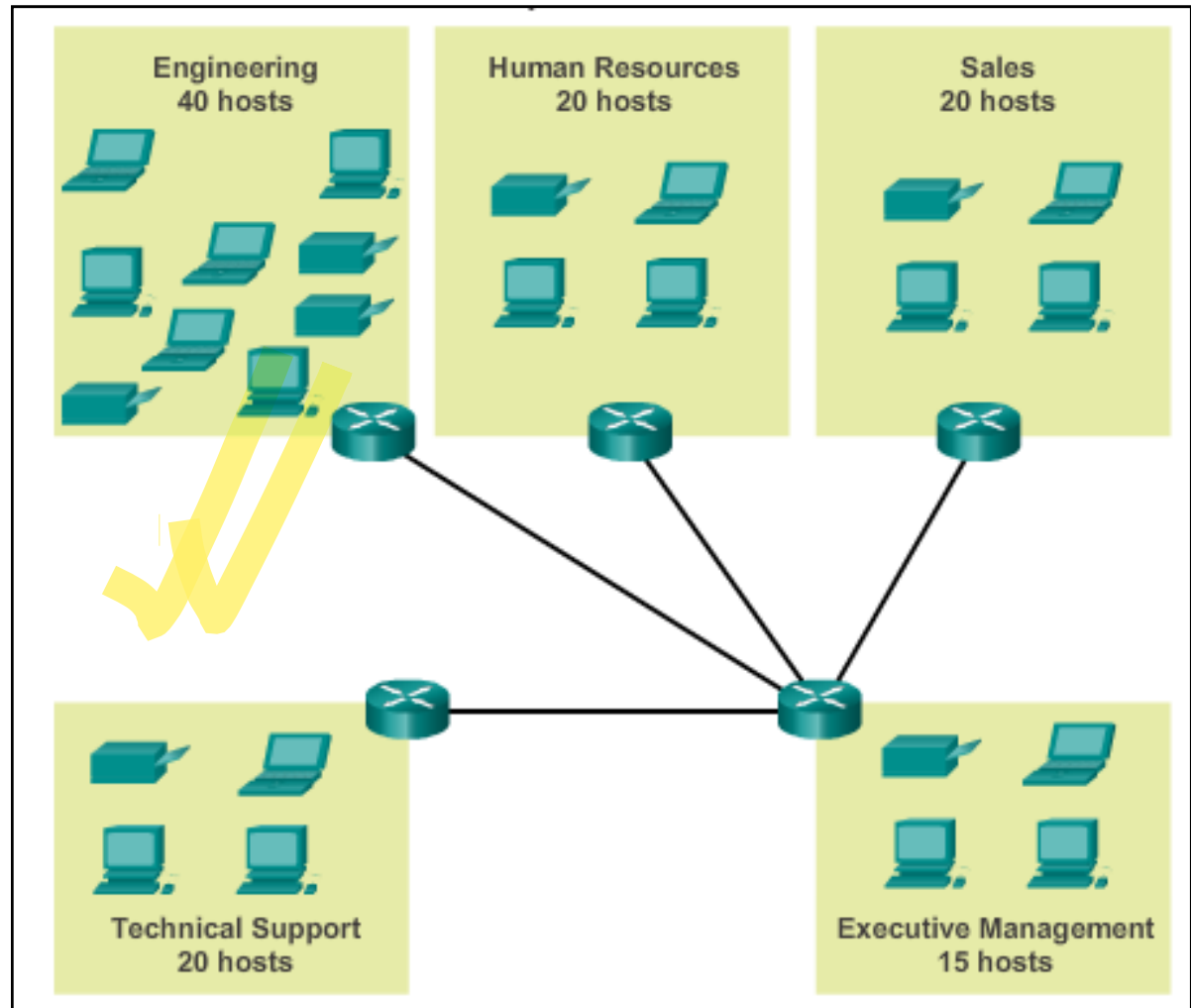
Subnetting Network-Based Requirements



Determining the Subnet Mask

Subnetting To Meet Network Requirements

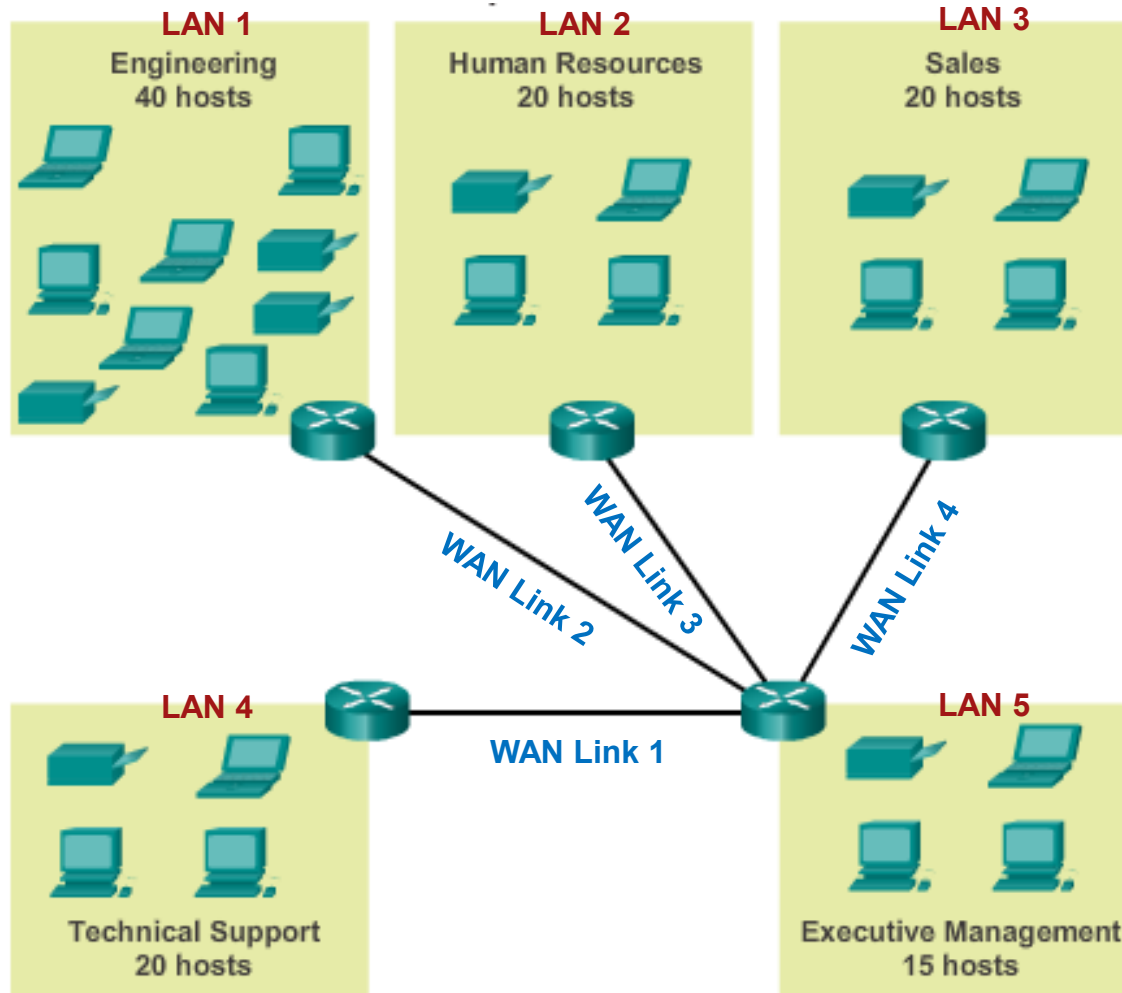
- Balance the required number of subnets and hosts for the largest subnet.
- Design the addressing scheme to accommodate the maximum number of hosts for each subnet.
- Allow for growth in each subnet.





Determining the Subnet Mask

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

	10101100.00010000.000000	00.00000000	172.16.0.0/22
0	10101100.00010000.000000	00.00000000	172.16.0.0/26
1	10101100.00010000.000000	00.01000000	172.16.0.64/26
2	10101100.00010000.000000	00.10000000	172.16.0.128/26
3	10101100.00010000.000000	00.11000000	172.16.0.192/26
4	10101100.00010000.000000	01.00000000	172.16.1.0/26
5	10101100.00010000.000000	01.01000000	172.16.1.64/26
6	10101100.00010000.000000	01.10000000	172.16.1.128/26

Nets 7 – 14 not shown

15	10101100.00010000.000000	11.10000000	172.16.3.128/26
16	10101100.00010000.000000	11.11000000	172.16.3.192/26

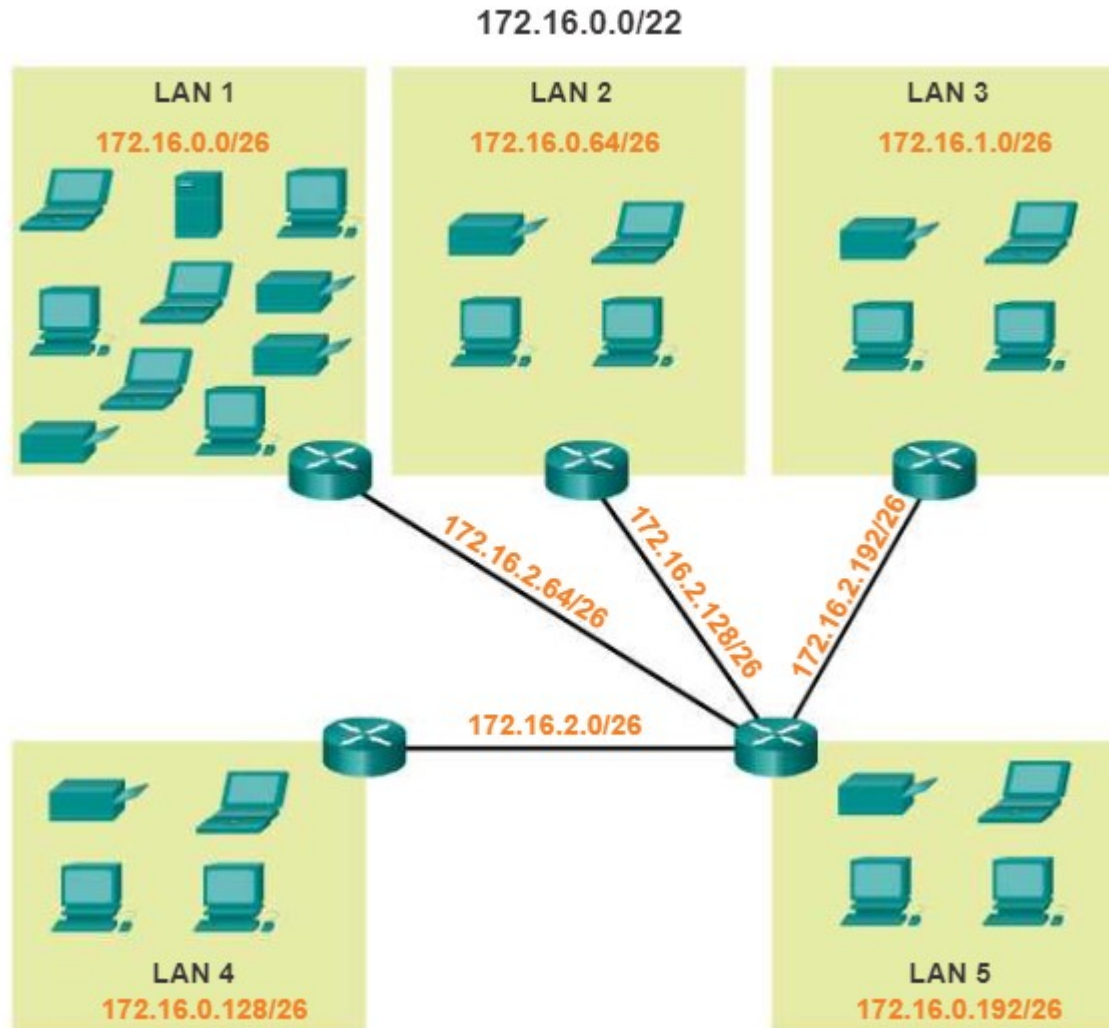

 $2^4 = 16$
 subnets


 $2^6 - 2 = 62$
 Hosts per
 subnet



Determining the Subnet Mask

Subnetting To Meet Network Requirements



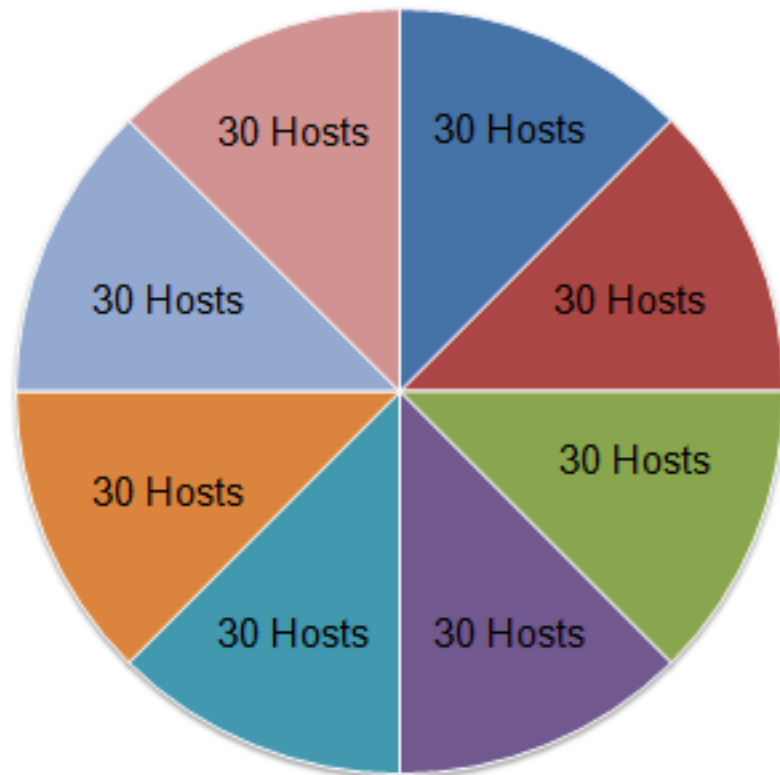


Benefits of Variable Length Subnet Masking

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.

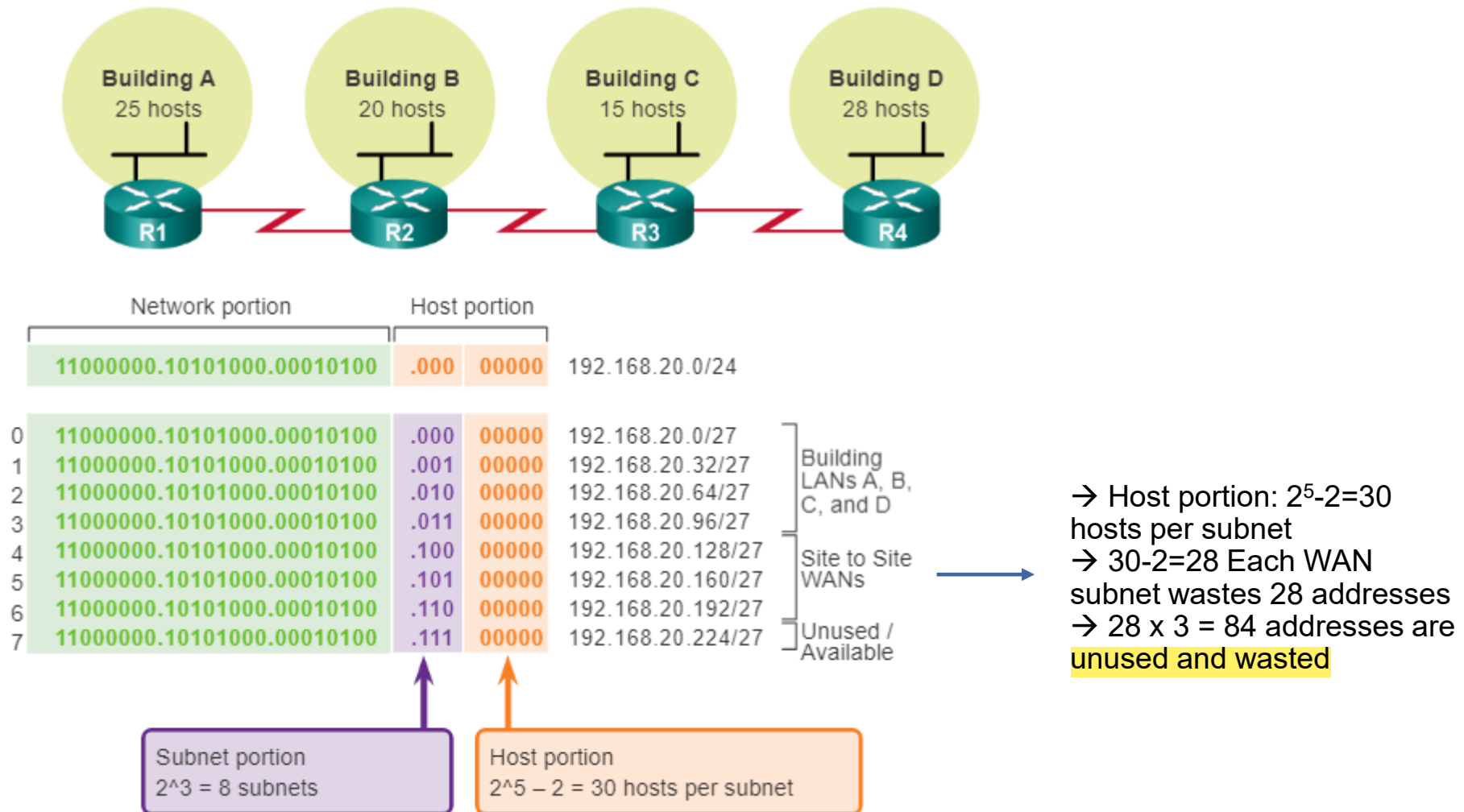
Traditional Subnetting Creates Equal Sized Subnets





Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes Addresses

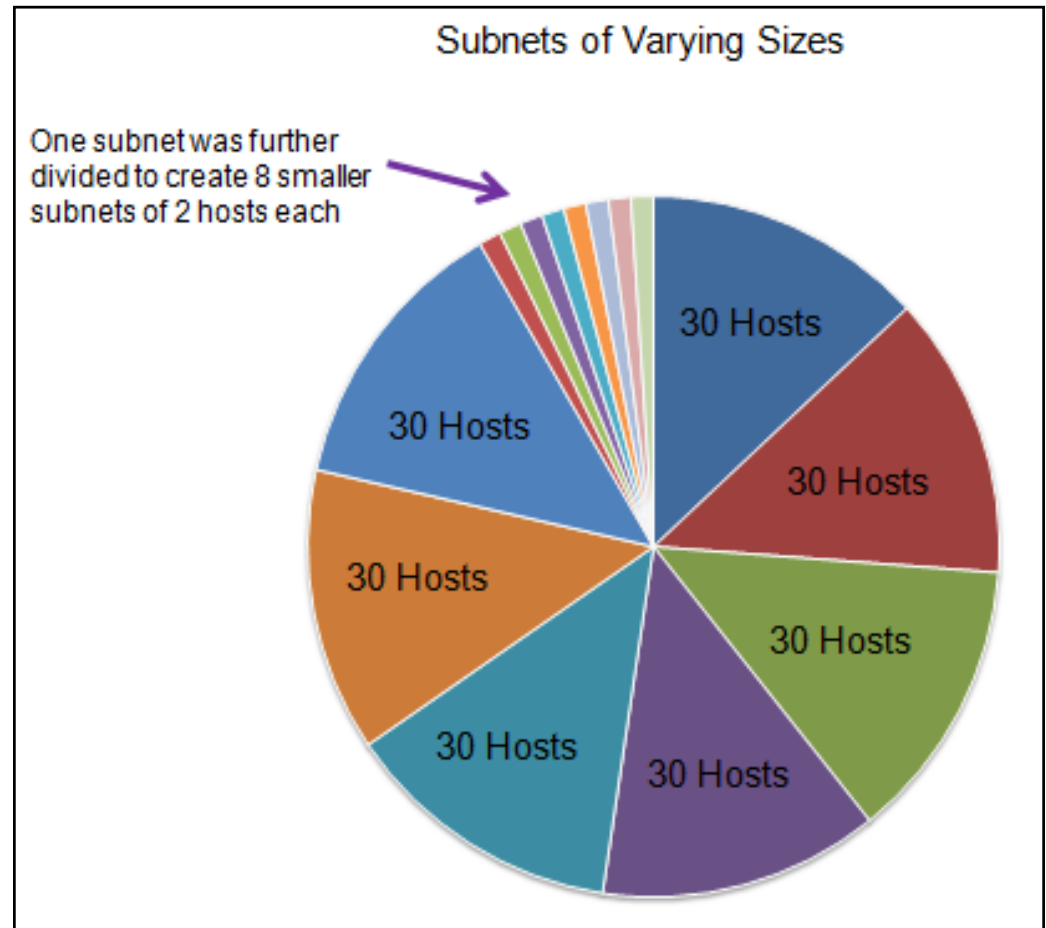




Benefits of Variable Length Subnet Masking

Variable Length Subnet Masks (VLSM)

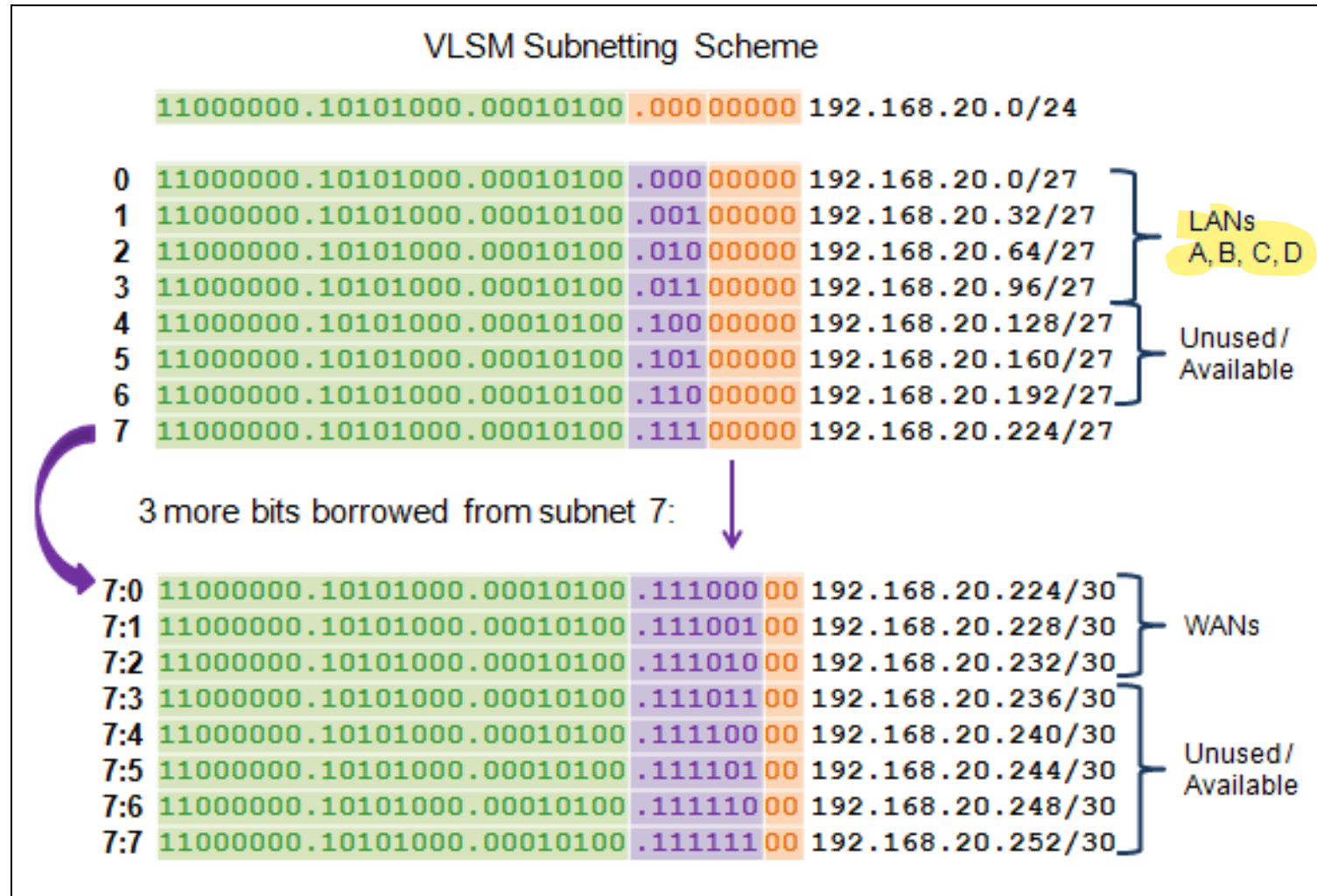
- The variable-length subnet mask (VLSM) or subnetting a subnet provides more efficient use of addresses.
- VLSM allows a network space to be divided in unequal parts.
- Subnet mask varies, depending on how many bits have been borrowed for a particular subnet.
- Network is first subnetted, and then the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





Benefits of Variable Length Subnet Masking

Basic VLSM

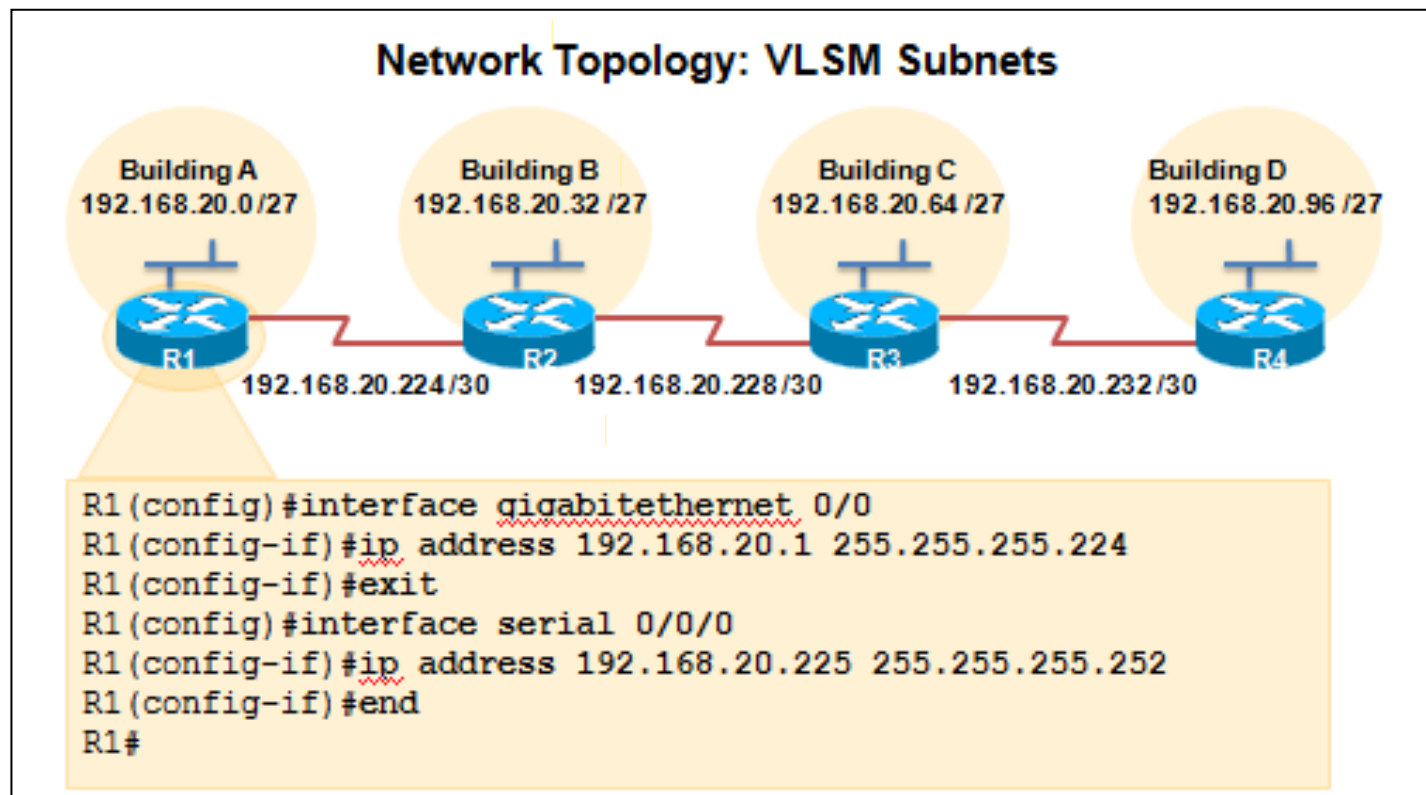




Benefits of Variable Length Subnet Masking

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

Basic Subnetting of 192.168.20.0/24

Traditional Subnetting wastes 114 Hosts(WAN+Unsued)

	/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

assigning $30 \times 4 = 120$ hosts for FOUR buildings, these are efficient, but others are not.



Benefits of Variable Length Subnet Masking

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

10 hosts remained unused here, but in traditional subnetting, 30 hosts remained unused. So, that's why VLSM saves the storage



9.2 Addressing Schemes



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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	