Cisco Networking Academy

CCNA R&S: Introduction to Networks

Chapter 9:

Subnetting IP Networks

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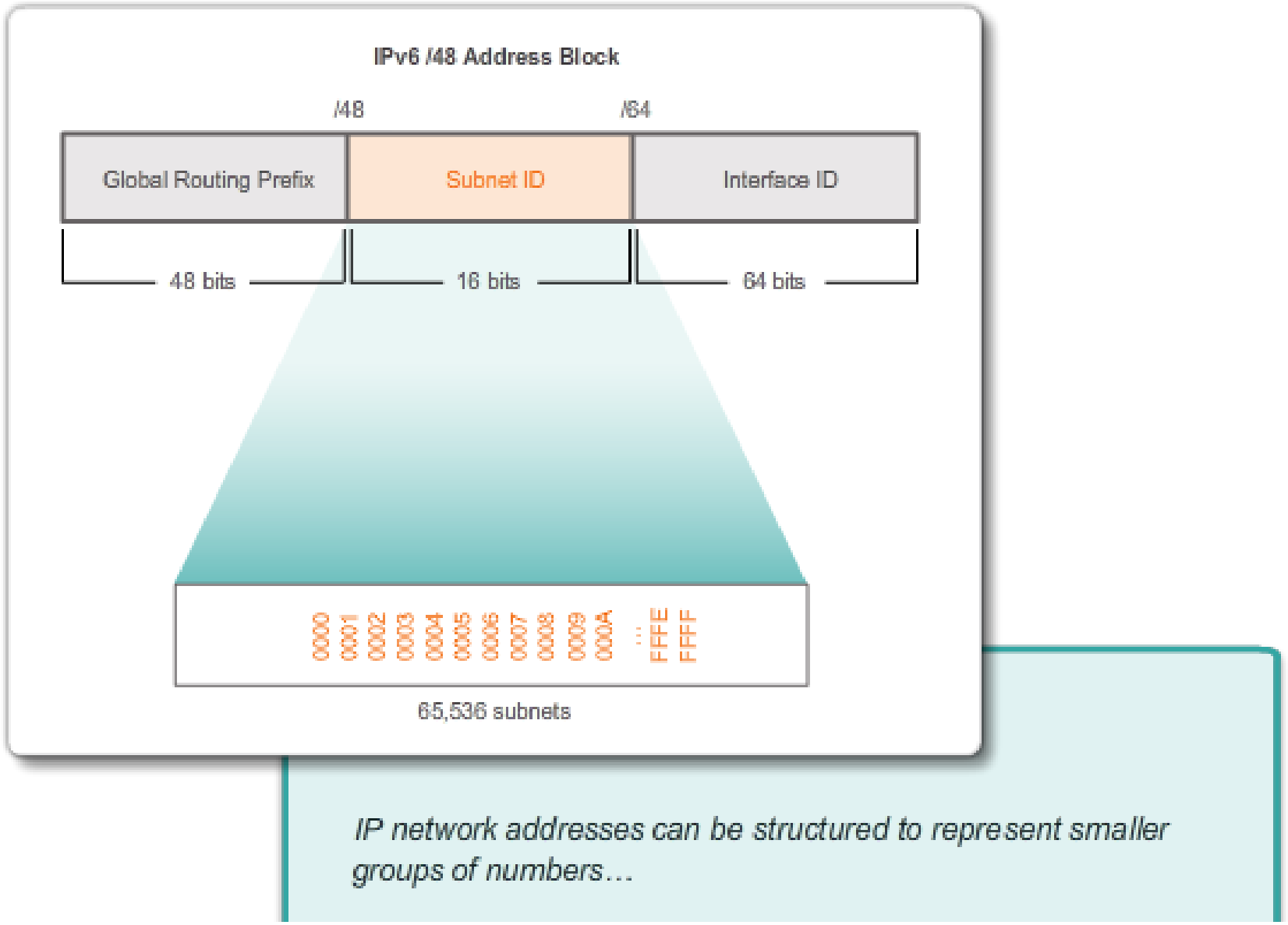
Upon completion of this chapter you will be able to:

- Explain why routing is necessary for hosts on different subnets to communicate.
- Describe IP as a communication protocol used to identify a single device on a network.
- Given a network and subnet mask, calculate the number of host addresses available.
- Calculate the necessary subnet mask in order to accommodate a given number of hosts.
- Describe the benefits of variable length subnet masking (VLSM).
- Design and implement a hierarchical addressing scheme.
- Explain how IPv6 address assignments are implemented in a business network.

Subnetting IP Networks

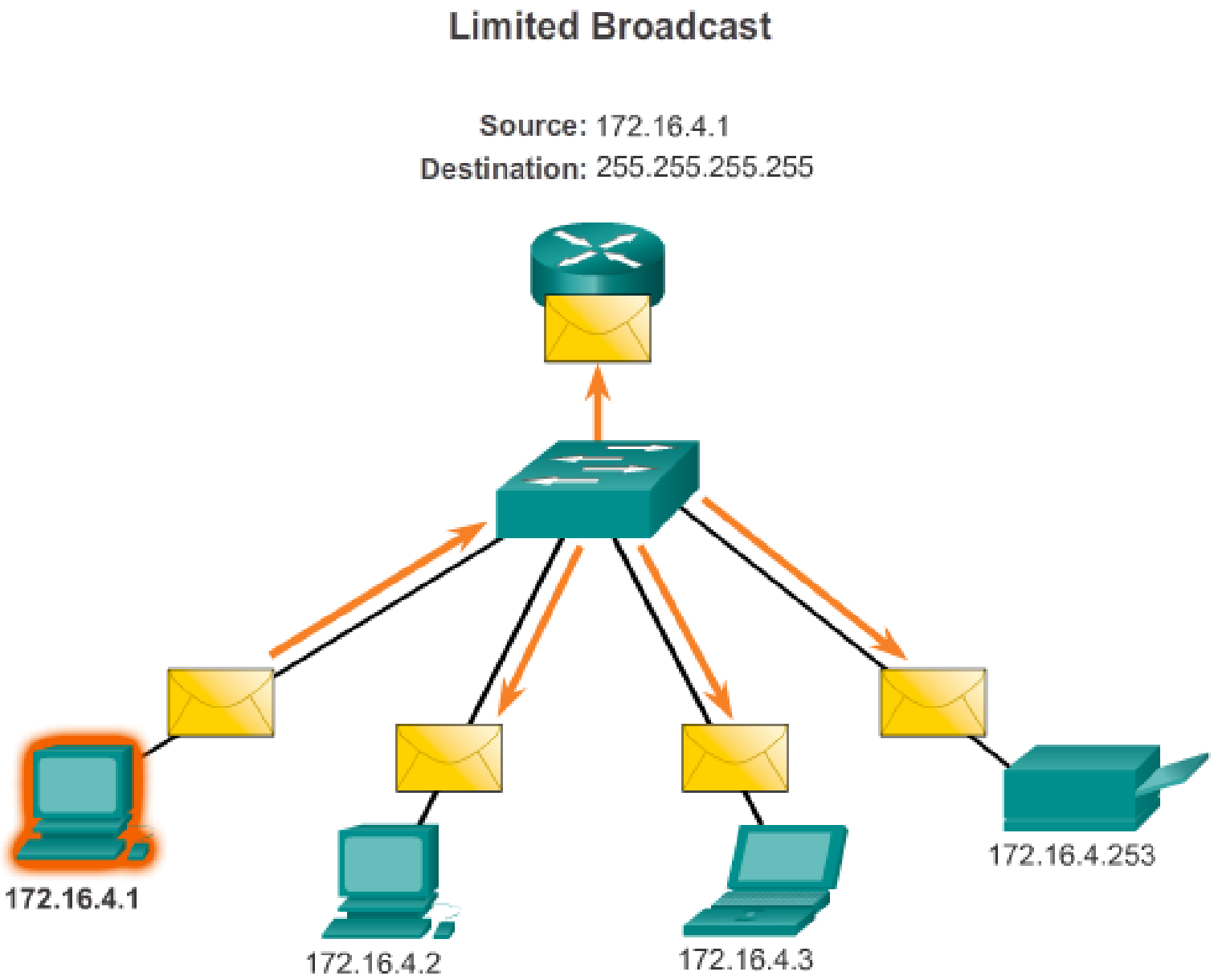


IP network addresses can be structured to represent smaller groups of numbers…

In this chapter, you will be learning how devices can be grouped into subnets, or smaller network groups, from a large network.

In this modeling activity, you are asked to think about a number you probably use every day, a number such as your telephone number. As you complete the activity, think about how your telephone number compares to strategies that network administrators might use to identify hosts for efficient data communication.

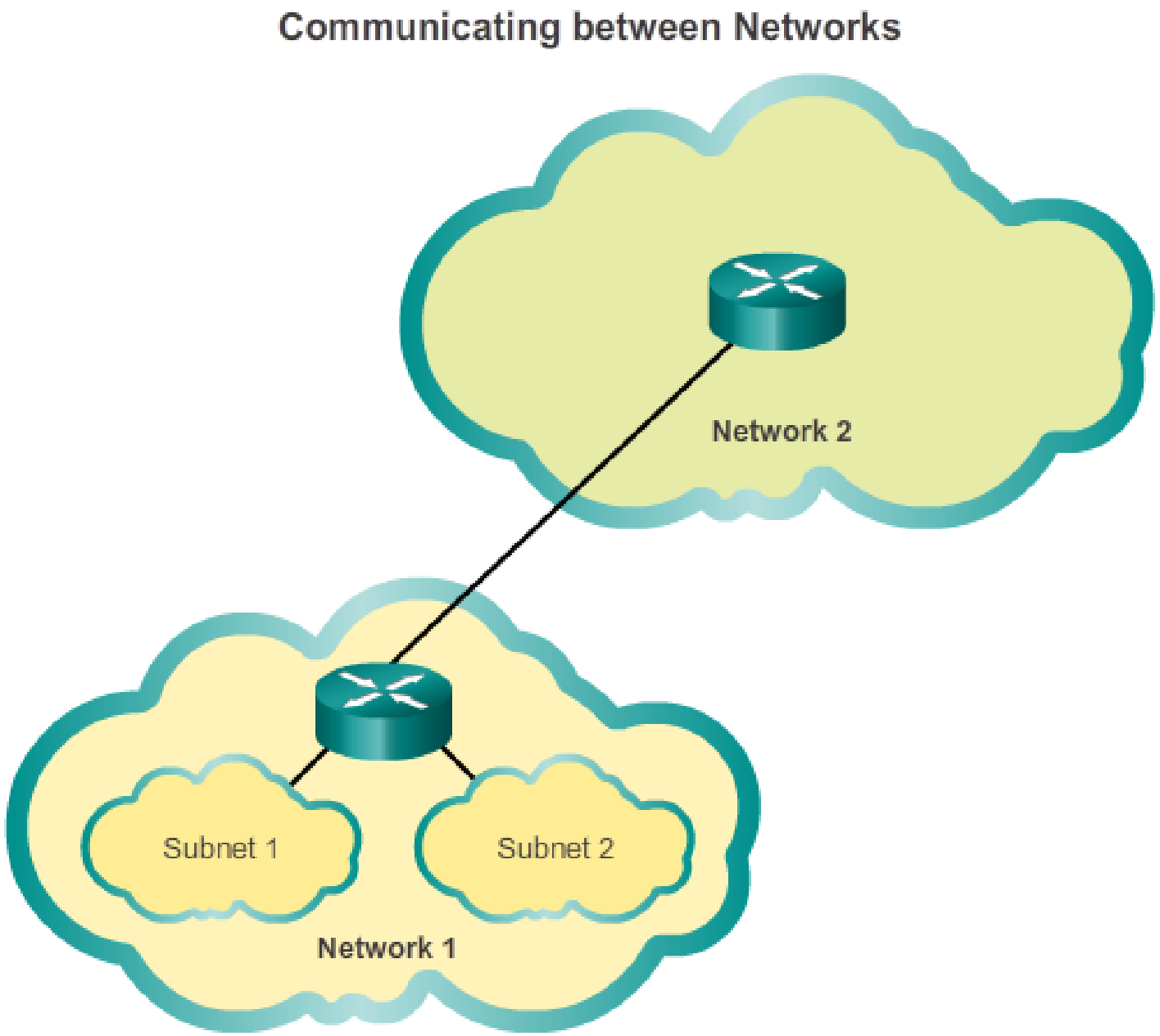
9.1.1.1 Reasons for Subnetting



The process of segmenting a network, by dividing it into multiple smaller network spaces, is called subnetting.

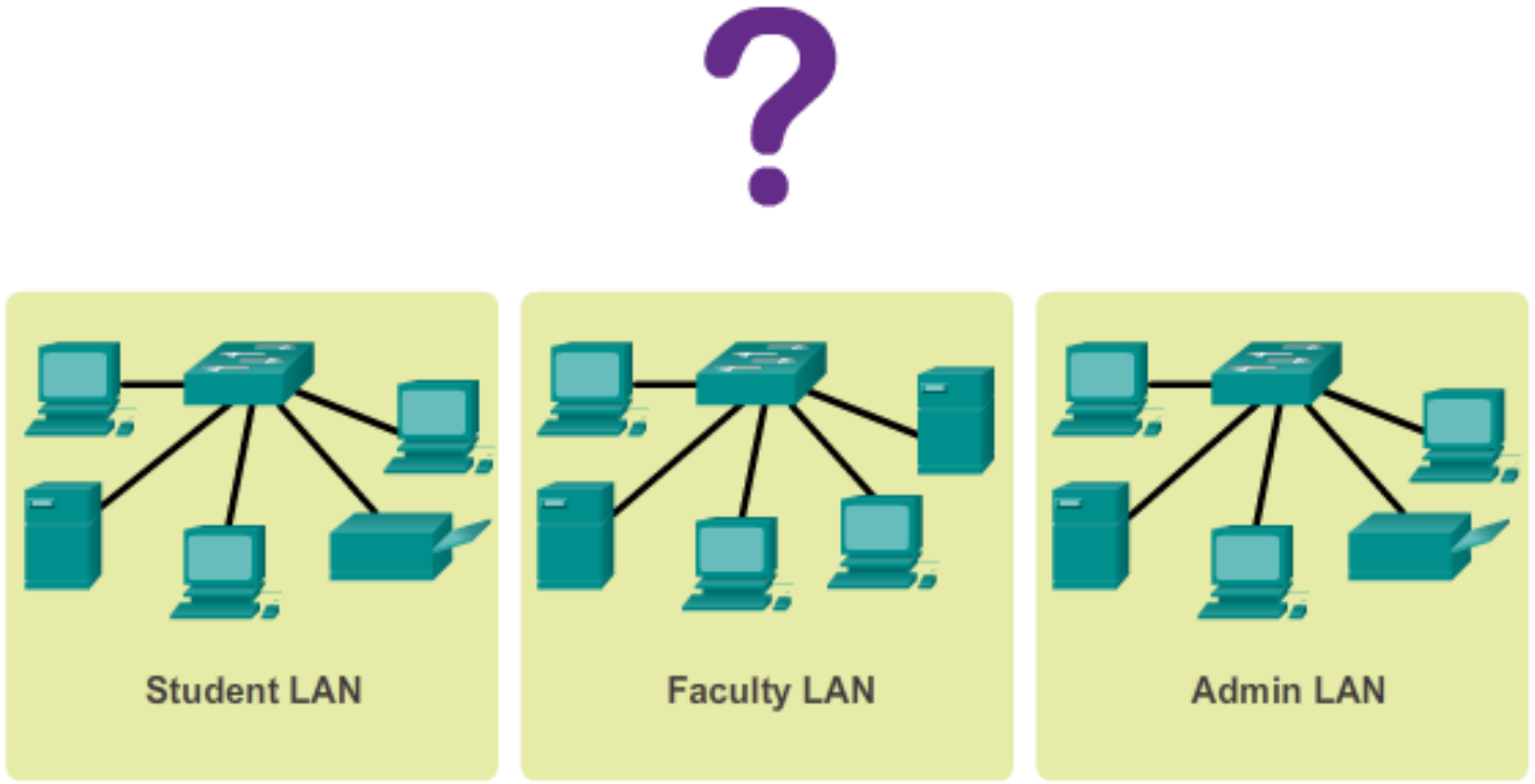
These sub-networks are called **subnets**. Network administrators can group devices and services into subnets that are determined by geographic location (perhaps the 3rd floor of a building), by organizational unit (perhaps the sales department), by device type (printers, servers, WAN), or any other division that makes sense for the network. Subnetting can reduce overall network traffic and improve network performance.

9.1.1.2 Communication Between Subnets



A router is necessary for devices on different networks to communicate. Devices on a network use the router interface attached to their LAN as their default gateway. Traffic that is destined for a device on a remote network will be processed by the router and forwarded toward the destination. To determine if traffic is local or remote, the router uses the subnet mask.

9.1.2.1 The Plan



Knowing your IP address requirements will determine the range or ranges of host addresses you implement. Subnetting the selected private IP address space will provide the host addresses to cover your network needs.

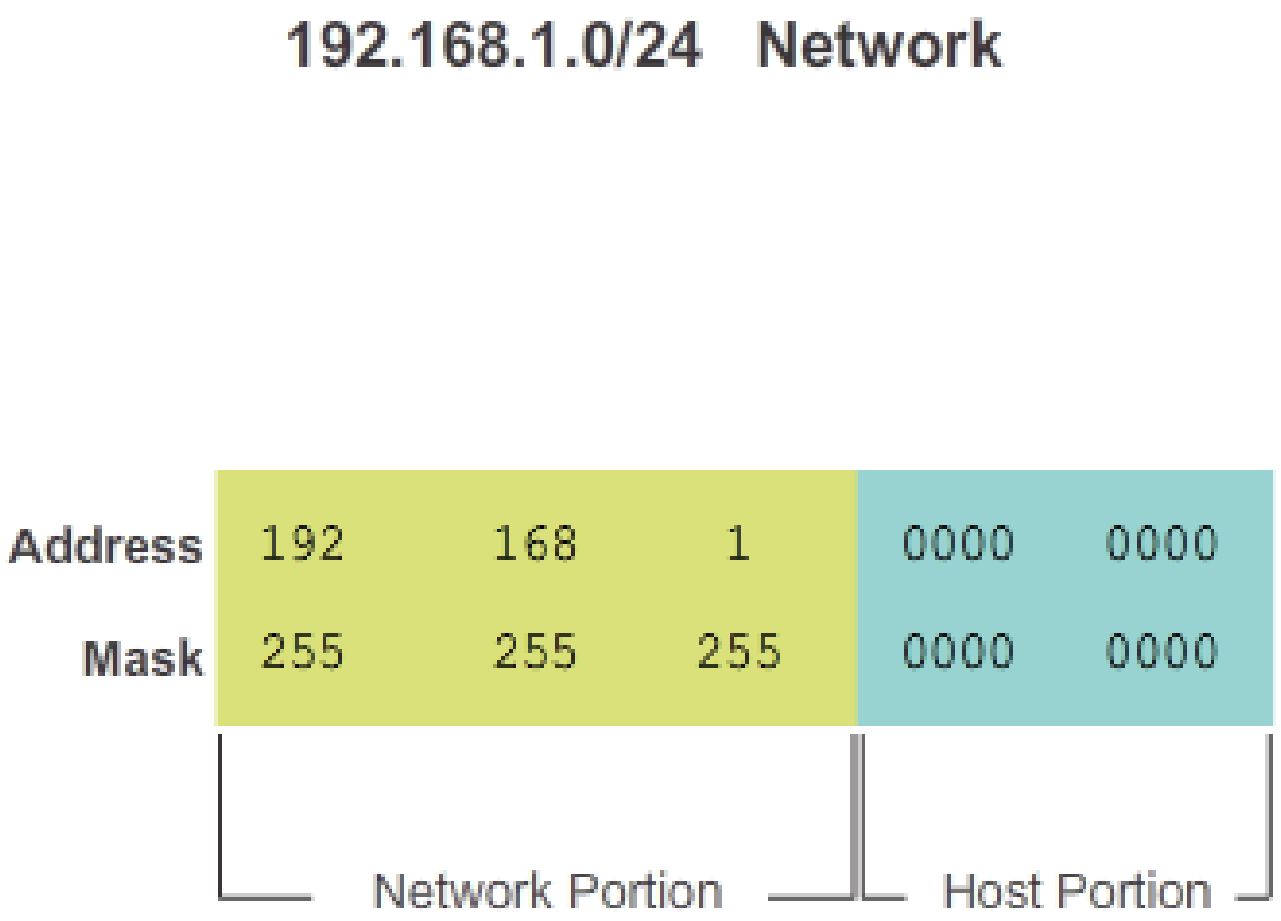
As discussed earlier, the private IP address range used on a LAN is the choice of the network administrator and needs careful consideration to be sure that enough host address will be available for the currently known hosts and for future expansion. Remember the private IP address ranges are:

- 10.0.0.0 with a subnet mask of 255.0.0.0
- 172.16.0.0 with a subnet mask of 255.240.0.0
- 192.168.0.0 with a subnet mask of 255.255.0.0

9.1.2.2 The Plan – Address Assignment

In the upcoming examples you will see subnetting based on address blocks that have subnet masks of 255.0.0.0, 255.255.0.0, and 255.255.255.0.

9.1.3.1 Basic Subnetting

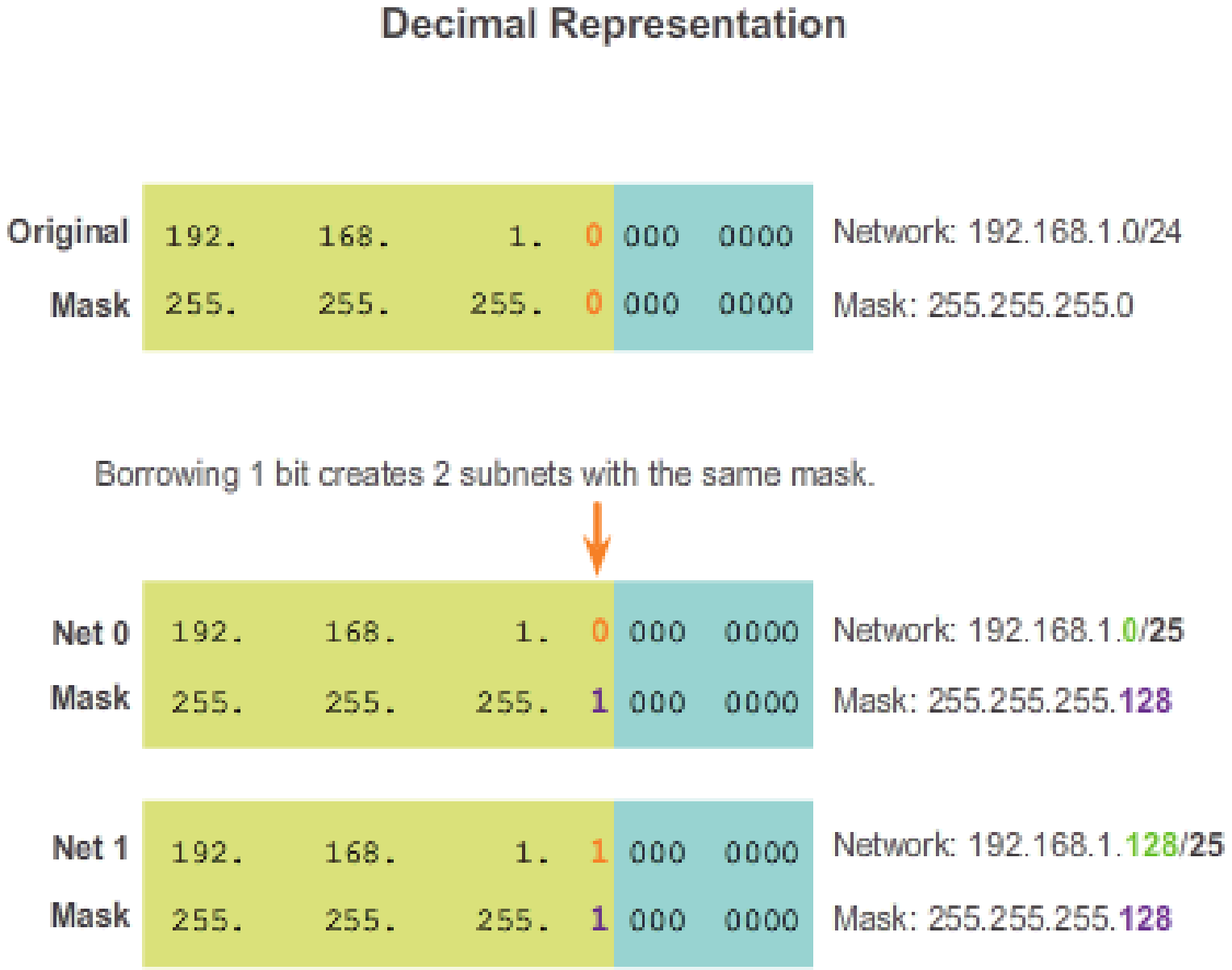


With no host bits borrowed, the host portion of both the network address and mask are all 0 bits.

Figure 1, the 192.168.1.0/24 network has 24 bits in the network portion and 8 bits in the host portion, which is indicated with the subnet mask 255.255.255.0 or /24 notation.

With no subnetting, this network supports a single LAN interface. If an additional LAN is needed, the network would need to be subnetted.

9.1.3.1 Basic Subnetting



in Figure 3, when we convert the binary octet to decimal we see that the first subnet address is 192.168.1.0 and the second subnet address is 192.168.1.128.

Because a bit has been borrowed, the subnet mask for each subnet is 255.255.255.128 or /25.

128	64	32	16	8	4	2	1

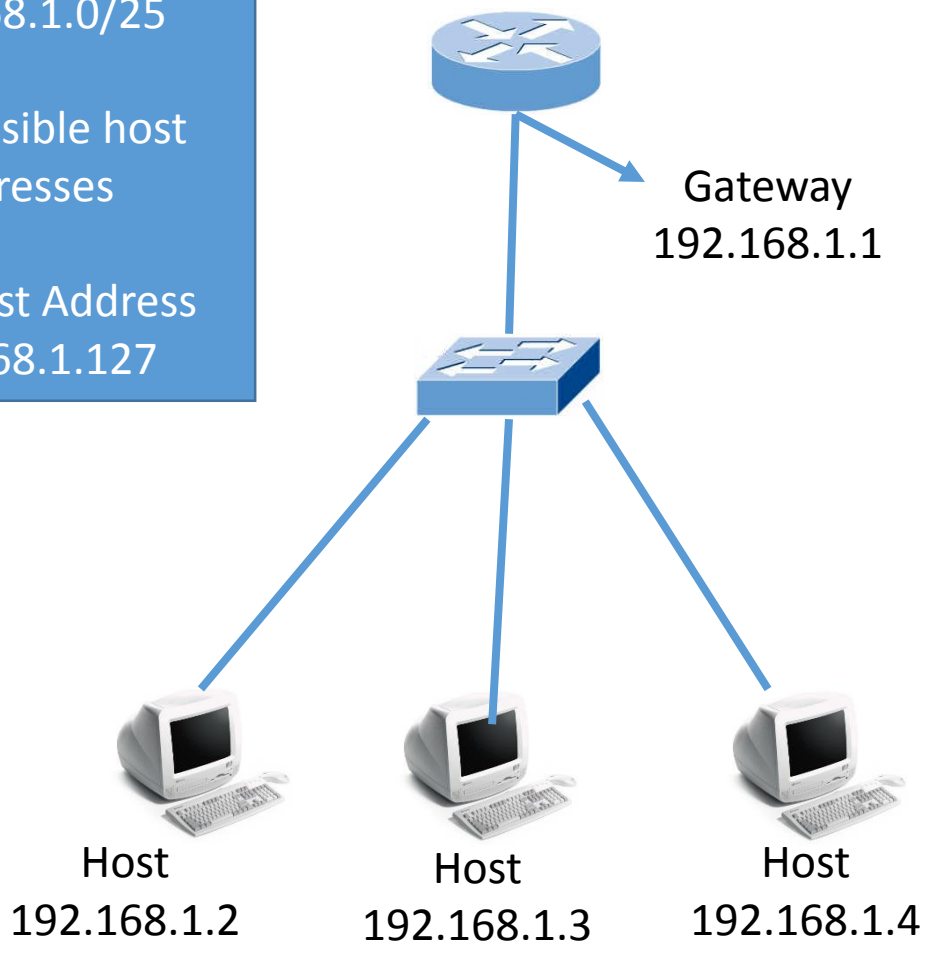
This example helps to explain subnetting
In real sub-netting you must borrow at least 2 bits

9.1.3.2 Subnets in Use

Network Address
192.168.1.0/25

128 possible host addresses

Broadcast Address
192.168.1.127



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

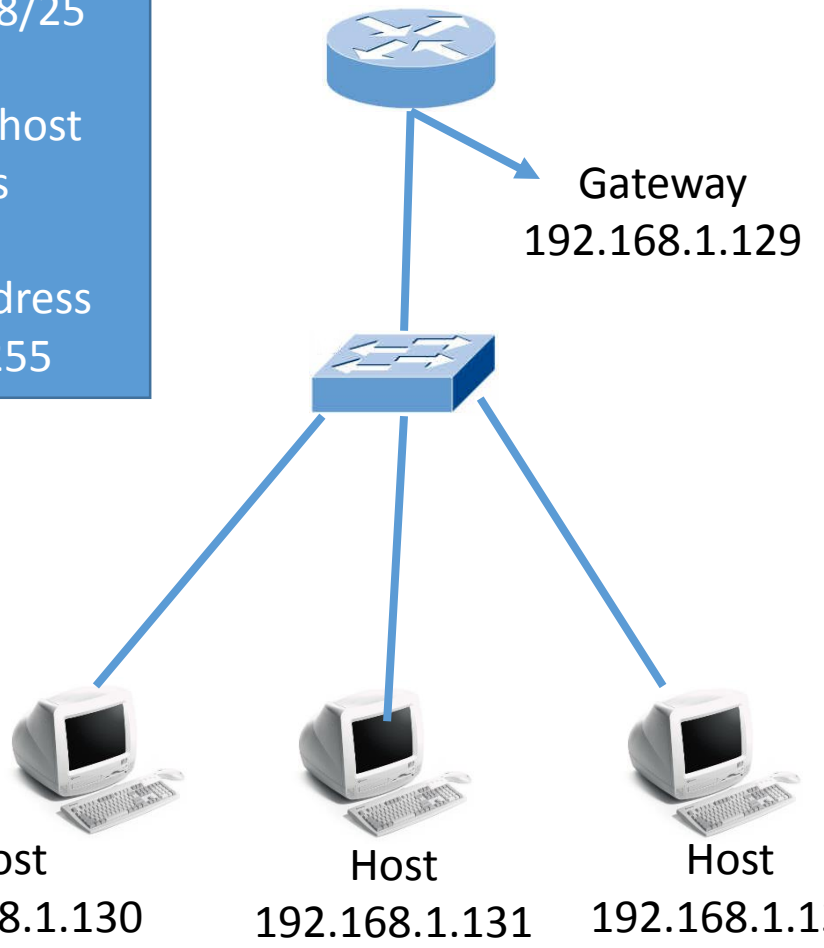
The first host address for the 192.168.1.0/25 network is 192.168.1.1, and the last host address is 192.168.1.126.

9.1.3.2 Subnets in Use

Network Address
192.168.1.128/25

128 possible host addresses

Broadcast Address
192.168.1.255



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

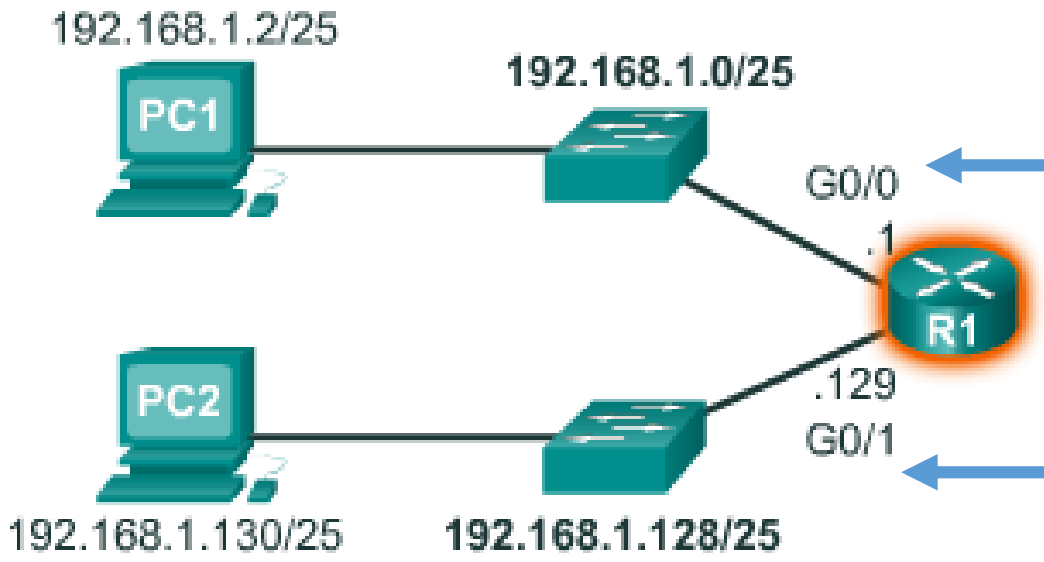
192.	168.	1.	1	111	1110	=	192.168.1.254

Broadcast Address

192.	168.	1.	1	111	1111	=	192.168.1.255

The first host address for the 192.168.1.128/25 network is 192.168.1.129, and the last host address is 192.168.1.254.

9.1.3.2 Subnets in Use



Address Range for 192.168.1.0/25 Subnet

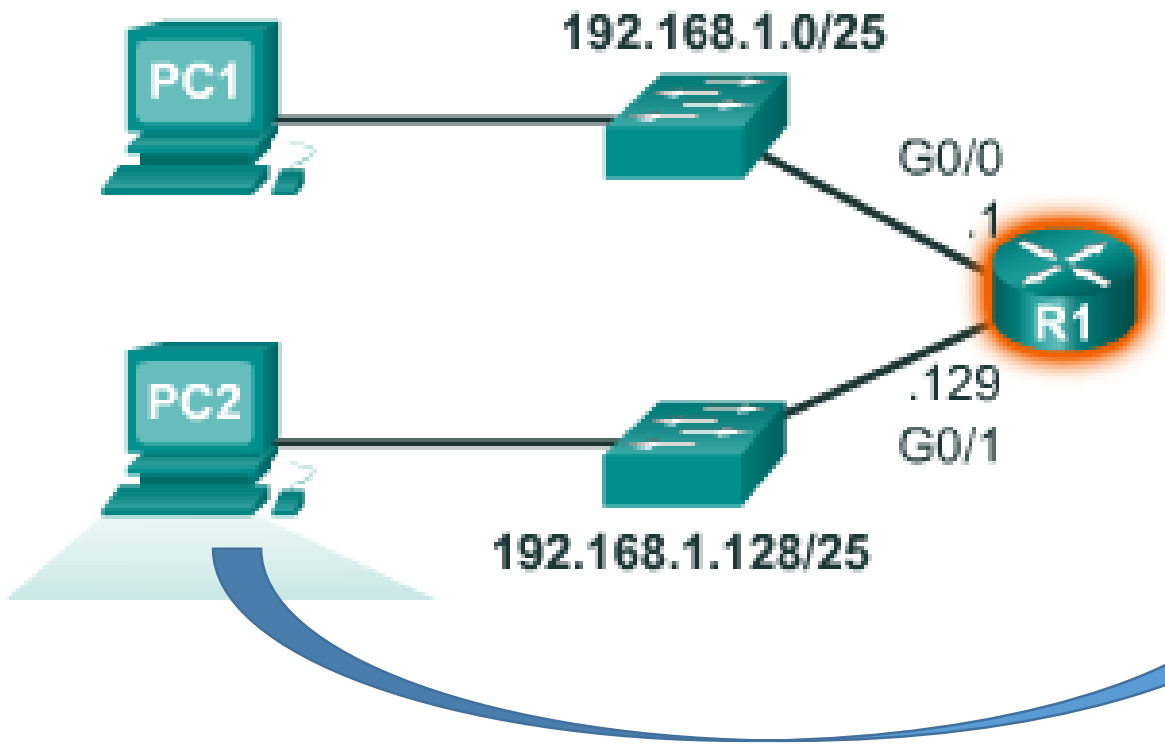
Network Address	192. 168. 1. 0 000 0000	= 192.168.1.0
First Host Address	192. 168. 1. 0 000 0001	= 192.168.1.1
Last Host Address	192. 168. 1. 0 111 1110	= 192.168.1.126
Broadcast Address	192. 168. 1. 0 111 1111	= 192.168.1.127

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

```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ip address 192.168.1.1 255.255.255.128
R1(config-if)#exit
R1(config)#interface gigabitethernet 0/1
R1(config-if)#ip address 192.168.1.129 255.255.255.128
```

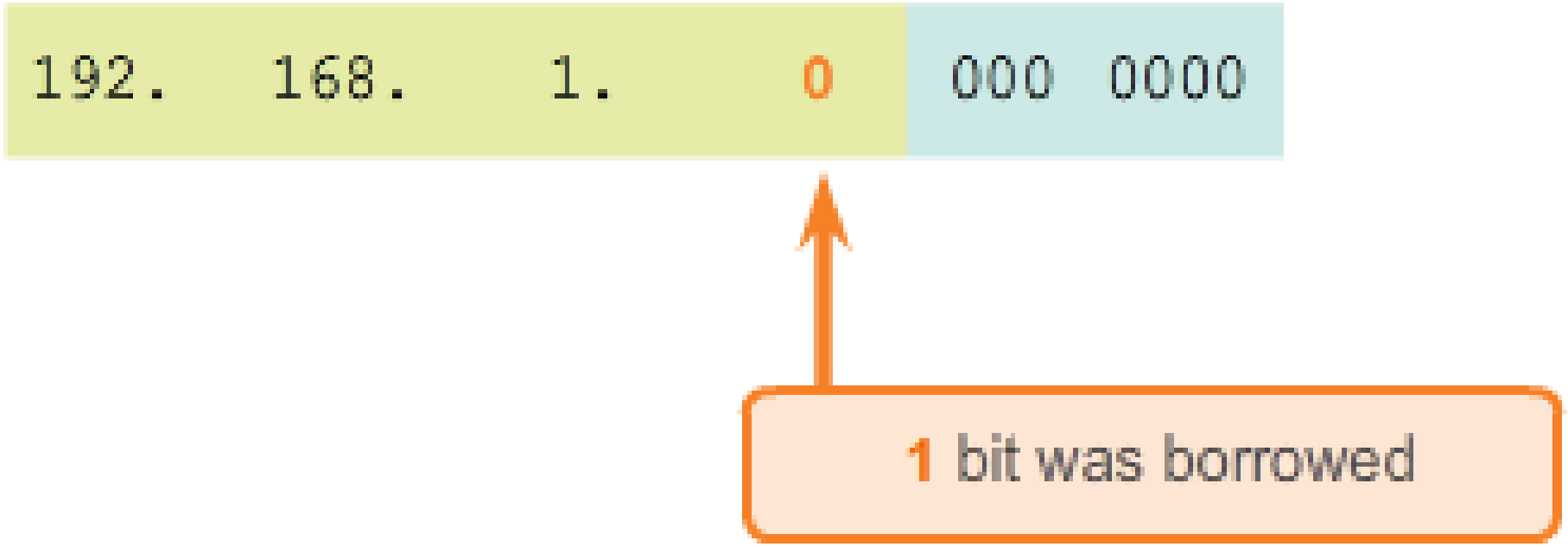
9.1.3.2 Subnets in Use



Network	**192.168.1.128**
Gateway	**192.168.1.129**
PC	**192.168.1.130**
Broadcast	**192.168.1.255**

Calculate Number of Subnets

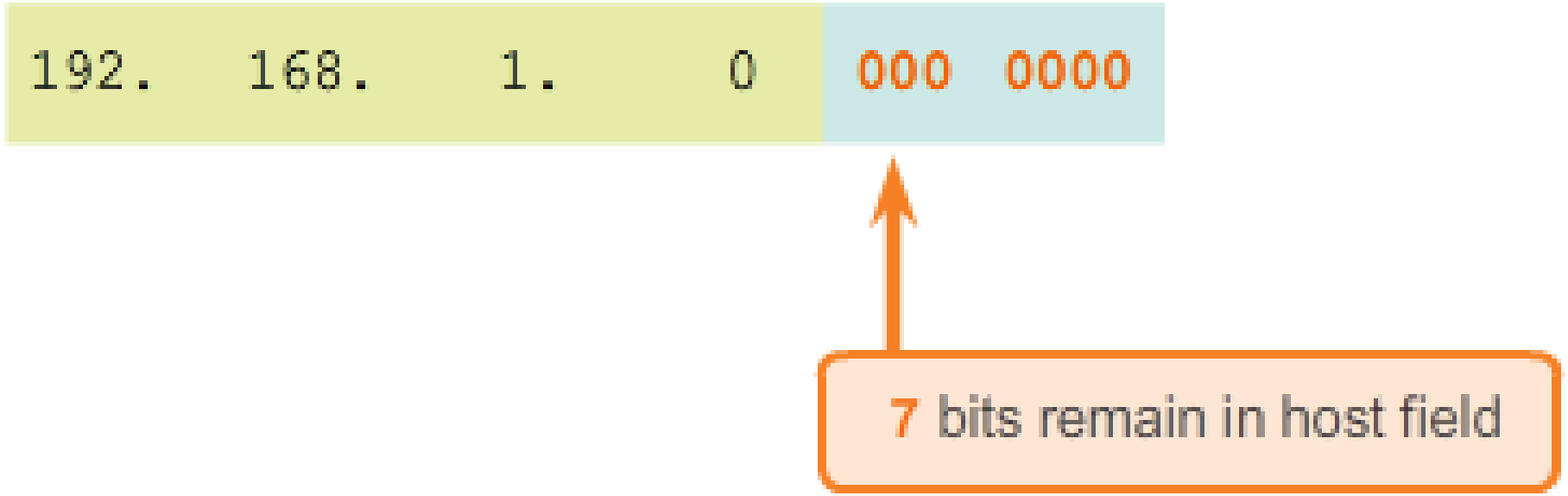
Subnets = 2^n
(where n = bits borrowed)



2^1 = 2 subnets

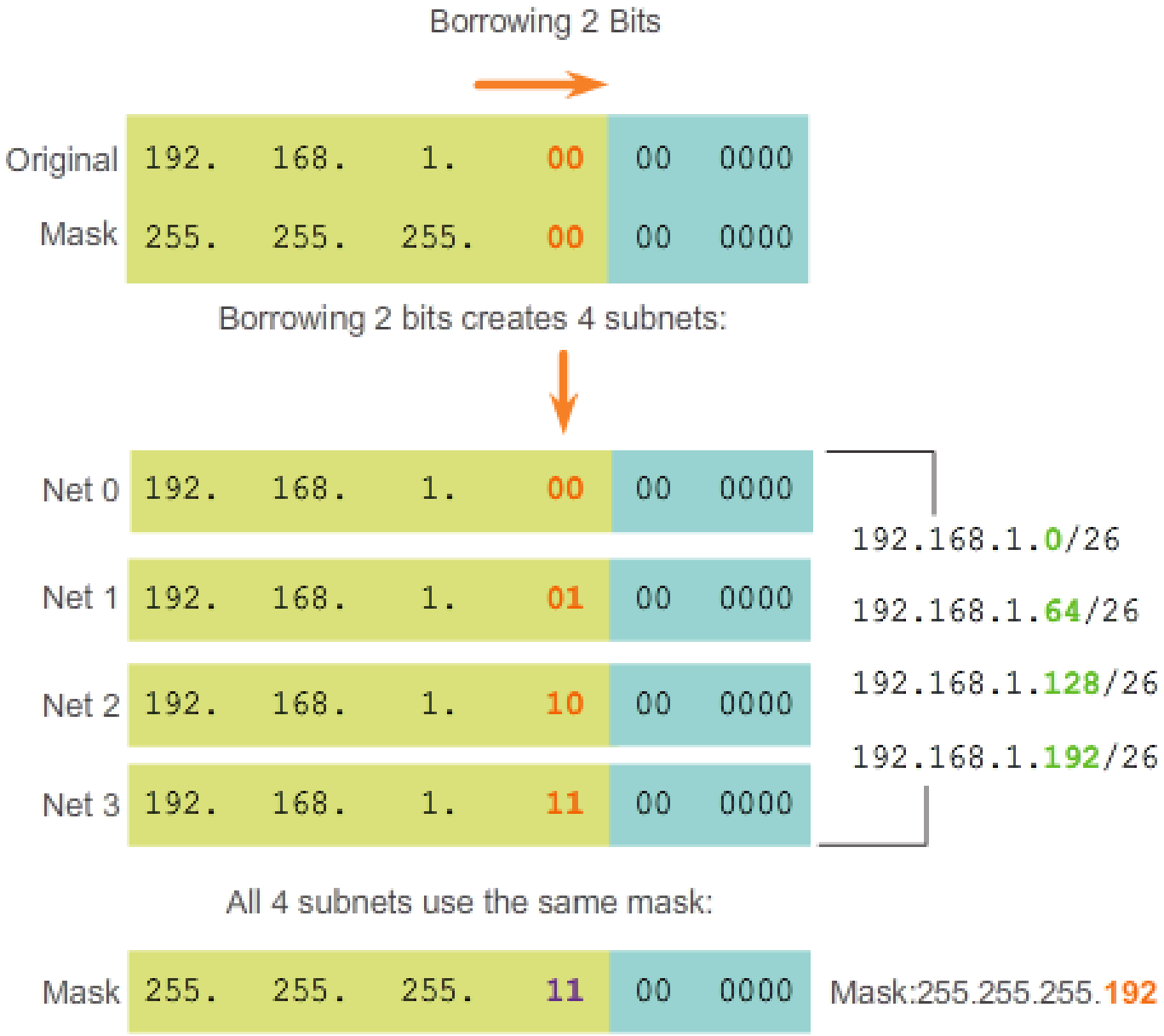
Calculate Number of Hosts

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



2^7 = 128 hosts per subnet
2^7 - 2 = 126 valid hosts per subnet

9.1.3.4 Creating 4 Subnets



Borrow 2 Bits
Count …….. 2 4
Borrowing 2 bits give you 4 subnets

6 Host Bits Remain
Count …. 2 4 8 16 32 64
So you will have 64 addresses on each subnet

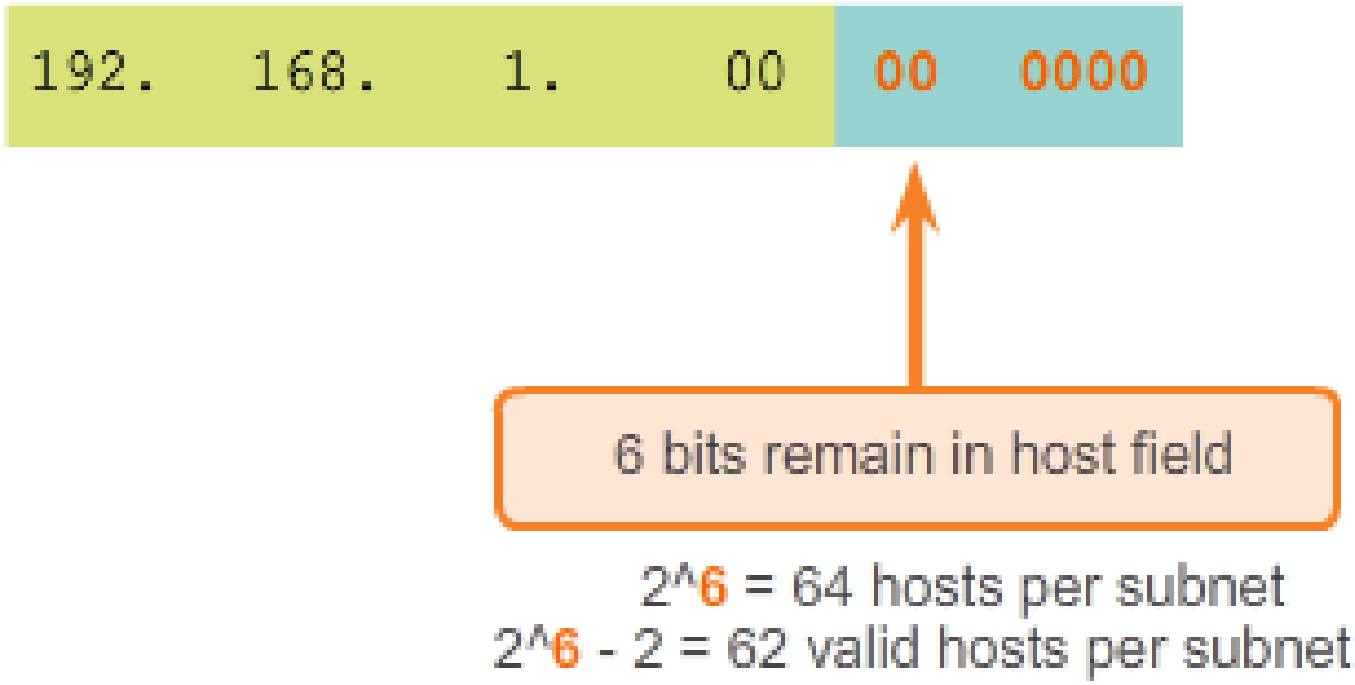
Subnet Mask
Remember you borrowed 2 bits for subnetting
The 128 bit and the 64 bit
128-64-32-16-8-4-2-1
Add them and the result is 192

That is your subnet mask
255.255.255.192

9.1.3.4 Creating 4 Subnets

Calculate Number of Hosts

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



Borrow 2 Bits
Count …….. 2 4
Borrowing 2 bits give you 4 subnets

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Subnet Mask
Remember you borrowed 2 bits for subnetting
The 128 bit and the 64 bit
128-64-32-16-8-4-2-1
Add them and the result is 192

That is your subnet mask
255.255.255.192

9.1.3.4 Creating 4 Subnets

Address Range for 192.168.1.0/26 Subnet

Network Address

192.	168.	1.	00	00	0000	= 192.168.1.0

First Host Address

192.	168.	1.	00	00	0001	= 192.168.1.1

Last Host Address

192.	168.	1.	00	11	1110	= 192.168.1.62

Broadcast Address

192.	168.	1.	00	11	1111	= 192.168.1.63

Borrow 2 Bits
Count …….. 2 4
Borrowing 2 bits give you 4 subnets

6 Host Bits Remain
Count …. 2 4 8 16 32 64
So you will have 64 addresses on each subnet

Subnet Mask
Remember you borrowed 2 bits for subnetting
The 128 bit and the 64 bit
128-64-32-16-8-4-2-1
Add them and the result is 192

That is your subnet mask
255.255.255.192

9.1.3.4 Creating 4 Subnets

Address Ranges Nets 0 - 2

Net 0	Network	192.	168.	1.	00	00	0000	192.168.1.0
	First	192.	168.	1.	00	00	0001	192.168.1.1
	Last	192.	168.	1.	00	11	1110	192.168.1.62
	Broadcast	192.	168.	1.	00	11	1111	192.168.1.63
Net 1	Network	192.	168.	1.	01	00	0000	192.168.1.64
	First	192.	168.	1.	01	00	0001	192.168.1.65
	Last	192.	168.	1.	01	11	1110	192.168.1.126
	Broadcast	192.	168.	1.	01	11	1111	192.168.1.127
Net 2	Network	192.	168.	1.	10	00	0000	192.168.1.128
	First	192.	168.	1.	10	00	0001	192.168.1.129
	Last	192.	168.	1.	10	11	1110	192.168.1.190
	Broadcast	192.	168.	1.	10	11	1111	192.168.1.191

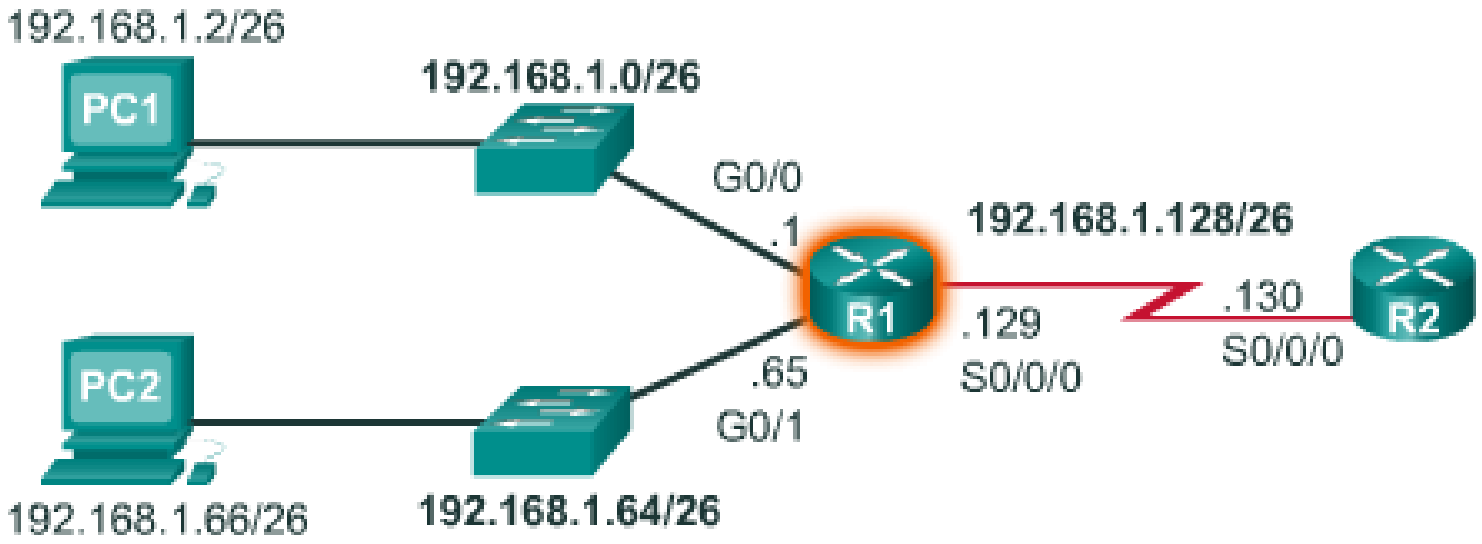
Borrow 2 Bits
Count …….. 2 4
Borrowing 2 bits give you 4 subnets

6 Host Bits Remain
Count …. 2 4 8 16 32 64
So you will have 64 addresses on each subnet

Subnet Mask
Remember you borrowed 2 bits for subnetting
The 128 bit and the 64 bit
128-64-32-16-8-4-2-1
Add them and the result is 192

That is your subnet mask
255.255.255.192

9.1.3.4 Creating 4 Subnets



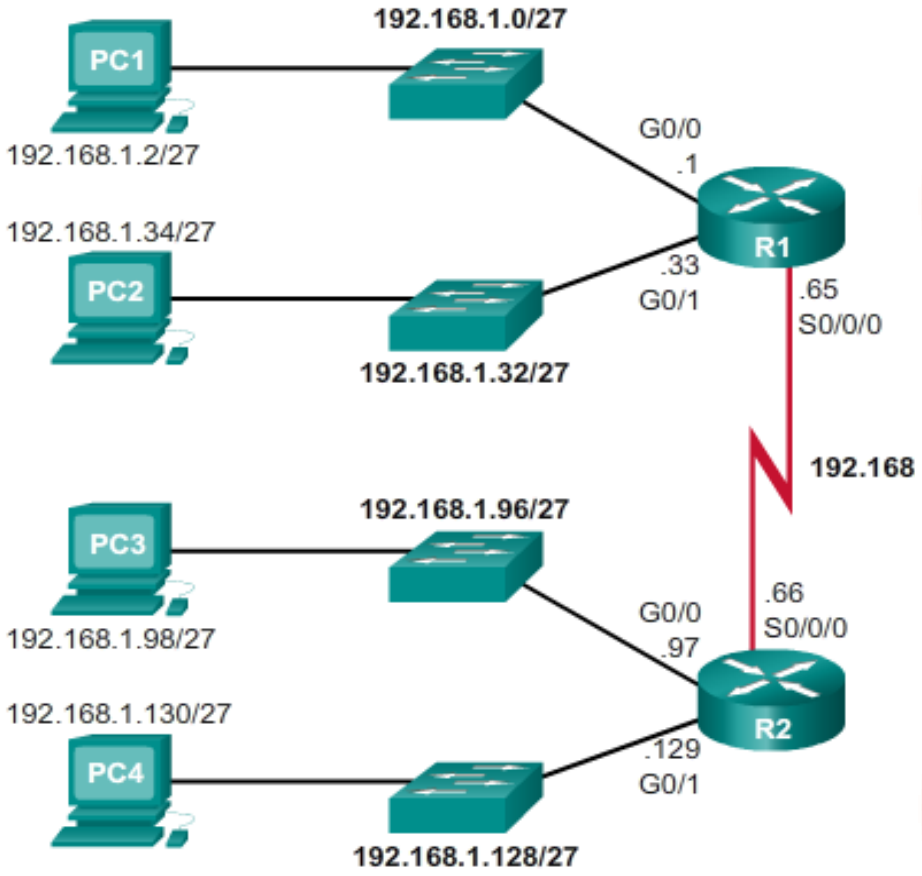

```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ip address 192.168.1.1 255.255.255.192
R1(config-if)#exit
R1(config)#interface gigabitethernet 0/1
R1(config-if)#ip address 192.168.1.65 255.255.255.192
R1(config-if)#exit
R1(config)#interface serial 0/0/0
R1(config-if)#ip address 192.168.1.129 255.255.255.192
```

9.1.3.5 Creating 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.	011	0	0000	192.168.1.96
	First	192.	168.	1.	011	0	0001	192.168.1.97
	Last	192.	168.	1.	011	1	1110	192.168.1.126
	Broadcast	192.	168.	1.	011	1	1111	192.168.1.127
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

9.1.3.5 Creating 8 Subnets

Subnet Allocation



Interface Address Configuration

R1

```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ip address 192.168.1.1 255.255.255.224
R1(config-if)#exit
R1(config)#interface gigabitethernet 0/1
R1(config-if)#ip address 192.168.1.33 255.255.255.224
R1(config-if)#exit
R1(config)#interface serial 0/0/0
R1(config-if)#ip address 192.168.1.65 255.255.255.224
```

R2

```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ip address 192.168.1.97 255.255.255.224
R1(config-if)#exit
R1(config)#interface gigabitethernet 0/1
R1(config-if)#ip address 192.168.1.129 255.255.255.224
R1(config-if)#exit
R1(config)#interface serial 0/0/0
R1(config-if)#ip address 192.168.1.66 255.255.255.224
```

Calculating Class B Subnets

Class B Subnets

You have an address of 185.15.0.0
You need 250 networks
You need 250 hosts

11111111.11111111.11111111.00000000/24

SUBNET 0	SUBNET 1	SUBNET 2
185.15.0.0	185.15.1.0	185.15.2.0
185.15.0.1	185.15.1.1	185.15.2.1
185.15.0.2	185.15.1.2	185.15.2.2
185.15.0.3	185.15.1.3	185.15.2.3
185.15.0.4	185.15.1.4	185.15.2.4
185.15.0.5	185.15.1.5	185.15.2.5
185.15.0.~ 255	185.15.1.~ 255	185.15.2.~ 255

The last address will be 185.15.255.255

Class B Subnets

159.15.0.0 (Class B Address)
10100000.00001111.00000000.00000000

Borrow 6
10100000.00001111.11111100.00000000
Count 2 4 8 16 32 64
64 Subnets

Subnet Mask Add the Bits you borrowed
128+64+32+16+8+4=252
255.255.252.0

Remaining Host Bits = 10
Count 10 bits 2 4 8 16 32 64 128 256 512 1024
1024 addresses on each subnet

Class B Subnets

Problem

- You have 1024 addresses on each subnet
- The largest number you can assign to a host is 255
- How do you number the rest of the hosts?

You have an address of 185.15.0.0
You need at least 60 subnets
You need at least 1000 hosts

11111111.11111111.11111100.00000000/22

Subnet 0
185.15.0.0 to 255
185.15.1.0 to 255
185.15.2.0 to 255
185.15.3.0 to 255

Subnet 1
185.15.4.0 to 255
185.15.5.0 to 255
185.15.6.0 to 255
185.15.7.0 to 255

Subnet 2
185.15.8.0 to 255
185.15.9.0 to 255
185.15.10.0 to 255
185.15.11.0 to 255

Subnet 3
185.15.12.0 to 255
185.15.13.0 to 255
185.15.14.0 to 255
185.15.15.0 to 255

The last address will be 185.15.255.255

Class B Subnets

You have an address of 185.15.0.0
You need at least 30 subnets
You need at least 2000 hosts

11111111.11111111.11111000.00000000/21

Subnet 0	Subnet 1	Subnet 2
185.15.0.0 to 255	185.15.8.0 to 255	185.15.16.0 to 255
185.15.1.0 to 255	185.15.9.0 to 255	185.15.17.0 to 255
185.15.2.0 to 255	185.15.10.0 to 255	185.15.18.0 to 255
185.15.3.0 to 255	185.15.11.0 to 255	185.15.19.0 to 255
185.15.4.0 to 255	185.15.12.0 to 255	185.15.20.0 to 255
185.15.5.0 to 255	185.15.130 to 255	185.15.21.0 to 255
185.15.6.0 to 255	185.15.14.0 to 255	185.15.22.0 to 255
185.15.7.0 to 255	185.15.15.0 to 255	185.15.23.0 to 255

The last address will be 185.15.255.255

Class B Subnets

You have an address of 185.15.0.0
You need at least 10 subnets
You need at least 4000 hosts

11111111.11111111.11110000.00000000/20

Subnet 0	Subnet 0	Subnet 1	Subnet 1
185.15.0.0 to 255	185.15.8.0 to 255	185.15.16.0 to 255	185.15.24.0 to 255
185.15.1.0 to 255	185.15.9.0 to 255	185.15.17.0 to 255	185.15.25.0 to 255
185.15.2.0 to 255	185.15.10.0 to 255	185.15.18.0 to 255	185.15.26.0 to 255
185.15.3.0 to 255	185.15.11.0 to 255	185.15.19.0 to 255	185.15.27.0 to 255
185.15.4.0 to 255	185.15.12.0 to 255	185.15.20.0 to 255	185.15.28.0 to 255
185.15.5.0 to 255	185.15.130 to 255	185.15.21.0 to 255	185.15.29.0 to 255
185.15.6.0 to 255	185.15.14.0 to 255	185.15.22.0 to 255	185.15.30.0 to 255
185.15.7.0 to 255	185.15.15.0 to 255	185.15.23.0 to 255	185.15.31.0 to 255

The last address will be 185.15.255.255

Class B Subnets

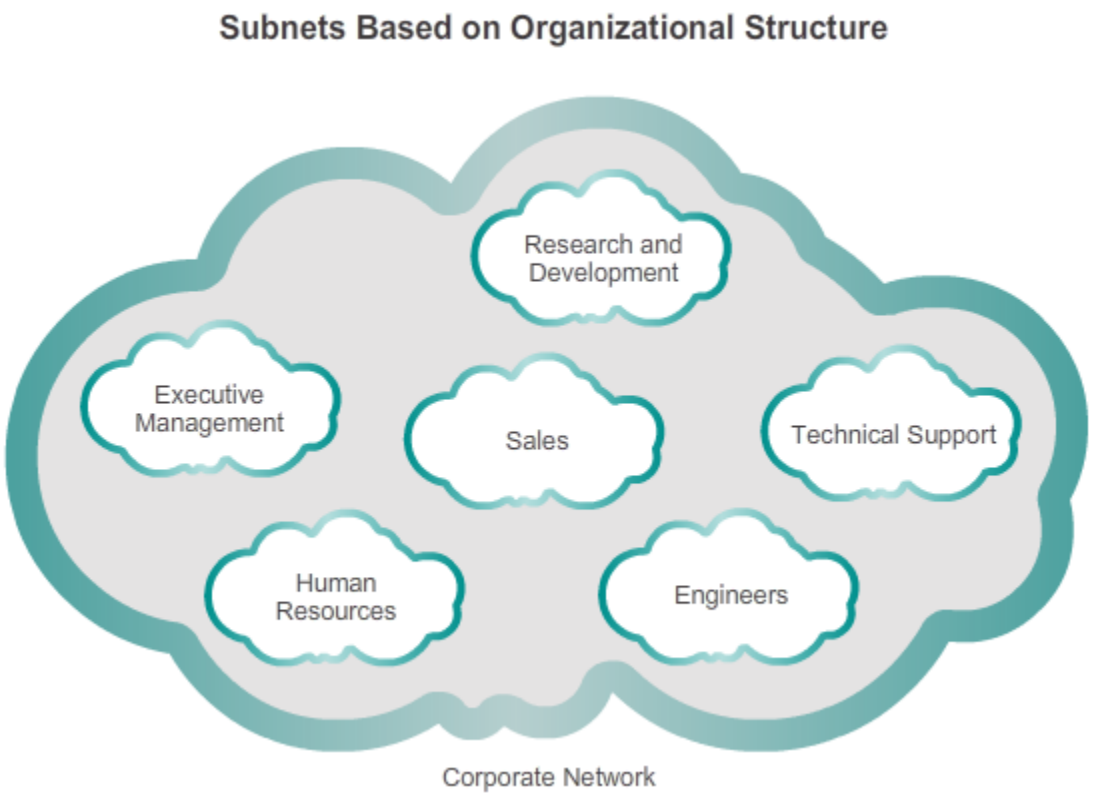
You have an address of 185.15.0.0
You need at least 10 subnets
You need at least 4000 hosts

11111111.11111111.11110000.00000000/20

Subnet 2	Subnet 2
185.15.32.0 to 255	185.15.40.0 to 255
185.15.33.0 to 255	185.15.41.0 to 255
185.15.34.0 to 255	185.15.42.0 to 255
185.15.35.0 to 255	185.15.43.0 to 255
185.15.36.0 to 255	185.15.44.0 to 255
185.15.37.0 to 255	185.15.45.0 to 255
185.15.38.0 to 255	185.15.46.0 to 255
185.15.39.0 to 255	185.15.47.0 to 255

The last address will be 185.15.255.255

9.1.4.2 Subnetting Network-Based Requirements

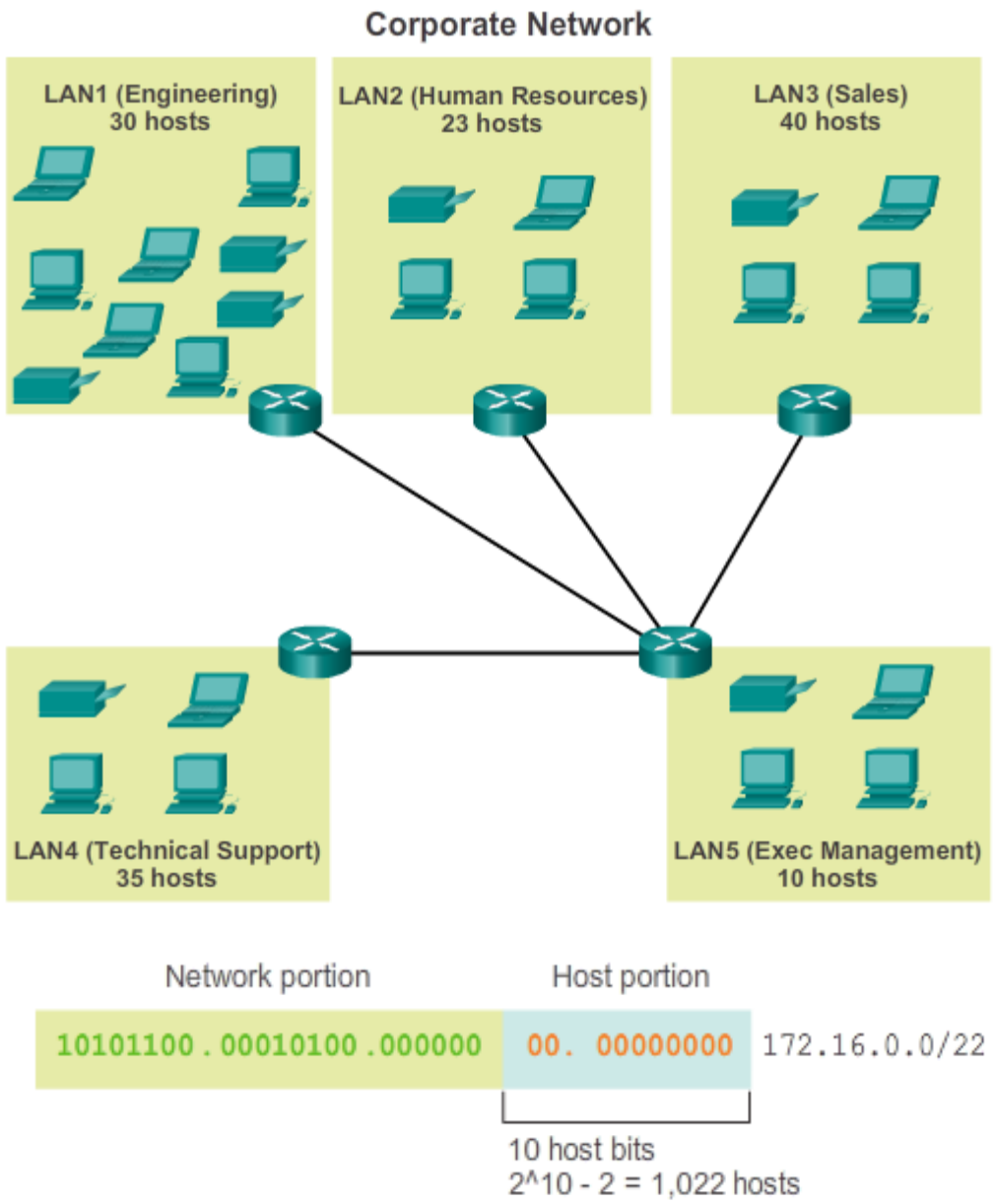


Sometimes a certain number of subnets is required, with less emphasis on the number of host addresses per subnet. This may be the case if an organization chooses to separate their network traffic based on internal structure or department setup. For example, an organization may choose to put all host devices used by employees in the Engineering department in one network, and all host devices used by management in a separate network. In this case, the number of subnets is most important in determining how many bits to borrow.

Recall the number of subnets created when bits are borrowed can be calculated using the formula 2^n (where n is the number of bits borrowed). There is no need to subtract any of the resulting subnets, as they are all usable.

The key is to balance the number of subnets needed and the number of hosts required for the largest subnet. The more bits borrowed to create additional subnets means fewer hosts available per subnet.

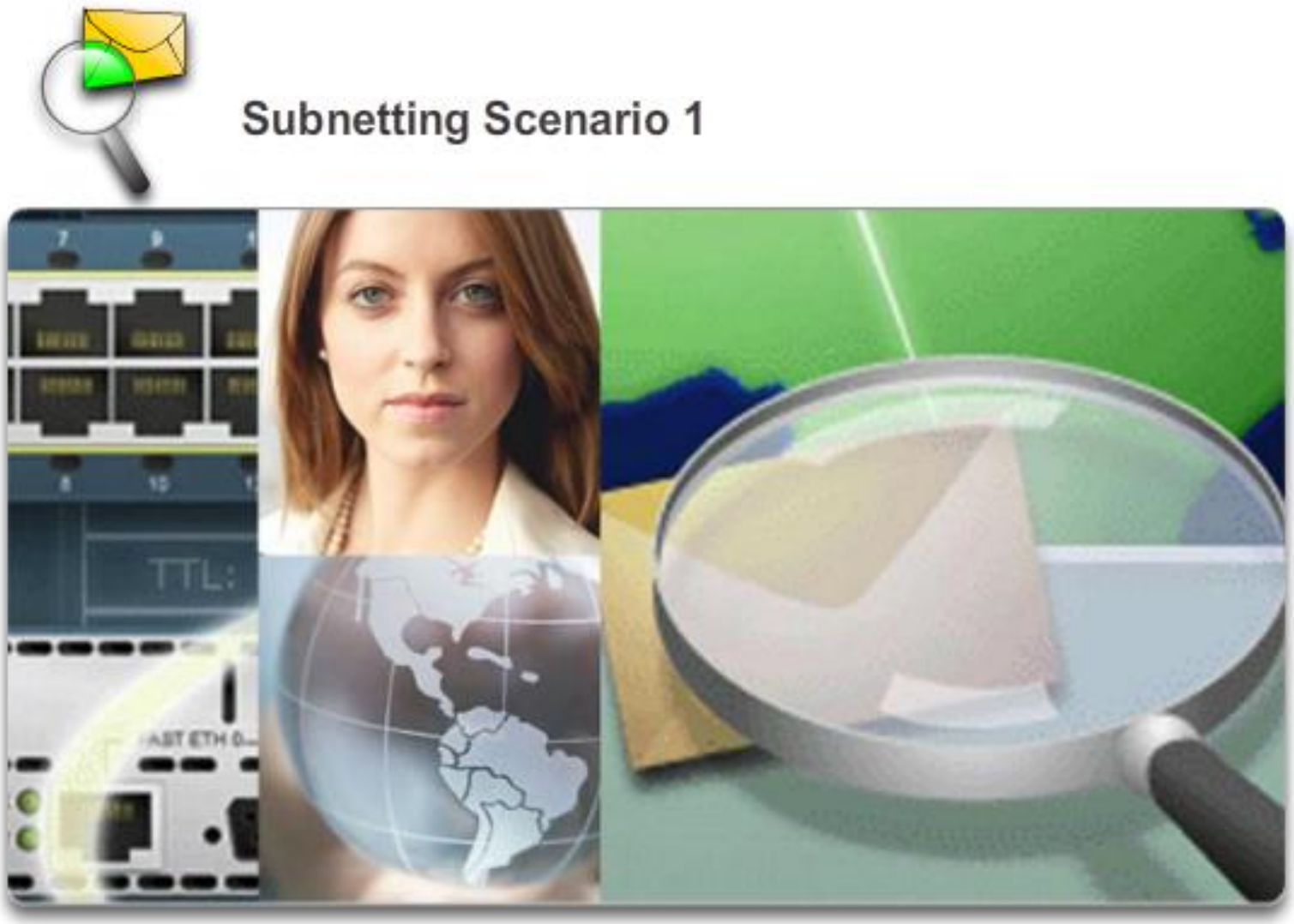
9.1.4.3 Subnetting to Meet Network Requirements



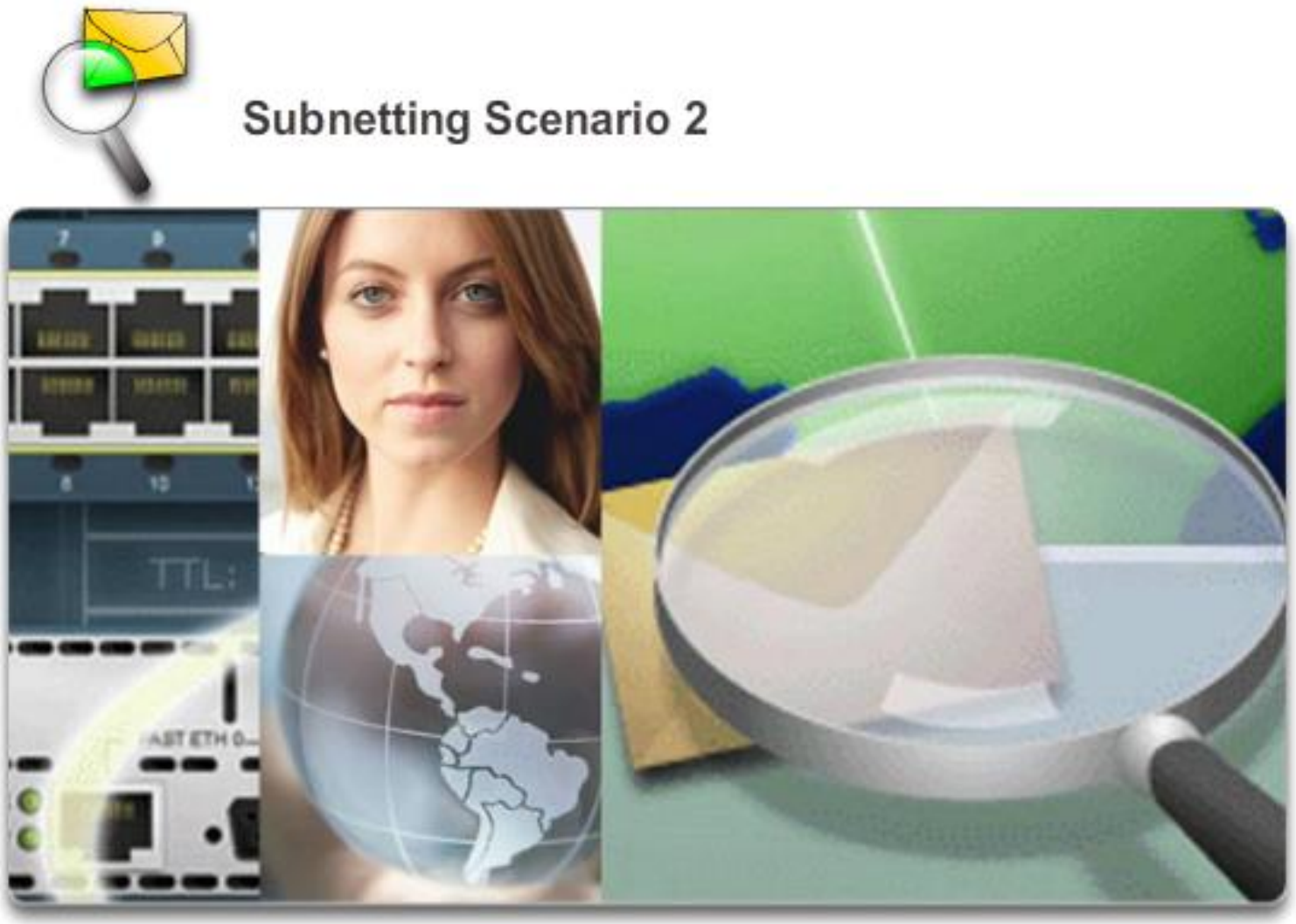
Determine the Total Number of Hosts

- First, consider the total number of hosts required by the entire corporate internetwork. A block of addresses large enough to accommodate all devices in all the corporate networks must be used.
- Consider the example of a corporate internetwork that must accommodate a total of 138 hosts in its five locations (see Figure 1). In this example, the service provider has allocated a network address of 172.16.0.0/22 (10 host bits). As shown in Figure 2, this will provide 1,022 host addresses, which will more than accommodate the addressing needs for this internetwork.

9.1.4.6 Packet Tracer - Subnetting Scenario 1

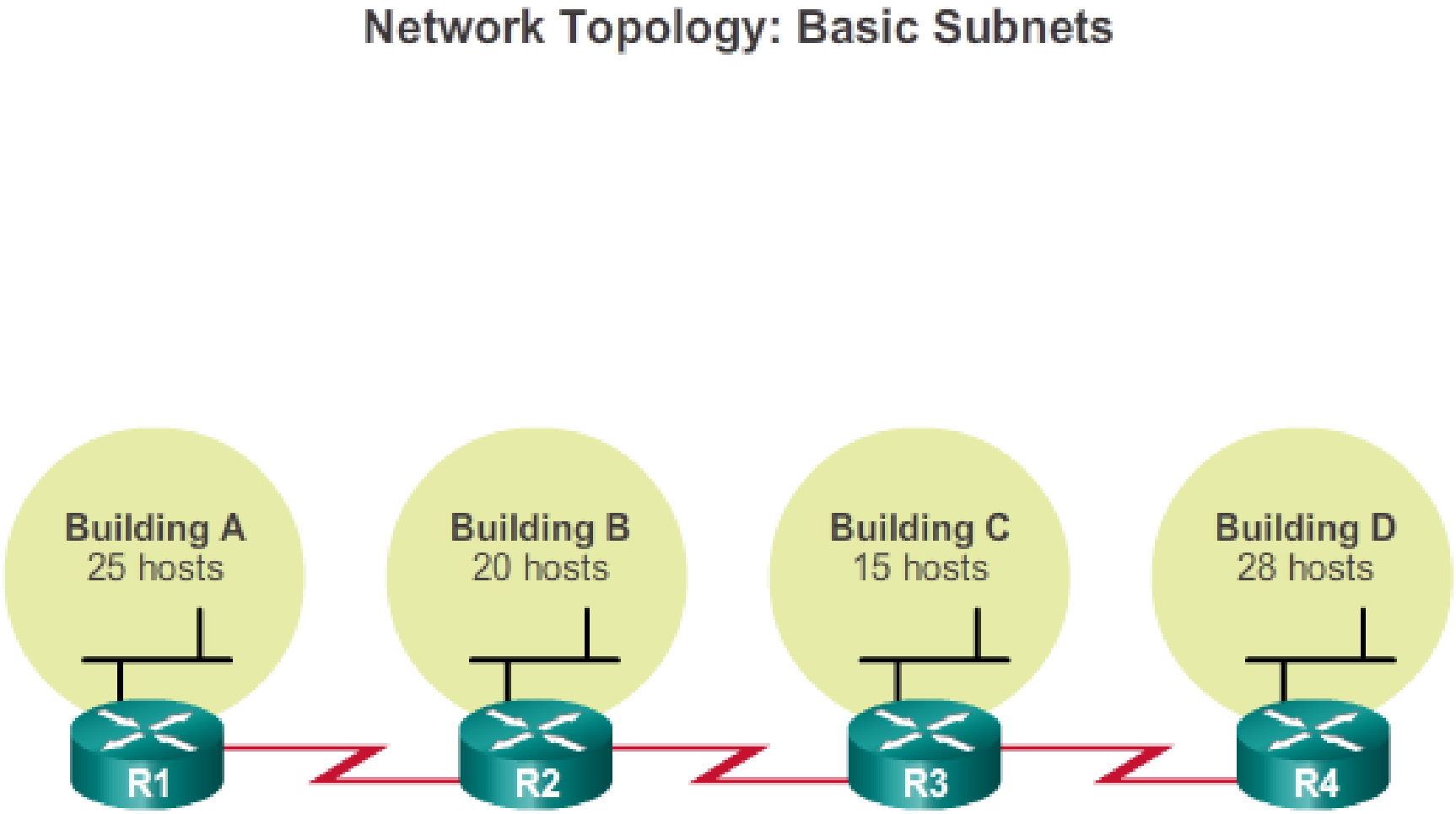


9.1.4.7 Packet Tracer - Subnetting Scenario 2

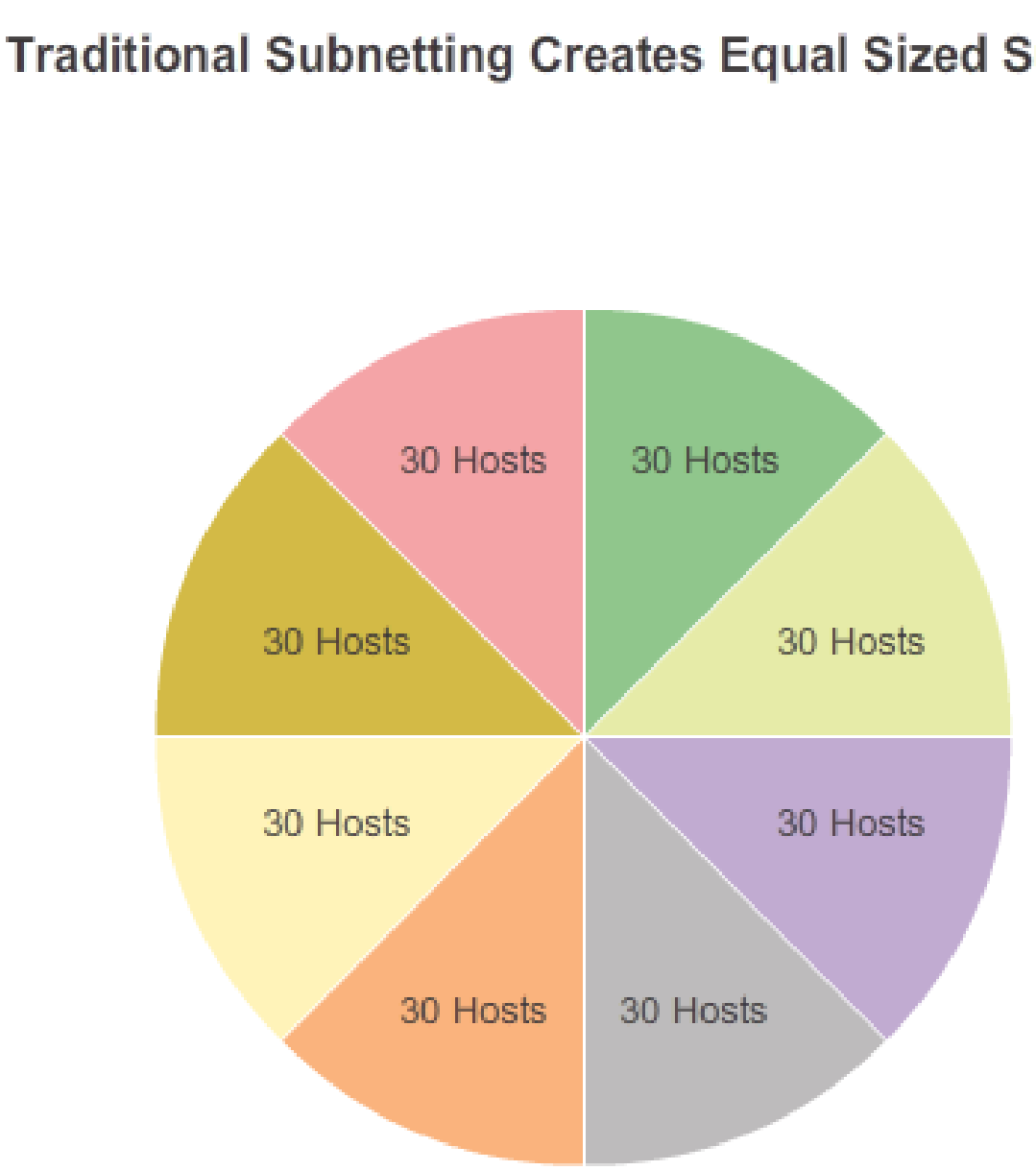


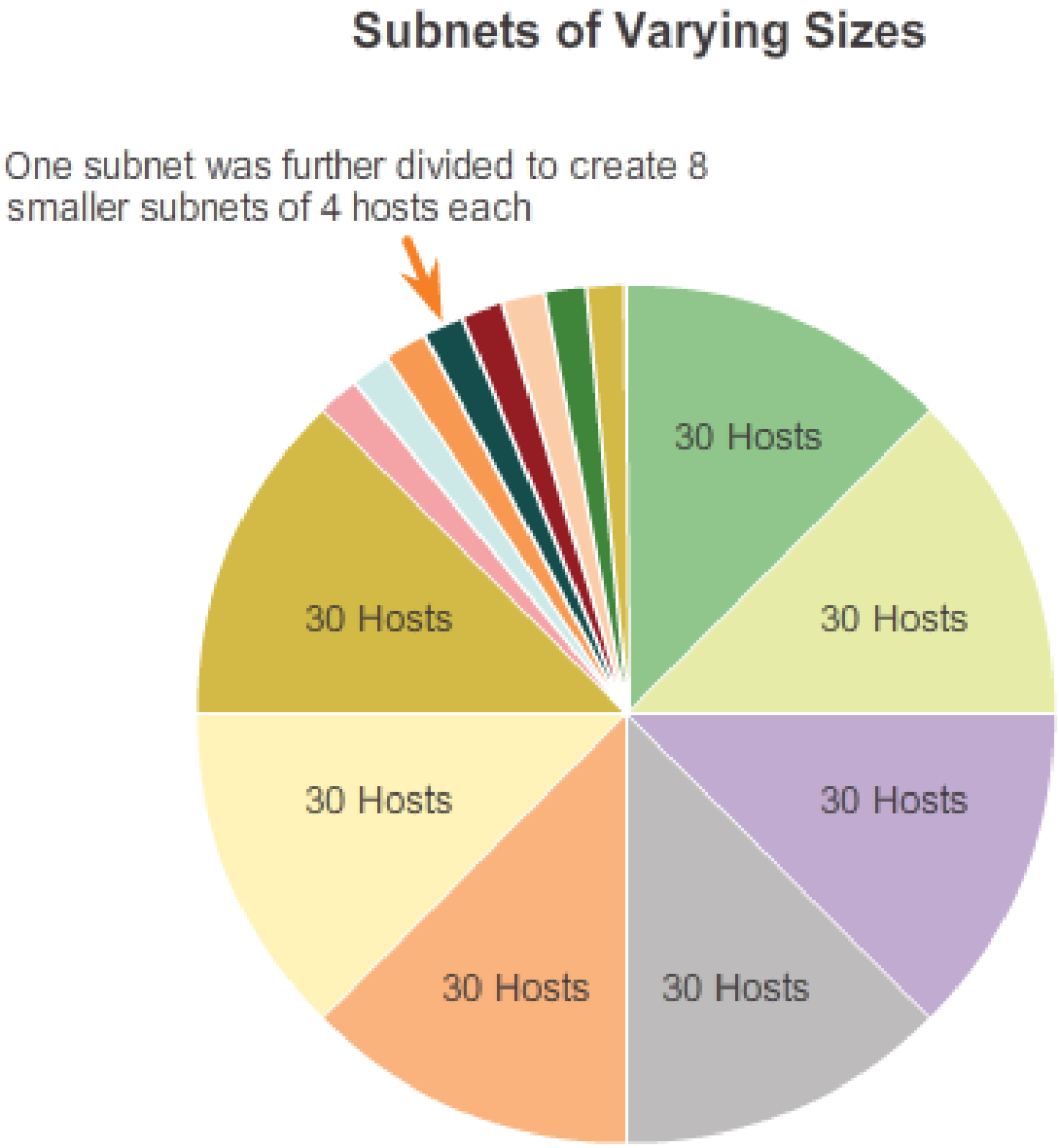
VLSM
Variable Length Subnet Mask

9.1.5.1 Traditional Subnetting Wastes Addresses

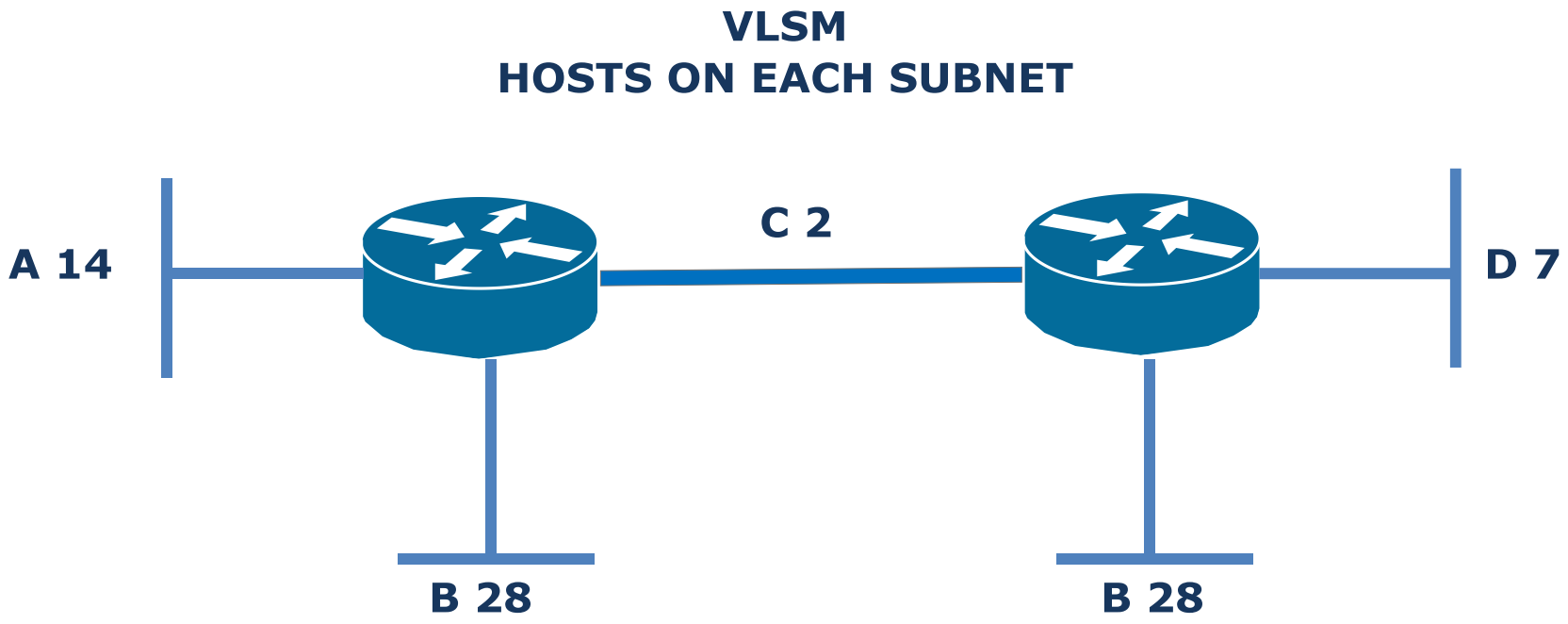


9.1.5.2 Variable Length Subnet Masks (VLSM)





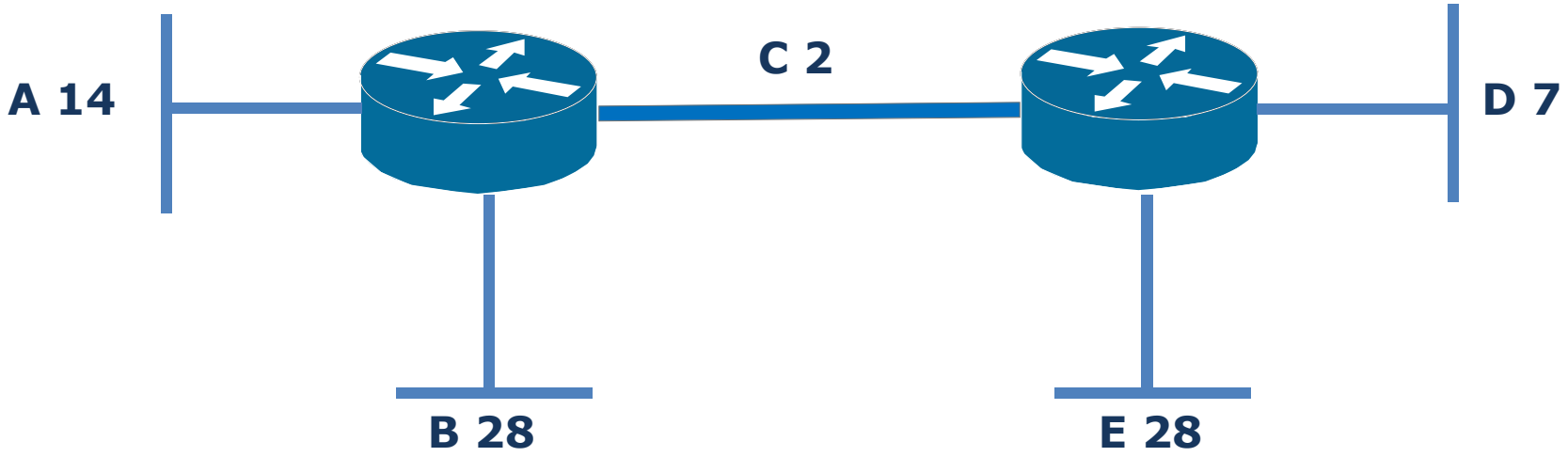
VLSM



NNNNNNNN.NNNNNNNN.NNNNNNNN.NNNHHHHH

- Using Classful addressing we would borrow 3 bits for the networks which would give us 8 subnets (we only need 5)
- The remaining 5 bits would be turned into host addresses giving us 32 addresses on each subnet
- This is a waist of addresses because we do not need 32 address on each subnet

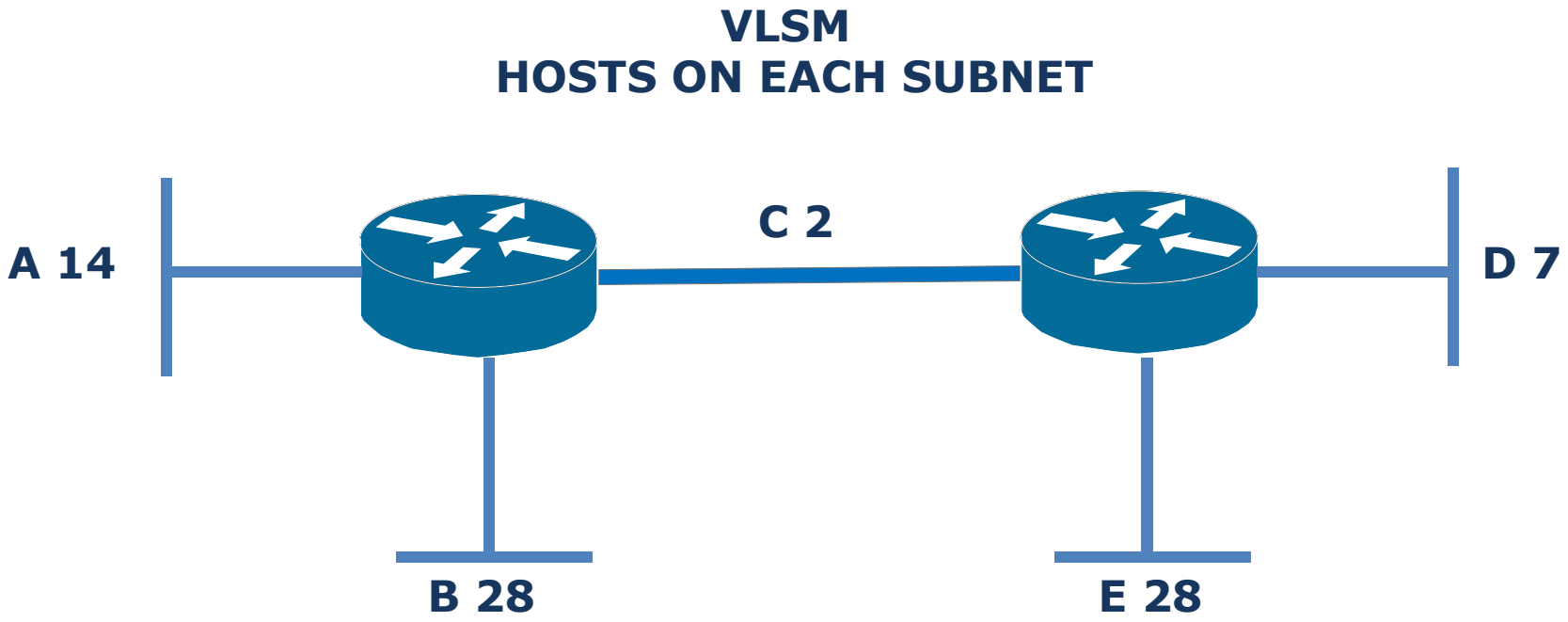
VLSM
HOSTS ON EACH SUBNET



NNNNNNNN.NNNNNNNN.NNNNNNNN.HHHHHHHH

A: must support 14 hosts
B: must support 28 hosts
C: must support 2 hosts
D: must support 7 hosts
E: must support 28 host

VLSM

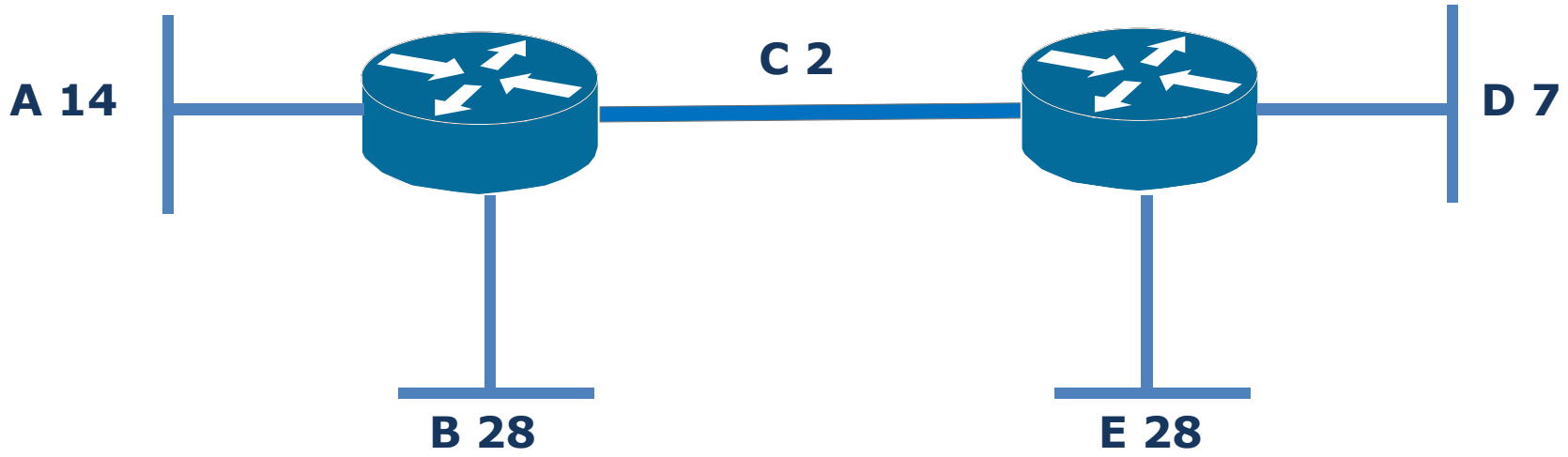


NNNNNNNN.NNNNNNNN.NNNNNNNN.HHHHHHHH

A: /28 (255.255.255.240) mask to support 14 hosts
B: /27 (255.255.255.224) mask to support 28 hosts
C: /30 (255.255.255.252) mask to support 2 hosts
D*: /28 (255.255.255.240) mask to support 7 hosts
E: /27 (255.255.255.224) mask to support 28 hosts

VLSM

VLSM
HOSTS ON EACH SUBNET



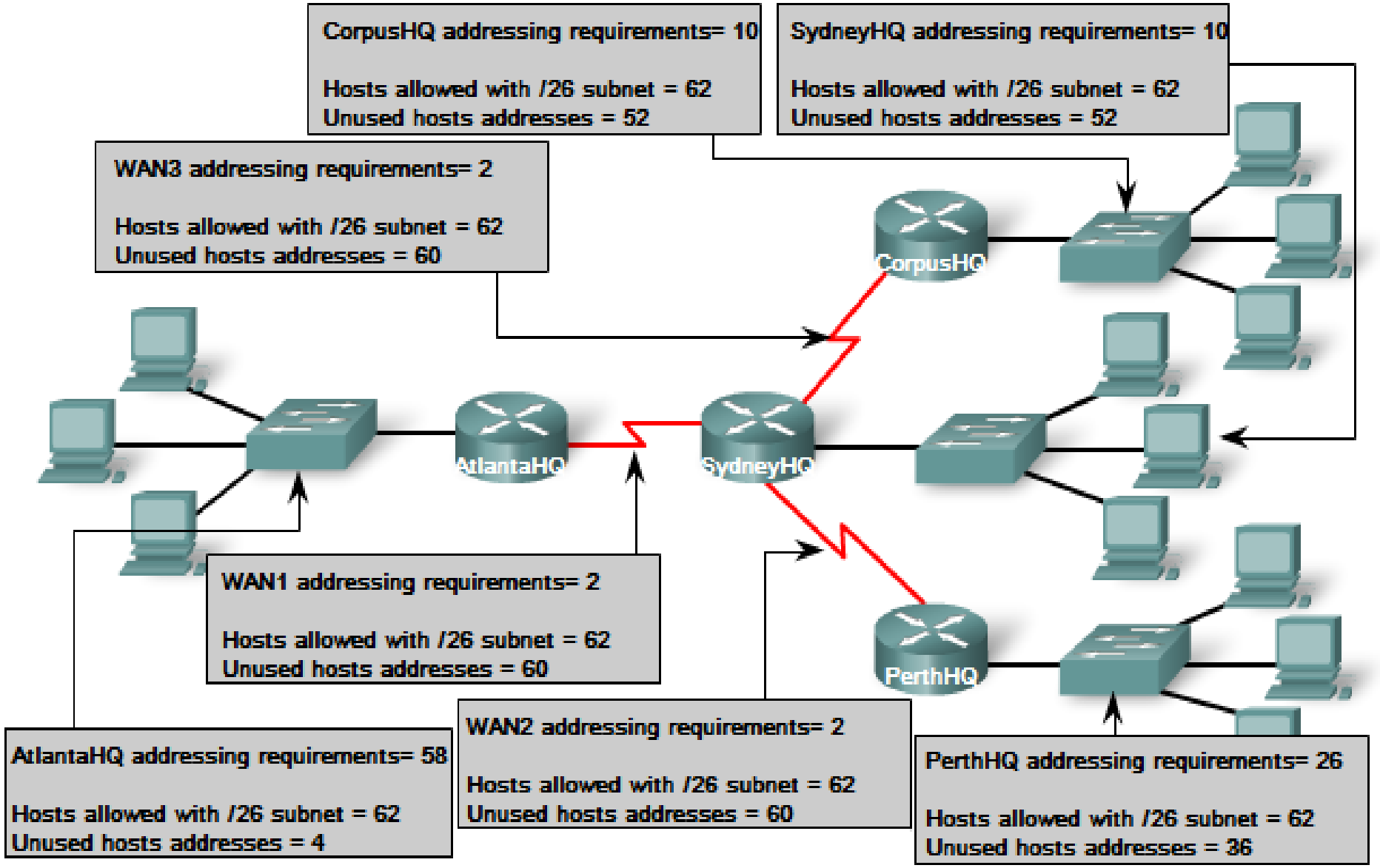
NNNNNNNN.NNNNNNNN.NNNNNNNN.HHHHHHHH

B: 204.15.5.0/27 host address range 1 to 30
E: 204.15.5.32/27 host address range 33 to 62
A: 204.15.5.64/28 host address range 65 to 78
D: 204.15.5.80/28 host address range 81 to 94
C: 204.15.5.96/30 host address range 97 to 98

NNNHHHHH
NNNHHHHH
NNNNHHHH
NNNNHHHH
NNNNNNHH

VLSM

Network Requirements: Using standard subnetting would be inefficient.



VLSM

	Actual Requirements	Total Wasted Addresses
AtlantaHQ	58 host addresses	4 addresses
PerthHQ	26 host addresses	36 addresses
SydneyHQ	10 host addresses	52 addresses
CorpusHQ	10 host addresses	52 addresses
WAN links	2 host addresses (each)	60 addresses

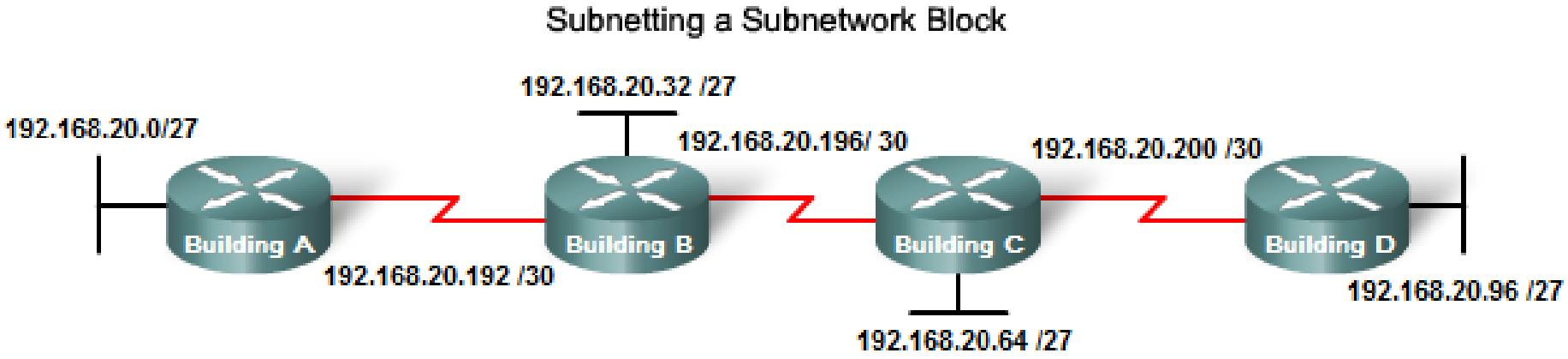
VLSM

Name-required addresses	Subnet address	Address range	Broadcast Address	Network/prefix
AtlantaHQ - 58	192.168.15.0	.1 - .62	.63	192.168.15.0 /26
PerthHQ - 28	192.168.15.64	.65 - .94	.95	192.168.15.64 /27
SydneyHQ - 10	192.168.15.96	.97 - .110	.111	192.168.15.96 /28
CorpusHQ - 10	192.168.15.112	.113 - .126	.127	192.168.15.112 /28
WAN1 - 2	192.168.15.128	.129 - .130	.131	192.168.15.128 /30
WAN2 - 2	192.168.15.132	.133 - 134	.135	192.168.15.132 /30
WAN3 - 2	192.168.15.136	.137 - .138	.139	192.168.15.136 /30

The networking problem is solved

NNNNNNNN.NNNNNNNN.NNNNNNNN.HHHHHHHH

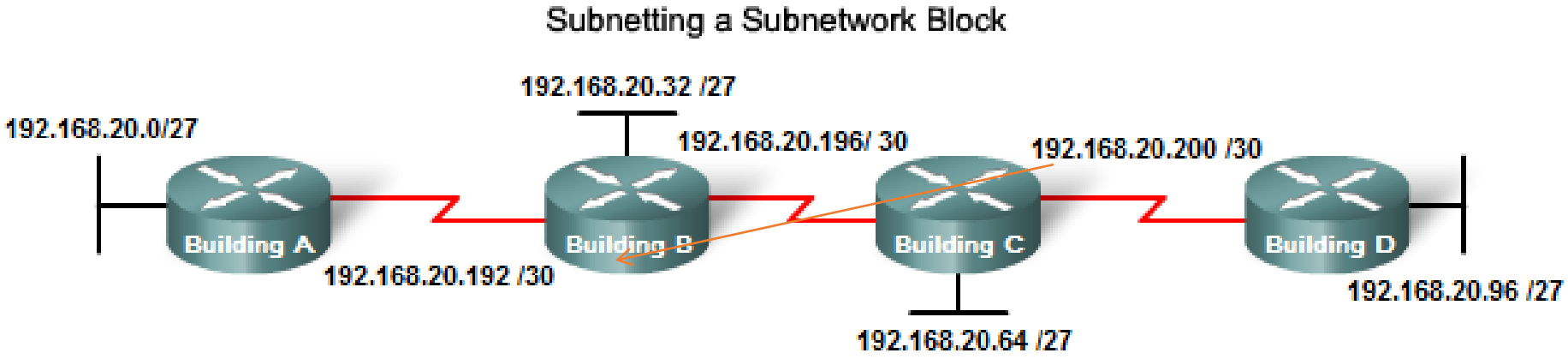
VLSM



Subnet Number	Subnet Address
Subnet 0	192.168.20.0/27
Subnet 1	192.168.20.32/27
Subnet 2	192.168.20.64/27
Subnet 3	192.168.20.96/27
Subnet 4	192.168.20.128/27
Subnet 5	192.168.20.160/27
Subnet 6	192.168.20.192/27
Subnet 7	192.168.20.224/27

NNNNNNNN.NNNNNNNN.NNNNNNNN.HHHHHHHH

VLSM



Subnet Number	Subnet Address
Subnet 0	192.168.20.0/27
Subnet 1	192.168.20.32/27
Subnet 2	192.168.20.64/27
Subnet 3	192.168.20.96/27
Subnet 4	192.168.20.128/27
Subnet 5	192.168.20.160/27
Subnet 6	192.168.20.192/27
Subnet 7	192.168.20.224/27

Subnet Number	Subnet Address
Subnet 0	192.168.20.192/30
Subnet 1	192.168.20.196/30
Subnet 2	192.168.20.200/30
Subnet 3	192.168.20.204/30
Subnet 4	192.168.20.208/30
Subnet 5	192.168.20.212/30
Subnet 6	192.168.20.216/30
Subnet 7	192.168.20.220/30

NNNNNNNN.NNNNNNNN.NNNNNNNN.HHHHHHHH

Thanks for your attention!!