REDES DE COMPUTADORES

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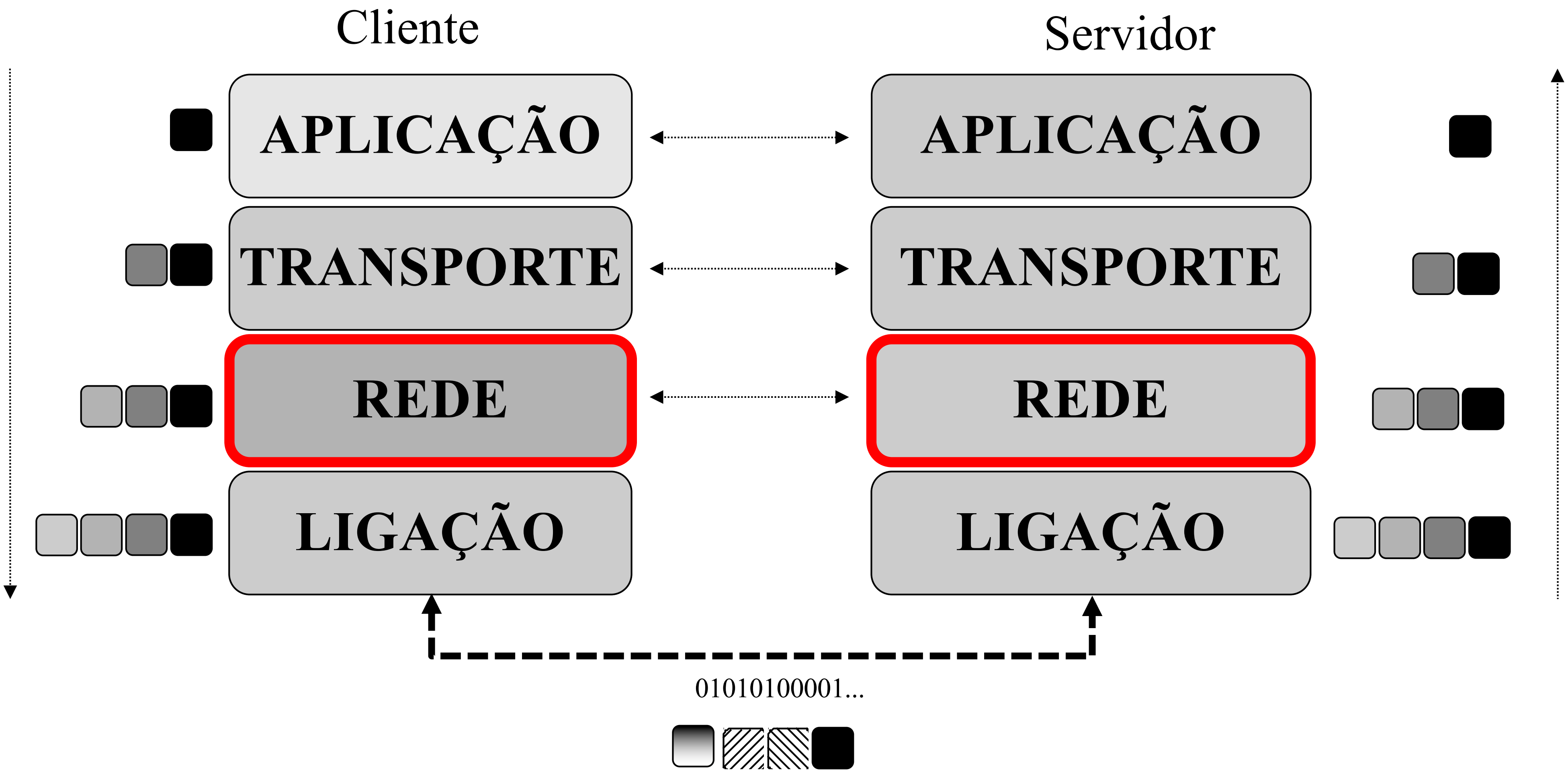
Chapter 6

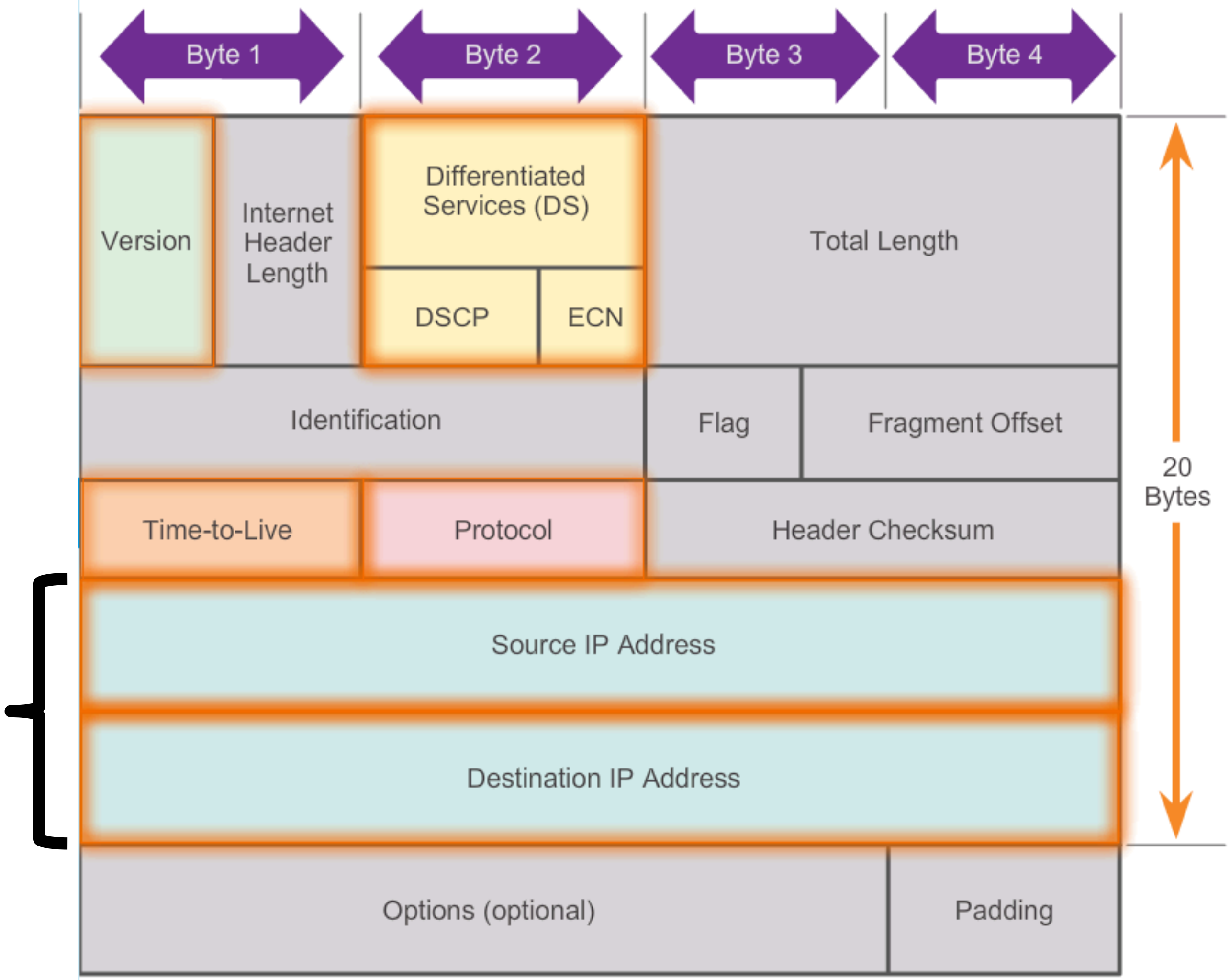
REVISÃO

Modelo de comunicação TCP/IP



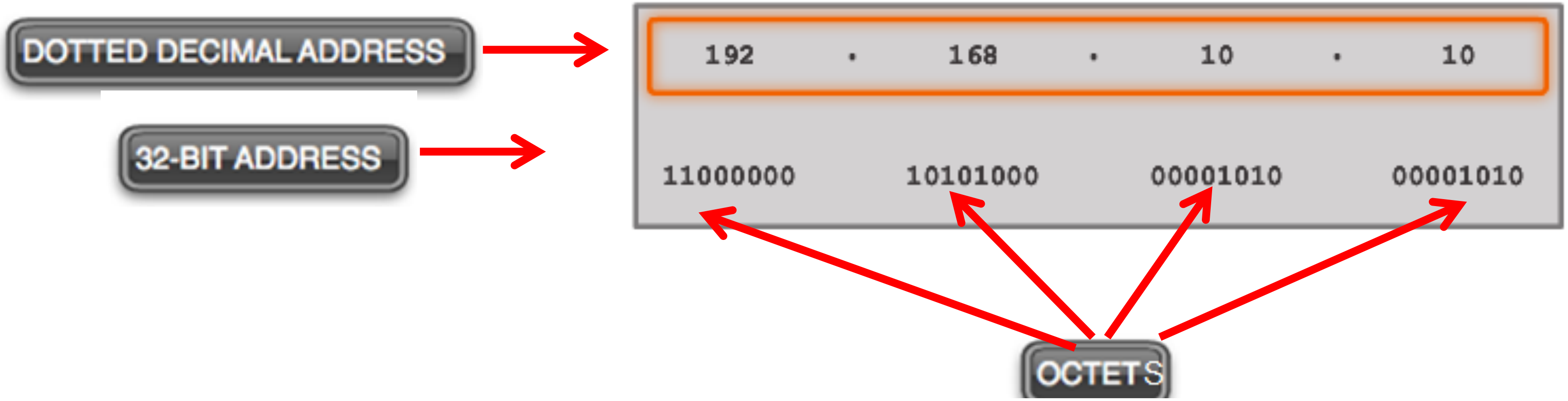
IPv4 Packet Header

Contents of the IPv4 packet header



IPv4 Address Structure

Binary Number System



Radix	2	2	2	2	2	2	2	2
Exponent	7	6	5	4	3	2	1	0
Octet Bit Values	128	64	32	16	8	4	2	1
Binary Address	1	1	0	0	0	0	0	0
Binary Bit Values	128	64	0	0	0	0	0	0

Add the binary bit values. 128 + 64 = 192

Converting a Binary Address to Decimal

Practice

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1
1	0	1	1	0	0	0	0

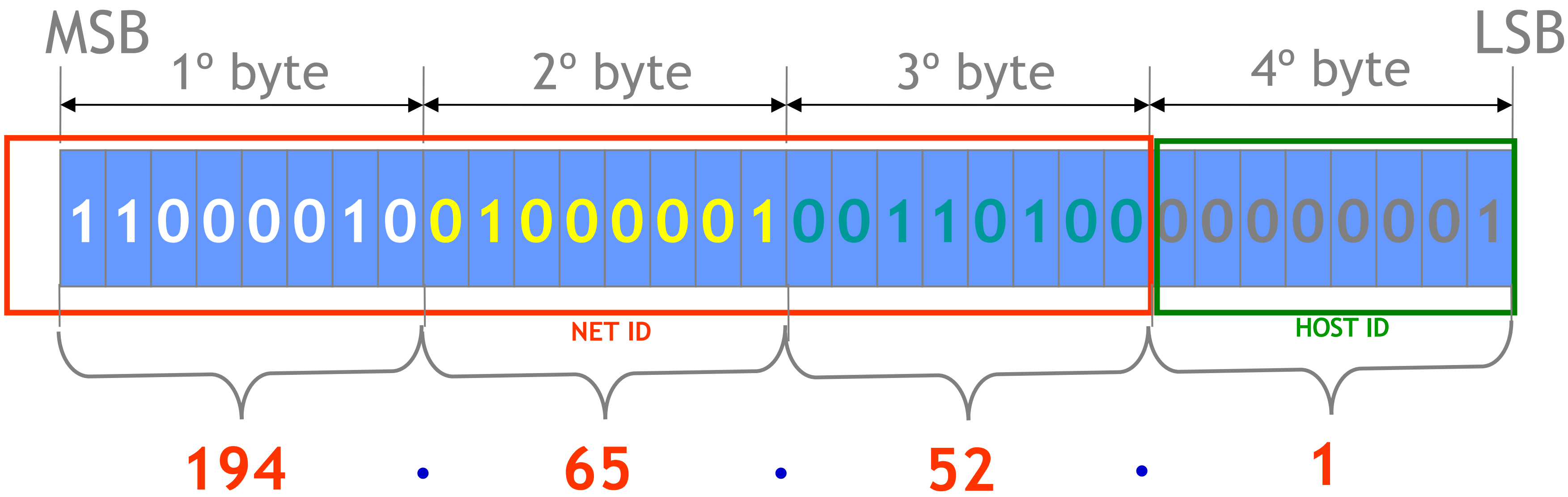
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1
1	1	1	1	1	1	1	1

?

Binary	128	64	32	16	8	4	2	1	Decimal
11001100	1	1	0	0	1	1	0	0	128+64+8+4 = 204
10101010									
11100011									
10110011									
00110101									

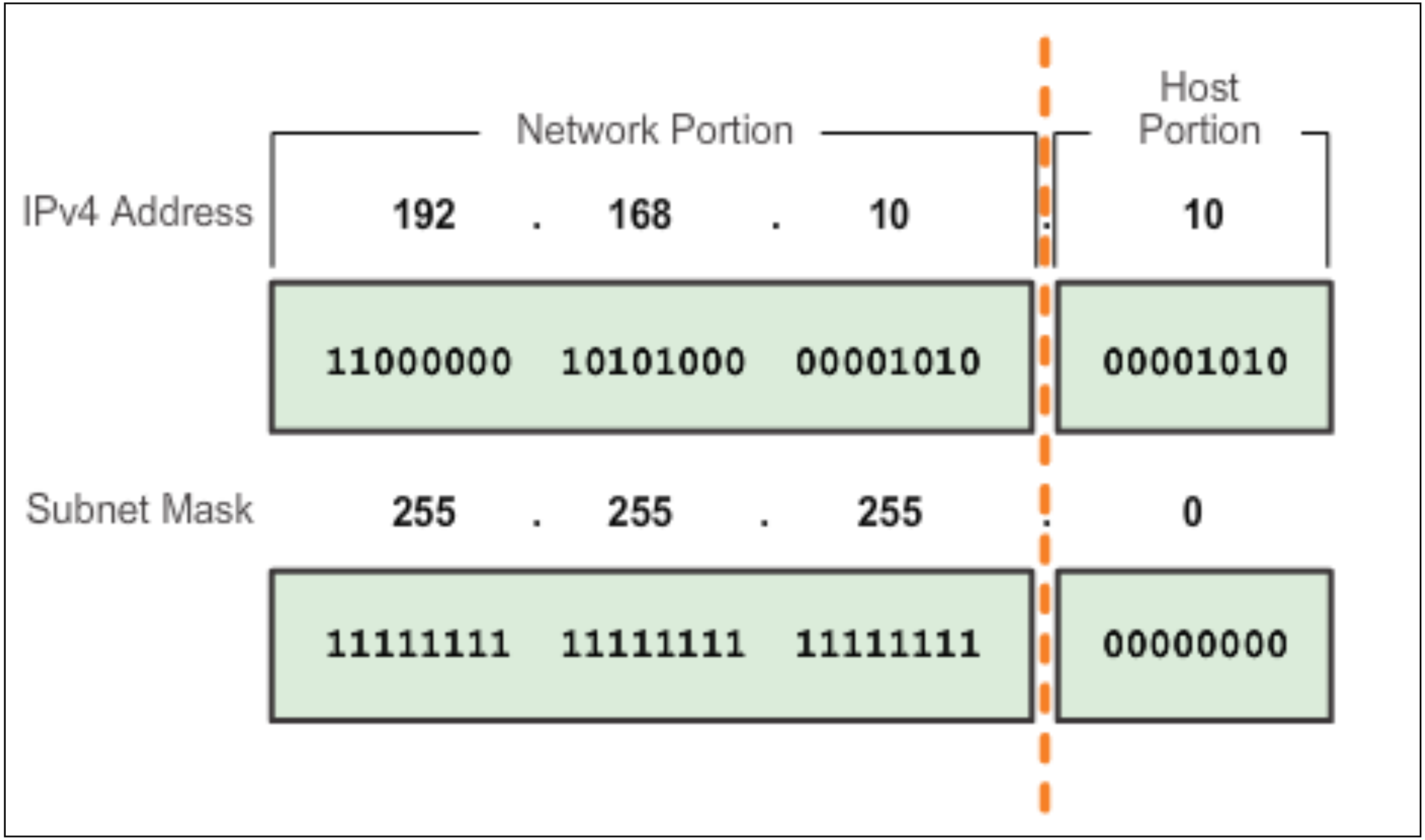
Decimal	128	64	32	16	8	4	2	1	Binary
48	0	0	1	1	0	0	0	0	$48=32+16=00110000_2$
222									
119									
135									
60									

“dotted decimal” notation



IPv4 Subnet Mask

Network Portion and Host Portion of an IPv4 Address



IPv4 Subnet Mask
Examining the Prefix Length

	Dotted Decimal	Significant bits shown in binary
Network Address	**10.1.1.0/24**	**10.1.1.00000000**
First Host Address	10.1.1.1	**10.1.1.00000001**
Last Host Address	10.1.1.254	**10.1.1.11111110**
Broadcast Address	10.1.1.255	**10.1.1.11111111**
Number of hosts: 2^8 – 2 = 254 hosts		

Network Address	**10.1.1.0/25**	**10.1.1.00000000**
First Host Address	10.1.1.1	**10.1.1.00000001**
Last Host Address	10.1.1.126	**10.1.1.01111110**
Broadcast Address	10.1.1.127	**10.1.1.01111111**
Number of hosts: 2^7 – 2 = 126 hosts		

Network Address	**10.1.1.0/26**	**10.1.1.00000000**
First Host Address	10.1.1.1	**10.1.1.00000001**
Last Host Address	10.1.1.62	**10.1.1.00111110**
Broadcast Address	10.1.1.63	**10.1.1.00111111**
Number of hosts: 2^6 – 2 = 62 hosts		

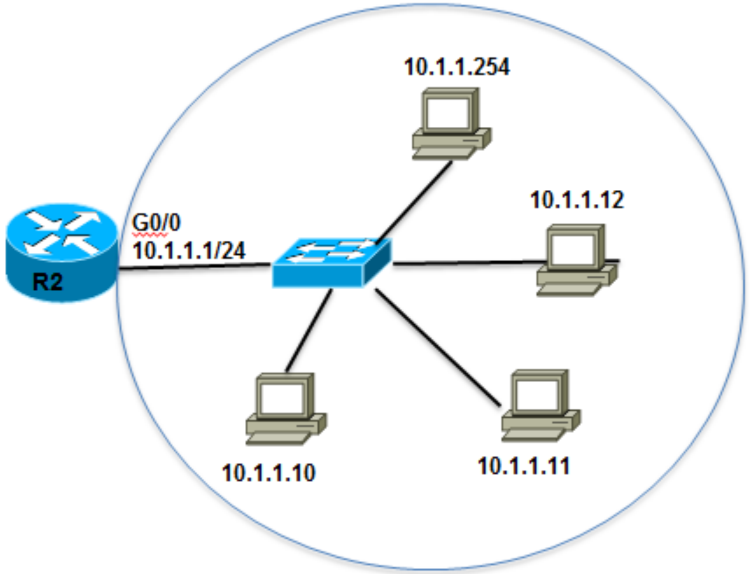
IPv4 Subnet Mask

Examining the Prefix Length (cont.)

	Dotted Decimal	Significant bits shown in binary
Network Address	**10.1.1.0/27**	**10.1.1.00000000**
First Host Address	10.1.1.1	10.1.1.00000001
Last Host Address	10.1.1.30	10.1.1.00011110
Broadcast Address	10.1.1.31	10.1.1.00011111
Number of hosts: 2^5 – 2 = 30 hosts		

Network Address	**10.1.1.0/28**	**10.1.1.00000000**
First Host Address	10.1.1.1	10.1.1.00000001
Last Host Address	10.1.1.14	10.1.1.00001110
Broadcast Address	10.1.1.15	10.1.1.00001111
Number of hosts: 2^4 – 2 = 14 hosts		

IPv4 Network, Host, and Broadcast Address

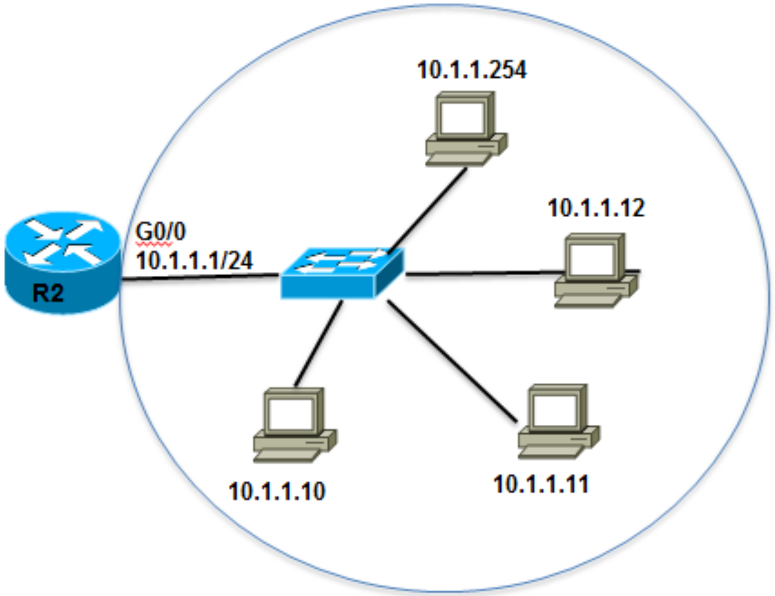


10.1.1.0/24

Network Portion			Host Portion	
10	1	1	0	
00001010	00000001	00000001	00000000	All 0s – NETWORK ADDRESS
10	1	1	10	
00001010	00000001	00000001	00001010	0s and 1s in host portion
10	1	1	255	
00001010	00000001	00000001	11111111	All 1s – BROADCAST ADDRESS

IPv4 Subnet Mask

First Host and Last Host Addresses



10.1.1.0/24

Network Portion			Host Portion	
10	1	1	1	FIRST HOST
00001010	00000001	00000001	00000001	All 0s and a 1 in the host portion
10	1	1	254	LAST HOST
00001010	00000001	00000001	11111110	All 1s and a 0 in the host portion

IPv4 Subnet Mask

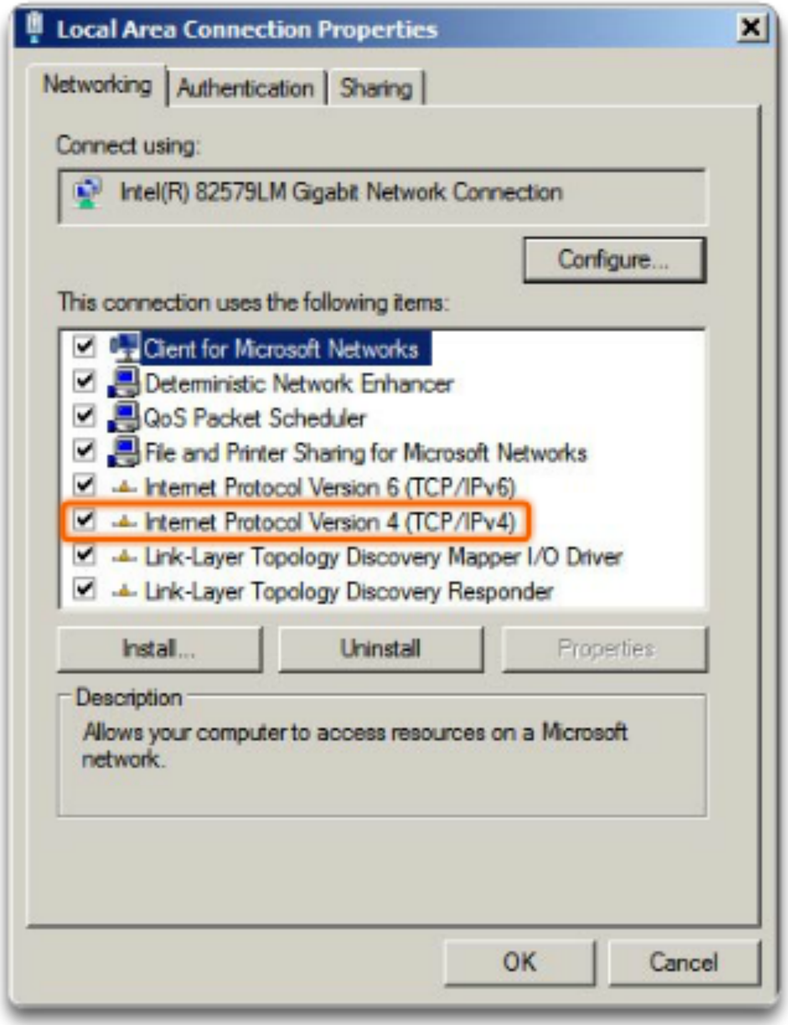
Bitwise AND Operation

1 AND 1 = 1   1 AND 0 = 0   0 AND 1 = 0   0 AND 0 = 0

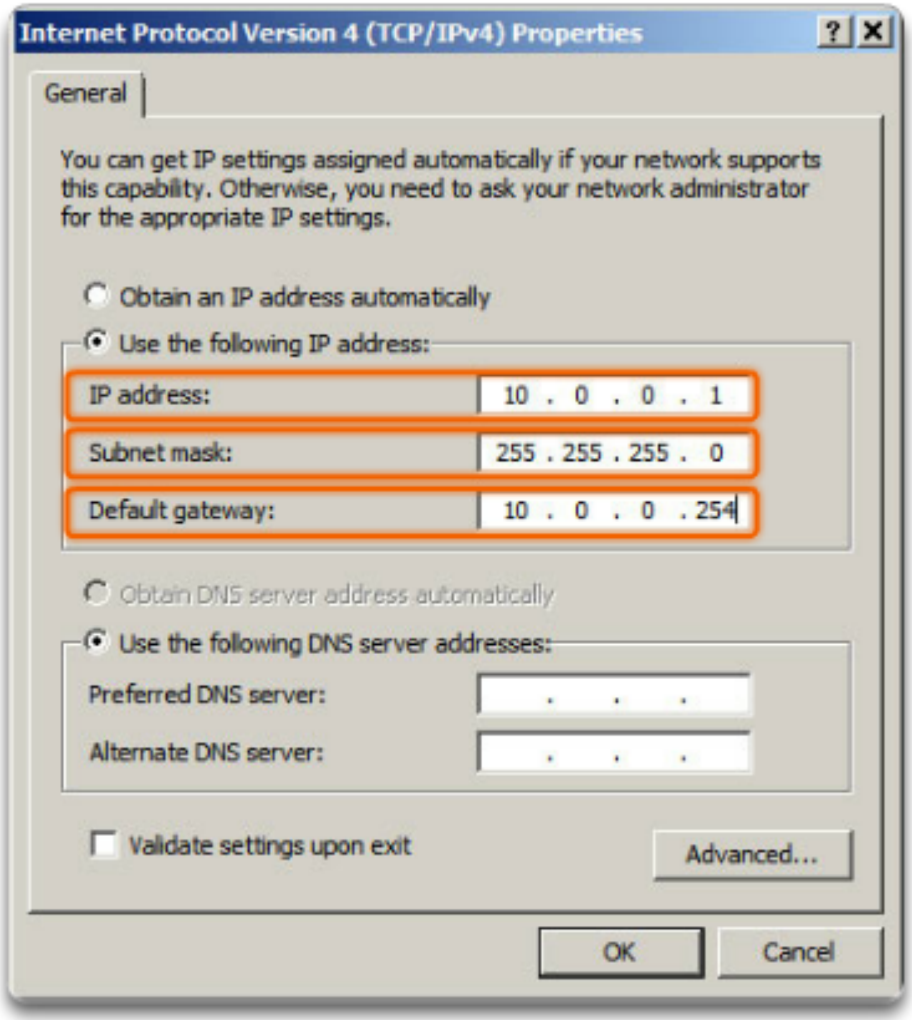
IPv4 Address	192 .	168 .	10 .	10
	11000000	10101000	00001010	00001010
Subnet Mask	255 .	255 .	255 .	0
	11111111	11111111	11111111	00000000
Network Address	192 .	168 .	10 .	0
	11000000	10101000	00001010	00000000

Assigning a Static IPv4 Address to a Host

LAN Interface Properties



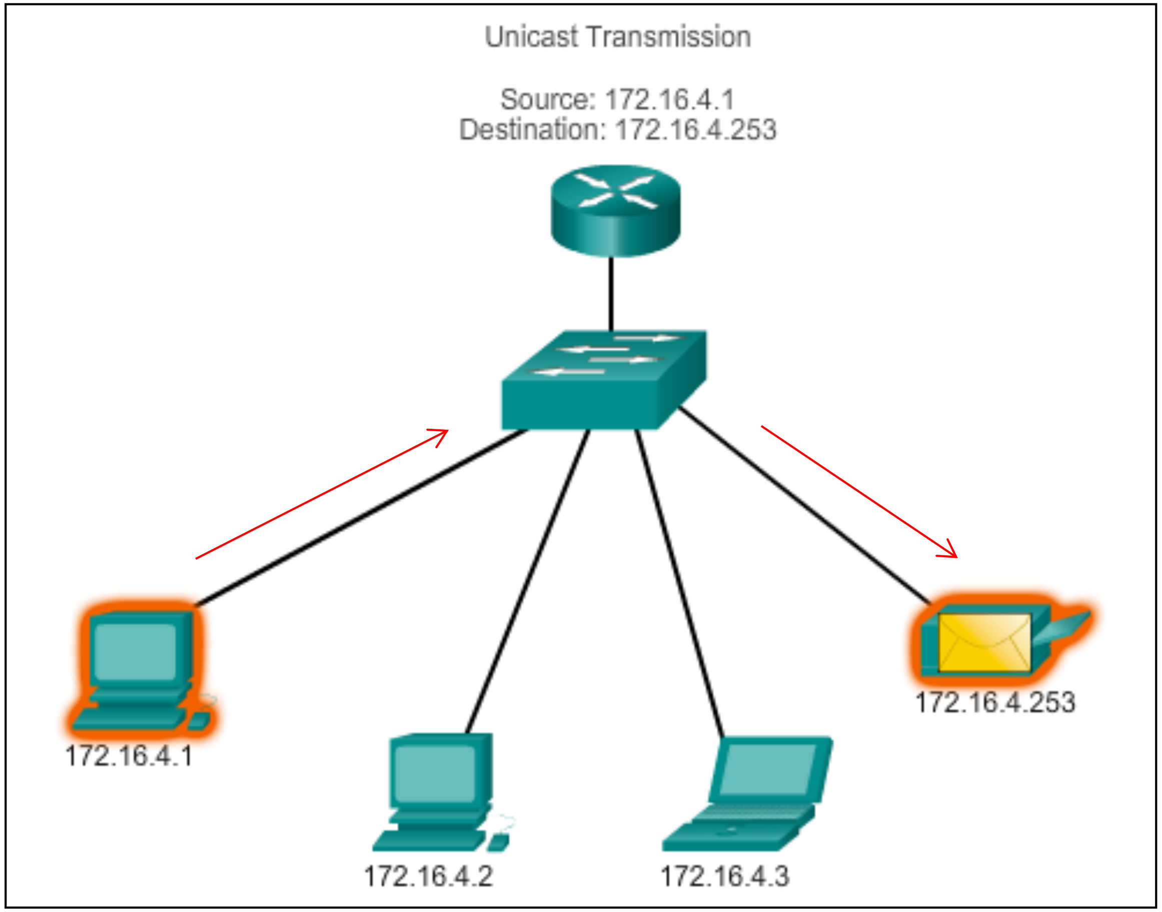
Configuring a Static IPv4 Address



Unicast Transmission

In an IPv4 network, the hosts can communicate one of three different ways: **Unicast**, Broadcast, and Multicast

#1 Unicast – the process of sending a packet from one host to an individual host.



Broadcast Transmission

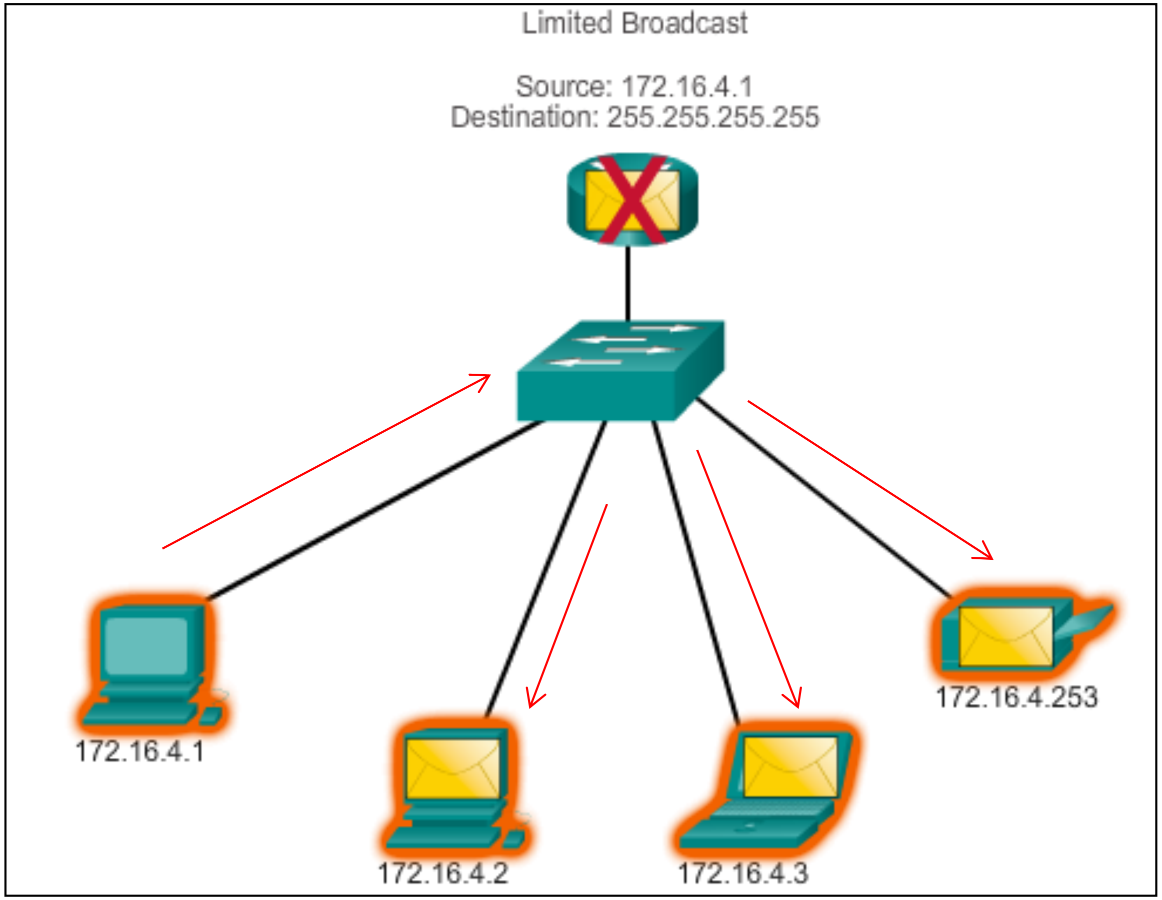
In an IPv4 network, the hosts can communicate one of three different ways: Unicast, **Broadcast**, and Multicast.

#2 Broadcast – the process of sending a packet from one host to all hosts in the network.

NOTE: Routers do not forward a limited broadcast!

Directed broadcast

- Destination 172.16.4.255
- Hosts within the 172.16.4.0/24 network



Multicast Transmission

In an IPv4 network, the hosts can communicate one of three different ways: Unicast, Broadcast, and **Multicast.**

#3 Multicast – The process of sending a packet from one host to a selected group of hosts, possibly in different networks.

- Reduces traffic
- Reserved for addressing multicast groups – 224.0.0.0 to 239.255.255.255.
- Link local – 224.0.0.0 to 224.0.0.255 (Example: routing information exchanged by routing protocols)
- Globally scoped addresses – 224.0.1.0 to 238.255.255.255 (Example: 224.0.1.1 has been reserved for Network Time Protocol)

Types of IPv4 Address

Public and Private IPv4 Addresses

Private address blocks are:

- Hosts that do not require access to the Internet can use private addresses
  - 0.0.0.0 to 0.255.255.255 (0.0.0.0/8)
  - 10.0.0.0 to 10.255.255.255 (10.0.0.0/8)
  - 172.16.0.0 to 172.31.255.255 (172.16.0.0/12)
  - 192.168.0.0 to 192.168.255.255 (192.168.0.0/16)
  - 169.254.0.0 to 169.254.255.255 (169.254.0.0/16)

Types of IPv4 Address

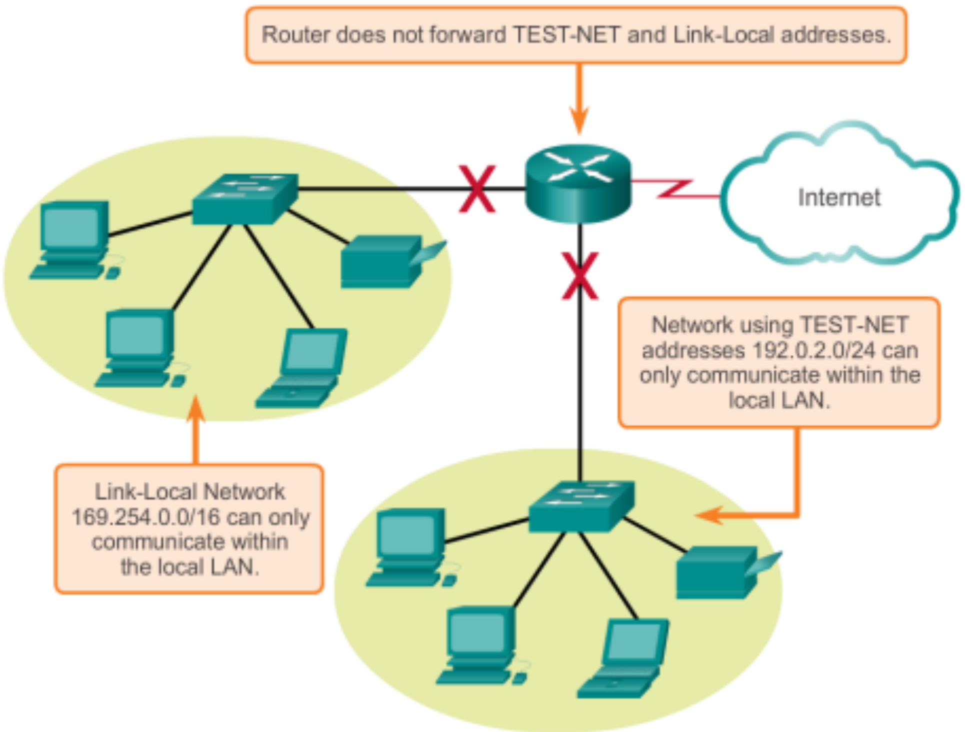
Special Use IPv4 Addresses

- **Network and Broadcast addresses** – within each network the first and last addresses cannot be assigned to hosts
- **Loopback address** – 127.0.0.1 a special address that hosts use to direct traffic to themselves (addresses 127.0.0.0 to 127.255.255.255 are reserved)
- **Experimental addresses** – 240.0.0.0 to 255.255.255.254 are listed as reserved

`http://www.iana.org/numbers`

Special Use IPv4 Addresses

- (**Link-Local address** – 169.254.0.0 to 169.254.255.255 (169.254.0.0/16) addresses can be automatically assigned to the local host
- **TEST-NET addresses** – 192.0.2.0 to 192.0.2.255 (192.0.2.0/24) set aside fo teaching and learning purposes, used in documentation and network examples



Types of IPv4 Address

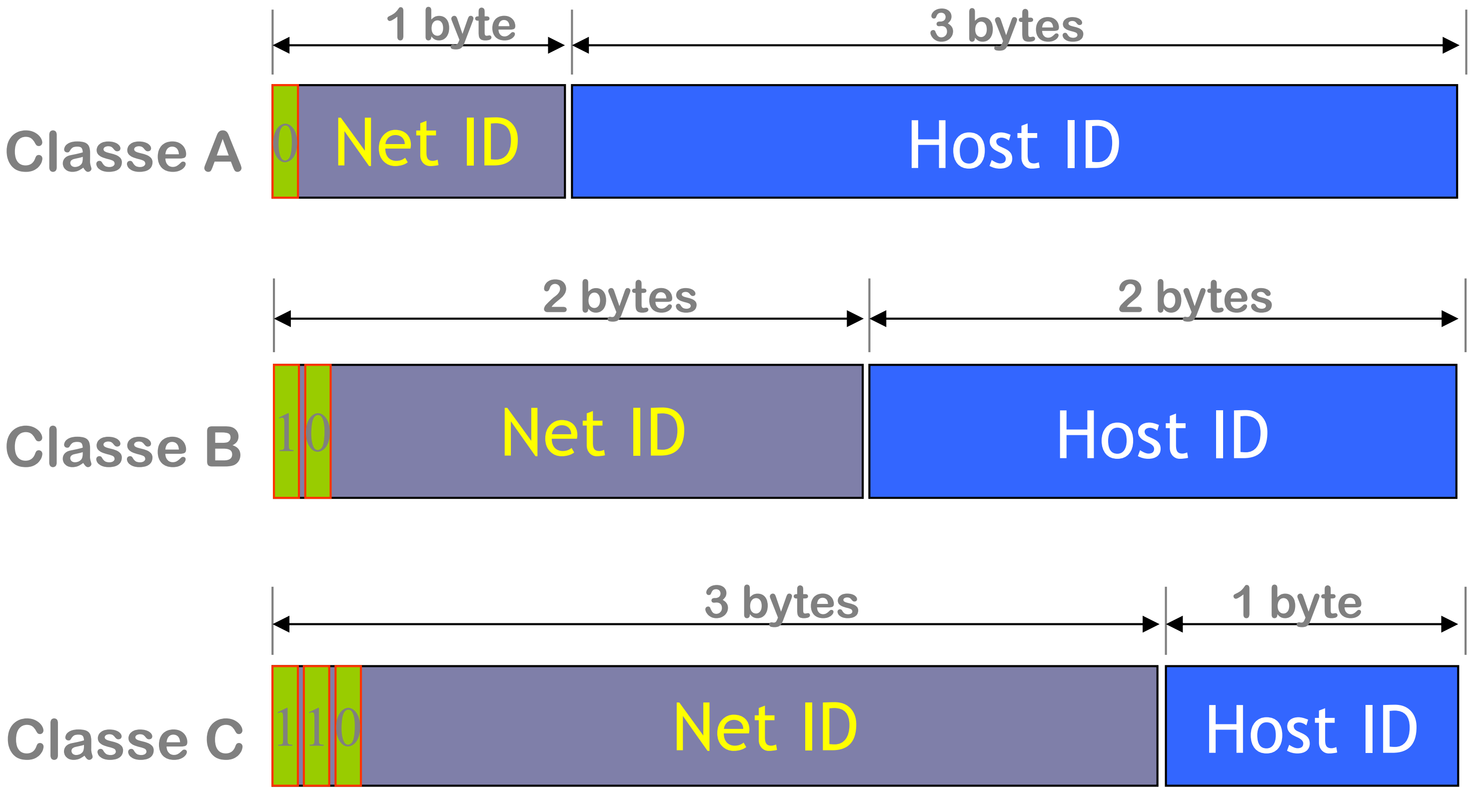
Legacy Classful Addressing

IP Address Classes

Address Class	1st octet range (decimal)	1st octet bits (green bits do not change)	Network(N) and Host(H) parts of address	Default subnet mask (decimal and binary)	Number of possible networks and hosts per network
A	1-127**	00000000-01111111	N.H.H.H	255.0.0.0	128 nets (2^7) 16,777,214 hosts per net (2^24-2)
B	128-191	10000000-10111111	N.N.H.H	255.255.0.0	16,384 nets (2^14) 65,534 hosts per net (2^16-2)
C	192-223	11000000-11011111	N.N.N.H	255.255.255.0	2,097,150 nets (2^21) 254 hosts per net (2^8-2)
D	224-239	11100000-11101111	NA (multicast)		
E	240-255	11110000-11111111	NA (experimental)		

Types of IPv4 Address

Legacy Classful Addressing



Types of IPv4 Address
Legacy Classful Addressing (cont.)

Classless Addressing

- Formal name is Classless Inter-Domain Routing (CIDR, pronounced "cider")
- Created a new set of standards that allowed service providers to allocate IPv4 addresses on any address bit boundary (prefix length) instead of only by a class A, B, or C address

IP addresses waste management:

- Private addressing
- Subnetting (the meaning of mask and VLSM)
- DHCP Protocol
- Proxy to access the Internet
- NAT/PAT protocols

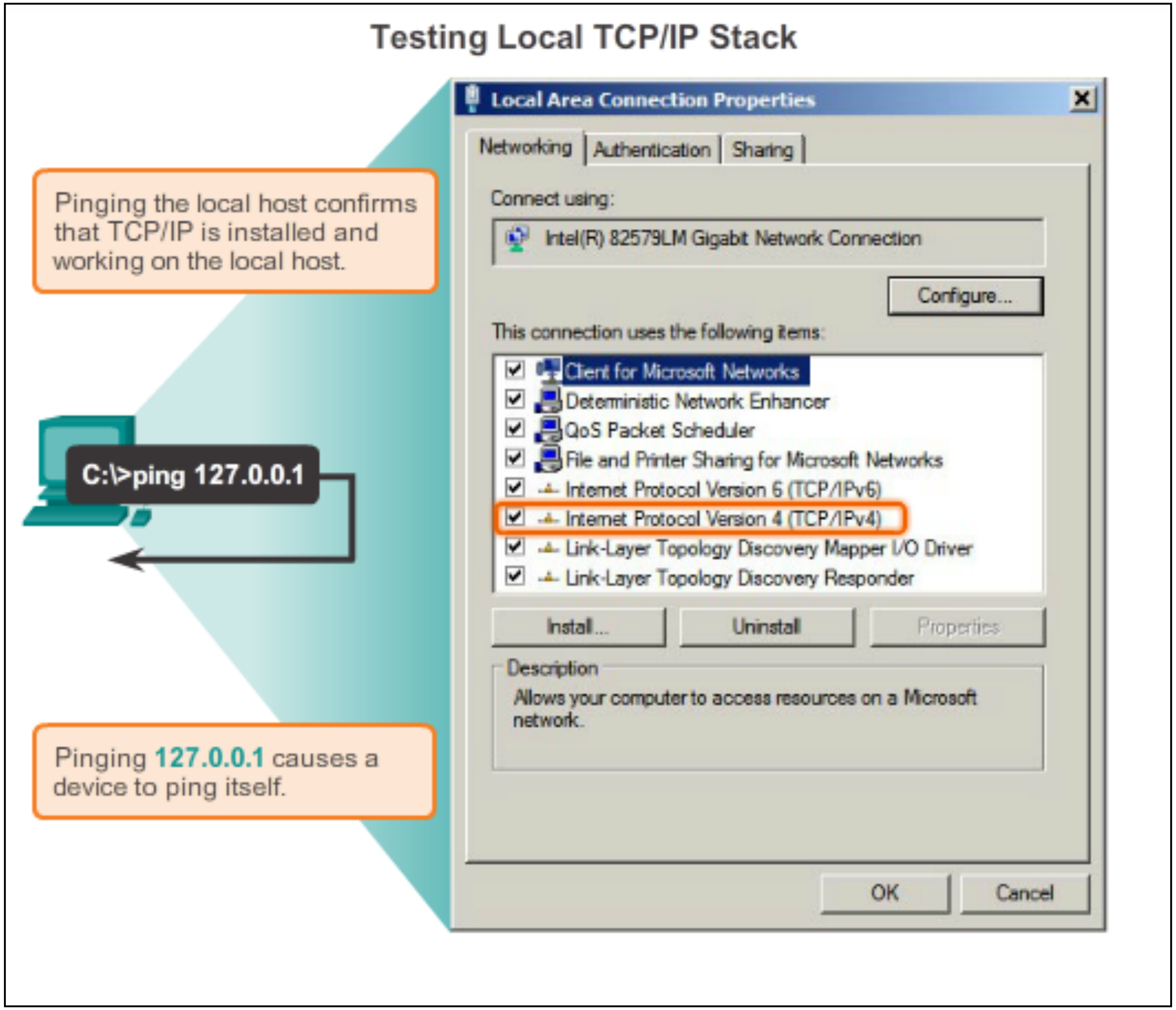
ICMP Messages

- ICMP messages include:
  - Host confirmation
  - Destination or Service Unreachable
  - Time exceeded
  - Route redirection

- Although IP is not a reliable protocol, the TCP/IP suite does provide for messages to be sent in the event of certain errors, sent using the services of ICMP.

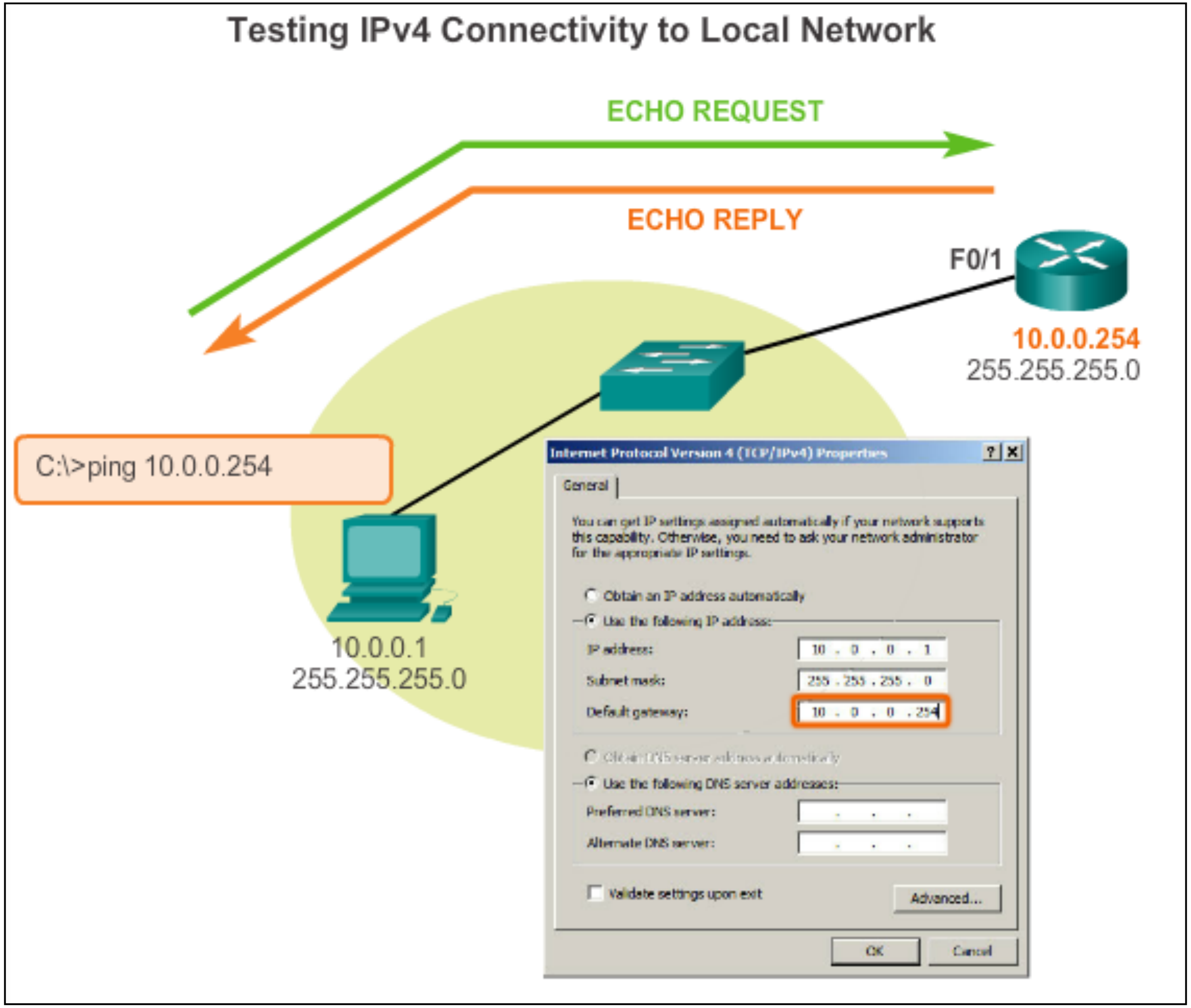
Testing and Verification

Ping – Testing the Local Stack

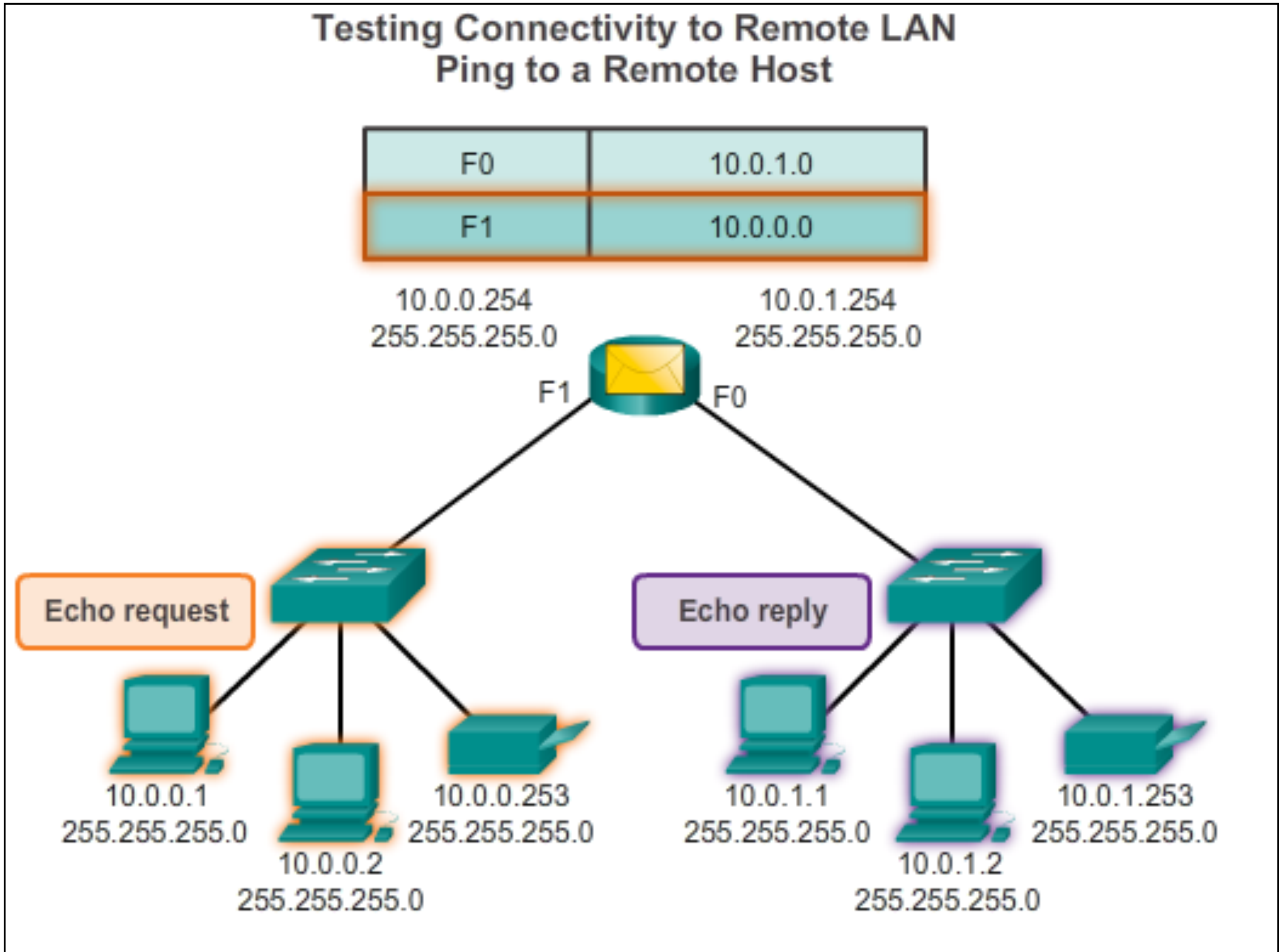


Testing and Verification

Ping – Testing Connectivity to the Local LAN



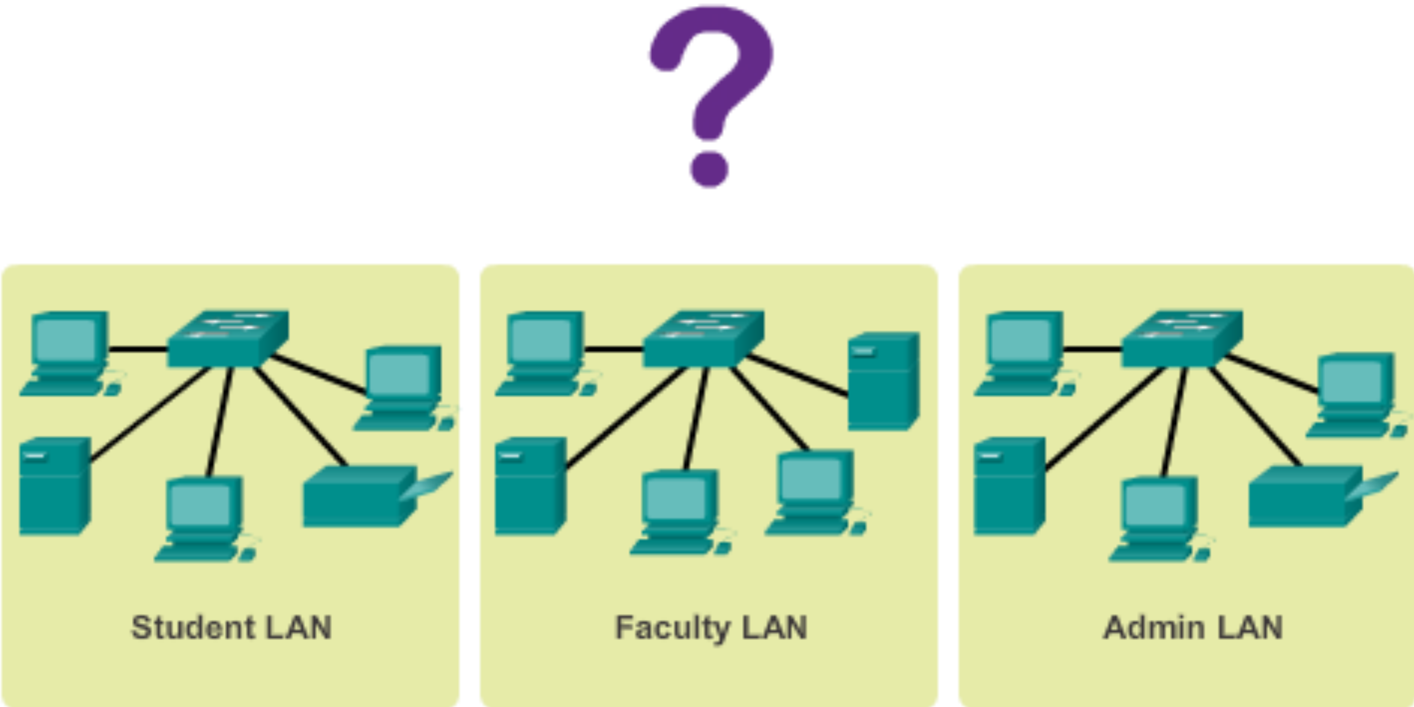
Ping – Testing Connectivity to Remote



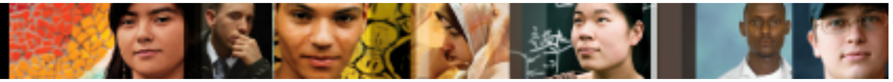
Chapter 7

The Plan - Reasons for Subnetting

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

- Borrowing Bits to Create Subnets
- Borrowing 1 bit $2^1 = 2$ subnets

Address	192	168	1	0000 0000
Mask	255	255	255	0000 0000

$\underbrace{\text{192 168 1 / 255 255 255}}_{\text{Network Portion}}$ $\underbrace{\text{0000 0000}}_{\text{Host Portion}}$

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**

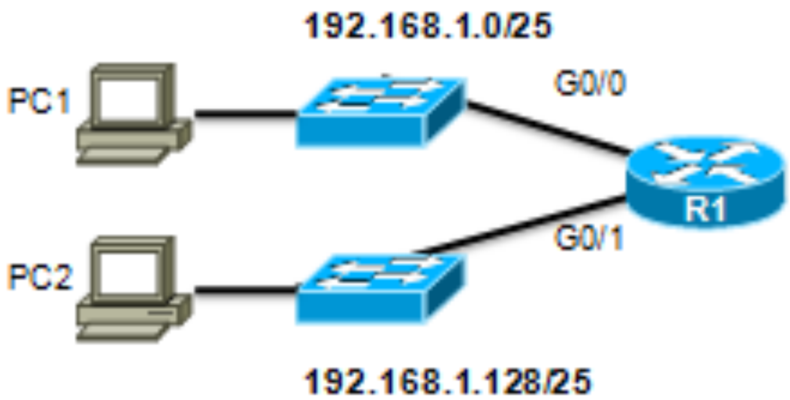
Mask: 255.255.255.**128**

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

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

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:

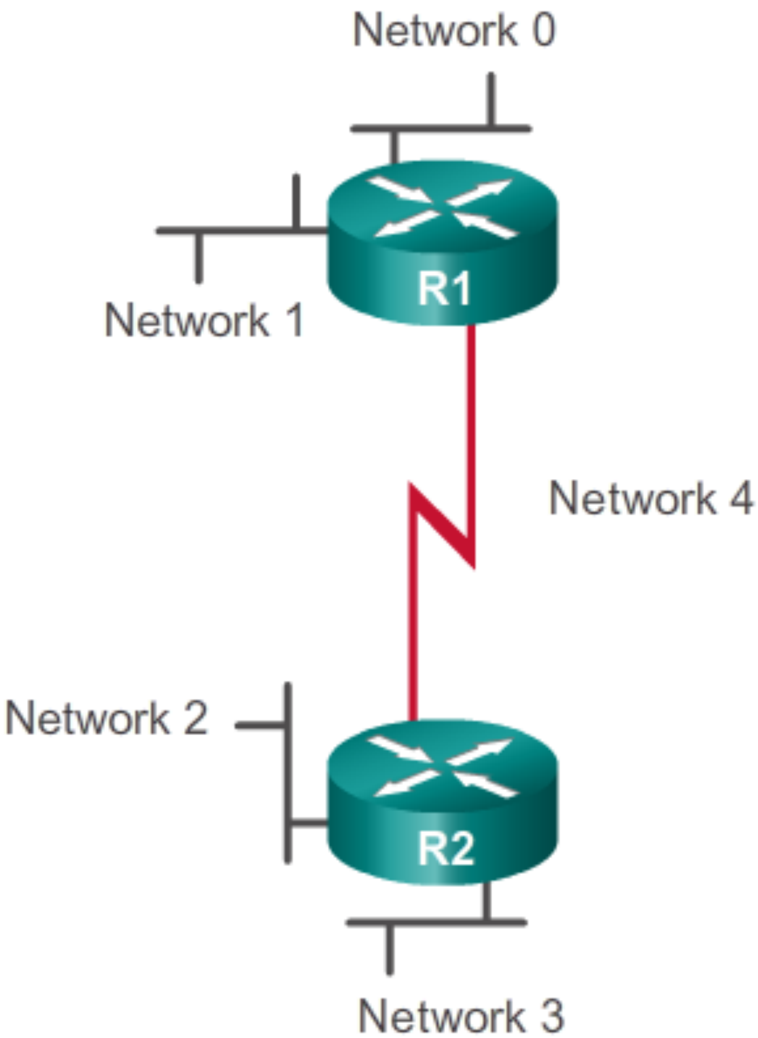
Net 0	192.	168.	1.	00	00 0000	192.168.1.**0**/**26**
Net 1	192.	168.	1.	01	00 0000	192.168.1.**64**/**26**
Net 2	192.	168.	1.	10	00 0000	192.168.1.**128**/**26**
Net 3	192.	168.	1.	11	00 0000	192.168.**192**/**26**

All 4 subnets use the same mask:

Mask	255.	255.	255.	11	00 0000	Mask: 255.255.255.**192**

Subnetting an IPv4 Network

5 subnets required



Subnetting an IPv4 Network

Creating Eight Subnets

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

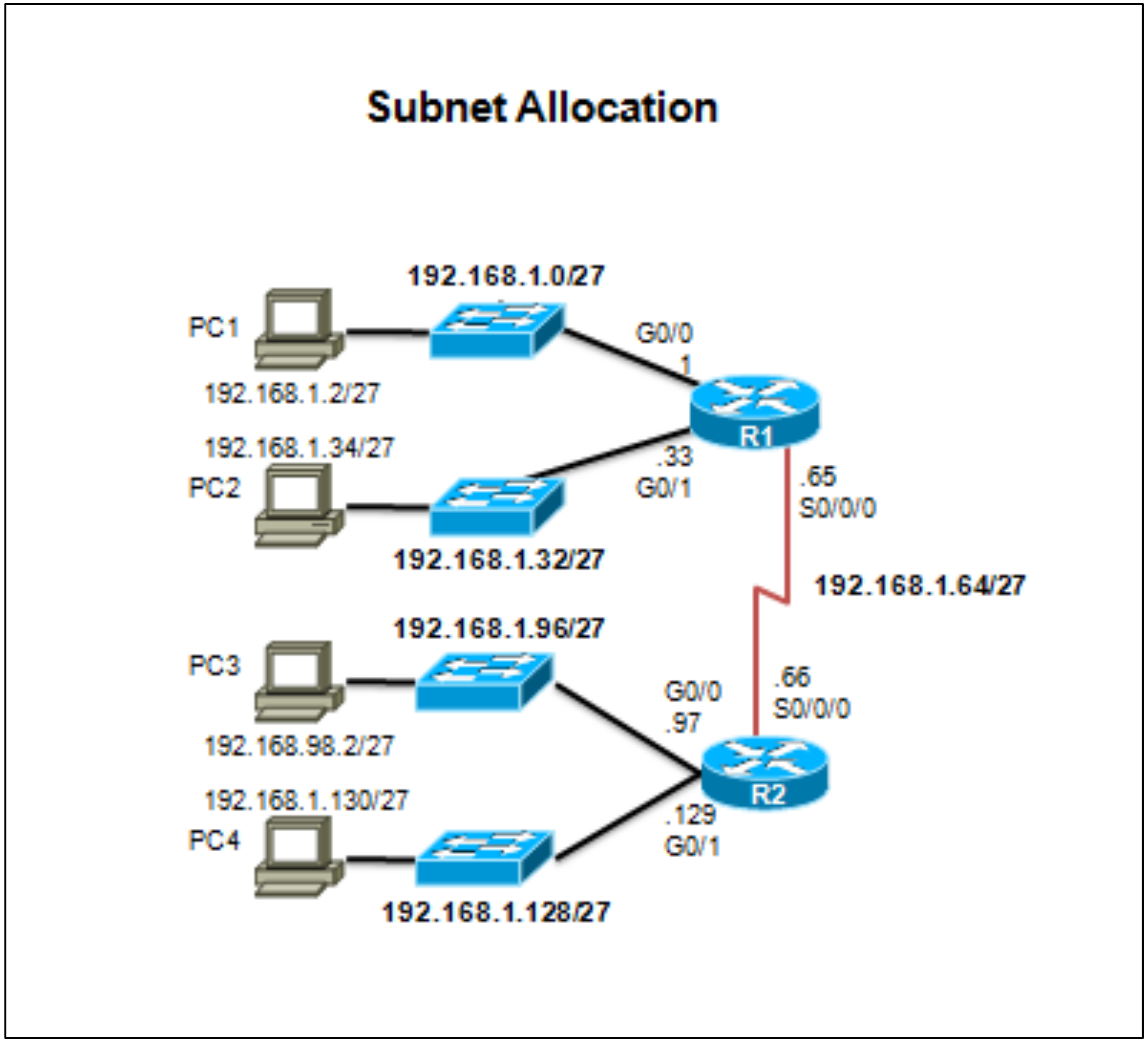
Net 0	Network	192.	168.	1.	000	0 0000	192.168.1.1
	Fist	192.	168.	1.	000	0 0001	192.168.1.1
	Last	192.	168.	1.	000	1 1110	192.168.1.30
	Broadcast	192.	168.	1.	000	1 1111	192.168.1.31
Net 1	Network	192.	168.	1.	001	0 0000	192.168.1.32
	Fist	192.	168.	1.	001	0 0001	192.168.1.33
	Last	192.	168.	1.	001	1 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 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

Creating Eight Subnets (Cont.)



Subnetting Based on Host Requirements

Two considerations when planning subnets:

- Number of subnets required
- Number of host addresses required

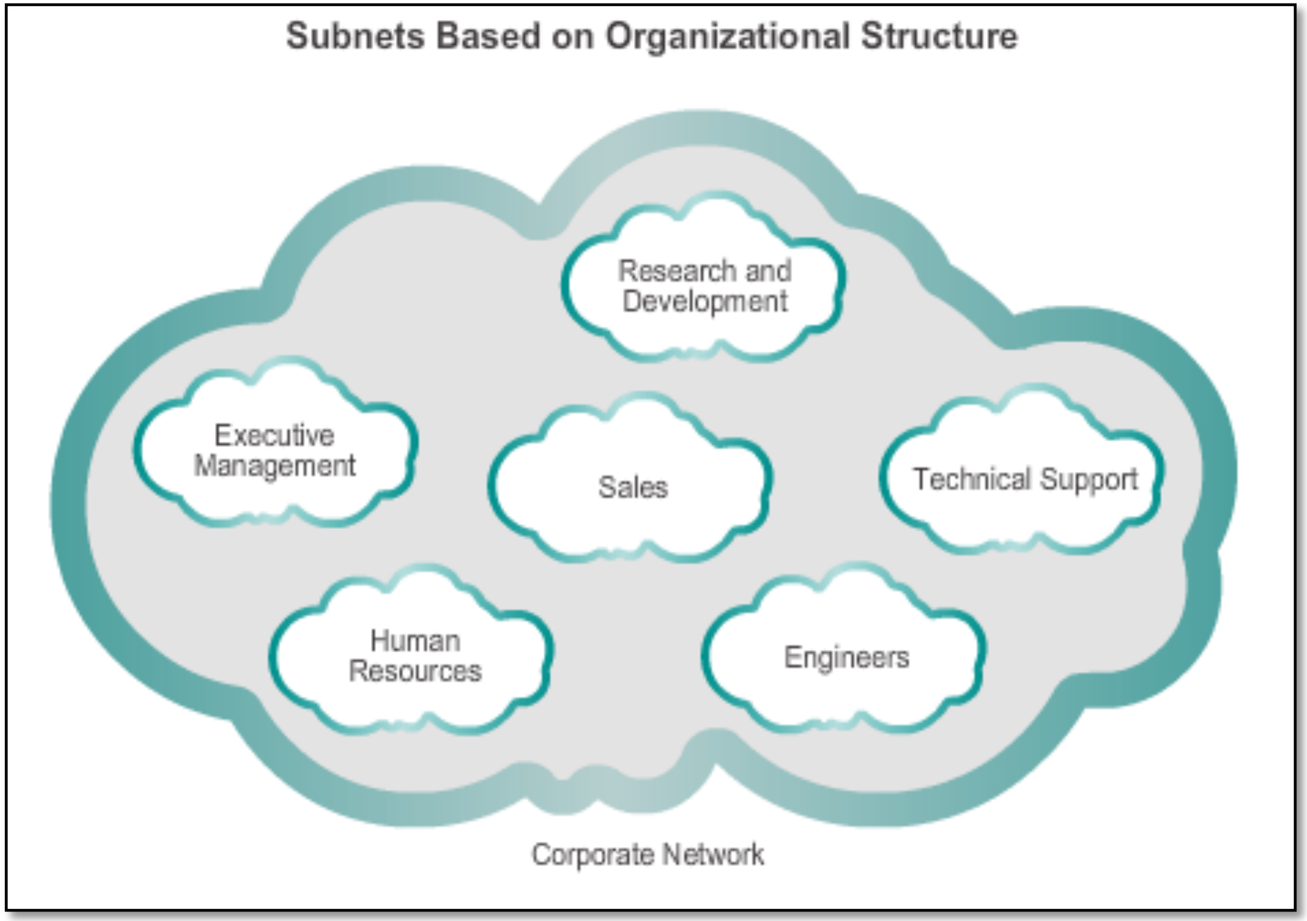
Formula to determine number of usable hosts: 2^n-2

- 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:

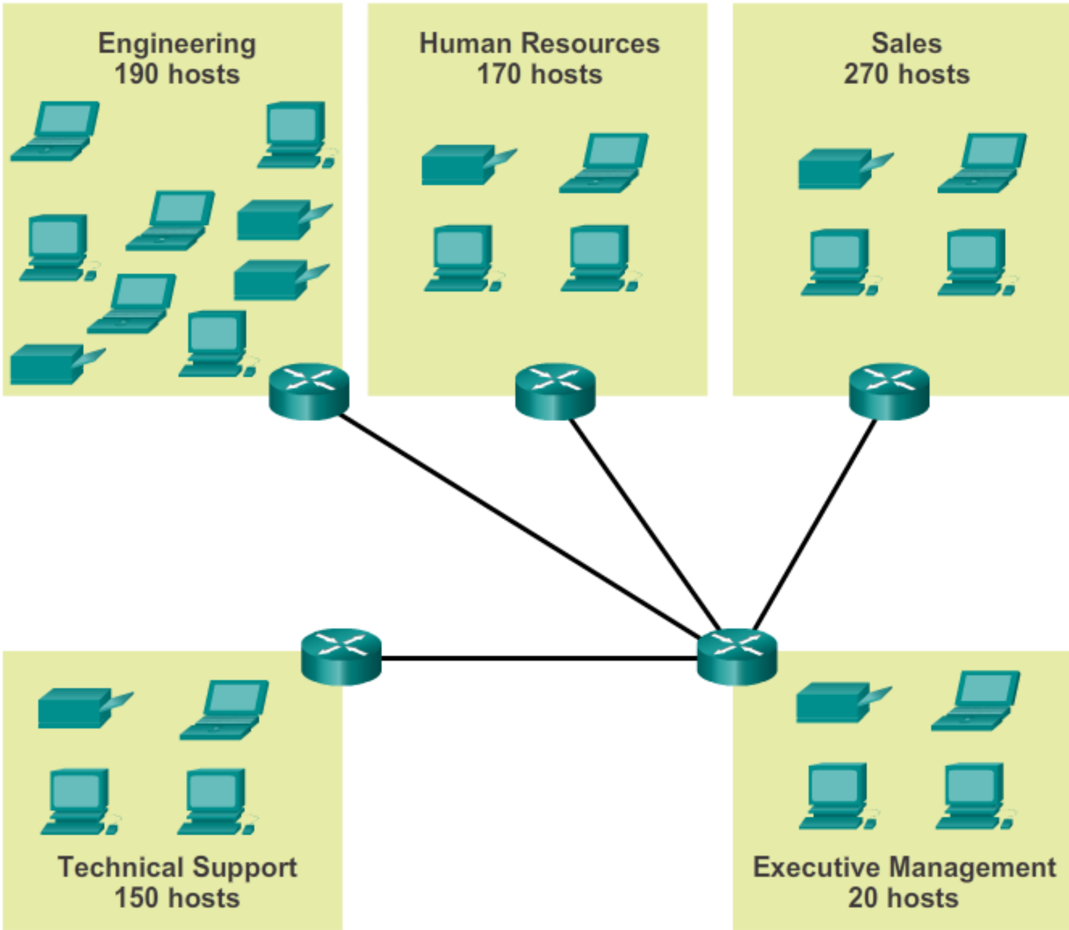
- **2^n** (where n is the number of bits borrowed)
- Subnet needed for each department.



Determining the Subnet Mask

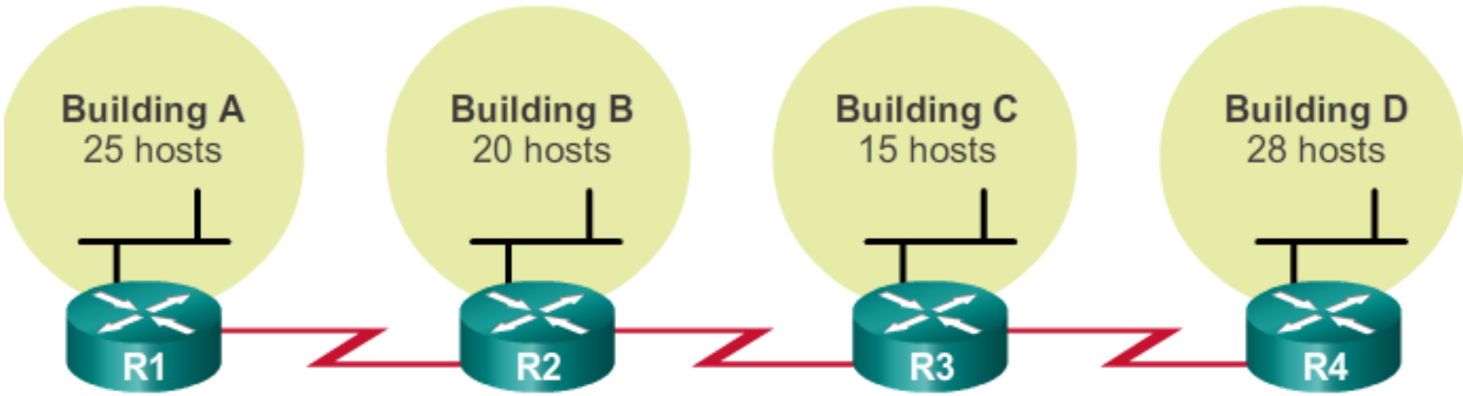
Subnetting To Meet Network Requirements

- 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.



Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes 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

Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes Addresses

4	11000000.10101000.00010100	.100	00000	192.168.20.128/27
5	11000000.10101000.00010100	.101	00000	192.168.20.160/27
6	11000000.10101000.00010100	.110	00000	192.168.20.192/27

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

30 – 2 = 28
Each WAN subnet wastes 28 addresses

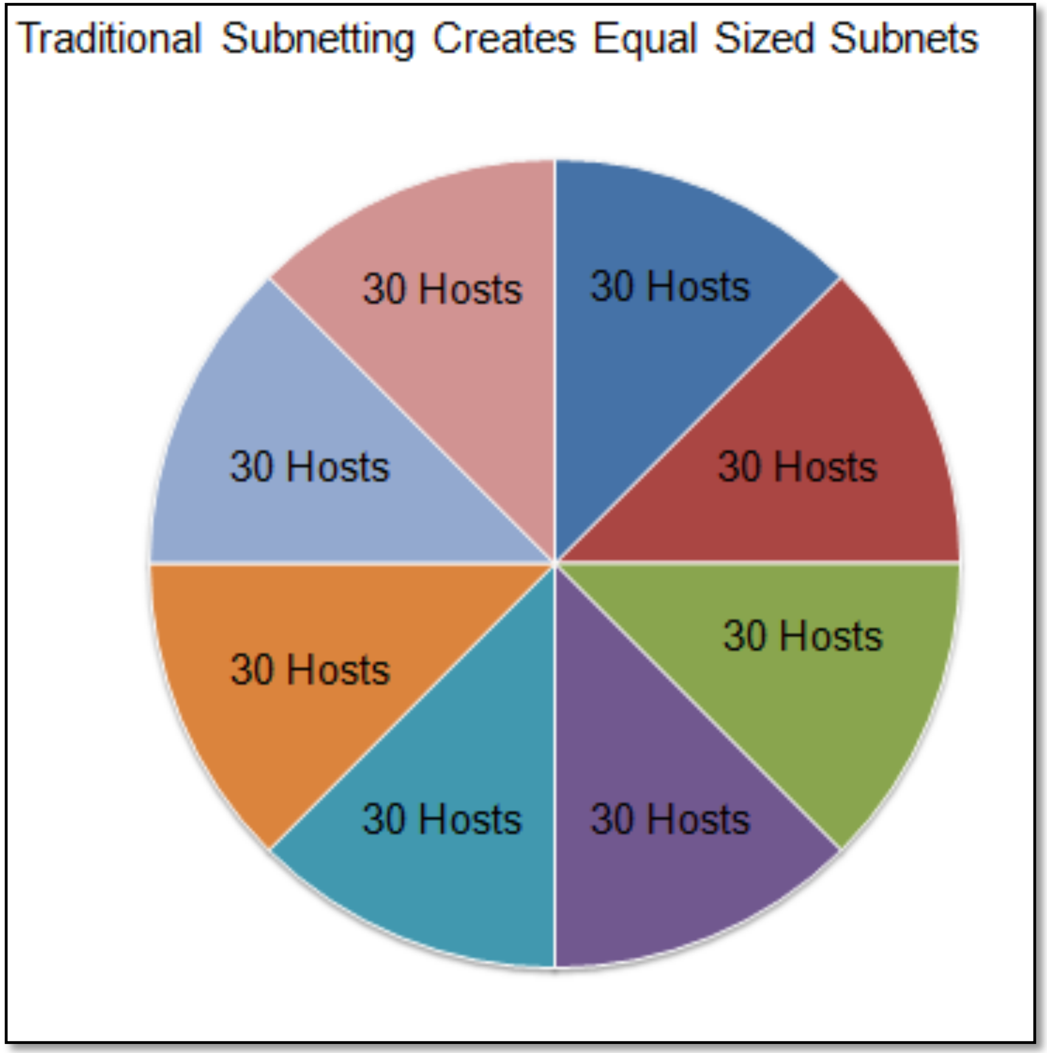
28 x 3 = 84
84 addresses are unused

Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes Addresses

- Traditional subnetting – Uses the same number of addresses is allocated for each subnet.

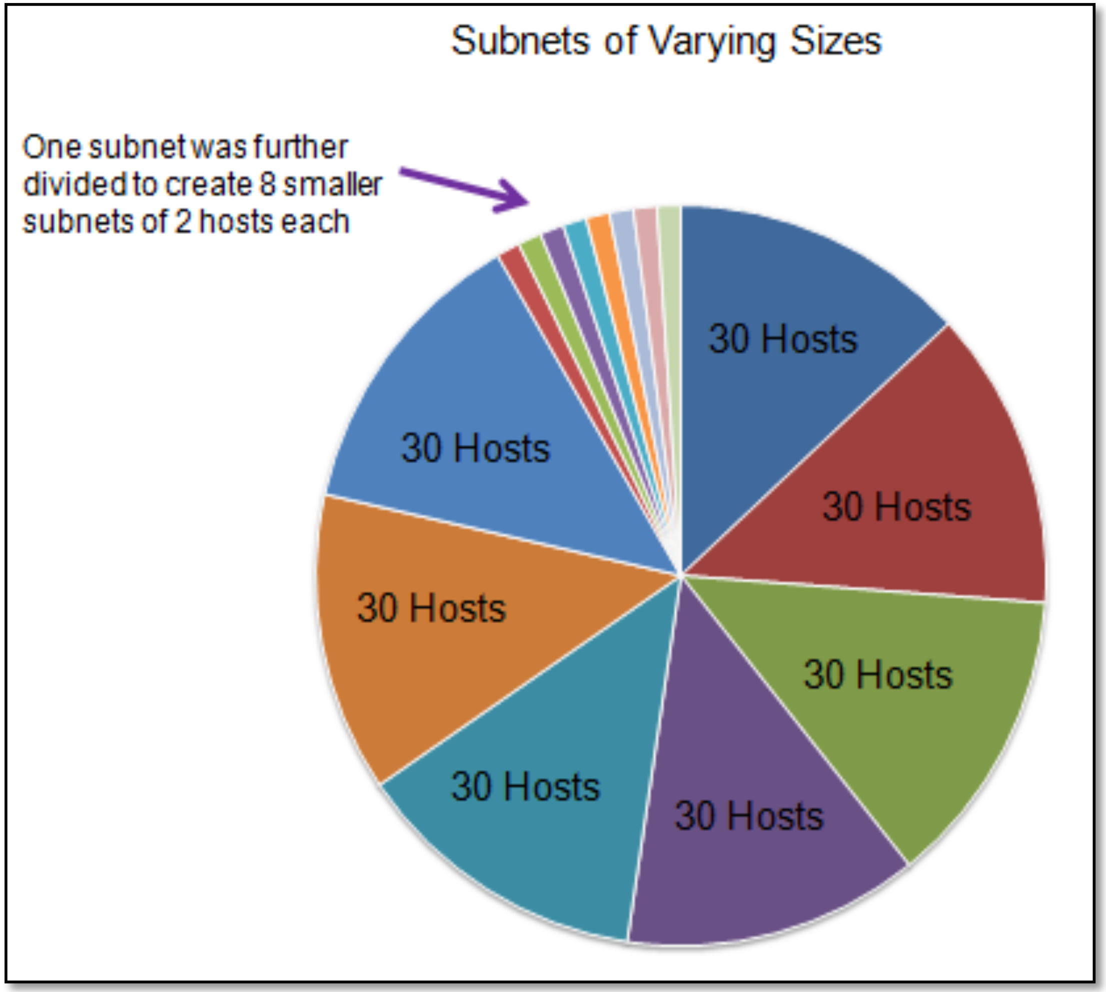
- Subnets that require fewer addresses have unused (wasted) addresses; for example, WAN links only need two addresses.



Benefits of Variable Length Subnet Masking

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

	11000000.10101000.00010100.00000000	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	

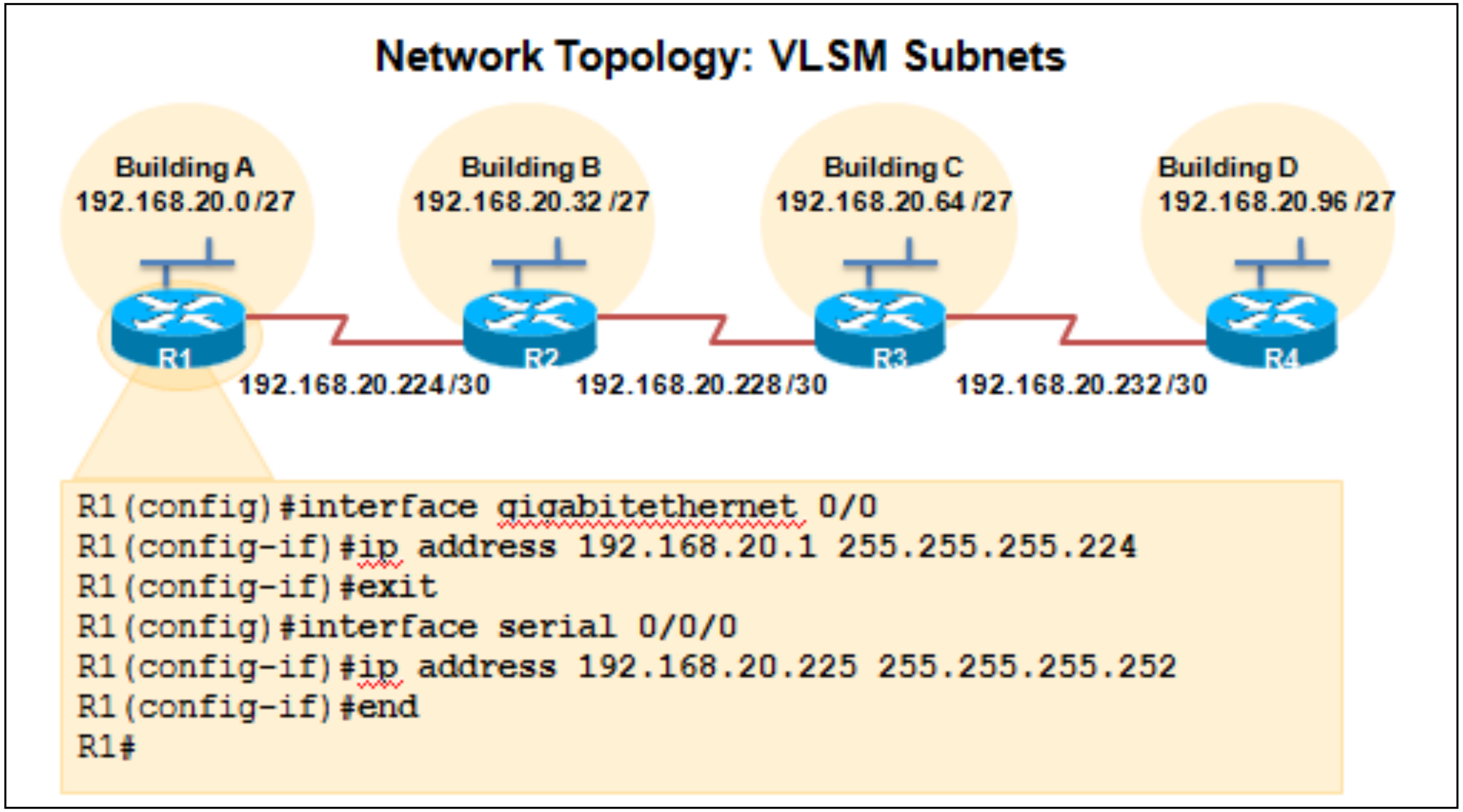
3 more bits borrowed from subnet 7:

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

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).