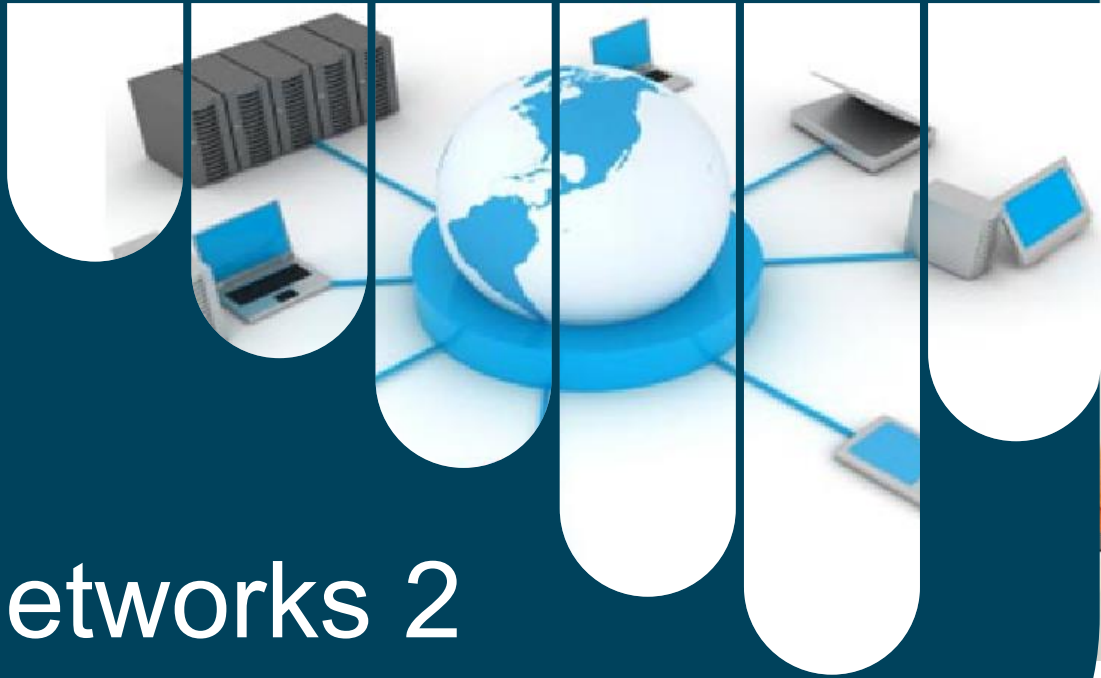
Ashur University
Engineering Collage
CyberSecutity Engineering Department



Computer Networks 2

IPv4 Addresses

Lecture 02

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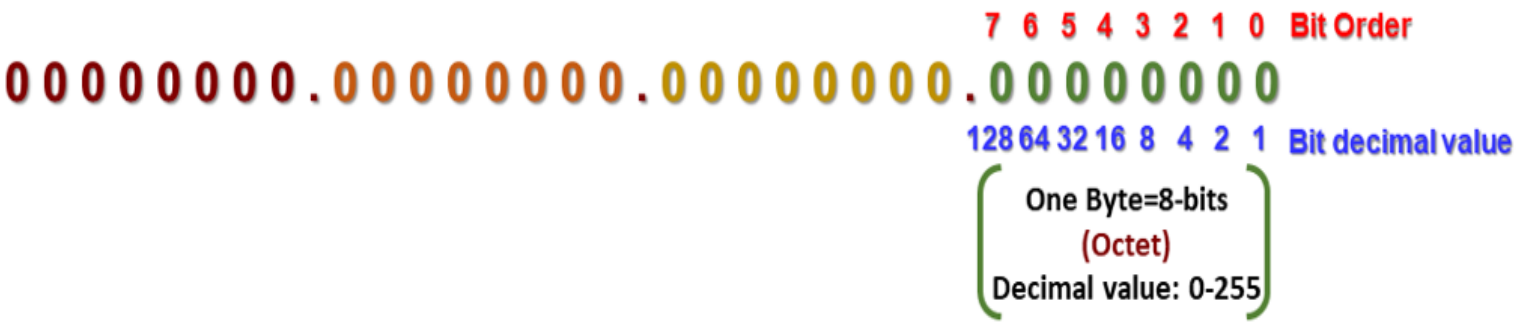
IPv4

What is an IP Address v4.0?

Internet Protocol Address version 4.0 (IP Address v4.0) is a 32-bit Dotted Decimal Notation assigned to each device connected to a computer network that uses Transmission Control Protocol (TCP) / Internet Protocol(IP) for communication, each device in the same network should has a unique IP Address.



IPv4

Example of IP Address v4.0:

192.168.10.5

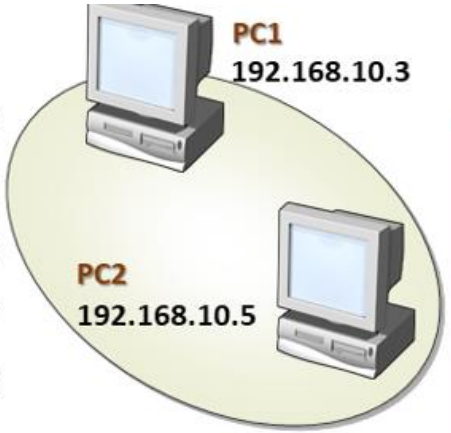
human-readable IP Address	192	168	10	5
Device-readable IP Number	11000000	10101000	00001010	00000101
	128 64 32 16 8 4 2 1	128 64 32 16 8 4 2 1	128 64 32 16 8 4 2 1	128 64 32 16 8 4 2 1

Each IP address has an IP number that is written in binary for it to be read and transmitted by computers across a network. This binary number is translated into an IP address, which is displayed in a decimal format that is human-readable.

Subnet Mask

Subnet Mask:

IP address v4.0 is consisting to two portions, network ID portion that identify the network where the computer sets, and host ID portion that identify the computer on its network. Subnet Mask is used to identify the two portions by indicating the network ID within the IP address. A subnet mask is a 32-bit number created by setting host bits to all 0s and setting network bits to all 1s. In this way, the subnet mask separates the IP address into the network and host addresses, **for example**:



Host	IP address	Subnet mask	Network ID	Shortcut IP/Mask
PC1	192.168.10.3	255.255.0.0	192.168.0.0	192.168.10.3/16
PC2	192.168.10.5	255.255.255.0	192.168.10.0	192.168.10.5/24

Subnet Mask

How does the subnet mask work?

IP Address 192.168.10.5 11000000.10101000.00001010.00000101

Subnet mask 255.255.255.0 11111111.11111111.11111111.00000000

X	Y	Z
0	0	0
1	0	0
0	1	0
1	1	1



Network ID: 192.168.10.0 11000000.10101000.00001010.00000000

Subnet Mask

Number of hosts of a given network:

$$No.\ of\ hosts\ of\ a\ given\ network = (base\ of\ binary\ numeral\ system)^{no.\ of\ bits\ of\ the\ host\ portion} - 2$$

$$= 2^{no.\ of\ bits\ of\ the\ host\ portion} - 2$$

Example:

A network has an ID 172.16.10.0 calculate the number of hosts that this network can hold.

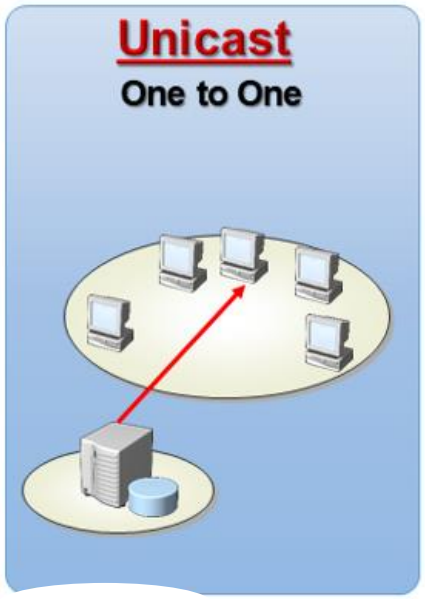
OR

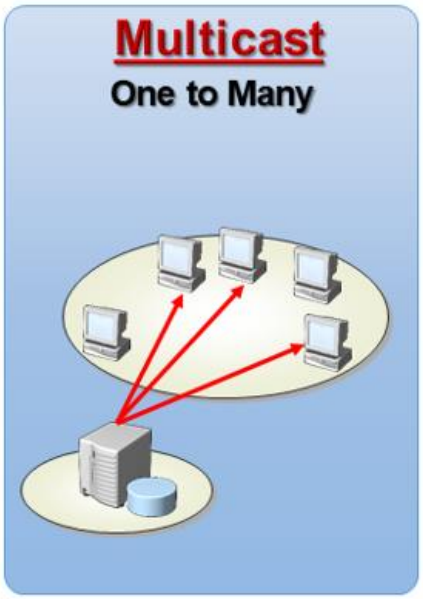
A host of an IP address of 172.16.10.9 and the subnet mask is 255.255.255.0 calculate the number of hosts that this network can hold.

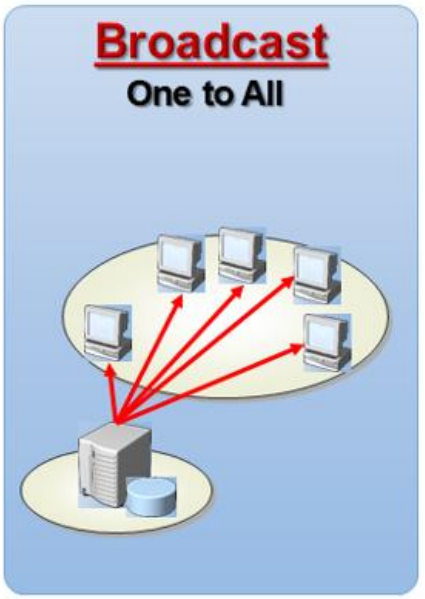
The number of bits of the host portion for this network = 8-bits.

The number of hosts of this network $= 2^8 - 2 = 254$ *hosts*

IPv4 Types


Unicast
One to One


Multicast
One to Many

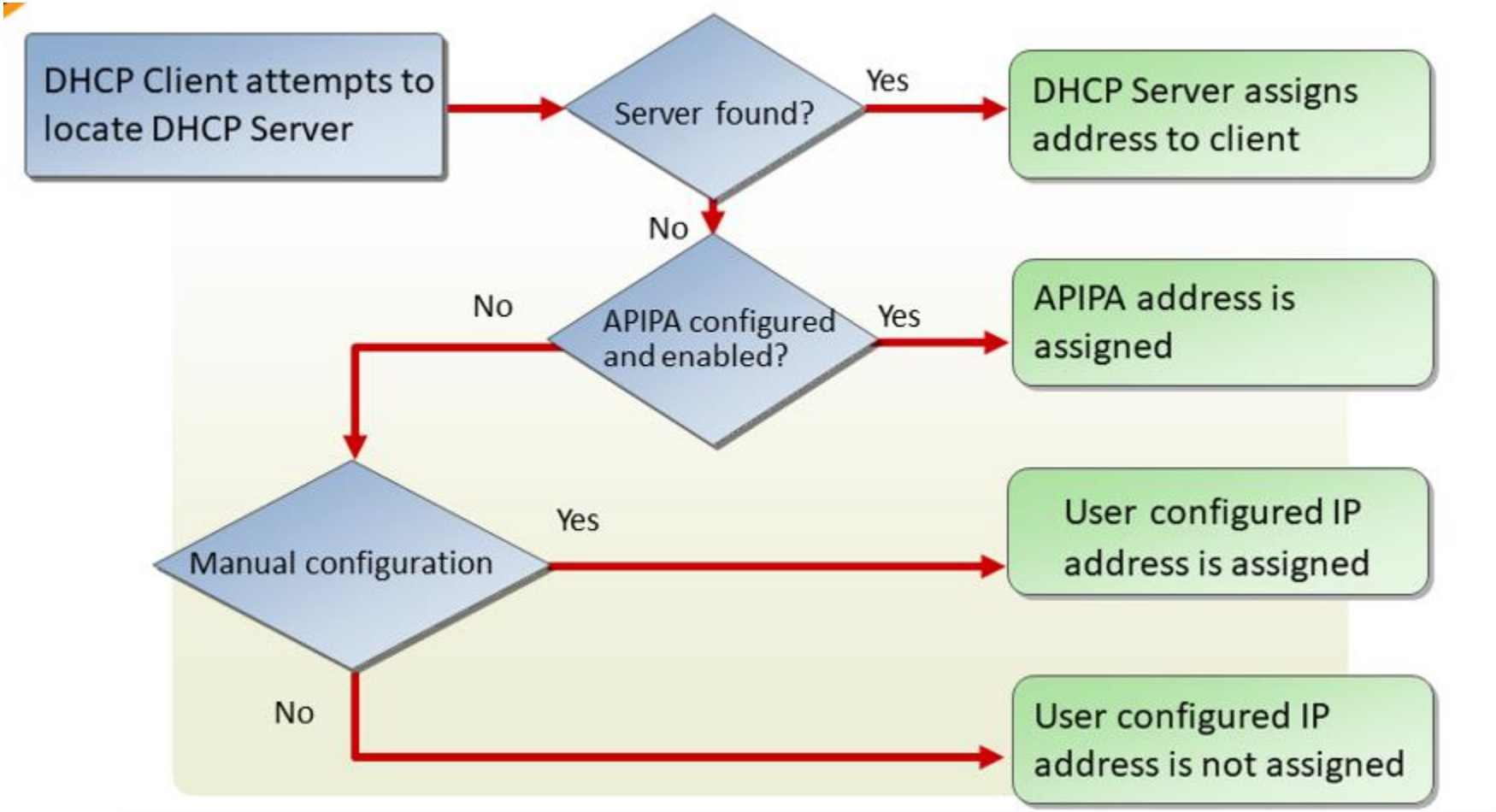

Broadcast
One to All

Get an IPv4

How a host get an IP Address v4.0?

- **Statically**; Where a user assign an IP address in the IP configuration window statically.
- **Dynamic Host Configuration Protocol (DHCP);** DHCP assigns dynamic IP addresses to devices on a network. With dynamic addressing, a device can have a different IP address every time it connects to the network.
- **Automatic Private IP Addressing (APIPA);** APIPA is a feature of later Windows operating systems that allows DHCP clients to automatically self-configure an IP address and subnet mask when a DHCP server isn't available.

Get an IPv4


DHCP Client attempts to locate DHCP Server
Server found?
Yes
DHCP Server assigns address to client
No
APIPA configured and enabled?
No
Yes
APIPA address is assigned
Manual configuration
Yes
User configured IP address is assigned
No
User configured IP address is not assigned

Why IP Addresses?

- They uniquely identify each device on an IP network.
- Every host (computer, networking device, peripheral) must have a unique address.
- Host ID:
  - Identifies the individual host
  - Is assigned by organizations to individual devices

IP Address Format: Dotted Decimal Notation

	Example			
An IP address is a 32-bit binary number	10101100	00010000	10000000	00010001
For readability, the 32-bit binary number can be divided into four 8-bit octets	10101100	00010000	10000000	00010001
Each octet (or byte) can be converted to decimal	172	16	128	17
The address can be written in dotted decimal notation	172.	16.	128.	17

301P_311

Decimal-to-Binary Conversion

Base^{Exponent}	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Place Value	128	64	32	16	8	4	2	1
Example: Convert decimal 35 to binary	0	0	1	0	0	0	1	1

022P_141

$2^0 + 2^1 + 2^5 = 35$

$+ (1 * 1)(2 * 1) + (32 * 1) = 35$

$1 + 1 + 0 + 0 + 0 + 1 + 0 + 0 = 35$

$= 00100011_{35}$

Binary-to-Decimal Conversion

Base^{Exponent}	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Place Value	128	64	32	16	8	4	2	1
Example: Binary Number	1	0	1	1	1	0	0	1
Decimal Number Total: 185	128	0	32	16	8	0	0	1

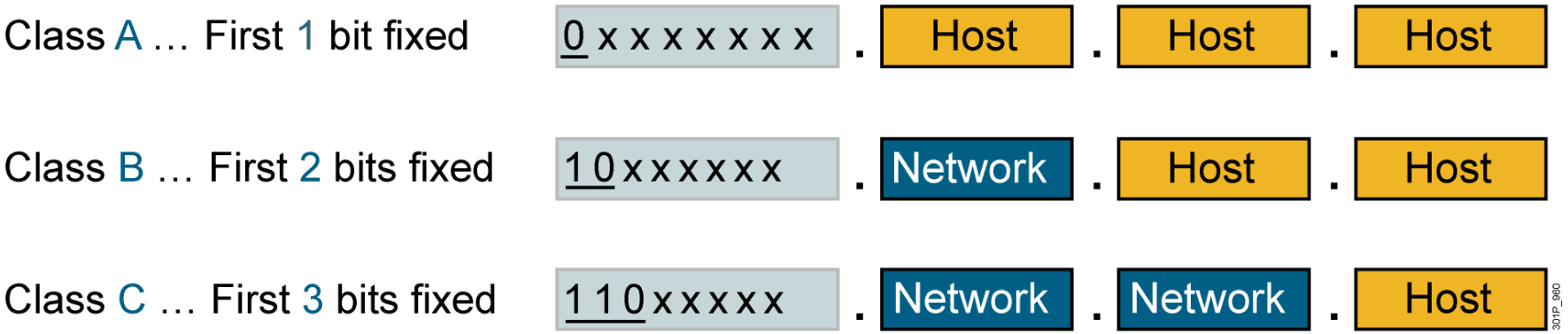
301P_142

1 0 1 1 1 0 0 1 = (128 * 1) + (64 * 0) + (32 * 1) + (16 * 1) + (8 * 1) + (4 * 0) + (2 * 0) + (1 * 1)

128+0+32+16+8+0+0+1 1 0 1 1 1 0 0 1 = 185

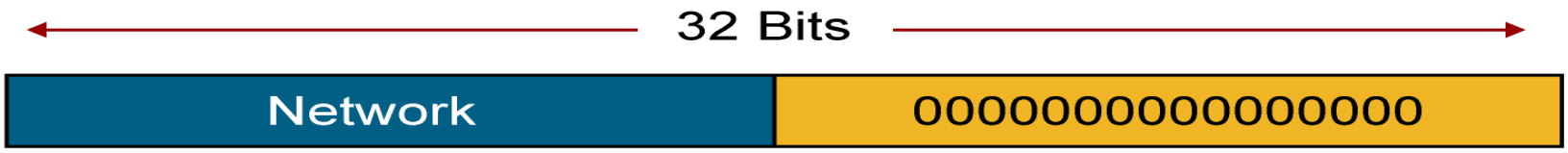
IP Address Classes: The First Octet

A B C … Easy as 1 2 3

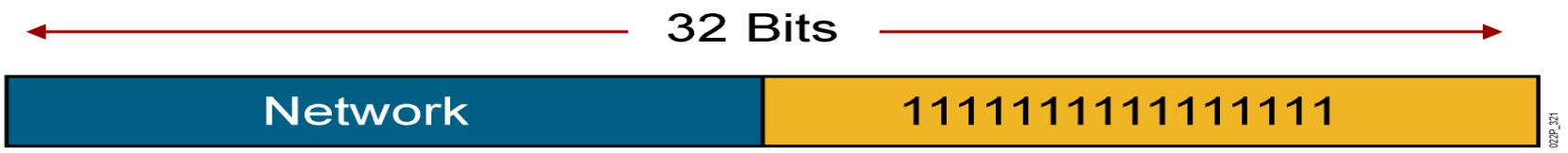


Reserved Address:

- Network Addresses



- Broadcast Addresses



IP Address Ranges:

IP Address Class	First Octet Binary Value	First Octet Decimal Value	Possible Number of Hosts
Class A	1-126	00000001 to 01111110*	16,777,214
Class B	128-191	10000000 to 10111111	65,534
Class C	192-223	11000000 to 11011111	254

301P_959

*127 (01111111) is a Class A address reserved for loopback testing and cannot be assigned to a network.

Address Class	Number of Networks	Number of Host per Network
A	126 *	16,777,216
B	16, 384	65,535
C	2,097,152	254
D (Multicast)	N/A	N/A

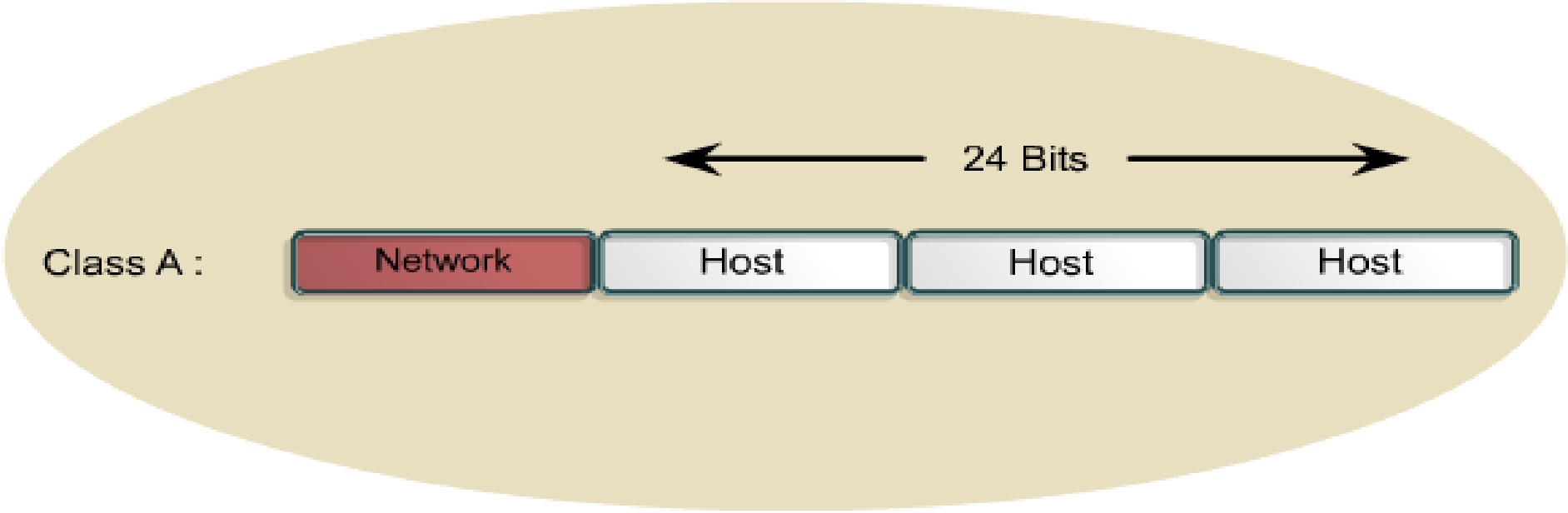
Private and Public IPv4 Addresses:

Class	Private Address Ranges
Class A	10.0.0.0–10.255.255.255
Class B	172.16.0.0–172.31.255.255
Class C	192.168.0.0–192.168.255.255

Class	Public Address Ranges
Class A	1.0.0.0–9.255.255.255
	11.0.0.0–126.255.255.255
Class B	128.0.0.0–172.15.255.255
	172.32.0.0–191.255.255.255
Class C	192.0.0.0–192.167.255.255
	192.169.0.0–223.255.255.255

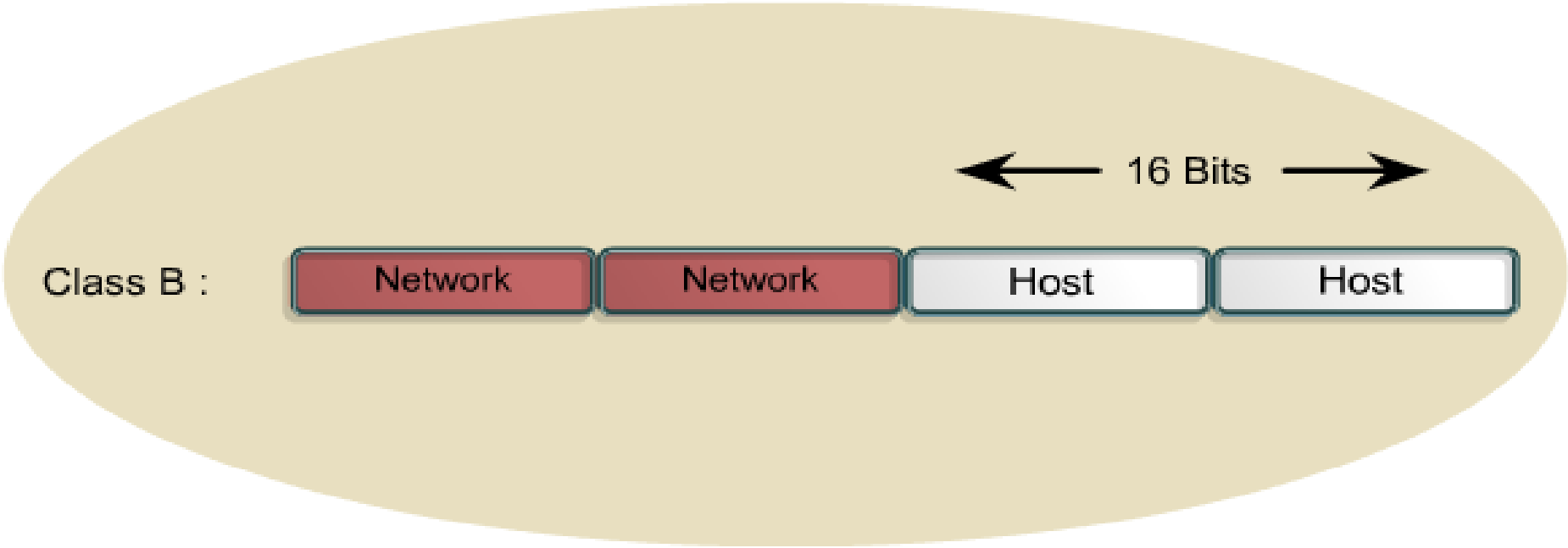
Class A Addresses:

The Class A address was designed to support extremely large networks, with more than 16 million host addresses available. Class A IP addresses use only the first octet to indicate the network address. The remaining three octets provide for host addresses.



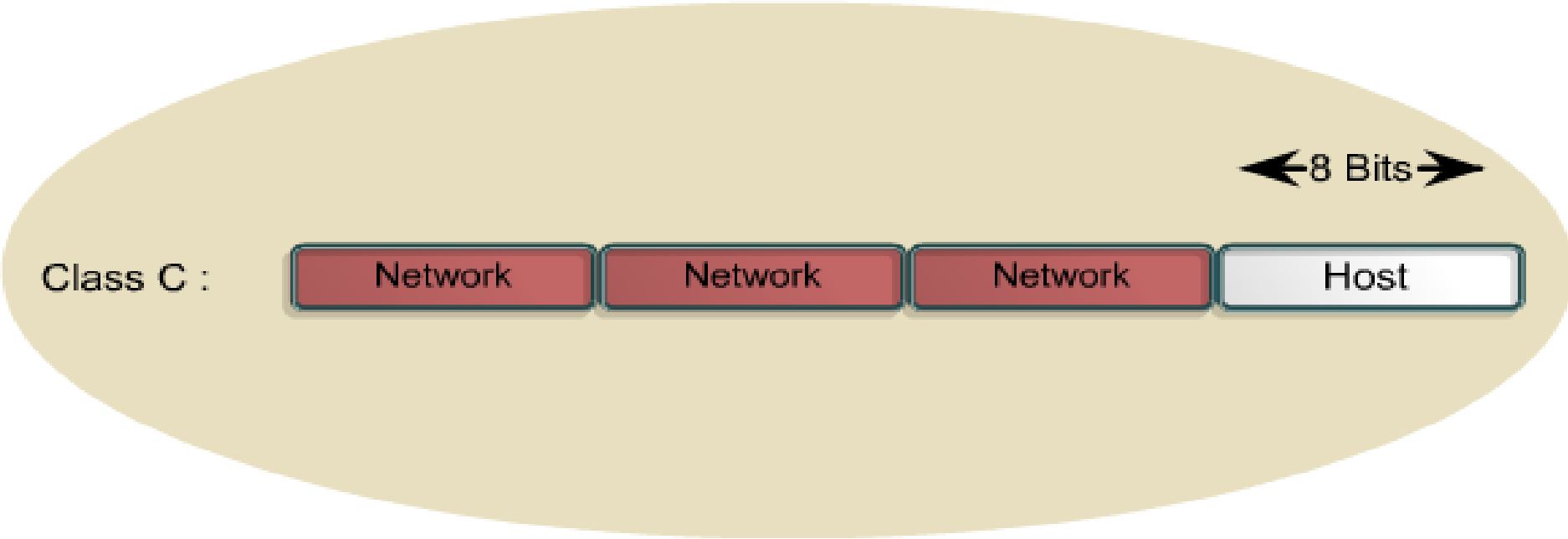
Class B Addresses:

The Class B address was designed to support the needs of moderate to large-sized networks. A Class B IP address uses the first two of the four octets to indicate the network address. The other two octets specify host addresses.



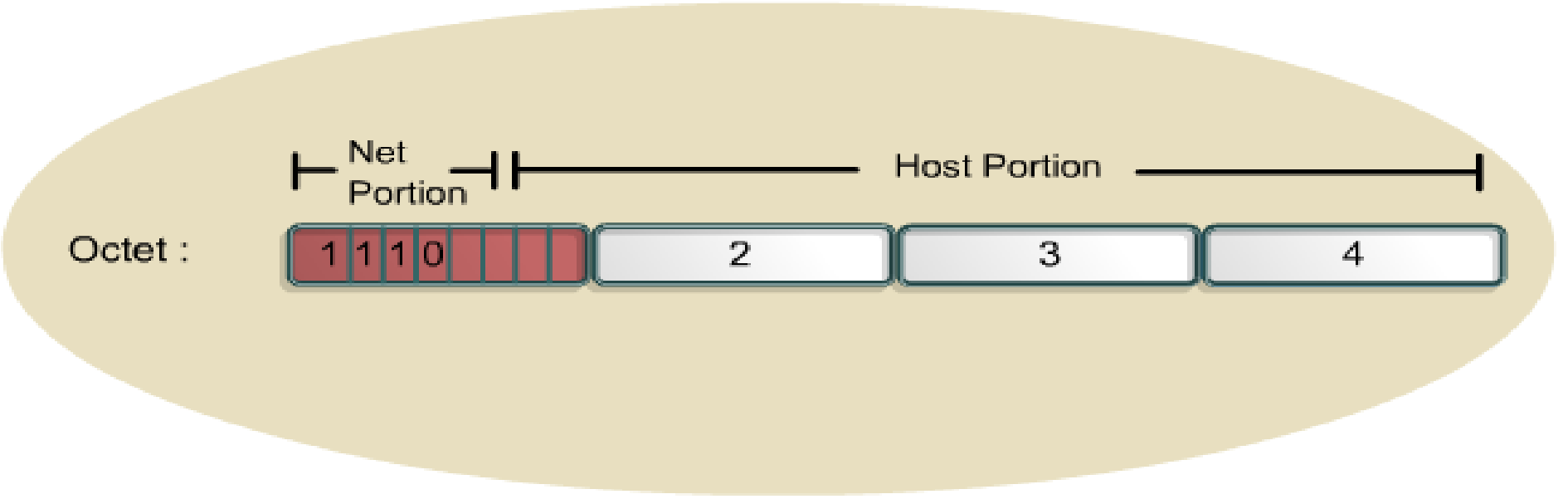
Class C Addresses

The Class C address space is the most commonly used of the original address classes. This address space was intended to support small networks with a maximum of 254 hosts.



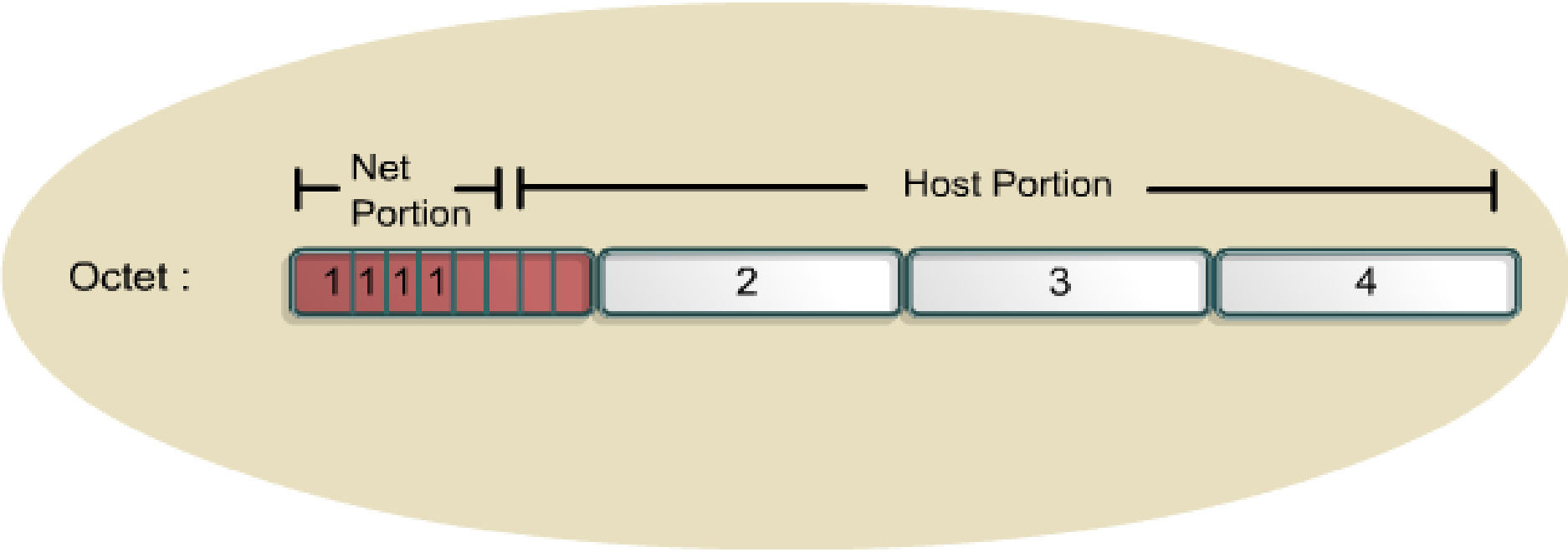
Class D Addresses

The Class D address class was created to enable multicasting in an IP address. A multicast address is a unique network address that directs packets with that destination address to predefined groups of IP addresses. Therefore, a single station can simultaneously transmit a single stream of data to multiple recipients.



Class E Addresses

A Class E address has been defined. However, the Internet Engineering Task Force (IETF) reserves these addresses for its own research. Therefore, no Class E addresses have been released for use in the Internet.

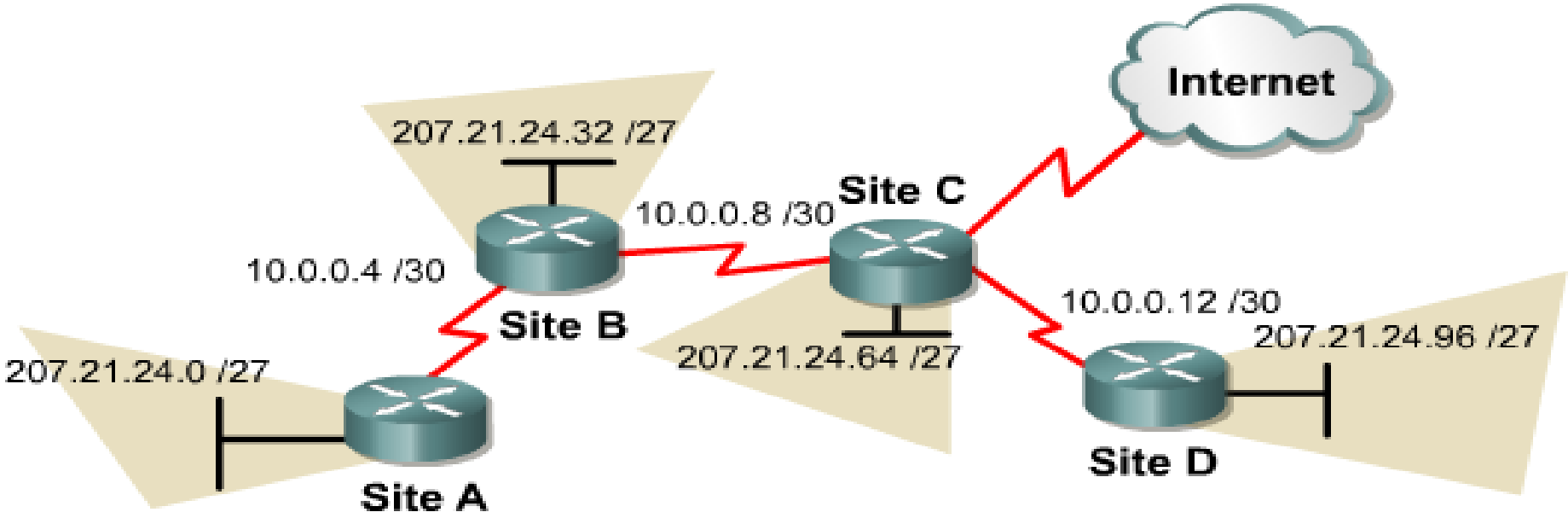


IP Address Ranges:

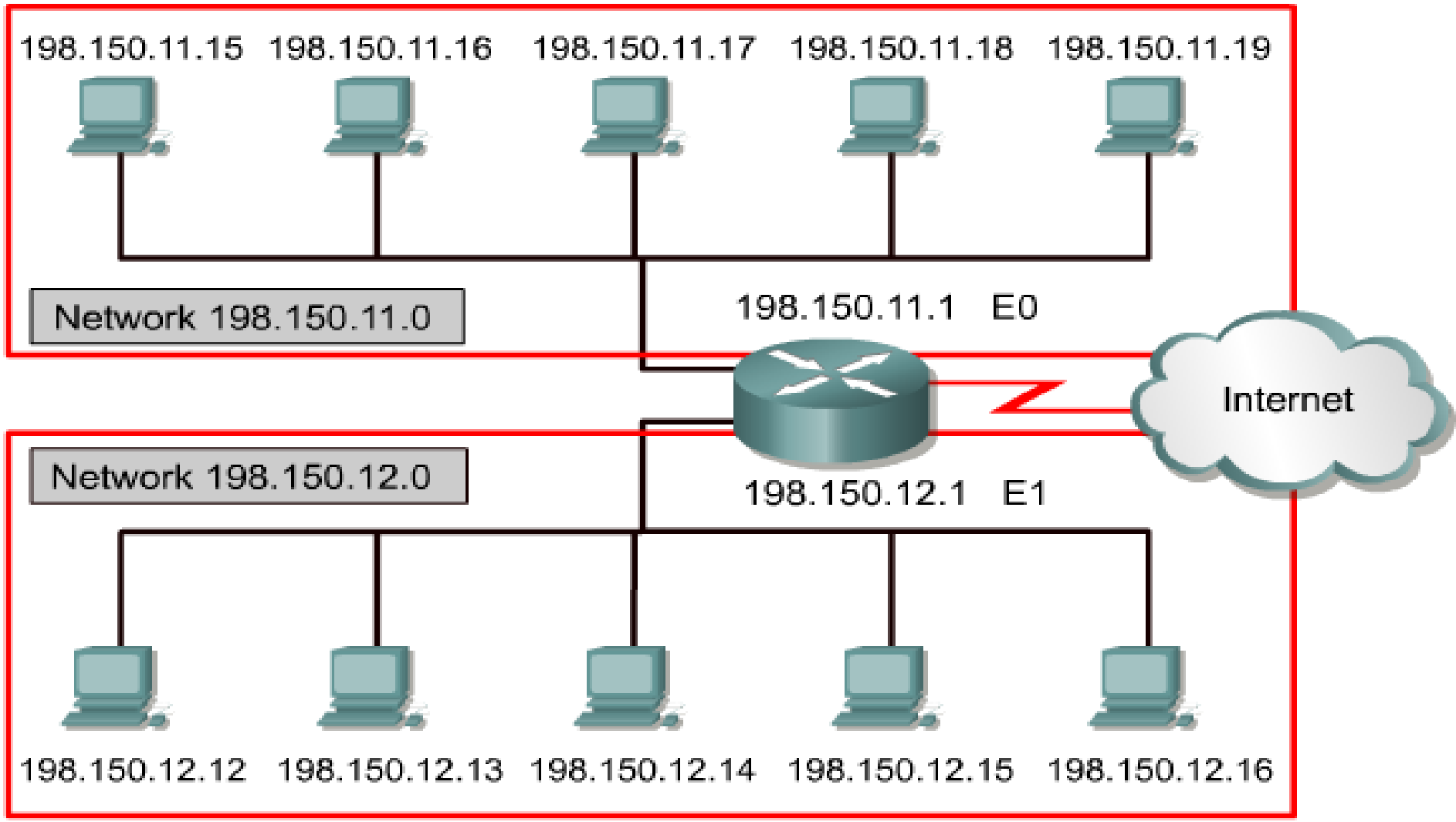
IP address class	IP address range (First Octet Decimal Value)
Class A	1-126 (00000001-01111110) *
Class B	128-191 (10000000-10111111)
Class C	192-223 (11000000-11011111)
Class D	224-239 (11100000-11101111)
Class E	240-255 (11110000-11111111)

Mixing Public and Private IP Addresses:

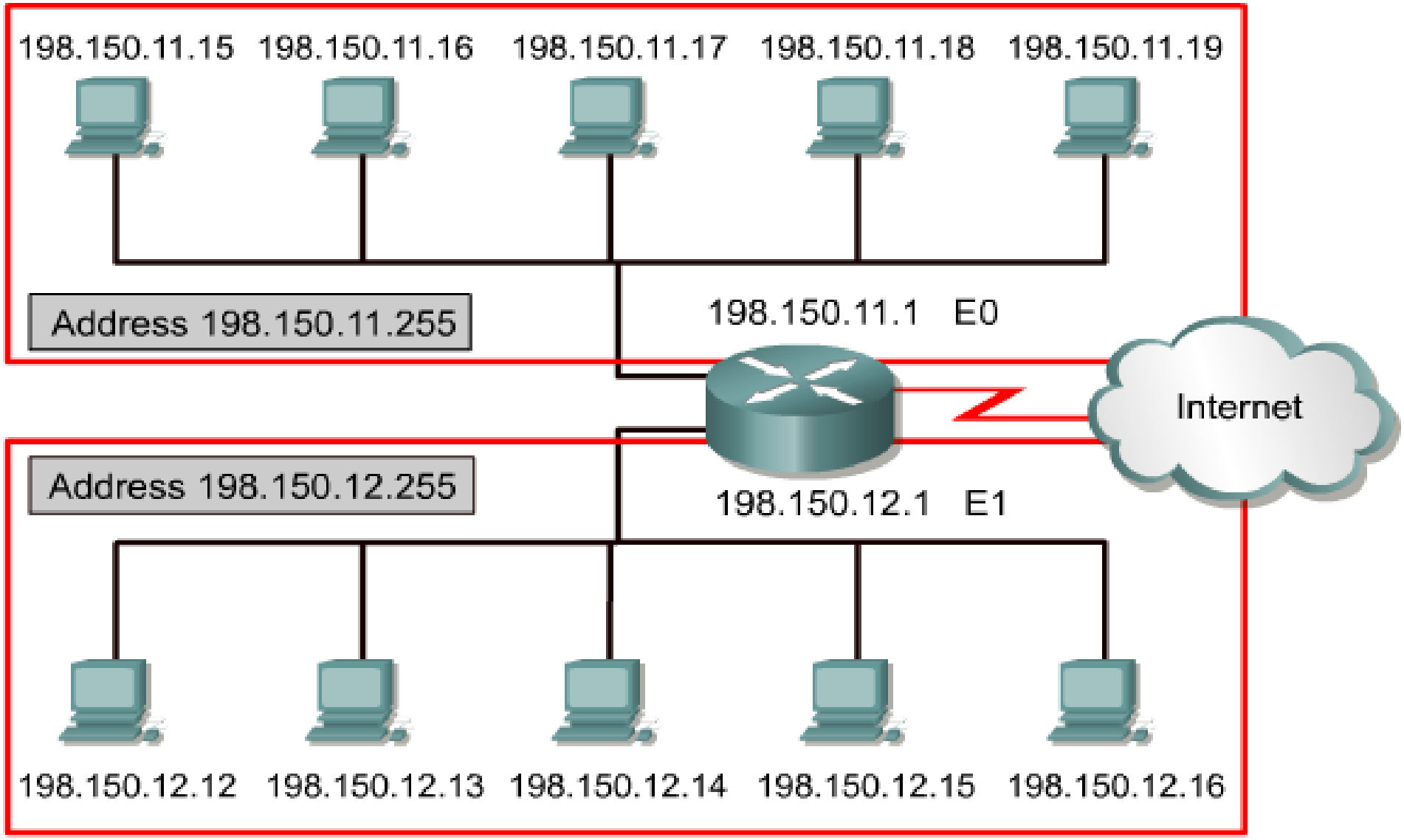
Private IP addresses can be intermixed, as shown in the graphic, with public IP addresses. This will conserve the number of addresses used for internal connections. Connecting a network using private addresses to the Internet requires translation of the private addresses to public addresses. This translation process is referred to as Network Address Translation (NAT).



Network Address:

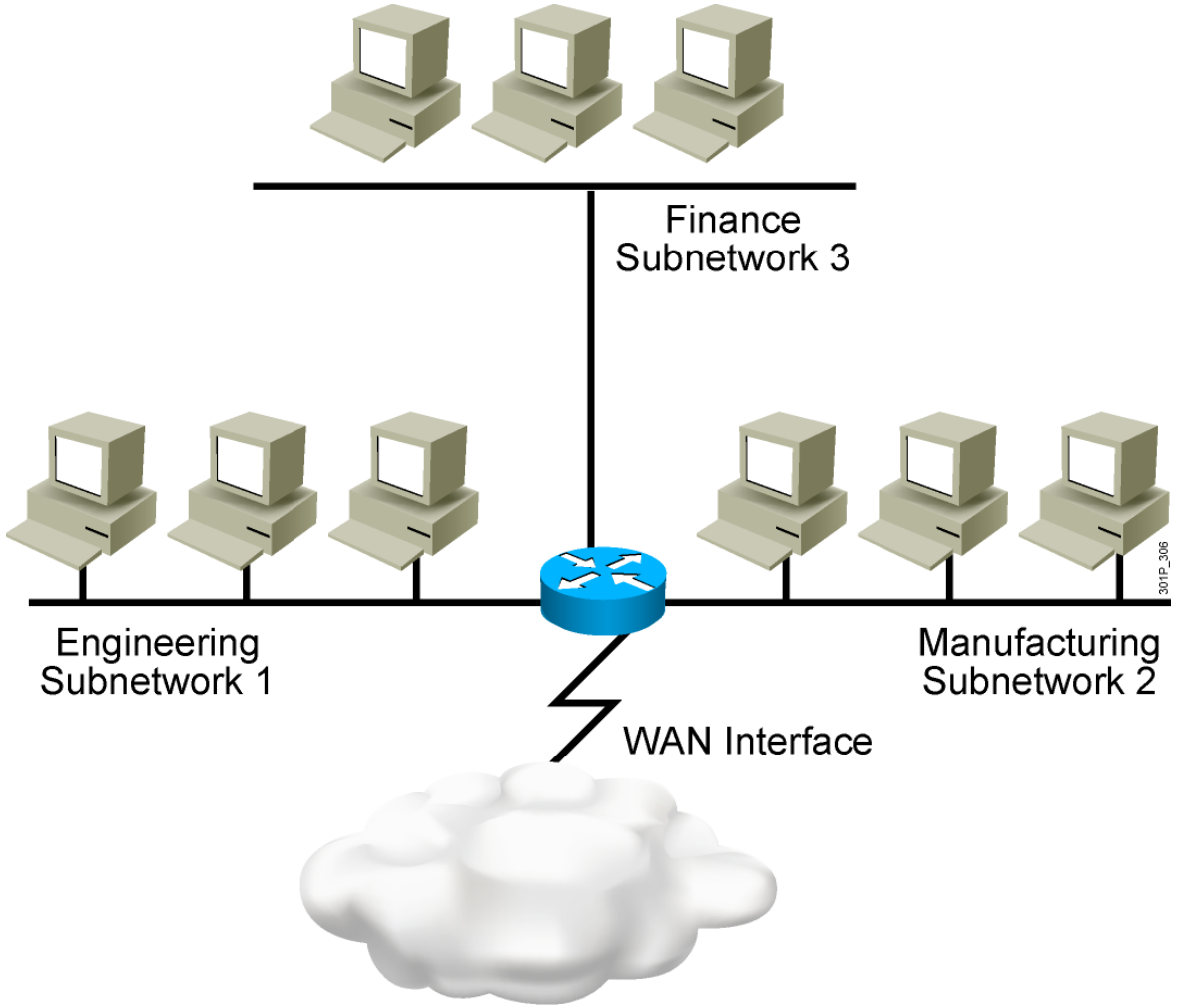


Broadcast Address:

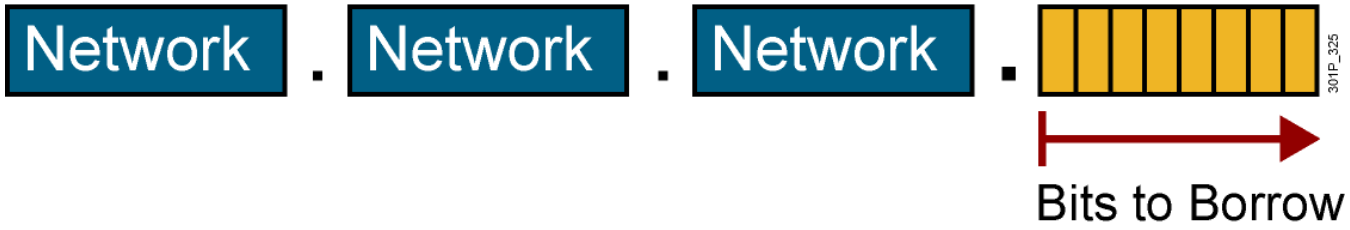


Sub networks:

- Smaller networks are easier to manage.
- Overall traffic is reduced.
- You can more easily apply network security policies.



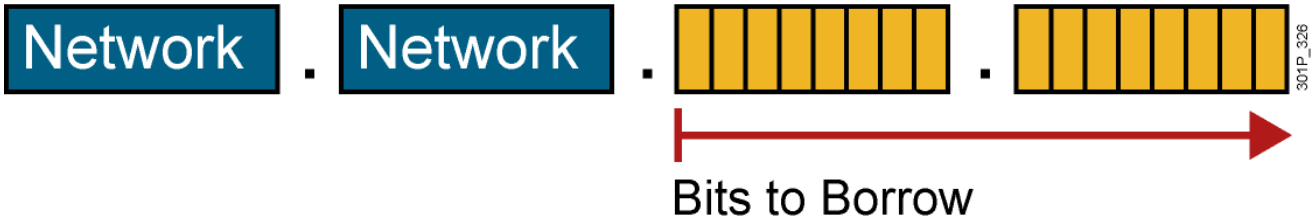
Possible Subnets and Hosts for a Class C Network:



Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID (8 - s = h)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	7	126
2	4	6	62
3	8	5	30
4	16	4	14
5	32	3	6
6	64	2	2
7	128	1	2

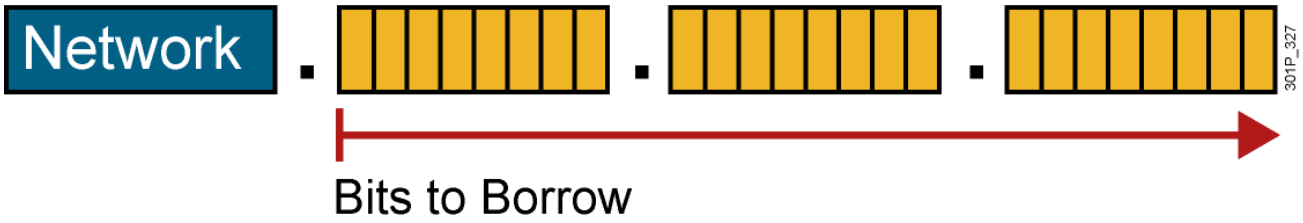
022P_305

Possible Subnets and Hosts for a Class B Network:



Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID ($16 - s = h$)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	15	32,766
2	4	14	16,382
3	8	13	8,190
4	16	12	4,094
5	32	11	2,046
6	64	10	1,022
7	128	9	510
…	…	…	…

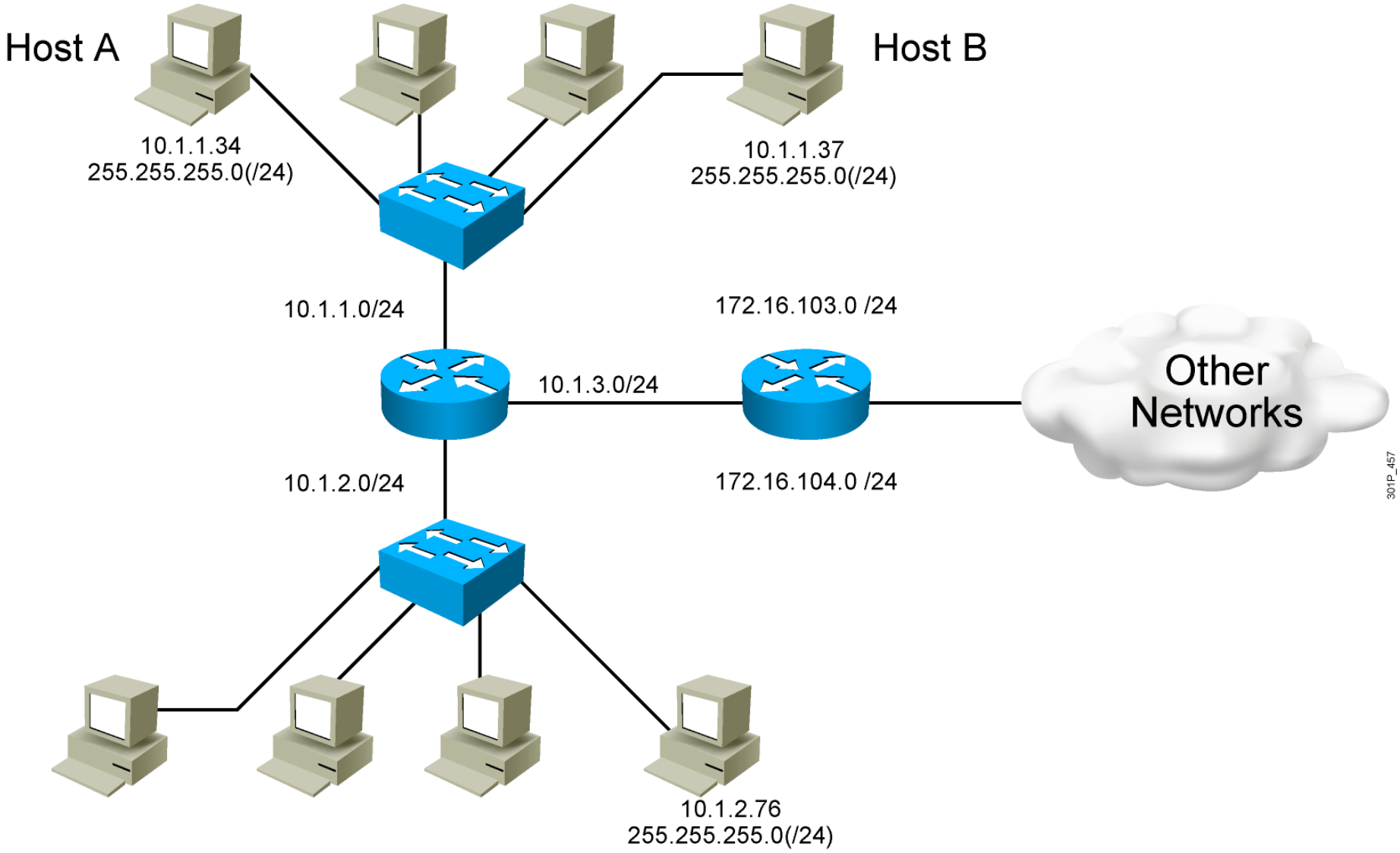
Possible Subnets and Hosts for a Class A Network:



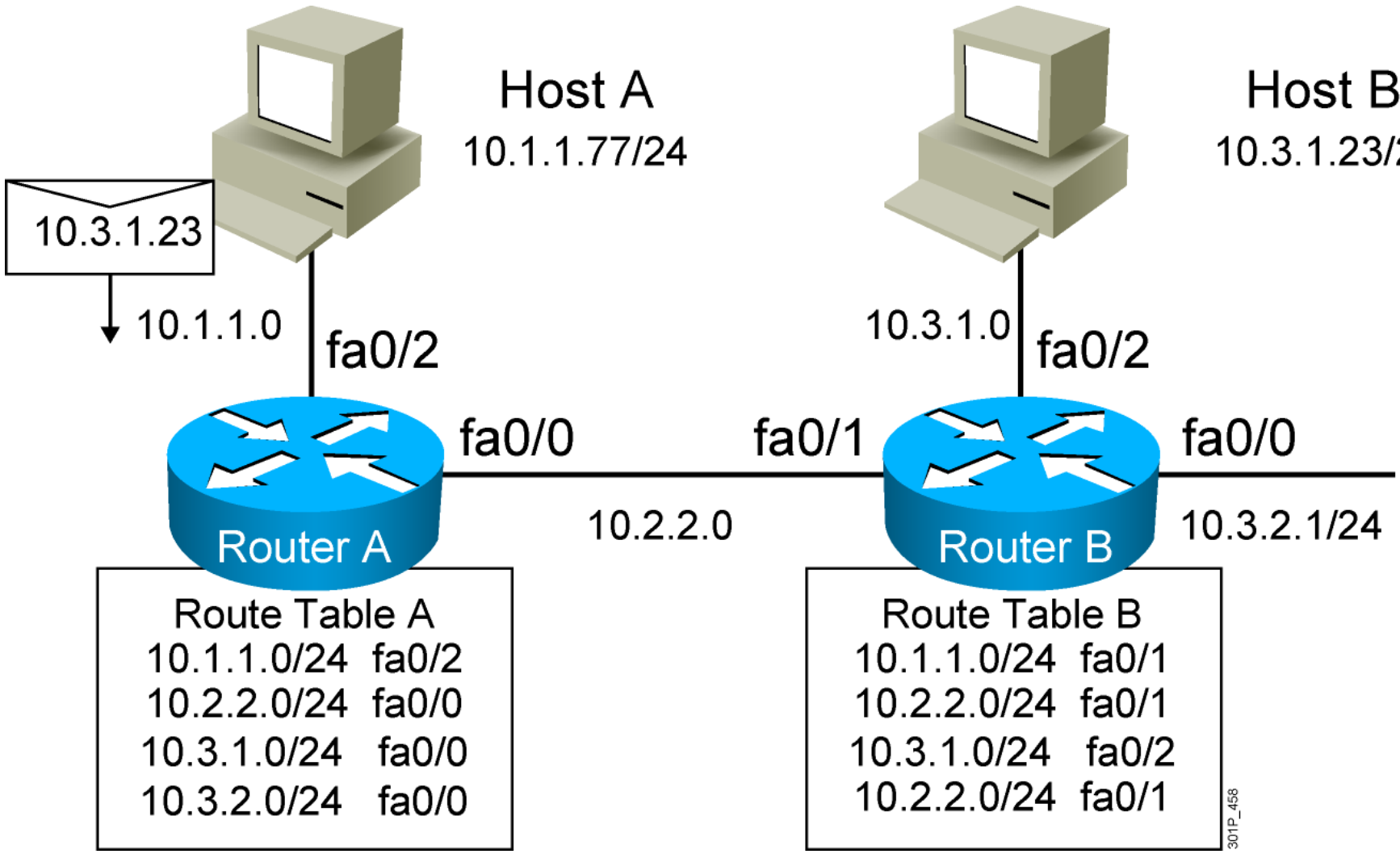
Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID ($24 - s = h$)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	23	8,388,606
2	4	22	4,194,302
3	8	21	2,097,150
4	16	20	1,048,574
5	32	19	524,286
6	64	18	262,142
7	128	17	131,070
…	…	…	…

301P_303

End System Subnet Mask Operation:



How Routers Use Subnet Masks:



Octet Values of a Subnet Mask:

128	64	32	16	8	4	2	1		
1	0	0	0	0	0	0	0	=	128
1	1	0	0	0	0	0	0	=	192
1	1	1	0	0	0	0	0	=	224
1	1	1	1	0	0	0	0	=	240
1	1	1	1	1	0	0	0	=	248
1	1	1	1	1	1	0	0	=	252
1	1	1	1	1	1	1	0	=	254
1	1	1	1	1	1	1	1	=	255

022P_164

Subnet masks, like IP addresses, are represented in the dotted decimal format like 255.255.255.0

Default Subnet Masks:

Example Class A address (decimal):	10.0.0.0
Example Class A address (binary):	00001010.00000000.00000000.00000000
Default Class A mask (binary):	11111111.00000000.00000000.00000000
Default Class A mask (decimal):	255.0.0.0
Default classful prefix length:	/8

Example Class B address (decimal):	172.16.0.0
Example Class B address (binary):	10010001.10101000.00000000.00000000
Default Class B mask (binary):	11111111.11111111.00000000.00000000
Default Class B mask (decimal):	255.255.0.0
Default classful prefix length:	/16

Example Class C address (decimal):	192.168.42.0
Example Class C address (binary):	11000000.10101000.00101010.00000000
Default Class C mask (binary):	11111111.11111111.11111111.00000000
Default Class C mask (decimal):	255.255.255.0
Default classful prefix length:	/24

Fixed-Length Subnet Mask:

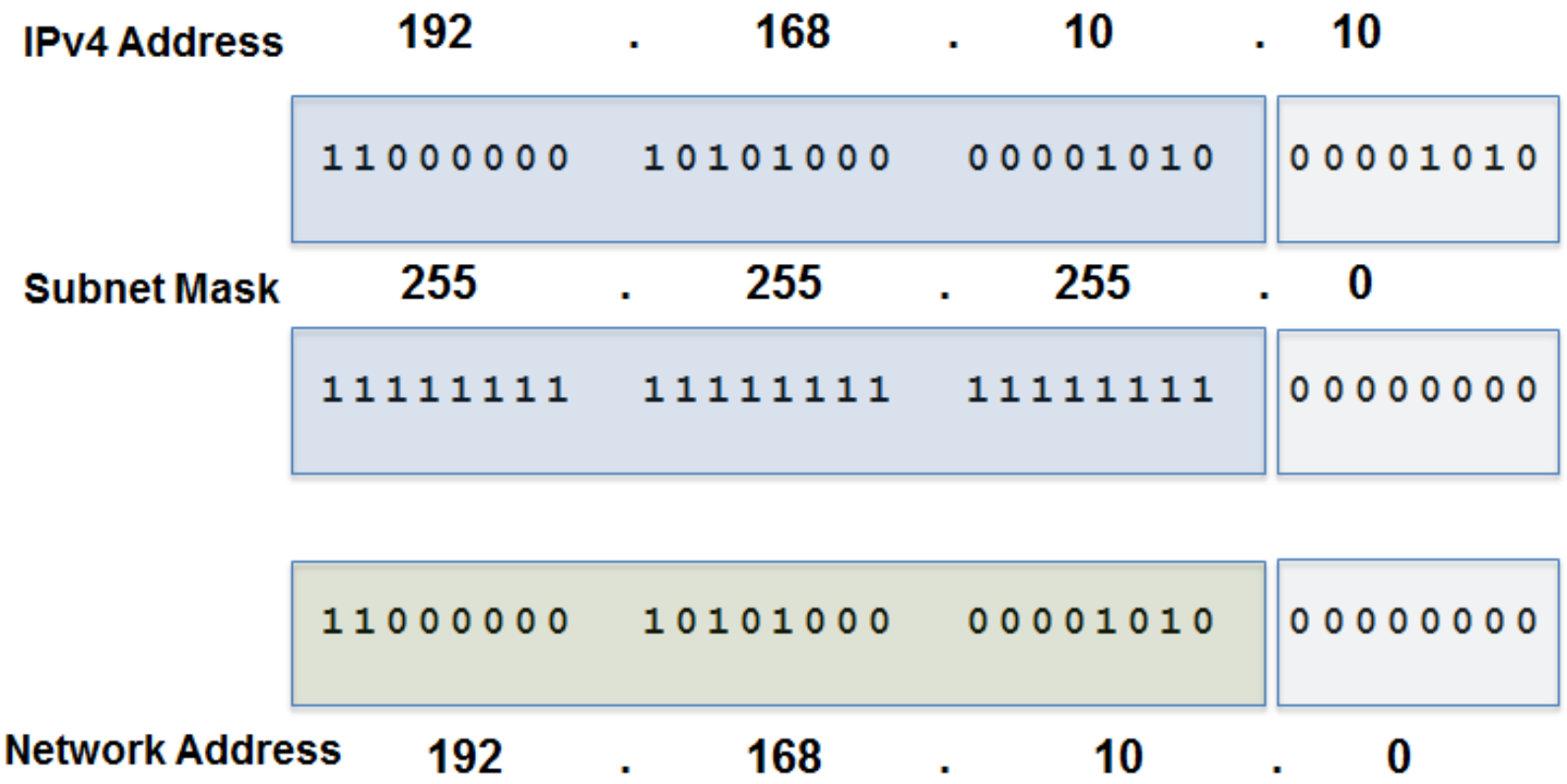
- 192.168.1.0/24 Subnet into networks contain:
  - 30 hosts
  - 62 hosts
  - 126 hosts

- 172.16.0.0/16 Subnet into networks contain:
  - 500 hosts
  - 1022 hosts
  - 2046 hosts

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		

Bitwise AND Operation

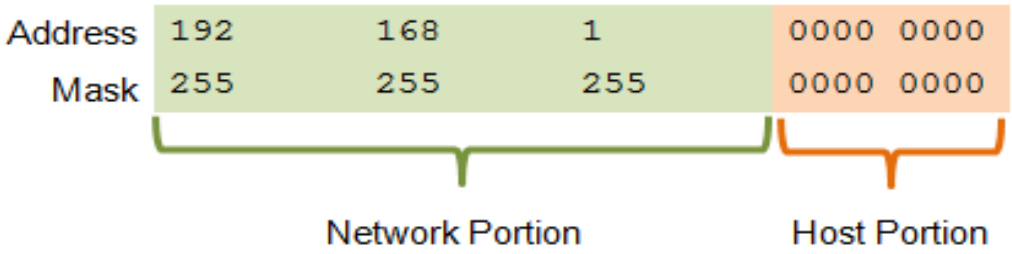


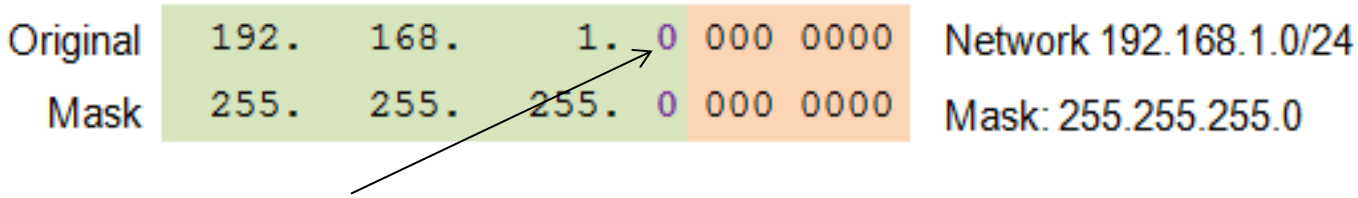
1 AND 1 = 1 1 AND 0 = 0 0 AND 1 = 0 0 AND 0 = 0

Basic Subnetting

Borrowing Bits to Create Subnets

Borrowing 1 bit $2^1 = 2$ subnets





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

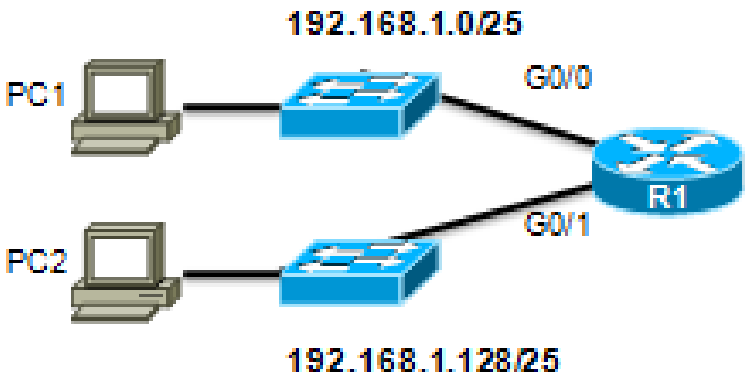
Network 192.168.1.**128-255**/**25**

Mask: 255.255.255.**128**

Basic Subnetting

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

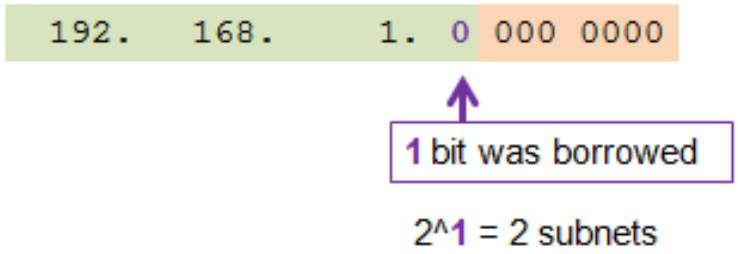
Broadcast Address

192. 168. 1. 1 111 1111 = 192.168.1.255

Subnetting Formulas

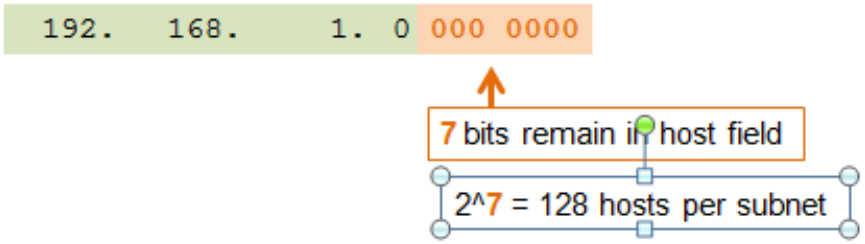
Calculate Number of Subnets

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



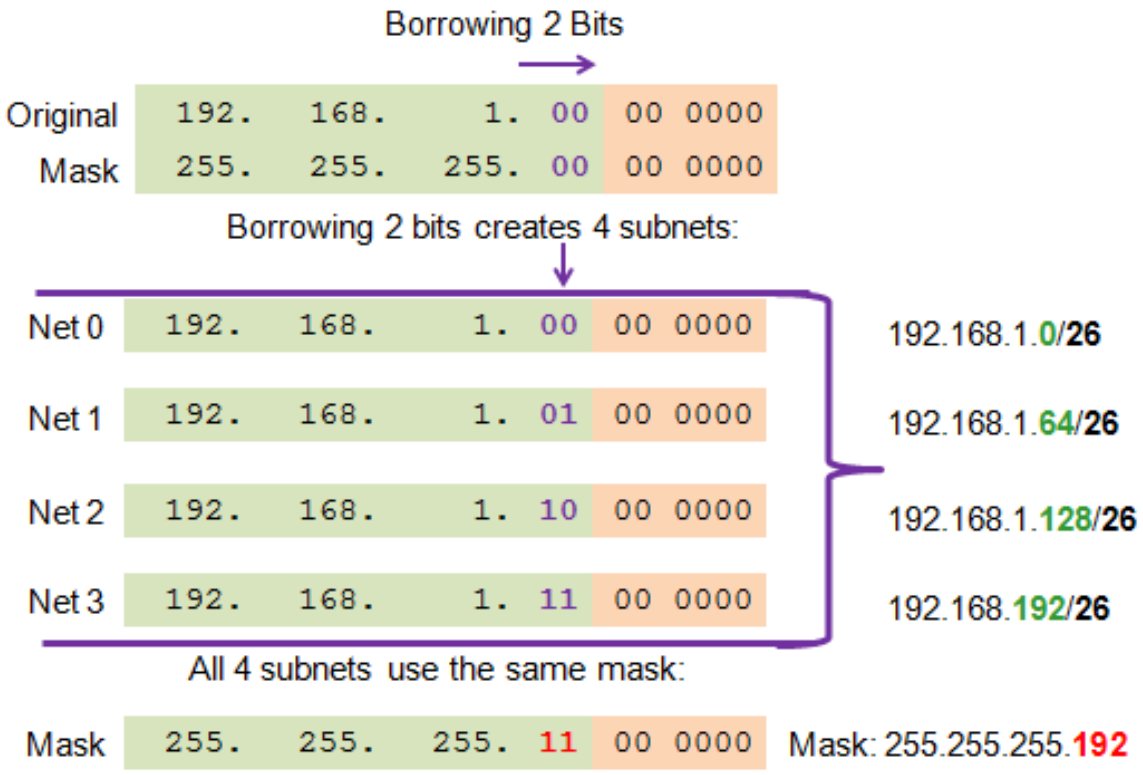
Calculate Number of Hosts

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



Creating 4 Subnets

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



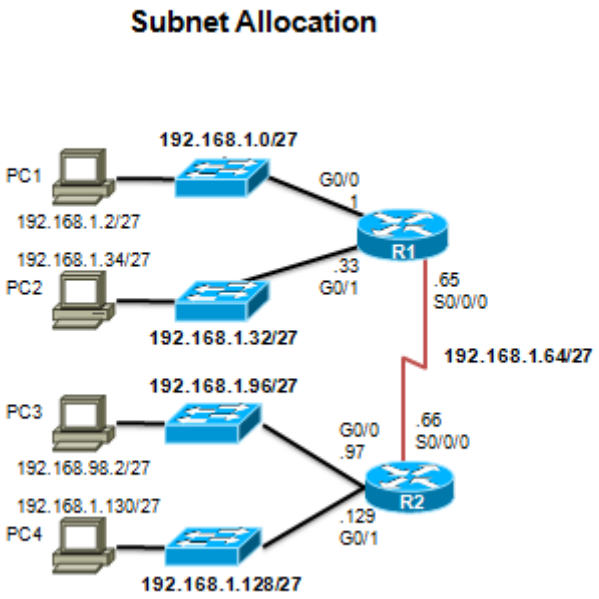
Creating 8 Subnets

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

Creating 8 Subnets(continued)

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



Eight Easy Steps for Determining Subnet Addresses:

IP Address: 192.168.221.37 Subnet Mask /29

Step	Description	Example
1.	Write the octet that is being split in binary.	Fourth octet: 00100101
2.	Write the mask or classful prefix length in binary.	Assigned mask: 255.255.255.248 (/29) Fourth octet: 11111000
3.	Draw a line to delineate the significant bits in the assigned IP address. Cross out the mask so you can view the significant bits in the IP address.	Split octet (binary): 00100101 Split mask (binary): 11111000

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Eight Easy Steps for Determining Subnet Addresses (Cont.)

Step	Description	Example
4.	Copy the significant bits four times.	00100 000 (network address) 00100 001 (first address in subnet) 00100 110 (last address in subnet) 00100 111 (broadcast address)?
5.	In the first line, define the network address by placing all zeros in the significant bits.	
6.	In the last line, define the broadcast address by placing all ones in the significant bits.	
7.	In the middle lines, define the first and last host number.	
8.	Increment the subnet bits by one.	00101 000 (next subnet)

Completed Subnet Addresses

Network address: 192.168.221.32
Subnet mask: 255.255.255.248
First subnet: 192.168.221.32
First host address: 192.168.221.33
Last host address: 192.168.221.38
Broadcast address: 192.168.221.39
Next subnet: 192.168.221.40

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Example: Applying a Subnet Mask for a Class C Address

IP Address 192.168.5.139 Subnet Mask 255.255.255.224

IP Address	192	168	5	139	
IP Address	11000000	10101000	00000101	10001011	
Subnet Mask	11111111	11111111	11111111	11100000	/27
Subnetwork	11000000	10101000	00000101	10000000	
Subnetwork	192	168	5	128	
First Host	192	168	5	10000001=129	
Last Host	192	168	5	10011110=158	
Directed Broadcast	192	168	5	10011111=159	
Next Subnet	192	168	5	10100000=160	

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Example: Applying a Subnet Mask for a Class B Address

IP Address 172.16.139.46 Subnet Mask /20

IP Address	172	16	139	46	
IP Address	10101100	00010000	10001011	00101110	
Subnet Mask	11111111	11111111	11110000	00000000	/20
Subnetwork	10101100	00010000	10000000	00000000	
Subnetwork	172	16	128	0	
First Host	172	16	10000000	00000001=128.1	
Last Host	172	16	10001111	11111110=143.254	
Directed Broadcast	172	16	10001111	11111111=143.255	
Next Subnet	172	16	10010000	00000000=144.0	

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Example: Applying a Subnet Mask for a Class A Address

IP Address 10.172.16.211 Subnet Mask /18

IP Address	10	172	16	211	
IP Address	00001010	10101100	00010000	11010011	
Subnet Mask	11111111	11111111	11000000	00000000	/18
Subnetwork	00001010	10101100	00000000	00000000	
Subnetwork	10	172	0	0	
First Host	10	172	00000000	00000001=0.1	
Last Host	10	172	00111111	11111110=63.254	
Directed Broadcast	10	172	00111111	11111111=63.255	
Next Subnet	10	172	01000000	00000000=64.0	

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Reference

1. Introduction to Networks Companion Guide (CCNAv7)
2. Introduction to Networks Labs and Study Guide (CCNAv7)
3. Computer Networking: A Top-Down Approach