Understanding the TCP/IP Internet Layer

Internet Protocol Characteristics

- Operates at network layer of OSI
- Connectionless protocol
- Packets treated independently
- Hierarchical addressing
- Best-effort delivery
- No data-recovery features

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

Network.Host

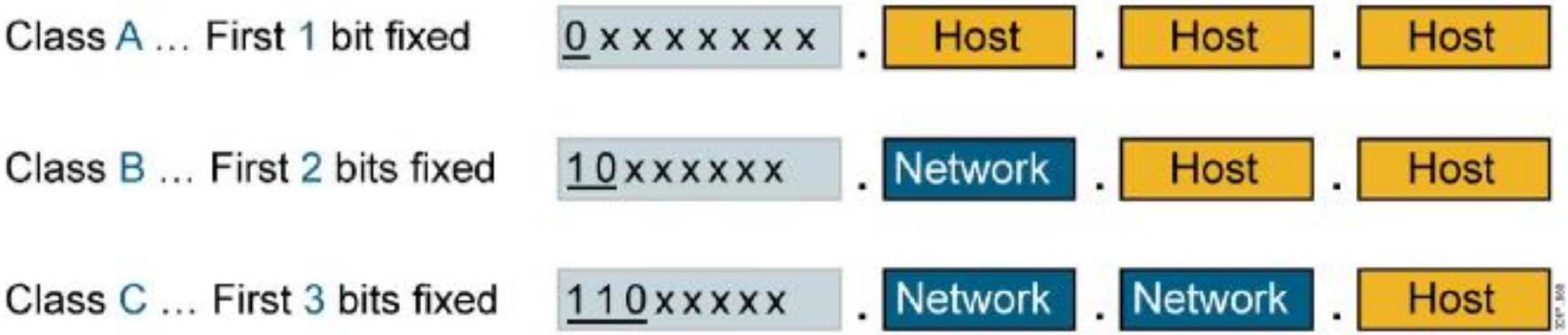
IP Address Format: Dotted Decimal Notation

	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

The binary-to-decimal and decimal-to-binary conversion will be detailed later in this course.

IP Address Classes: The First Octet

A B C … Easy as 1 2 3



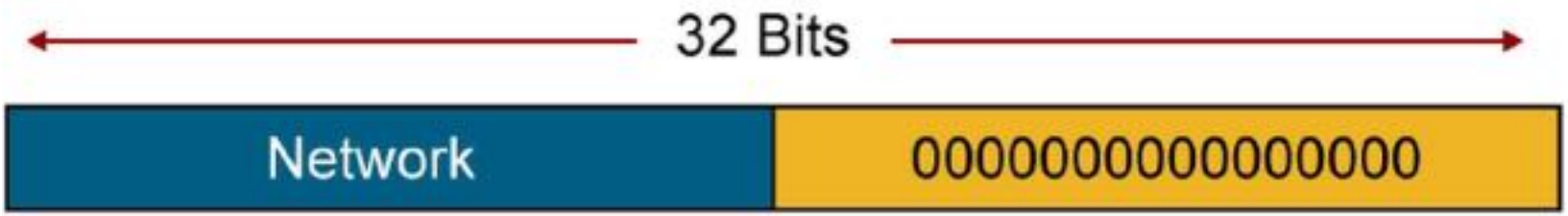
IP Address Ranges

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

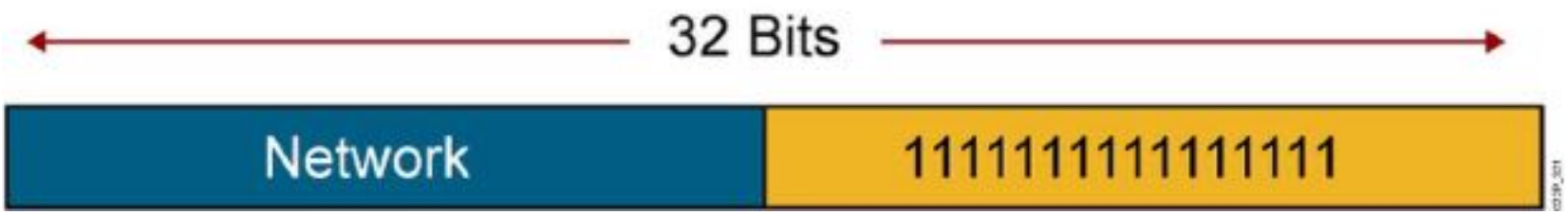
*127 (01111111) is a Class A address reserved for loopback testing and cannot be assigned to a network.

Reserved Address

- Network Addresses



- Broadcast Addresses



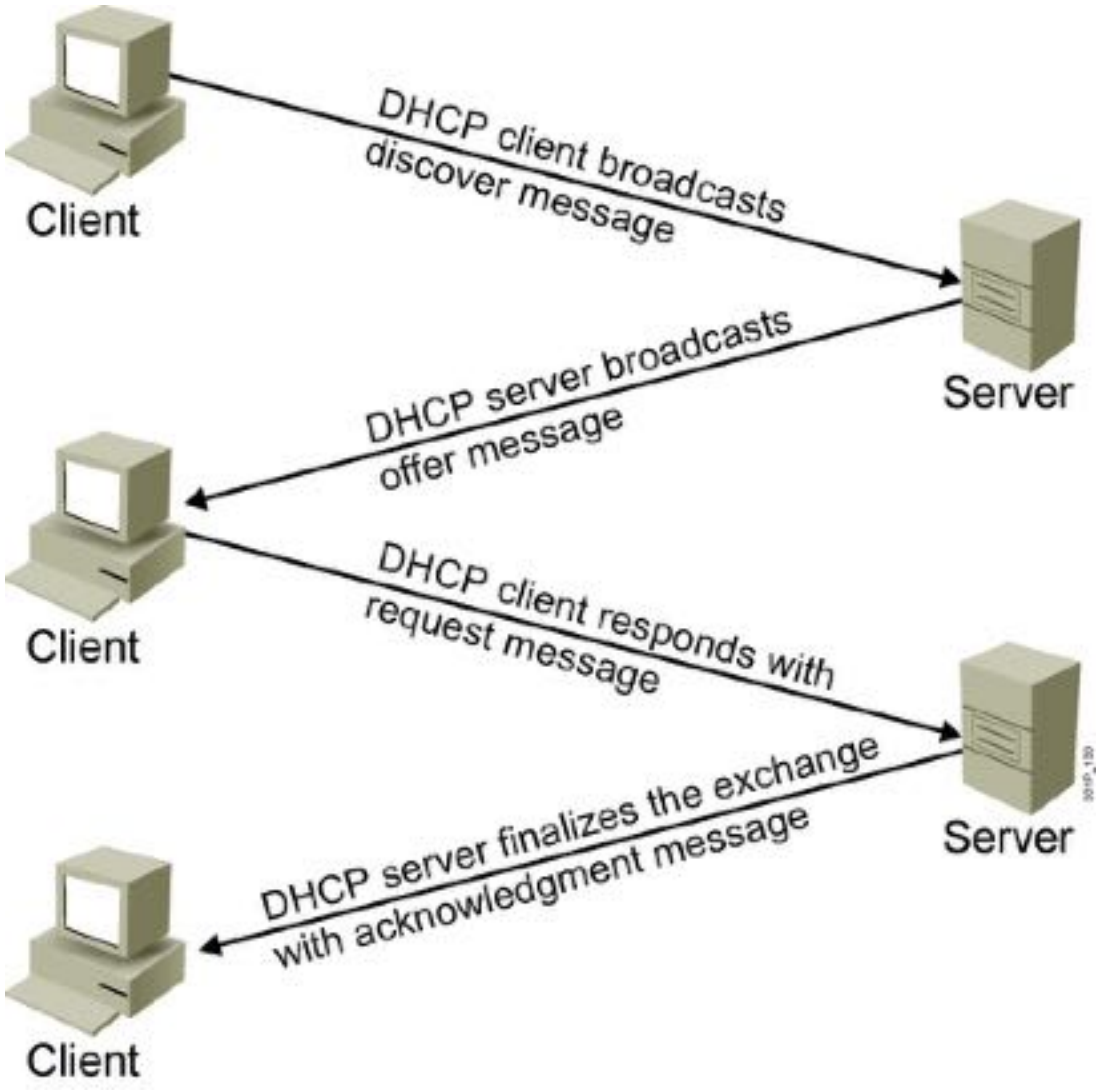
Public IP Addresses

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

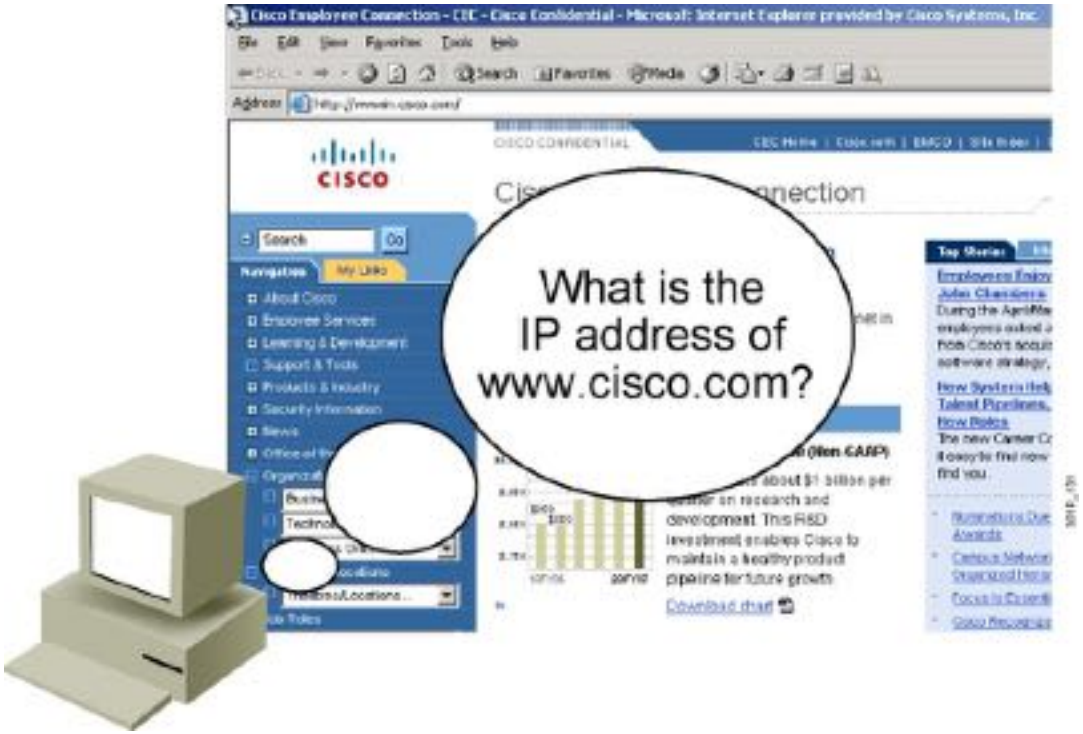
Private IP Addresses

Class	Private Address Range
A	10.0.0.0 to 10.255.255.255
B	172.16.0.0 to 172.31.255.255
C	192.168.0.0 to 192.168.255

DHCP

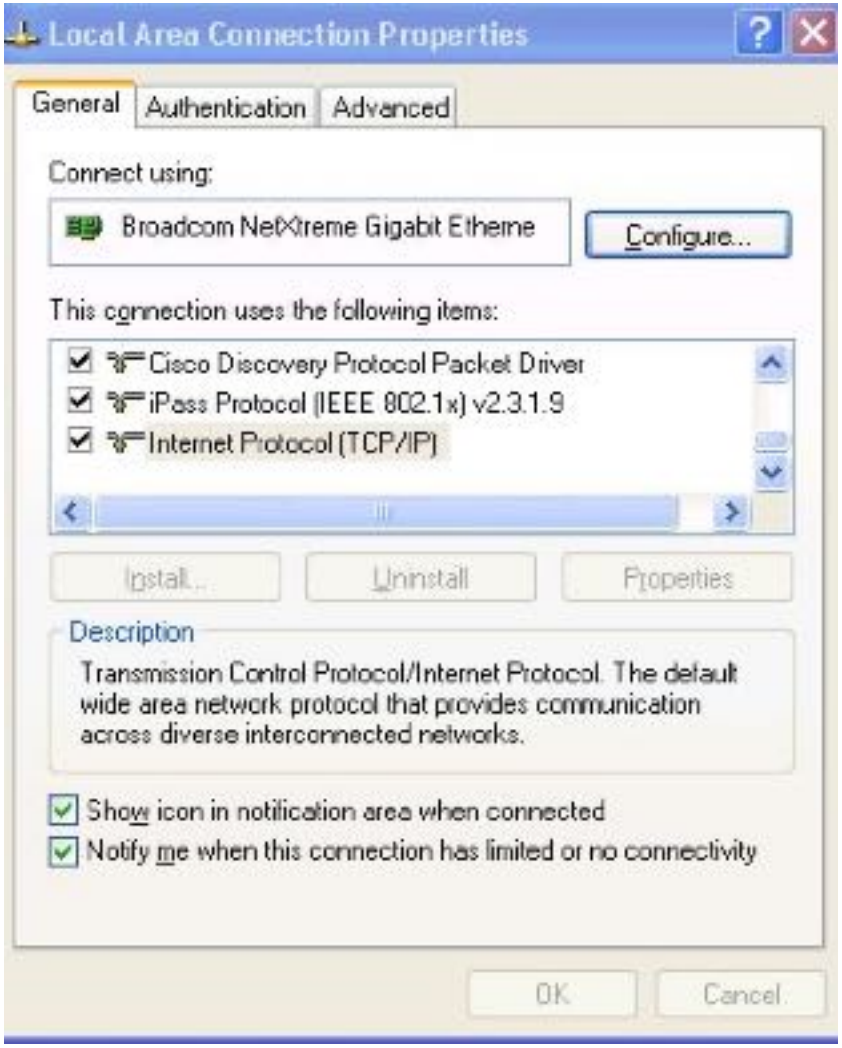


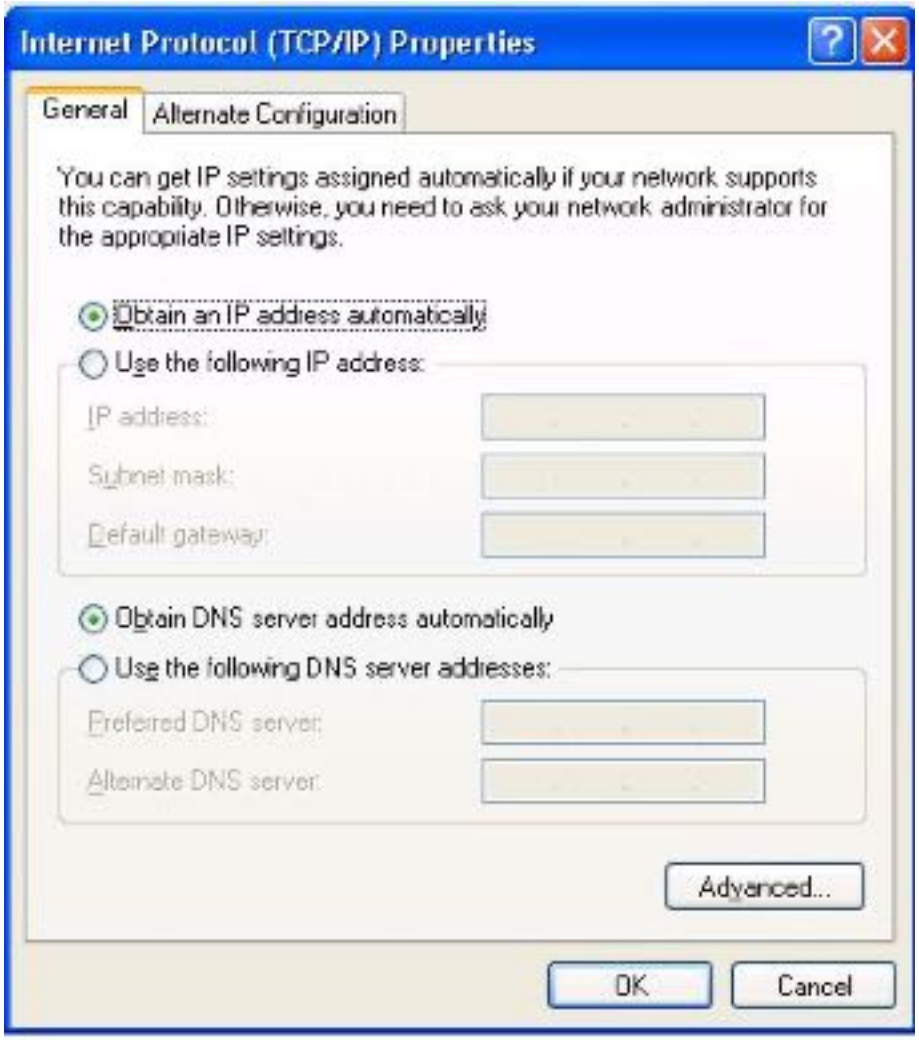
DNS



- Application specified in the TCP/IP suite
- A way to translate human-readable names into IP addresses

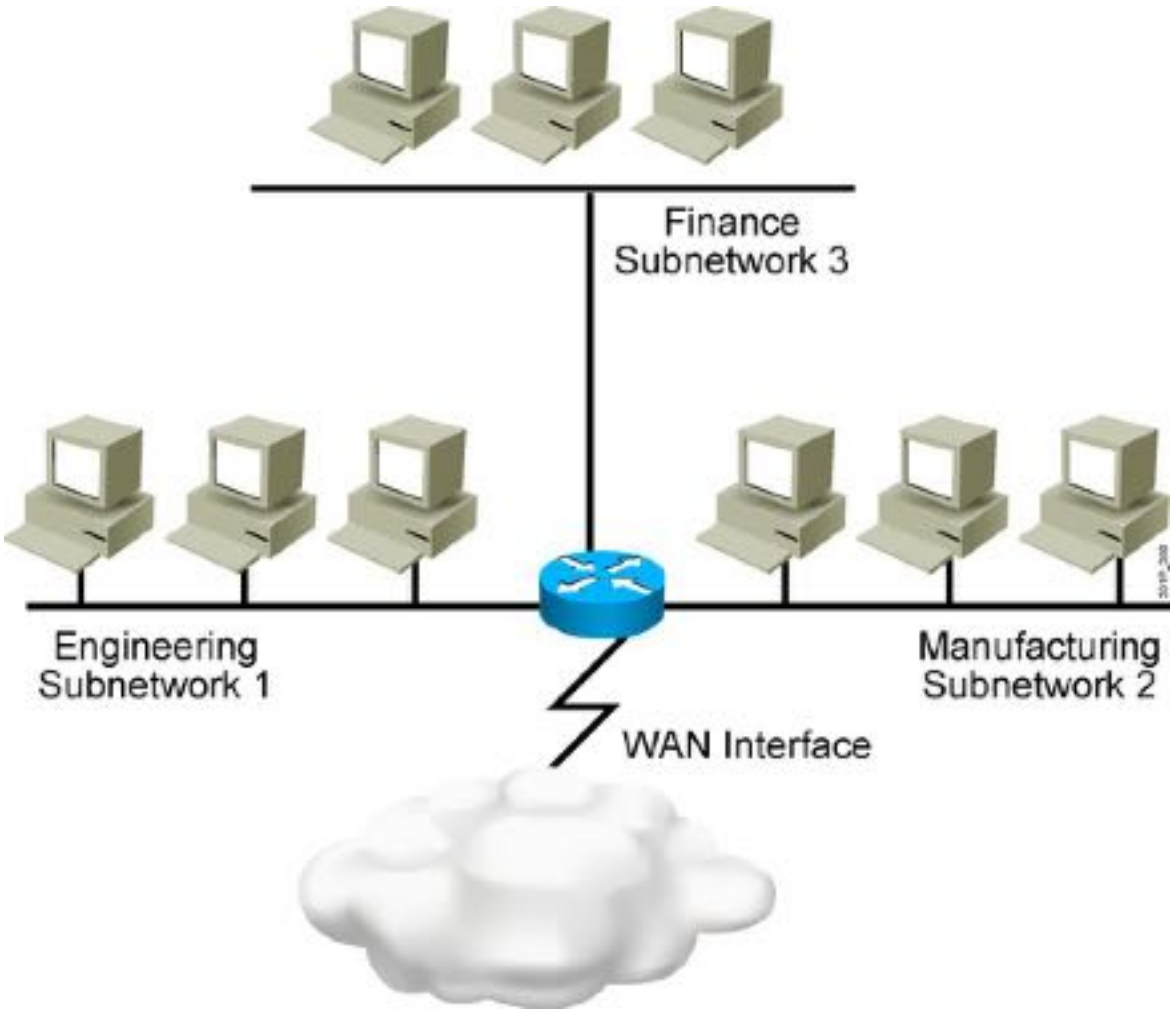
Network Connection





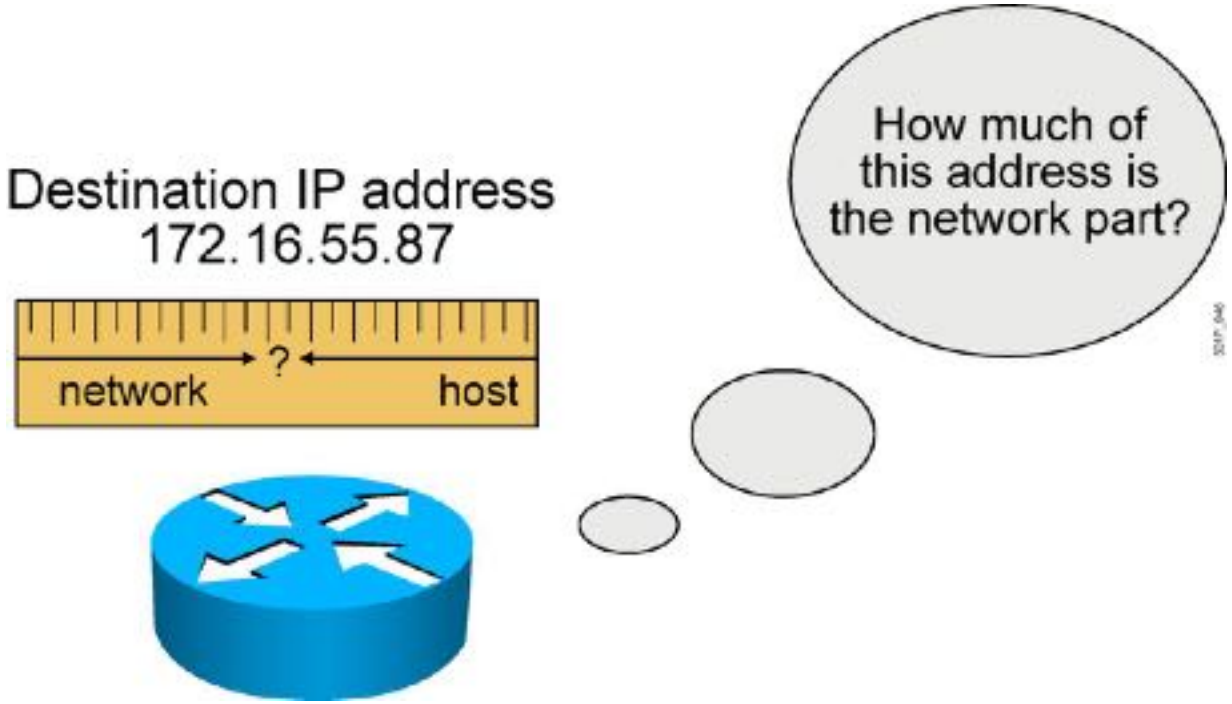
Subnetworks

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



What a Subnet Mask Does

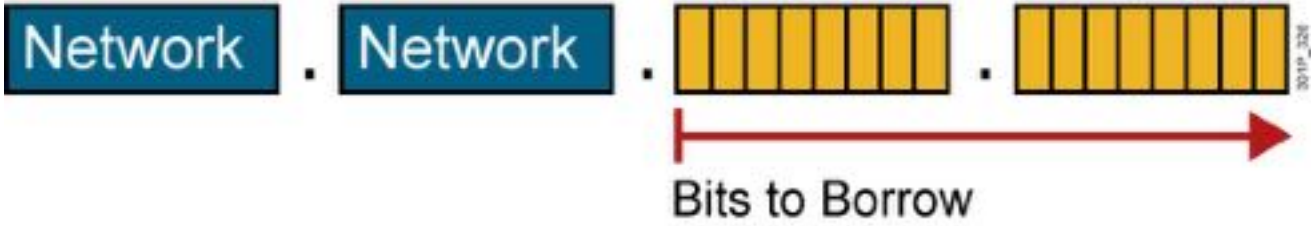
- Tells the router the number of bits to look at when routing
- Defines the number of bits that are significant
- Used as a measuring tool, not to hide anything



Possible Subnets and Hosts for a Class C Network

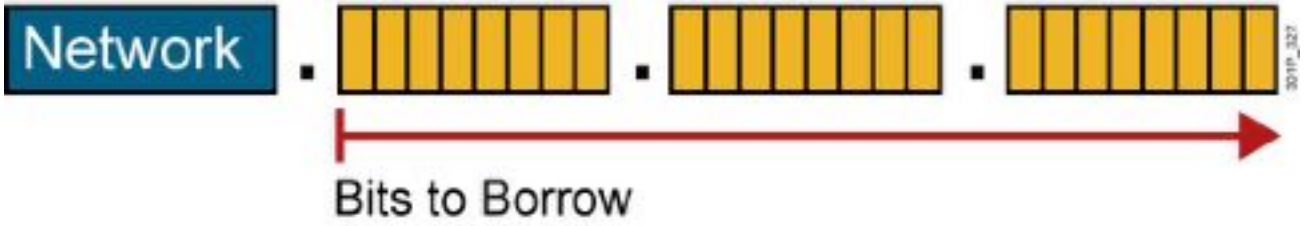
Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID (8 - s = h)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	7	126
2	4	6	62
3	8	5	30
4	16	4	14
5	32	3	6
6	64	2	2
7	128	1	2

Possible Subnets and Hosts for a Class B Network



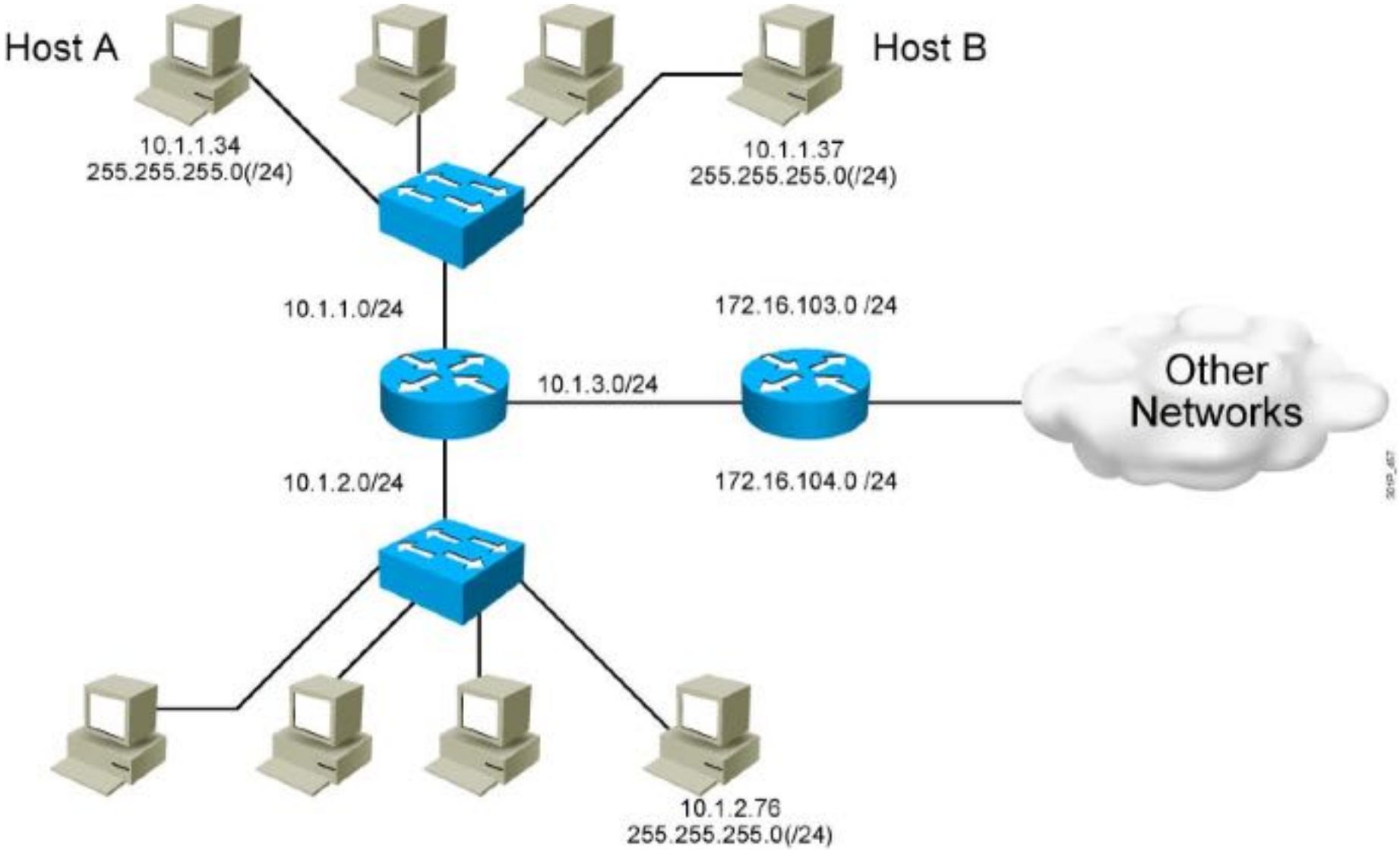
Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID ($16 - s = h$)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	15	32,766
2	4	14	16,382
3	8	13	8,190
4	16	12	4,094
5	32	11	2,046
6	64	10	1,022
7	128	9	510
…	…	…	…

Possible Subnets and Hosts for a Class A Network

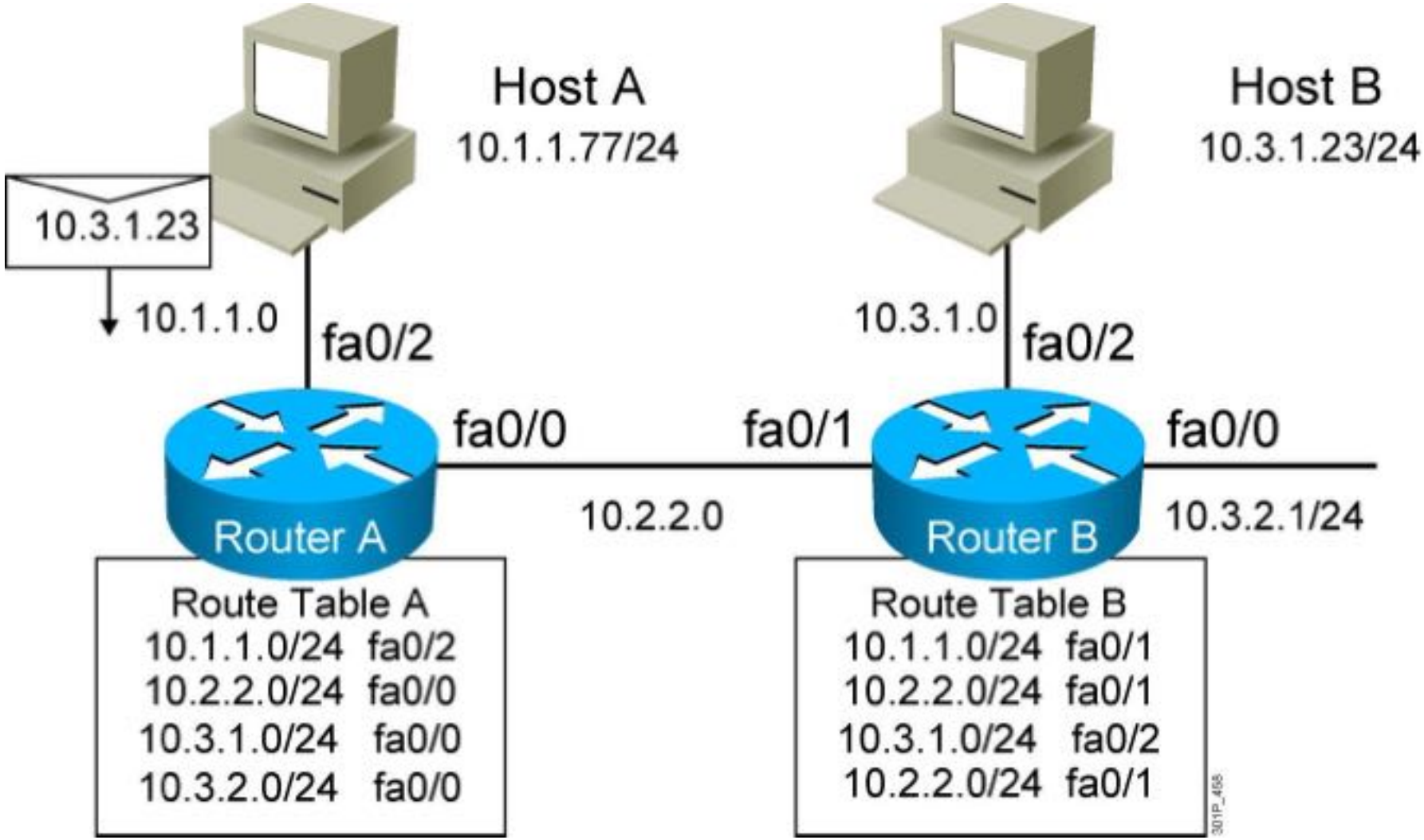


Number of Bits Borrowed (s)	Number of Subnets Possible (2^s)	Number of Bits Remaining in Host ID ($24 - s = h$)	Number of Hosts Possible Per Subnet ($2^h - 2$)
1	2	23	8,388,606
2	4	22	4,194,302
3	8	21	2,097,150
4	16	20	1,048,574
5	32	19	524,286
6	64	18	262,142
7	128	17	131,070
…	…	…	…

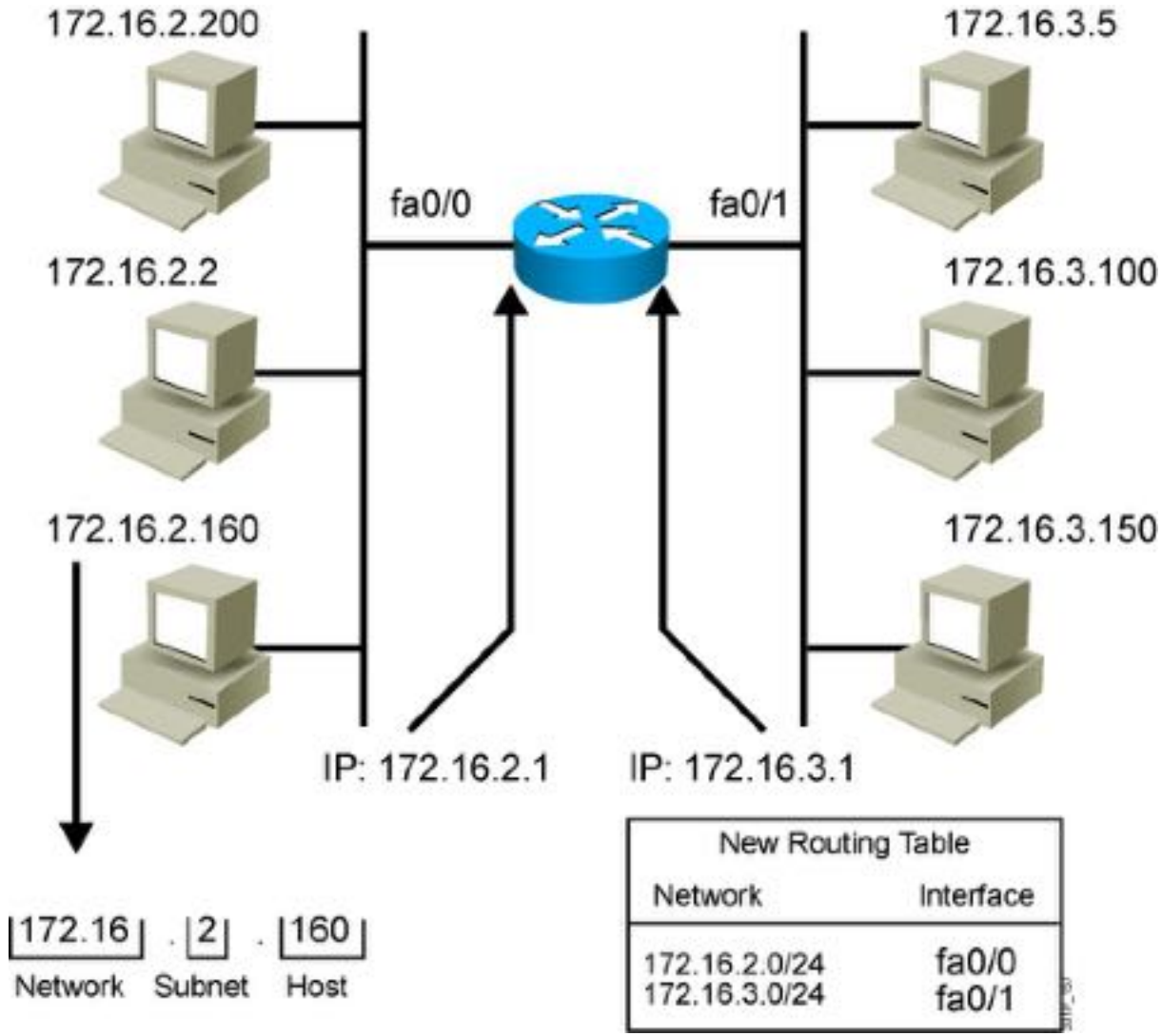
End System Subnet Mask Operation



How Routers Use Subnet Masks



Applying the Subnet Address Scheme



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

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

Procedure for Implementing Subnets

1. Determine the IP address assigned by the registry authority.
2. Based on the organizational and administrative structure, determine the number of subnets required.
3. Based on the address class and required number of subnets, determine the number of bits you need to borrow from the host ID.
4. Determine the binary and decimal value of the subnet mask.
5. Apply the subnet mask to the network IP address to determine the subnet and host addresses.
6. Assign subnet addresses to specific interfaces.

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

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

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	

Example: Applying a Subnet Mask for a Class B Address

IP Address 172.16.139.46 Subnet Mask /20

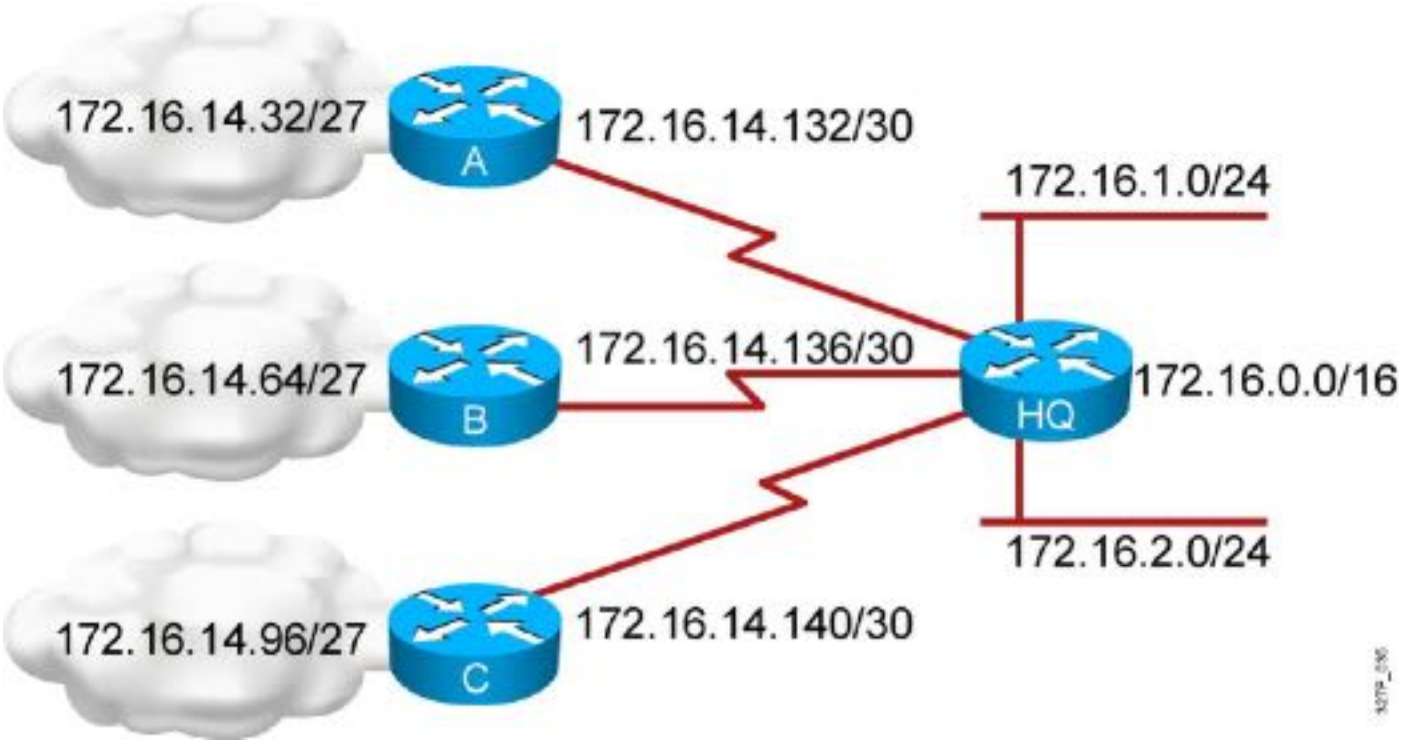
IP Address	172	16	139	46	
IP Address	10101100	00010000	10001011	00101110	
Subnet Mask	11111111	11111111	11110000	00000000	/20
Subnetwork	10101100	00010000	10000000	00000000	
Subnetwork	172	16	128	0	
First Host	172	16	10000000	00000001=128.1	
Last Host	172	16	10001111	11111110=143.254	
Directed Broadcast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

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	

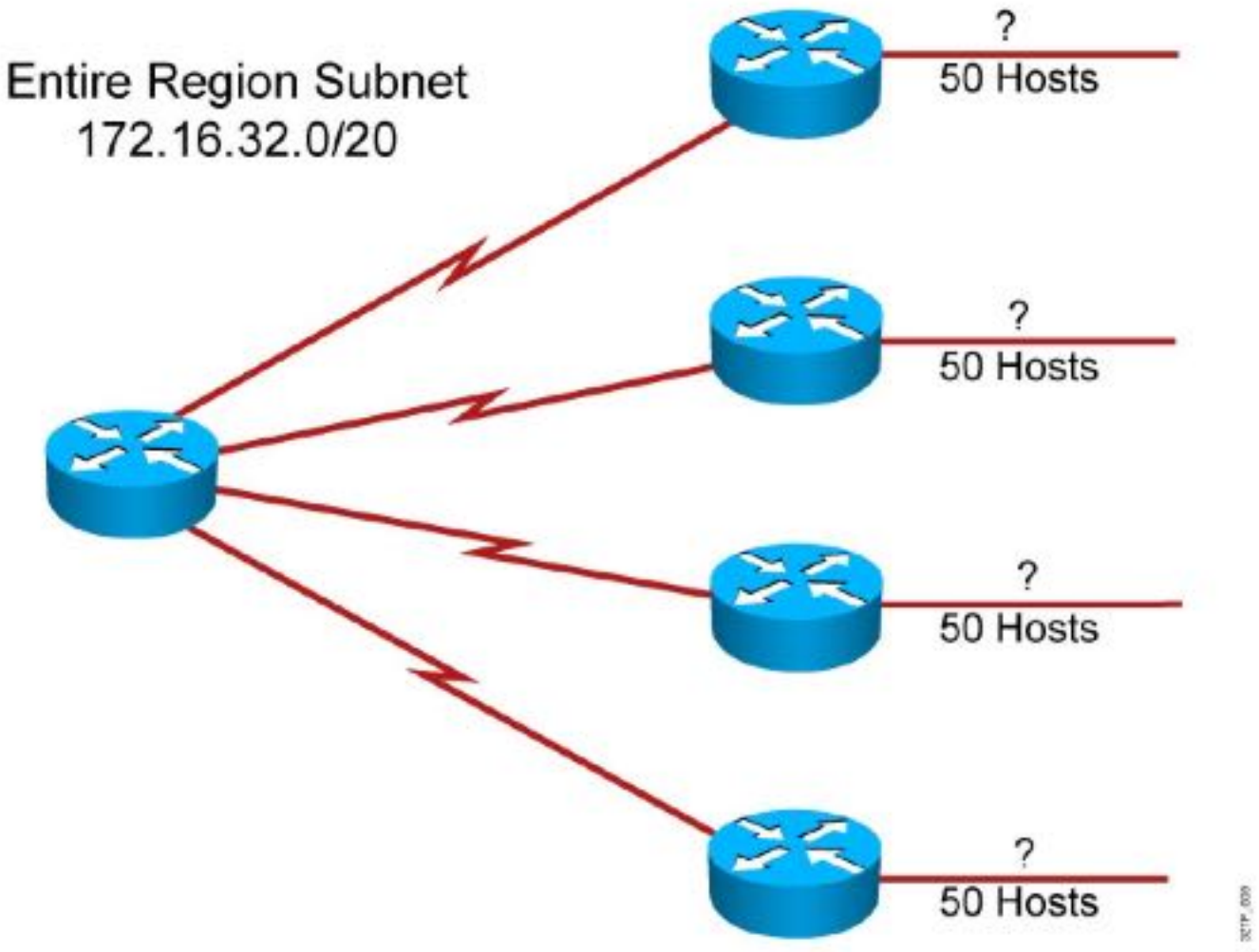
What Is a Variable-Length Subnet Mask?



Subnet 172.16.14.0/24 is divided into smaller subnets.

- Subnet with one mask (/27).
- Then further subnet one of the unused /27 subnets into multiple /30 subnets.

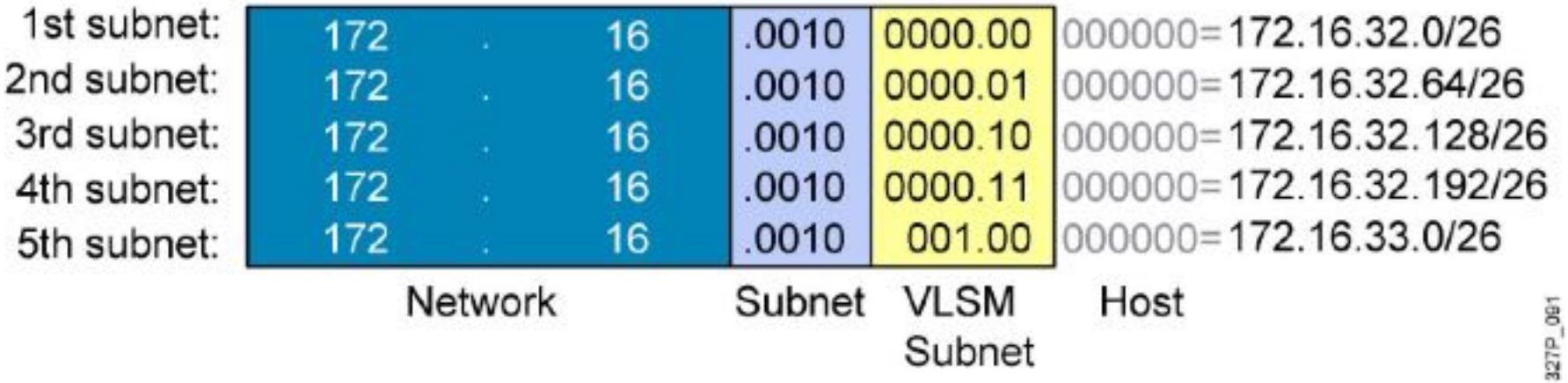
A Working VLSM Example



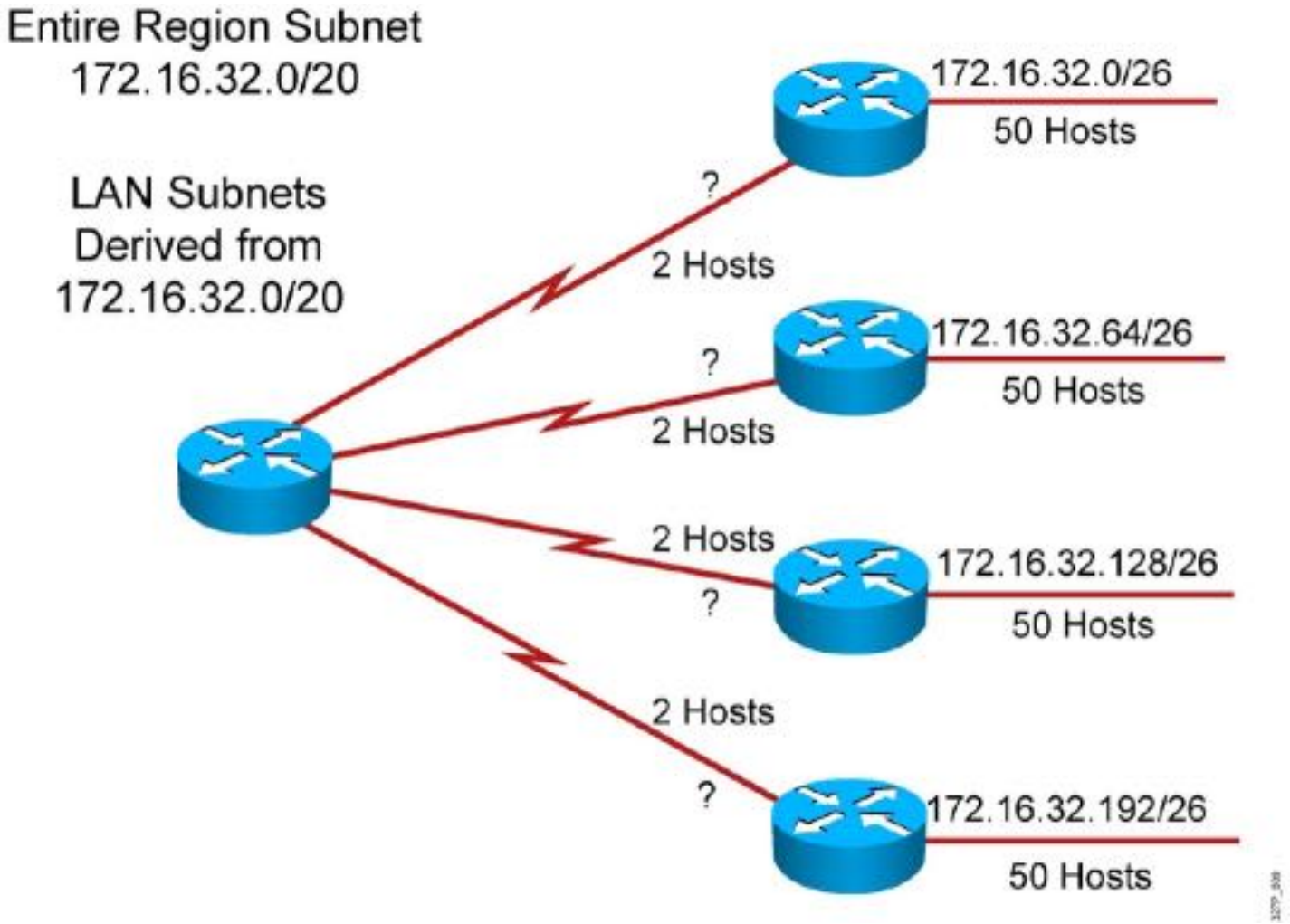
A Working VLSM Example (Cont.)

Subnetted Address: 172.16.32.0/20
In Binary 10101100. 00010000.00100000.00000000

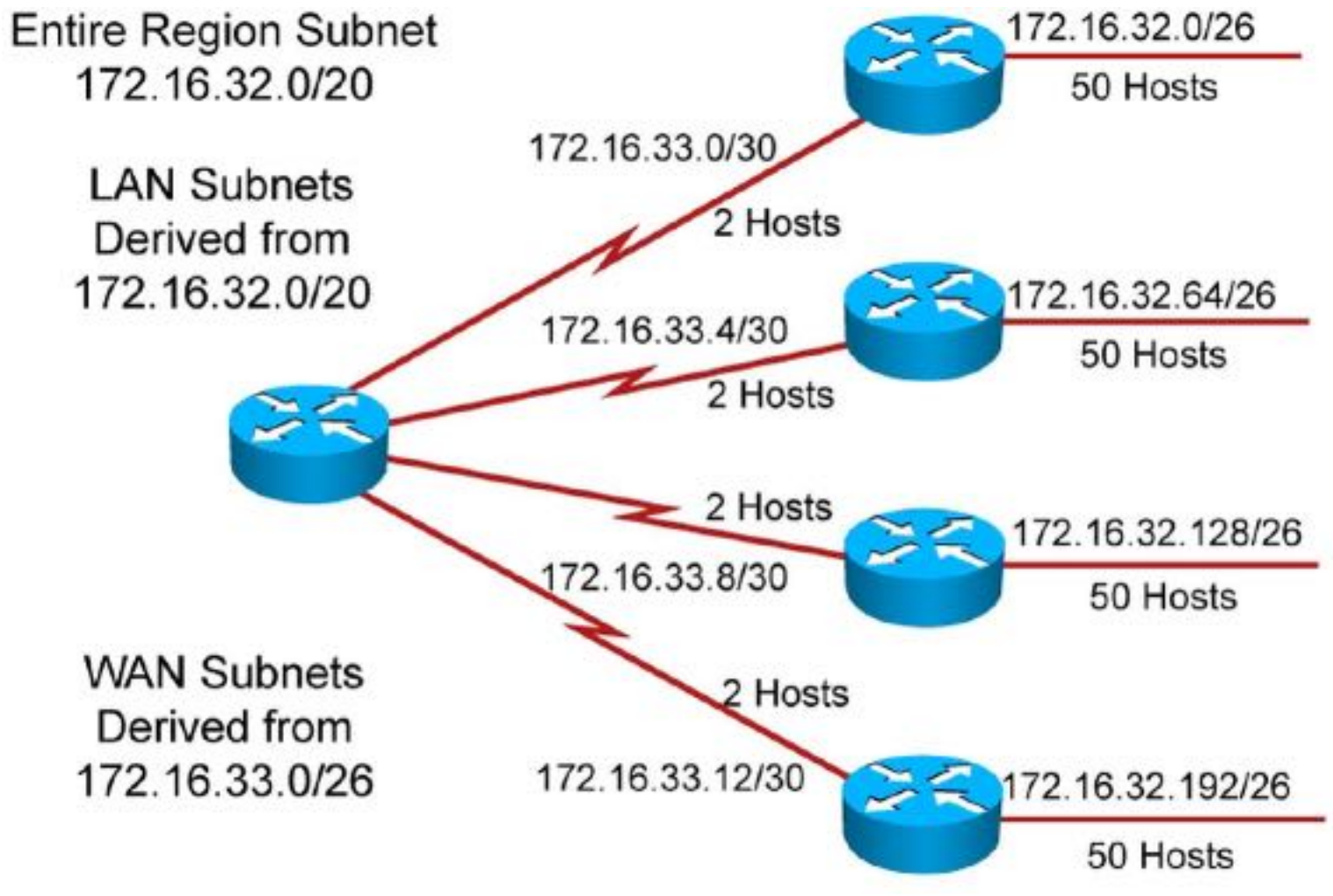
VLSM Address: 172.16.32.0/26
In Binary 10101100. 00010000.00100000.00000000



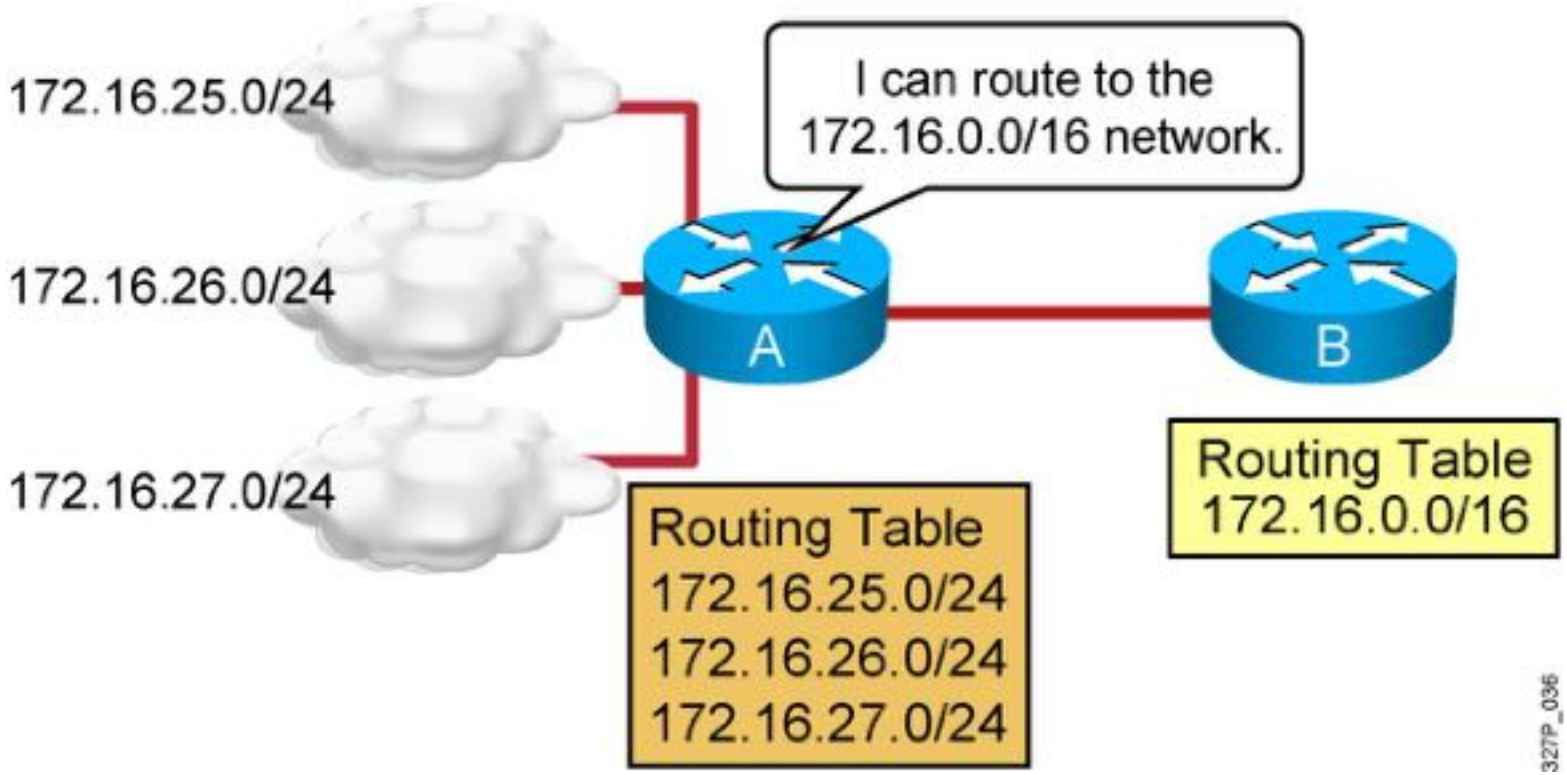
A Working VLSM Example (Cont.)



A Working VLSM Example (Cont.)

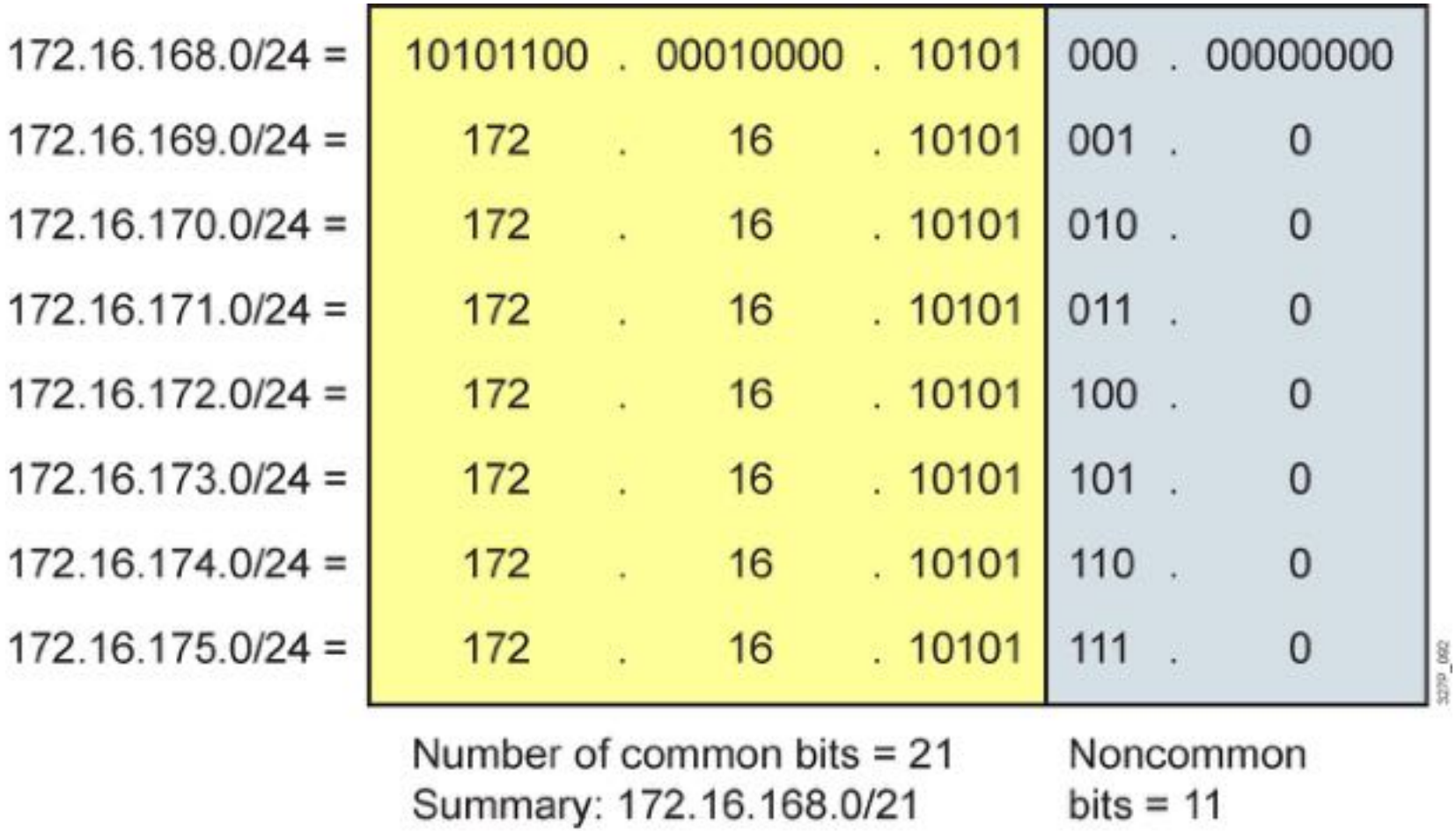


Understanding Route Summarization

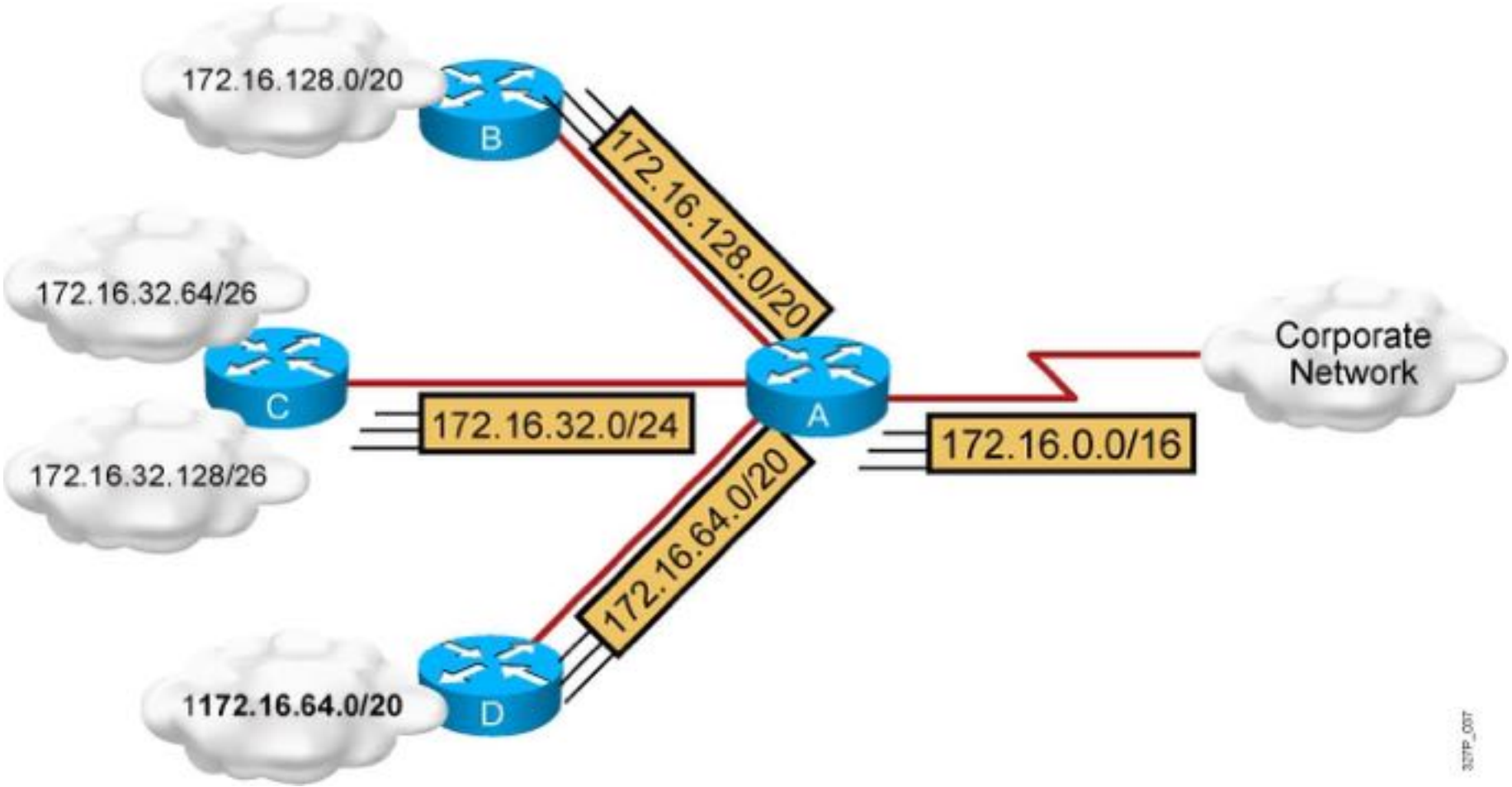


Routing protocols can summarize addresses of several networks into one address.

Summarizing Within an Octet



Summarizing Addresses in a VLSM-Designed Network



Route Summarization Operation in Cisco Routers

192.16.5.33	/32	Host
192.16.5.32	/27	Subnet
192.16.5.0	/24	Network
192.16.0.0	/16	Block of Networks
0.0.0.0	/0	Default

- Supports host-specific routes, blocks of networks, and default routes
- Routers use longest prefix match