



Establishing Internet Connectivity

Interconnecting Cisco Networking Devices, Part 1 (ICND1) v2.0



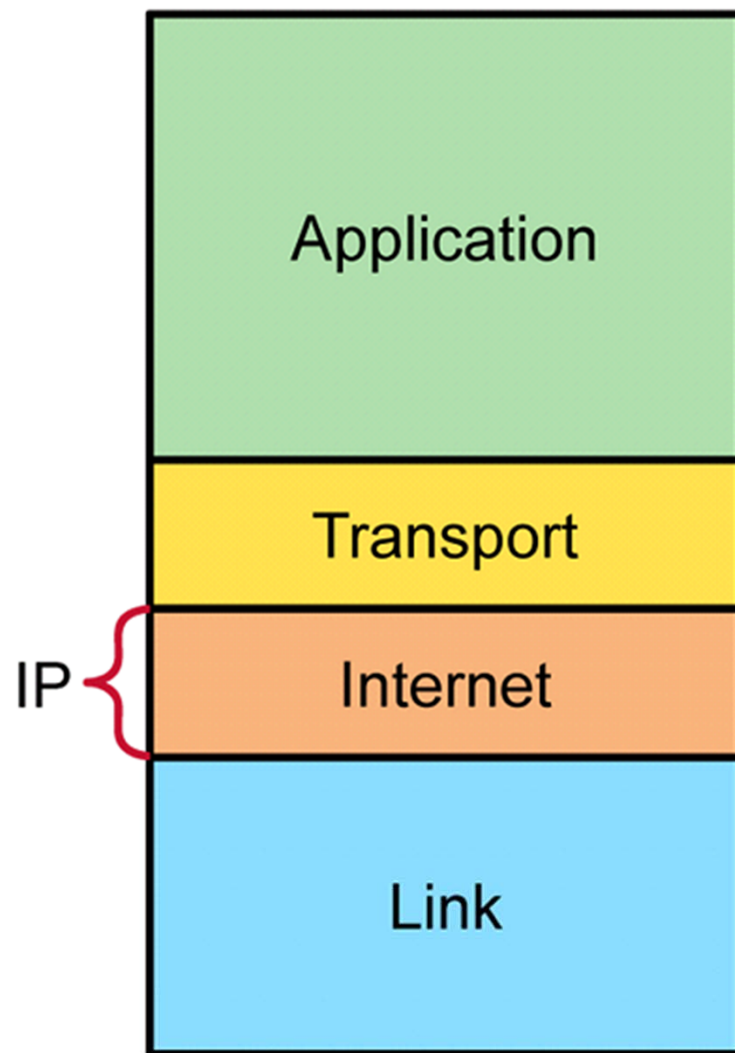
Understanding the TCP/IP Internet Layer

Establishing Internet Connectivity

Internet Protocol

IP characteristics:

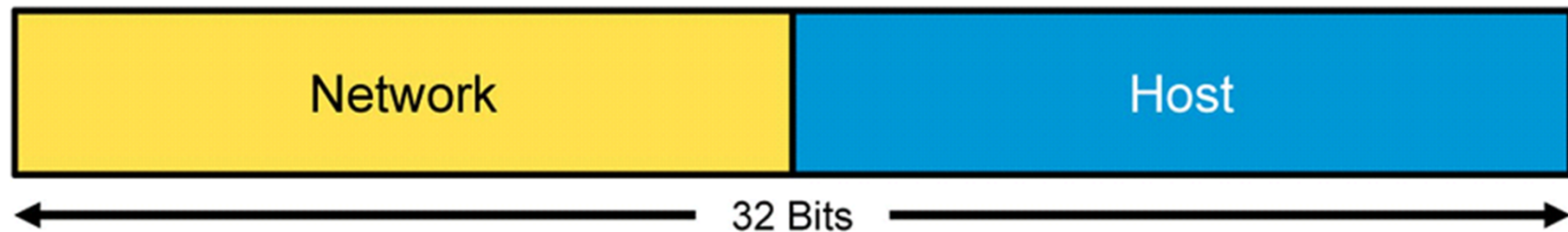
- Operates at the internet layer of the TCP/IP stack
- Connectionless protocol
- Packets treated independently
- Hierarchical addressing
- Best-effort delivery
- No data-recovery features
- Media-independent
- Two variants: IPv4 and IPv6



IPv4 Address Representation

- Every host (computer, networking device, peripheral) must have a unique address.
- An IP address consists of two parts:
 - Network ID:
 - Identifies the network of which the host is a part
 - Used by routers to maintain information about routes
 - Host ID:
 - Identifies the individual host
 - Assigned by organizations to individual devices

172.16.12.22



IPv4 Header Address Fields

Ver.	IHL	Service Type	Total Length	
Identification			Flag	Fragment Offset
Time to Live	Protocol		Header Checksum	
Source Address				
Destination Address				
Options				Padding

Decimal and Binary Systems

- Decimal numbers are represented by the numbers 0 through 9.
- Binary numbers are represented by a series of 1s and 0s.

Decimal	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001

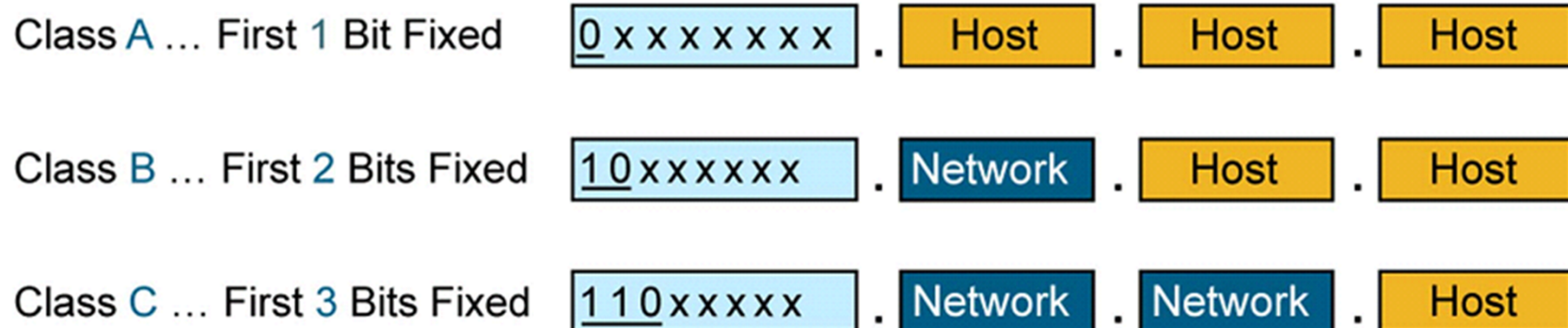
Decimal	Binary
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111
16	10000
17	10001
18	10010
19	10011

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
$35 =$	(2^7*0) +	(2^6*0) +	(2^5*1) +	(2^4*0) +	(2^3*0) +	(2^2*0) +	(2^1*1) +	(2^0*1)
$35 =$			$(32*1)$		+		$(2*1) + (1*1)$	
$35 =$	0 +	0 +	1 +	0 +	0 +	0 +	0 +	0
$35 =$	1	1						
$35 =$ <u>00100011</u>								

IP Address Classes

A B C ... Easy as 1 2 3



IP Address Classes (Cont.)

IP Address Ranges			
IP Address Class	First Octet Decimal Value	First Octet Binary Value	Possible Number of Hosts
Class A	1–126	<u>0</u> 0000001 to <u>0</u> 1111110*	16,777,214
Class B	128–191	<u>10</u> 000000 to <u>10</u> 111111	65,534
Class C	192–223	<u>110</u> 00000 to <u>110</u> 11111	254

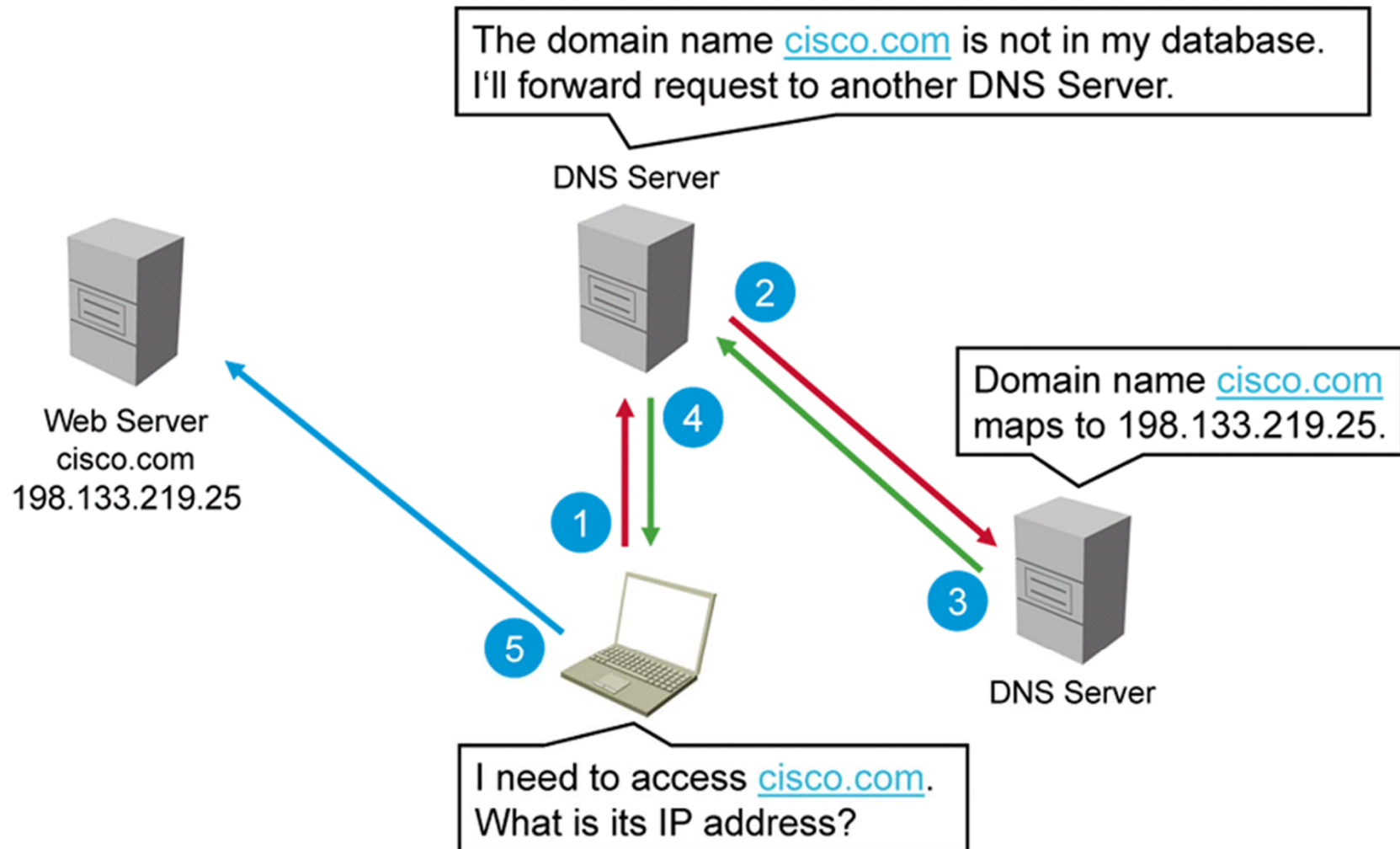
*127 (01111111) is a Class A address reserved for loopback testing and cannot be assigned to a network.

Reserved IPv4 Address

These are reserved IPv4 addresses:

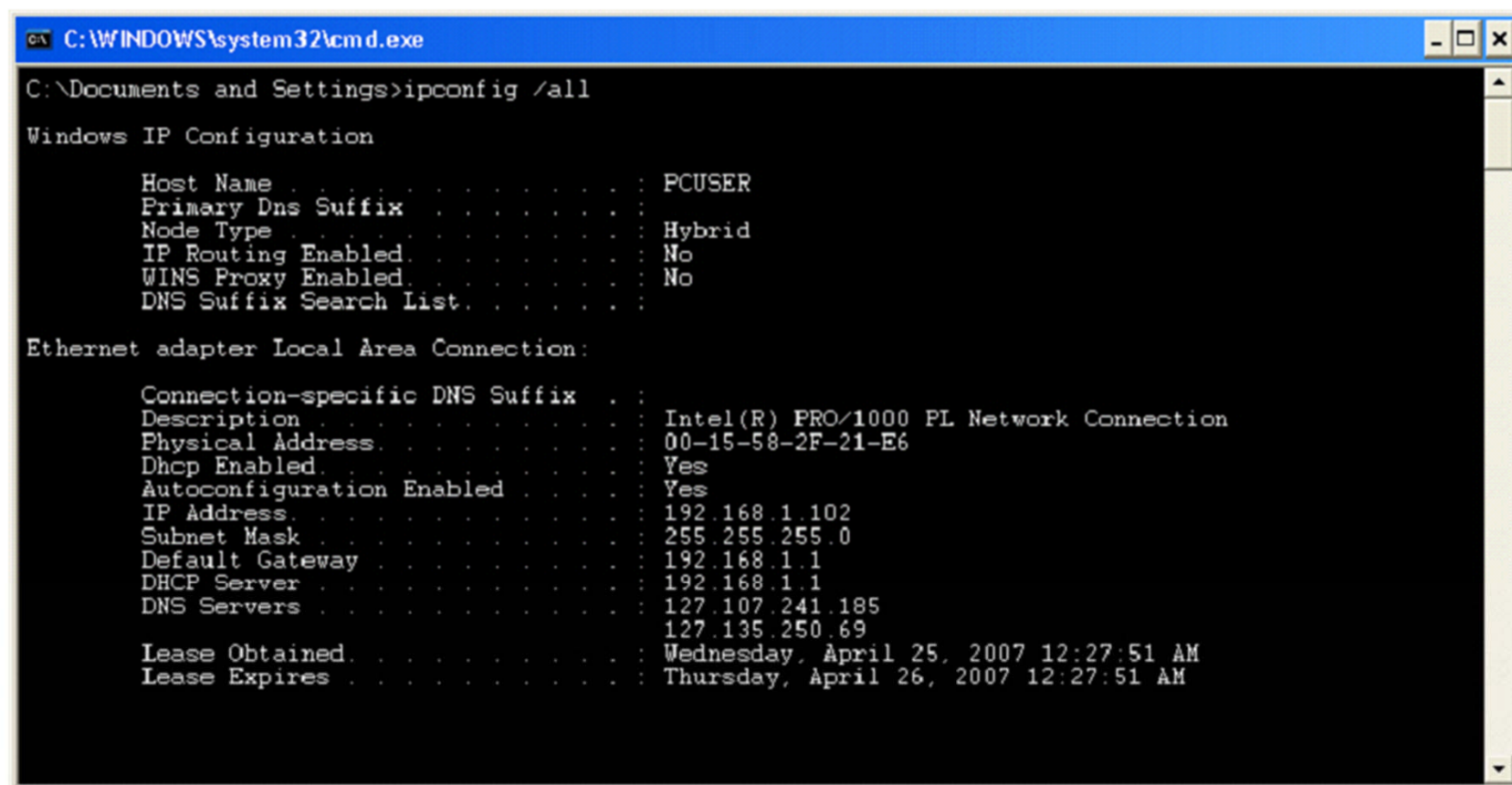
- Network address
- Directed broadcast address
- Local broadcast address
- Local loopback address
- All zeros address

Domain Name System



Verifying the IPv4 Address of a Host

Windows Platform



```
C:\WINDOWS\system32\cmd.exe
C:\Documents and Settings>ipconfig /all

Windows IP Configuration

    Host Name . . . . . : PCUSER
    Primary Dns Suffix . . . . . :
    Node Type . . . . . : Hybrid
    IP Routing Enabled . . . . . : No
    WINS Proxy Enabled . . . . . : No
    DNS Suffix Search List . . . . . :

Ethernet adapter Local Area Connection:

    Connection-specific DNS Suffix . . . . . :
    Description . . . . . : Intel(R) PRO/1000 PL Network Connection
    Physical Address . . . . . : 00-15-58-2F-21-E6
    Dhcp Enabled . . . . . : Yes
    Autoconfiguration Enabled . . . . . : Yes
    IP Address . . . . . : 192.168.1.102
    Subnet Mask . . . . . : 255.255.255.0
    Default Gateway . . . . . : 192.168.1.1
    DHCP Server . . . . . : 192.168.1.1
    DNS Servers . . . . . : 127.107.241.185
    . . . . . : 127.135.250.69
    Lease Obtained . . . . . : Wednesday, April 25, 2007 12:27:51 AM
    Lease Expires . . . . . : Thursday, April 26, 2007 12:27:51 AM
```

Verifying the IPv4 Address of a Host (Cont.)

Verifying IP address of a switch

```
Switch#show ip interface brief
Interface          IP-Address      OK?  Method  Status  Protocol
Vlan1              10.1.1.11      YES  manual  up      up
FastEthernet0/1    unassigned      YES  unset   up      up
FastEthernet0/2    unassigned      YES  unset   down    down
FastEthernet0/3    unassigned      YES  unset   up      up
FastEthernet0/4    unassigned      YES  unset   up      up
FastEthernet0/5    unassigned      YES  unset   down    down
<output omitted>
```

Summary

- IP is a Layer 3 media-independent connectionless protocol that uses hierarchical logical addressing and provides service in a best-effort manner.
- Every node that is connected to the Internet has a unique IP address that identifies it. An IP address consists of two parts: the network ID and the host ID.
- Every packet that travels through the network contains a source address and a destination address.
- Certain IP addresses (for example, network and broadcast addresses) are reserved and cannot be assigned to individual network devices.
- DNS is an application that is specified in the TCP/IP suite. It provides a means to translate human-readable names into IP addresses.





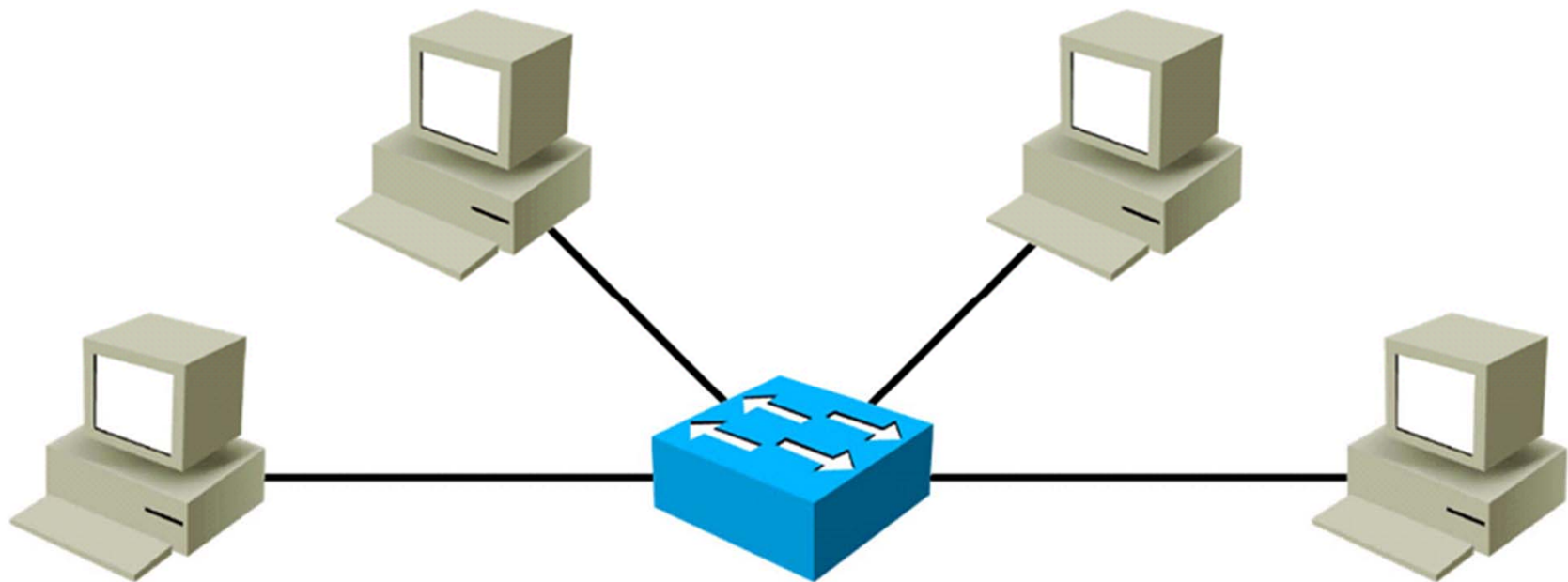
Understanding IP Addressing and Subnets

Establishing Internet Connectivity

Subnets

There can be problems within a single broadcast domain:

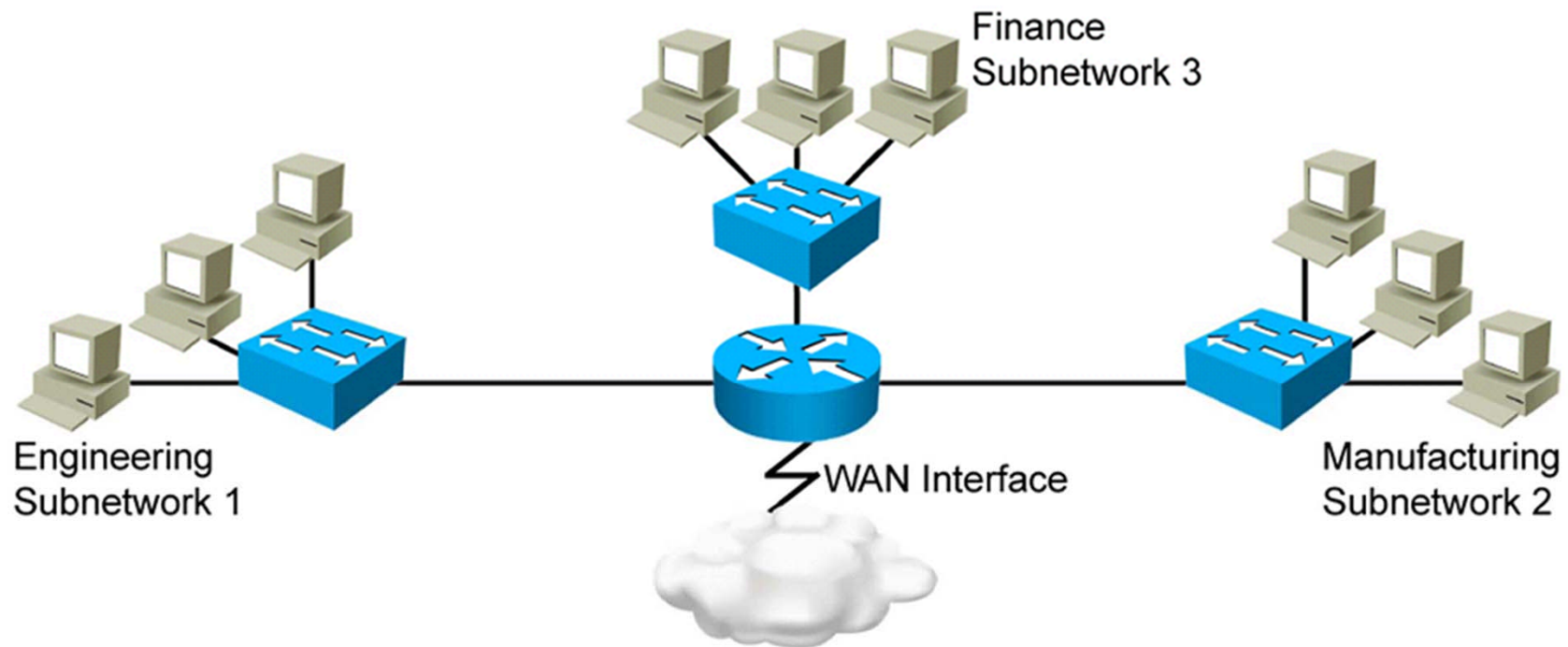
- The domain relies on MAC addresses for packet delivery.
- Larger amounts of broadcast traffic consume resources.
- All devices share the same broadcast domain.



Subnets (Cont.)

Solution: Subnetworks

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



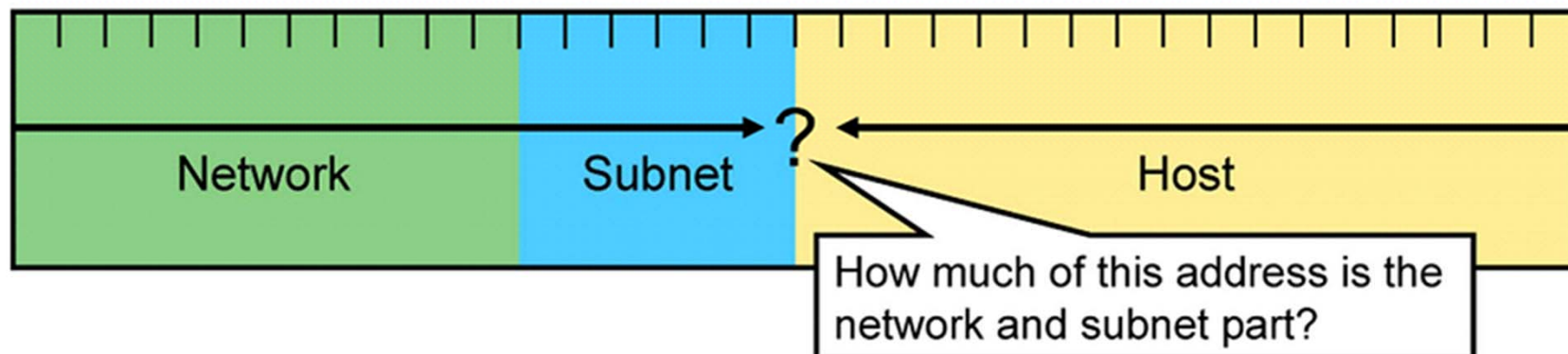
Subnet Masks

A subnet mask:

- Defines the number of bits that represent the network and subnet part of the address
- Used by end systems to identify the destination IP address as either local or remote
- Used by Layer 3 devices to determine network path

Subnet mask: 255.255.0.0 or /16

IP Address: 172.16.55.87



Octet Values of a Subnet Mask

- Subnet masks, like IP addresses, are represented in the dotted decimal format, such as 255.255.255.0.
- The binary 1 reflects the network and subnetwork part of the IP address.

Octet Values of a Subnet Mask (Cont.)

128	64	32	16	8	4	2	1		
0	0	0	0	0	0	0	0	=	0
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

Octet Values of a Subnet Mask (Cont.)

Default Subnet Masks, Class A

Example Class A address (decimal):	10.0.0.0
Example Class A address (binary):	00001010.00000000.00000000.00000000 0
Default Class A mask (binary):	11111111.00000000.00000000.00000000
Default Class A mask (decimal):	255.0.0.0
Default classful prefix length:	/8

Octet Values of a Subnet Mask (Cont.)

Default Subnet Masks, Class B

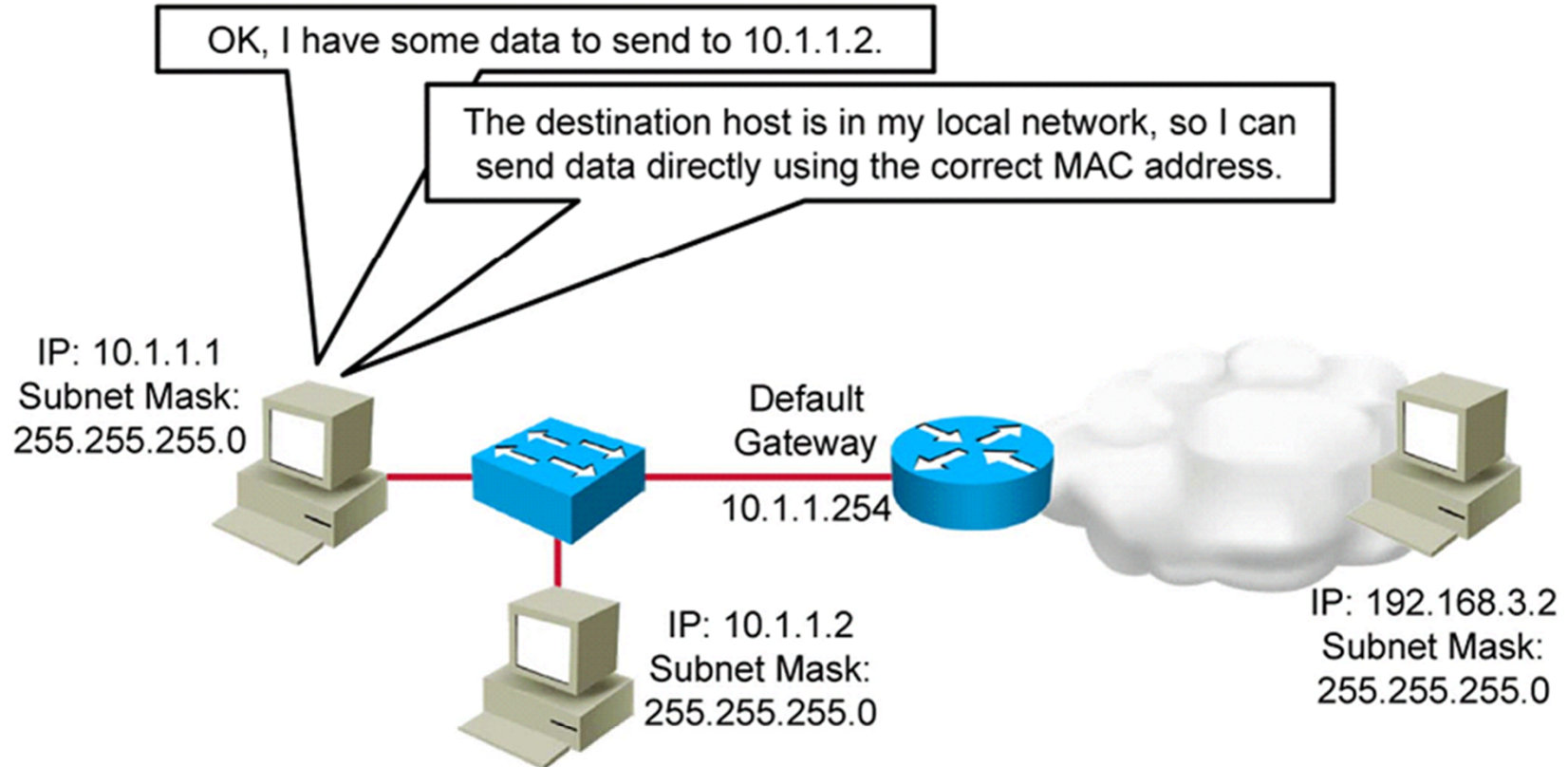
Example Class B address (decimal):	172.16.0.0
Example Class B address (binary):	10101100.00010000.00000000.00000000
Default Class B mask (binary):	11111111.11111111.00000000.00000000
Default Class B mask (decimal):	255.255.0.0
Default classful prefix length:	/16

Octet Values of a Subnet Mask (Cont.)

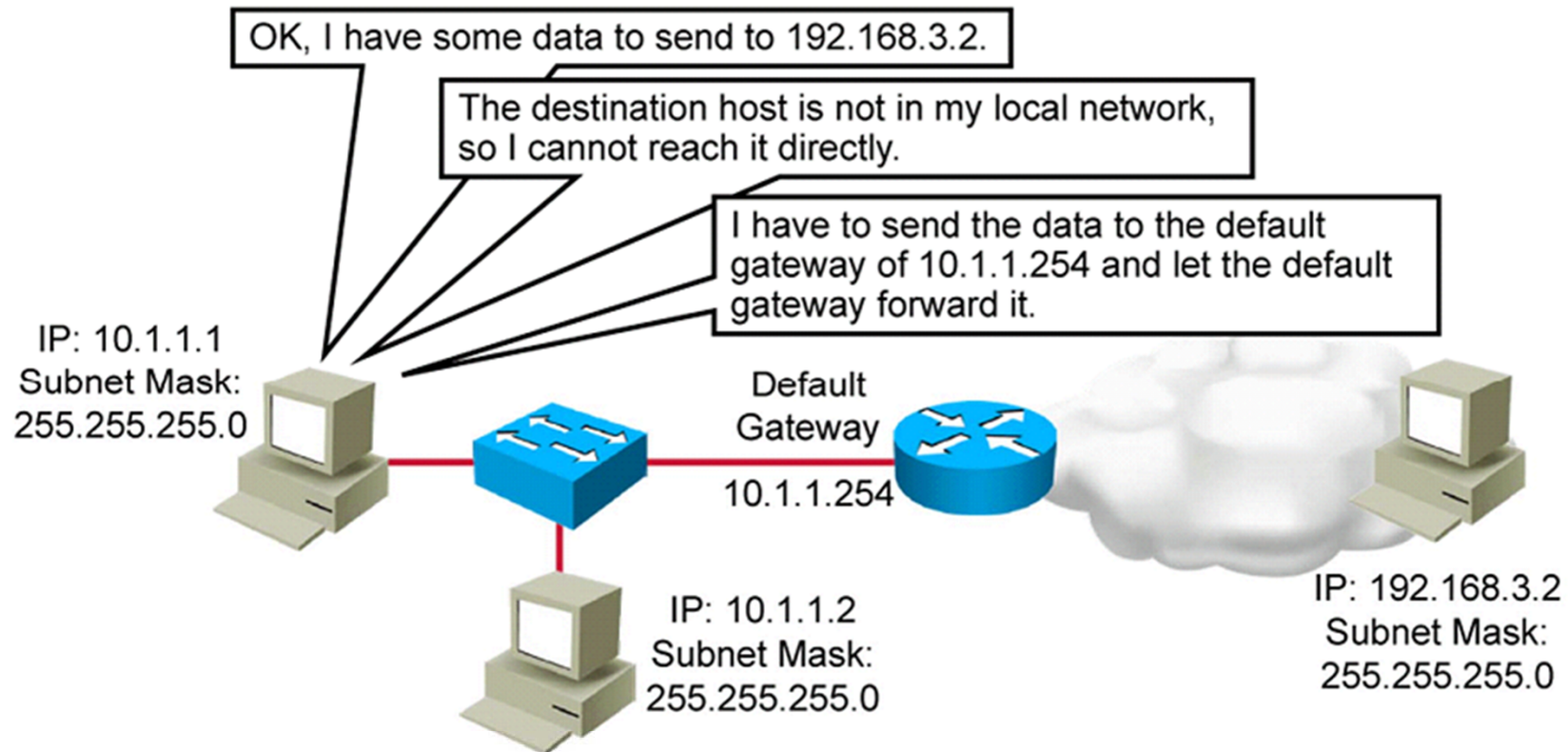
Default Subnet Masks, Class C

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

Default Gateways



Default Gateways (Cont.)



Possible Subnets and Hosts for a Class B Network



Bits Borrowed (s)	Subnets Possible (2^s)	Bits Remaining in Host ID ($h=16-s$)	Hosts Possible per Subnet (2^h-2)
1	2	15	32,766
2	4	14	16,382
3	8	13	8,190
...
13	8192	3	6
14	16384	2	2
15	32768	1	0
16	65536	0	0

Applying Subnet Masks

Procedure for implementing subnets:

1. Determine the IP address space.
2. Based on the organizational and administrative structure, determine the number of subnets that are required.
3. Based on the address class and required number of subnets, determine the number of bits that 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 for all devices that are connected to the network.

Determining the Network Addressing Scheme

Example 1: The IP address with subnet mask is 172.16.36.42/24.

The following tables show the eight steps that are used to determine the subnet addresses of a given IP address. In this example, the IP address and subnet mask are as follows:

- **IP address:** 172.16.36.42
- **Subnet mask:** 255.255.255.0

Determining the Network Addressing Scheme (Cont.)

Step	Description	Example
1	Write down the octet that is being split and all remaining octets on the right in binary.	Third and fourth octet (36.42): 00100100.00101010
2	Write down the mask or classful prefix length in binary.	Assigned mask (/24): 11111111.11111111.11111111.00000000
3	Draw a line to delineate the subnet and host bits in the assigned IP address. Write the IP address and the mask on top of each other so that you are able to identify the significant bits in the IP address.	Split octet (binary): 00100100 00101010 Split mask (binary): 11111111 00000000

Determining the Network Addressing Scheme (Cont.)

Step	Description	Example
4	Copy the subnet bits four times.	00100100.00000000 (subnet address)
5	In the first line, define the network address by placing all 0s in the host bits.	00100100.00000001 (first address in subnet) 00100100.11111110 (last address in subnet)
6	In the last line, define the broadcast address by placing all 1s in the host bits.	00100100.11111111 (broadcast address)
7	In the middle lines, define the first and last host number.	
8	Increment the subnet bits by 1 to determine the next subnet.	00100101.00000000

Determining the Network Addressing Scheme (Cont.)

After converting the addresses from binary to decimal, the addresses for the subnets are as follows:

- **Subnet address:** 172.16.36.0
- **First host address:** 172.16.36.1
- **Last host address:** 172.16.36.254
- **Broadcast address:** 172.16.36.255
- **Next subnet address:** 172.16.37.0

Determining the Network Addressing Scheme (Cont.)

Example 2: The IP address with subnet mask is 192.168.221.37/29.

The following tables show the eight steps that are used to determine the subnet addresses of a given IP address. In this example, the IP address and subnet mask are as follows:

- **IP address:** 192.168.221.37
- **Subnet mask:** 255.255.255.248

Determining the Network Addressing Scheme (Cont.)

Step	Description	Example
1	Write down the octet that is being split and all remaining octets on the right in binary.	Fourth octet (37): 00100101
2	Write down the mask or classful prefix length in binary.	Assigned mask (/29): 11111111.11111111.11111111.11111000
3	Draw a line to delineate the subnet and host bits in the assigned IP address. Write the IP address and the mask on top of each other so that you are able to identify the significant bits in the IP address.	Split octet (binary): 00100 101 Split mask (binary): 11111 000

Determining the Network Addressing Scheme (Cont.)

Step	Description	Example
4	Copy the subnet bits four times.	00100000 (network address)
5	In the first line, define the network address by placing all 0s in the host bits.	00100001 (first address in subnet) 00100110 (last address in subnet) 00100111 (broadcast address)
6	In the last line, define the broadcast address by placing all 1s in the host bits.	
7	In the middle lines, define the first and last host number.	
8	Increment the subnet bits by 1 to determine the next subnet.	00101000

Determining the Network Addressing Scheme (Cont.)

After converting the addresses from binary to decimal, the addresses for the subnets are as follows:

- **Subnet address:** 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 address:** 192.168.221.40

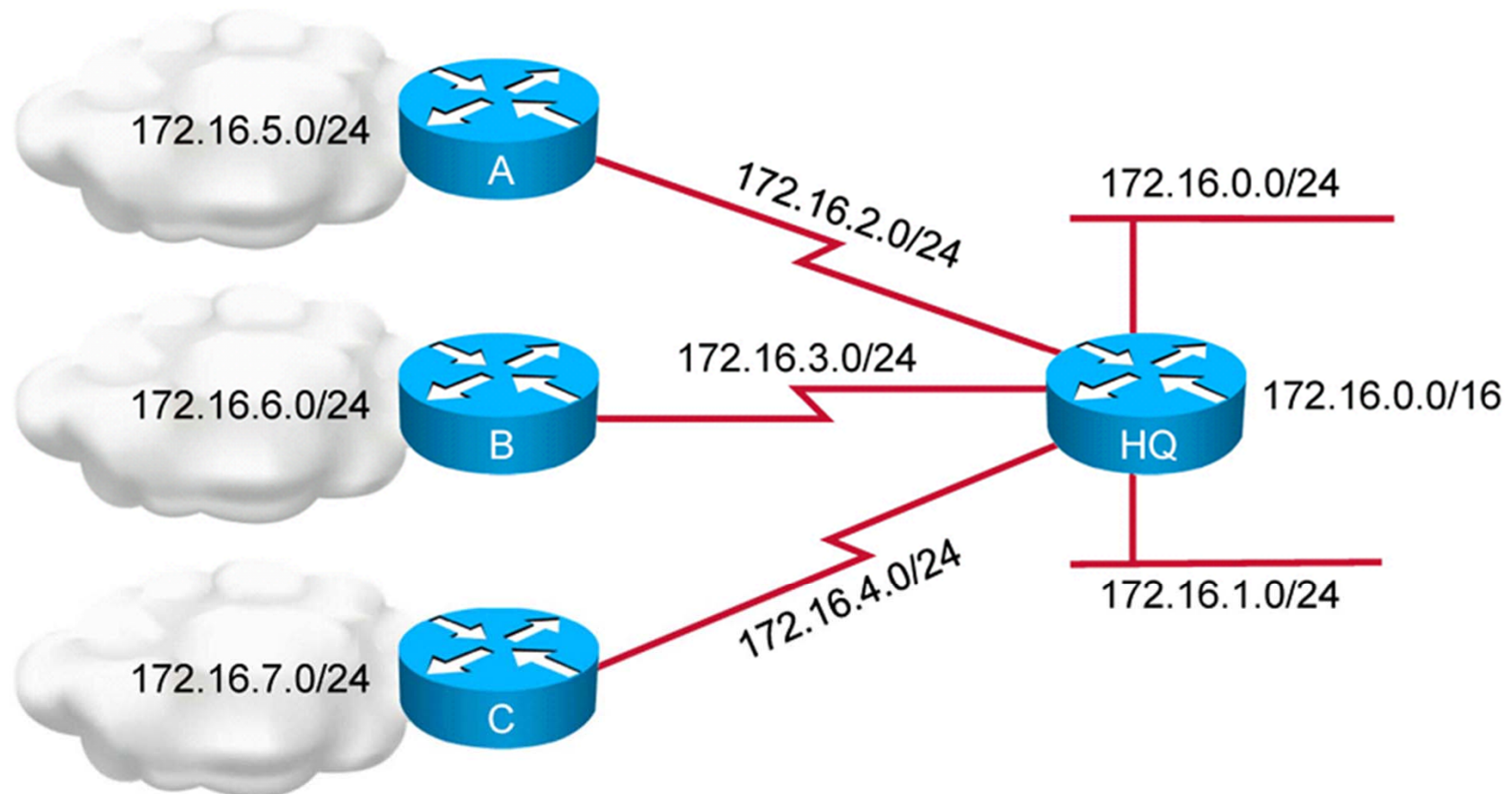
Example: Addressing Scheme

The IP address with subnet mask is 192.168.5.139/27.

IP Address	192	168	5	139
IP Address	11000000	10101000	00000101	100 01011
Subnet Mask	11111111	11111111	11111111	111 00000
Network (2)	11000000	10101000	00000101	100 00000
Network (10)	192	168	5	128
First Host	192	168	5	100 00001 = 129
Last Host	192	168	5	100 11110 = 158
Directed Broadcast	192	168	5	100 11111 = 159
Next Network	192	168	5	101 00000 = 160

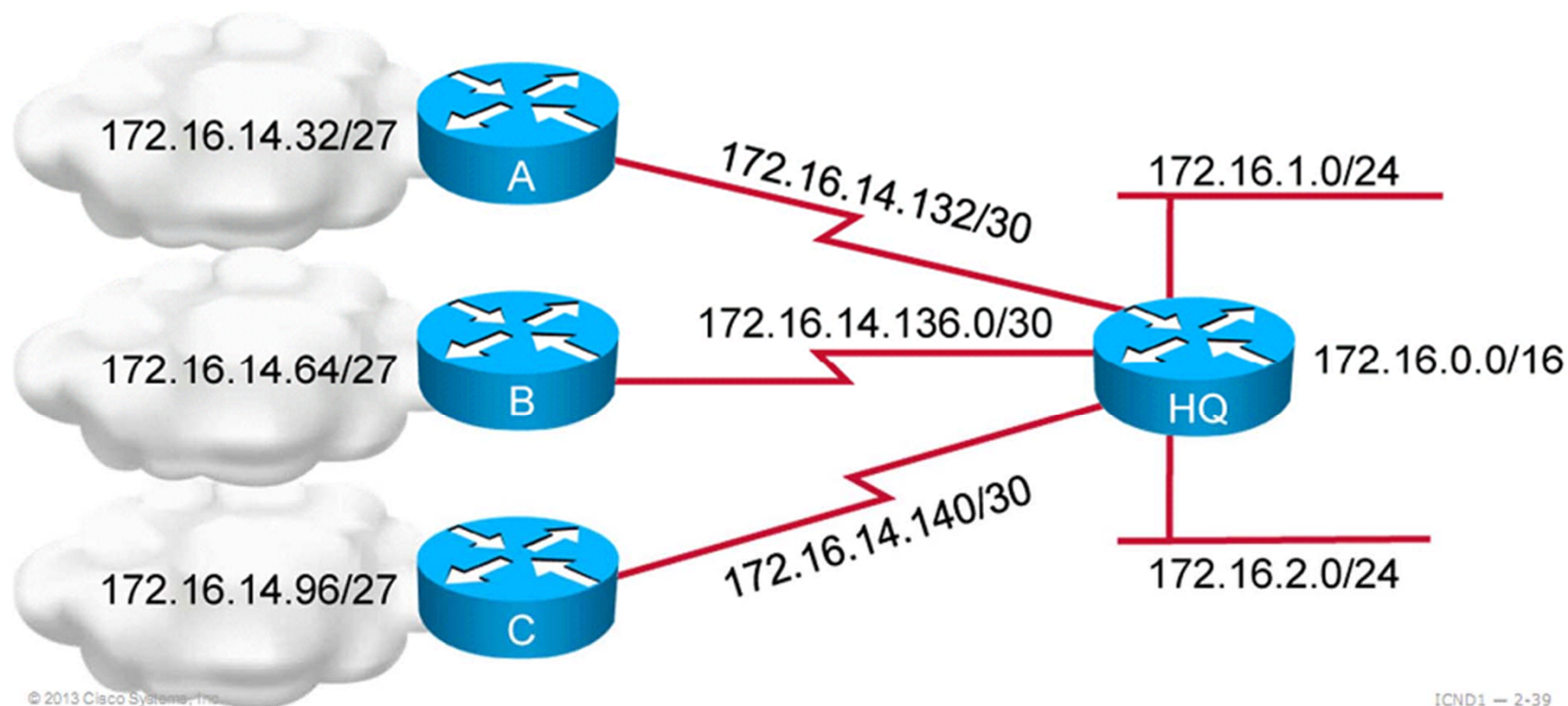
Variable-Length Subnet Masking

- Network using fixed-length subnet masking:



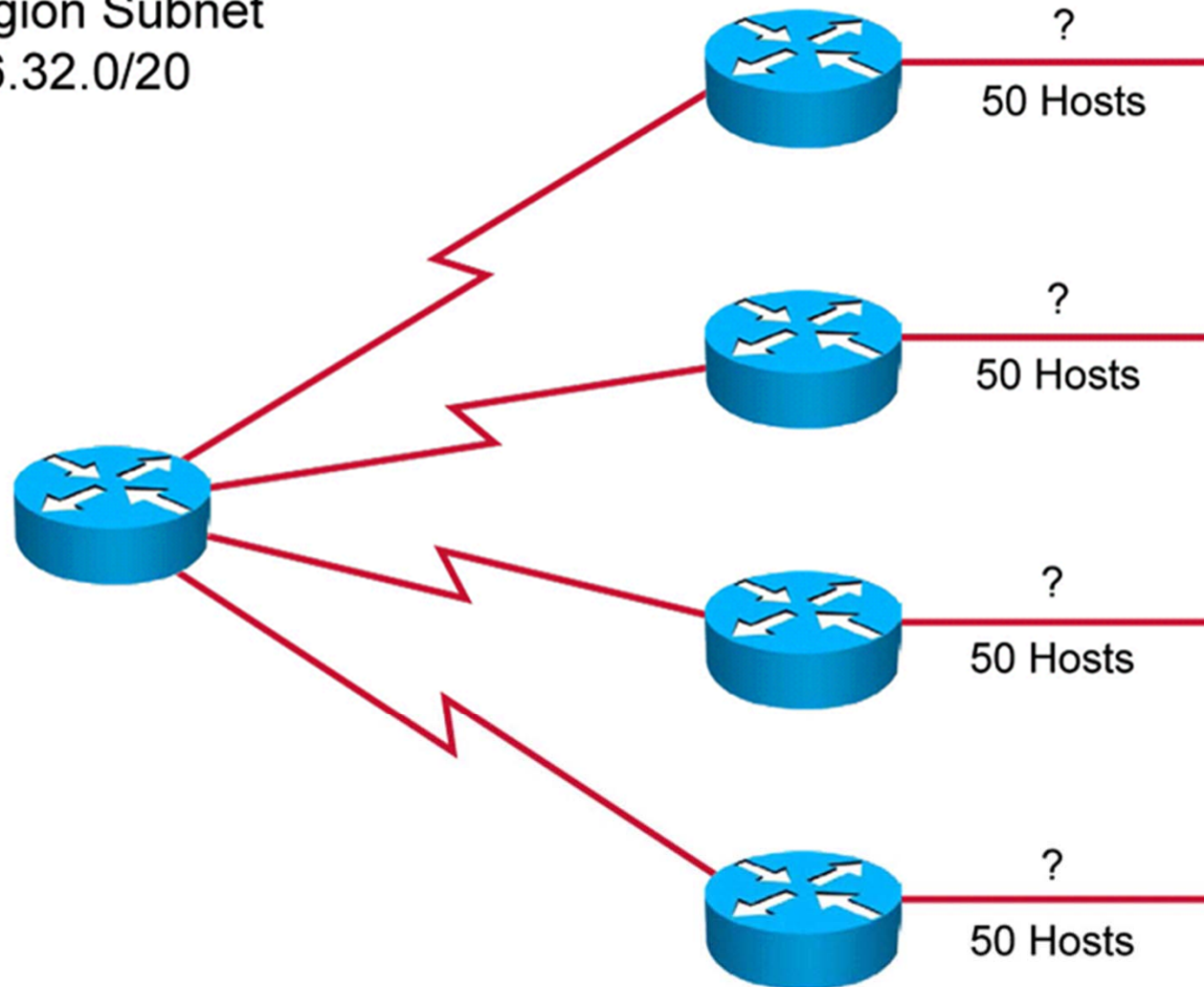
Variable-Length Subnet Masking (Cont.)

- Network using VLSM:
 - The subnet 172.16.14.0/24 is divided into smaller subnets.
 - One subnet has a subnet mask /27.
 - Further subnetting of one of the unused /27 subnets into multiple /30 subnets.



VLSM Example

Entire Region Subnet
172.16.32.0/20



VLSM Example (Cont.)

Subnetted address: 172.16.32.0/20

In binary: 10101100.00010000.**0010**0000.00000000

VLSM address: 172.16.32.0/26

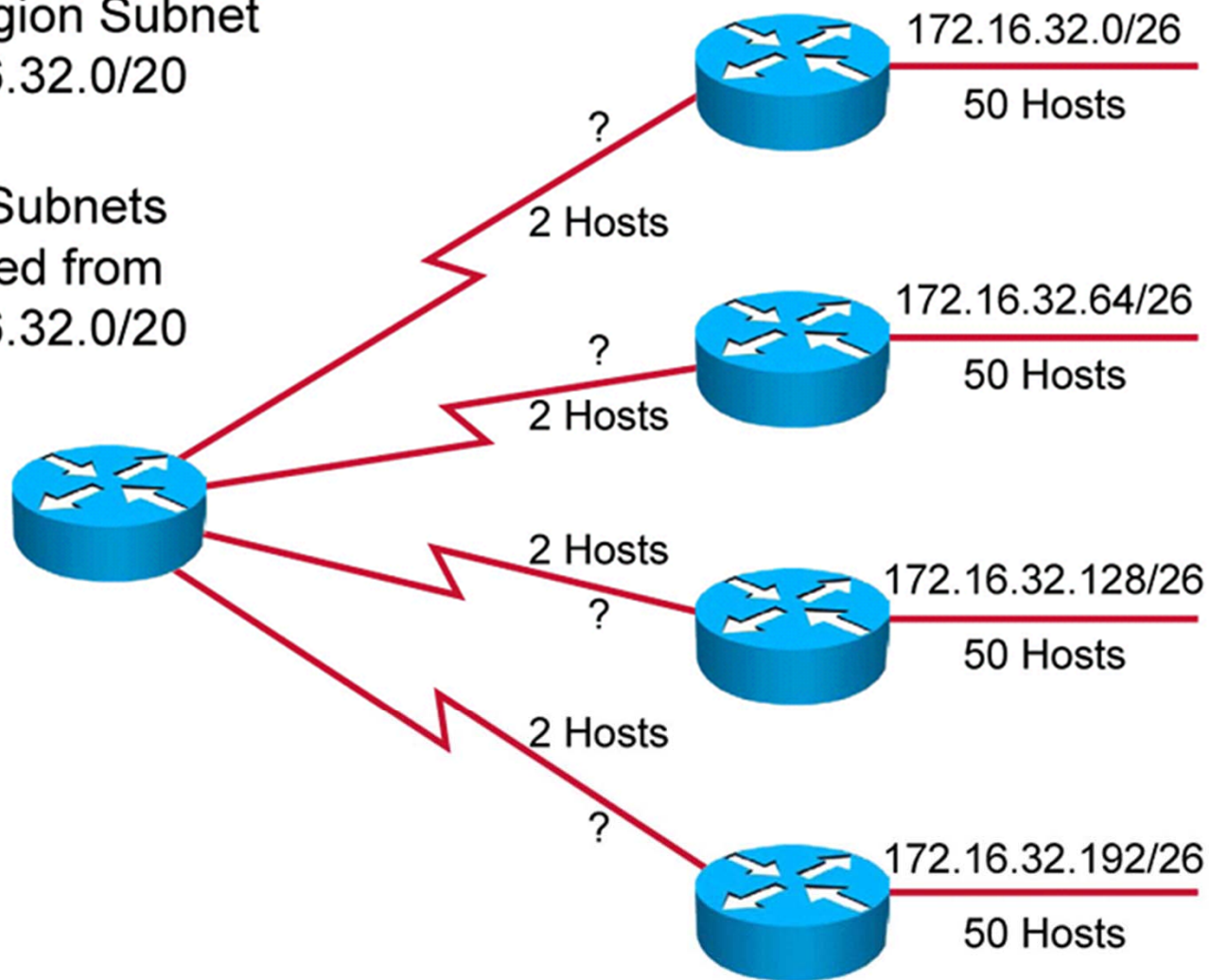
In binary: 10101100.00010000.**0010**0000.**00**000000

1st subnet:	172	.	16	.0010	0000.00	000000 =	172.16.32.0/26
2nd subnet:	172	.	16	.0010	0000.01	000000 =	172.16.32.64/26
3rd subnet:	172	.	16	.0010	0000.10	000000 =	172.16.32.128/26
4th subnet:	172	.	16	.0010	0000.11	000000 =	172.16.32.192/26
5th subnet:	172	.	16	.0010	0001.00	000000 =	172.16.33.0/26
	Network		Subnet		VLSM Subnet	Host	

VLSM Example (Cont.)

Entire Region Subnet
172.16.32.0/20

LAN Subnets
Derived from
172.16.32.0/20



VLSM Example (Cont.)

Subnetted address: 172.16.33.0/26

In binary: 10101100.00010000.00100001.00000000

VLSM address: 172.16.33.0/30

In binary: 10101100.00010000.00100001.00000000

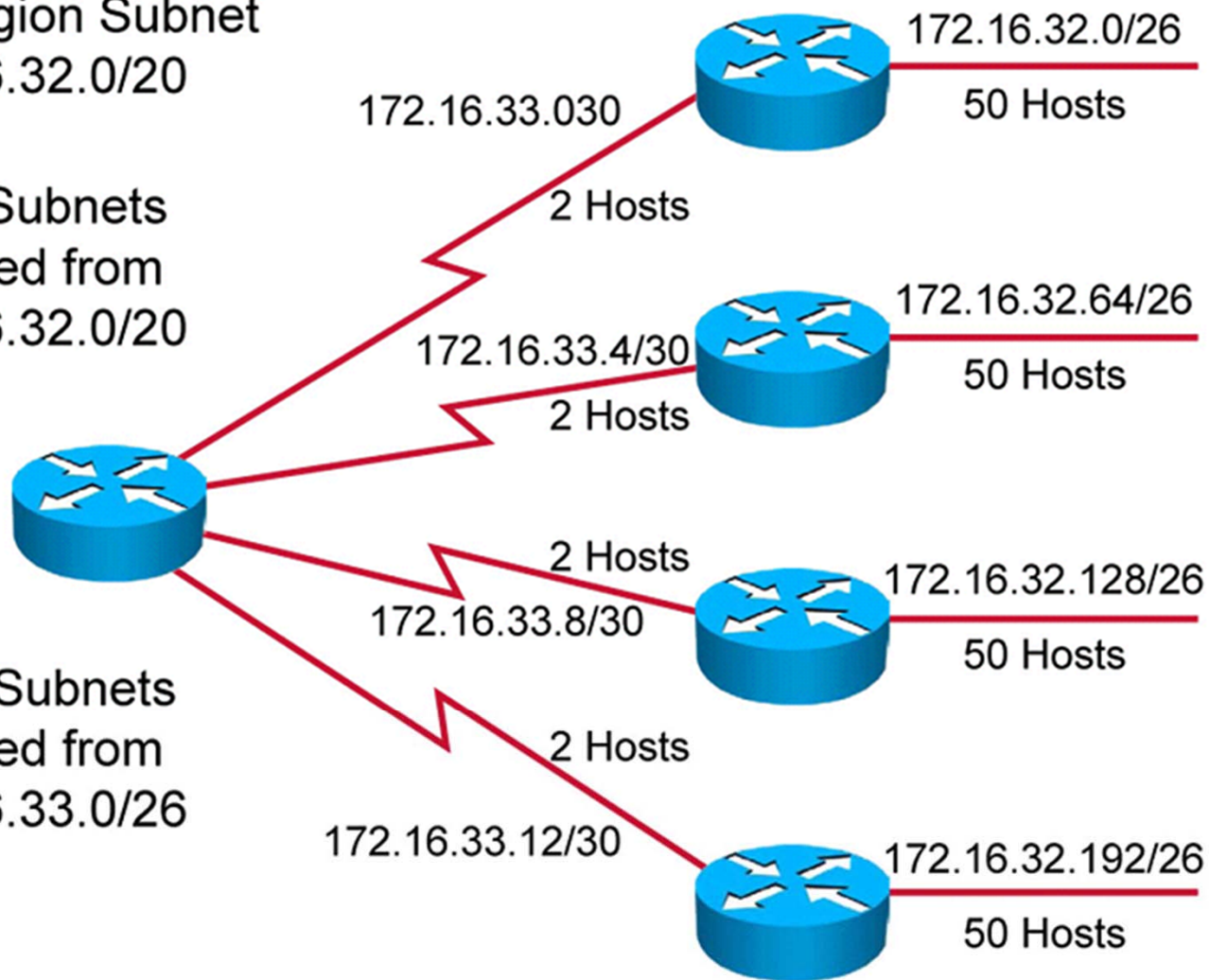
1st subnet:	172	.	16	.33	.0000	00	00 =	172.16.33.0/30
2nd subnet:	172	.	16	.33	.0000	01	00 =	172.16.33.4/30
3rd subnet:	172	.	16	.33	.0000	10	00 =	172.16.33.8/30
4th subnet:	172	.	16	.33	.0000	11	00 =	172.16.33.12/30
	Network		Subnet		VLSM Subnet		Host	

VLSM Example (Cont.)

Entire Region Subnet
172.16.32.0/20

LAN Subnets
Derived from
172.16.32.0/20

WAN Subnets
Derived from
172.16.33.0/26



Summary

- Networks, particularly large networks, are often divided into smaller subnetworks, or subnets, which can improve network performance and control.
- The subnet mask defines the number of bits that represent the network part or subnet part of an IP address.
- End systems use subnet masks to identify the destination IP address as either local or remote.
- A default gateway is needed to send a packet out of the local network.
- Determining the optimal number of subnets and hosts depends on the type of network and the number of host addresses required.
- The algorithm for computing a number of subnets is 2^n , where n is the number of subnet bits.
- VLSM lets you allocate IP addresses more efficiently by adding multiple layers to the addressing hierarchy.