# *IP ADDRESSING AND SUBNETTING*

# Objectives:

- Explain the different classes of IP
- Addresses Configure IP addresses
- Subdivide an IP network
- Discuss advanced routing concepts such as CIDR(Classless Inter-Domain Routing), summarization, and VLSM(Variable Length Subnet Masking)
- Convert between decimal, binary, and hexadecimal numbering systems
- Explain the differences between IPv4 and IPv6

# IP Addressing

An IP address has 32 bits divided into four octets

To make the address easier to read, people use decimal numbers to represent the binary digits

– Example: 192.168.1.1

Dotted decimal notation

– When binary IP addresses are written in decimal format

# IP Addressing (continued)

| | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|
| 192 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 168 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 255 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 4-1** Binary to decimal conversion

# MAC to IP Address Comparison

MAC address

- Identifies a specific NIC in a computer on a network
- Each MAC address is unique
- TCP/IP networks can use MAC addresses in communication

Network devices cannot efficiently route traffic using MAC addresses because they:

- Are not grouped logically
- Cannot be modified
- Do not give information about physical or logical network configuration

# MAC to IP Address Comparison (continued)

**IP addressing**

– Devised for use on large networks

IP addresses have a hierarchical structure and do provide logical groupings

– IP address identifies both a network and a host

# IP Classes

- **Internet Assigned Numbers Authority (IANA)**
  - Devised the hierarchical IP addressing structure
- **American Registry of Internet Numbers (ARIN)**
  - Manages IP addresses in the United States
- **Internet Corporation for Assigned Names and Numbers (ICANN)**
  - A global, government-independent entity with overall responsibility for the Internet
  - ICANN has effectively replaced IANA

# IP Classes (continued)

Class A

- Reserved for governments and large corporations throughout the world
- Each Class A address supports 16,777,214 hosts

Class B

- Addresses are assigned to large- and medium-sized companies
- Each Class B address supports 65,534 hosts

# IP Classes (continued)

| Binary Place Values | | | | | | | | | Decimal Equivalent | Description |
|---|---|---|---|---|---|---|---|---|---|---|
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | = | 0 | Subnet identifier |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | = | 1 | Bottom of Class A range |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | = | 126 | Top of Class A range |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | = | 127 | Loopback address |

**Figure 4-1** Class A addresses begin with a number between 1 and 126

| Binary Place Values | | | | | | | | | Decimal Equivalent | Description |
|---|---|---|---|---|---|---|---|---|---|---|
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | = | 128 | First Class B address |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | = | 191 | Last Class B address |

**Figure 4-2** Class B addresses begin with a number between 128 and 191

# IP Classes (continued)

- Class C
  - Addresses are assigned to groups that do not meet the qualifications to obtain Class A or B addresses
  - Each Class C address supports 254 hosts
- Class D
  - Addresses (also known as multicast addresses) are reserved for multicasting
  - **Multicasting** is the sending of a stream of data (usually audio and video) to multiple computers simultaneously

# IP Classes (continued)

| Binary Place Values | | | | | | | | | Decimal Equivalent | Description |
|---|---|---|---|---|---|---|---|---|---|---|
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | | | |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | = | 192 | First Class C address |
| 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | = | 223 | Last Class C address |

**Figure 4-3** Class C addresses begin with numbers between 192 and 223

| Binary Place Values | | | | | | | | | Decimal Equivalent | Description |
|---|---|---|---|---|---|---|---|---|---|---|
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | | | |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | = | 224 | First Class D address |
| 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | = | 239 | Last Class D address |

**Figure 4-4** Class D addresses begin with a number between 224 and 239

# IP Classes (continued)

- Class E
  - Addresses are reserved for research, testing, and experimentation
  - The Class E range starts where Class D leaves off
- Private IP ranges
  - Many companies use private IP addresses for their internal networks
    - Will not be routable on the Internet
  - Gateway devices have network interface connections to the internal network and the Internet
    - Route packets between them

# IP Classes (continued)

| Binary Place Values | | | | | | | | | Decimal Equivalent | Description |
|---|---|---|---|---|---|---|---|---|---|---|
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | | | |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | = | 240 | First Class E address |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | = | 255 | Last Class E address |

**Figure 4-5** Class E addresses begin with a number between 240 and 255

| Class | Private Address Range |
|---|---|
| A | 10.x.x.x |
| B | 172.16.x.x – 172.31.x.x |
| C | 192.168.x.x |

**Table 4-2** The private IP ranges

# Network Addressing

- IP addresses identify both the network and the host
  - The division between the two is not specific to a certain number of octets
- **Subnet mask**
  - Indicates how much of the IP address represents the network or subnet
- Standard (default) subnet masks:
  - Class A subnet mask is 255.0.0.0
  - Class B subnet mask is 255.255.0.0
  - Class C subnet mask is 255.255.255.0

# Network Addressing (continued)

- TCP/IP hosts use the combination of the IP address and the subnet mask
  - To determine if other addresses are local or remote
  - The binary AND operation is used to perform the calculation
- **Subnetting**
  - Manipulation of the subnet mask to get more network numbers

# Network Addressing (continued)

- Subnet address
  - Network is identified by the first, or first few, octets
  - A TCP/IP host must have a nonzero host identifier
- Broadcast address
  - When the entire host portion of an IP address is all binary ones
  - Examples: 190.55.255.255 and 199.192.65.63

# Network Addressing (continued)

| | | |
|---|---|---|
| Subnet ID: | 199.192.65.0 | 11000111.11000000.01000001.00000000 |
| Subnet mask: | 255.255.255.0 | 11111111.11111111.11111111.00000000 |
| Broadcast Address: | 199.192.65.255 | 11000111.11000000.01000001.11111111 |

**Figure 4-7** Broadcast addresses

| | | |
|---|---|---|
| Subnet ID: | 199.192.65.32 | 11000111.11000000.01000001.00100000 |
| Subnet mask: | 255.255.255.224 | 11111111.11111111.11111111.11100000 |
| Broadcast Address: | 199.192.65.63 | 11000111.11000000.01000001.00111111 |

**Figure 4-8** Broadcasts on partially masked octets

# Broadcast Types

- **Flooded broadcasts**
  - Broadcasts for any subnet
  - Use use the IP address 255.255.255.255
  - A router does not propagate flooded broadcasts because they are considered local
- **Directed broadcasts** are for a specific subnet
  - Routers can forward directed broadcasts
  - For example, a packet sent to the Class B address 129.30.255.255 would be a broadcast for network 129.30.0.0

# Subdividing IP Classes

- Reasons for subnetting
  - To match the physical layout of the organization
  - To match the administrative structure of the organization
  - To plan for future growth
  - To reduce network traffic

# Subdividing IP Classes (continued)

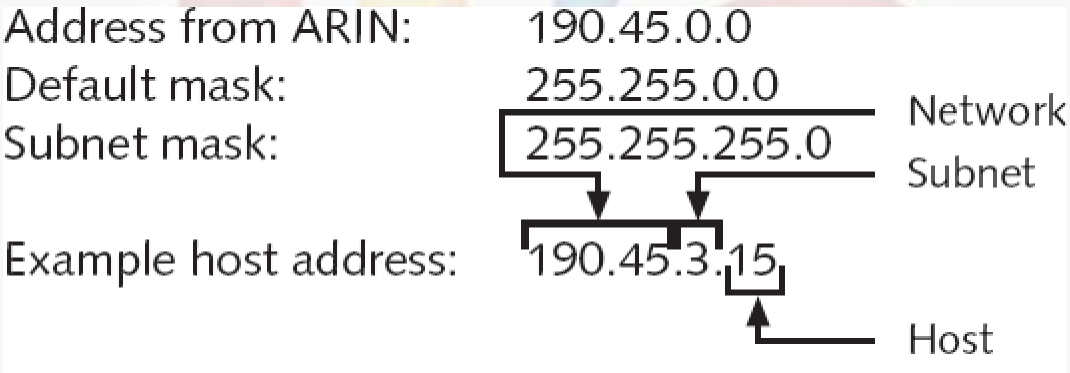


**Figure 4-9** Dividing a Class B network

# Subnet Masking

- When network administrators create subnets
  - They borrow bits from the original host field to make a set of subnetworks
  - The number of borrowed bits determines how many subnetworks and hosts will be available
- Class C addresses also can be subdivided
  - Not as many options or available masks exist because only the last octet can be manipulated with this class

| Subnet Mask | Subnets on Network | Hosts per Subnet |
|---|---|---|
| 255.255.128.0 | 2 | 32,766 |
| 255.255.192.0 | 4 | 16,382 |
| 255.255.224.0 | 8 | 8,190 |
| 255.255.240.0 | 16 | 4,094 |
| 255.255.248.0 | 32 | 2,046 |
| 255.255.252.0 | 64 | 1,022 |
| 255.255.254.0 | 128 | 510 |
| 255.255.255.0 | 256 | 254 |
| 255.255.255.128 | 512 | 126 |
| 255.255.255.192 | 1,024 | 62 |
| 255.255.255.224 | 2,048 | 30 |
| 255.255.255.240 | 4,096 | 14 |
| 255.255.255.248 | 8,192 | 6 |
| 255.255.255.252 | 16,384 | 2 |

**Table 4-3** Class B subnet masks

# Subnet Masking (continued)

| Subnet Mask | Subnets on Network | Hosts per Subnet |
|---|---|---|
| 255.255.255.128 | 2 | 126 |
| 255.255.255.192 | 4 | 62 |
| 255.255.255.224 | 8 | 30 |
| 255.255.255.240 | 16 | 14 |
| 255.255.255.248 | 32 | 6 |
| 255.255.255.252 | 64 | 2 |

**Table 4-4** Class C subnet masks

# Subnet Masking (continued)

| Binary Place Values → | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | Decimal Equivalents |
|---|---|---|---|---|---|---|---|---|---|
| Binary Digits | 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 |

**Figure 4-10** Subnet mask values

# Learning to Subnet

- Suppose you had a network with:
  - Five different segments
  - Somewhere between 15 and 20 TCP/IP hosts on each network segment
- You just received your Class C address from ARIN (199.1.10.0)
- Only one subnet mask can handle your network configuration: 255.255.255.224
  - This subnet mask will allow you to create eight subnetworks and to place up to 30 hosts per network

# Learning to Subnet (continued)

- Determine the subnet identifiers (IP addresses)
  - Write the last masking octet as a binary number
  - Determine the binary place of the last masking digit
- Calculate the subnets
  - Begin with the major network number (subnet zero) and increment by 32
  - Stop counting when you reach the value of the mask
- Determine the valid ranges for your hosts on each subnet
  - Take the ranges between each subnet identifier
  - Remove the broadcast address for each subnet

# Learning to Subnet (continued)

Class C Address: 199.1.10.0
Standard Mask: 255.255.255.0
Selected Mask: 255.255.255.224

| | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|
| 224 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |

**Figure 4-11** Subnet masking example

# Learning to Subnet (continued)

| Subnet Identifier | Valid Host Range | Broadcast Address for Subnet |
|---|---|---|
| 199.1.10.0 | 199.1.10.1 – 199.1.10.30 | 199.1.10.31 |
| 199.1.10.32 | 199.1.10.33 – 199.1.10.62 | 199.1.10.63 |
| 199.1.10.64 | 199.1.10.65 – 199.1.10.94 | 199.1.10.95 |
| 199.1.10.96 | 199.1.10.97 – 199.1.10.126 | 199.1.10.127 |
| 199.1.10.128 | 199.1.10.129 – 199.1.10.158 | 199.1.10.159 |
| 199.1.10.160 | 199.1.10.161 – 199.1.10.190 | 199.1.10.191 |
| 199.1.10.192 | 199.1.10.193 – 199.1.10.222 | 199.1.10.223 |
| 199.1.10.224 | 199.1.10.225 – 199.1.10.254 | 199.1.10.255 |

**Table 4-5** Class C address 199.1.10.0 masking 255.255.255.224

# Learning to Subnet (continued)

| | | Binary | | | Binary |
|---|---|---|---|---|---|
| Decimal | 0 | 000 00000 | Decimal | 32 | 001 00000 |
| Mask | 224 | 111 00000 | Mask | 224 | 111 00000 |
| Decimal | 64 | 010 00000 | Decimal | 96 | 011 00000 |
| Mask | 224 | 111 00000 | Mask | 224 | 111 00000 |
| Decimal | 128 | 100 00000 | Decimal | 160 | 101 00000 |
| Mask | 224 | 111 00000 | Mask | 224 | 111 00000 |
| Decimal | 192 | 110 00000 | Decimal | 224 | 111 00000 |
| Mask | 224 | 111 00000 | Mask | 224 | 111 00000 |

**Figure 4-12** A binary look at the mask

# Subnetting Formulas

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Consider memorizing the following two formulas:

$2^y$ = # of usable subnets (where *y* is the number of bits borrowed)

$2^x - 2$ = # of usable hosts per subnet (where *x* is the number of bits remaining in the host field after borrowing)

# Subnetting Formulas (continued)

| | | |
|---|---|---|
| C Address | 199.4.10.0 | 11000111.11000000.01000001.00000000 |
| Standard mask | 255.255.255.0 | 11111111.11111111.11111111.00000000 |
| Mask | 255.255.255.240 | 11111111.11111111.11111111.11110000 |

y = 4 (borrowed bits)

x = 4 (bits left in host field after borrowing)

Formulas:

$2^y$ = # of usable subnets

$2^x - 2$ = # of usable hosts per subnet

$2^4$ = 16 usable subnets

$2^4 - 2$ = 14 usable hosts per subnet

**Figure 4-13** Sample calculation using formulas

# Subnetting Formulas (continued)

| | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|
| 240 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

Subnetwork numbers will increment by 16, as it is the decimal equivalent of the right-most significant digit in the mask

Below is a list of the last octets for the 16 subnets created from network number 199.4.10.0 with the subnet mask 255.255.255.240

| | |
|---|---|
| 0 | 128 |
| 16 | 144 |
| 32 | 160 |
| 48 | 176 |
| 64 | 192 |
| 80 | 208 |
| 96 | 224 |
| 112 | 240 |

**Figure 4-14** 255.255.255.240 subnet mask

# CIDR

**Classless Inter-Domain Routing (CIDR)**

- Developed to slow the exhaustion of IP addresses
- Based on assigning IP addresses on criteria other than octet boundaries

- CIDR addressing method allows the use of a **prefix** to designate the number of network bits in the mask
  - Example: 200.16.1.48 /25 (CIDR notation)
  - The first 25 bits in the mask are network bits (1s)
- The prefix can be longer than the default subnet mask (subnetting) or it can be shorter than the default mask (**supernetting**)

# Summarization

- **Summarization**
  - Also know as route aggregation or supernetting
  - Allows many IP subnets to be advertised as one
    - Reduces the number of entries in the router's routing table
- Summarize a group of subnets
  - Count the number of bits that are common to all of the networks you want to advertise
  - Then use the prefix that identifies the number of common bits

# Summarization (continued)

| Decimal | Binary Equivalent |
|---|---|
| 213.64.132.0 /24 | 11010101.01000000.10000100.00000000 |
| 213.64.133.0 /24 | 11010101.01000000.10000101.00000000 |
| 213.64.134.0 /24 | 11010101.01000000.10000110.00000000 |
| 213.64.135.0 /24 | 11010101.01000000.10000111.00000000 |

**Table 4-6** Example summarization

# Variable Length Subnet Masks

- **Variable length subnet masking (VLSM)**
  - Allows different masks on the subnets
  - Essentially done by subnetting the subnets
- Basic routing protocols such as RIP version 1 and IGRP
  - Do not support VLSM because they do not carry subnet mask information in their routing table updates
  - Are classful routing protocols
- RIP version 2, OSPF, or EIGRP are classless protocols

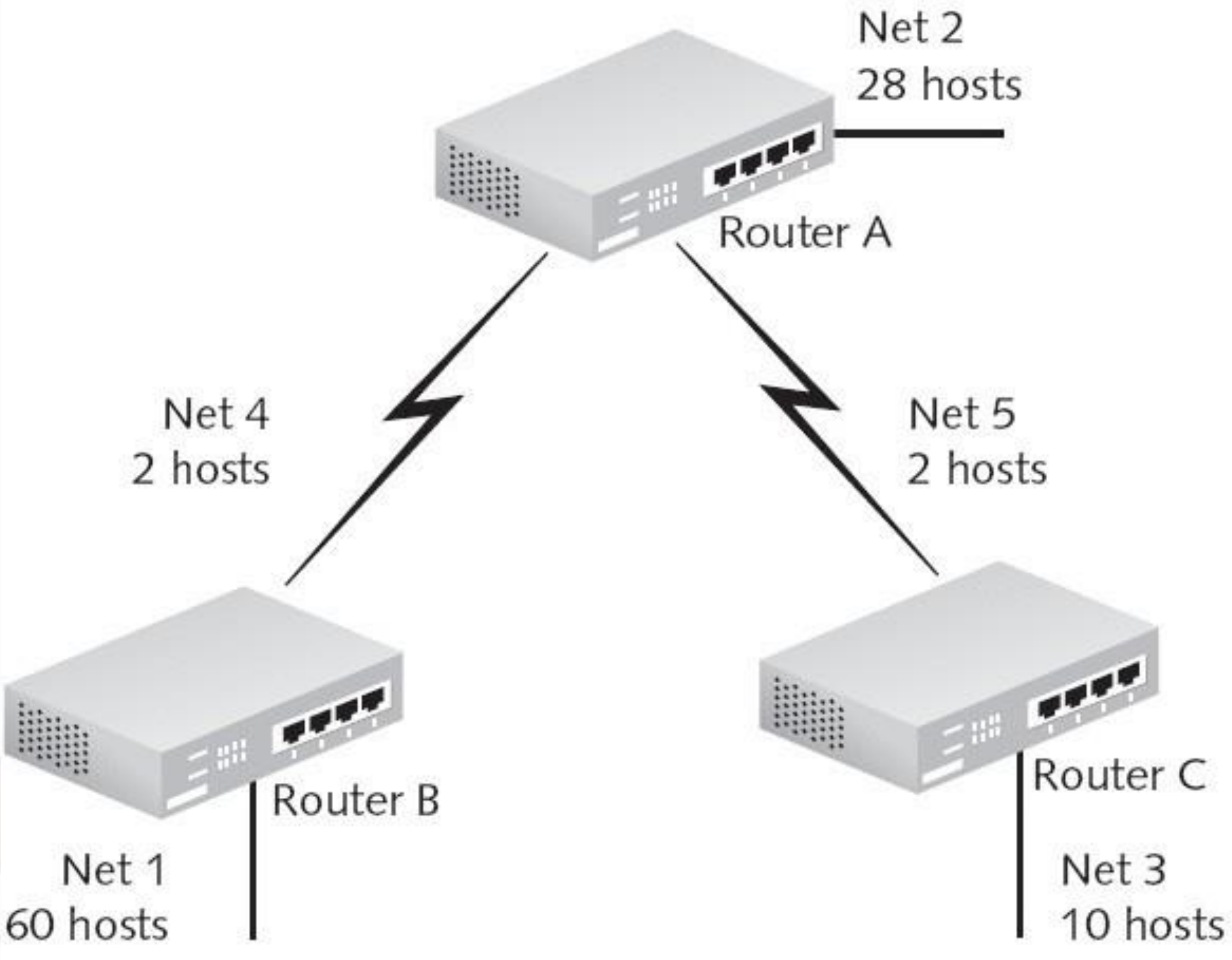


**Figure 4-15** Example internetwork for VLSM

# Variable Length Subnet Masks (continued)

| | |
|---|---|
| 192.168.59.128 /30 | 192.168.59.160 /30 |
| 192.168.59.132 /30 | 192.168.59.164 /30 |
| 192.168.59.136 /30 | 192.168.59.168 /30 |
| 192.168.59.140 /30 | 192.168.59.172 /30 |
| 192.168.59.144 /30 | 192.168.59.176 /30 |
| 192.168.59.148 /30 | 192.168.59.180 /30 |
| 192.168.59.152 /30 | 192.168.59.184 /30 |
| 192.168.59.156 /30 | 192.168.59.188 /30 |

**Table 4-7** VLSM subnets created from 192.168.59.128 /26

# Variable Length Subnet Masks (continued)

| Major Network | Original Subnets | Subnetted Subnets Using VLSM | Subnet Assignments |
|---|---|---|---|
| 192.168.59.0 /24 | 192.168.59.0 /26 | | Net 1 |
| | 192.168.59.64 /26 | 192.168.59.64 /27 | Net 2 |
| | | 192.168.59.96 /27 | Net 3 |
| | 192.168.59.128 /26 | 192.168.59.128 /30 | Net 4 |
| | | 192.168.59.132 /30 | Net 5 |
| | | 192.168.59.136 through 192.168.59.188 | Reserved |
| | 192.168.59.192 /26 | | Reserved |

**Table 4-8** VLSM IP scheme for 192.168.59.0

# Working with Hexadecimal Numbers

- **Hexadecimal** numbering system is base 16
  - 16 numerals are used to express any given number
  - Numerals include 0 through 9 as well as A through F
  - For example, the decimal number 192 is C0 in hexadecimal
- Often you will come across hexadecimal numbers when working with computers and networking
  - The MAC address is a 12-digit hexadecimal number
- Computers typically process information in 8-bit chunks (bytes)
  - Easier to express bytes with two hex digits

| Binary | Hexadecimal | Decimal |
|---|---|---|
| 0000 | 0 | 0 |
| 0001 | 1 | 1 |
| 0010 | 2 | 2 |
| 0011 | 3 | 3 |
| 0100 | 4 | 4 |
| 0101 | 5 | 5 |
| 0110 | 6 | 6 |
| 0111 | 7 | 7 |
| 1000 | 8 | 8 |
| 1001 | 9 | 9 |
| 1010 | A | 10 |
| 1011 | B | 11 |
| 1100 | C | 12 |
| 1101 | D | 13 |
| 1110 | E | 14 |
| 1111 | F | 15 |

**Table 4-9** Binary to hex to decimal conversion

# IPv4 versus IPv6

- IP version 4 (**IPv4**)
  - The version of IP currently deployed on most systems today
- IP version 6 (**IPv6**)
  - Originally designed to address the eventual depletion of IPv4 addresses
- CIDR has slowed the exhaustion of IPv4 address space and made the move to IPv6 less urgent
  - However, CIDR is destined to become obsolete because it is based on IPv4

# IPv4 versus IPv6 (continued)

- Network address translation **(NAT)**
  - Another technique developed in part to slow the depletion of IPv4 addresses
  - Allows a single IP address to provide connectivity for many hosts
- NAT is CPU intensive and expensive
  - Some protocols do not work well with NAT, such as the IP Security Protocol (**IPSec**)
- IPv4 does not provide security in itself
  - Has led to security issues with DNS and ARP

# IPv4 versus IPv6 (continued)

- Security concerns were factored into the design of IPv6
- IPv4 networks rely on broadcasting
  - Inefficient because many hosts unnecessarily see and partially process traffic not ultimately destined for them
- IPv6 does away completely with broadcasting and replaces it with multicasting
- IPv6 addresses are 128 bits compared with IPv4's 32-bit structure

# IPv4 versus IPv6 (continued)

- IPv6 addresses are expressed as hexadecimal numbers
  - Example: 3FFE:0501:0008:0000:0260:97FF:FE40:EFAB
- IPv6 can be subnetted
  - CIDR notation is also used with IPv6
    - Example: 2001:702:21:: /48
- Organizations requesting an IPv6 address may be assigned a /64 prefix
  - Minimum subnet with space for over a billion hosts

# Transitioning to IPv6

- **Dual stack**
  - Involves enabling IPv6 on all routers, switches, and end nodes but not disabling IPv4
  - Both version 4 and version 6 stacks run at the same time
- **Tunneling**
  - Encapsulates IPv6 traffic inside IPv4 packets
  - Done when portions of a network are running IPv6 and other network areas have not been upgraded yet
  - Greatest concern: security

# Summary

- The ICANN and the ARIN work together to subdivide and issue addresses for Internet clients
- Three classes of addresses (A, B, and C) are available to organizations
- The two additional address categories are Class D and Class E
- Subnetting involves subdividing assigned addresses
- Routing tables can be created manually and dynamically

# Summary (continued)

- Advanced routing protocols such as RIP version 2, OSPF, and EIGRP support variable length subnet masking (VLSM)
- The hexadecimal numbering system is also known as base 16 because it has 16 available numerals
- IPv6 is the latest version of IP addressing