Chapter 8
IP Addressing

Binary Notation

Computers communicate in 1s and 0s

Numbering System used is Binary

1 represents a voltage

0 represent no voltage

Positional Notation

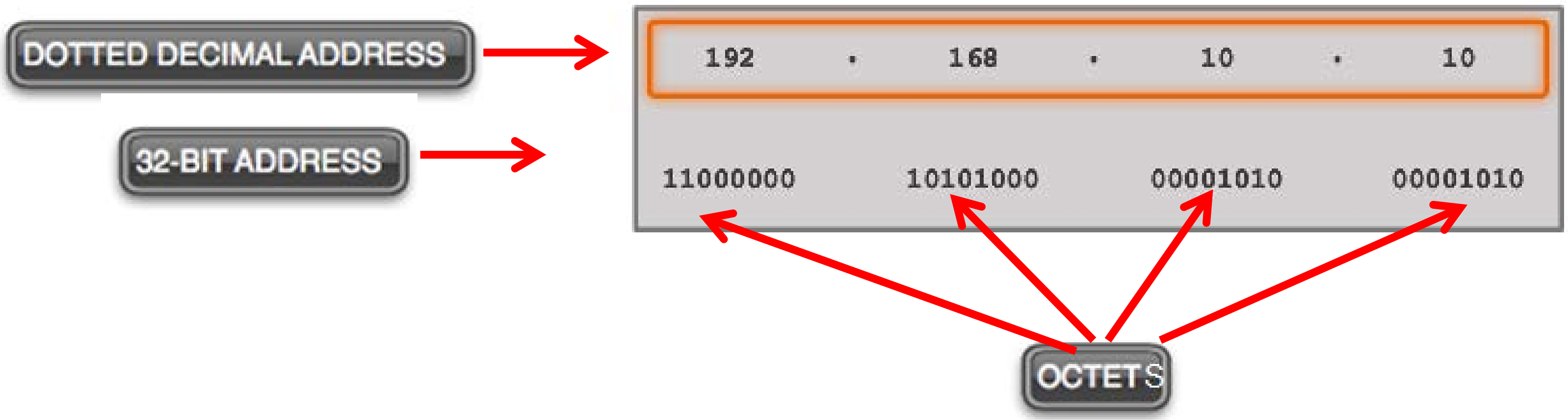
192

	Hundreds	Tens	Ones
Radix	10	10	10
Exponent	2	1	0
Positional Value	100	10	1
Numerical Identifier	1	9	2
Numerical Value	1*100=100	9*10=90	2*1=2

100+90+2

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

Converting a Binary Address to Decimal

Practice

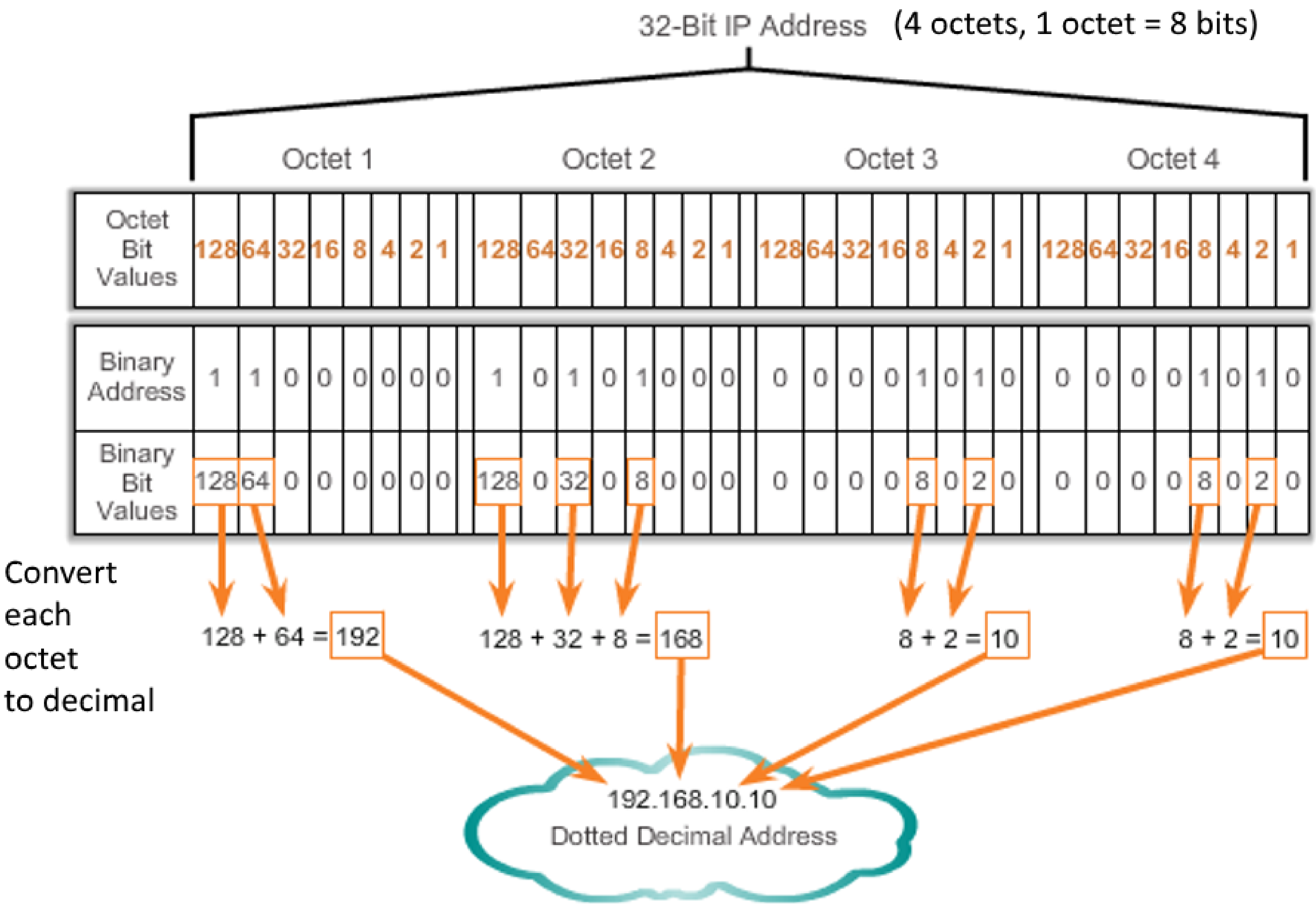
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1
1	0	1	1	0	0	0	0

Answer = 176

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

Answer = 255

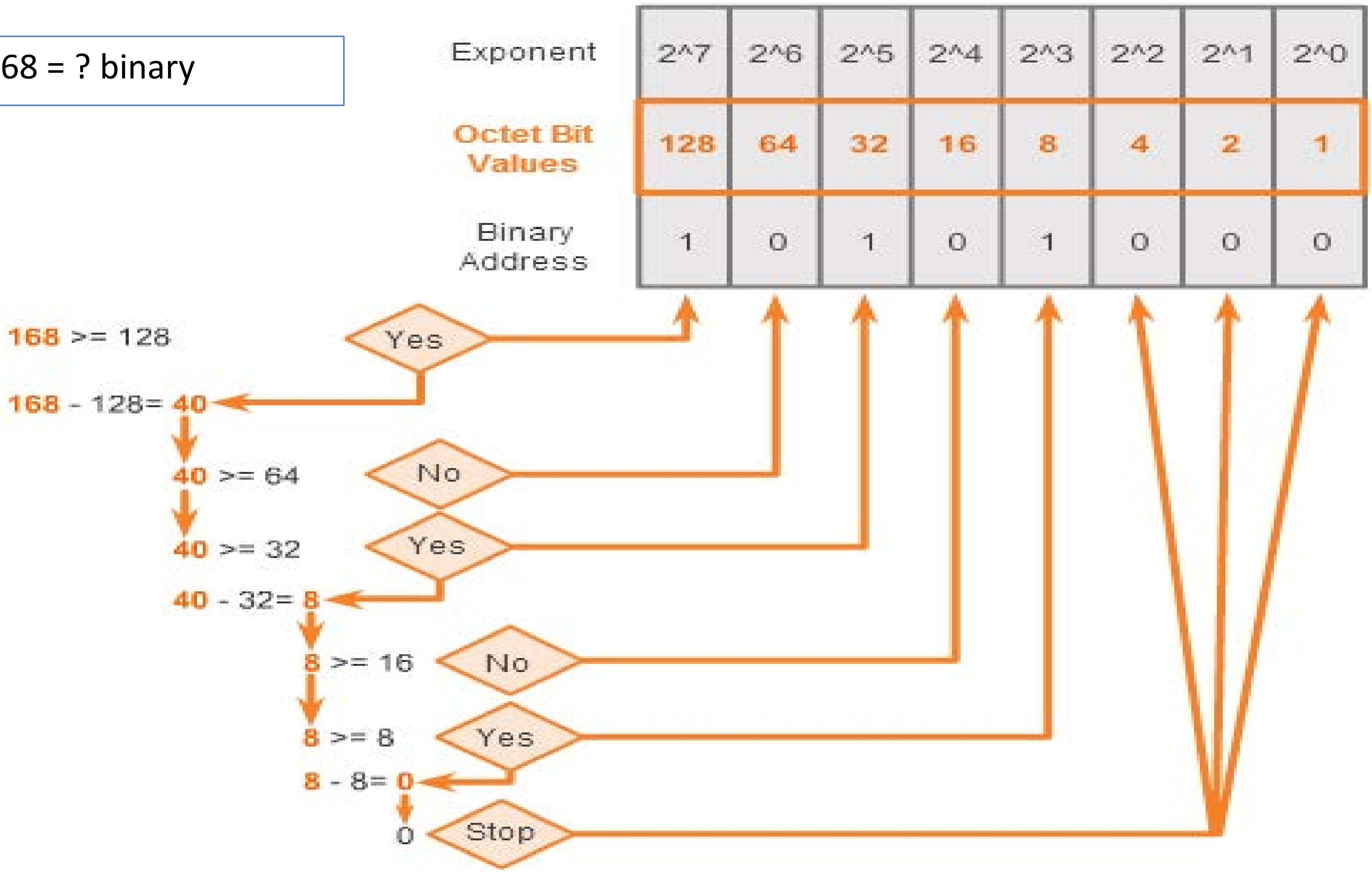
Converting a Binary Address IP to Decimal



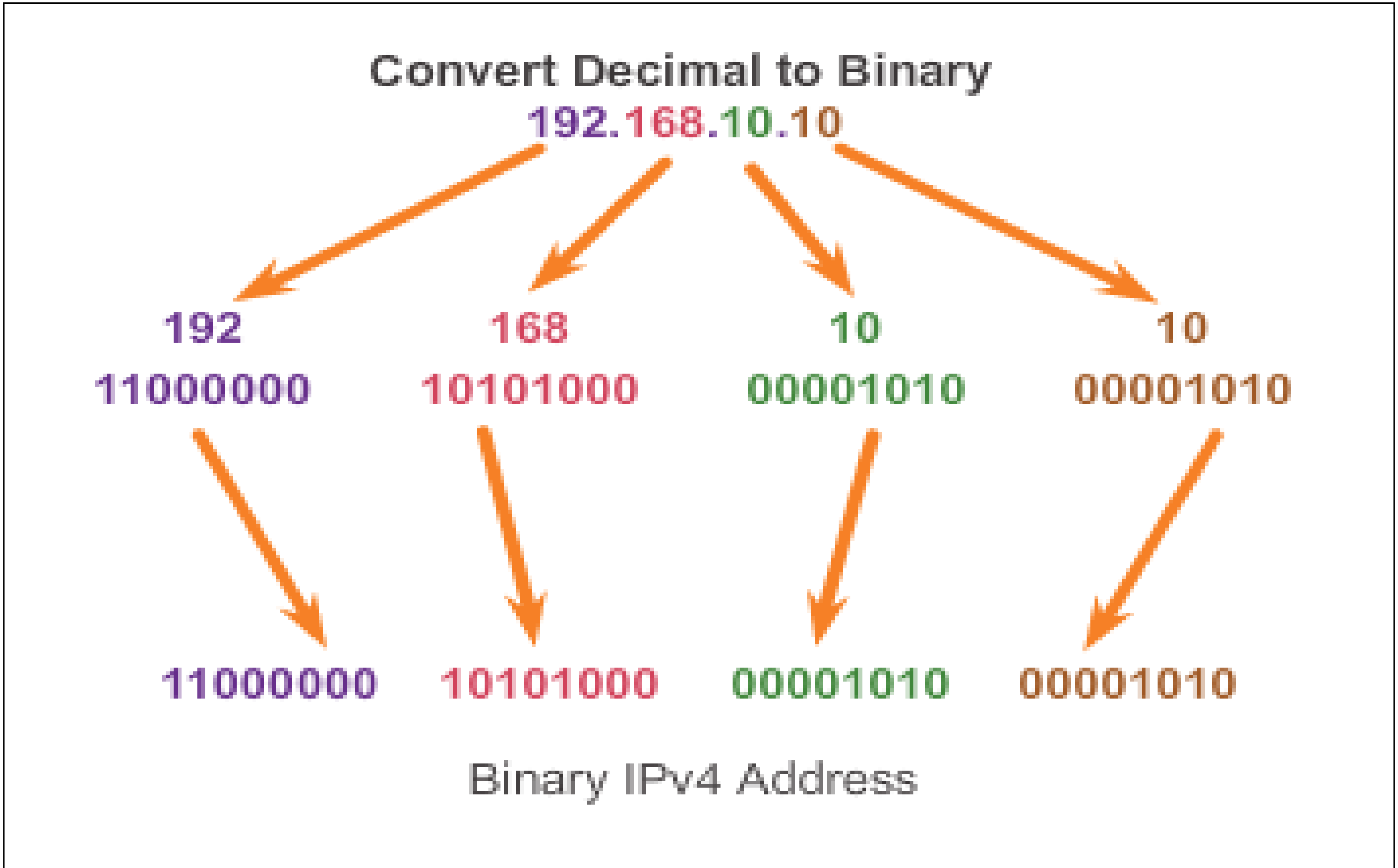
IPv4 Address Structure

Converting from Decimal to Binary

168 = ? binary



Converting from Decimal to Binary

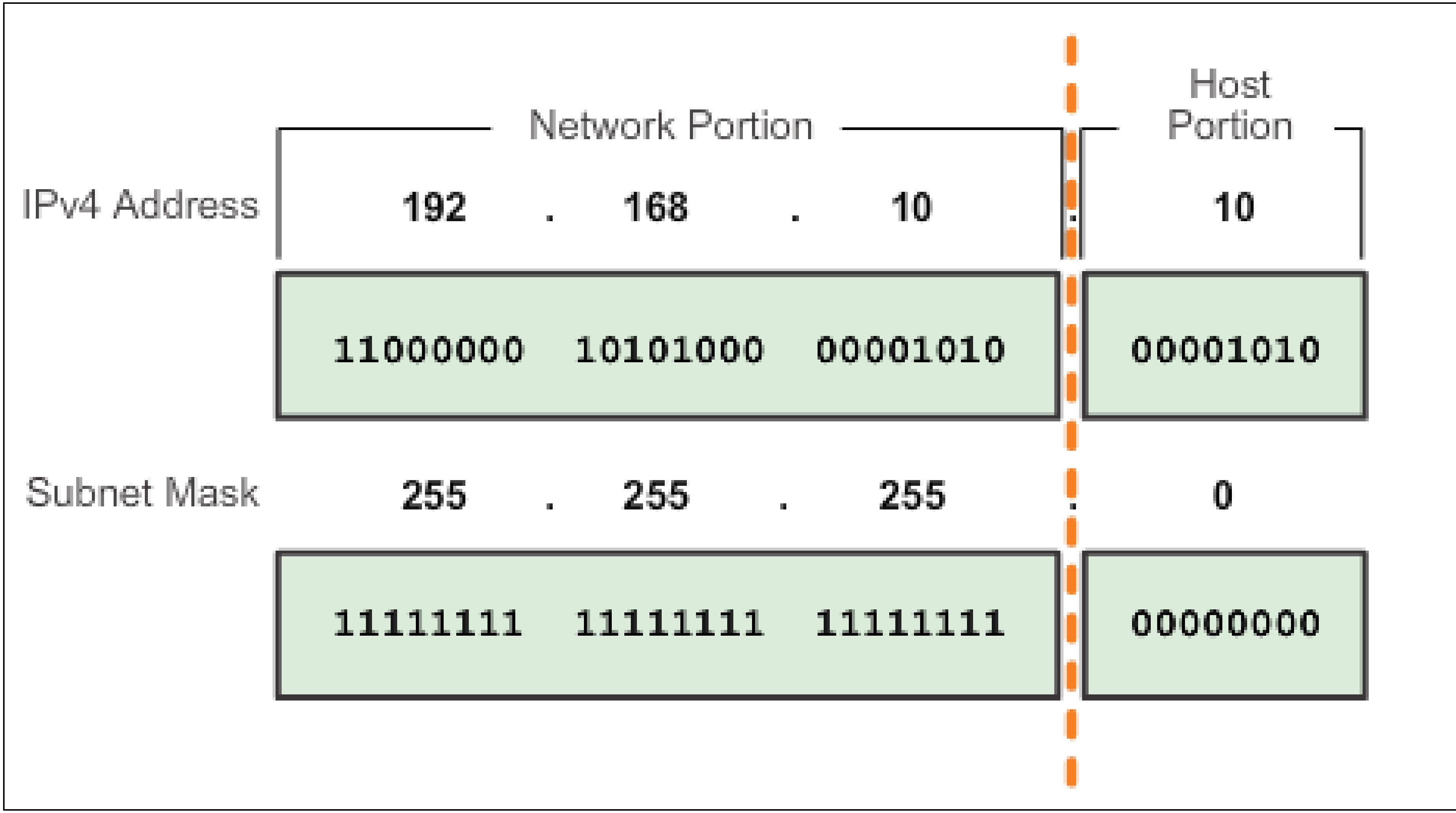


Network Portion and Host Portion

- A 32-bit IPv4 address has 32 bits.
- An address consists of a Network address and a Host address.
- To define the network and host portions of an address, devices use a separate 32-bit pattern called a subnet mask.

- A **Subnet mask** is a 32-bit number that **masks** an IP address, and divides the IP address into network address and host address.

Network Portion and Host Portion



The IPv4 Subnet Mask has 8 bits, and take any of these 8 values.

Valid Subnet Masks

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

Calculating Max Number of Hosts

	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		

Number of hosts $= 2^{H} - 2$

$= 2^{8} - 2$

$= 256 - 2 = 254$

/24 means 24 bits of 32 bits used for network address, which is 10.1.1

The remaining 8 bits are available for host address (H)

The last two addresses (.254 and .255) are reserved

In this network, the maximum number of hosts = 254.

Calculating Max Number of 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		

25 bits used for network address

7 bits left for hosts, thus H=7

Number of hosts = $2^7 - 2 = 128 - 2 = 126$

A network that needs more than 126 hosts cannot use this design.

Calculating Number of 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		

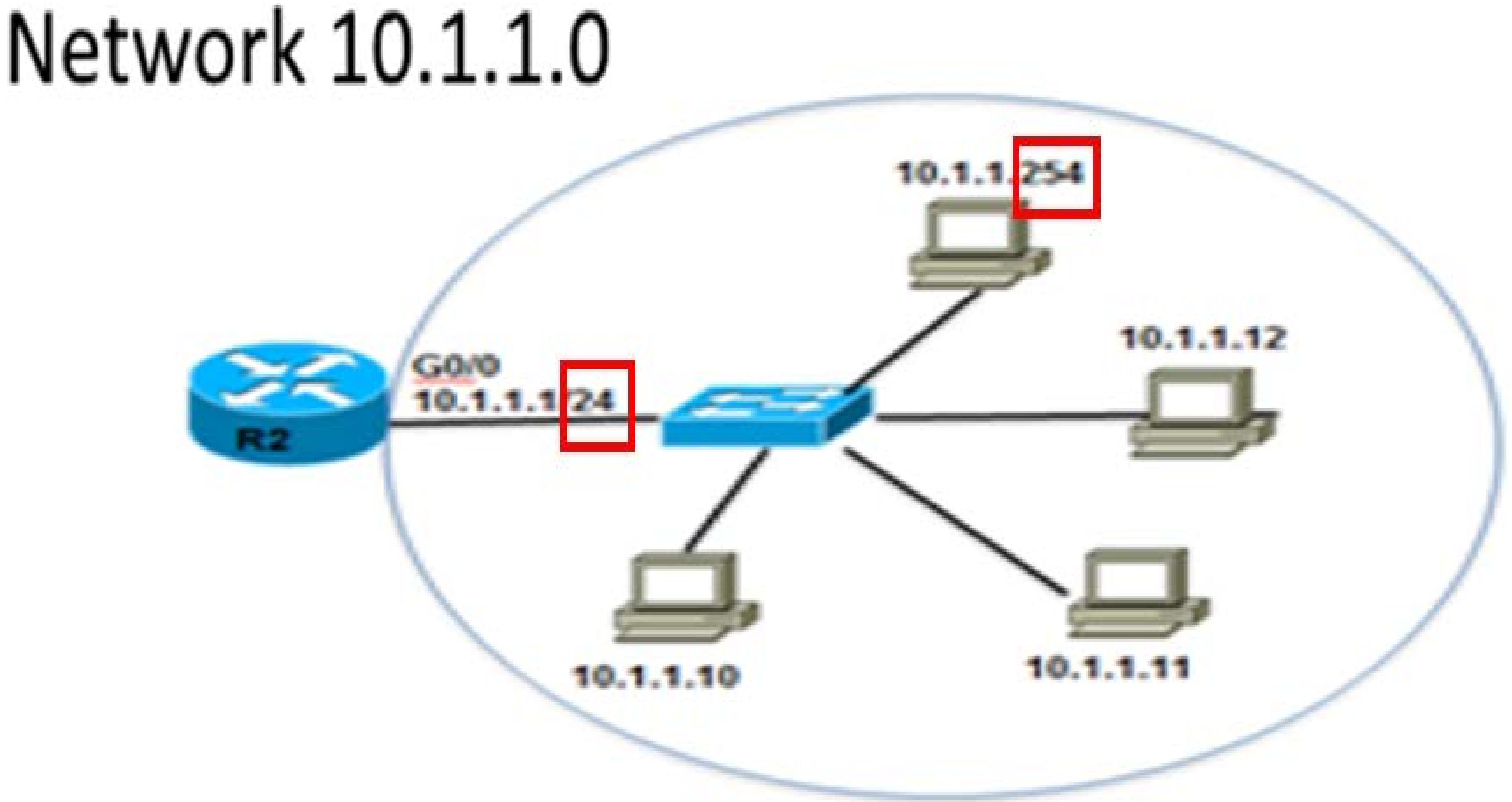
Determine the maximum number of hosts for this network.

(ans : 62)

	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		

Network and Router Addresses



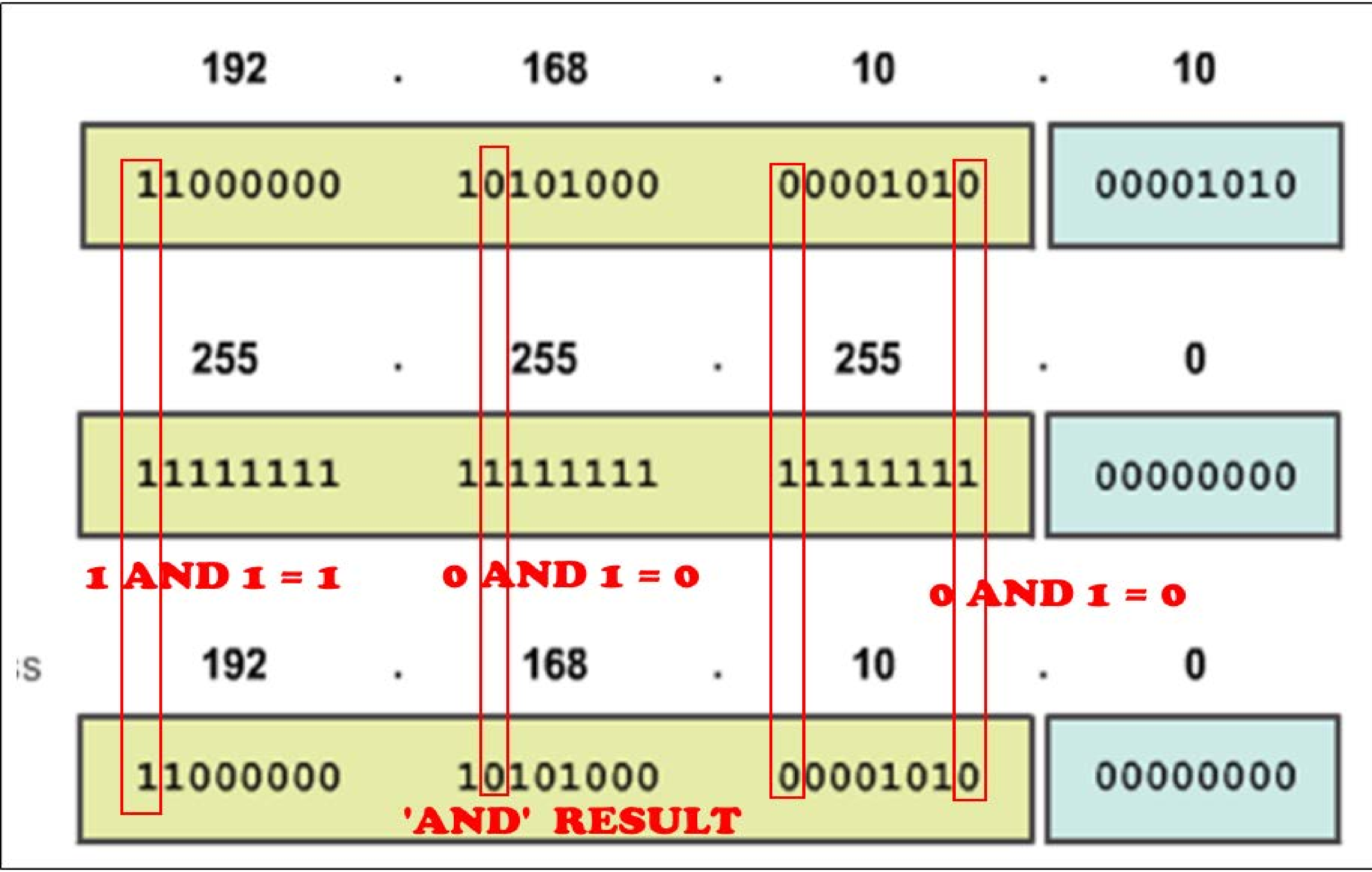
IPv4 Subnet Mask Bitwise AND Operation

IP Address AND Subnet Mask = Network address

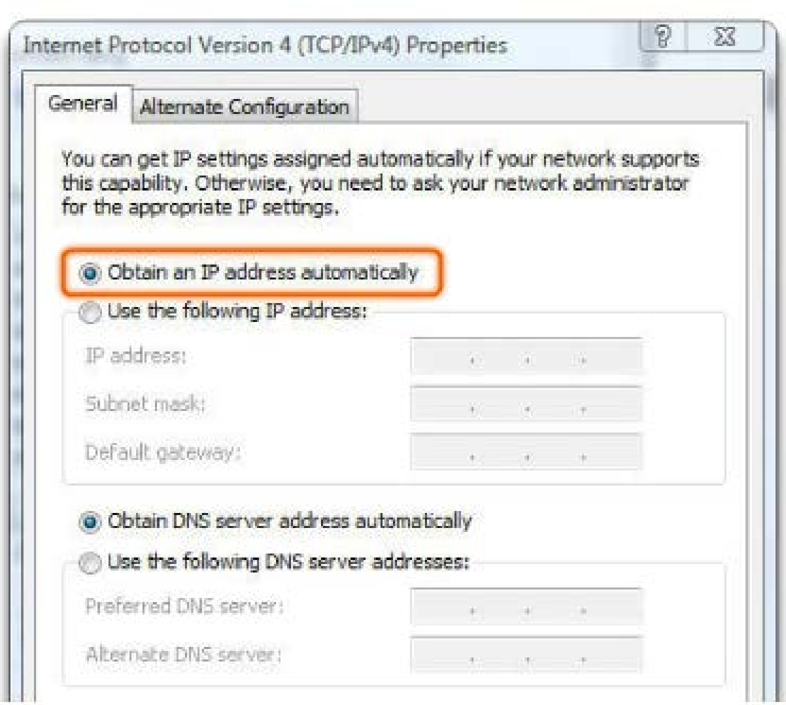
IPv4 Address known	192	168	10	10
	11000000	10101000	00001010	00001010
Subnet Mask known	255	255	255	0
	11111111	11111111	11111111	00000000
Network Address calculated	192	168	10	0
	11000000	10101000	00001010	00000000

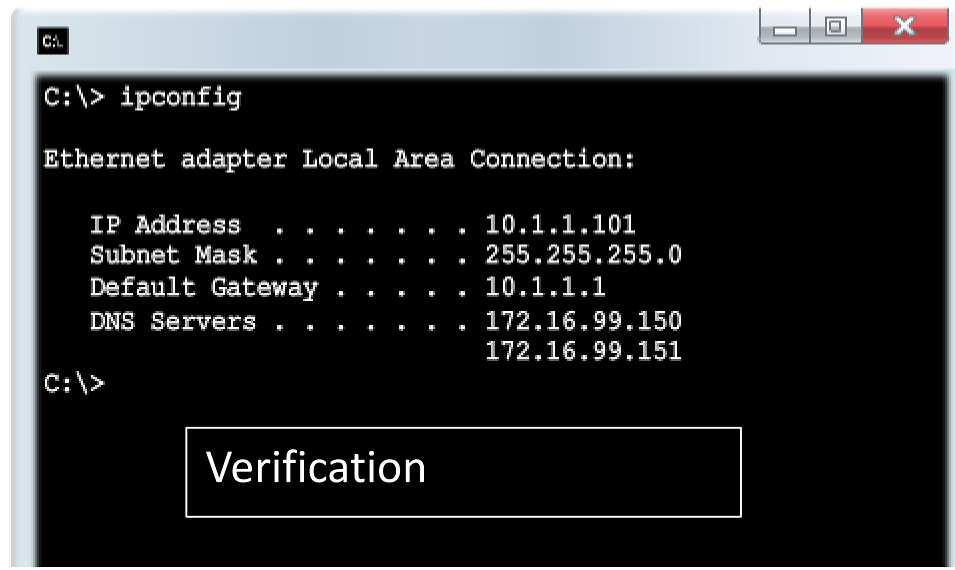
IPv4 Subnet Mask Bitwise AND Operation

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



Assigning a Dynamic IPv4 Address to a Host





DHCP – The preferred method of assigning IPv4 addresses to hosts on large networks; it reduces the burden on network support staff and eliminates entry errors.

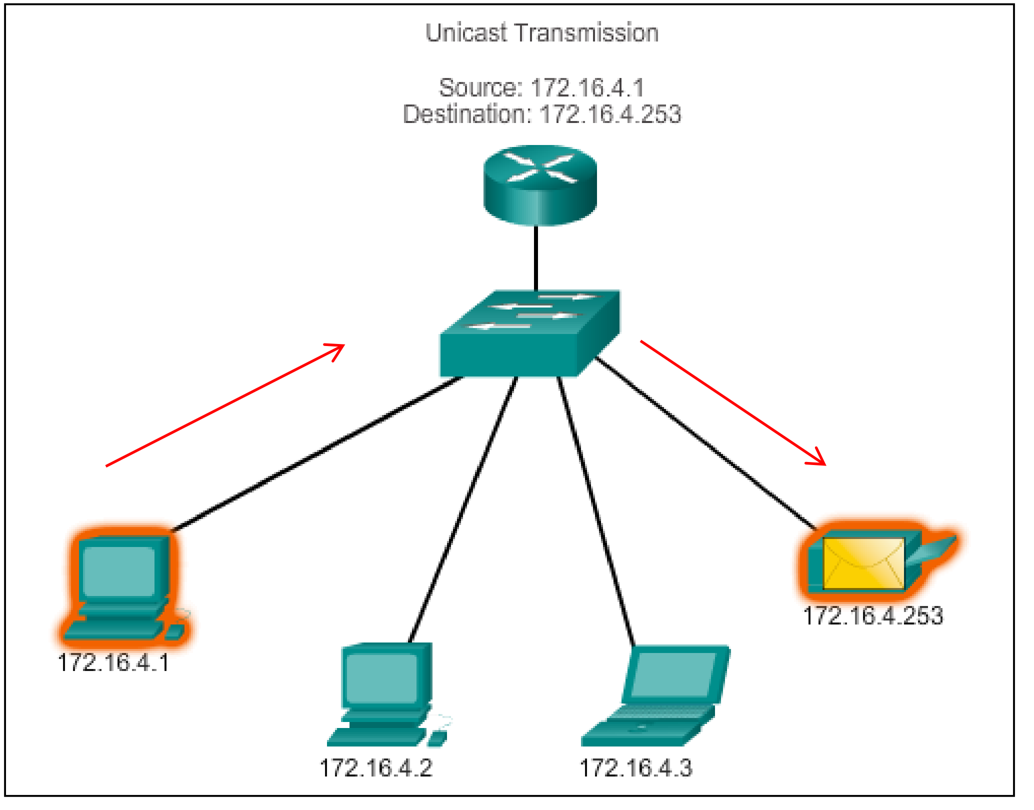
DHCP - Dynamic Host Configuration Protocol

IPv4 Unicast, Broadcast, and Multicast

Unicast Transmission

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

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



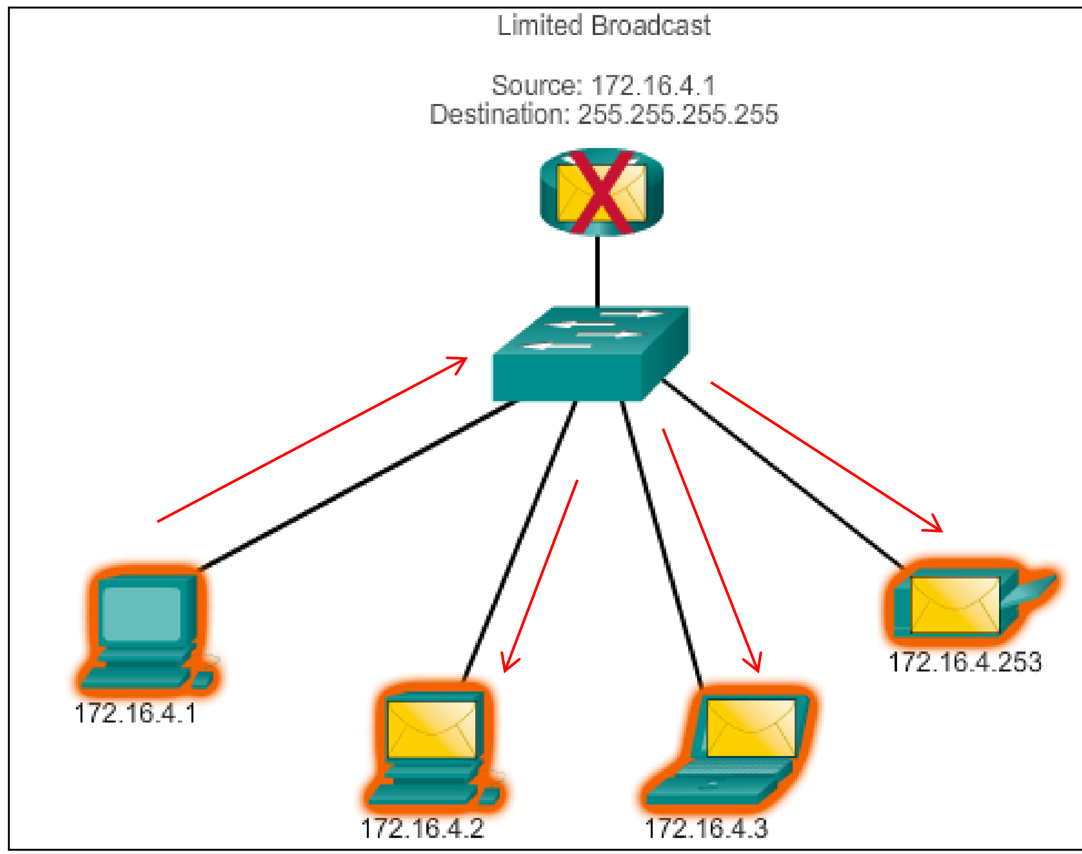
Broadcast Transmission

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

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

Directed broadcast

- Destination 172.16.4.255 (broadcast address)
- All hosts in 172.16.4.0/24 network will receive packet



Multicast Transmission

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

#3 Multicast – sending a packet from one host to a selected group of hosts

- Reduces traffic

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
  - 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)

- Address block is 100.64.0.0/10

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)

- **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 for teaching and learning purposes,
  used in documentation and network examples
- **Experimental addresses** – 240.0.0.0 to 255.255.255.254 are listed as reserved

Types of IPv4 Address

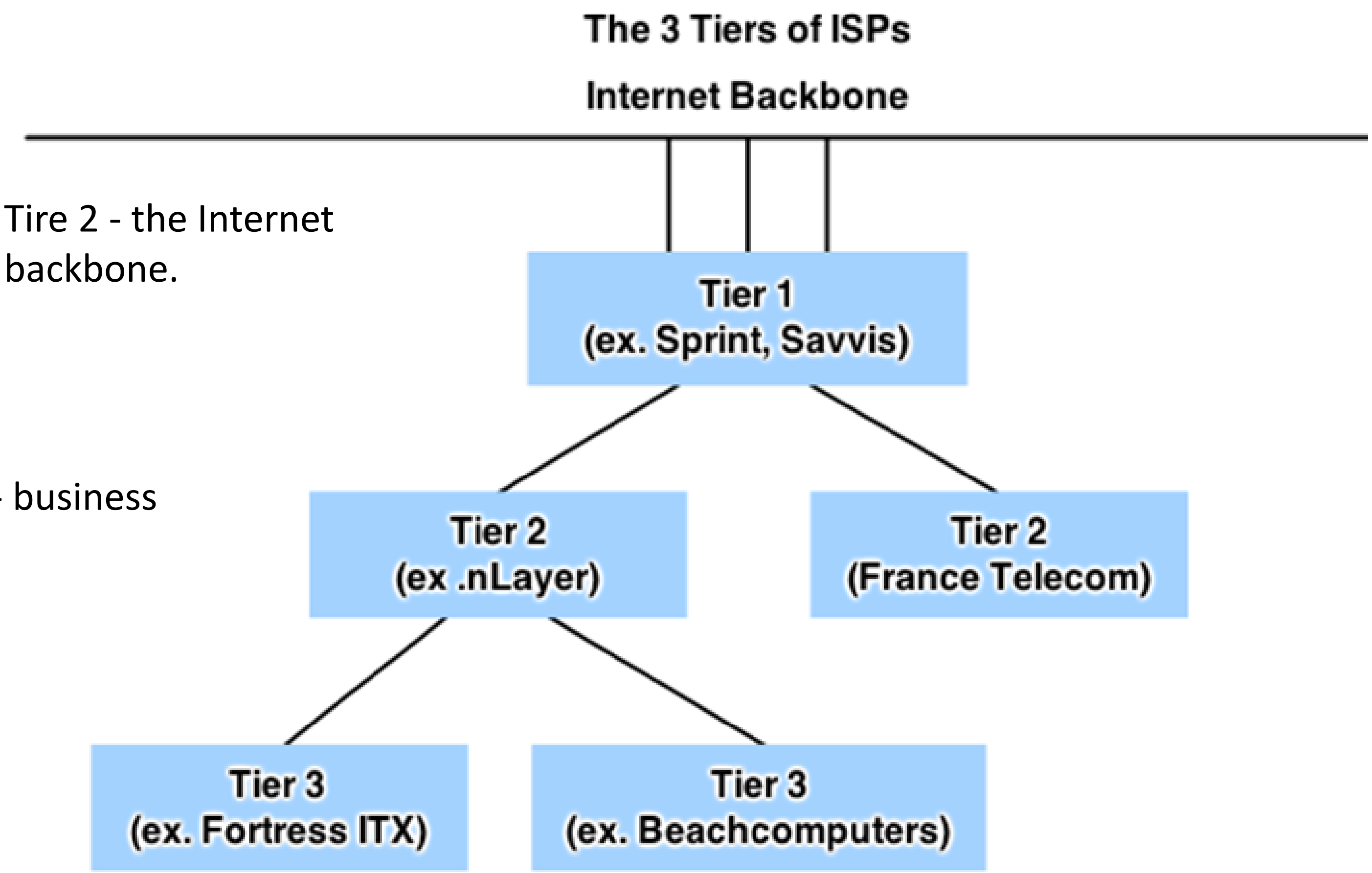
Legacy Classful Addressing

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

Assignment of IP Addresses (Cont.)



Tire 2 - the Internet backbone.

Tier 2 ISPs - business customers.

Tier 3 ISPs for customers.

Tier 3 ISPs purchase their Internet service from Tier 2 ISPs.

IPv6

IPv4 Issues

The Need for IPv6

- successor to IPv4.
- IPv4 has maximum of 4.3 billion addresses,
- IPv6 provides for 340 undecillion addresses.
- IPv6 fixes the limitations of IPv4 and includes additional enhancements, such as ICMPv6.

IPv4 and IPv6 Coexistence

Three migration techniques categories:
Dual-stack, Tunnelling, and Translation.

Dual-stack: Allows IPv4 and IPv6 to coexist on the same network. Devices run both IPv4 and IPv6 protocol stacks simultaneously.

Tunnelling: A method of transporting an IPv6 packet over an IPv4 network. The IPv6 packet is encapsulated inside an IPv4 packet.

Translation: The Network Address Translation 64 (NAT64) allows IPv6-enabled devices to communicate with IPv4-enabled devices.
An IPv6 packet is translated to an IPv4 packet, and vice versa.

Hexadecimal Number System

- Hexadecimal is a base sixteen system.
- Base 16 numbering system uses the numbers 0 to 9 and the letters A to F.
- Four bits (half of a byte) can be represented with a single hexadecimal value.

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

Hexadecimal Number System (cont.)

Look at the binary bit patterns that match the decimal and hexadecimal values

Hexadecimal	Decimal	Binary
00	0	0000 0000
01	1	0000 0001
02	2	0000 0010
03	3	0000 0011
04	4	0000 0100
05	5	0000 0101
06	6	0000 0110
07	7	0000 0111
08	8	0000 1000
0A	10	0000 1010
0F	15	0000 1111
10	16	0001 0000
20	32	0010 0000
40	64	0100 0000
80	128	1000 0000
C0	192	1100 0000
CA	202	1100 1010
F0	240	1111 0000
FF	255	1111 1111

IPv6 Address Representation

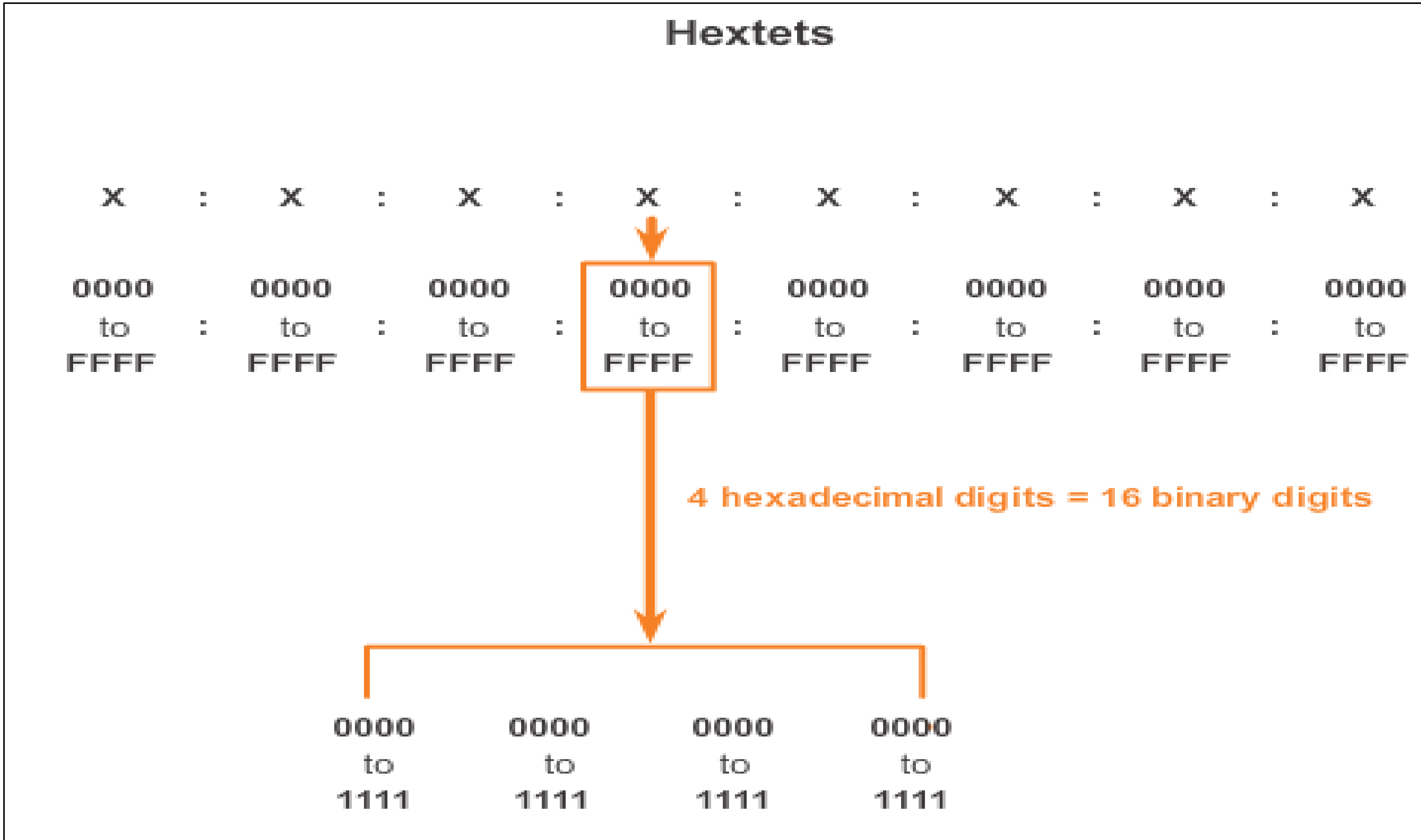
- 128 bits in length
- hexadecimal values
- 4 bits represents a single hexadecimal digit
- 32 hexadecimal value = IPv6 address

  – **2001:0DB8:0000:1111:0000:0000:0000:0200**

  – **FE80:0000:0000:0000:0123:4567:89AB:CDEF**

- Hextet used to refer to a segment of 16 bits or four hexadecimals
- Can be written in either lowercase or uppercase

IPv6 Address Representation



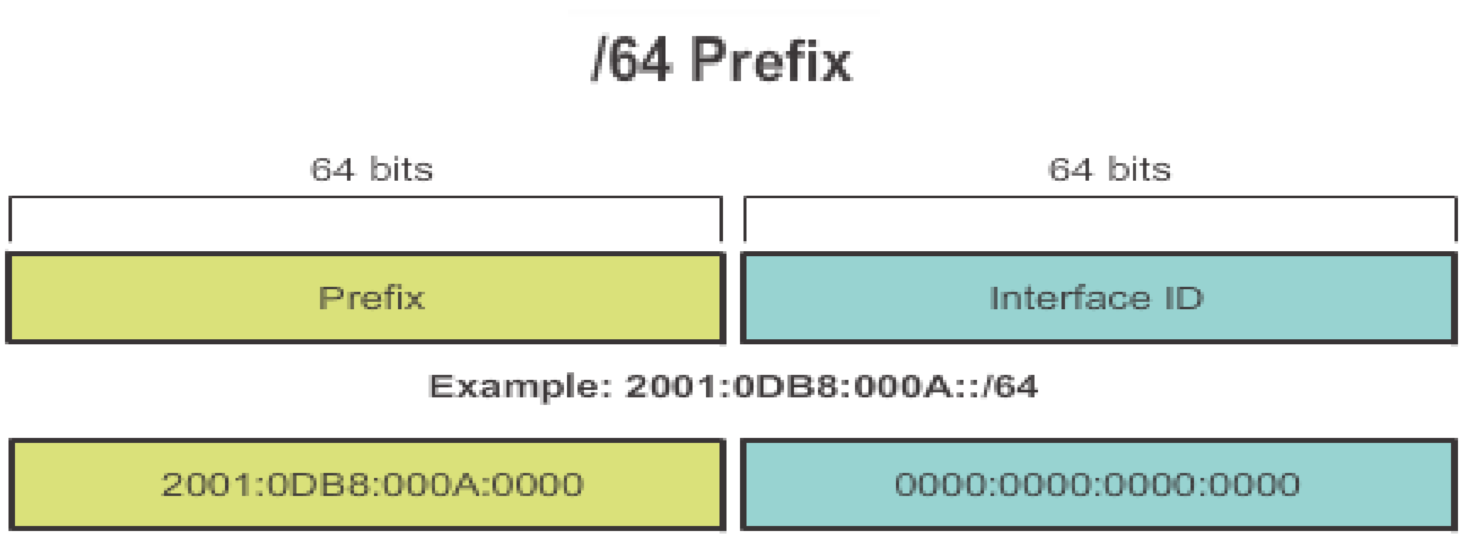
Rule 1- Omitting Leading 0s

- any leading 0s (zeros) in any 16-bit section or hextet can be omitted.
- 01AB can be represented as 1AB.
- 09F0 can be represented as 9F0.
- 0A00 can be represented as A00.
- 00AB can be represented as AB.
- A double colon (::) can replace any single, contiguous string of one or more 16-bit segments (hextets) consisting of all 0's.

Preferred	2001:0DB8:000A:1000:0000:0000:0000:0100
No leading 0s	2001: DB8: A:1000: 0: 0: 0: 100
Compressed	2001:DB8:A:1000:0:0:0:100

IPv6 Prefix Length

- Prefix length indicates the network portion of an IPv6 address using the following format:
  - IPv6 address/prefix length
  - Prefix length can range from 0 to 128
  - Typical prefix length is /64



IPv6 Address Types

There are three types of IPv6 addresses:

- Unicast
- Multicast
- Anycast.

Note: IPv6 does not have broadcast addresses.

IPv6 Unicast Addresses

Unicast

- Uniquely identifies one an IPv6-enabled device.

Global Unicast

- Globally unique
- Internet routable addresses
- Can be configured statically or assigned dynamically

Link-local

- Used to communicate with other devices on the same local link
- Confined to a single link; not routable beyond the link

IPv6 Unicast Addresses (cont.)

Loopback

- Used by a host to send a packet to itself
- cannot be assigned to a physical interface.
- Ping an IPv6 loopback address to test the configuration of TCP/IP on the local host.
- All-0s except for the last bit, represented as ::1/128 or just ::1.

Unspecified Address

- All-0’s address represented as ::/128 or just ::
- Cannot be assigned to an interface
- only used as a source address.

IPv6 Unicast Addresses (cont.)

Unique Local

- Similar to private addresses for IPv4.
- Used for local addressing within a site or between a limited number of sites.
- In the range of FC00::/7 to FDFF::/7.

IPv6 Link-Local Unicast Addresses

- Every IPv6-enabled network interface is REQUIRED to have a link-local address
- Enables a device to communicate with other IPv6-enabled devices on the same link and only on that link (subnet)
- FE80::/10 range, first 10 bits are 1111 1110 10xx xxxx
- 1111 1110 10**00 0000** (FE80) - 1111 1110 10**11 1111** (FEBF)

Structure of an IPv6 Global Unicast Address

- IPv6 global unicast addresses are globally unique and routable on the IPv6 Internet
- Equivalent to public IPv4 addresses
- ICANN allocates IPv6 address blocks to the five RIRs

Currently, only global unicast addresses with the first three bits of 001 or 2000::/3 are being assigned

Structure of an IPv6 Global Unicast Address

A global unicast address has three parts: Global Routing Prefix, Subnet ID, and Interface ID.

Global Routing Prefix is the prefix or network portion of the address

Subnet ID is used to identify subnets within its site

Interface ID is equivalent to the host portion of an IPv4 address.

Dynamic Link-local Addresses

Link-Local Address

- a link-local address enables a device to communicate with other IPv6-enabled devices on the same subnet.
- the link-local address of the local router is ued for its default gateway IPv6 address.
- Routers exchange dynamic routing protocol messages using link-local addresses.
- Routers' routing tables use it to identify the next-hop router when forwarding IPv6 packets.

Assigned IPv6 Multicast Addresses

- IPv6 multicast addresses have the prefix FF00::/8
- There are two types of IPv6 multicast addresses:
  - Assigned multicast
  - Solicited node multicast

IPv6 Multicast Addresses
Solicited Node IPv6 Multicast Addresses

- matches only the last 24 bits of the IPv6 global unicast address of a device
- Automatically created when the global unicast or link-local unicast addresses are assigned
- Created by combining a special FF02:0:0:0:0:0:FF00::/104 prefix with the right-most 24 bits of its unicast address

Traceroute – Testing the Path

Traceroute

- Generates a list of hops that were successfully reached along the path.
- If the data reaches the destination, then the trace lists the interface of every router in the path between the hosts.
- If the data fails at some hop along the way, the address of the last router that responded to the trace can provide an indication of where the problem or security restrictions are found.