Cisco Networking Academy
Mind Wide Open

Chapter 7:
IP Addressing

Introduction to Networks v5.1

Chapter Outline

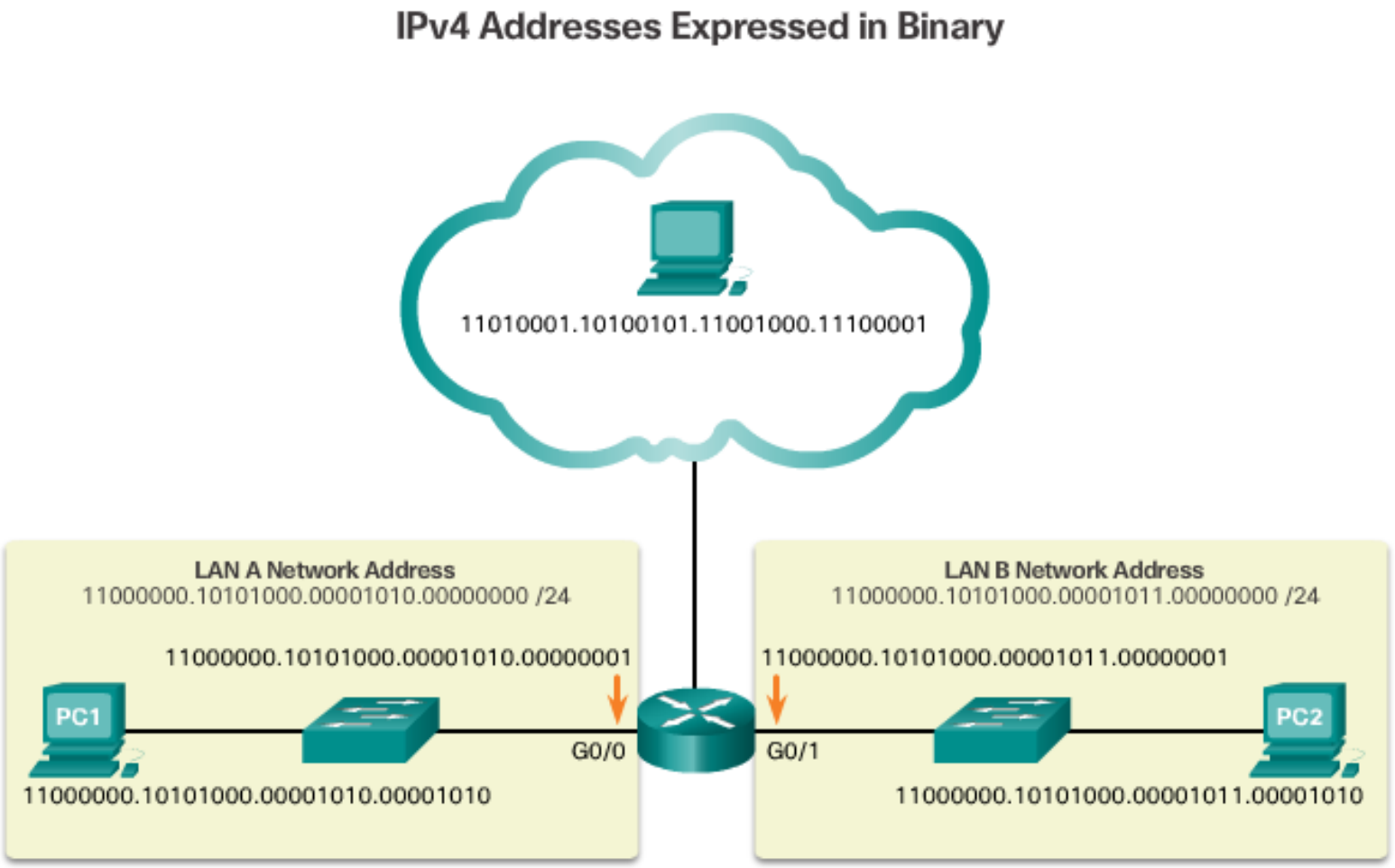
Section 7.1: IPv4 Network Addresses

Upon completion of this section, you should be able to:

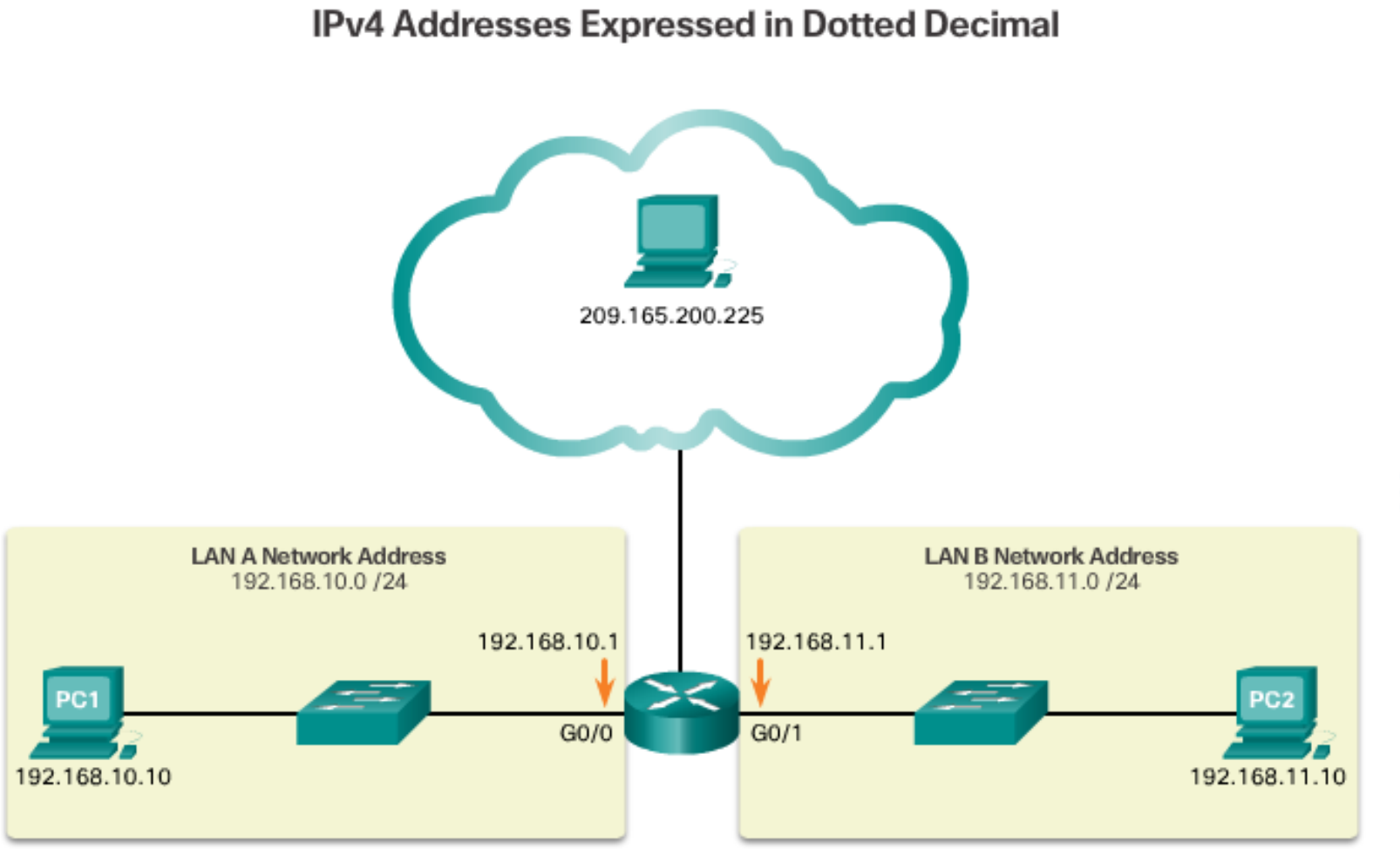
- Convert between binary and decimal numbering systems.
- Describe the structure of an IPv4 address including the network portion, the host portion, and the subnet mask.
- Compare the characteristics and uses of the unicast, broadcast, and multicast IPv4 addresses.
- Explain public, private, and reserved IPv4 addresses.

Topic 7.1.1:
Binary and Decimal Conversion

IPv4 Addresses

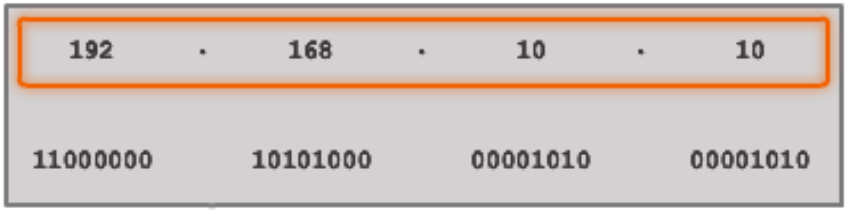


IPv4 Addresses (cont.)



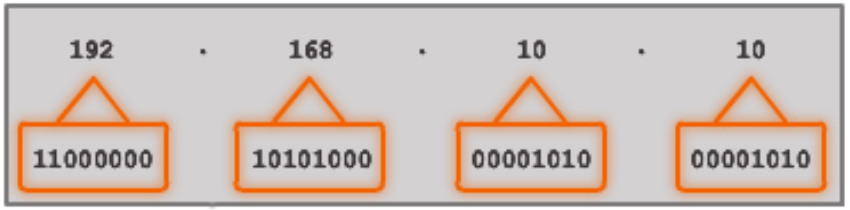
IPv4 Addresses (cont.)

Dotted Decimal Address



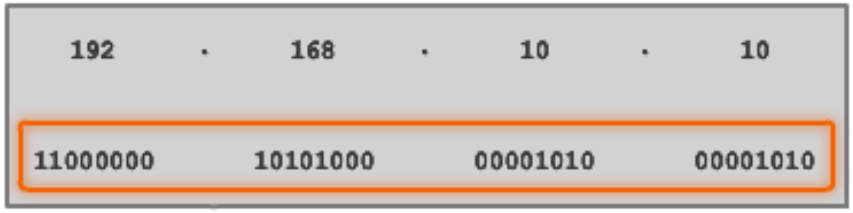
192.168.10.10 is an IP address that is assigned to a computer.

Octets



This address is made up of four different octets.

32-Bit Address



The computer stores the address as the entire 32-bit data stream.

Positional Notation

Decimal Positional Notation

Radix	10	10	10	10
Position in #	3	2	1	0
Calculate	(10^3)	(10^2)	(10^1)	(10^0)
Positional Value	1000	100	10	1

Positional Value

The first row identifies the number base or radix. Therefore the value listed, from left to right, represents units of thousands, hundreds, tens, and ones.

Positional Notation (cont.)

Applying Decimal Positional Notation

1234

	Thousands	Hundreds	Tens	Ones
Positional Value	1000	100	10	1
Decimal Number	1	2	3	4
Calculate	1 x1000	2 x100	3 x10	4 x1
Add them up ...	1000	+ 200	+ 30	+ 4
Result	1,234			

Positional Notation (cont.)

Binary Positional Notation

Radix	2	2	2	2	2	2	2	2
Position in #	7	6	5	4	3	2	1	0
Calculate	(2^7)	(2^6)	(2^5)	(2^4)	(2^3)	(2^2)	(2^1)	(2^0)
Positional Value	128	64	32	16	8	4	2	1

Radix

The binary notation system is based on 2, therefore the radix is 2.

Positional Notation (cont.)

Applying Binary Positional Notation

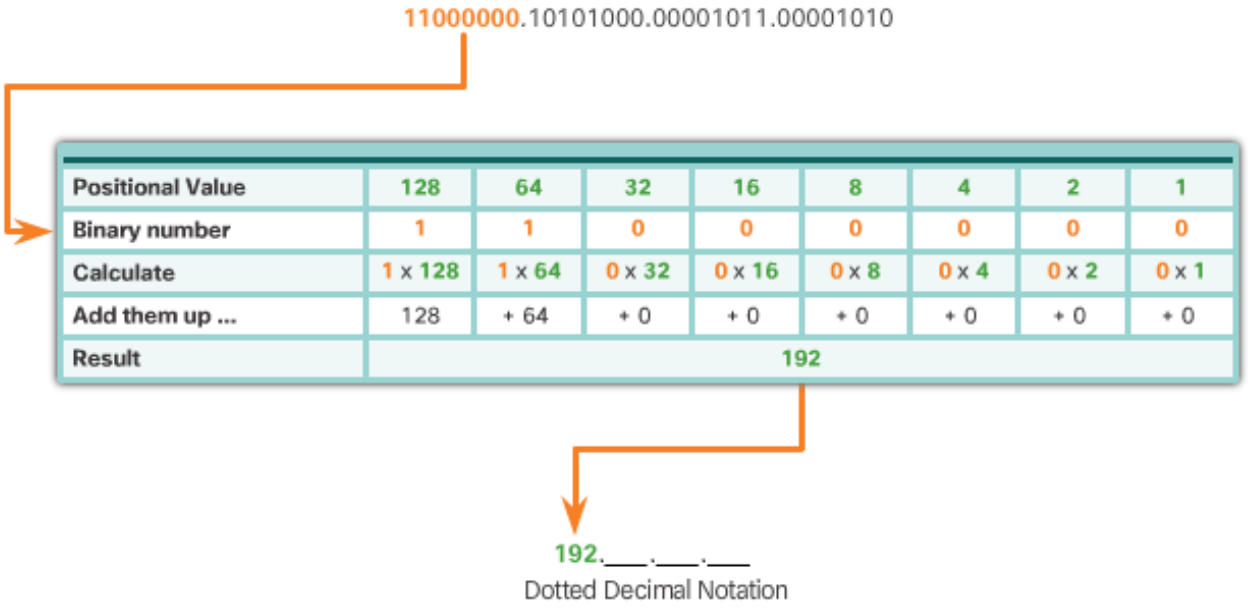
11000000

Positional Value	128	64	32	16	8	4	2	1
Binary number	1	1	0	0	0	0	0	0
Calculate	1 x 128	1 x 64	0 x 32	0 x 16	0 x 8	0 x 4	0 x 2	0 x 1
Add them up ...	128	+ 64	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0
Result	192							

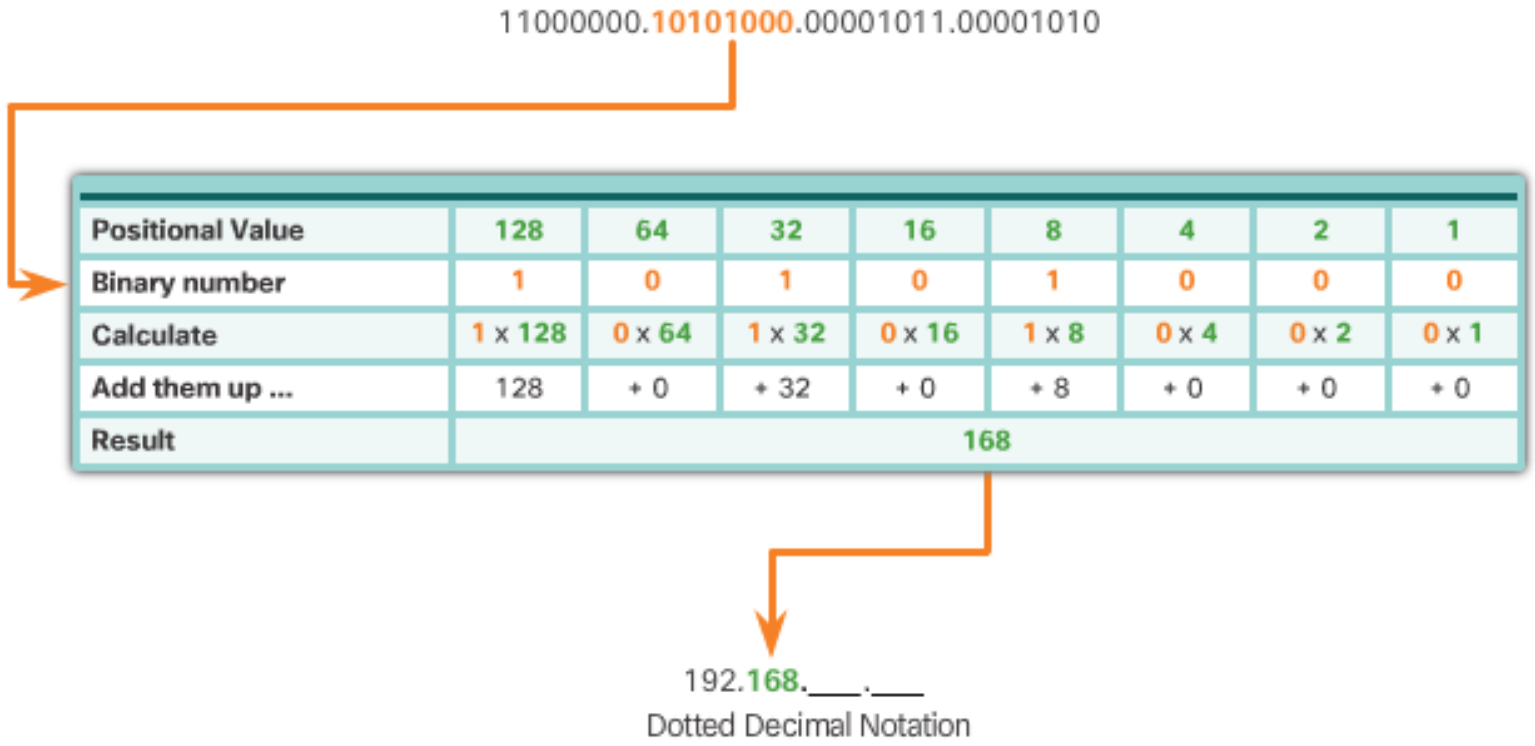
Binary to Decimal Conversion

To convert a binary IPv4 address to its dotted decimal equivalent:

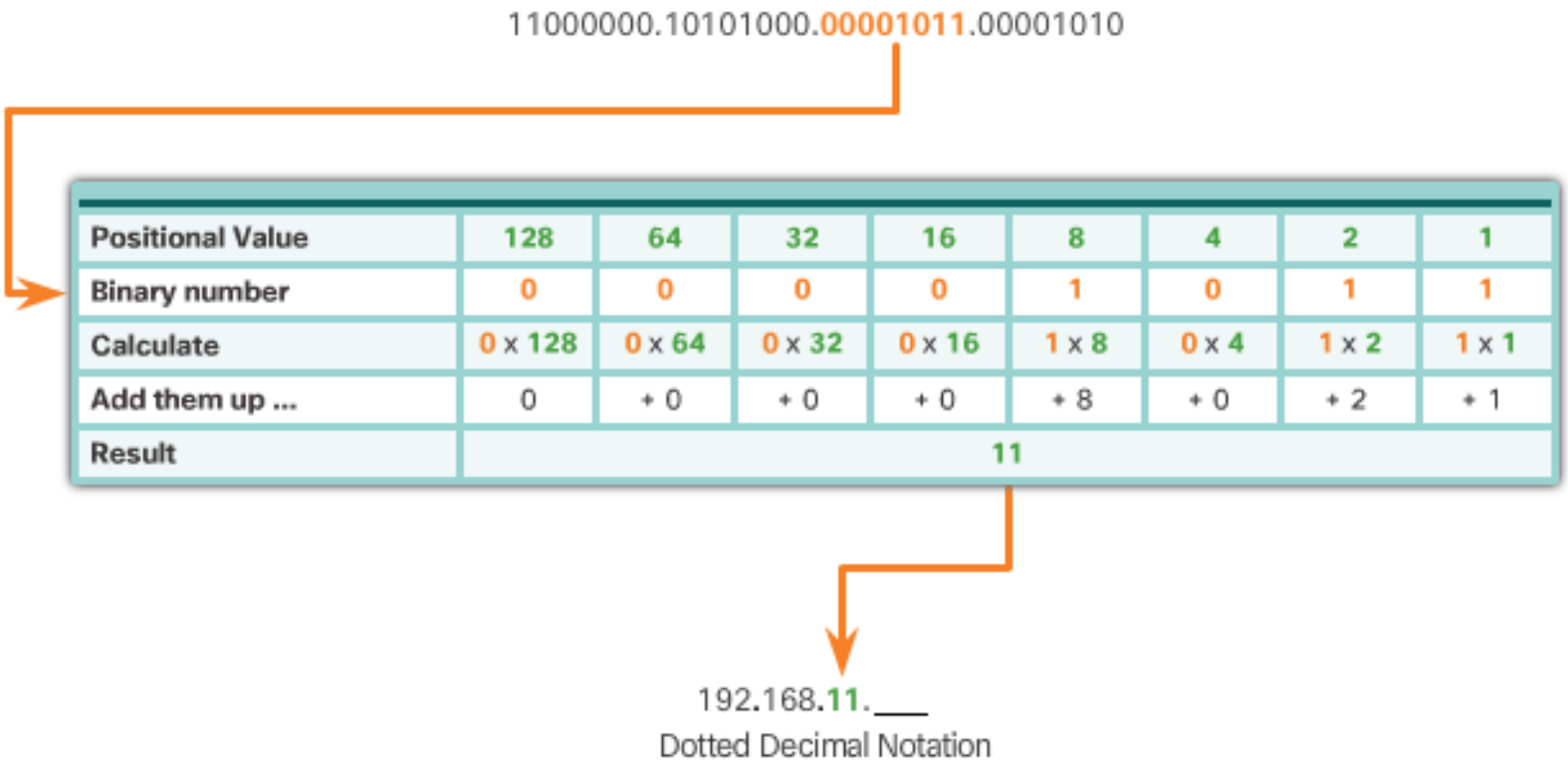
- Divide the IPv4 address into four 8-bit octets. Apply the binary positional value to the first octet binary number and calculate accordingly.
- Repeat for each octet.



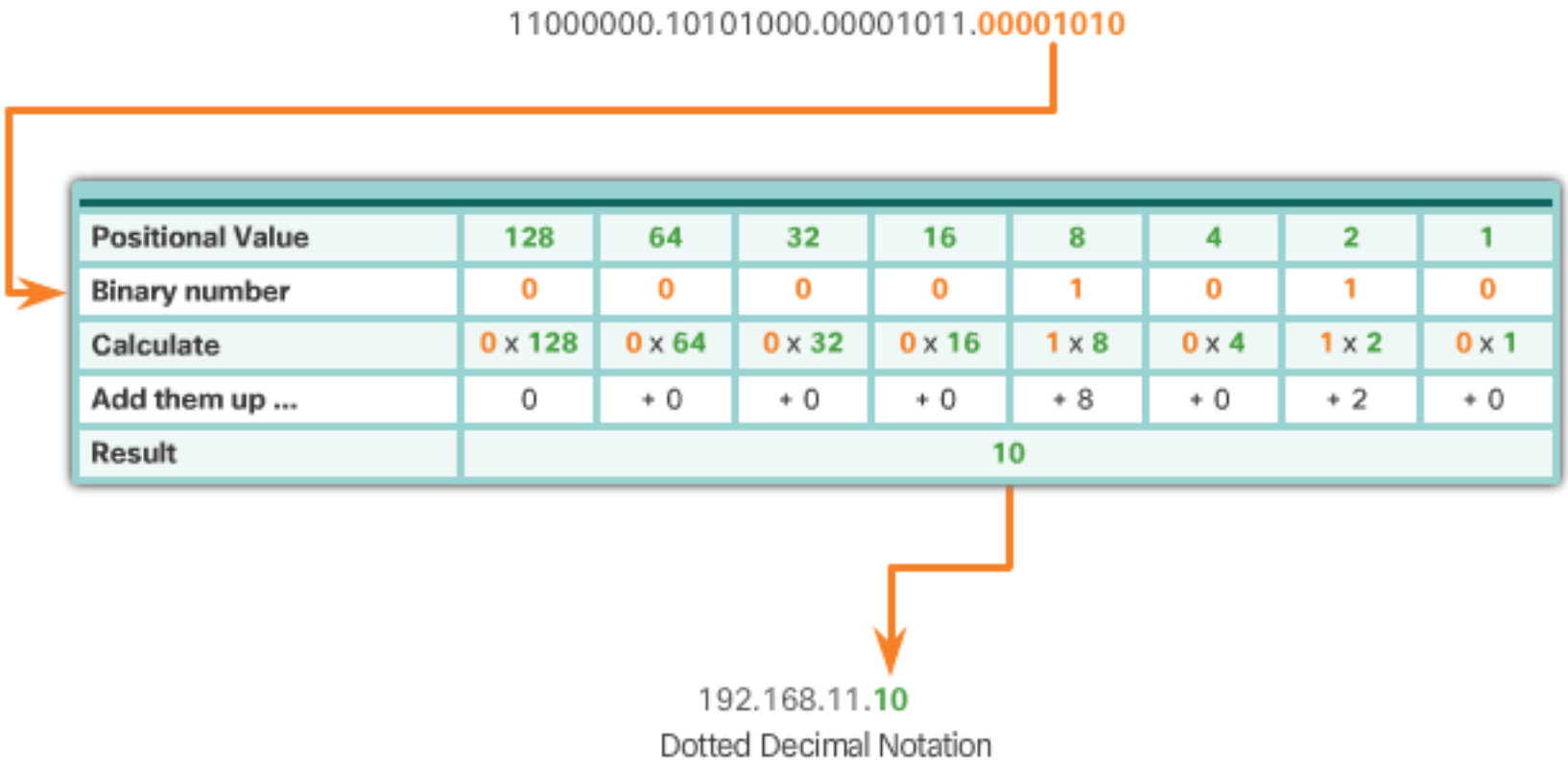
Binary to Decimal Conversion (cont.)



Binary to Decimal Conversion (cont.)

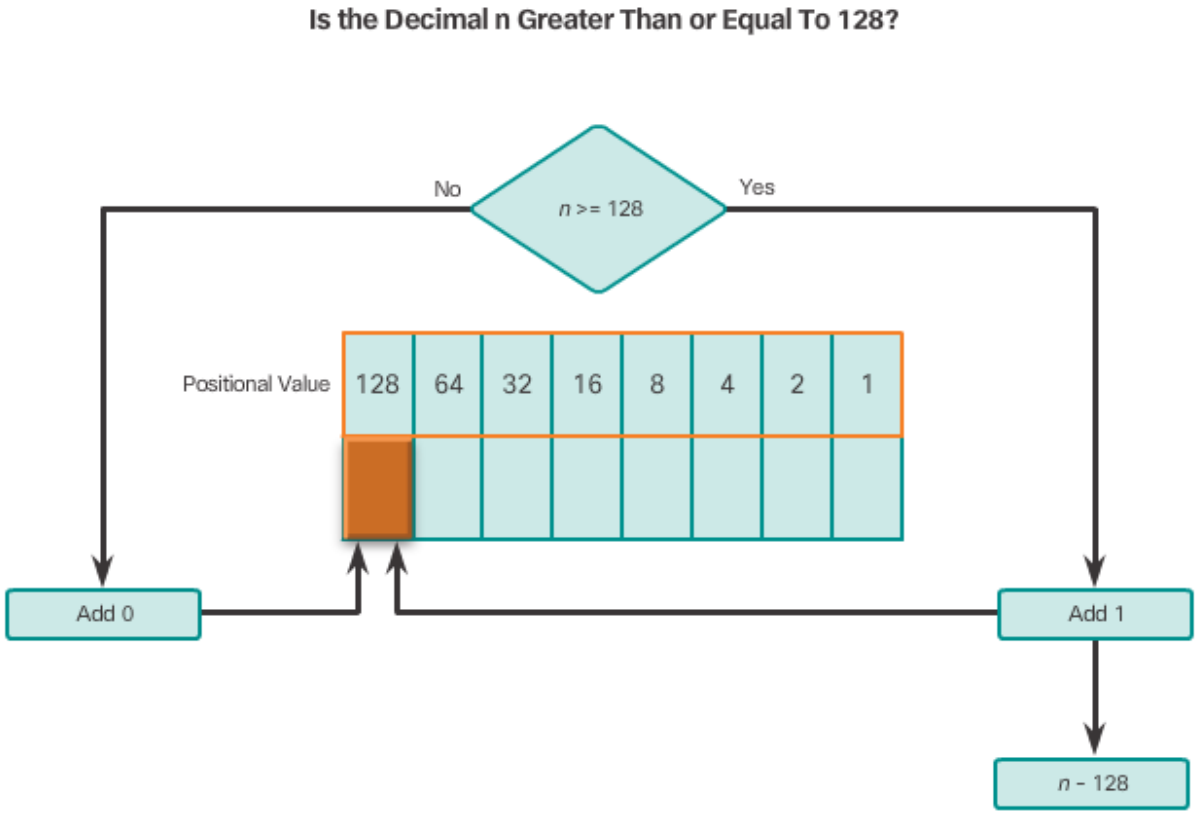


Binary to Decimal Conversion (cont.)

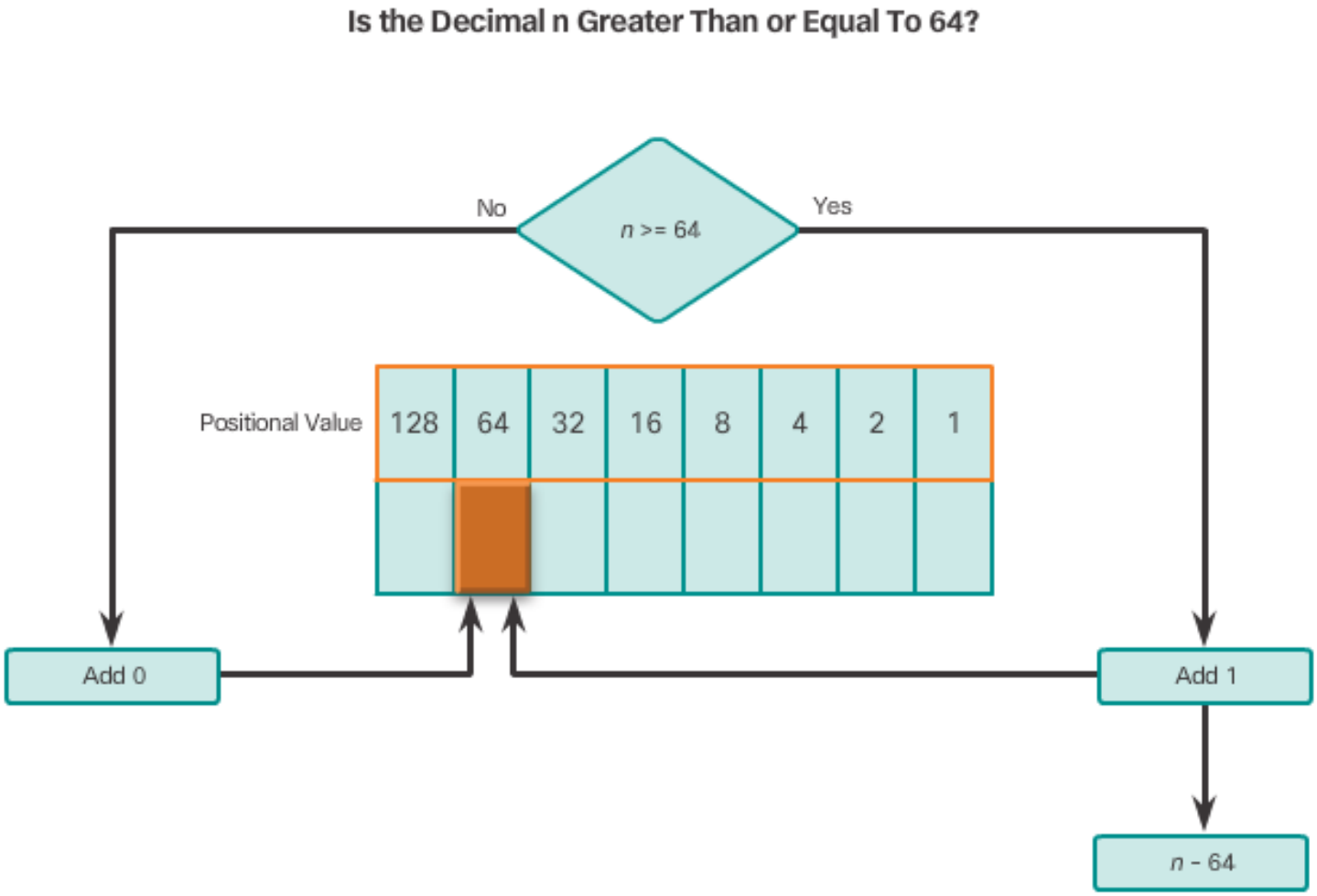


Decimal to Binary Conversion

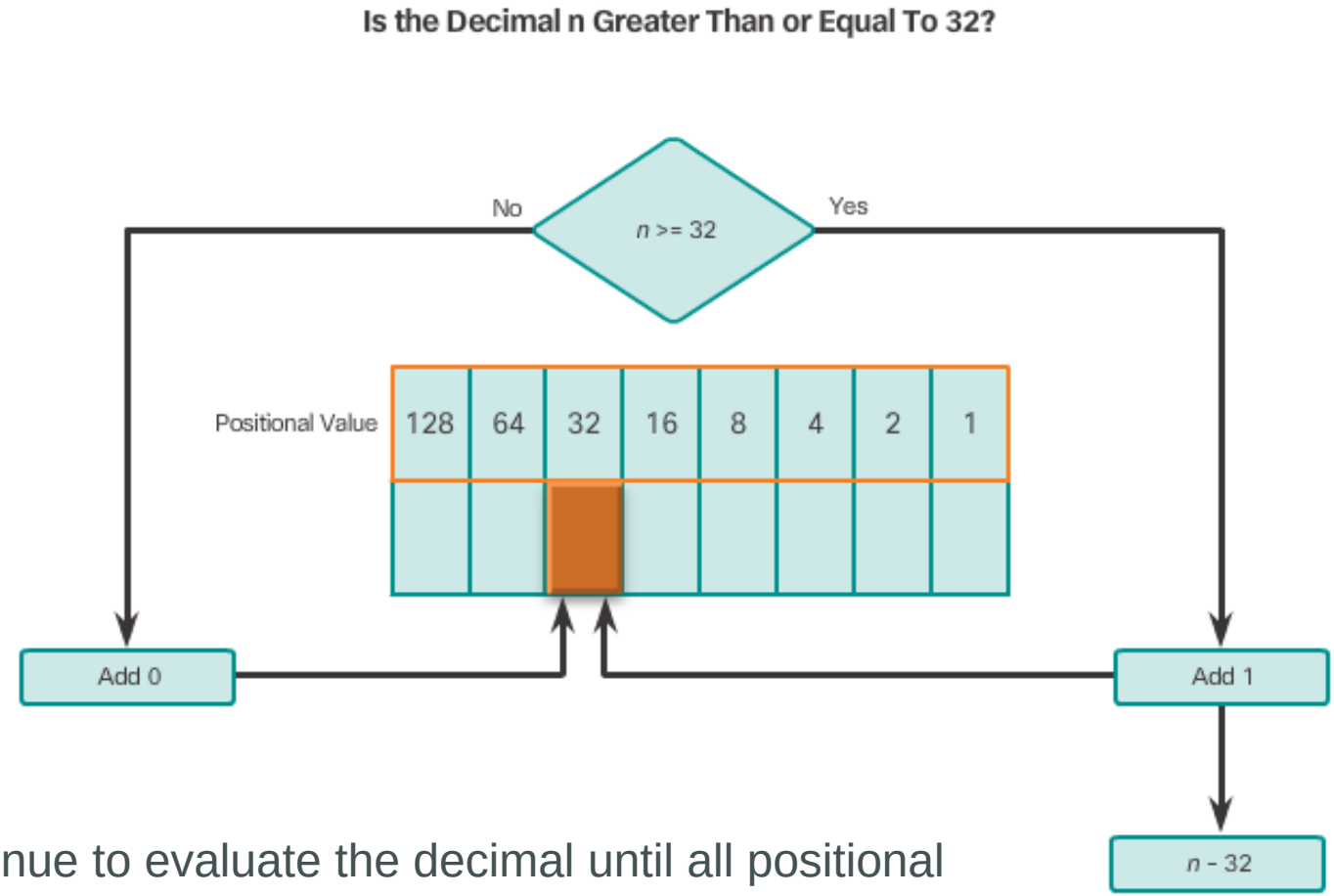
The following illustrates how to use the binary positional value table to convert decimal to binary.



Decimal to Binary Conversion (cont.)

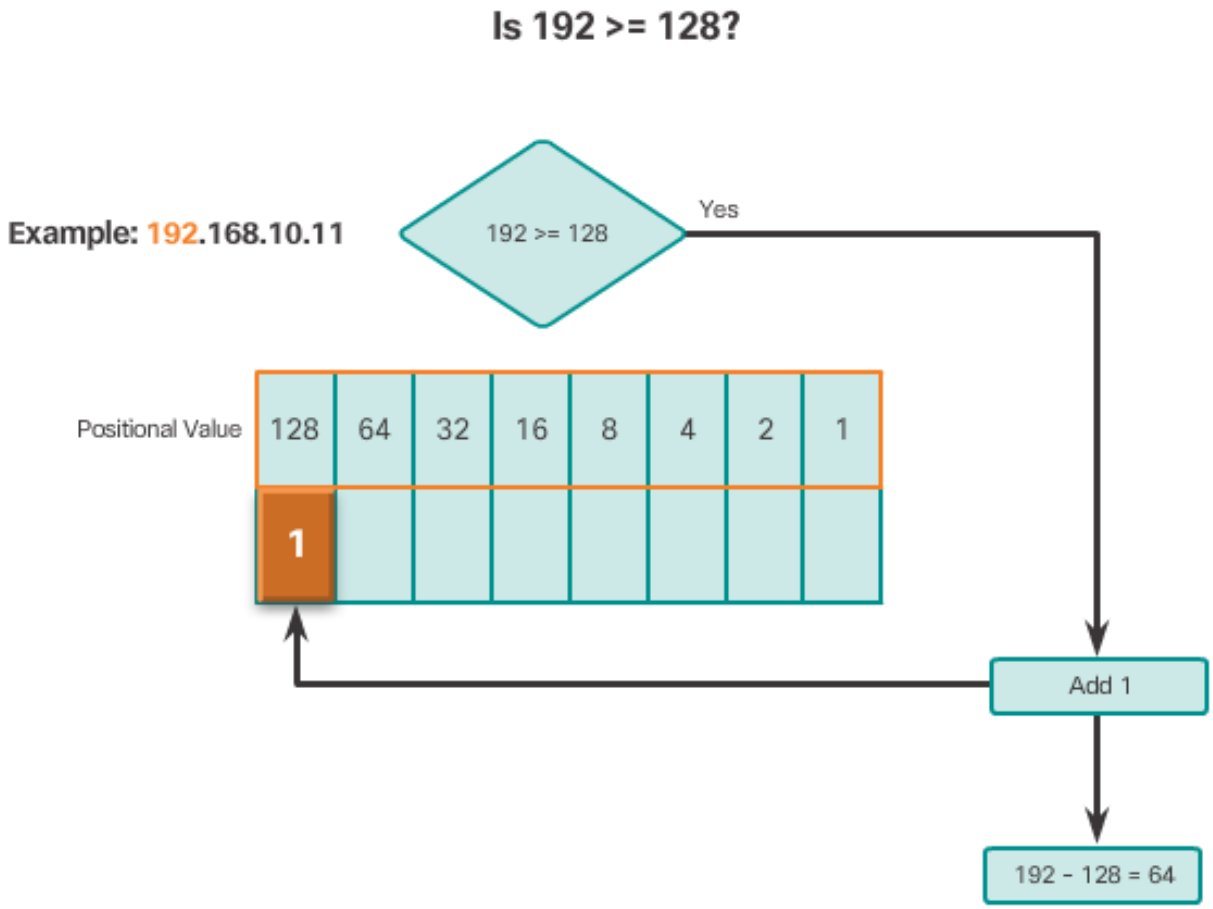


Decimal to Binary Conversion (cont.)

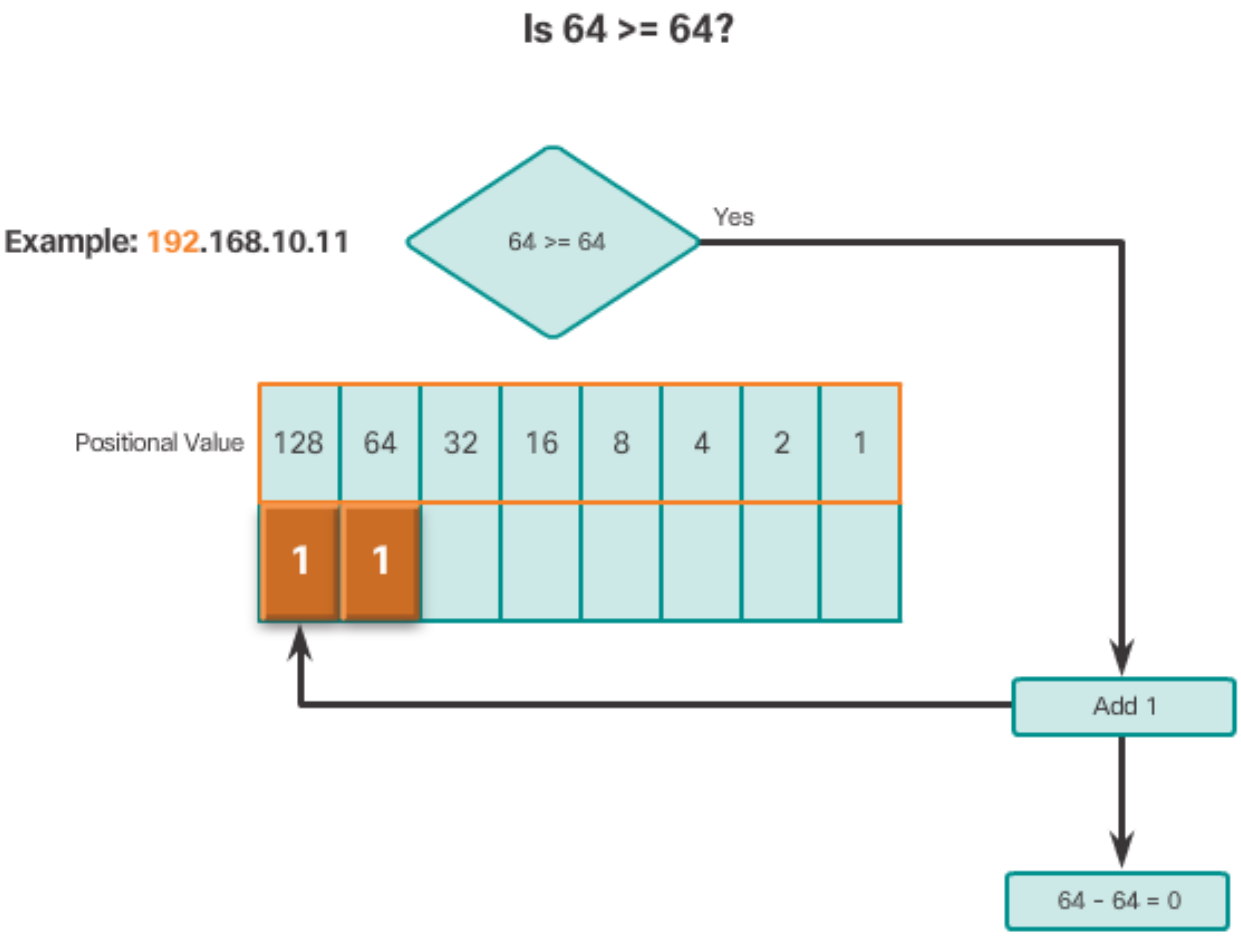


Continue to evaluate the decimal until all positional values have been entered, which results in the equivalent binary value.

Decimal to Binary Conversion Example



Decimal to Binary Conversion Example (cont.)



Decimal to Binary Conversion Example (cont.)

192 = 11000000

Example: 192.168.10.11

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

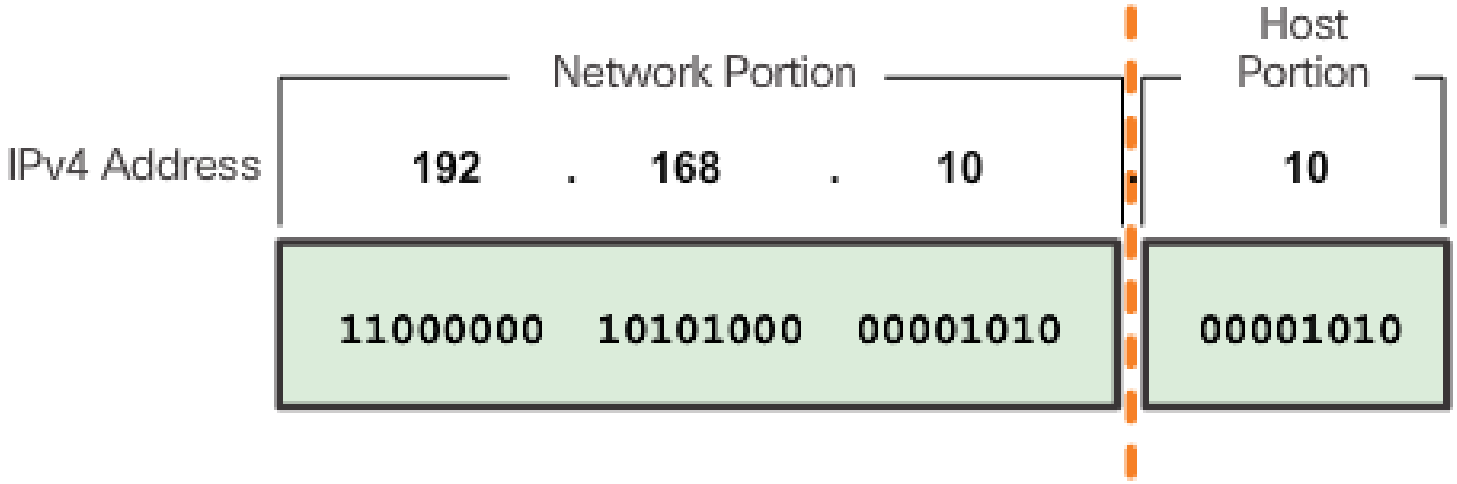
11000000 . _____ . _____ . _____

See VIDEO DEMONSTRATION

Topic 7.1.2:
IPv4 Address Structure

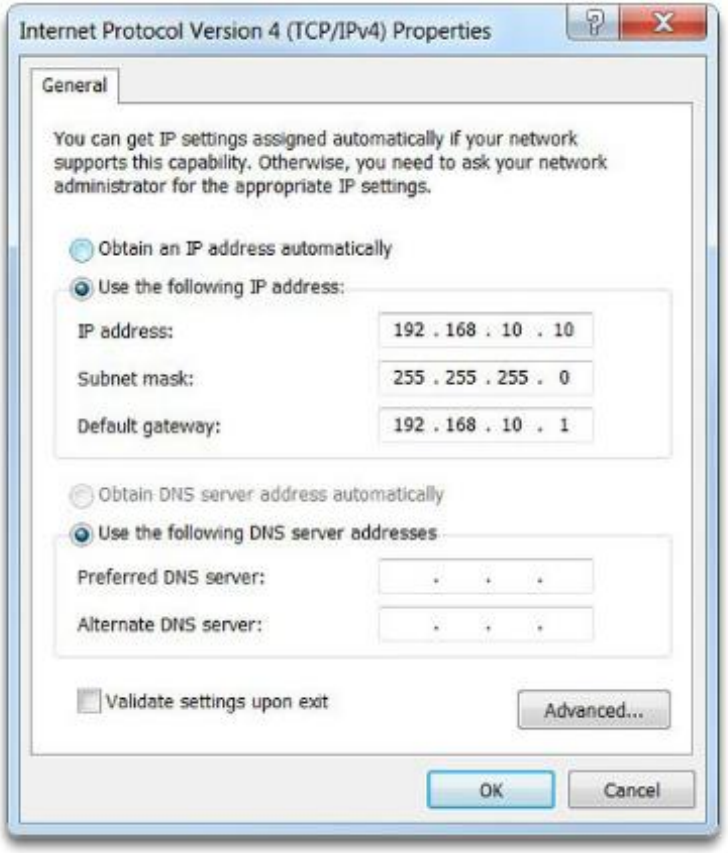
Network and Host Portions

One portion of the 32 bit IPv4 address identifies the network, and another portion identifies the host.



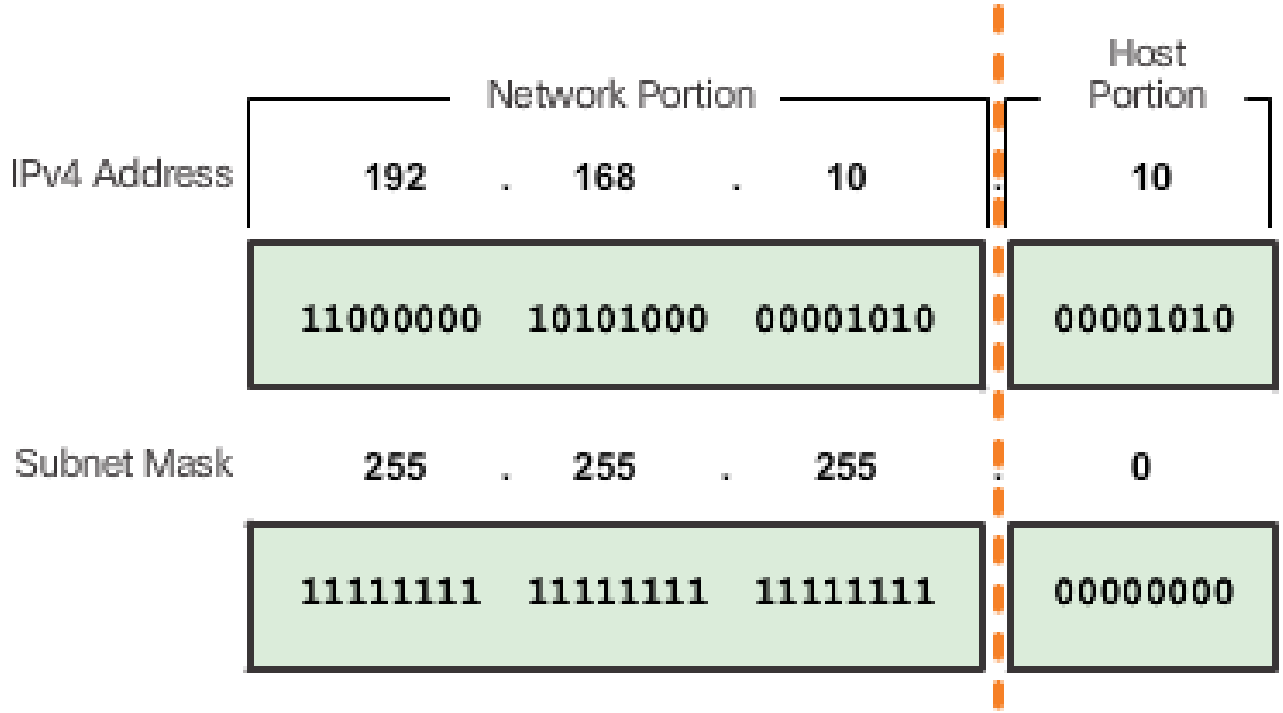
The Subnet Mask

IP Configuration on a Host



The Subnet Mask (cont.)

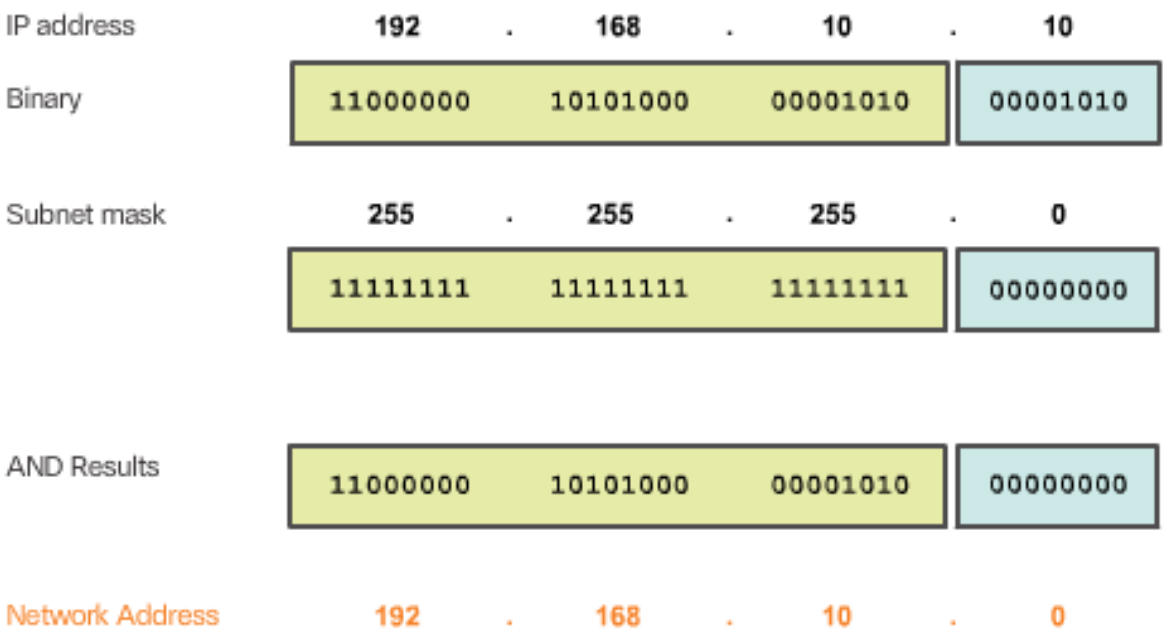
- Comparing the IP Address and the Subnet Mask
- The 1s in the subnet mask identify the network portion while the 0s identify the host portion.



ANDing

- Logical AND is the comparison of two bits.
- ANDing between the IP address and the subnet mask yields the network address.

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

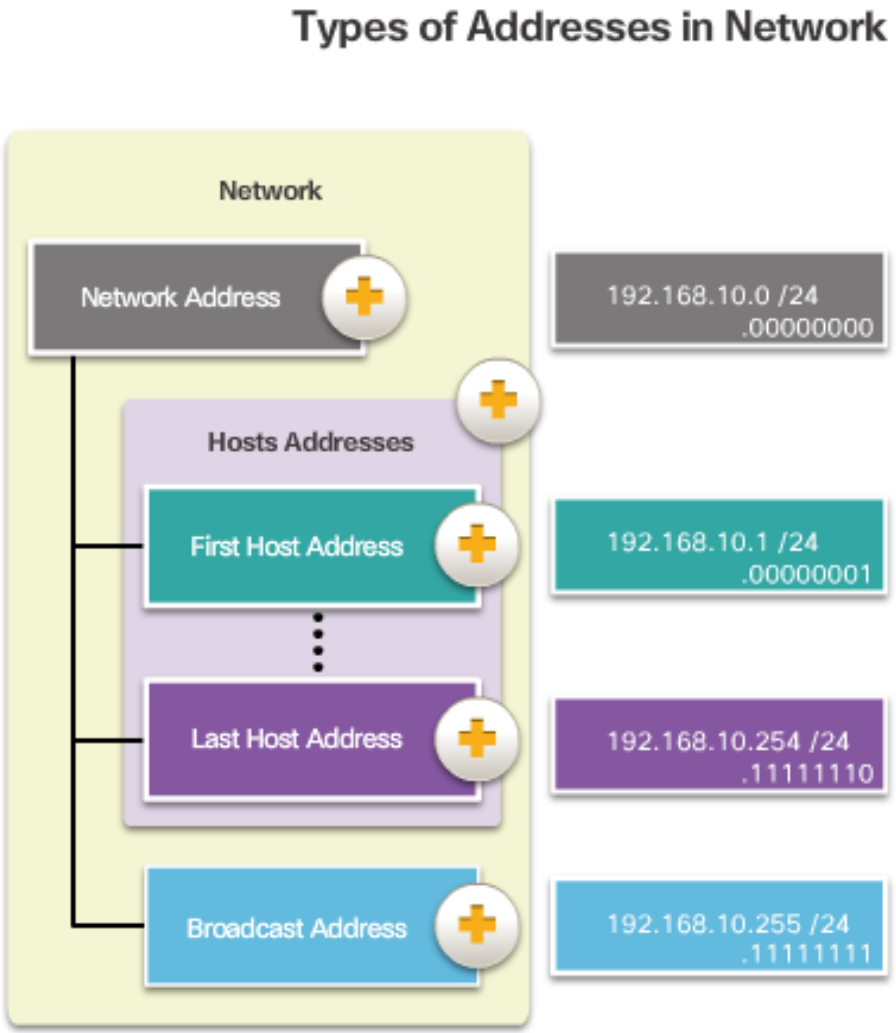


The Prefix Length

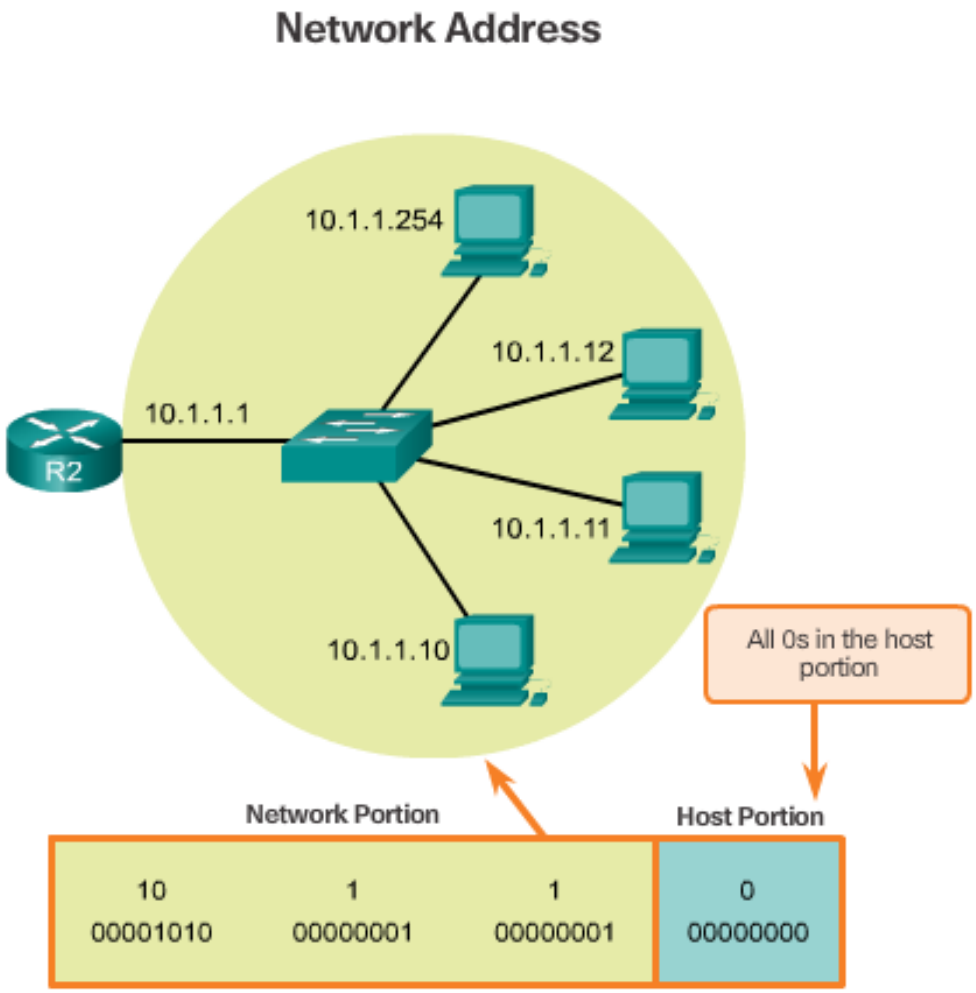
- Shorthand method of identifying a subnet mask.
- It is the number of bits set to 1 in the subnet mask.
- Written in “slash notation”, a “/” followed by the number of bits set to 1.

Subnet Mask	32-bit Address	Prefix Length
255.0.0.0	11111111.00000000.00000000.00000000	/8
255.255.0.0	11111111.11111111.00000000.00000000	/16
255.255.255.0	11111111.11111111.11111111.00000000	/24
255.255.255.128	11111111.11111111.11111111.10000000	/25
255.255.255.192	11111111.11111111.11111111.11000000	/26
255.255.255.224	11111111.11111111.11111111.11100000	/27
255.255.255.240	11111111.11111111.11111111.11110000	/28
255.255.255.248	11111111.11111111.11111111.11111000	/29
255.255.255.252	11111111.11111111.11111111.11111100	/30

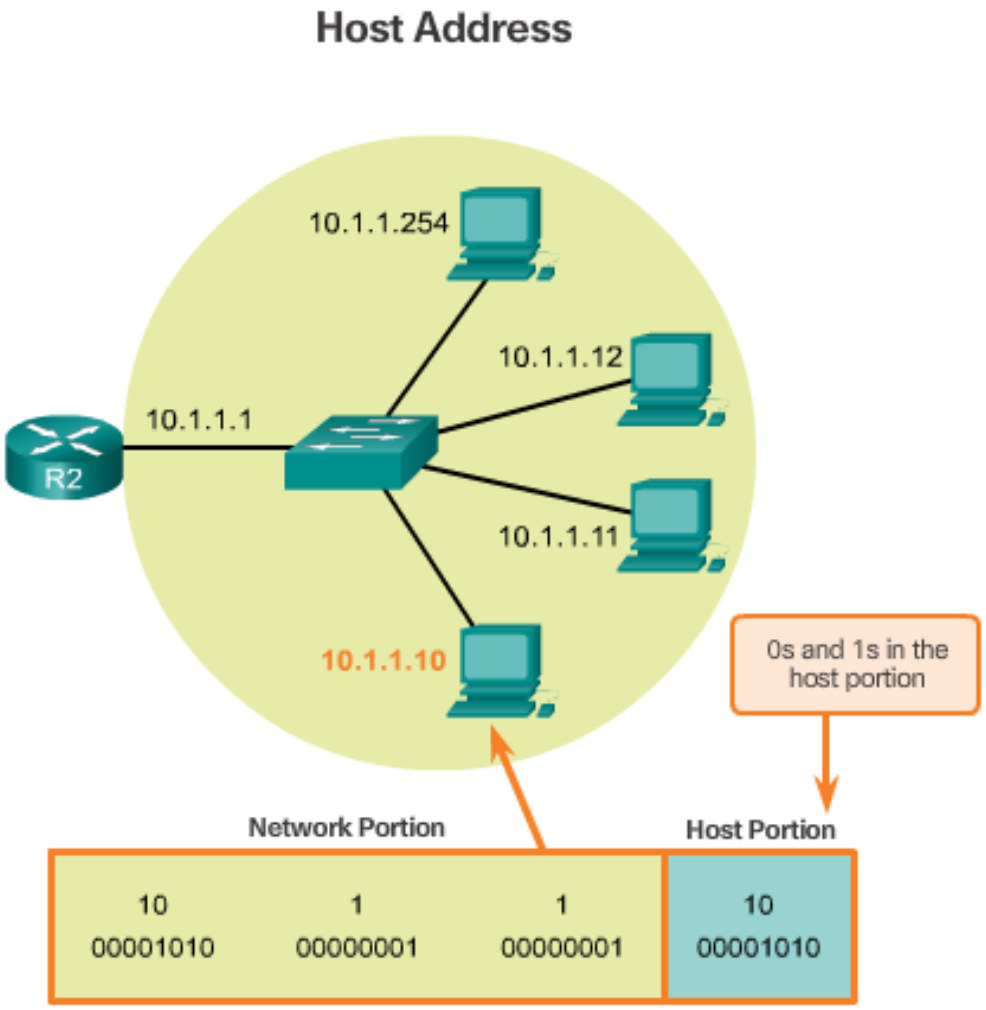
Network, Host, and Broadcast Addresses



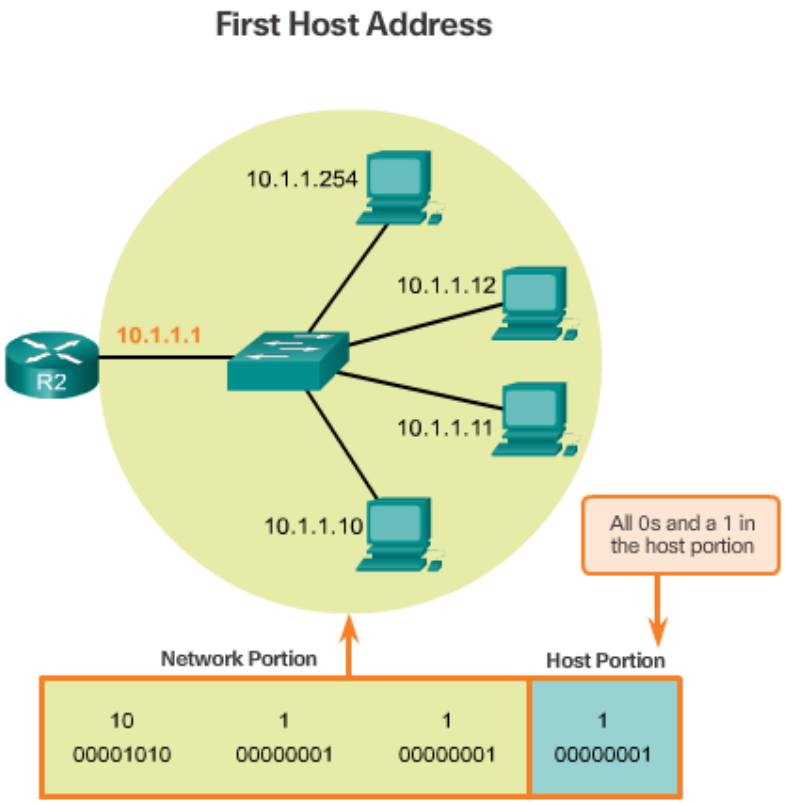
Network, Host, and Broadcast Addresses (cont.)

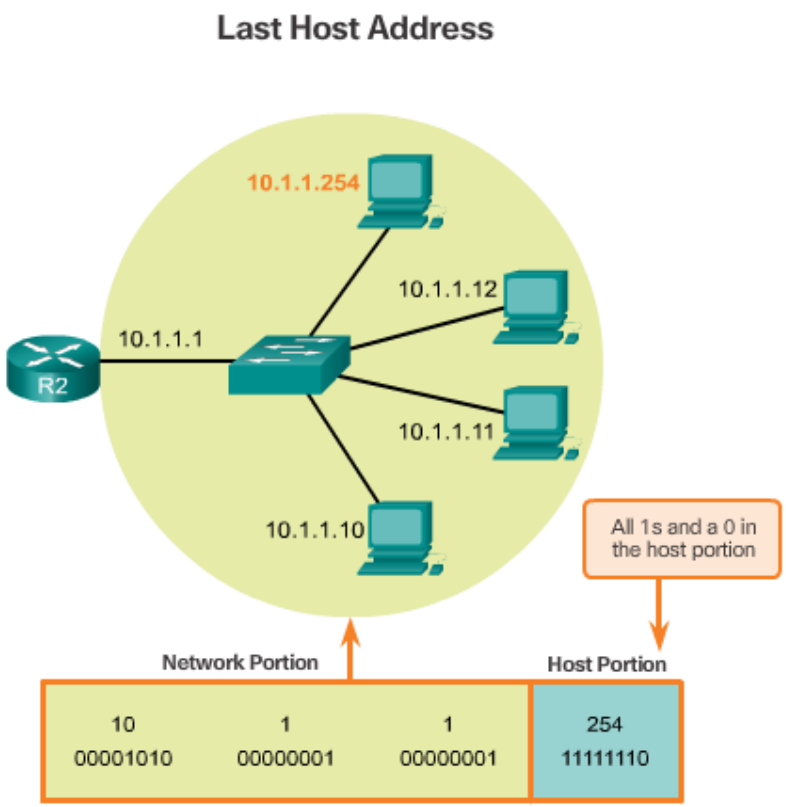


Network, Host, and Broadcast Addresses (cont.)

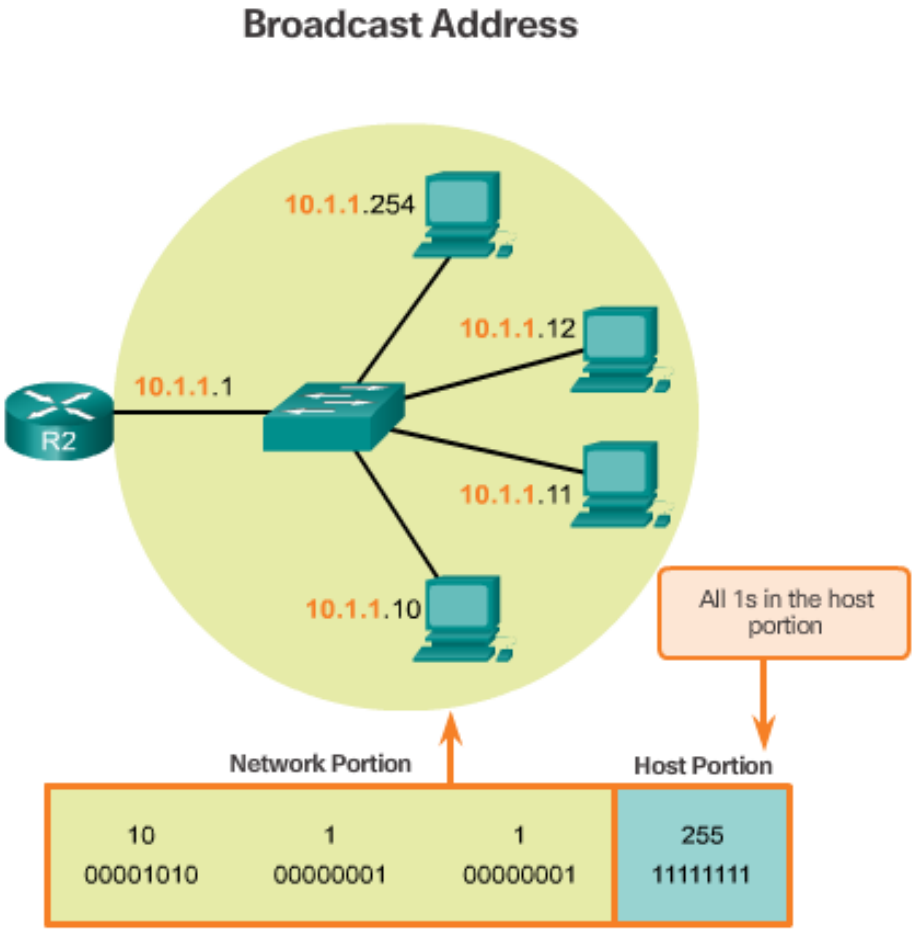


Network, Host, and Broadcast Addresses (cont.)





Network, Host, and Broadcast Addresses (cont.)

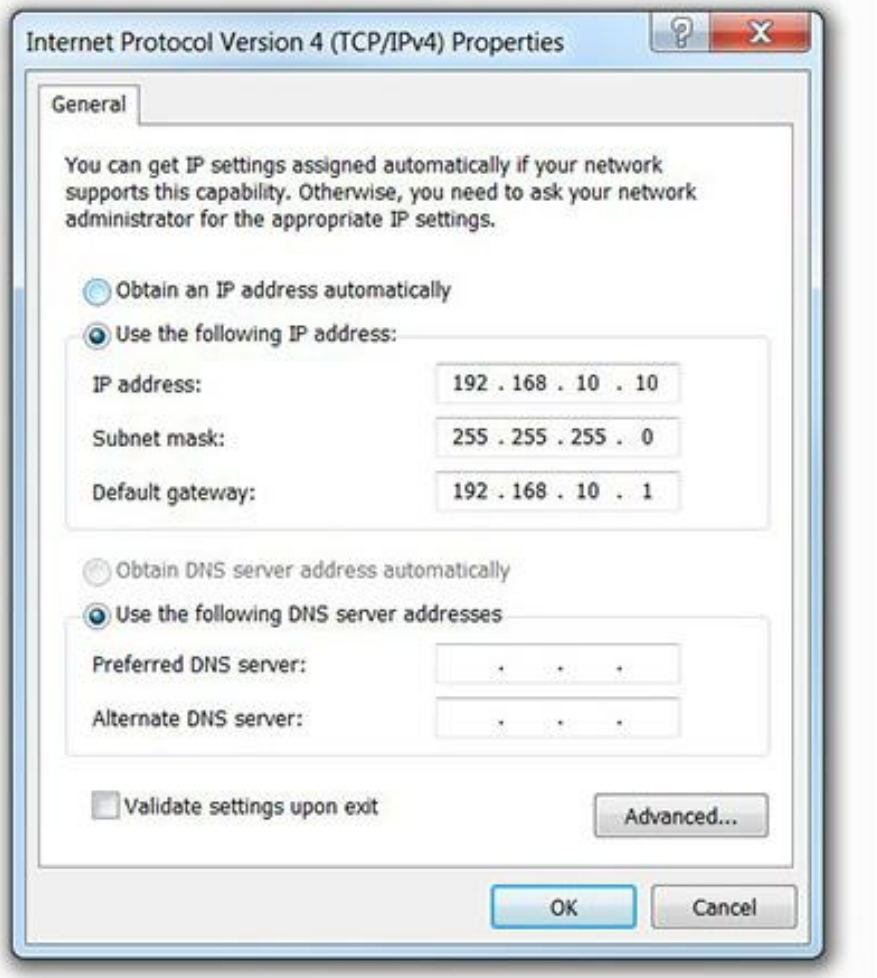


See VIDEO DEMONSTRATION

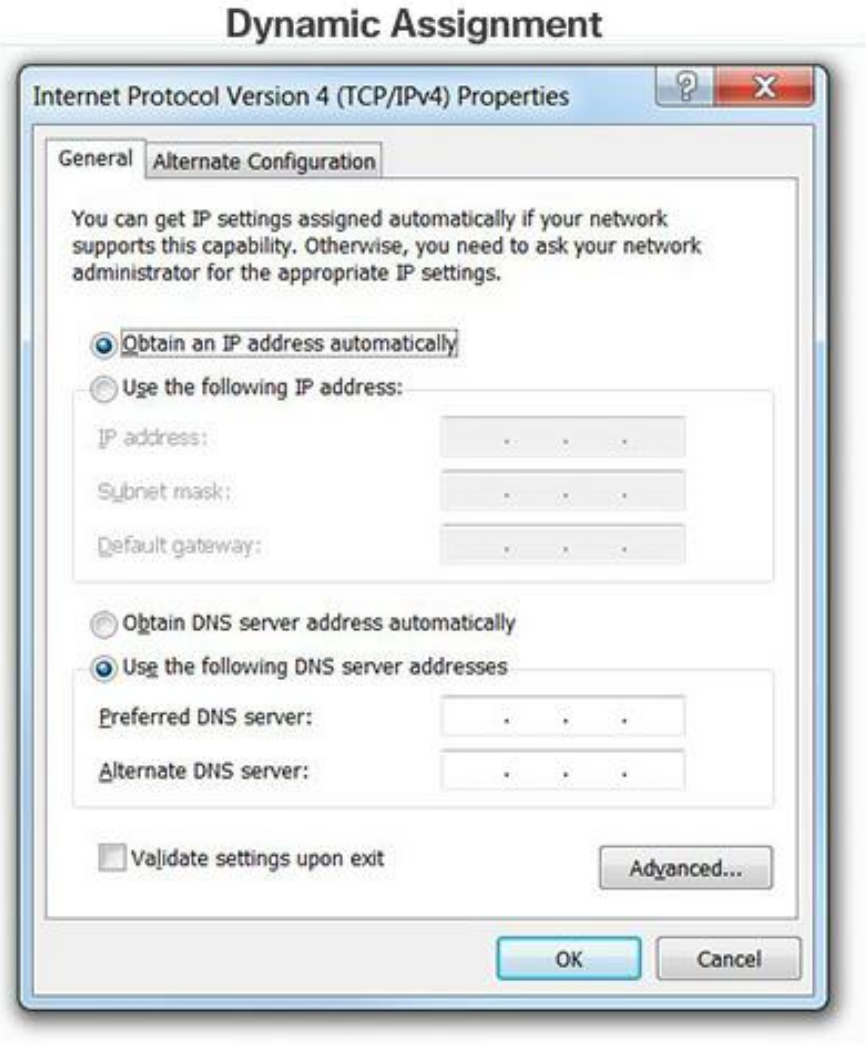
Topic 7.1.3:
IPv4 Unicast, Broadcast, and Multicast

Static IPv4 Address Assignment to a Host

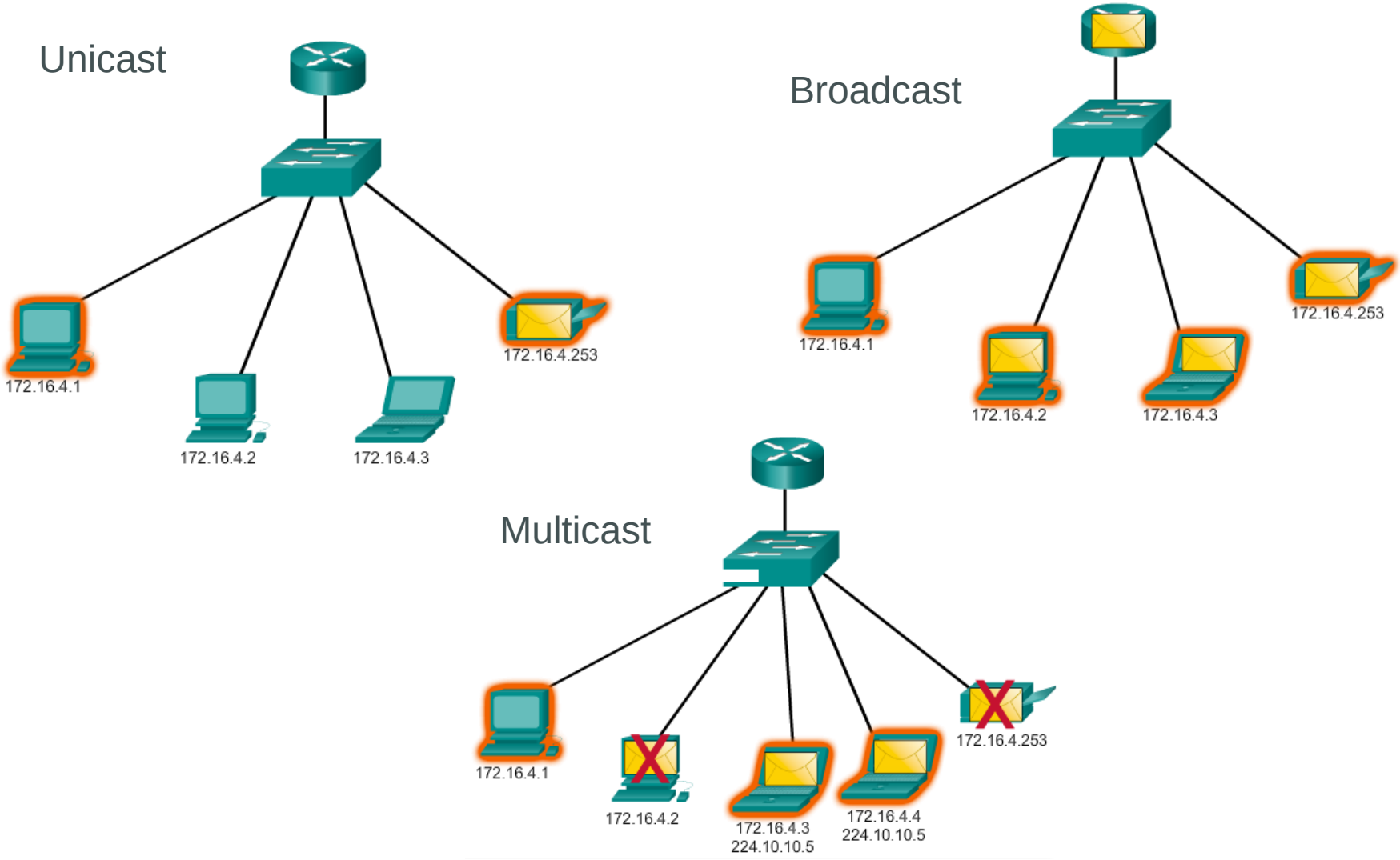
Static Assignment



Dynamic IPv4 Address Assignment to a Host

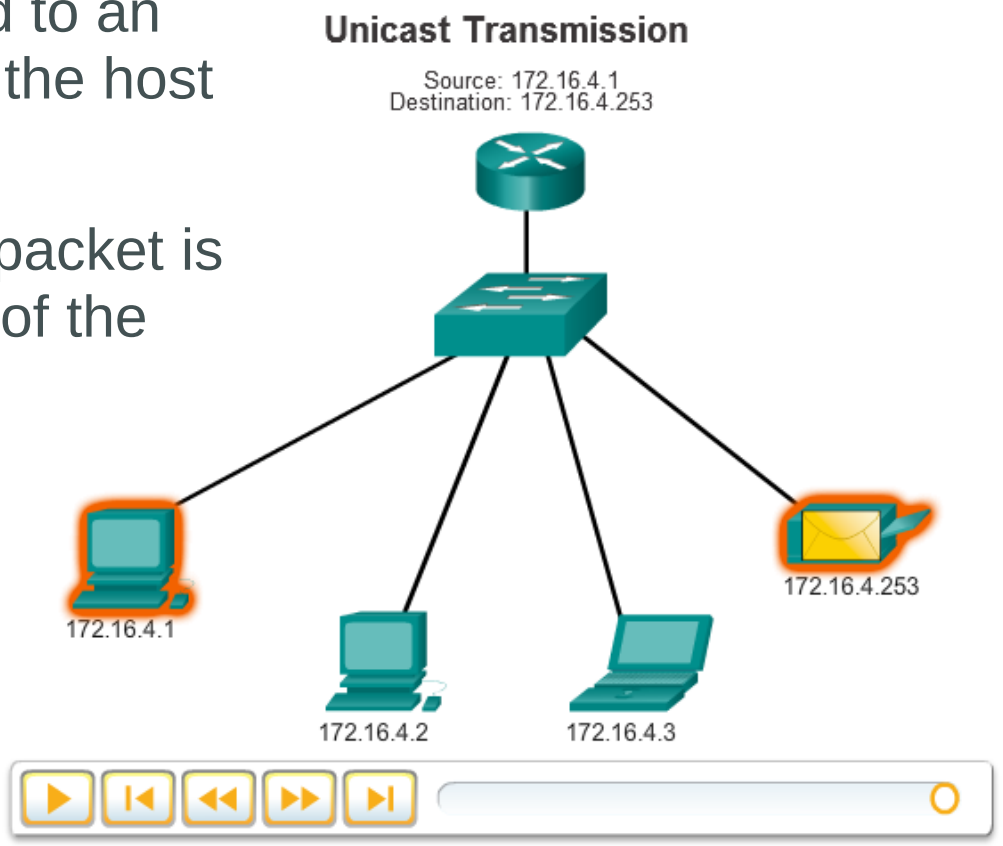


IPv4 Communication

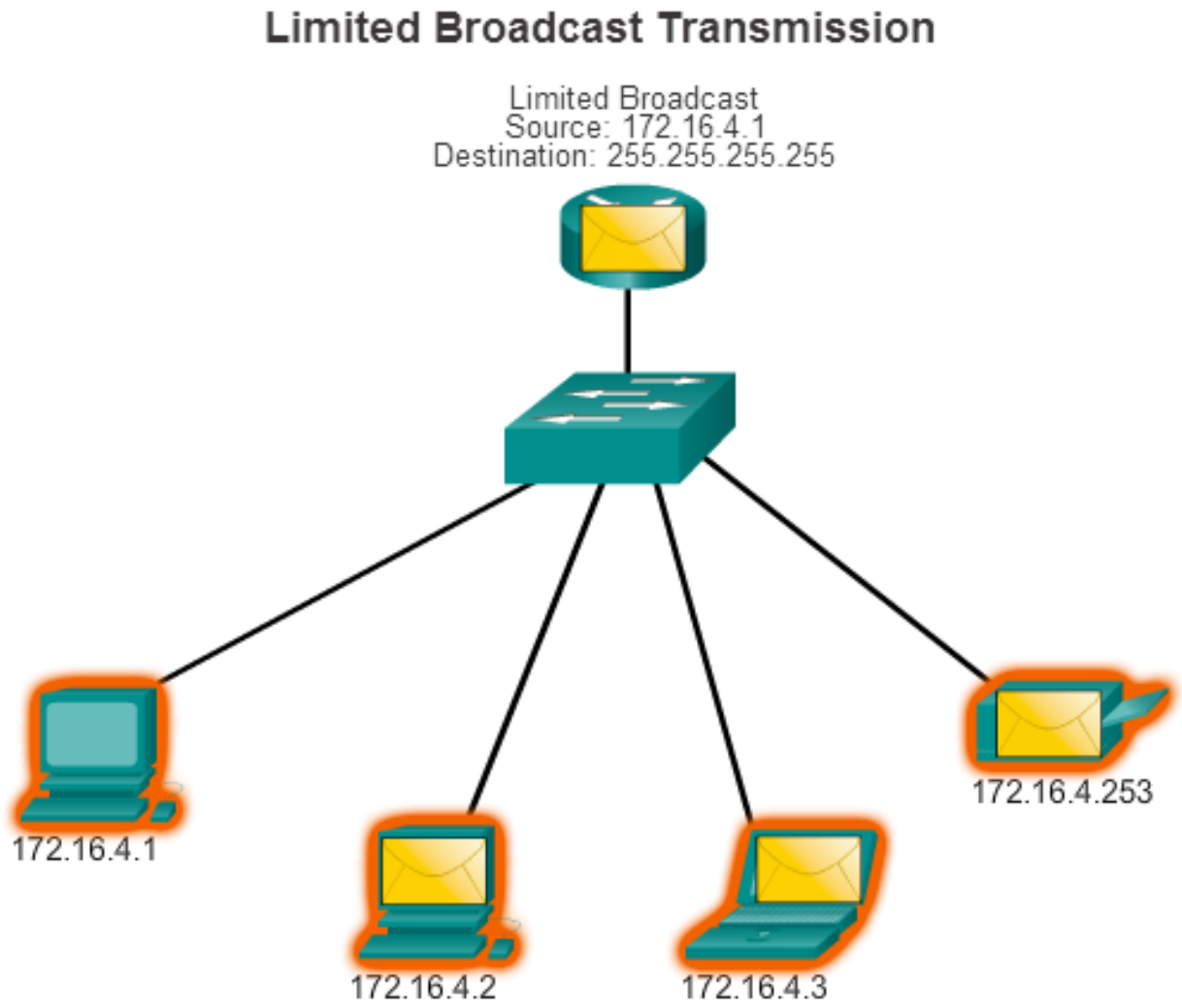


Unicast Transmission

- Unicast communication is used for normal host-to-host communication.
- The unicast address applied to an end device is referred to as the host address.
- The source address of any packet is always the unicast address of the originating host.

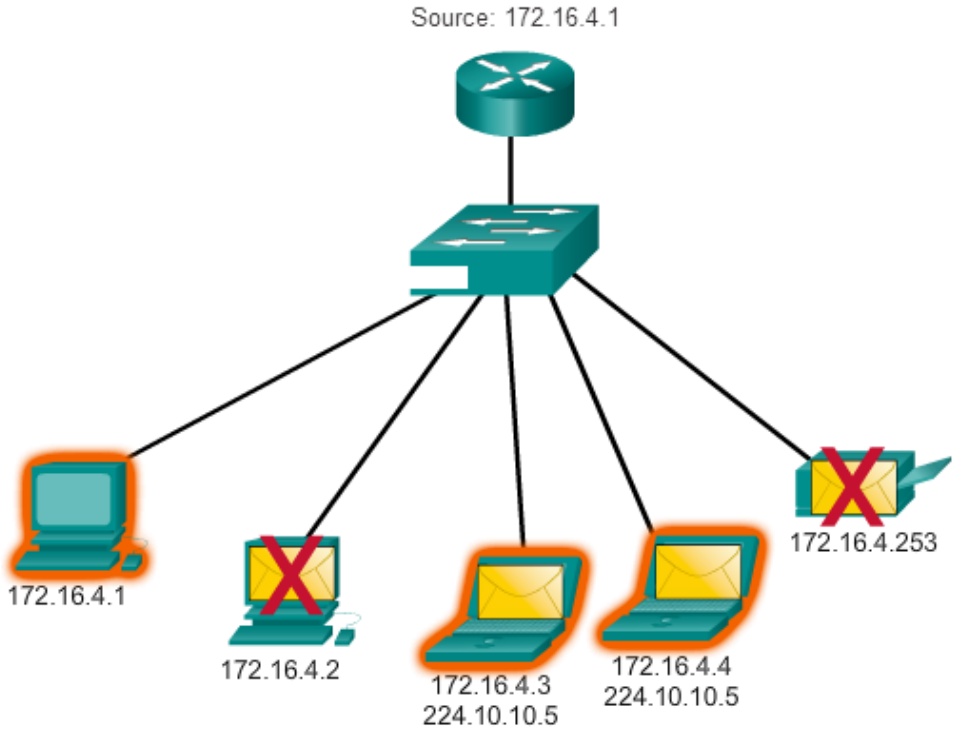


Broadcast Transmission



Multicast Transmission

- A host sends a single packet to a selected set of hosts that subscribe to a multicast group.
- The 224.0.0.0 to 239.255.255.255 range of addresses are reserved for multicast.

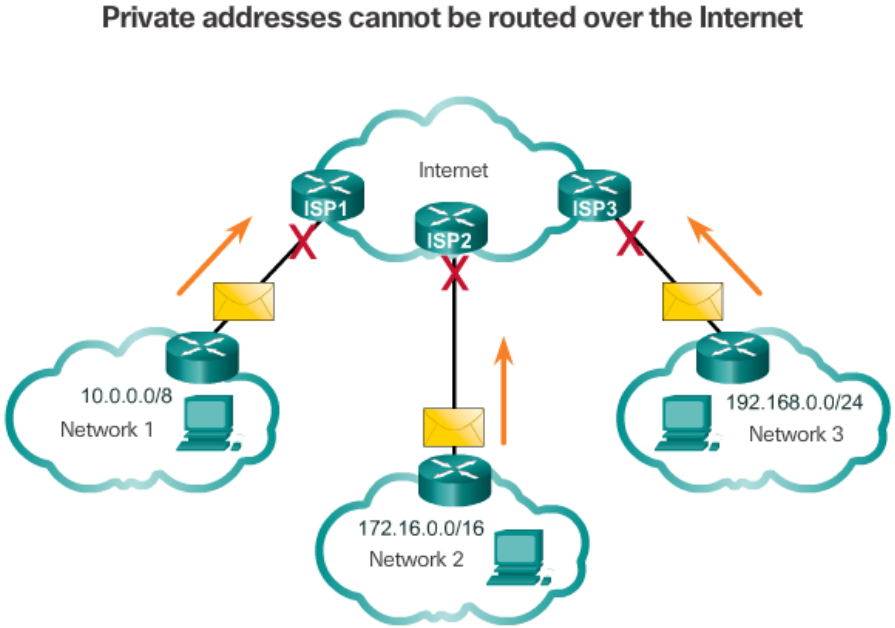


Topic 7.1.4:
Types of IPv4 Addresses

Public and Private IPv4 Addresses

Private Addresses:

- 10.0.0.0/8 or 10.0.0.0 to10.255.255.255
- 172.16.0.0 /12 or 172.16.0.0 to 172.31.255.255
- 192.168.0.0 /16 or 192.168.0.0 to 192.168.255.255



Special Use IPv4 Addresses

- Loopback addresses
  127.0.0.0 /8 or 127.0.0.1 to 127.255.255.254
- Link-Local addresses or Automatic Private IP Addressing (APIPA) addresses
  169.254.0.0 /16 or
  169.254.0.1 to 169.254.255.254
- TEST-NET addresses
  192.0.2.0/24 or 192.0.2.0
  to 192.0.2.255

Pinging the Loopback Interface

```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\NetAcad> ping 127.0.0.1

Pinging 127.0.0.1 with 32 bytes of data:
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128

Ping statistics for 127.0.0.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\NetAcad> ping 127.1.1.1

Pinging 127.1.1.1 with 32 bytes of data:
Reply from 127.1.1.1: bytes=32 time<1ms TTL=128
Reply from 127.1.1.1: bytes=32 time<1ms TTL=128
Reply from 127.1.1.1: bytes=32 time<1ms TTL=128
Reply from 127.1.1.1: bytes=32 time<1ms TTL=128

Ping statistics for 127.1.1.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\NetAcad>
```

Legacy Classful Addressing

Class A Specifics	
Address block	0.0.0.0 – 127.0.0.0*
Default Subnet Mask	/8 (255.0.0.0)
Maximum Number of Networks	128
Number of Host per Network	16,777,214
High order bit	0xxxxxxx.___.___.___

* 0.0.0.0 and 127.0.0.0 are reserved and cannot be assigned

Class B Specifics	
Address block	128.0.0.0 – 191.255.0.0
Default Subnet Mask	/16 (255.255.0.0)
Maximum Number of Networks	16,384
Number of Host per Network	65,534
High order bit	10xxxxxx.___.___.___

Class C Specifics	
Address block	192.0.0.0 – 223.255.255.0
Default Subnet Mask	/24 (255.255.255.0)
Maximum Number of Networks	2,097,152
Number of Host per Network	254
High order bit	110xxxxx.___.___.___

Classless Addressing

- Formal name is Classless Inter-Domain Routing (CIDR, pronounced “cider”).
- Created a new set of standards that allowed service providers to allocate IPv4 addresses on any address bit boundary (prefix length) instead of only by a class A, B, or C address.

Assignment of IP Addresses

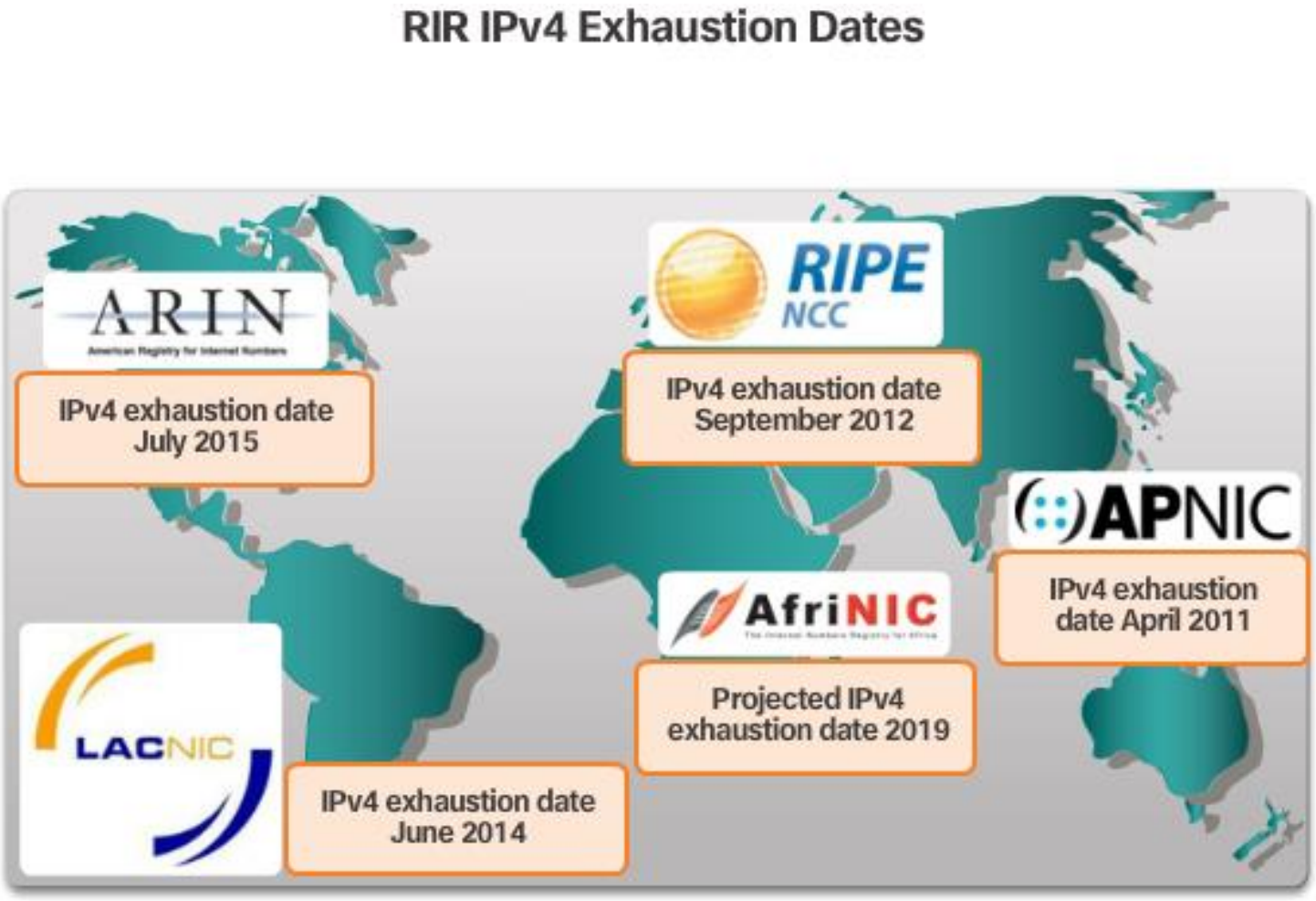
Section 7.2: IPv6 Addresses

Upon completion of this section, you should be able to:

- Explain the need for IPv6 addressing.
- Describe the representation of an IPv6 address.
- Describe types of IPv6 network addresses.
- Configure global unicast addresses.
- Describe multicast addresses.

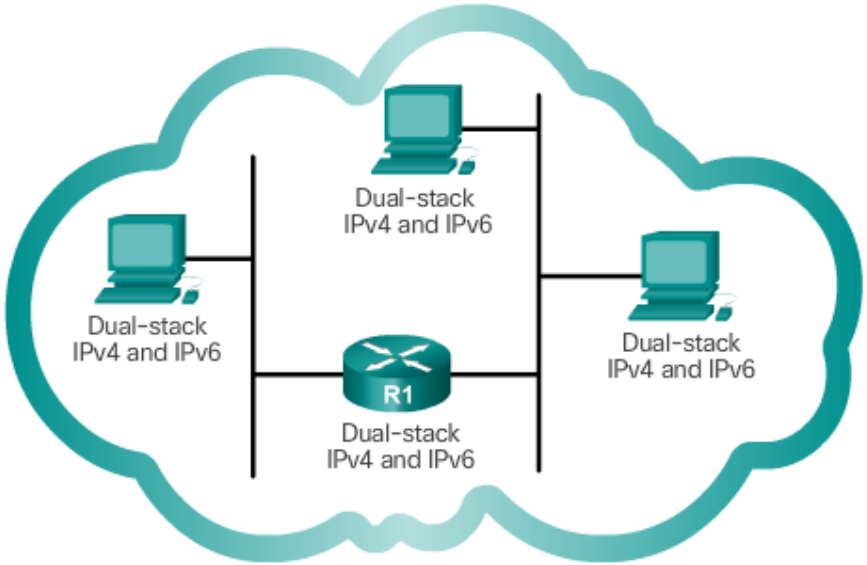
Topic 7.2.1:
IPv4 issues

The Need for IPv6



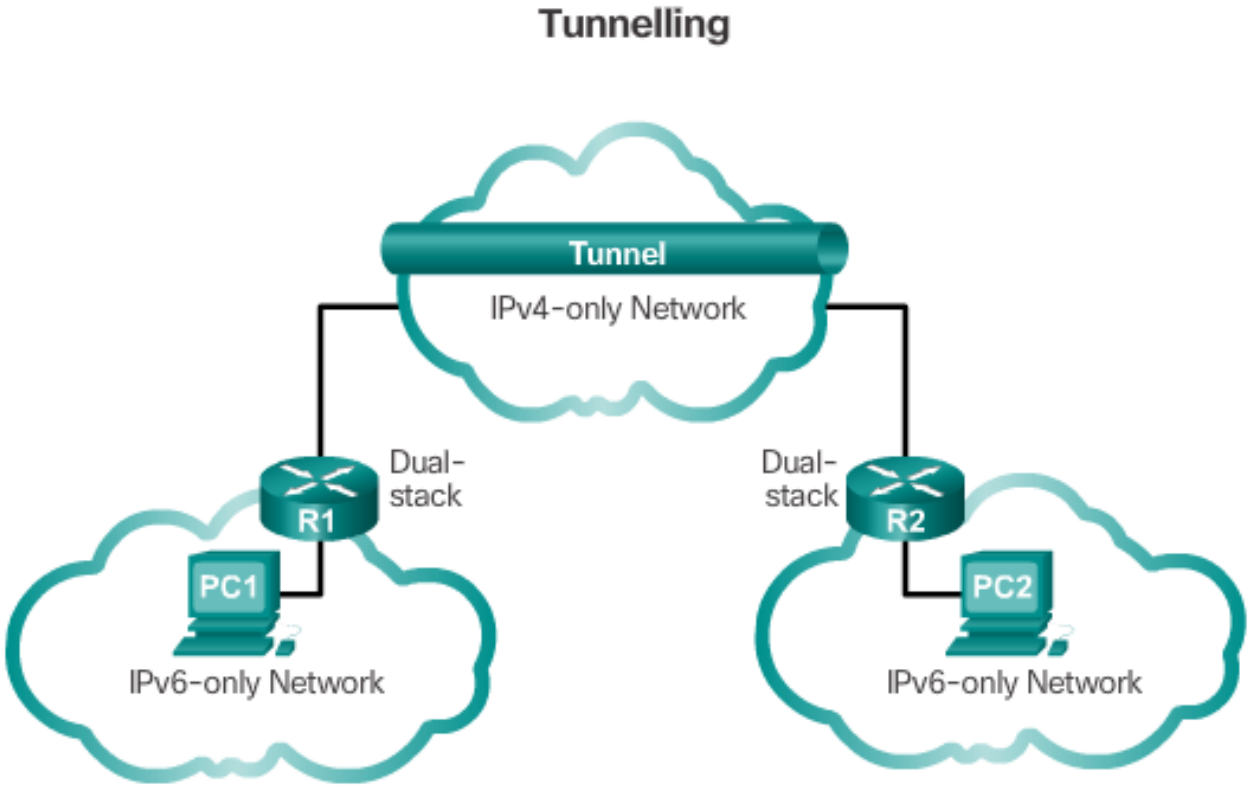
IPv4 and IPv6 Coexistence

- The migration techniques can be divided into three categories: Dual Stack, Tunneling, and Translation.
- **Dual-stack** allows IPv4 and IPv6 to coexist on the same network. Devices run both IPv4 and IPv6 protocol stacks simultaneously.



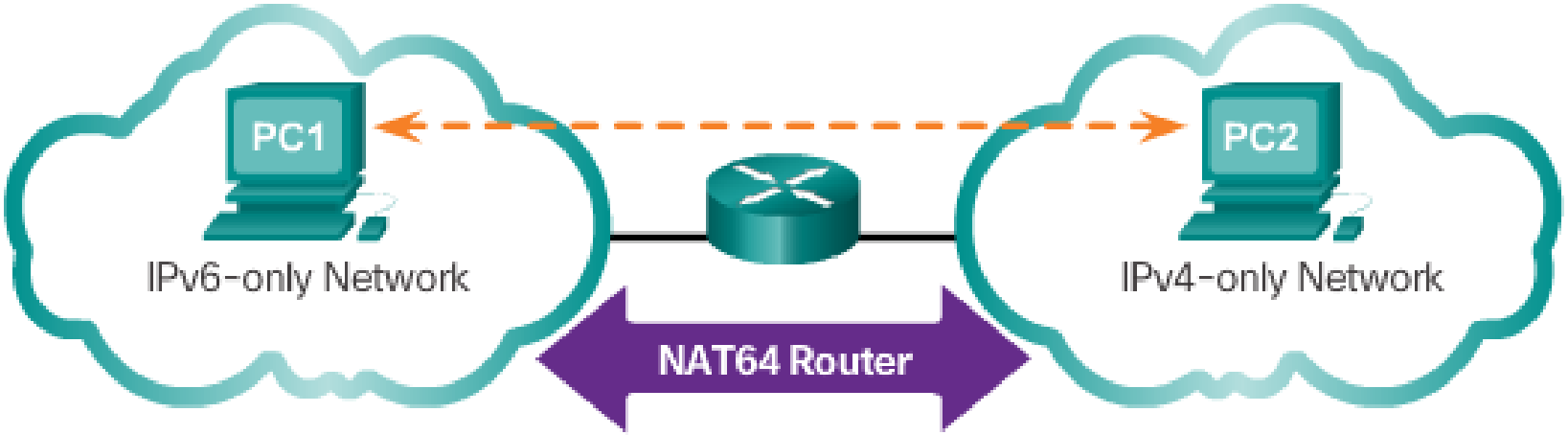
IPv4 and IPv6 Coexistence (cont.)

- **Tunneling** is a method of transporting an IPv6 packet over an IPv4 network. The IPv6 packet is encapsulated inside an IPv4 packet.



IPv4 and IPv6 Coexistence (cont.)

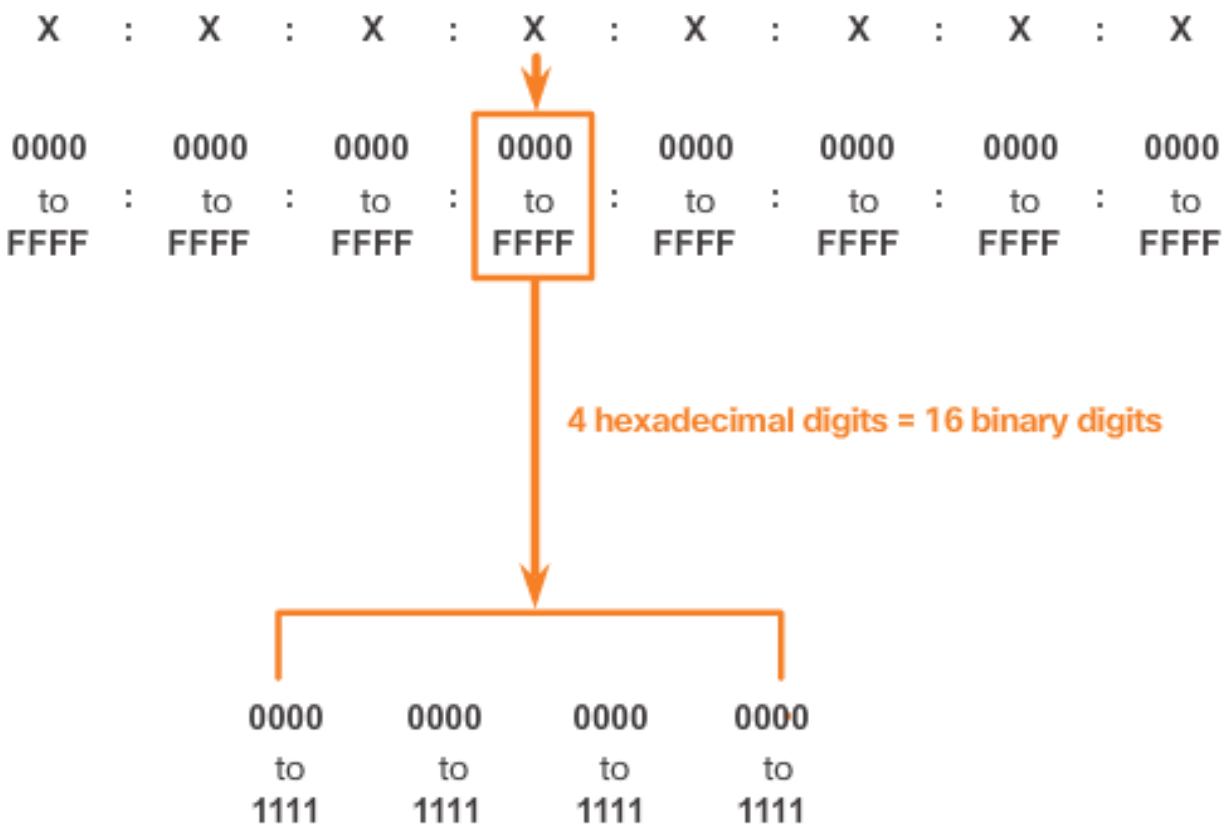
- **Translation**: Network Address Translation 64 (NAT64) allows IPv6-enabled devices to communicate with IPv4-enabled devices using a translation technique similar to NAT for IPv4. An IPv6 packet is translated to an IPv4 packet, and vice versa.



Topic 7.2.2:
IPv6 Address Structure

IPv6 Address Representation

Hextets – 4 Hexadecimal digits = 16 binary digits



IPv6 Address Representation (cont.)

Hexadecimal Numbering

Decimal and Binary equivalents of 0 to F Hexadecimal

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

IPv6 Address Representation (cont.)

Preferred Format Examples

2001	0DB8	0000	1111	0000	0000	0000	0200
2001	0DB8	0000	00A3	ABCD	0000	0000	1234
2001	0DB8	000A	0001	0000	0000	0000	0100
2001	0DB8	AAAA	0001	0000	0000	0000	0200
FE80	0000	0000	0000	0123	4567	89AB	CDEF
FE80	0000	0000	0000	0000	0000	0000	0001
FF02	0000	0000	0000	0000	0000	0000	0001
FF02	0000	0000	0000	0000	0001	FF00	0200
0000	0000	0000	0000	0000	0000	0000	0001
0000	0000	0000	0000	0000	0000	0000	0000

Rule 1 – Omit Leading 0's

Example 1

Preferred	2001:0DB8:0000:1111:0000:0000:0000:0200
No leading 0s	2001: DB8: 0:1111: 0: 0: 0: 200

Example 2

Preferred	2001:0DB8:0000:A300:ABCD:0000:0000:1234
No leading 0s	2001: DB8: 0:A300:ABCD: 0: 0:1234

Example 3

Preferred	FF02:0000:0000:0000:0000:0001:FF00:0200
No leading 0s	FF02: 0: 0: 0: 0: 1:FF00: 200

Rule 2 – Omit All 0 Segments

Example 1

Preferred	2001:0DB8:0000:1111:0000:0000:0000:0200
No leading 0s	2001: DB8: 0:1111: 0: 0: 0: 200
Compressed	2001:DB8:0:1111::200

Example 2

Preferred	2001:0DB8:0000:0000:ABCD:0000:0000:0100
No leading 0s	2001: DB8: 0: 0:ABCD: 0: 0: 100
Compressed	2001:DB8::ABCD:0:0:100
or	
Compressed	2001:DB8:0:0:ABCD::100

Only one :: may be used.

Rule 2 – Omit All 0 Segments (cont.)

Example 3

Preferred	FF02:0000:0000:0000:0000:0000:0000:0001
No leading 0s	FF02: 0: 0: 0: 0: 0: 0: 1
Compressed	FF02::1

Example 4

Preferred	0000:0000:0000:0000:0000:0000:0000:0000
No leading 0s	0: 0: 0: 0: 0: 0: 0: 0
Compressed	::

Topic 7.2.3:
Types of IPv6 Addresses

IPv6 Address Types

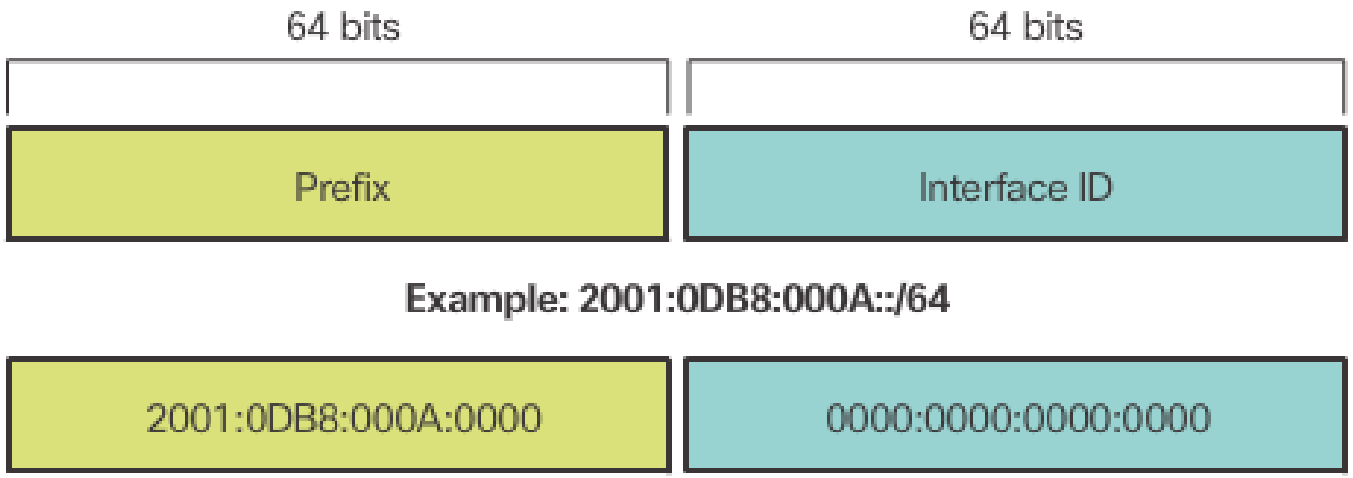
There are three types of IPv6 addresses:

- Unicast
- Multicast
- Anycast

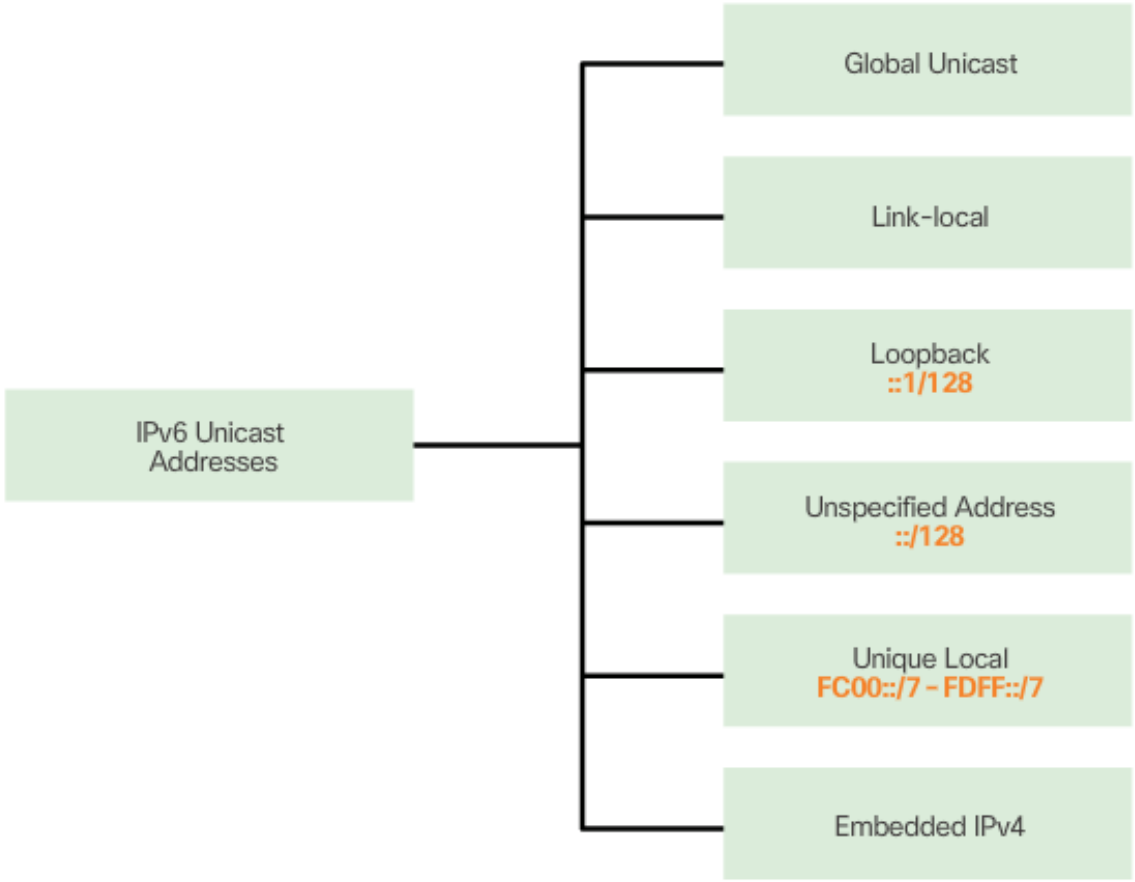
Note: IPv6 does not have broadcast addresses.

IPv6 Prefix Length

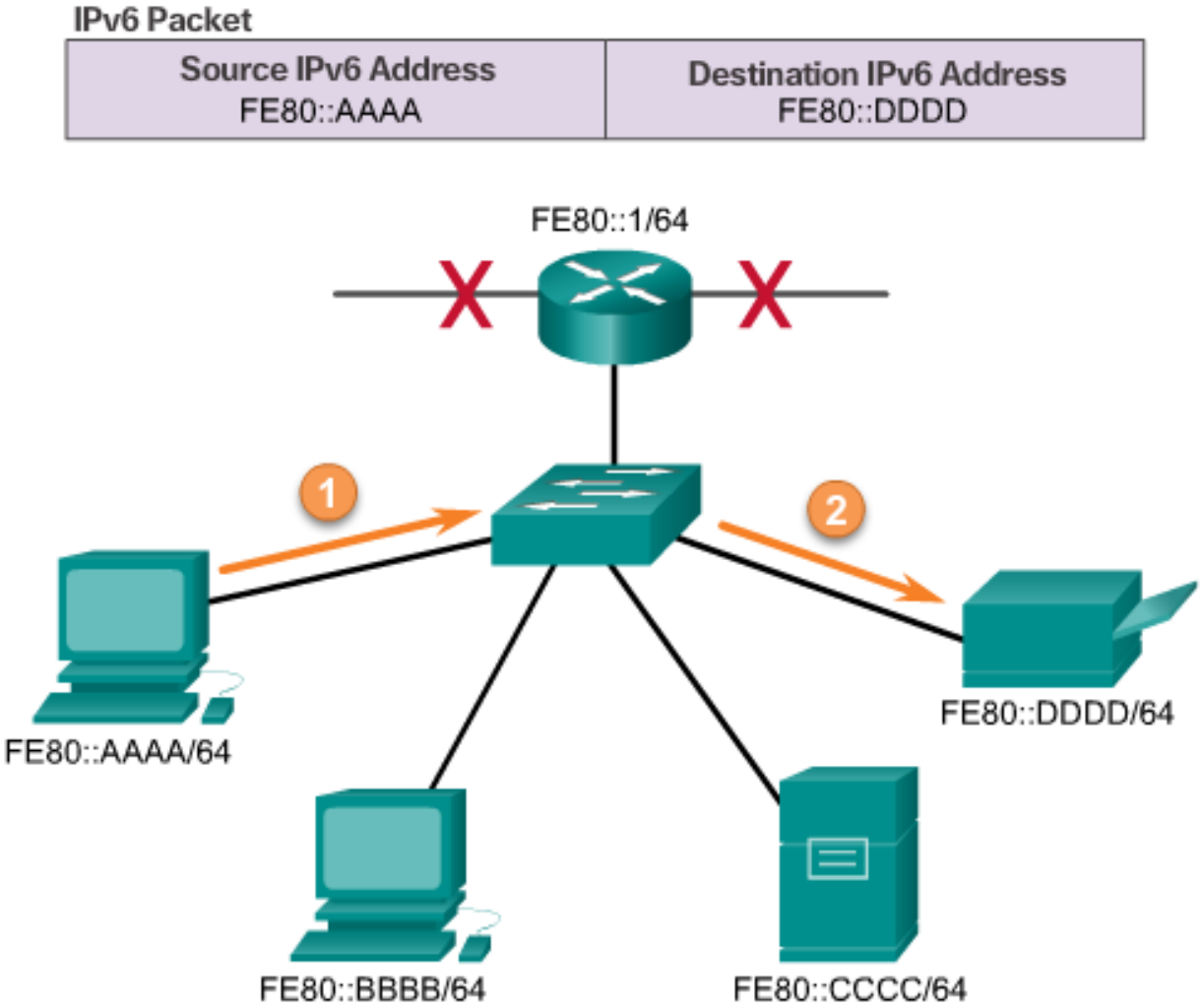
- IPv6 does not use the dotted-decimal subnet mask notation.
- Prefix length indicates the network portion of an IPv6 address using the following format:
  - IPv6 address /prefix length
  - Prefix length can range from 0 to 128
  - Typical prefix length is /64



IPv6 Unicast Addresses

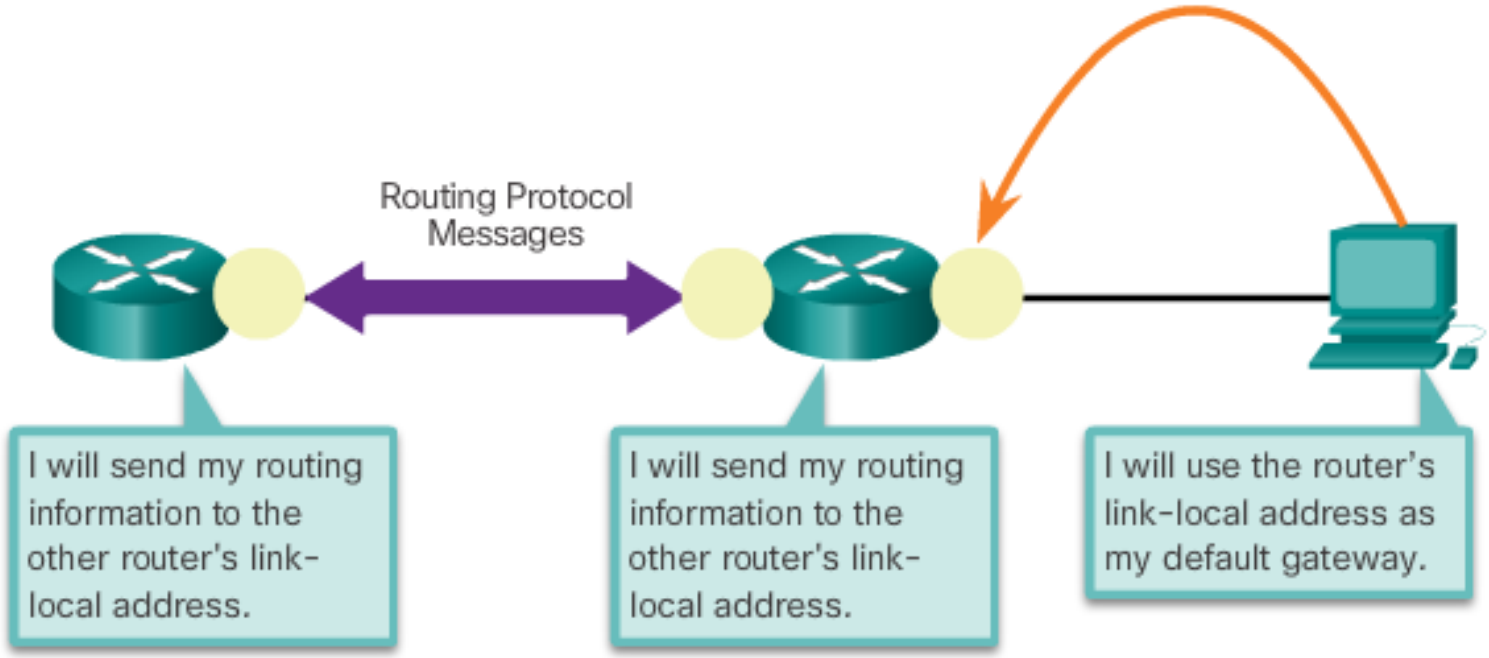


IPv6 Link-Local Unicast Addresses



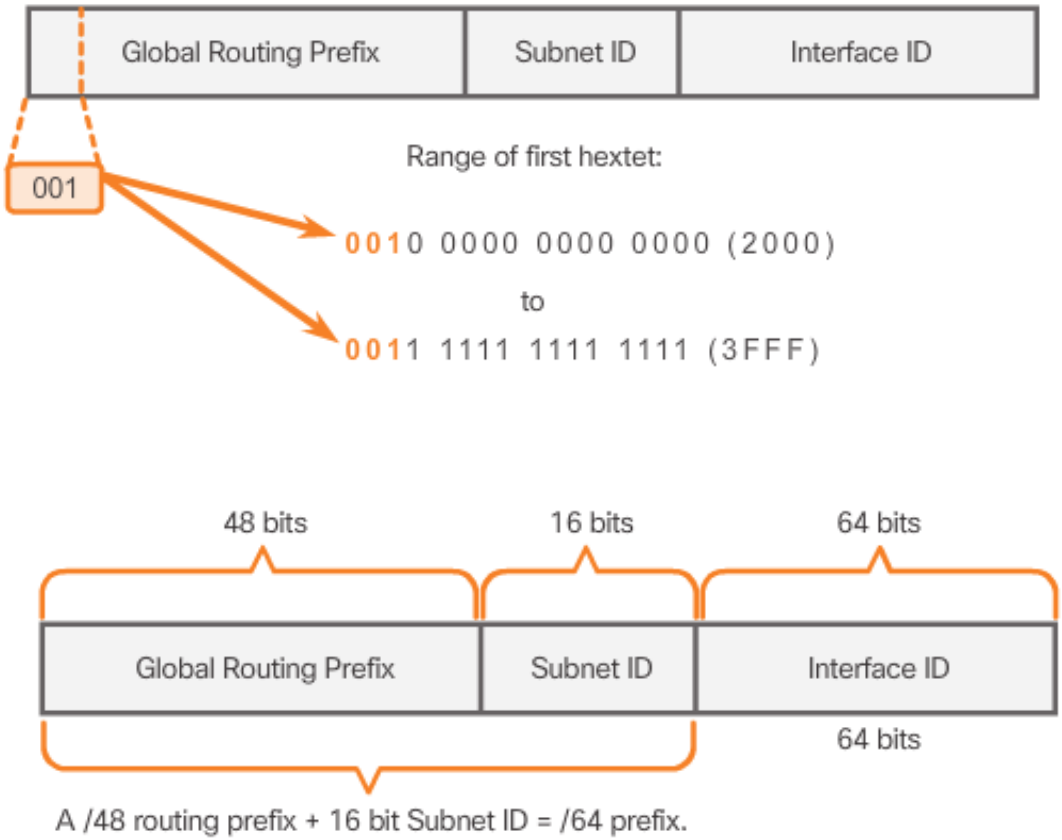
IPv6 Link-Local Unicast Addresses (cont.)

Uses of an IPv6 Link-local address



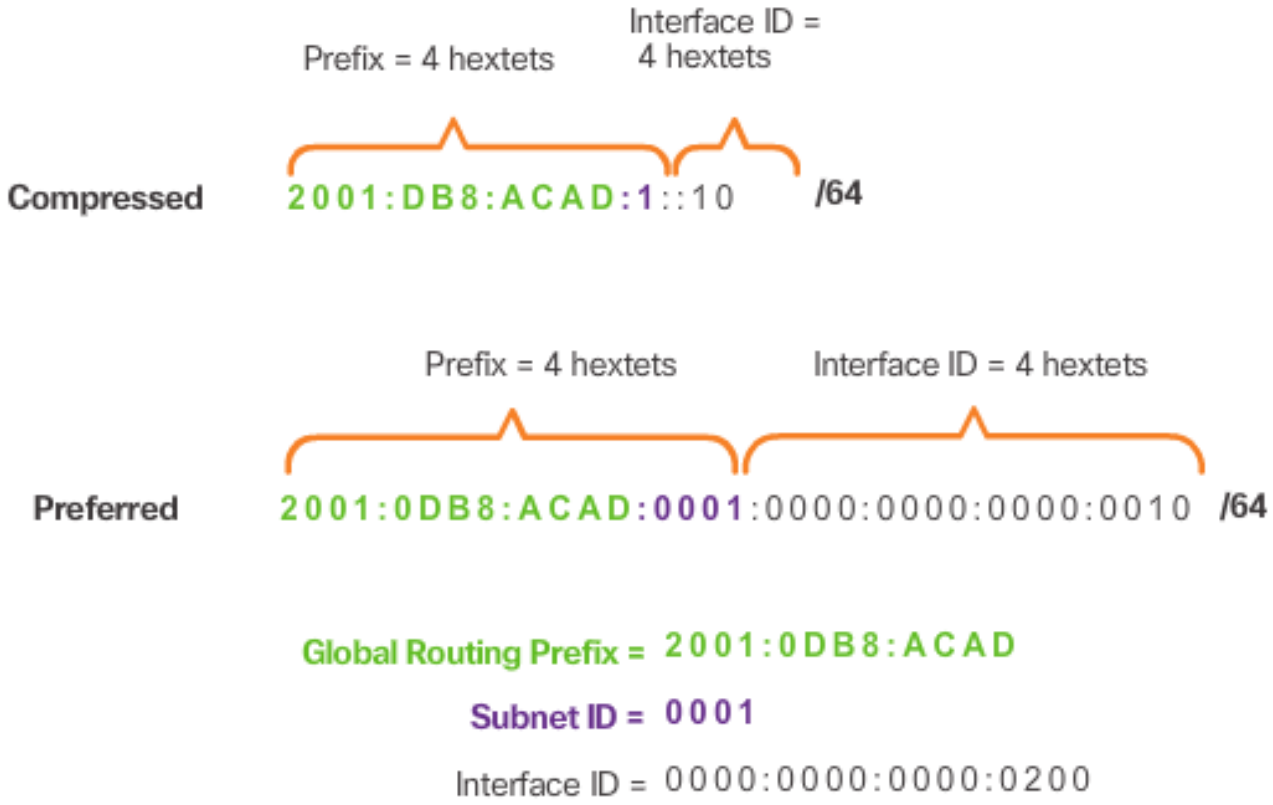
Topic 7.2.4:
IPv6 Unicast Addresses

Structure of an IPv6 Global Unicast Address

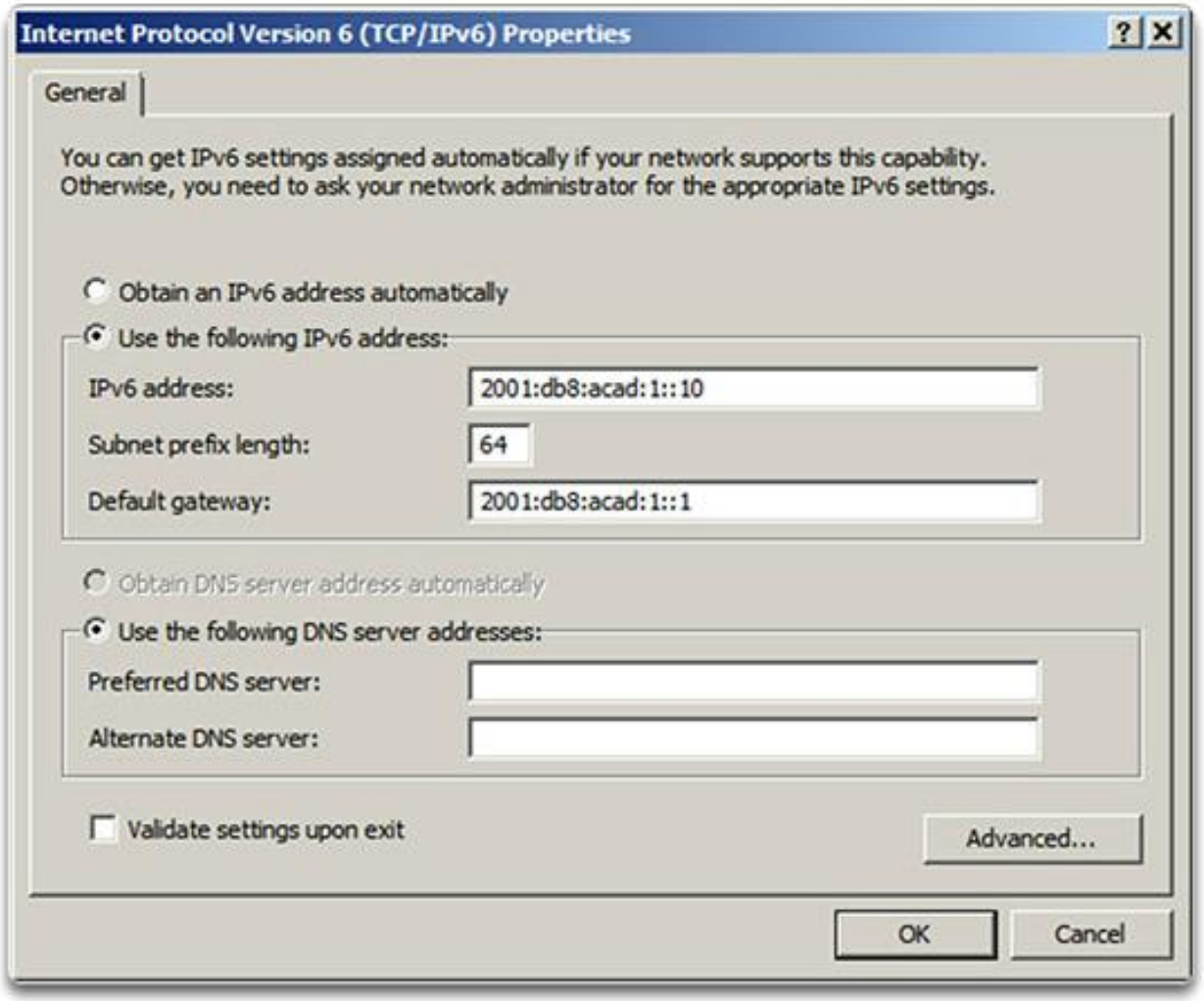


Structure of an IPv6 Global Unicast Address (cont.)

Reading a Global Unicast Address

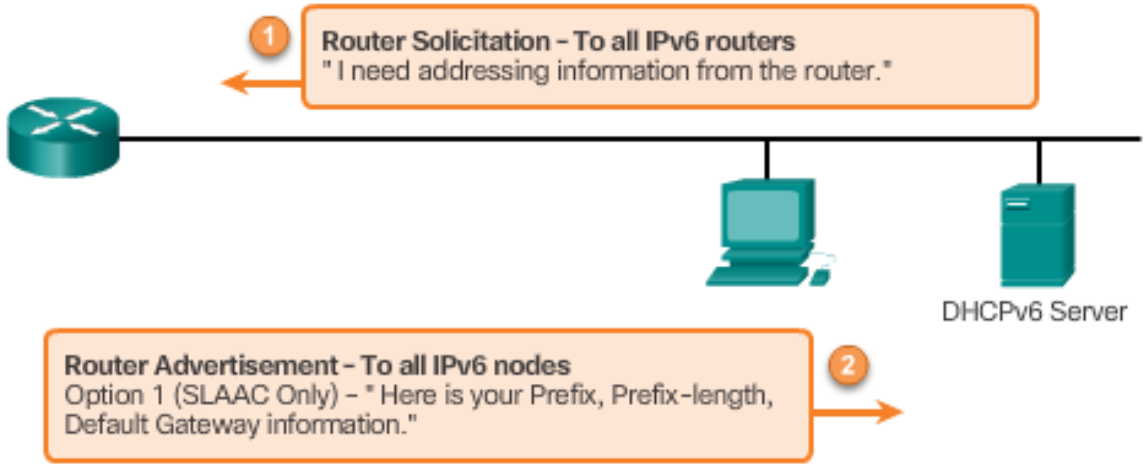


Static Configuration of a Global Unicast Address (cont.)



Dynamic Configuration - SLAAC

Router Solicitation and Router Advertisement Messages



Router Advertisement Options

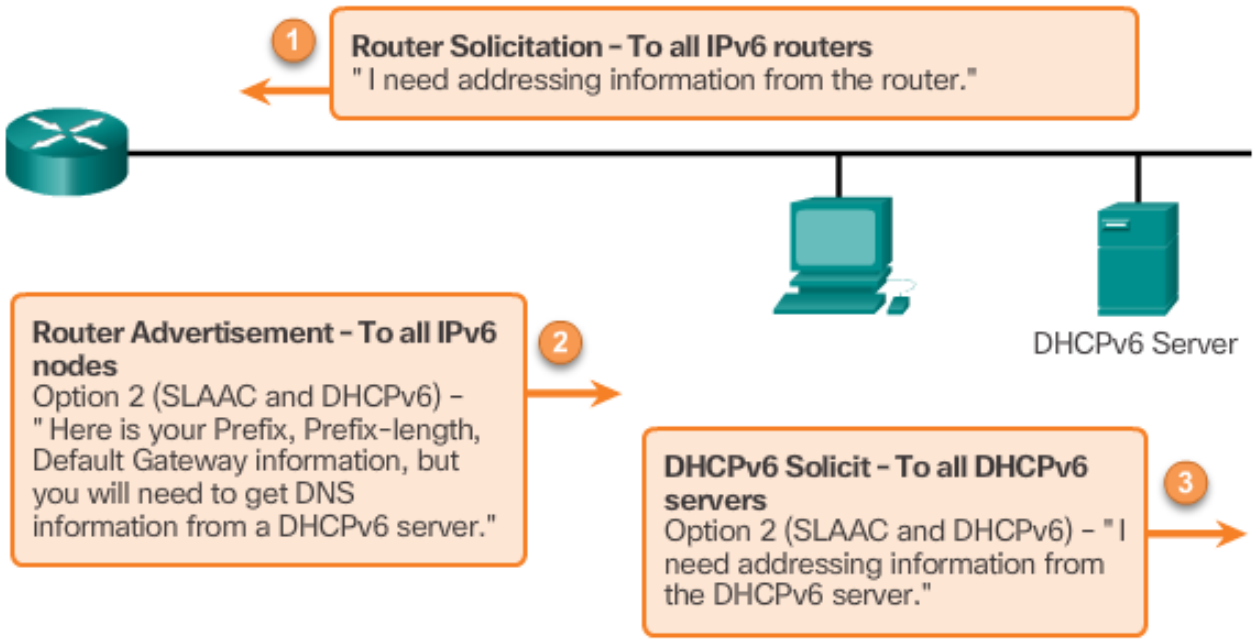
Option 1 (SLAAC Only) – " I'm everything you need (Prefix, Prefix-length, Default Gateway)"

Option 2 (SLAAC and DHCPv6) – " Here is my information but you need to get other information such as DNS addresses from a DHCPv6 server."

Option 3 (DHCPv6 Only) – " I can't help you. Ask a DHCPv6 server for all your

Dynamic Configuration – DHCPv6

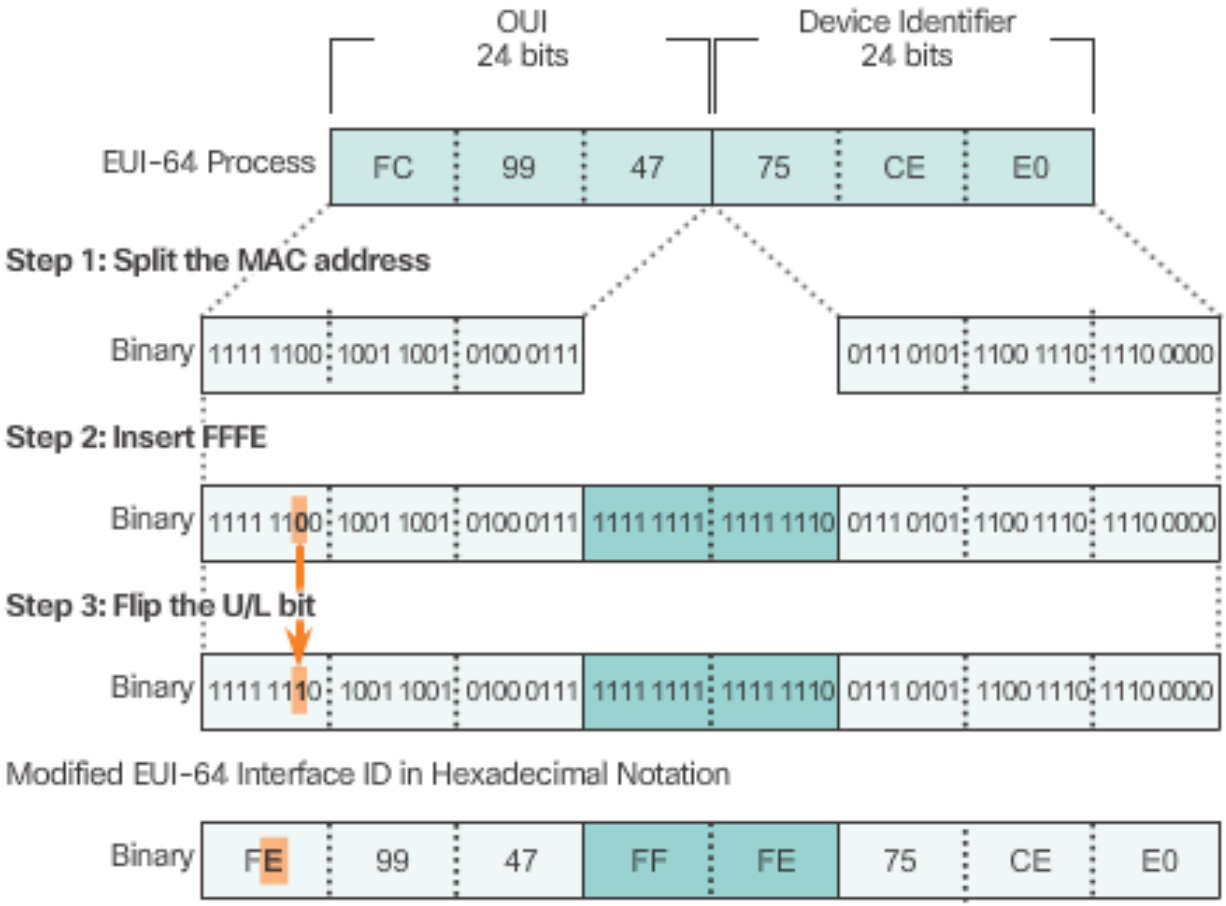
Router Solicitation and Router Advertisement Messages



Note: An RA with option 3 (DHCPv6 Only) enabled will require the client to obtain all information from the DHCPv6 server except the default gateway address. The default gateway address is the RA's source IPv6 address.

EUI-64 Process and Randomly Generated

EUI-64 Process



EUI-64 Process and Randomly Generated

EUI-64 Process

```
PCA> ipconfig
Windows IP Configuration
Ethernet adapter Local Area Connection:
   Connection-specific DNS Suffix  :
   IPv6 Address. . . . . . . . . . : 2001:db8:acad:1:fc99:47ff:Ffe75:cee0
   Link-local IPv6 Address . . . . : fe80::fc99:47FF:FE75:CEE0
   Default Gateway   . . . . . . . : fe80::1
```

From RA Message

EUI-64 generated

Randomly Generated Interface ID

```
PCB> ipconfig
Windows IP Configuration
Ethernet adapter Local Area Connection:
   Connection-specific DNS Suffix  :
   IPv6 Address. . . . . . . . . . : 2001:db8:acad:1:50a5:8a35:a5bb:66e1
   Link-local IPv6 Address . . . . : fe80::50a5:8a35:a5bb:66e1
   Default Gateway   . . . . . . . : fe80::1
```

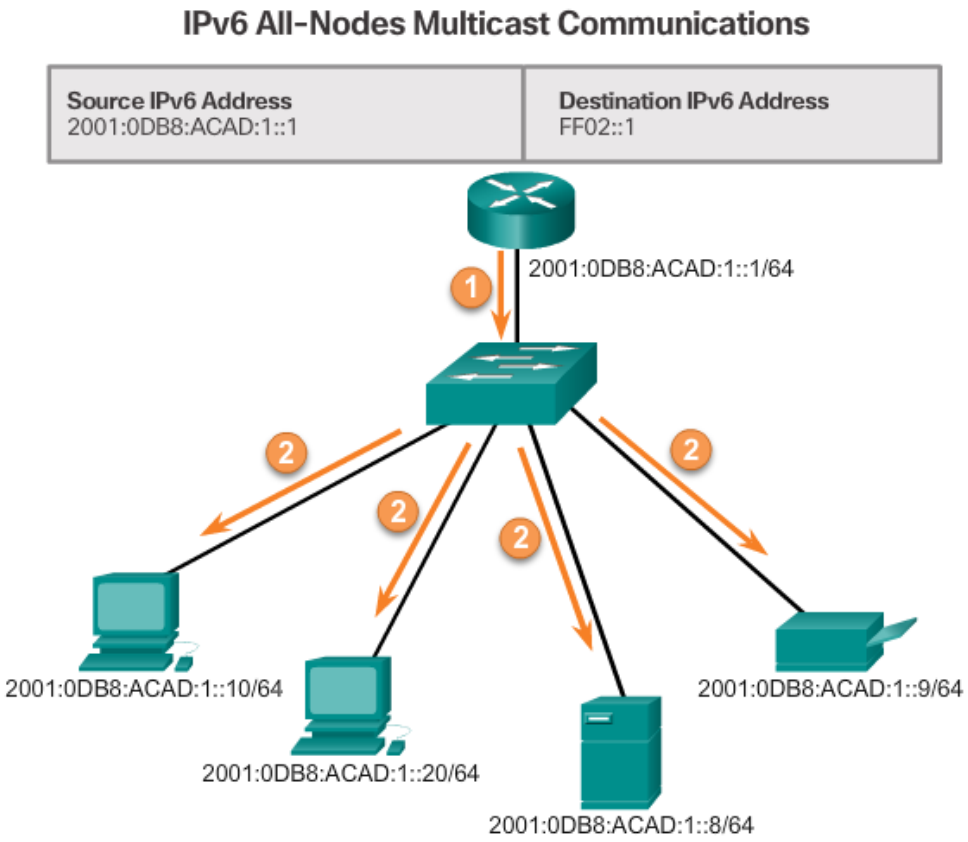
From RA Message

Random 64-bit number

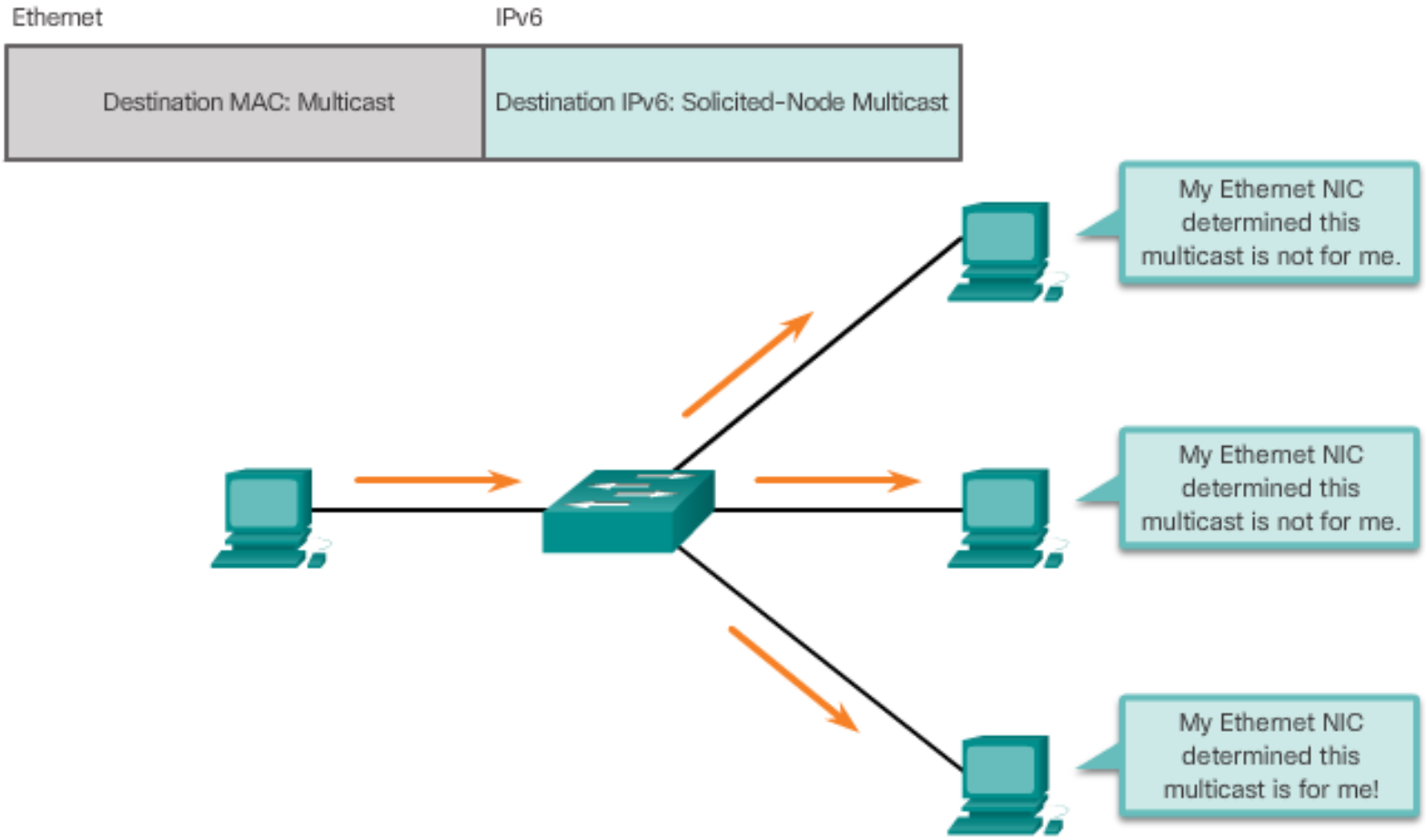
Topic 7.2.5:
IPv6 Multicast Addresses

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



Solicited-Node IPv6 Multicast Addresses



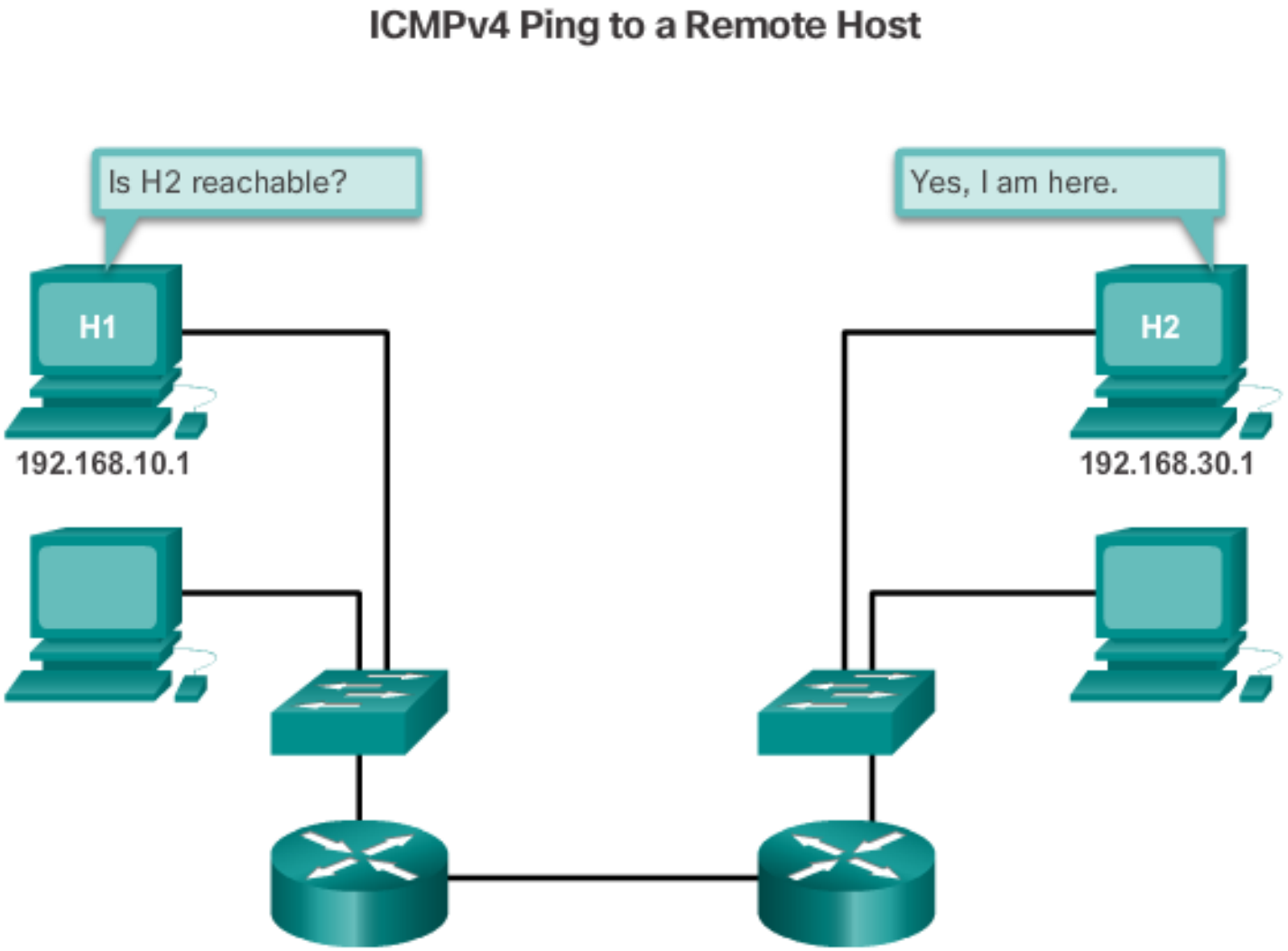
Section 7.3: Connectivity Verification

Upon completion of this section, you should be able to:

- Explain how ICMP is used to test network connectivity.
- Use ping and traceroute utilities to test network connectivity.

Topic 7.3.1: ICMP

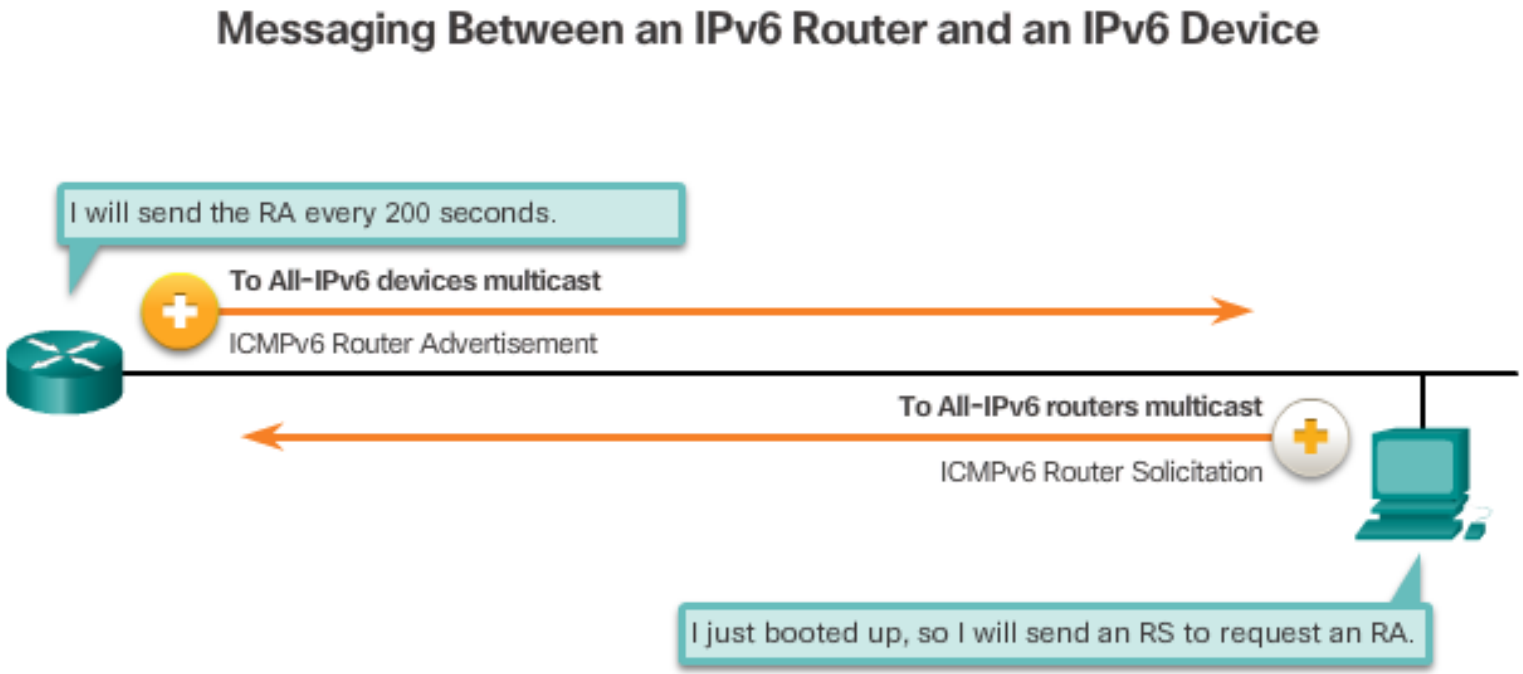
ICMPv4 and ICMPv6



ICMPv4 and ICMPv6 (cont.)

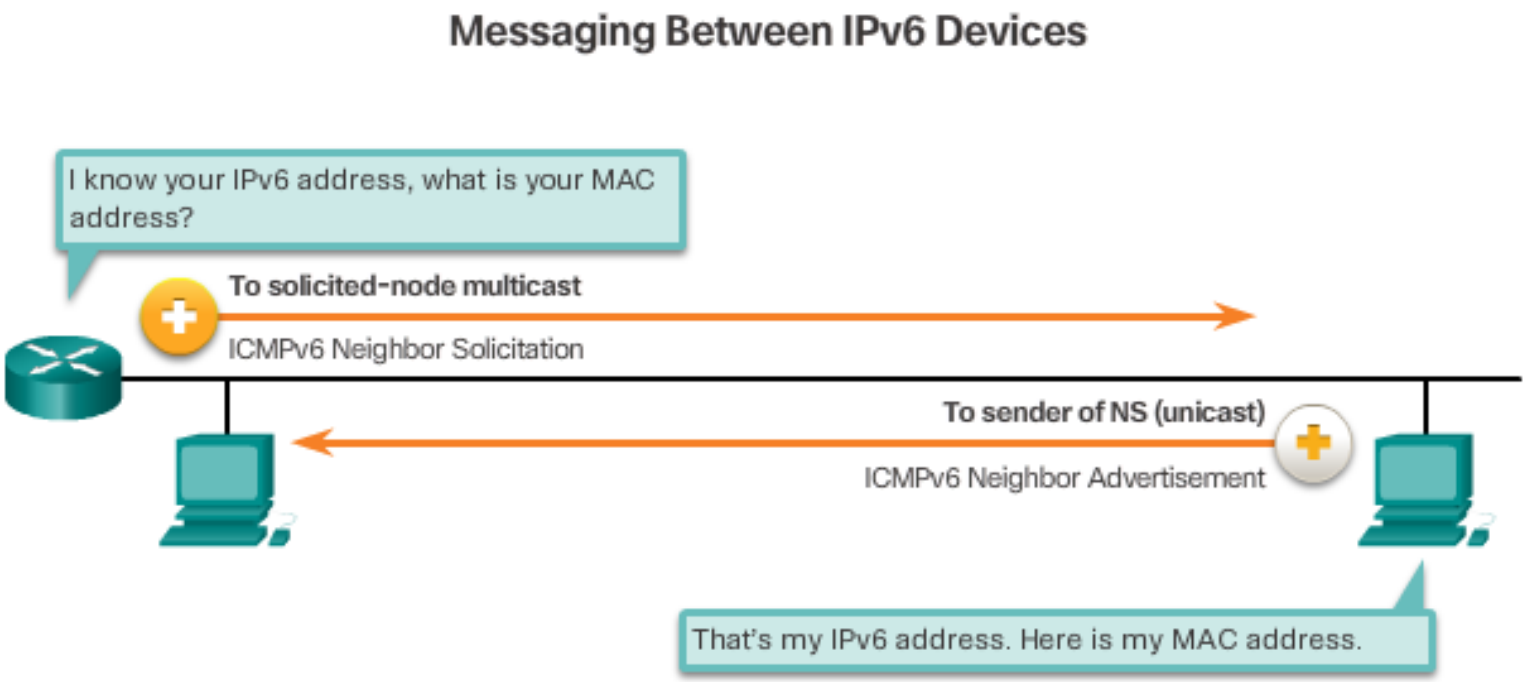
- ICMP messages common to both ICMPv4 and ICMPv6 include:
  - Host confirmation
  - Destination or service unreachable
  - Time exceeded
  - Route redirection
- Although IP is not a reliable protocol, the TCP/IP suite provides for messages to be sent in the event of certain errors. They are sent using the services of ICMP.

ICMPv6 Router Solicitation and Router Advertisement Messages



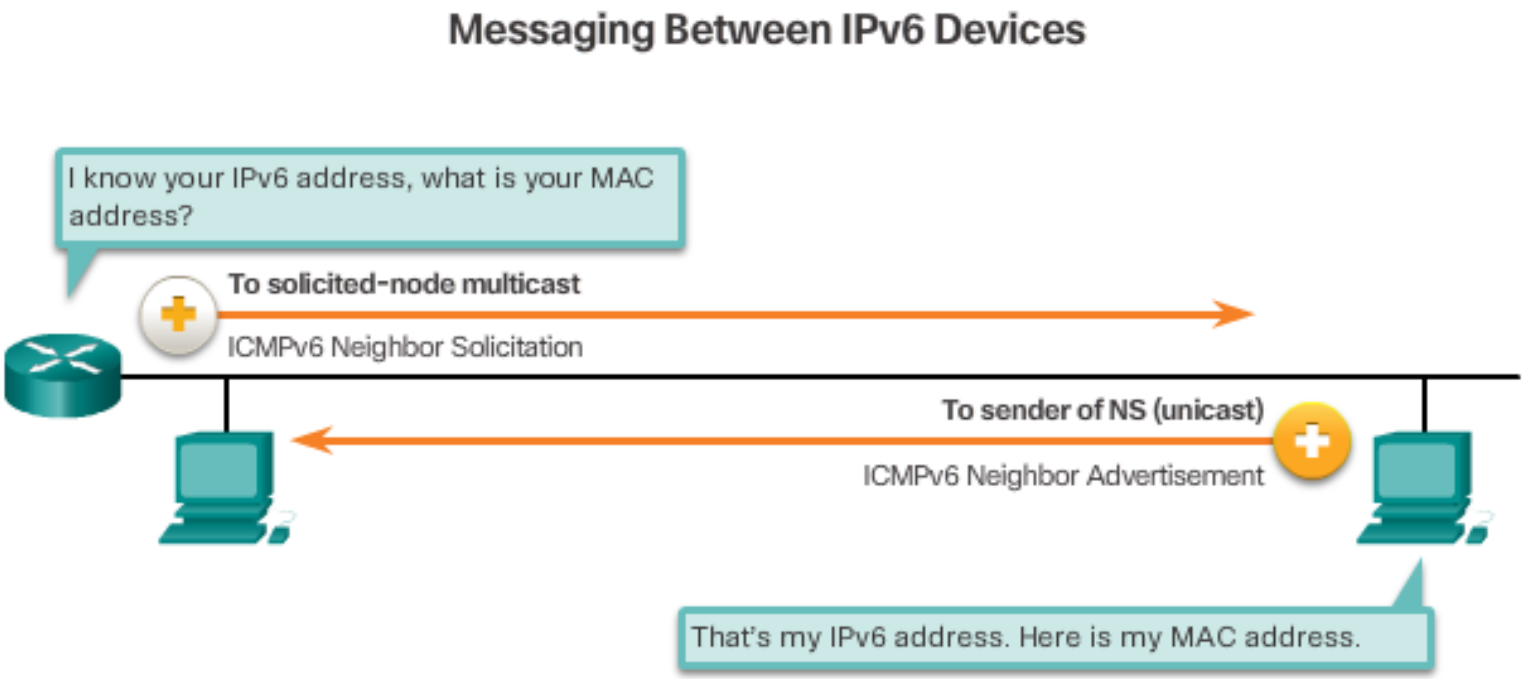
RA messages are sent by routers to provide addressing information to hosts using SLAAC. The RA message can include addressing information for the host such as the prefix, prefix length, DNS address and domain name. A router will send an RA message periodically or in response to an RS message. A host using SLAAC will set its default gateway to the link-local address of the router that sent the RA.

ICMPv6 Router Solicitation and Router Advertisement Messages (cont.)



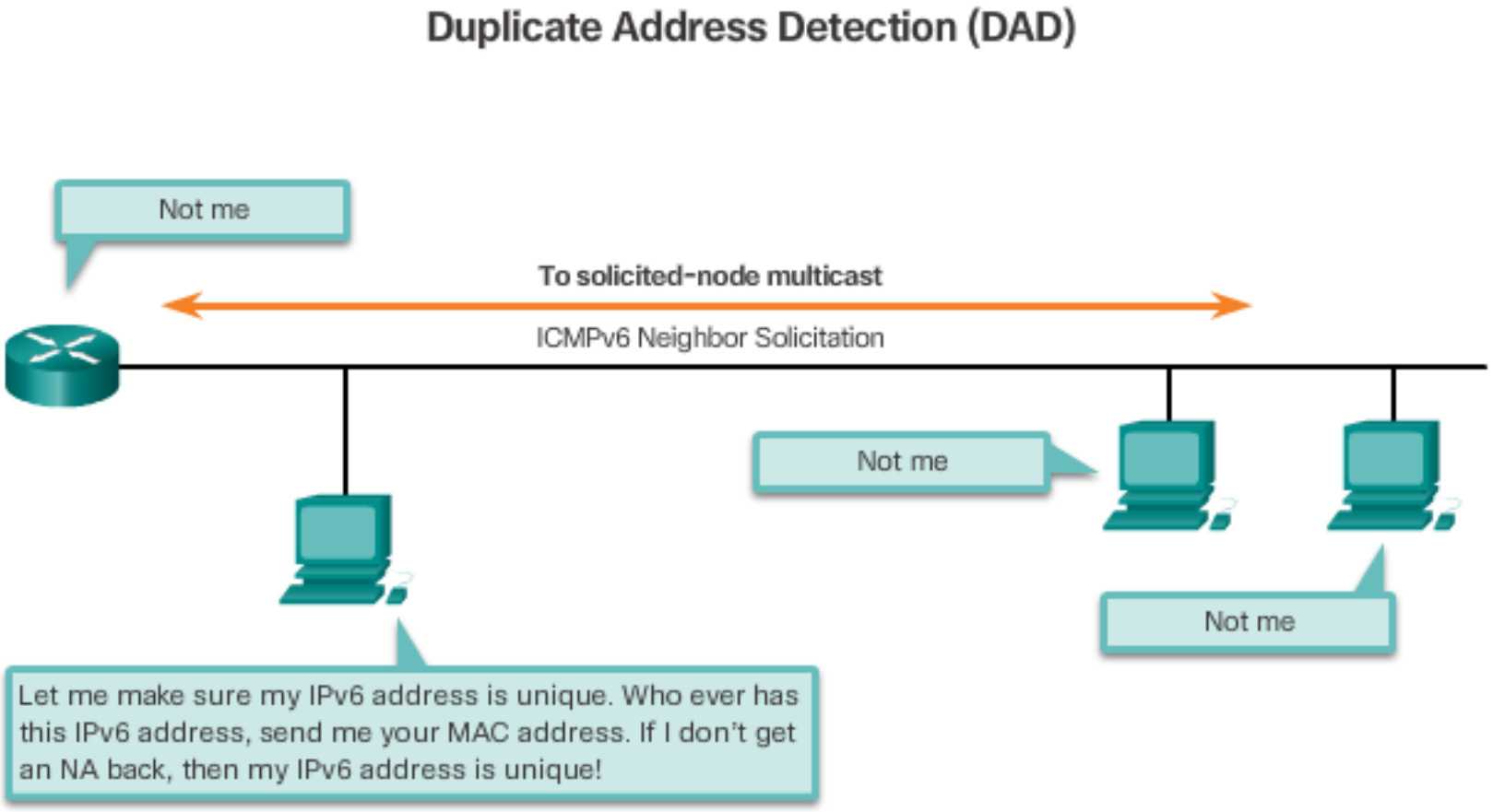
NS messages are sent when a device knows the IPv6 address of a device but does not its MAC address. This is equivalent to an ARP Request for IPv4.

ICMPv6 Router Solicitation and Router Advertisement Messages (cont.)



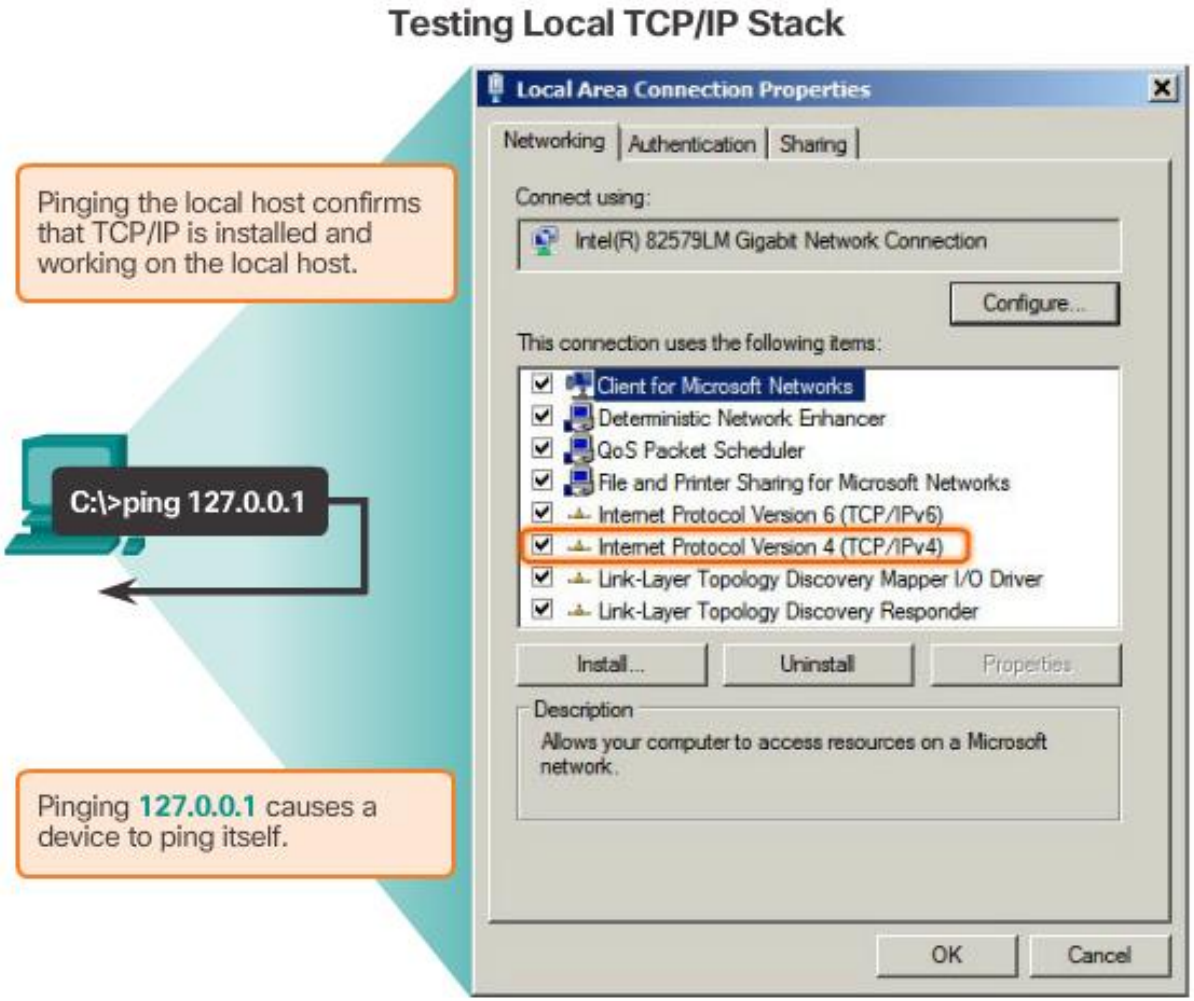
NA mesages are sent in response to an NS message and matches the target IPv6 address in the NS. The NA message includes the device's Ethernet MAC address. This is equivalent to an ARP Reply for IPv4.

ICMPv6 Router Solicitation and Router Advertisement Messages (cont.)

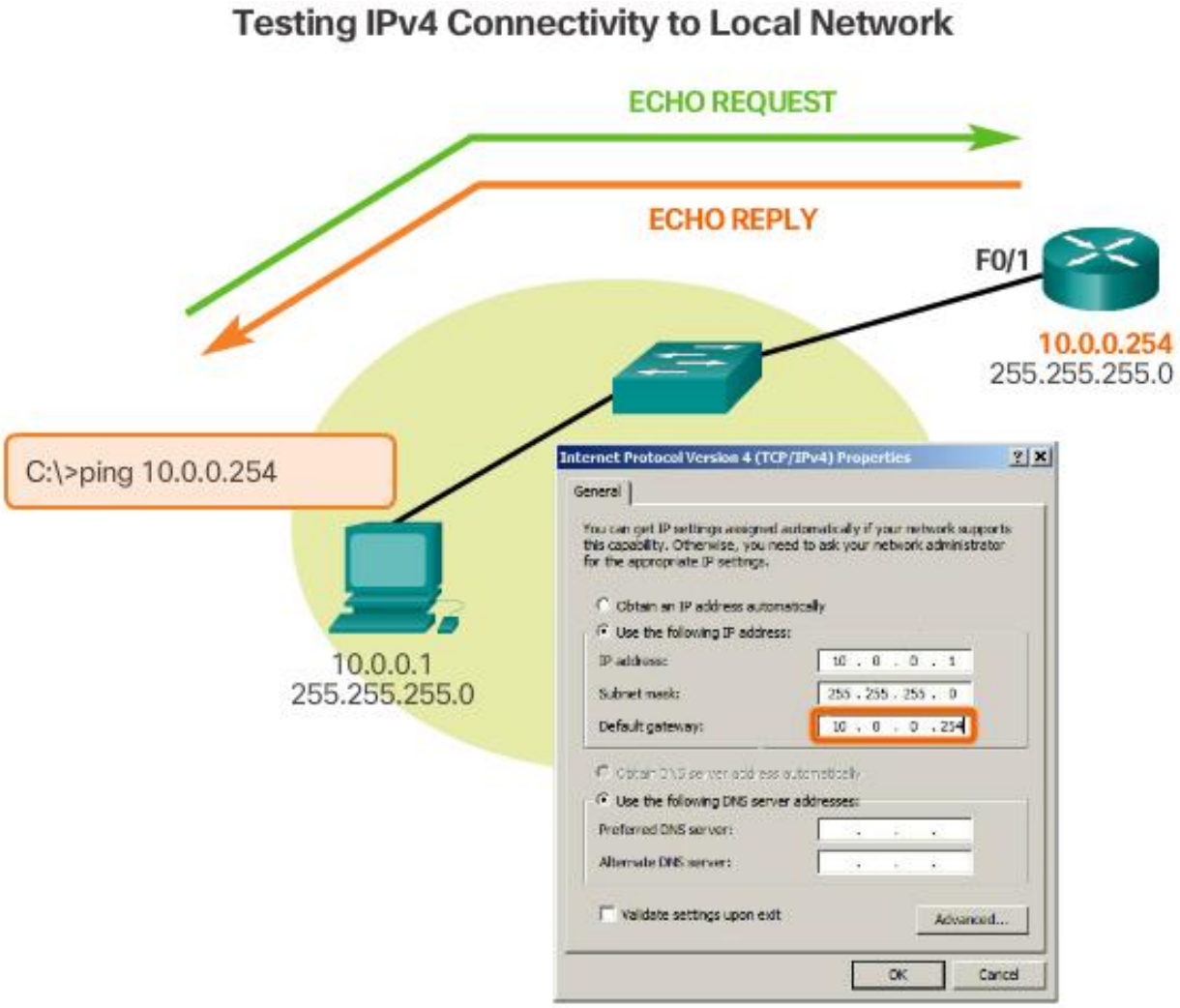


Topic 7.3.2:
Testing and Verification

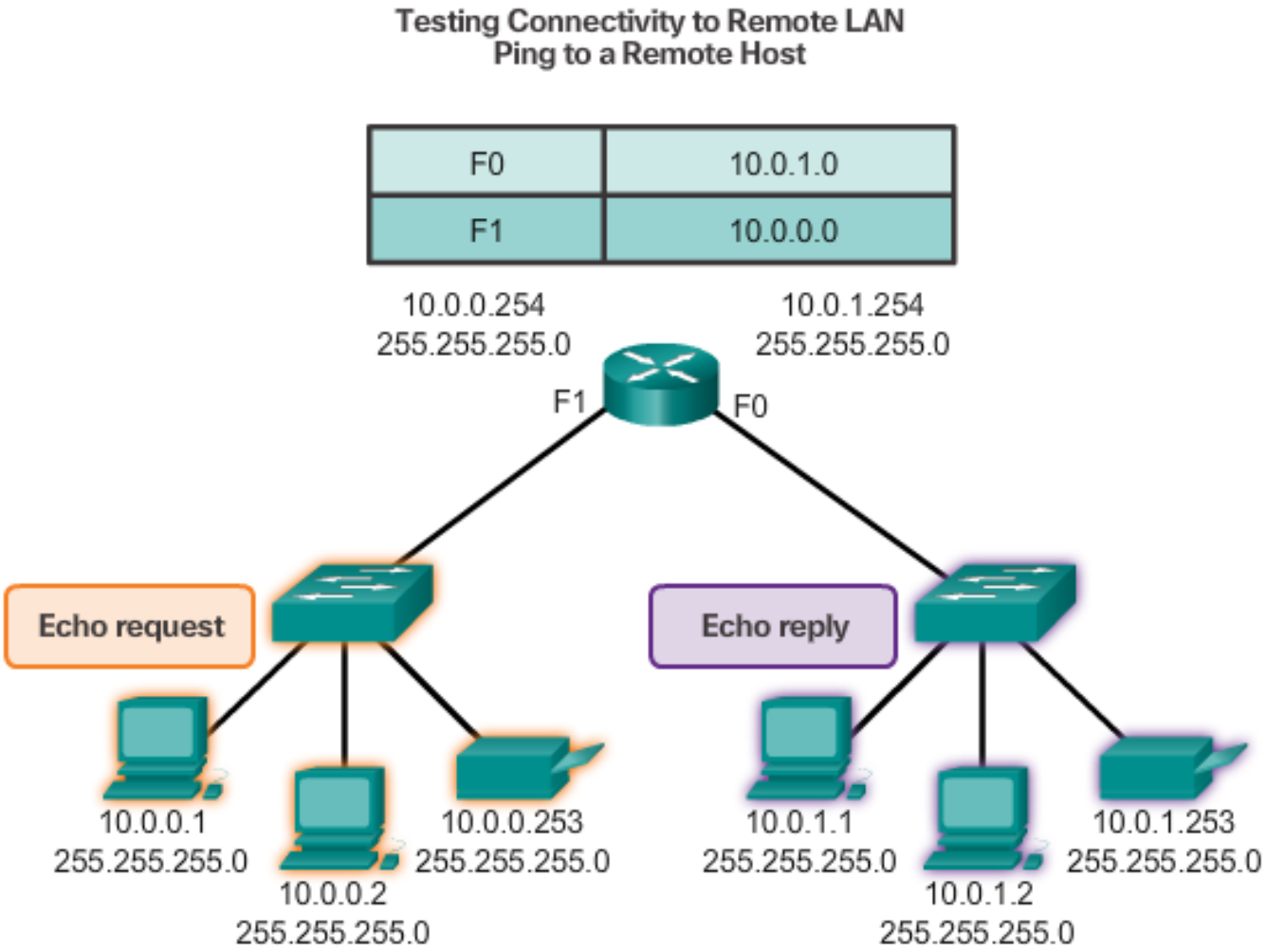
Ping - Testing the Local Stack



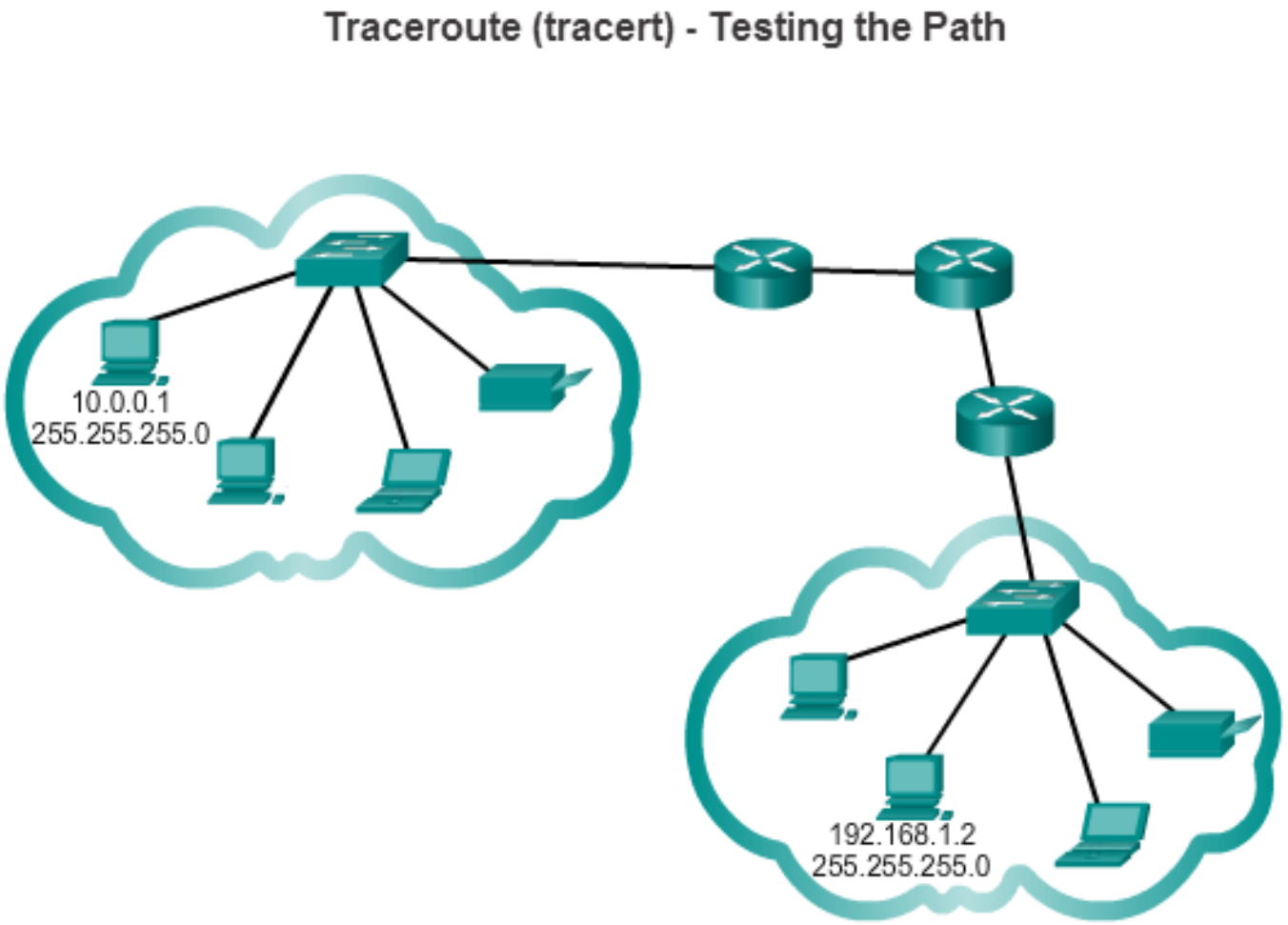
Ping – Testing Connectivity to the Local LAN



Ping – Testing Connectivity to Remote



Traceroute – Testing the Path



Section 7.4: Summary

Chapter Objectives:

- Explain the use of IPv4 addresses to provide connectivity in a small to medium-sized business network.
- Configure IPv6 addresses to provide connectivity in small to medium-sized business networks.
- Use common testing utilities to verify network connectivity.

Thank you.

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Mind Wide Open