Redes de Datos

Direccionamiento y Enrutamiento

Objectives

Network Layer Protocols

- Describe the purpose of the network layer in data communication.
- Explain why the IPv4 protocol requires other layers to provide reliability.
- Explain the role of the major header fields in the IPv4 and IPv6 packet.

Routing

- Explain how a host device uses routing tables to direct packets to itself, a local destination, or a default gateway.
- Compare a host routing table to a routing table in a router.

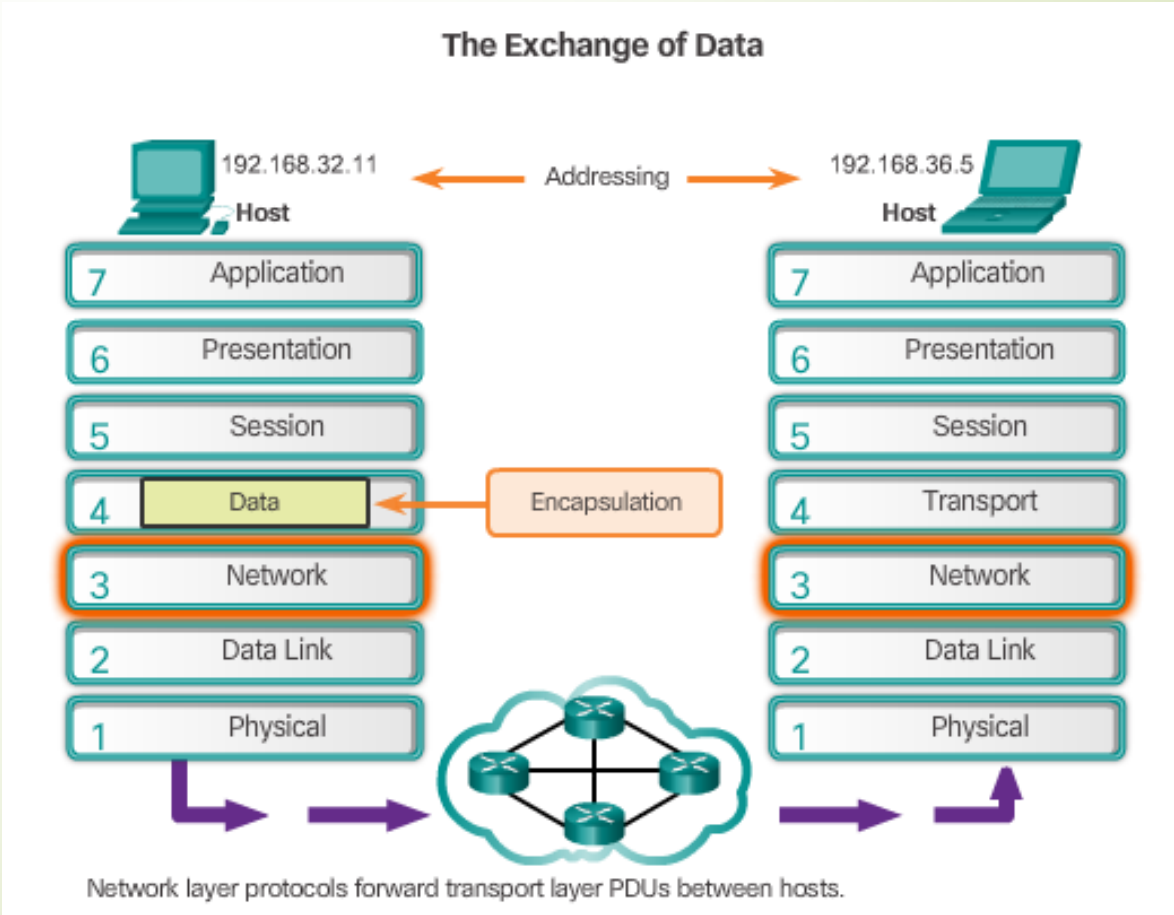
Addressing

Subnetting & VLSM

Supernetting

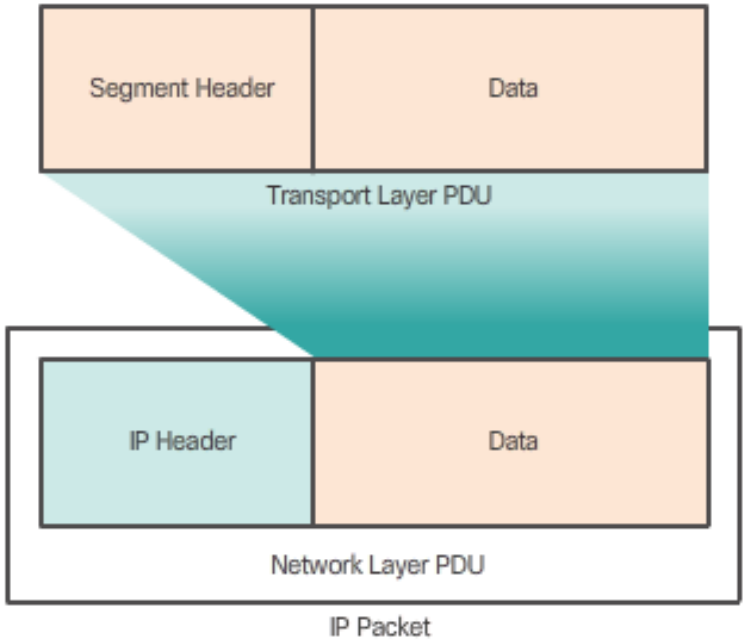
Network Layer in Communications

- The Network Layer
  - End to End Transport processes operations
    - Addressing end devices
    - Encapsulation
    - Routing
  - Fragmentation
  - QoS
- Network Layer Protocols
  - IPv4
  - IPv6



Characteristics of the IP Protocol

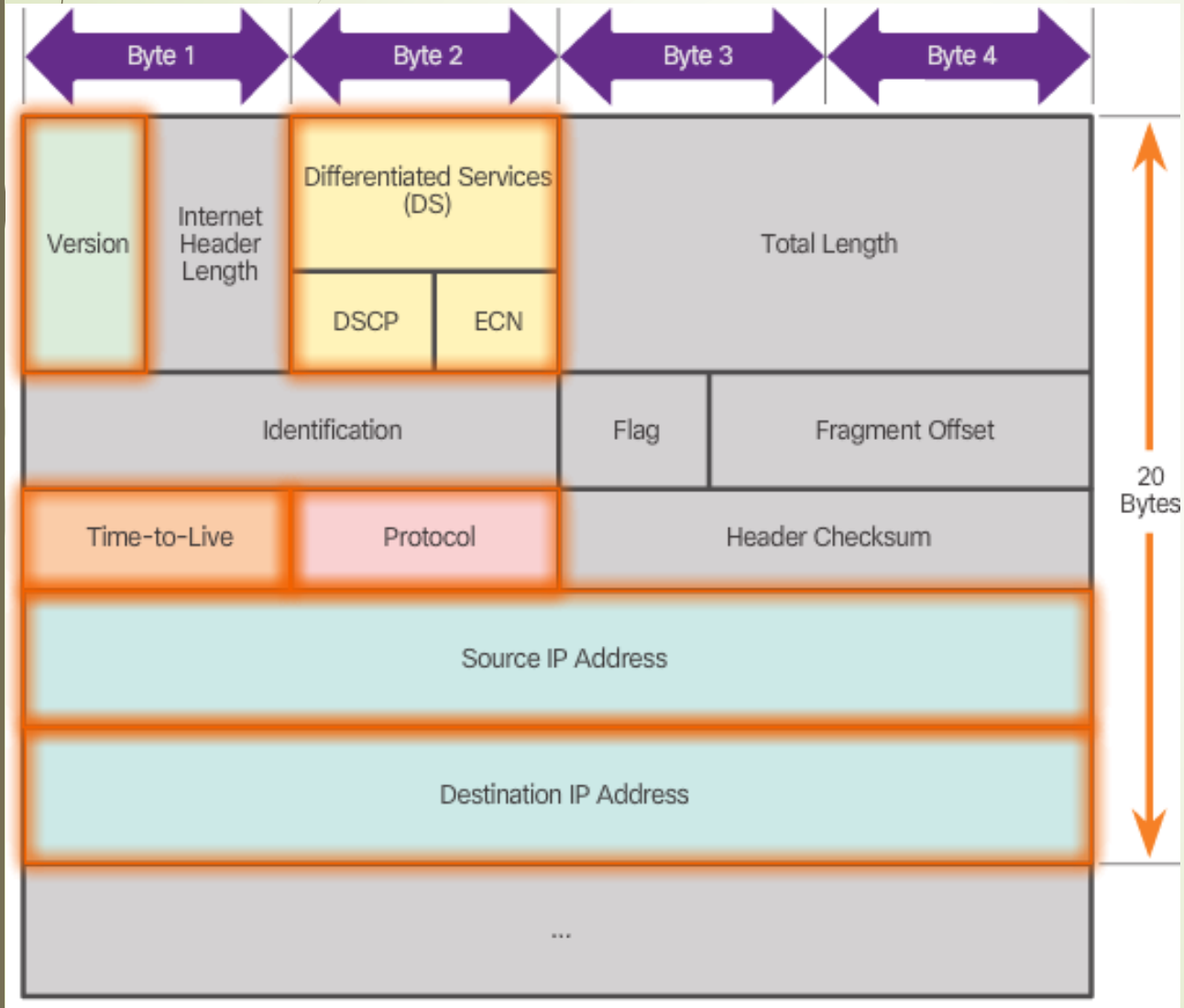
- IP - Connectionless
  - Sender doesn't know if the receiver is listening, or the message arrived on time.
  - Receiver doesn't know data is coming.
- IP – Best Effort Delivery
  - No guarantees of delivery are made.
- IP – Media Independent
  - IP can travel over different types of media.
- Encapsulating IP
  - Segments are encapsulated into IP packets for transmission.
  - The network layer adds a header so packets can be routed to the destination.



Network Layer Protocols

IPv4 Packet

- IPv4 Packet Header



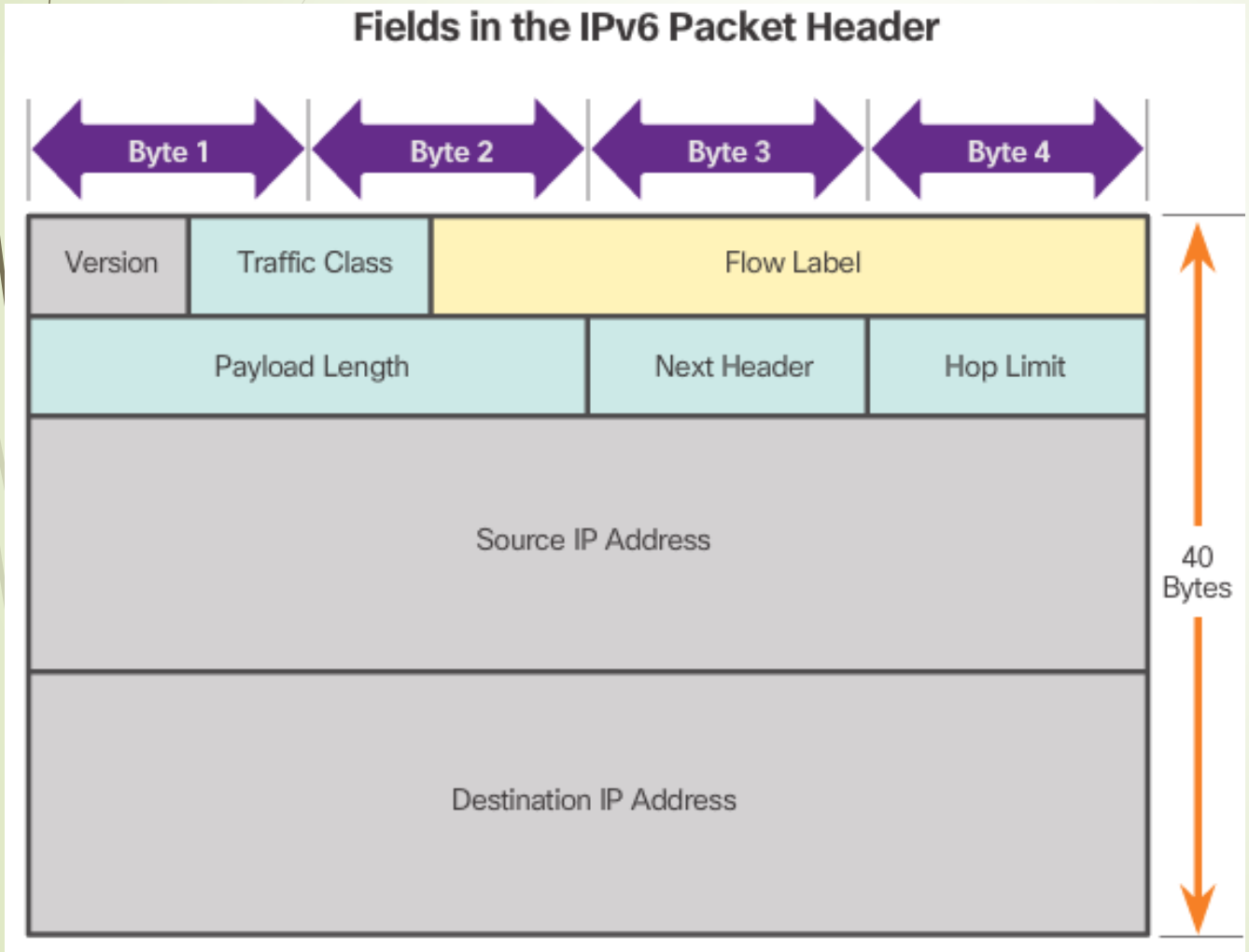
- Version = 0100
- DS = Packet Priority
- TTL = Limits life of Packet
- Protocol = Upper layer protocol such as TCP
- Source IP Address = source of packet
- Destination IP Address = destination of packet

IPv6 Packet

- Limitations of IPv4
  - IP address depletion
  - Internet routing table expansion
  - Lack of end-to-end connectivity
- Introducing IPv6
  - Increased address space
  - Improved packet handling
  - Eliminates the need for NAT
- EncapsulatingIPv6
  - Simplified header format
  - No checksum process requirement
  - More efficient Options Header mechanism
  - Flow Label field makes it more efficient.

IPv6 Packet (Cont.)

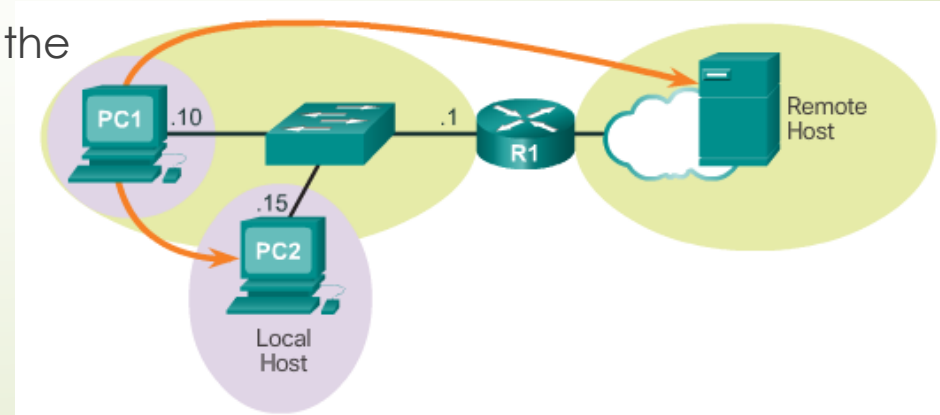
- IPv6 Packet Header

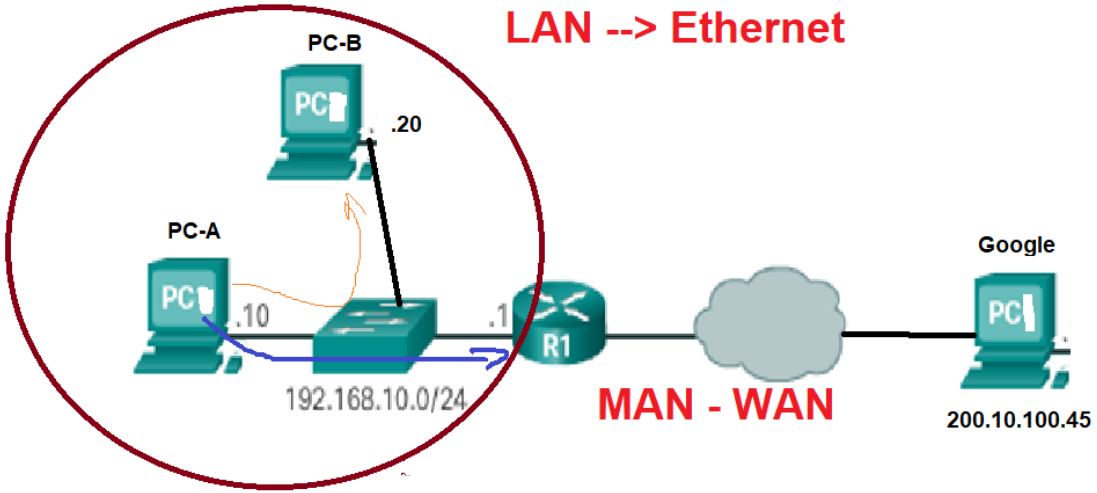


- Version = 0110
- Traffic Class = Priority
- Flow Label = same flow will receive same handling
- Payload Length = same as total length
- Next Header = Layer 4 Protocol
- Hop Limit = Replaces TTL field

How a Host Routes

- Host Forwarding Decision
  - Three types of destination: itself, local host, remote host.
- Default Gateway
  - Routes traffic to other networks
  - Has a local IP address in the same address range as other hosts on the network
  - Can take data in and forward data out
- Using the Default Gateway
  - Hosts will use the default gateway when sending packets to remote networks.
- Host Routing Tables
  - Use the **netstat –r** command to display the host routing table on a Windows machine.





LAN --> Ethernet

MAN - WAN

A: 192.168.10.10
B: 192.168.10.20

misma red -->
entrega directa

A: 192.168.10.10
G: 200.20.100.45

redes diferentes --->
entrega indirecta

R1 ..... Rn
extaer la ip destino
consulta a su tabla
enruta
forwarding

How a Host Routes (Cont.)

IPv4 Routing Table for PC1


```
C:\Users\PC1>netstat -r

<output omitted>

IPv4 Route Table
---------------------------------------------------------------------------
Active Routes:
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0    192.168.10.1   192.168.10.10     25
        127.0.0.0        255.0.0.0         On-link        127.0.0.1    306
        127.0.0.1  255.255.255.255         On-link        127.0.0.1    306
  127.255.255.255  255.255.255.255         On-link        127.0.0.1    306
    192.168.10.0    255.255.255.0         On-link   192.168.10.10    281
   192.168.10.10  255.255.255.255         On-link   192.168.10.10    281
  192.168.10.255  255.255.255.255         On-link   192.168.10.10    281
        224.0.0.0        240.0.0.0         On-link        127.0.0.1    306
        224.0.0.0        240.0.0.0         On-link   192.168.10.10    281
  255.255.255.255  255.255.255.255         On-link        127.0.0.1    306
  255.255.255.255  255.255.255.255         On-link   192.168.10.10    281
---------------------------------------------------------------------------

<output omitted>
```

How a Host Routes

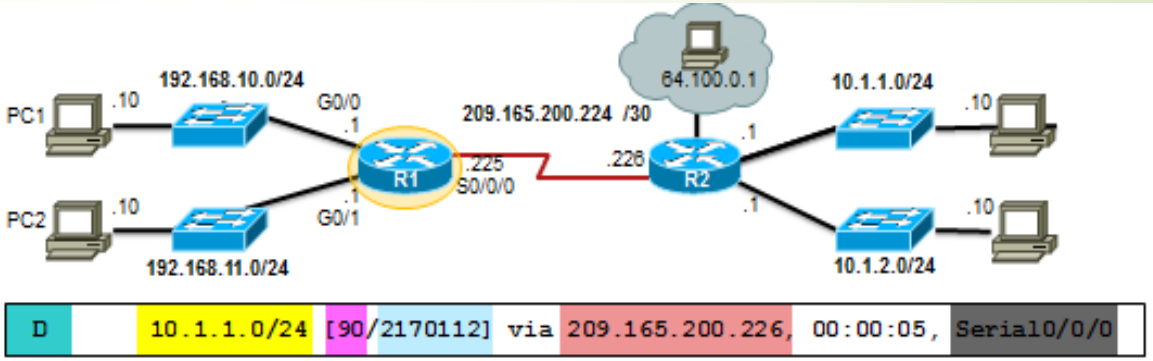
Router Routing Tables

- Router Packet Forwarding Decision
  - Routers and hosts forward packets in a similar fashion.
  - The main difference is that routers have more interfaces while hosts often have only one.
  - Devices on directly connected networks can be reached directly.
  - Devices on remote networks are reached through gateway.
- IPv4 Router Routing Table
  - The router routing table stores network routes the router knows about.
  - Use the **show ip route** command to display the routing table on a Cisco router.
  - The router routing table also has information on: how the route was learned, its trustworthiness and rating.
  - It also contains which interface to use to reach that specifc destination.
- Directly Connected Routing Table Entries
  - C - Identifies a directly-connected network, automatically created when an interface is configured with an IP address and activated.
  - L - Identifies that this is a local interface. This is the IPv4 address of the interface on the router.
- Remote Network Routing Table Entries
  - Connected to other routers
- Next-Hop Address
  - Next router in path

How a Host Routes

Router Routing Tables (Cont.)

- Remote Network Routing Table Entries
  - Remote destinations can't be reached directly.
  - Remote routes contain the address of the intermediate network device to be used to reach the destination.
- Next-Hop Address
  - Next-Hop address is the address of the intermediate device used to reach a specifc remote destination.

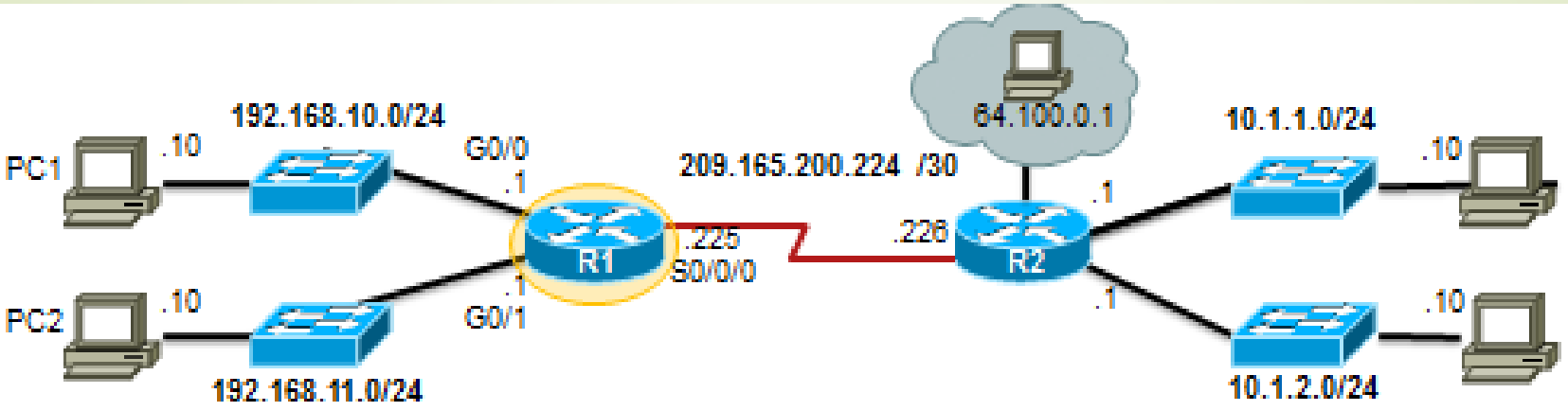


D	10.1.1.0/24	[90/2170112]	via	209.165.200.226,	00:00:05,	Serial0/0/0

A	Identifies how the network was learned by the router.
B	Identifies the destination network.
C	Identifies the administrative distance (trustworthiness) of the route source.
D	Identifies the metric to reach the remote network.
E	Identifies the next hop IP address to reach the remote network.
F	Identifies the amount of elapsed time since the network was discovered.
G	Identifies the outgoing interface on the router to reach the destination network.

How a Host Routes

Router Routing Tables (Cont.)



D	10.1.1.0/24	[90/2170112]	via	209.165.200.226,	00:00:05,	Serial0/0/0

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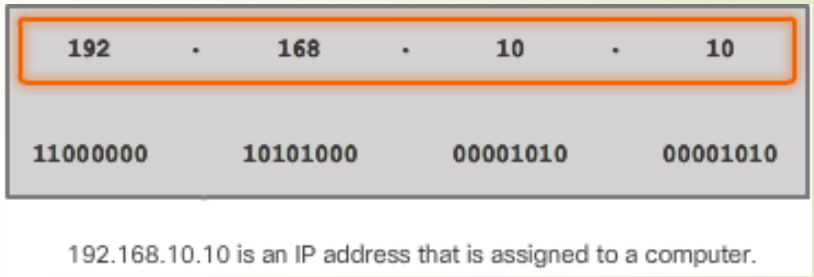
G	Identifies the outgoing interface on the router to reach the destination network.

IPv4 Network Addresses

Binary and Decimal Conversion

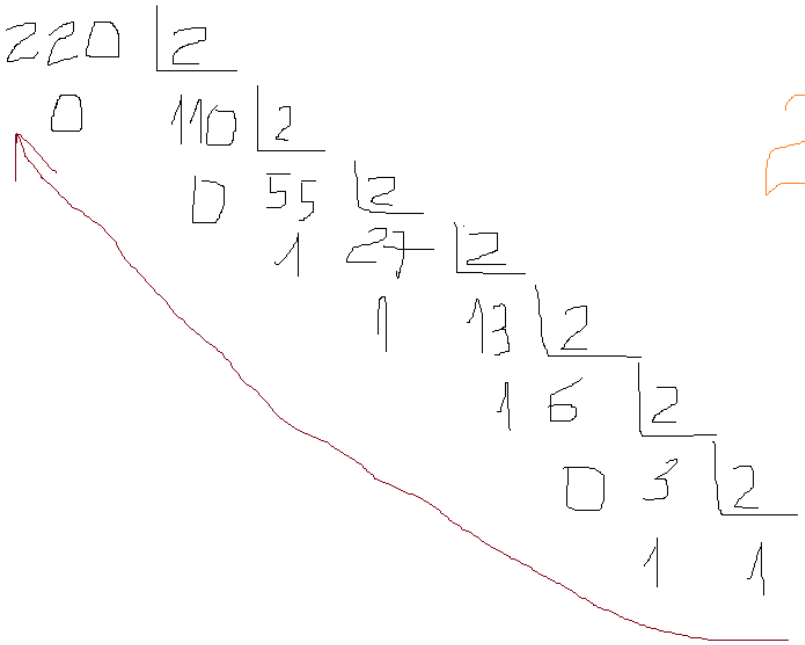
- IPv4 Addresses
  - consists of a string of 32 bits, divided into four sections called *octets*.
  - Each octet contains 8 bits (or 1 byte) separated with a dot.
- Conversion between Binary to Decimal
  - Use the chart to help with conversion

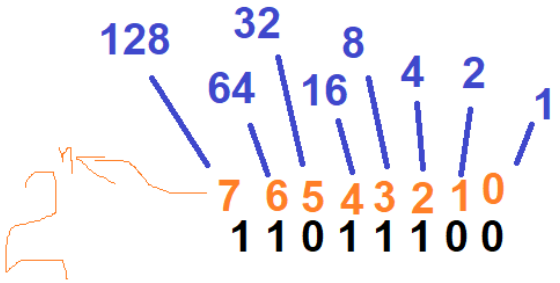


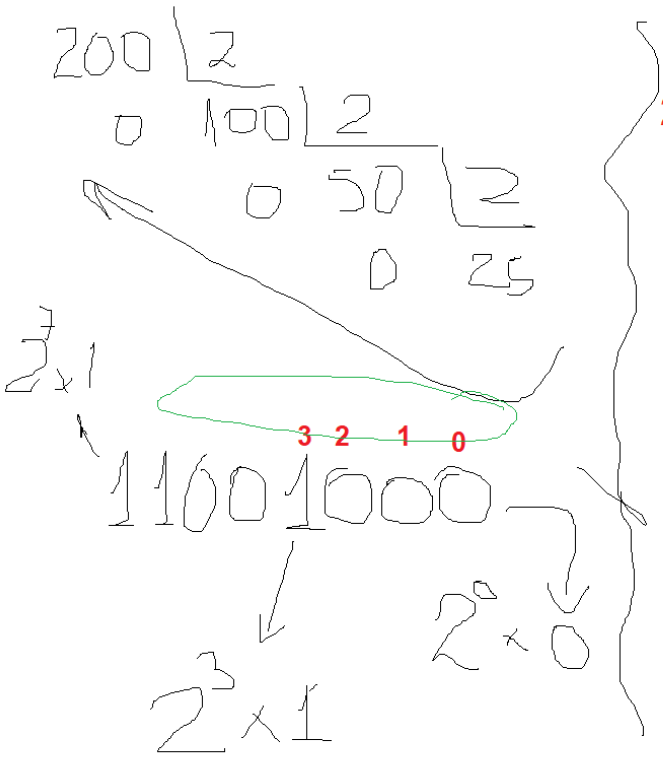
192.168.10.10 is an IP address that is assigned to a computer.

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

220 --> binario **11011100**







	128	64	32	16	8	4	2	1
200	1	1	0	0	1	0	0	0
170	1	0	1	0	1	0	1	0
99	0	1	1	0	0	0	1	1
237	1	1	1	0	1	1	0	1
123	0	1	1	1	1	0	1	1

:9D9F: ==> :9DA0:

0 = 0000
1 = 0001
2 = 0010
.
.
.
9 = 1001
A = 1010
B = 1011
C = 1100
D = 1101
E = 1110
F = 1111

decimal --> hexadecimal

0000 = 0
0001 = 1
0010 = 2
0011 = 3
0100 = 4
0101 = 5
0110 = 6
0111 = 7
1000 = 8
1001 = 9
1010 = A
1011 = B
1100 = C
1101 = D
1110 = E
1111 = F

120 = 0111 1000 78 hexadecimal

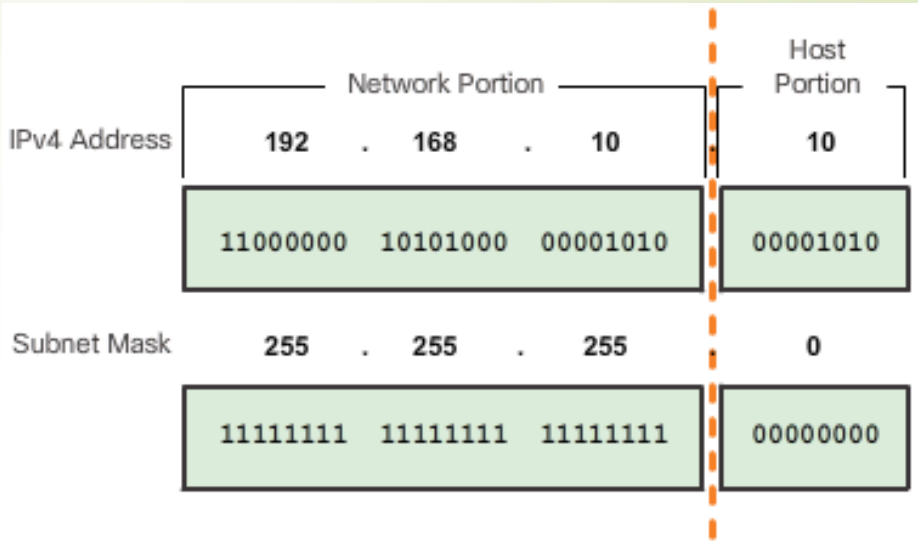
7 8

E5 --> decimal

1110 0101 = 229

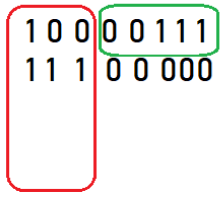
IPv4 Address Structure

- Network and Host Portions
- The Subnet Mask
- Logical AND
  - What is the network address for graphics?
- Prefix Length
  - What is the prefix length for the graphics?
- Network, Host, and Broadcast Addresses
  - Network Address?
  - Range of Valid Hosts?
  - Broadcast Address?



/27

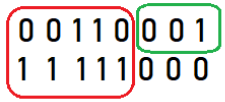
200. 10. 100 135
255.255.255.224



1 0 0 0 0 0 0 0 = 128 ->subred
1 0 0 1 1 1 1 1 = 159 ->broadcast
.129 al .158 --> rango válido

/29

157. 100.225 49
255.255.255 248



0 0 1 1 0 0 0 0 = 48 -> subred
0 0 1 1 0 1 1 1 = 55 -> broadcast
.49 al .54 --> rango útil

/22

200. 9 176 82
255.255 252. 0

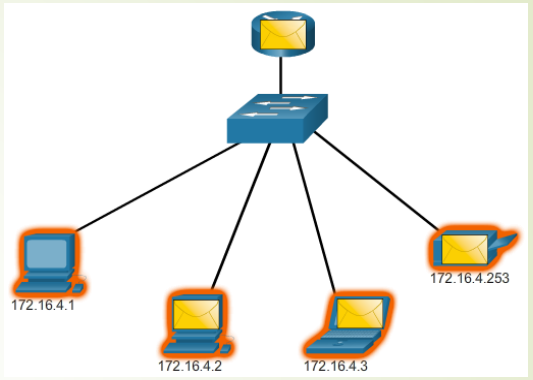
10110000.00000000 = 176.0 -> subred
10110011.11111111 = 179.255 -> brodcast
.176.1 al .179.254 --> rango válido

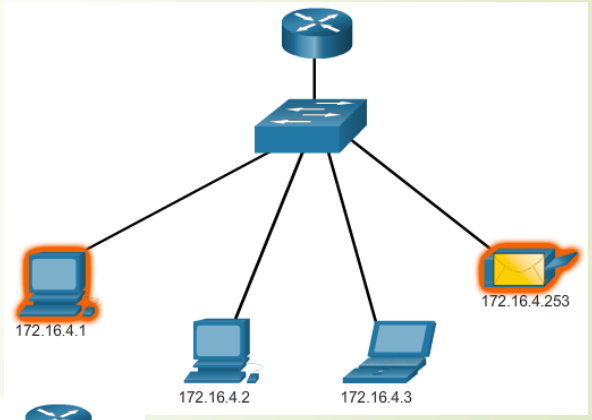
10000000 -> 128
11000000 -> 192
11100000 -> 224
11110000 -> 240
11111000 -> 248
11111100 -> 252

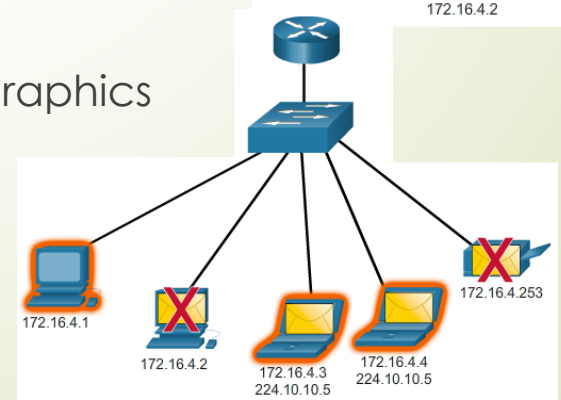
11001100 --> 204 no válida

IPv4 Unicast, Broadcast, and Multicast

- IPv4 Addressing Assignment to a Host
  - Static – Type in manually
  - Dynamic - Dynamic Host Configuration Protocol (DHCP)
- IPv4 Communication
  - Unicast - send packets from one host to an individual host
  - Broadcast - send packets from one host to all the hosts in the network
  - Multicast - send a packet from one host to a selected group of hosts in the same or different network
  - Which types of communication are the graphics on the right?



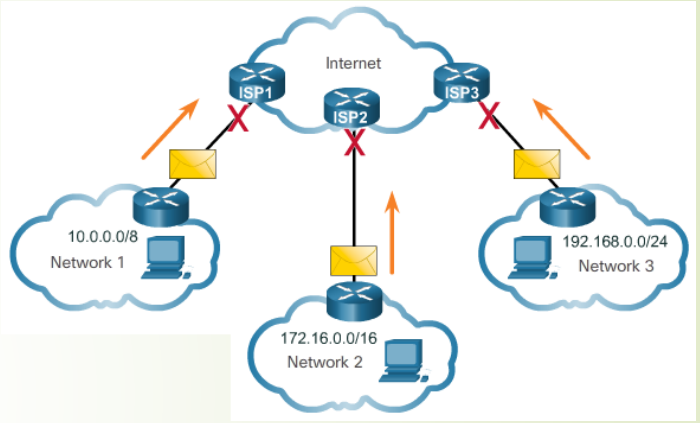




IPv4 Network Addresses

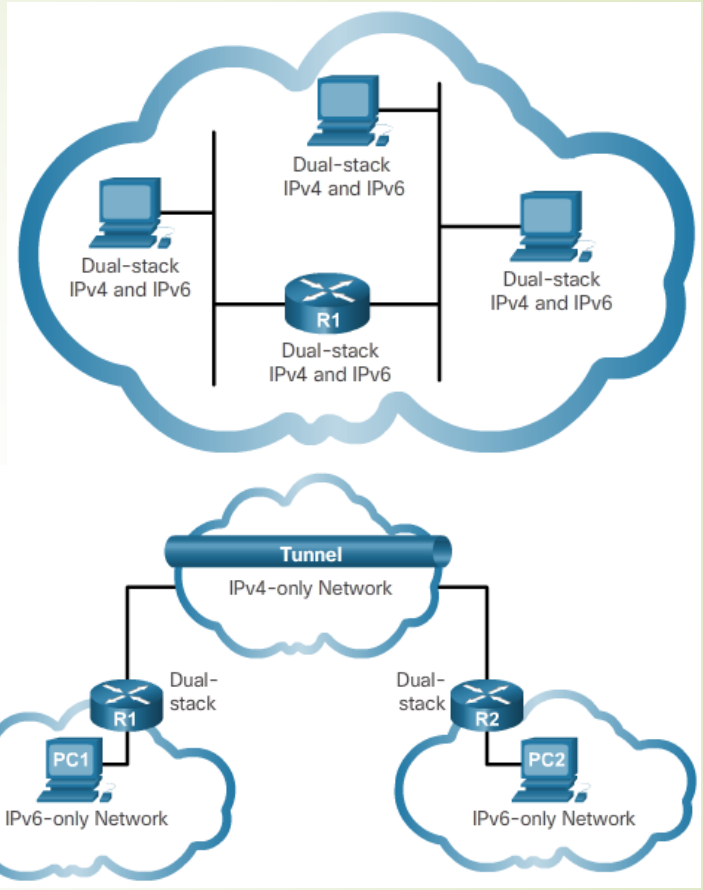
Types of IPv4 Addresses

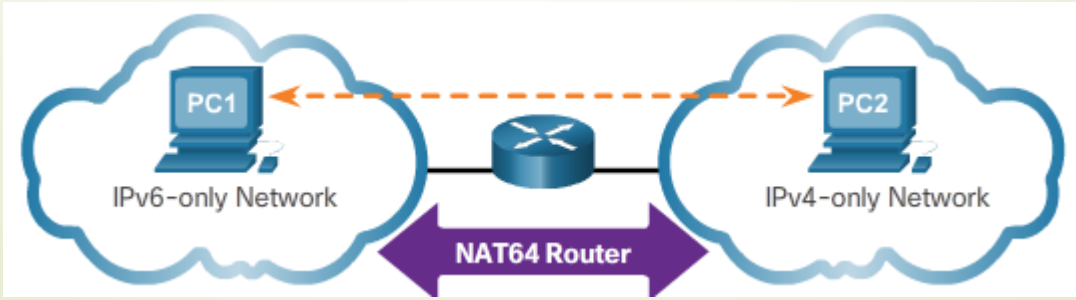
- Public and Private IPv4 Addresses
  - Private addresses are not routed over the Internet
  - Private Addresses:
    - 10.0.0.0/8 or 10.0.0.0 to10.255.255.255
    - 172.16.0.0 /12 or 172.16.0.0 to 172.31.255.255
    - 192.168.0.0 /16 or 192.168.0.0 to 192.168.255.255
- Special User IPv4 Addresses
  - 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
- Classless Addressing
  - CIDR
  - Allocated IPv4 addresses based on prefix length
- Assignment of IP Addresses



IPv4 Issues

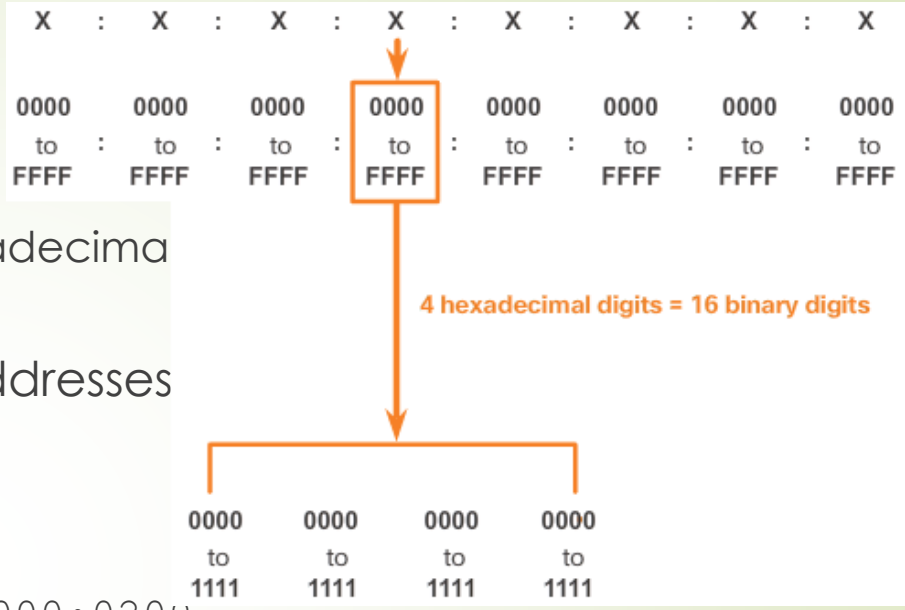
- The Need for IPv6
  - Depletion of IPv4 address space
  - Internet of Everything
- IPv4 and IPv6 Coexistence
  - Dual Stack – IPv4 and IPv6 on the same network
  - Tunneling – IPv6 packets inside IPv4 packets
  - Translation - IPv6 packet is translated to an IPv4 packet, and vice versa.





IPv6 Network Addresses

IPv6 Addressing



- IPv6 Address Representation
  - x:x:x:x:x:x:x:x, where x represents 4 hexadecima values
- Apply the rules to simply these IPv6 Addresses
  - Rule 1: Omit Leading 0s
  - Rule 2: Omit All 0 Segments
  - 2001:0DB8:0000:1133:0000:0000:0000:0200
  - 2001:0DB8:CAFE:0000:1111:0000:0000:0200
  - 2001:0DB8:000A:0000:0000:0000:0000:1000
  - 2001:0DB8:ACAD:1234:0000:0000:0000:0000
  - 2001:0DB8:0000:1111:0020:0000:ACAD:0000
  - FF02:0000:0000:0000:0000:0000:0000:0001
  - FE80:0000:0000:0000:0000:0000:0000:0003
  - 0000:0000:0000:0000:0000:0000:0000:0000

2800:BEBE:CA5A:002B:0001:0002:0000:000A

2800:BEBE:CA5A:2B:1:2.0:A

FE80:0000:0000:0000:0000:0000:0000:000A

FE80 0:0:0:0:0:0:A

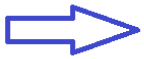
FE80 :: A

0:0:0:0:0:0:0:1 LOCAL HOST

:: 1

2800:0:0:0:B1:0:0:1

2800 :: B1:0:0:1



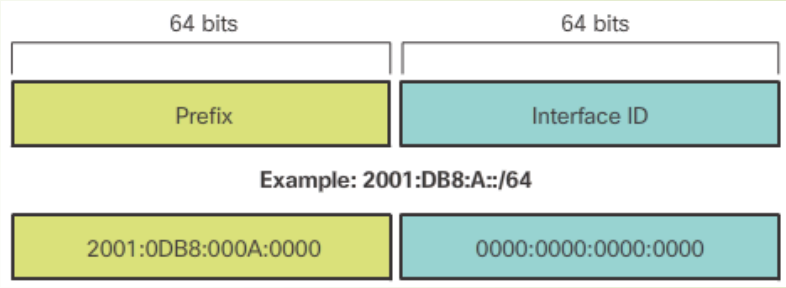
2800 :: B1:0:0:1

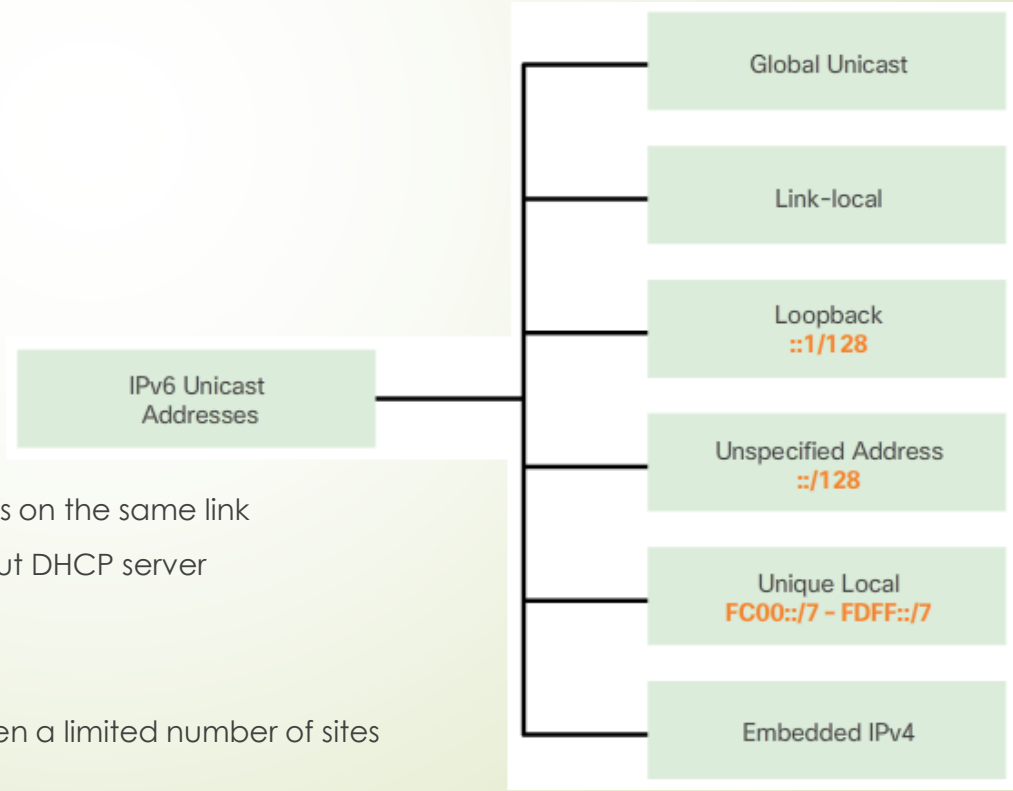
4 1
3 2 ?????
2 3
1 4

IPv6 Network Addresses

Types of IPv6 Addresses

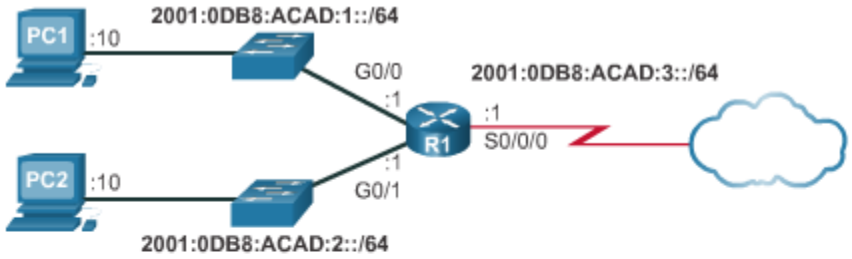
- IPv6 Address Types
  - Unicast
  - Multicast
  - Anycast
- IPv6 Prefix Length
  - Indicates the network portion
  - Format: IPv6 address /prefix length
  - Prefix length range from 0 to 128
  - Typical length is /64
- Common Types of IPv6 Addresses
  - Unicast Addresses
  - Unique, Internet routable addresses
  - Configured statically or assigned dynamically
  - Link-Local Unicast Addresses
  - Communicate with other IPv6 enabled devices on the same link
  - Device creates its own link local address without DHCP server
  - Unique Local Addresses
  - Unique local unicast
  - Used for local addresses within a site or between a limited number of sites



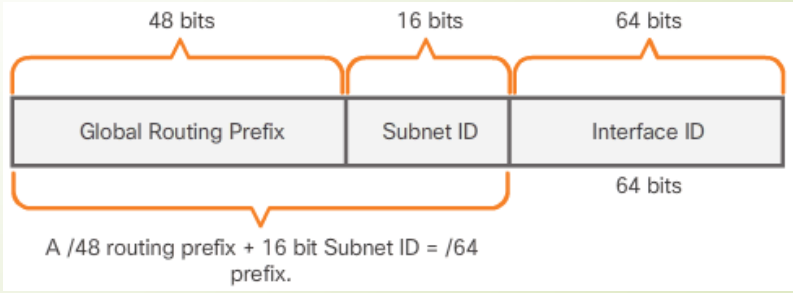


IPv6 Unicast Addresses

- Structure of an IPv6 Global Unicast Address
  - Global Routing Prefix
  - Subnet ID
  - Interface ID
- Static Configuration of a Global Unicast Address
  - **ipv6 address** *ipv6-address/prefix-length*
- Dynamic Configuration
  - SLAAC
  - DHCPv6
- Link-Local Addresses
  - Dynamic or Static
- Verifying IPv6 Address Configuration
  - show ipv6 interface brief




```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ipv6 address 2001:db8:acad:1::1/64
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#interface gigabitethernet 0/1
R1(config-if)#ipv6 address 2001:db8:acad:2::1/64
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#interface serial 0/0/0
R1(config-if)#ipv6 address 2001:db8:acad:3::1/64
R1(config-if)#clock rate 56000
R1(config-if)#no shutdown
```



Global-->

2000::/3 --> IETF

0010 0000 0000 0000

0010 = 2

0011 = 3

Prefijo + Interface

/64

Prefijo + Subred + Interface

48 16 64

Prefijo = /3 /12 /32 /48

IANA --> RIRs (ARIN, LACNIC, etc)

2000::/12 = 512 partes

2800::/12 --> LACNIC

2800::/12

LACNIC --> ISPs, End users, etc

2800:0000::/32

1´048.576 bloques /32 --> ISP

ISP --> End users, empresas, etc

2800:0000:0000::/48

65.536 bloques /48

End User --> redes, subredes, vlans

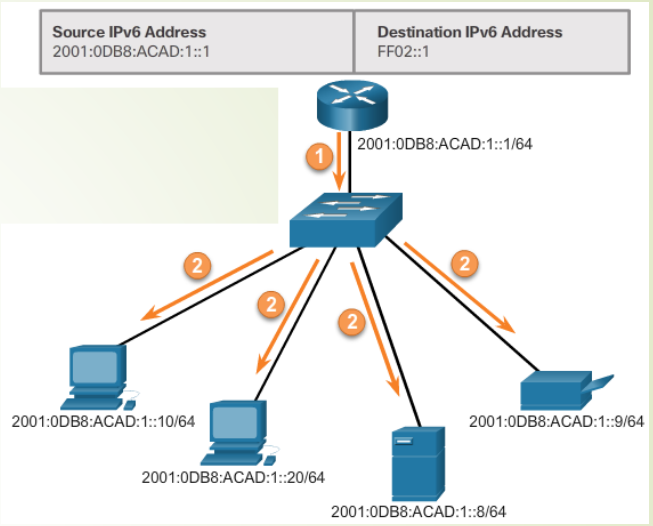
2800:0000:0000:0000::/64

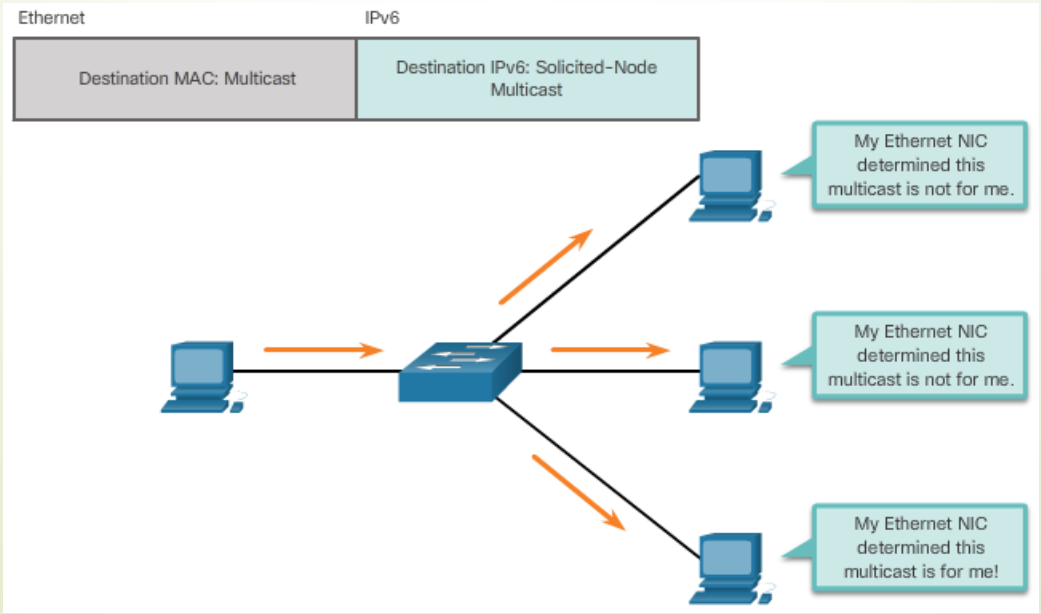
65.536 subredes

cada subred tiene 18 trillones de direcciones para los hosts !!!!

IPv6 Multicast Addresses

- Assigned IPv6 Multicast Addresses
  - IPv6 multicast addresses have the prefix FF00::/8
  - FF02::1 All-nodes multicast group
  - FF02::2 All-routers multicast group
- Solicited-Node IPv6 Multicast Addresses





Connectivity Verification

ICMP

- ICMPv4 and ICMPv6
  - Host Confirmation
  - Destination or Service Unreachable
  - Time Exceeded
  - Router Redirection
- ICMPv6 Router Solicitation and Router Advertisement Messages
  - Messaging between an IPv6 router and an IPv6 device:
  - Router Solicitation (RS) message
  - Router Advertisement (RA) message
  - Messaging between IPv6 devices:
  - Neighbor Solicitation (NS) message
  - Neighbor Advertisement (NA) message
  - Duplicate Address Detection (DAD)