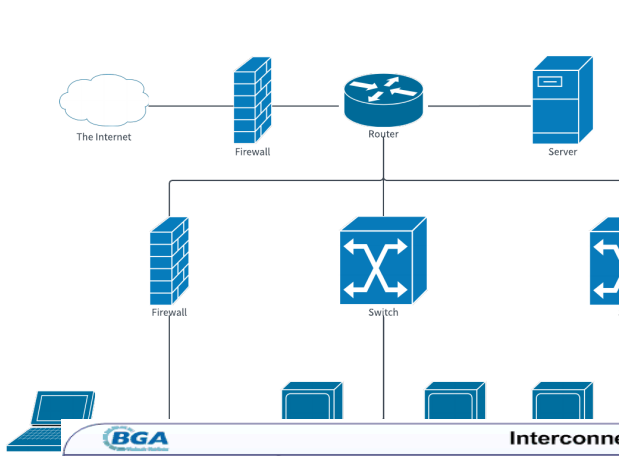
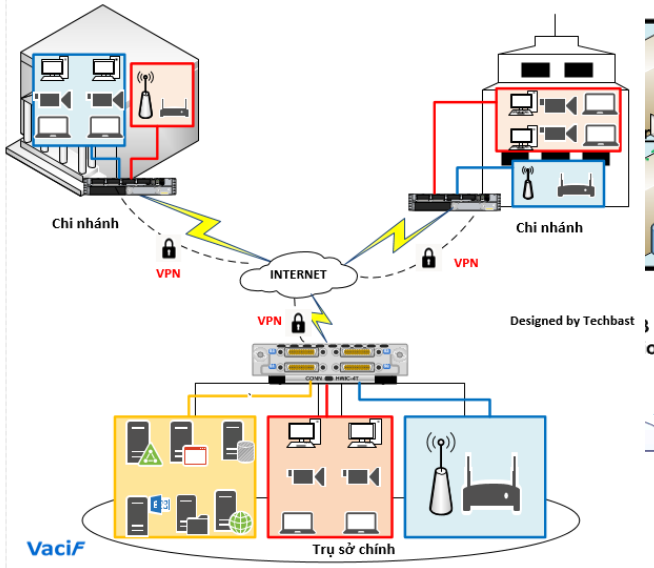
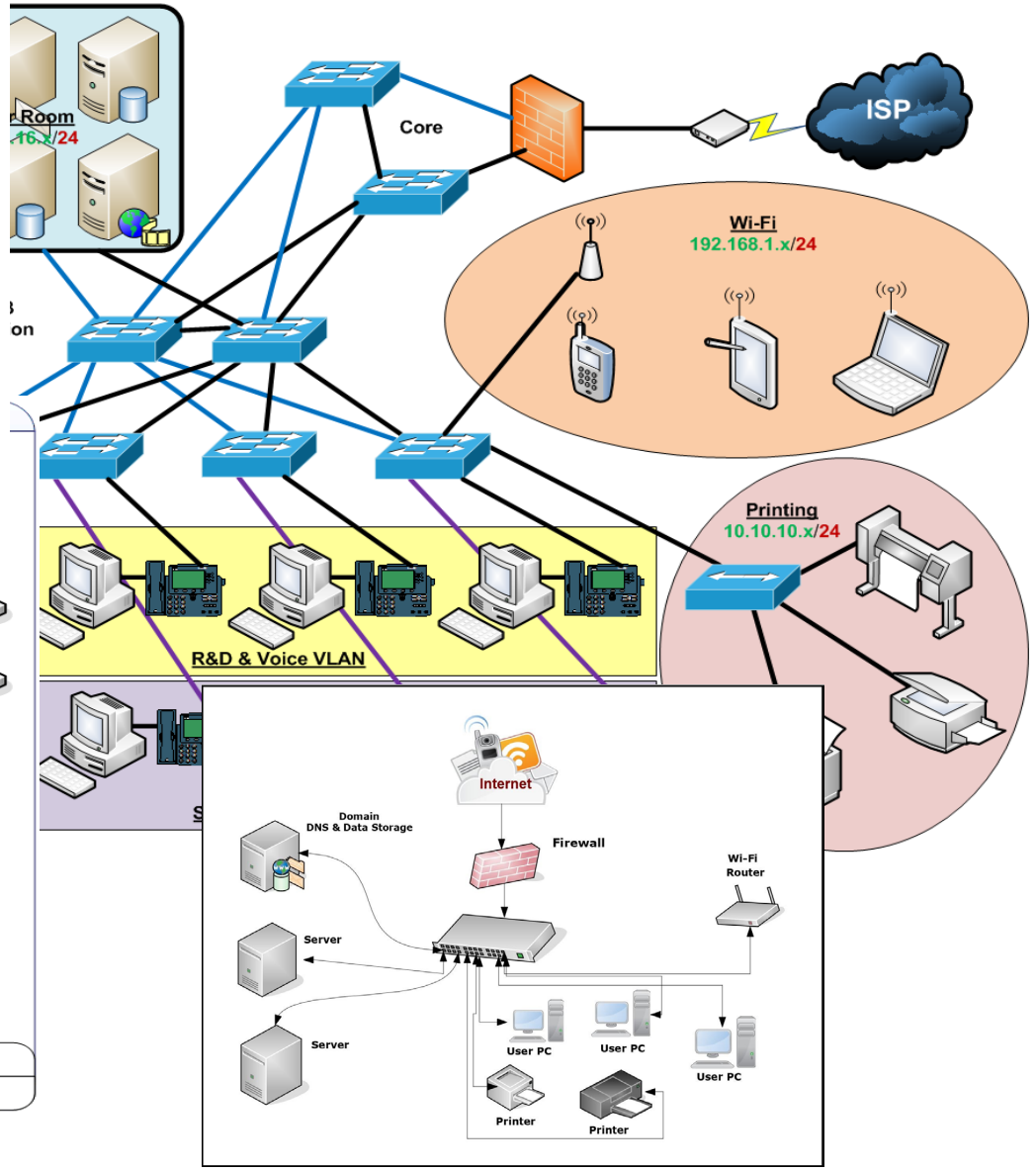
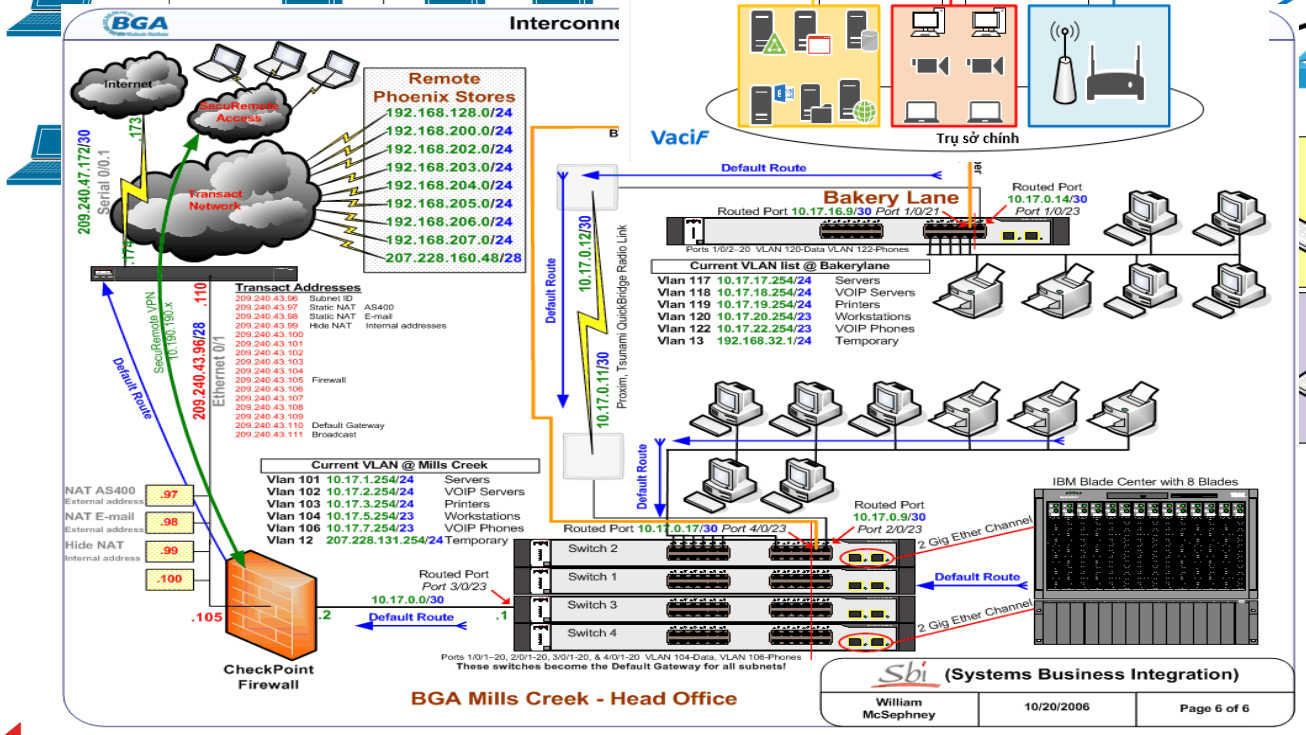
Routing


The Internet
Firewall
Router
Server
Firewall
Switch


Chi nhánh
Chi nhánh
VPN
INTERNET
VPN
VPN
Designed by Techbast
Trụ sở chính
VaciF


Core
ISP
Wi-Fi
192.168.1.x/24
Printing
10.10.10.x/24
R&D & Voice VLAN
Internet
Domain
DNS & Data Storage
Firewall
Wi-Fi
Router
Server
Server
User PC
User PC
User PC
Printer
Printer


BGA
Internet
Remote
Phoenix Stores
192.168.128.0/24
192.168.200.0/24
192.168.202.0/24
192.168.203.0/24
192.168.204.0/24
192.168.205.0/24
192.168.206.0/24
192.168.207.0/24
207.228.160.48/28
Transact Network
209.240.47.172/30
Serial 0/0.1
Transact Addresses
Default Route
Ethernet 0/1
209.240.43.96/28
Bakery Lane
Routed Port 10.17.16.9/30 Port 1/0/21
Routed Port 10.17.0.14/30 Port 1/0/23
Current VLAN list @ Bakerylane
Vlan 117 10.17.17.254/24 Servers
Vlan 118 10.17.18.254/24 VOIP Servers
Vlan 119 10.17.19.254/24 Printers
Vlan 120 10.17.20.254/23 Workstations
Vlan 122 10.17.22.254/23 VOIP Phones
Vlan 13 192.168.32.1/24 Temporary
10.17.0.12/30
10.17.0.11/30
Current VLAN @ Mills Creek
Vlan 101 10.17.1.254/24 Servers
Vlan 102 10.17.2.254/24 VOIP Servers
Vlan 103 10.17.3.254/24 Printers
Vlan 104 10.17.5.254/23 Workstations
Vlan 106 10.17.7.254/23 VOIP Phones
Vlan 12 207.228.131.254/24 Temporary
NAT AS400
NAT E-mail
Hide NAT
Routed Port 10.17.0.17/30 Port 4/0/23
Routed Port 10.17.0.9/30 Port 2/0/23
IBM Blade Center with 8 Blades
Switch 2
Switch 1
Switch 3
Switch 4
2 Gig Ether Channel
Routed Port Port 3/0/23 10.17.0.0/30
CheckPoint Firewall
BGA Mills Creek - Head Office
Sbi (Systems Business Integration)
William McSephney
10/20/2006
Page 6 of 6

House Keeping

INFO-6047 Switching and Routing

ISM1 - Information Security Management (ISM1-ITY-20189) Detailed Weekly Content

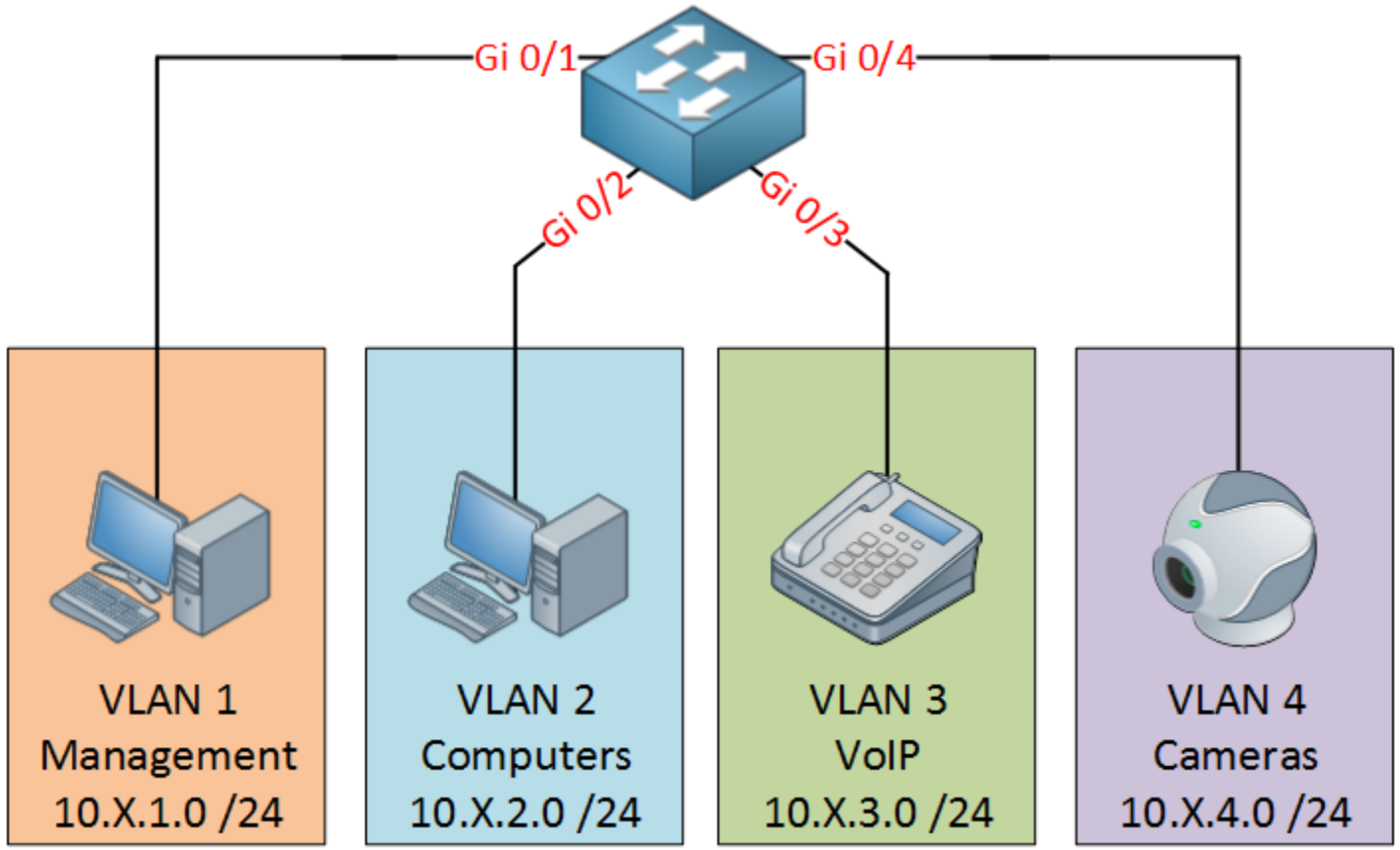
Week	Date of Lecture or Tests, 7:00 – 9:00 PM EST	Lecture/Test	Reading	Lab Time INFO-6047-01 Wednesday 5:00 – 8:00 PM EST INFO-6047-02 Tuesday 5:00 – 8:00 PM EST	Grade
Week 01	Monday, January 02, 2023	College-Wide Orientation			
Week 02	Monday, January 09, 2023	Introduction	N/A	Lab 01 - Basics of PT	3.0%
Week 03	Monday, January 16, 2023	Basics of Routing	**Chapter 01 & 02** *(Introduction to Networking, Network Media Copper)*	Lab 02 - Intro to Routing	3.0%
Week 04	Monday, January 23, 2023	Basics of Switching	**Chapter 03 & 04** *(Network Media Fiber Network Media Wireless)*	Lab 03 - Intro to Switching	3.0%
Week 05	Monday, January 30, 2023	VLANs	**Chapter 05** *(Data Encoding & Transmistion)*	Lab 04 - VLANs	3.0%
Week 06	Monday, February 06, 2023	Routing	**Chapter 06** *(Network OS & Comunications)*	Lab 05 - Routing	3.0%
Week 07	Monday, February 13, 2023	Mid-Term Test		Mid-Term (Test 1)	32.0%
Study Break	Monday, February 20, 2023	Study Break - No Class This Week			
Week 08	Monday, February 27, 2023	Inter-VLAN Routing	**Chapter 10** *(TCP/IP Fundamentals)*	Lab 06 - Inter VLAN Routing	3.0%
Week 09	Monday, March 06, 2023	Static Routing	**Chapter 11** *(Subnetting)*	Lab 07 - Static & Default Routs	3.0%
Week 10	Monday, March 13, 2023	Dynamic Routing - RIP	**Chapter 12** *(Additional Transmission Modalities)*	Lab 08 - RIP Protocol	3.0%
Week 11	Monday, March 20, 2023	Dynamic Routing - OSPF	**Chapter 14** *(RA & LD Communications)*	Lab 09 - OSPF Protocol	3.0%
Week 12	Monday, March 27, 2023	Access Control Lists	**Chapter 15** *(Network Security)*	Lab 10 - ACLs	3.0%
Week 13	Monday, April 03, 2023	DHCP	**Chapter 16** *Maintaining the Network)*	Lab 11 - DHCP	3.0%
Week 14	Monday, April 10, 2023	NAT	**Chapter 17** *(Troubleshooting Fundamentals of a Network)*	Lab 12 - NAT	3.0%
Week 15	Monday, April 17, 2023	Final Test		Final Test (Test 2)	32%

Labs and quizzes will open Monday at 00:01 AM EST and the quiz will close Sunday at 23:59 PM EST.
Tuesday Section-02 from 5:00 – 8:00 PM EST and Wednesday Section-01 from 5:00 – 8:00 PM EST

FANSHAWE

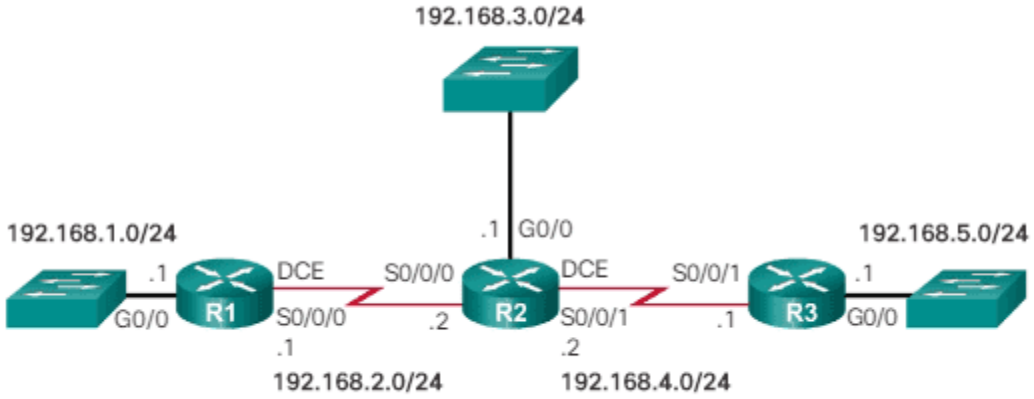
Review - Lecture 04 – VLANs

- Local Area Network (LAN)
- Solution Using Routers
- Solution Using VLANs
- VLANs
- Trunks
- Native VLAN
- Configure Trunk Port
- Configuring VLAN/Trunks
- DTP (**D**ynamic **T**runk **P**rotocol)
- VLAN Security
- VLAN Design Guidelines

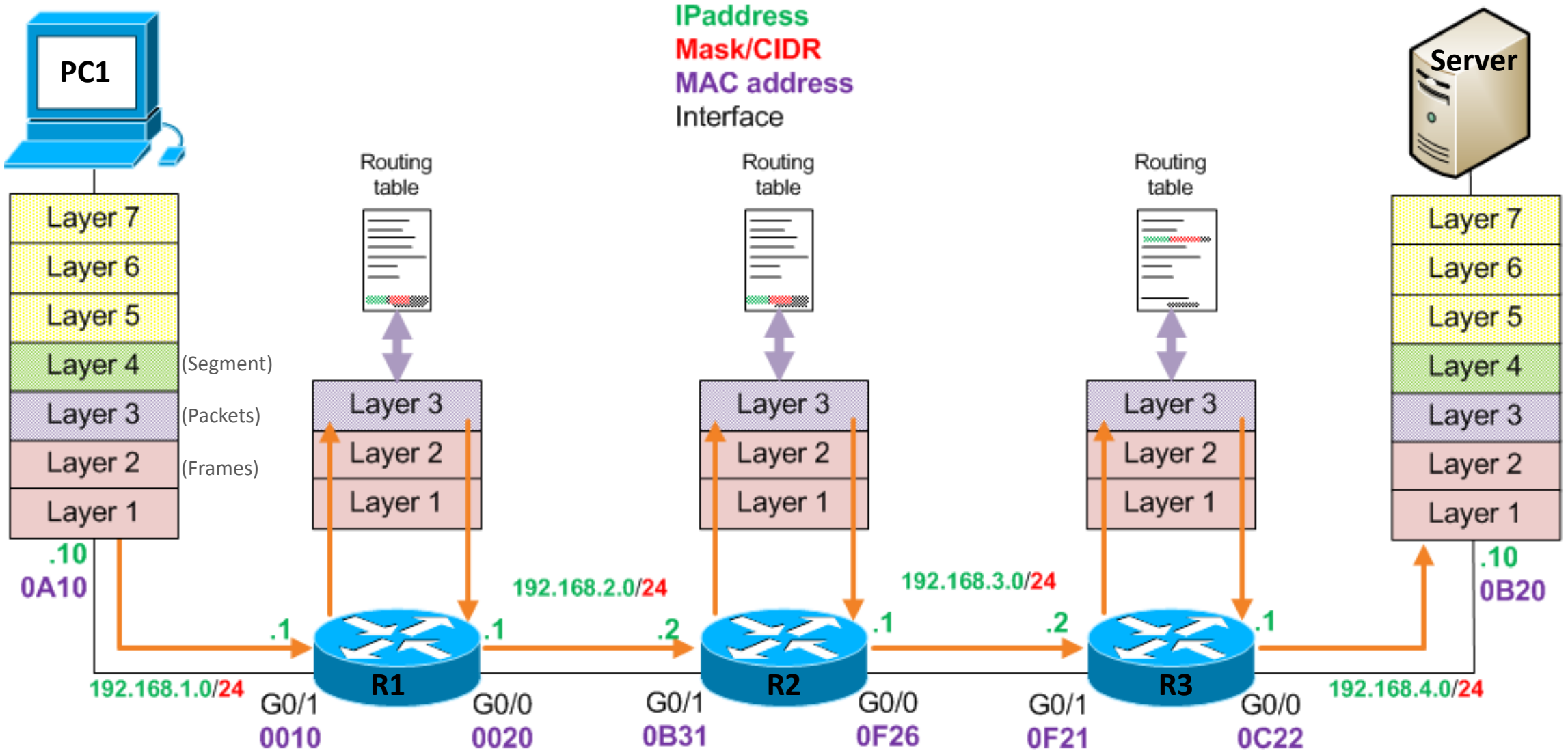


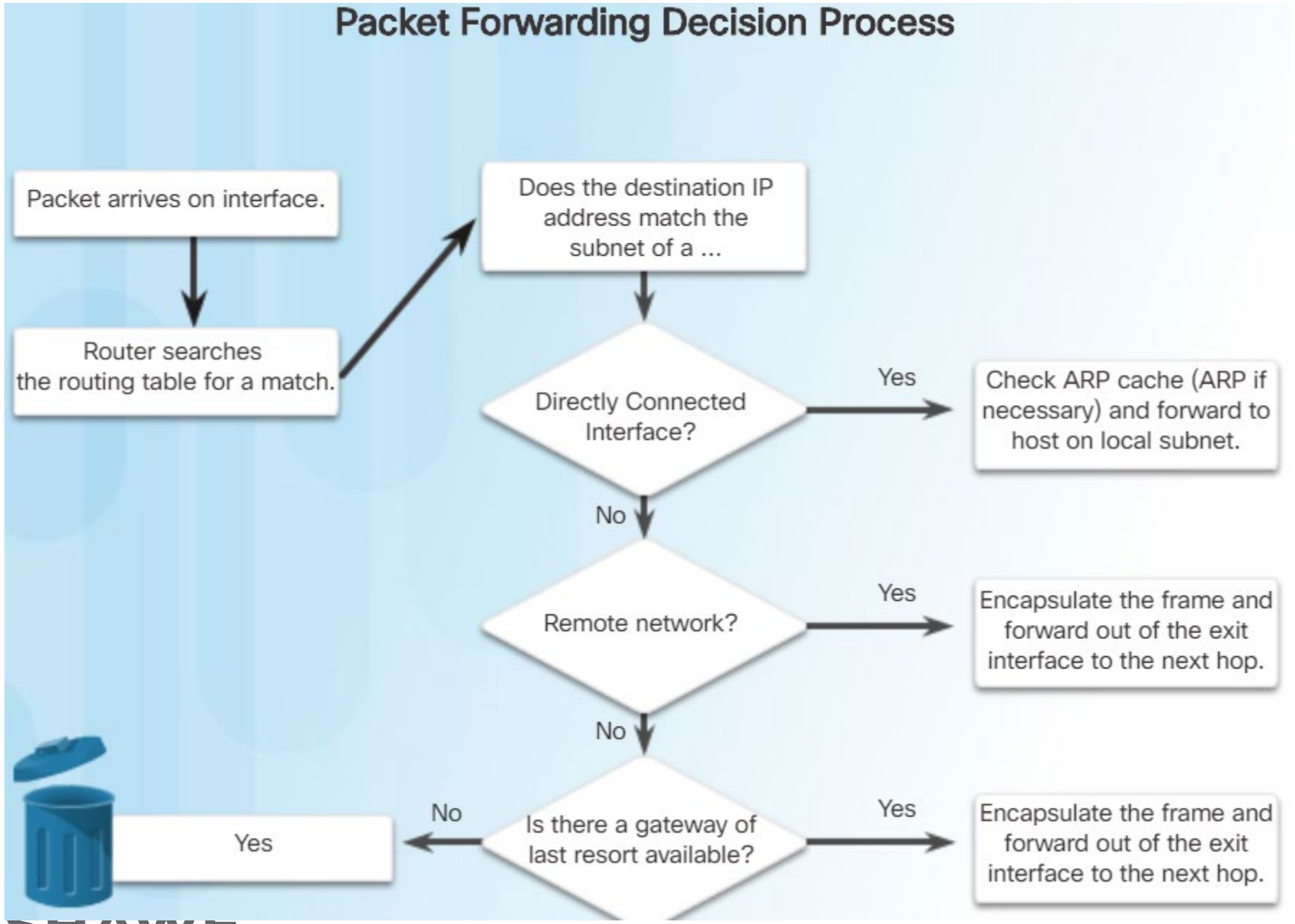
Summery - Routing

- Layer 3 / Routing
- Interface Addressing
- Default Gateway
- IP Addressing
- Routers
- Router Configuration
- Lab



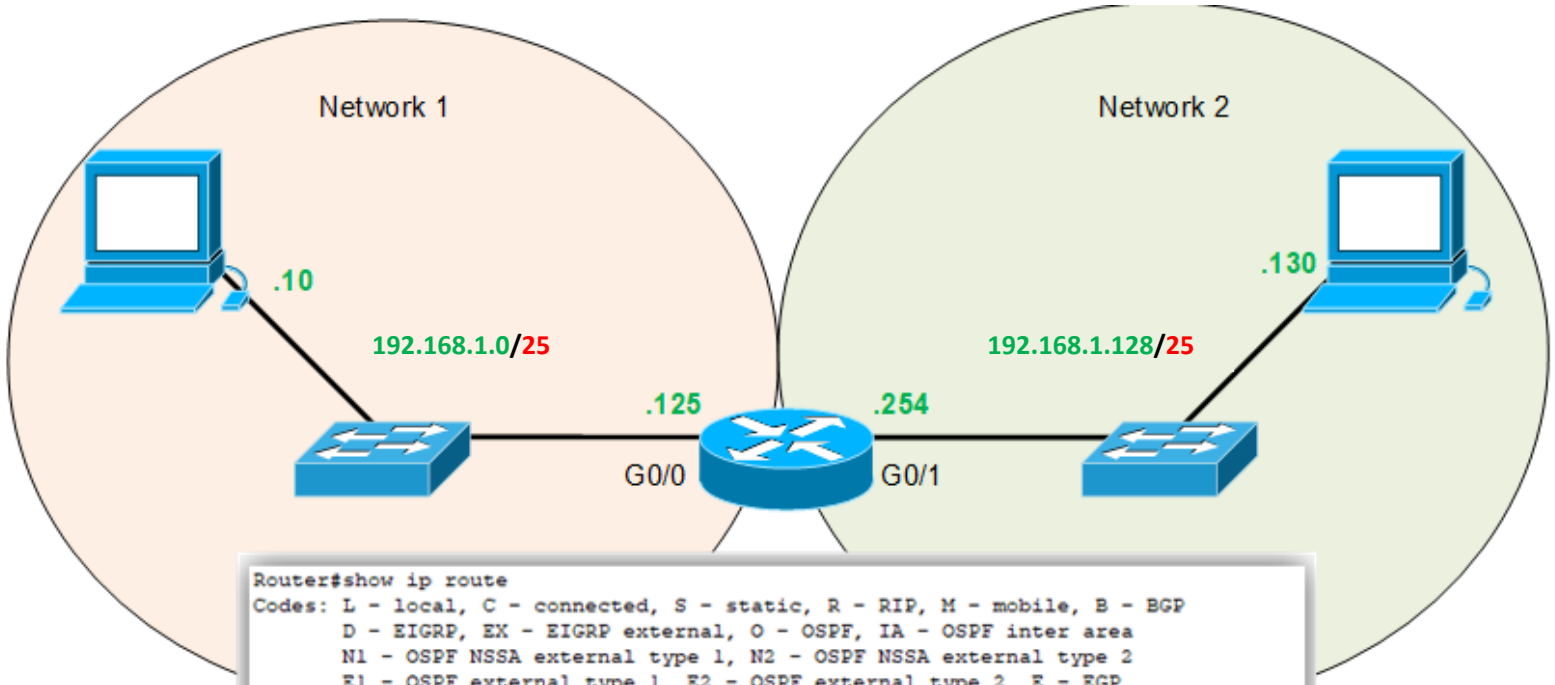
Layer 3 / Routing




Packet Forwarding Decision Process
Packet arrives on interface.
Router searches the routing table for a match.
Does the destination IP address match the subnet of a ...
Directly Connected Interface?
Yes
Check ARP cache (ARP if necessary) and forward to host on local subnet.
No
Remote network?
Yes
Encapsulate the frame and forward out of the exit interface to the next hop.
No
Is there a gateway of last resort available?
No
Yes
Yes
Encapsulate the frame and forward out of the exit interface to the next hop.

Layer 3 / Routing (Continued)

- The router is responsible for the routing of traffic between **networks**!



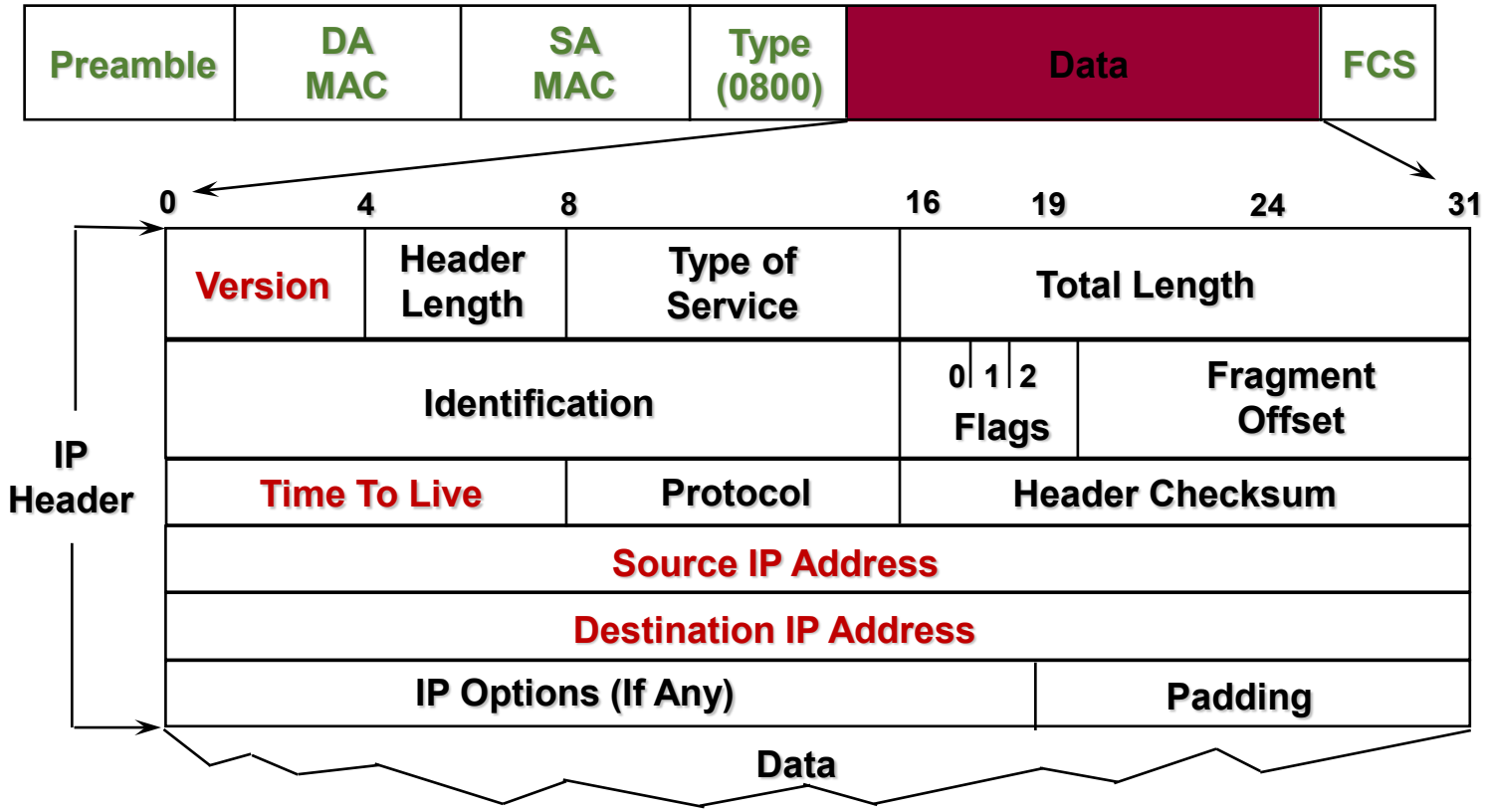

```
Router#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.1.0/24 is directly connected, GigabitEthernet0/0
L       192.168.1.254/32 is directly connected, GigabitEthernet0/0
     192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.2.0/24 is directly connected, GigabitEthernet0/1
L       192.168.2.254/32 is directly connected, GigabitEthernet0/1
```

Layer 3 / Routing (Continued)

- **Most Common Protocols at L3**
  - **Routing** protocols include and more (RIP, RIPv2, OSPF2, OSPF3, IGRP, EIGRP, BGP…..)
  - CLNP Connectionless Networking Protocol
  - IPX Internetwork Packet Exchange
  - **NAT** Network Address Translation
  - Routed-SMLT
  - SCCP Signaling Connection Control Part
  - **AppleTalk** DDP
  - HSRP Hot Standby Router protocol
  - VRRP Virtual Router Redundancy Protocol
  - **IP** Internet Protocol
  - **ICMP** Internet Control Message Protocol
- **Two versions of IP**
  - Version **4** (number of addresses 4,294,967,296 (4 billion))
  - Version **6** (number of addresses 340,282,366,920,938,463,463,374,607,431,768,211,456 (340 undecillion))

Interface Addressing

- Datagram L2 (Frames)
- Internet Protocol (IP) L3 packet contains fields that provide information about the packet and the sending and receiving hosts (Packets)
- Fields that are important: (for routing)



Remember everything in green gets removed or added as the packet moves through L2

Interface Addressing (continued)

- **Statically Assigned IP address** – The host is manually assigned an IP address, subnet mask and default gateway
  - Used to identify specific network resources such as network servers and printers
  - Can be used in small networks with few hosts

```
RT-1(config-if)# interface GigabitEthernet0/0
RT-1(config-if)# ip address 192.168.1.254 255.255.255.0
```

- **Dynamically Assigned IP Address** – IP Address information is dynamically assigned by a server using Dynamic Host Configuration Protocol (DHCP)
  - Most hosts acquire their IP address information through DHCP
  - DHCP services can be provided by Cisco routers
  - Or can use DHCP to receive and address for this interface

```
RT-1(config-if)# interface GigabitEthernet0/1
RT-1(config-if)# ip address dhcp
```

Default Gateway

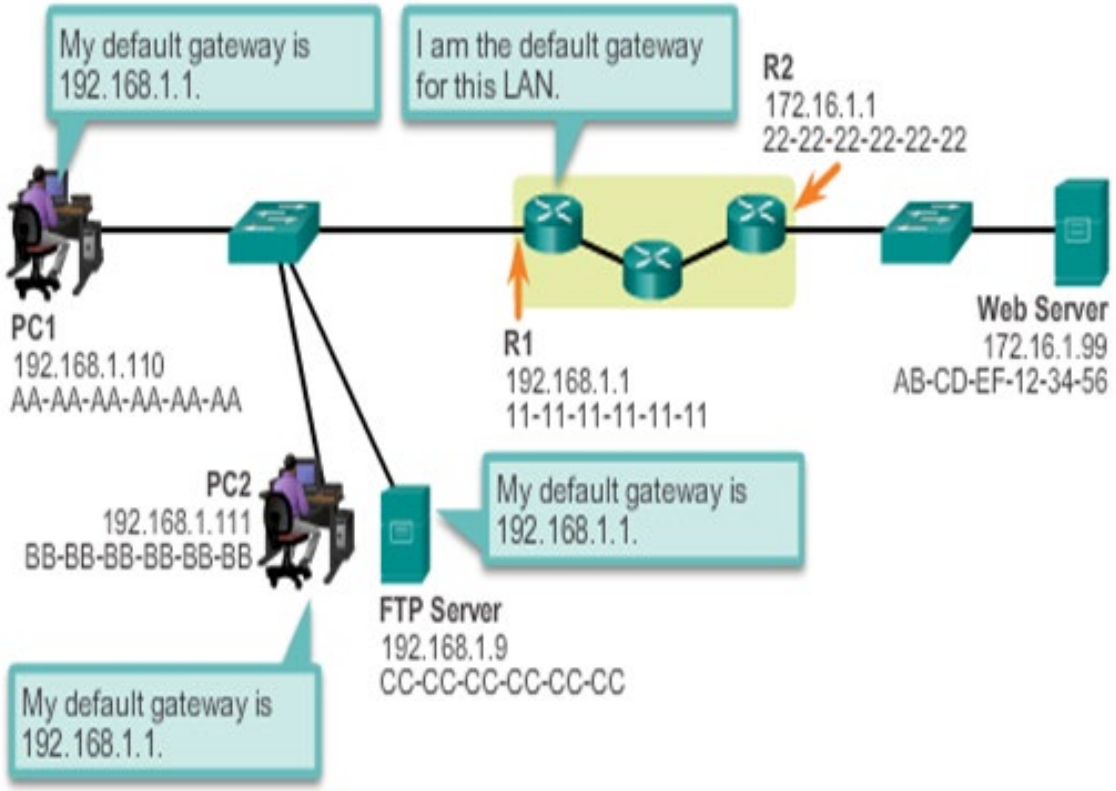
- To enable network access devices must be configured with IP address information
  - **IP address** - Identifies a unique host on a local network
  - **Subnet mask** - Identifies the host's network subnet
  - **Default gateway** - Identifies the router a packet is sent to when the destination is not on the same local network subnet

    This is one of the few commands to add a default gateway on a router

RT-1(config)# ip route 0.0.0.0 0.0.0.0 192.168.1.1

any address / any mask / go to next hop

Destination MAC Address	Source MAC Address	Source IP Address	Destination IP Address	Data
11-11-11-11-11-11	AA-AA-AA-AA-AA-AA	192.168.1.110	172.16.1.99	



IP Addressing

- IPv4

0000 0000 . 0000 0000 . 0000 0000 /. 0000 0000

Each group of 8 bits above, is counted in Binary the same way!

128 64 32 16 8 4 2 1 = Adding these bit values together equals the decimal value between 0 and 255 depending on which bits are set to "1"

0000 0000

HEX 0 1

Each bit of the 8, is represented by the digit above that bit. (the digit above the bit is the decimal value represented by that bit)

If you do not understand IPv4 addressing, PLEASE watch the video in FOL - - > Content - - > Other Resources - - > **Videos**

IP Addressing (continued)

- Classful Addressing
  - Only in IPv4 does **Classful** exist. (not see much these days)

Class	HOB	NET ID Bits	Host ID Bits	No of Networks	Host Per Network	Start Address	End Address
Class A	0	8	24	2^7=128	2^{24}=16,777,216	0.0.0.0	127.255.255.255
Class B	10	16	16	2^{14}=16,384	2^{16}=65,536	128.0.0.0	191.255.255.255
Class C	110	24	8	2^{21}=2,097,152	2^8=256	192.0.0.0	223.255.255.255
Class D	1110	-	-	-	-	224.0.0.0	239.255.255.255
Class E	1111	-	-	-	-	240.0.0.0	255.255.255.255

- IPv6 is only classless.

If you do not understand IPv4 addressing, PLEASE watch the video in FOL - - > Content - - > Other Resources - - > **Videos**

IP Addressing (continued)

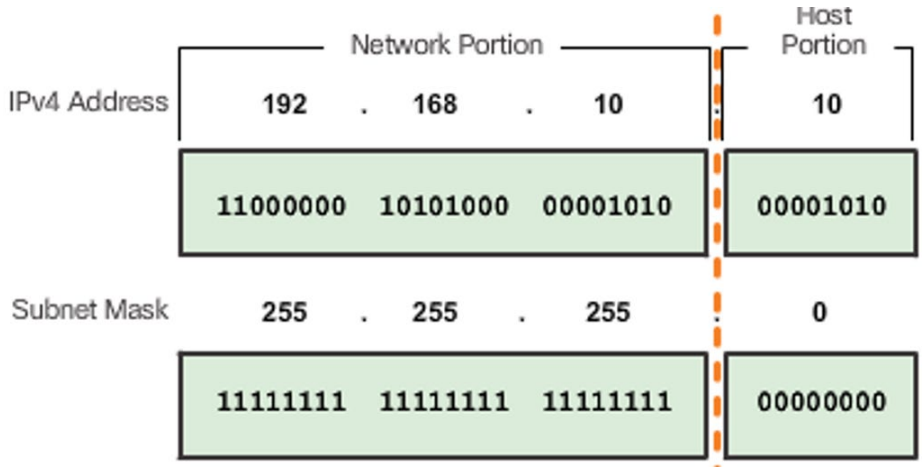
- Prefix Length
  - **C**lassless **I**nter-**D**omain **R**outing (CIDR) method of identifying a subnet mask.
  - It is the number of bits set to 1 in the subnet mask.
  - Written in “slash notation”, a “/” followed by the number of bits set to 1.

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

IP Addressing (continued)

- A network is defined by using a **mask** which is 32 bits (represented in dotted decimal notation) – subnet mask
- All ones indicate a valid network address in the network/subnet portion
- To determine the network portion must "**AND**" the IP address and the subnet mask – the result will be the network **(This is the mathematical AND)**
- 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.

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



IP Addressing (continued)

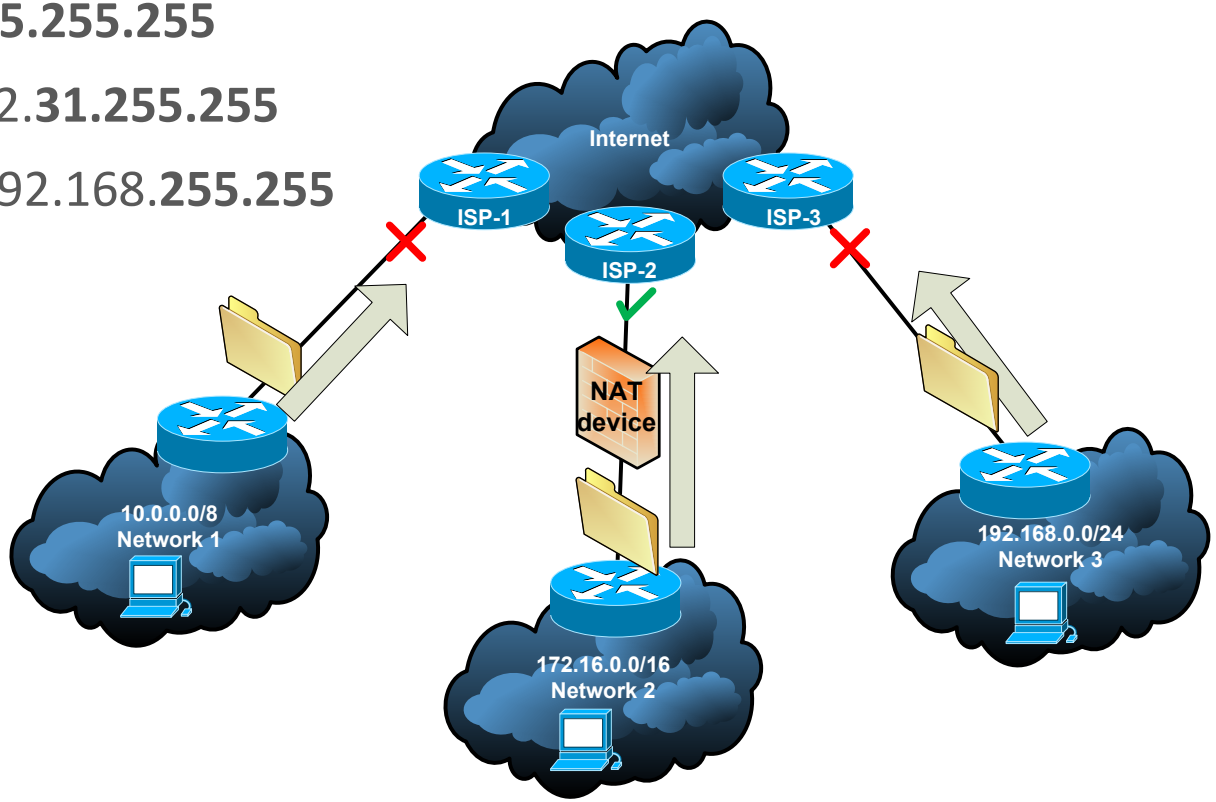
- Why Subnet
  - Break up broadcast domain into smaller manageable pieces
  - Allows easier management of the large address spaces especially in Class “A” and “B” networks
- How to Subnet
  - A subnet is defined by using a mask which is 32 bits
  - All ones indicate a valid network address in the network / subnet portion
  - The subnet portion consists of any number of leftmost significant host field bits used as network bits
  - Increase the number of binary ones in the subnet mask to the right to mask out the new subnet portion of the address that also identifies the network

If you do not understand IPv4 addressing, PLEASE watch the video in FOL - - > Content - - > Other Resources - - > **Videos**

IP Addressing (continued)

- 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**

Private addresses cannot be router over the Internet



IP Addressing (continued)

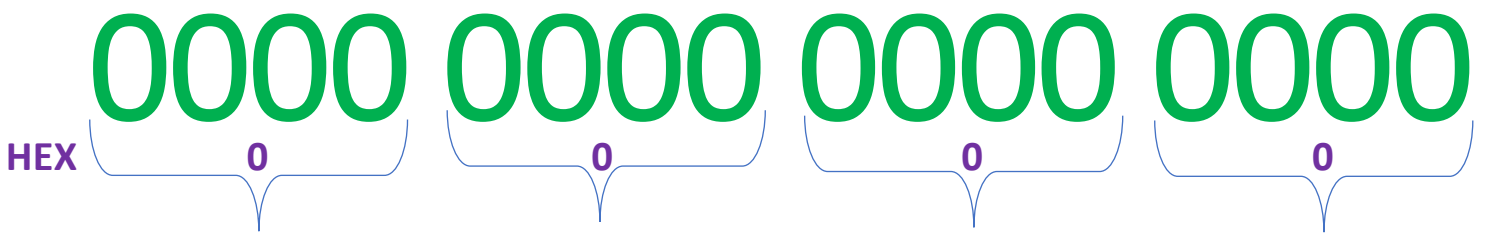
- IPv6

0000 0000 0000 0000 : 0000 0000 0000 0000 : 0000 0000 0000 0000 : 0000 0000 0000 0000 / : 0000 0000 0000 0000 : 0000 0000 0000 0000 : 0000 0000 0000 0000 : 0000 0000 0000 0000

Lets look at just one Hextet for the moment

Wow! This is going to be so hard, look at how big this binary number is….

Don't Panic! Break it down in to smaller parts… Each of the 8 Hextet works the same way



Lets breaking it down further, each group of 4 bits works the same way!

Wow, now look how simple this is, each one of the sections of 4 binary bits can only be one of the 16 number (0-F) from this table: (now we are counting to 15 in hex - instead of 255 in decimal)

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

Rule 1 – Omit Leading Os

The first rule to help reduce the notation of IPv6 addresses is to omit any leading 0s (zeros) in any in any 16-bit section (hextet). Here are four examples of ways to omit leading zeros:

- 01ab can be represented as 1ab
- 09f0 can be represented as 9f0
- 0a00 can be represented as a00
- 00ab can be represented as ab

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

This rule only applies to leading 0s, NOT to trailing 0s, otherwise the address would be ambiguous. For example, the hextet “abc” could be either “0abc” or “abc0”, but these do not represent the same value.

Rule 2 – Omit All 0 Segments

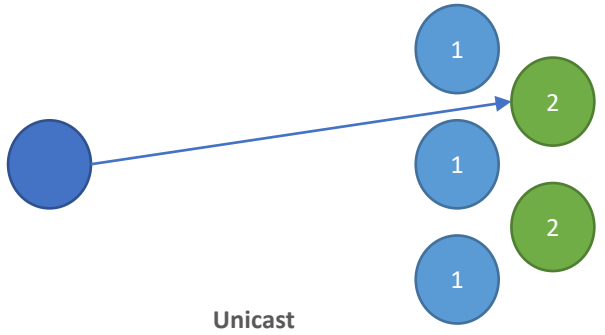
The second rule to help reduce the notation of IPv6 addresses is that a double colon (::) can replace any group of consecutive zeros. The double colon (::) can only be used once within an address, otherwise there would be more than one possible resulting address.

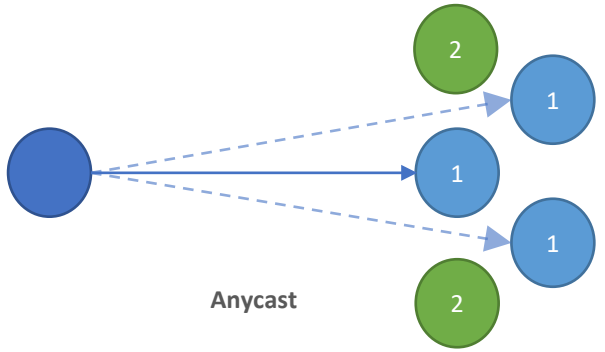
Fully expanded	2001:0db8:0000:1111:0000:0000:0000:0200
No leading 0s	2001: db8: 0:1111: 0: 0: 0: 200
Compressed	2001:db8:0:1111::200

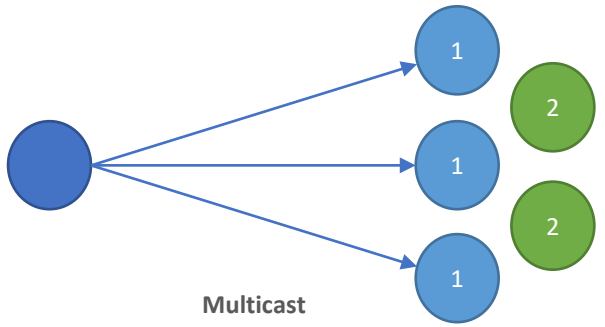
Fully expanded	fe80:0000:0000:0000:0123:4567:89ab:cdef
No leading 0s	fe80: 0: 0: 0: 123:4567:89ab:cdef
Compressed	fe80::123:4567:89ab:cdef

IP Addressing (continued)

- IPv6 Address Types
- There are three types of IPv6 addresses:
  - Unicast
  - Anycast
  - Multicast



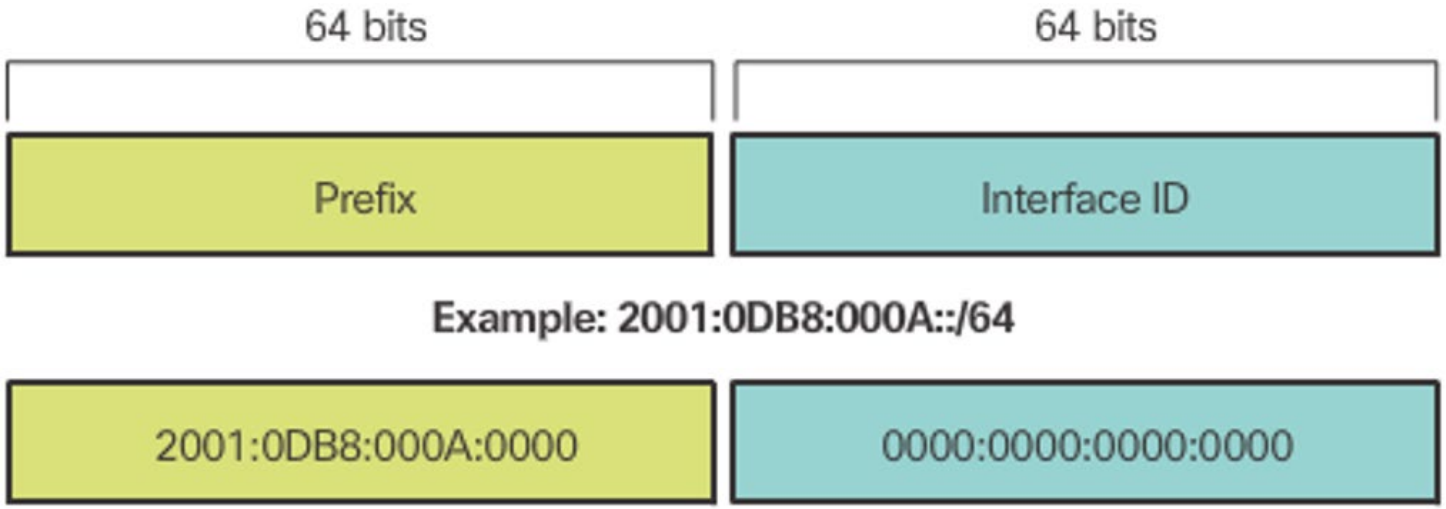




Note: IPv6 does not have **broadcast** addresses

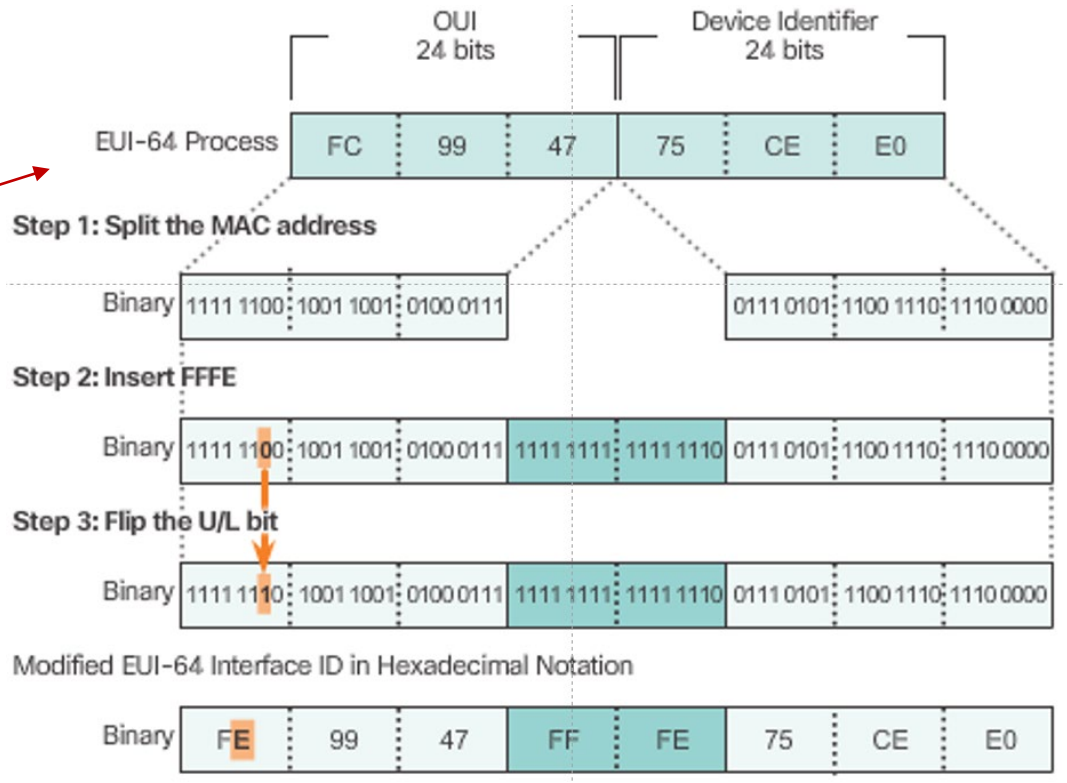
IP Addressing (continued)

- 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 (18 446 744 073 709 551 616 addresses.)



IP Addressing (continued)

- EUI-64 Process and Randomly Generated
  - **E**xtended **U**nique **I**dentifier
  - EUI-64 Process
  - 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

```
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

IP Addressing (continued)

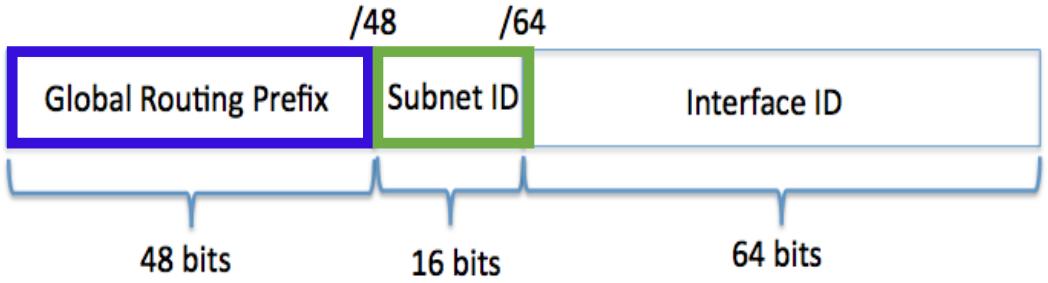
- Subnetting IPv6
  - Just increment by 1 in Hexadecimal:

    2001:0DB8:ACAD::/64

    2001:0DB8:ACAD:0001::/64

    2001:0DB8:ACAD:0002::/64

    2001:0DB8:ACAD:0003::/64



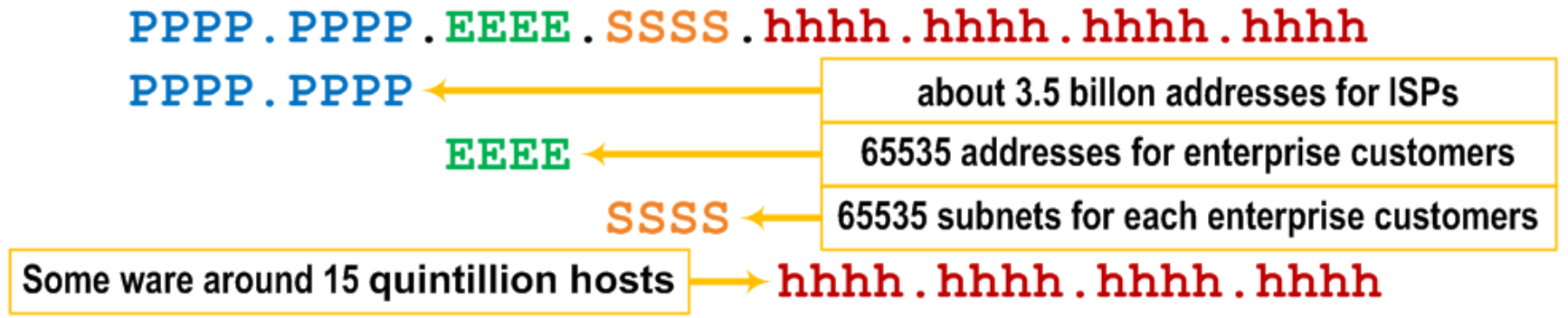
  - Valid abbreviation is to remove the 3 leading 0's from the first shown hextet

    2001:DB8:ACAD:1::/64

IP Addressing (continued)

IPv6 - 340 undecillion addresses ($1x10^{36}$)

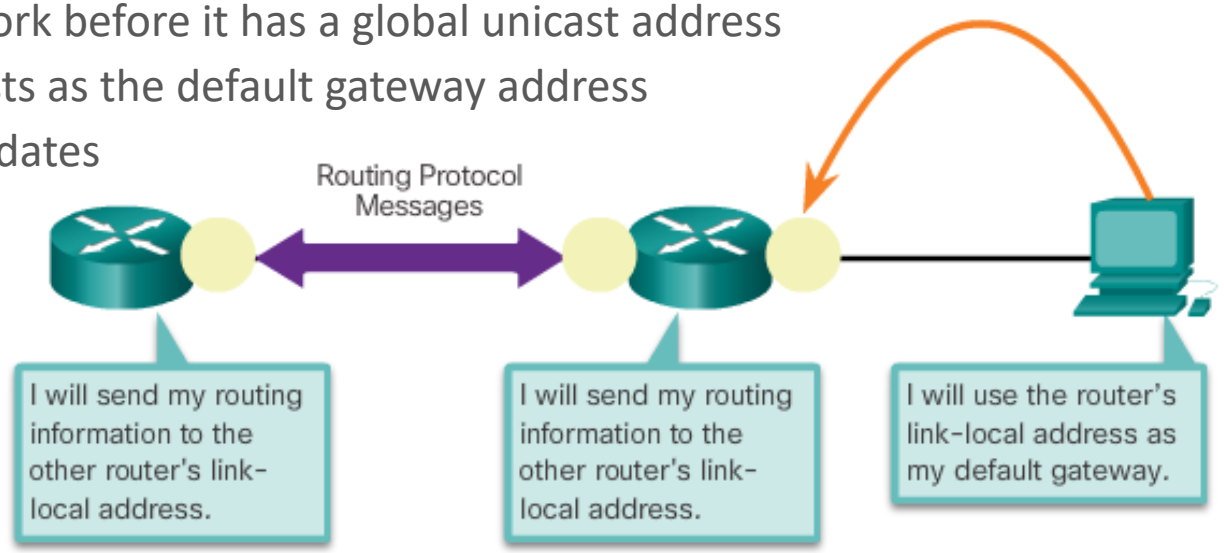
- IPv6 Special address blocks



Address block (CIDR)	First address	Last address	Number of addresses	Usage	Purpose
::/0	::	ffff:ffff:ffff:ffff:ffff:ffff:ffff:ffff	2^{128}	Routing	Default route.
::/128	::		1	Software	Unspecified address.
::1/128	::1		1	Host	Loopback address to the local host.
::ffff:0:0/96	::ffff:0.0.0.0	::ffff:255.255.255.255	2^{32} 4,294,967,296	Software	IPv4 mapped addresses.
::ffff:0:0:0/96	::ffff:0:0.0.0.0	::ffff:0:255.255.255.255	2^{32}	Software	IPv4 translated addresses.
64:ff9b::/96	64:ff9b::0.0.0.0	64:ff9b::255.255.255.255	2^{32}	Global Internet	IPv4/IPv6 translation.
100::/64	100::	100::ffff:ffff:ffff:ffff	2^{64}	Routing	Discard prefix.
2001::/32	2001::	2001::ffff:ffff:ffff:ffff:ffff:ffff	2^{96}	Global Internet	Teredo tunneling.
2001:20::/28	2001:20::	2001:2f:ffff:ffff:ffff:ffff:ffff:ffff	2^{100}	Software	ORCHIDv2.
2001:db8::/32	2001:db8::	2001:db8:ffff:ffff:ffff:ffff:ffff:ffff	2^{96}	Documentation	Addresses used in documentation and example source code.
2002::/16	2002::	2002:ffff:ffff:ffff:ffff:ffff:ffff:ffff	2^{112}	Global Internet	The 6to4 addressing scheme (now deprecated).
fc00::/7	fc00::	fdff:ffff:ffff:ffff:ffff:ffff:ffff:ffff	2^{121}	Private network	Unique local address.
fe80::/10	fe80::	febf:ffff:ffff:ffff:ffff:ffff:ffff:ffff	2^{118}	Link	Link-local address.
ff00::/8	ff00::	ffff:ffff:ffff:ffff:ffff:ffff:ffff:ffff	2^{120}	Global Internet	Multicast address.

IP Addressing (continued)

- Link-local unicast
  - Used to communicate with other devices on the link (subnet)
  - Are NOT routable off the link (subnet)
  - Only have to be unique on the link (subnet)
  - Are not included in the IPv6 routing table
  - An IPv6 device must have a link-local address
  - Used by:
    - Hosts to communicate on the IPv6 network before it has a global unicast address
    - Router's link-local address is used by hosts as the default gateway address
    - Adjacent routers to exchange routing updates



IP Addressing (continued)

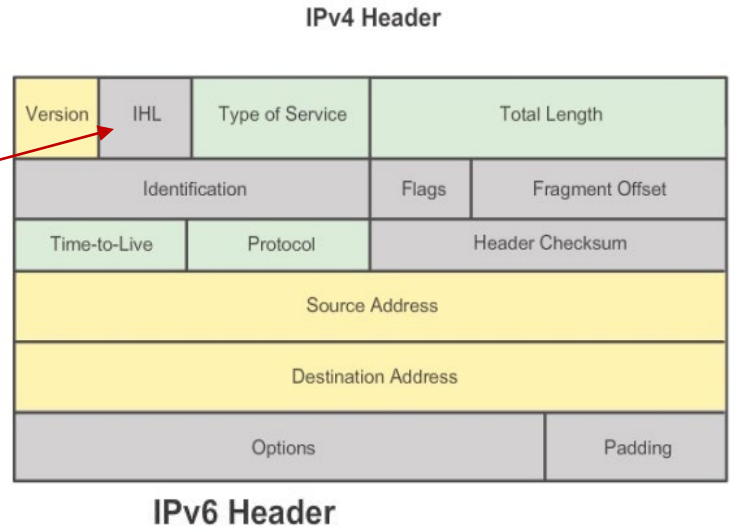
- Types of IPv6 Addresses
  - **Multicast Address**
    - A Multicast address identifies a group of interfaces
    - All Multicast address are identified by their reserved address range FF00::0/8
    - A packet sent to a multicast address is delivered to all devices that are identified by that address

Protocol	IPv4 Multicast	IPv6 Multicast
OSPF (Router)	224.0.0.5	FF02::5
OSPF (DR/BDR)	224.0.0.6	FF02::6
RIPv2	224.0.0.9	FF02::9
EIGRP	224.0.0.10	FF02::A

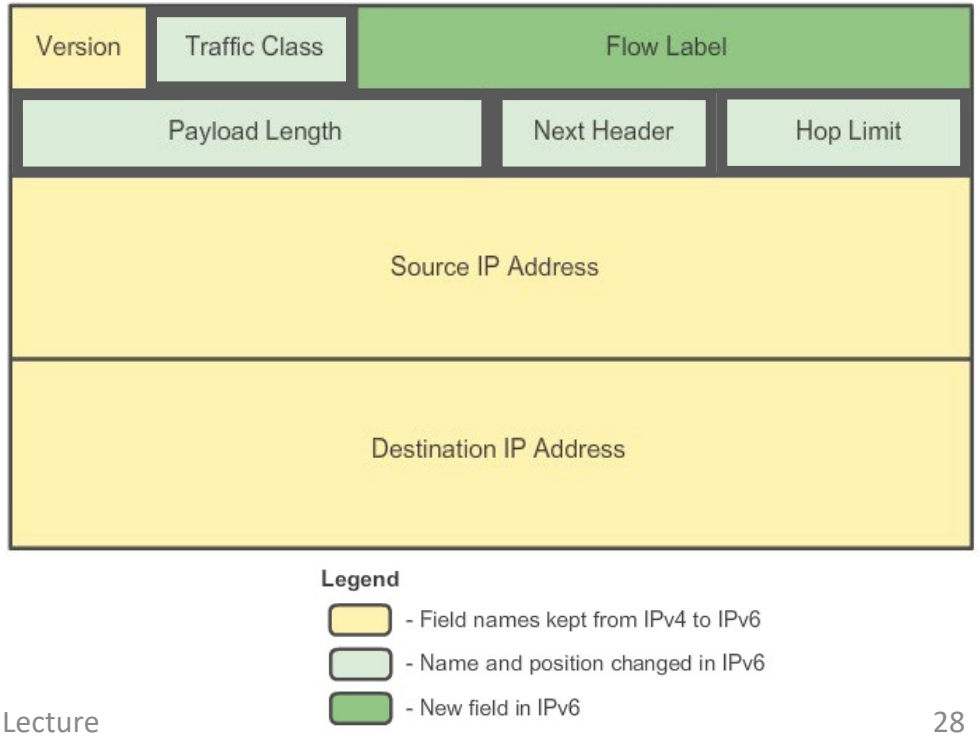
  - **Anycast Address**
    - A packet sent to an Anycast address goes only to the nearest member of the group, according to the routing protocols measures of distance
    - Anycast is described as a cross between a Unicast and Multicast
    - The difference between an Anycast and Multicast is that in Anycast packet is only delivered to a single device, while Multicast send it to multiple devices

IP Addressing (continued)

- IPv4 Vs IPv6
  - IPv4 header 20 – 60 Bytes (set by the Internet Header Length 4 bits)
  - IPv6 header 40 Bytes (fixed size)
  - IPv6 is more than just larger address space
  - Changed to make some improvements on the IP protocol



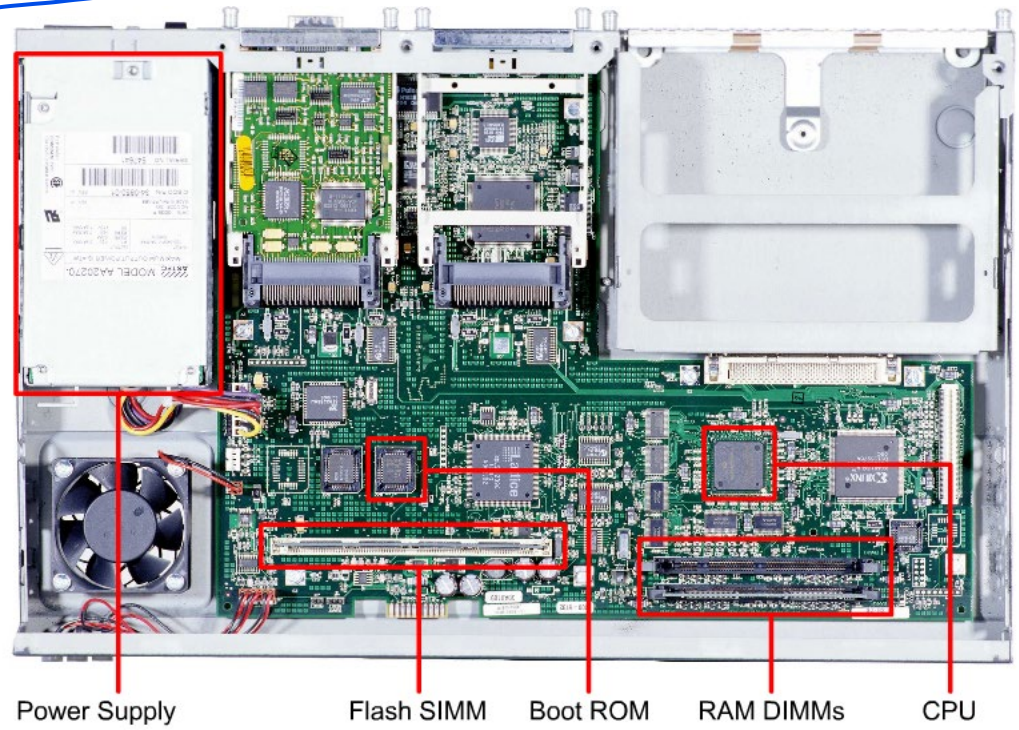
- **Next Header** = Protocol field in IPv4
- **Hop Limit** = TTL (Time to Live) in IPv4
- **Payload Length** = similar to Total Length in IPv4
- **Traffic Class** = type of service in IPv4 (QOS)



Routers

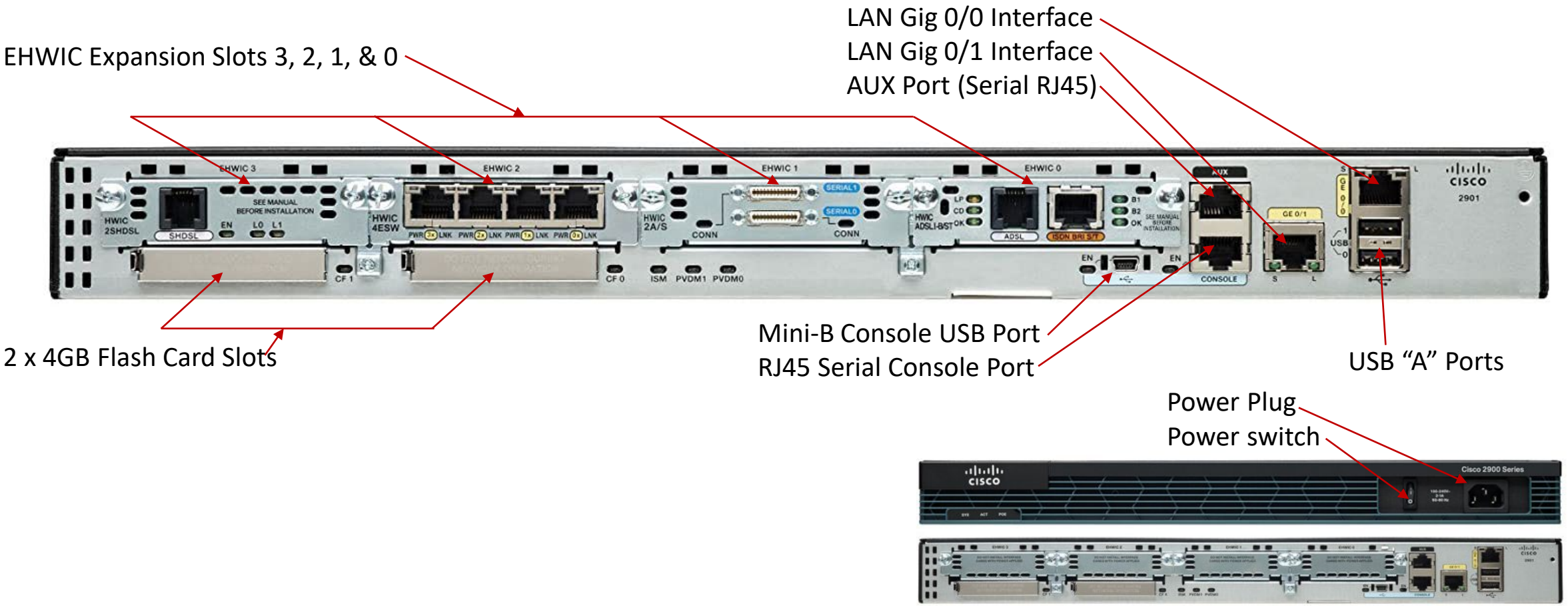
- Routers are Computers
  - Routers are specialized computers containing the following required components to operate:
    - Central processing unit (CPU)
    - Operating system (OS) - (Our routers use Cisco IOS)
    - Memory and storage (RAM, ROM, NVRAM, Flash, hard drive)

Memory	Volatile / Non-Volatile	Stores
RAM	Volatile	• Running IOS • Running configuration file • IP routing and ARP tables • Packet buffer
ROM	Non-Volatile	• Bootup instructions • Basic diagnostic software • Limited IOS
NVRAM	Non-Volatile	• Startup configuration file
Flash	Non-Volatile	• IOS • Other system files



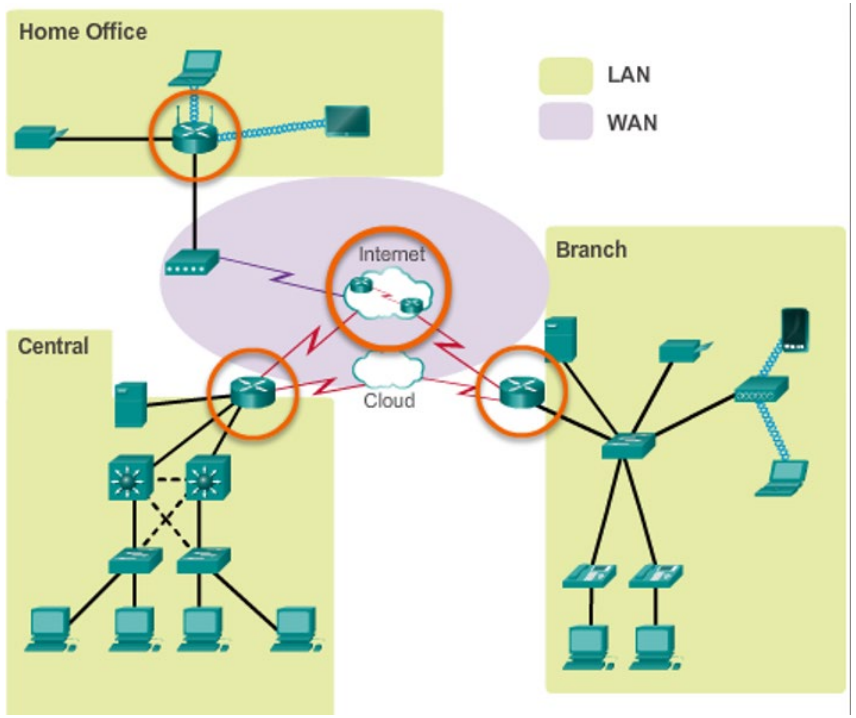
Routers (continued)

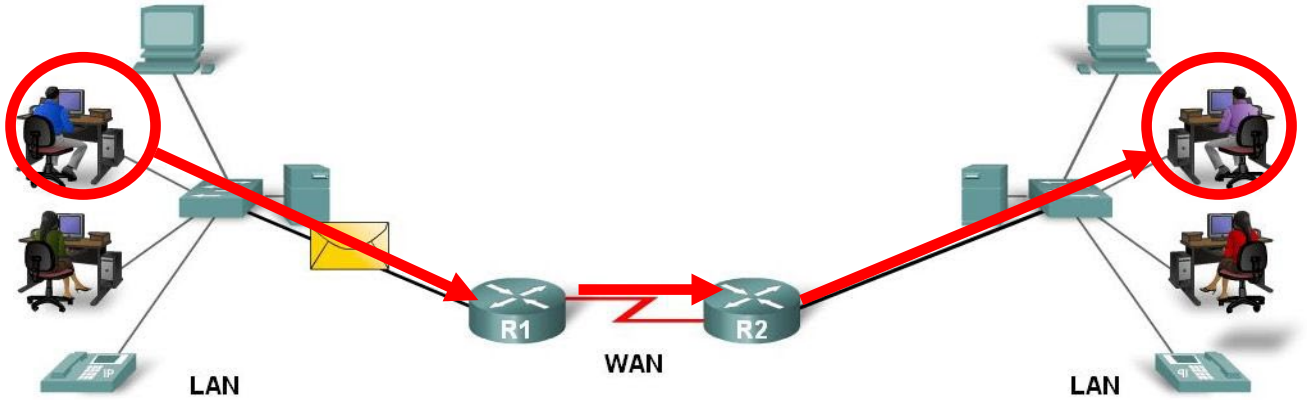
- Routers Ports
  - Routers use specialized ports and network interface cards to interconnect to other networks



Routers (continued)

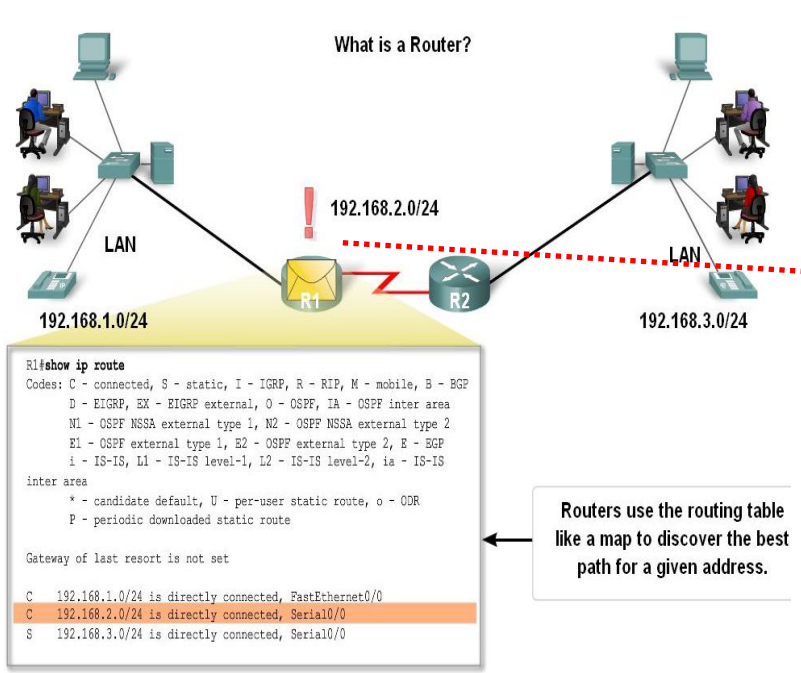
- Routers Interconnect Networks
  - Routers can connect multiple networks
  - Routers have multiple interfaces, each on a different network (IP address range)
- Routers Forward Packets
  - Forwards packets
    - From the original source to final destination
    - Selects best path
  - Connects multiple networks
    - Each interface on different IP network



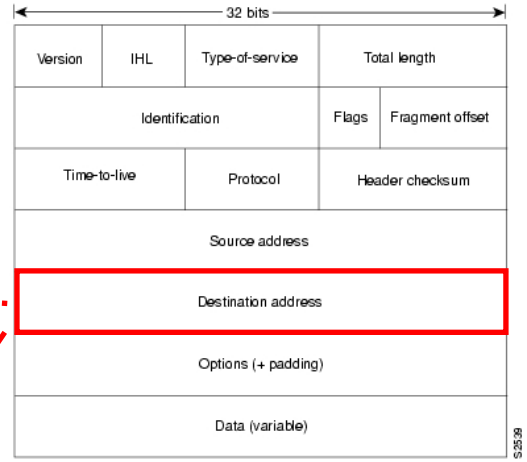


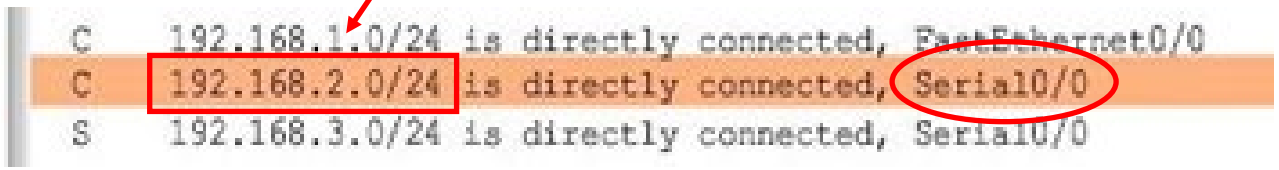
Routers (continued)

- Best Path
  - IP Packet enters router's Ethernet interface
  - Examines the packet's destination IP address
  - Searches in the routing table for a best match between packet's destination IP address and network address
  - Uses the exit-interface to forward the packet to the next router or the final destination



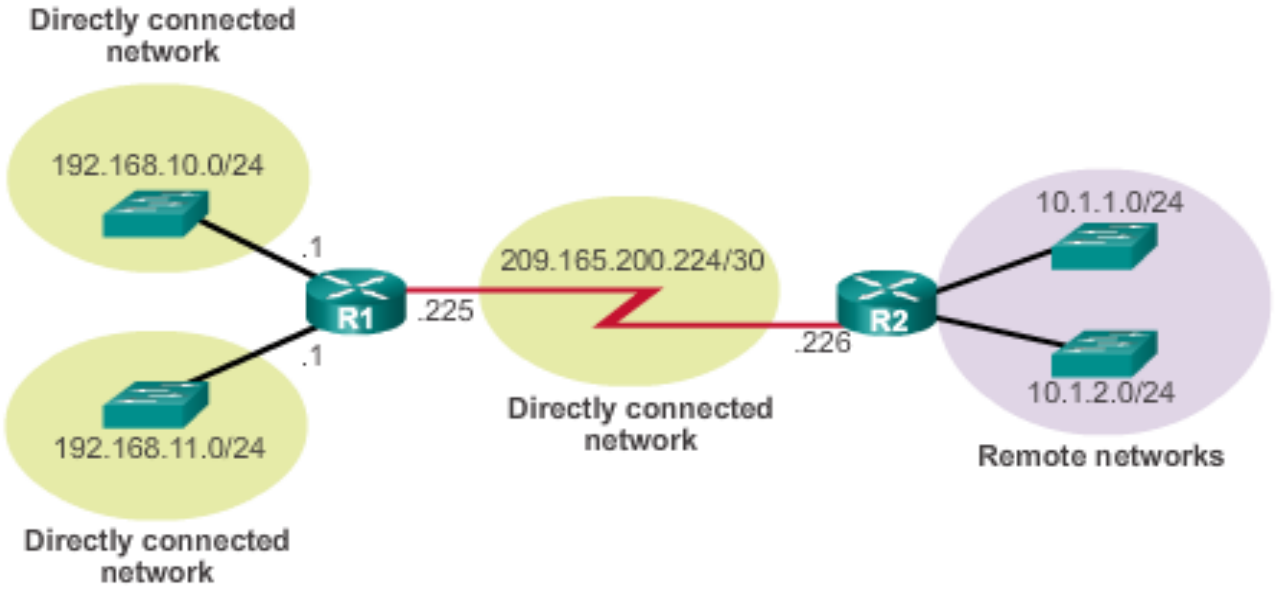
Routers use the routing table like a map to discover the best path for a given address.





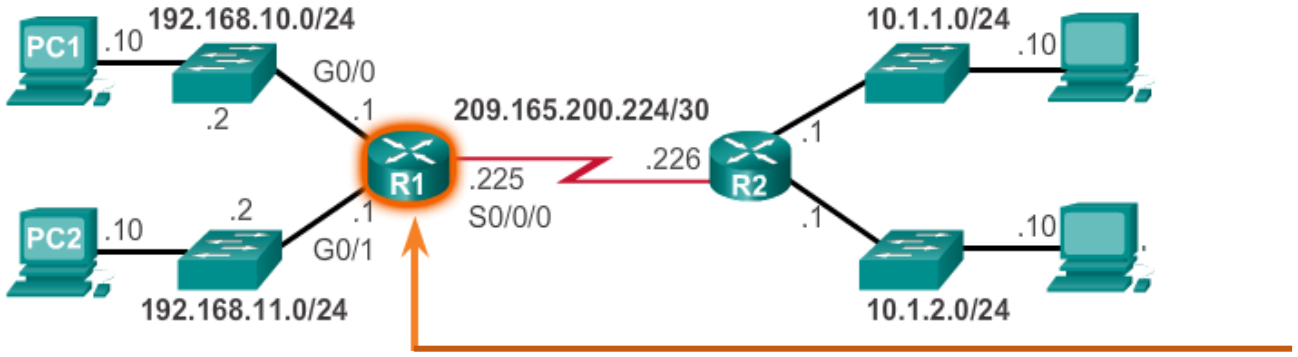
Routers (continued)

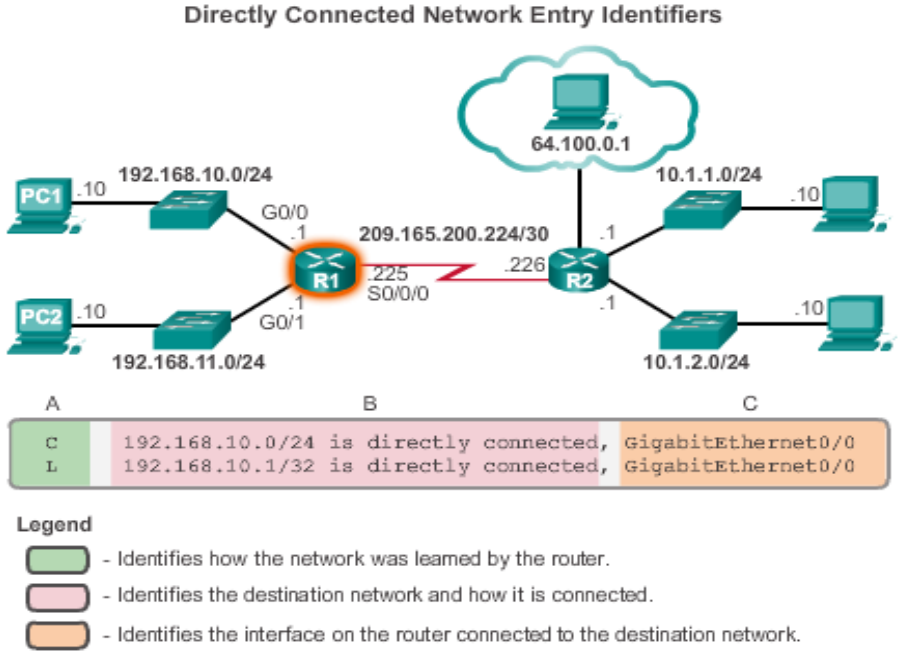
- Routing Table
  - Routing Table is stored in RAM and contains information about:
    - **Directly connected networks** - a device is connected to another router interface
    - **Remotely connected networks** - a network that is not directly connected to a particular router
    - **Detailed information** include source of information, network address & subnet mask, and IP address of next-hop router
  - **show ip route** command is used to view a routing table



Routers (continued)

- Directly Connected Interfaces
  - A newly deployed router, without any configured interfaces, has an empty routing table. An active, configured, directly connected interface creates two routing table entries:
    - "L" - Local Link (address)
    - "C" - Directly Connected (network)
  - A routing table with the directly connected interfaces of R1 configured and activated.



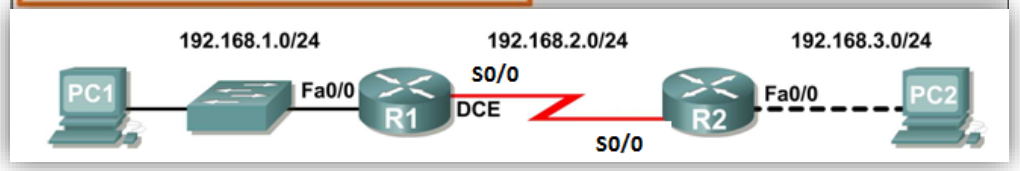


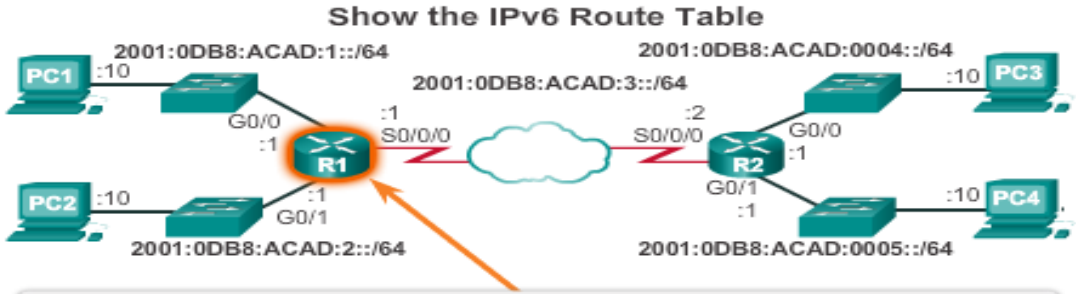

```
R1#sh ip rout | begin Gate
Gateway of last resort is not set

     192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.10.0/24 is directly connected, GigabitEthernet0/0
L       192.168.10.1/32 is directly connected, GigabitEthernet0/0
     192.168.11.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.11.0/24 is directly connected, GigabitEthernet0/1
L       192.168.11.1/32 is directly connected, GigabitEthernet0/1
     209.165.200.0/24 is variably subnetted, 2 subnets, 2 masks
C       209.165.200.224/30 is directly connected, Serial0/0/0
L       209.165.200.225/32 is directly connected, Serial0/0/0

R1#
```

Routers (continued)

- Routing Table
  - The **show ip route** command shows the ipv4 networks and routes:
  - A remote network is a network that is not directly connected to the router
  - Can only be reached by sending the packet to another router
  - Are added to the routing table using:
    - Dynamic routing protocol
    - Static routes

```
R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

C    192.168.1.0/24 is directly connected, FastEthernet0/0
C    192.168.2.0/24 is directly connected, Serial0/0
S    192.168.3.0/24 [1/0] via 192.168.2.2
```



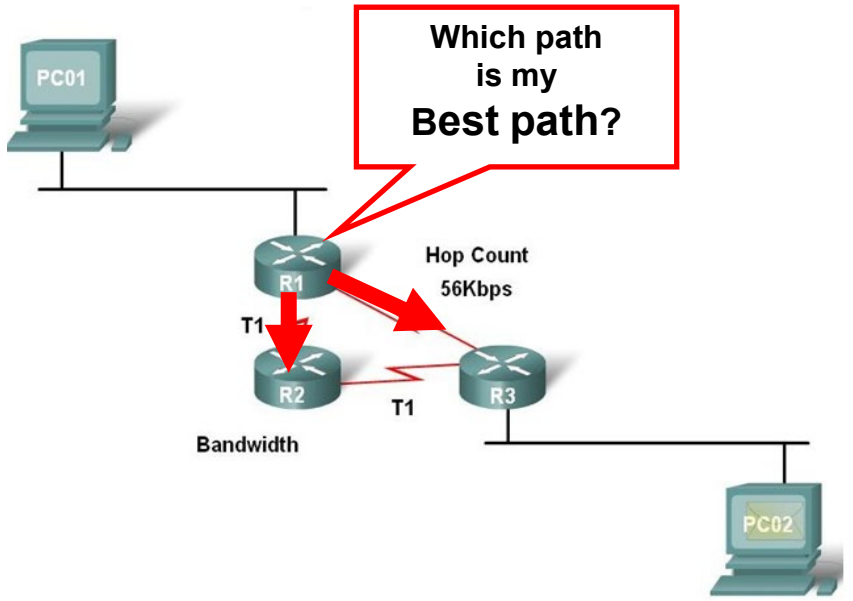



```
R1#sh ipv6 route
IPv6 Routing Table - 7 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
       U - Per-user Static route, M - MIPv6
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
       D - EIGRP, EX - EIGRP external
C   2001:DB8:ACAD:1::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:ACAD:1::1/128 [0/0]
     via GigabitEthernet0/0, receive
```

  - The **show ipv6 route** command shows the ipv6 networks and routes:

Routers (continued)

- Routing Table (continued)
  - Dynamic routing protocols
    - Add remote networks to a routing table
    - To discover networks
    - To update and maintain routing tables
    - Eg RIP, RIPv2, RIPng, IGRP, EIGRP, OSPFv2, OSPFv3
  - Automatic network discovery
    - Routers discover new networks by sharing routing table information
- Paths & Operations
  - Best-path to a network:
    - Depends on the routing protocol
  - Routing protocols use their own rules and metrics
  - A metric:
    - Quantitative value used to measure the distance to a given route
  - Best path:
    - Usually, the path with the lowest metric



Routers (continued)

- Paths & Operations
  - Path determination - process used by a router to pick the best path to a destination
  - A Metric is a numerical value used by routing protocols help determine the best path to a destination
    - The smaller the metric value the better the path
  - Just a few of the types of values used by routing protocols:
    - Hop count - the number of routers a packet must travel through to get to its destination usually the “Metric”
    - Bandwidth - the “speed” of a link
    - Latency – the time it takes packets to move through the network
    - Routing type – RIP, EIGRP, OSPF, Connected
    - Route Timestamp – last time route was updated
    - Outgoing Interface – faster is better…

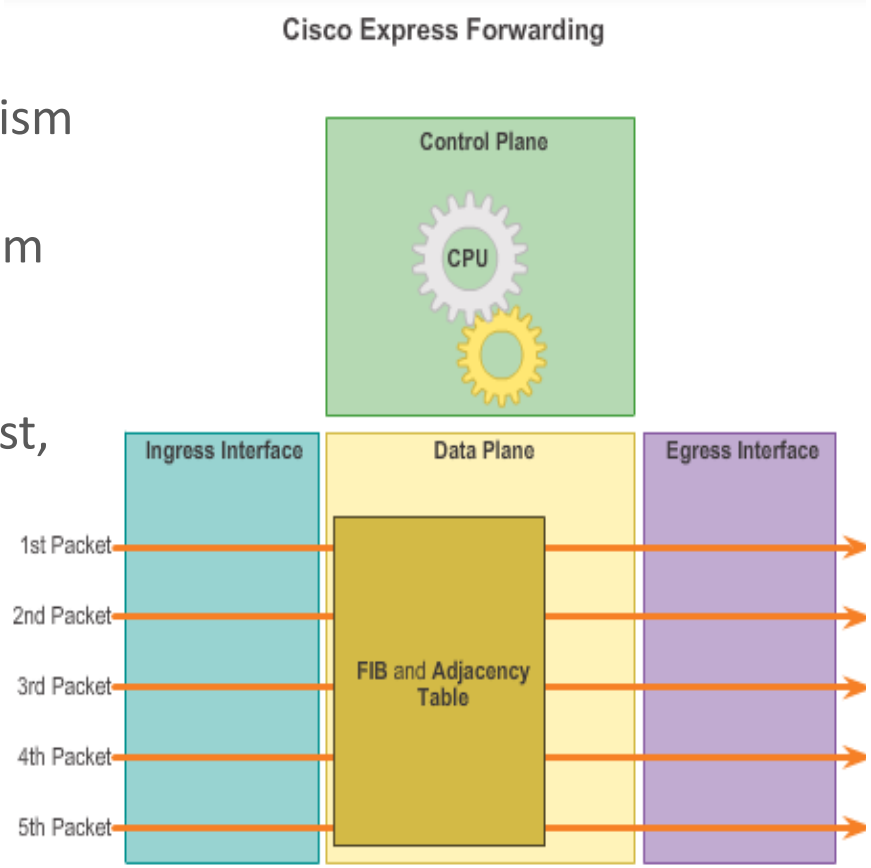
Routers (continued)

- Load Balancing
  - When a router has two or more paths to a destination with equal cost metrics, then the router forwards the packets using both paths equally
  - Equal cost load balancing can improve network performance
  - Equal cost load balancing can be configured to use both dynamic routing protocols and static routes
  - RIP, OSPF and EIGRP support equal cost load balancing
- Administrative Distance
  - If multiple paths to a destination are learned from different routing protocols, the path installed in the routing table is the one with the lowest Administrative Distance (AD)
  - A static route with an AD of 1 is more reliable than an EIGRP-discovered route with an AD of 90
  - A directly connected route with an AD of 0 is more reliable than a static route with an AD of 1

Route Source	Administrative Distance
Connected	0
Static	1
EIGRP summary route	5
External BGP	20
Internal EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
External EIGRP	170
Internal BGP	200

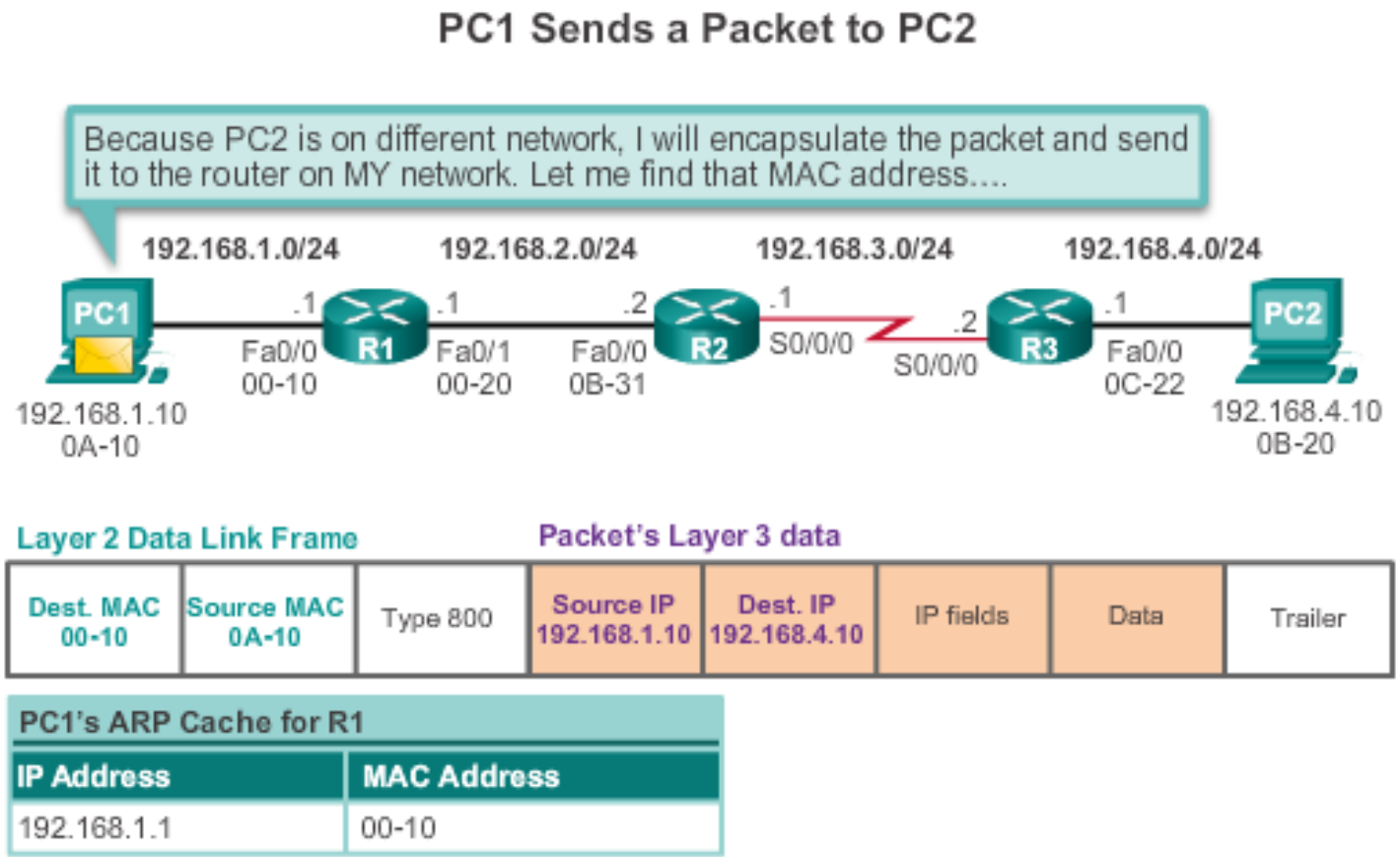
Routers (continued)

- Packet Forwarding Methods
  - **Process switching** – An older packet forwarding mechanism still available for Cisco routers
  - **Fast switching** – A common packet forwarding mechanism which uses a fast-switching cache to store next hop information
  - **Cisco Express Forwarding (CEF)** – The most recent, fastest, and preferred Cisco IOS packet-forwarding mechanism. Table entries are not packet-triggered like fast switching but change-triggered



Routers (continued)

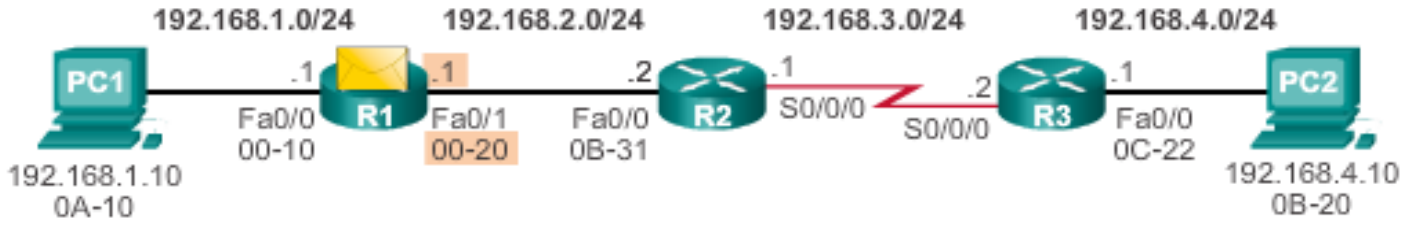
- Send a Packet

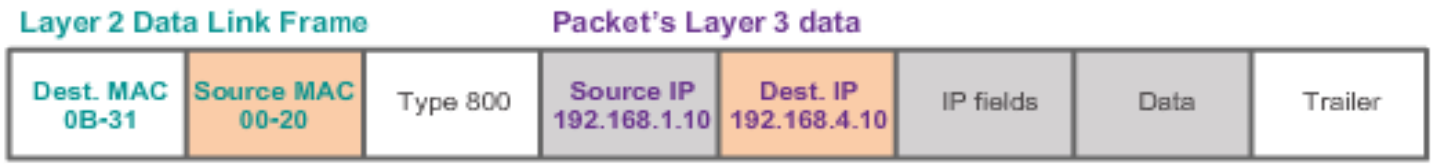


Routers (continued)

- Forward to the Next Hop

R3 Forwards the Packet to PC2



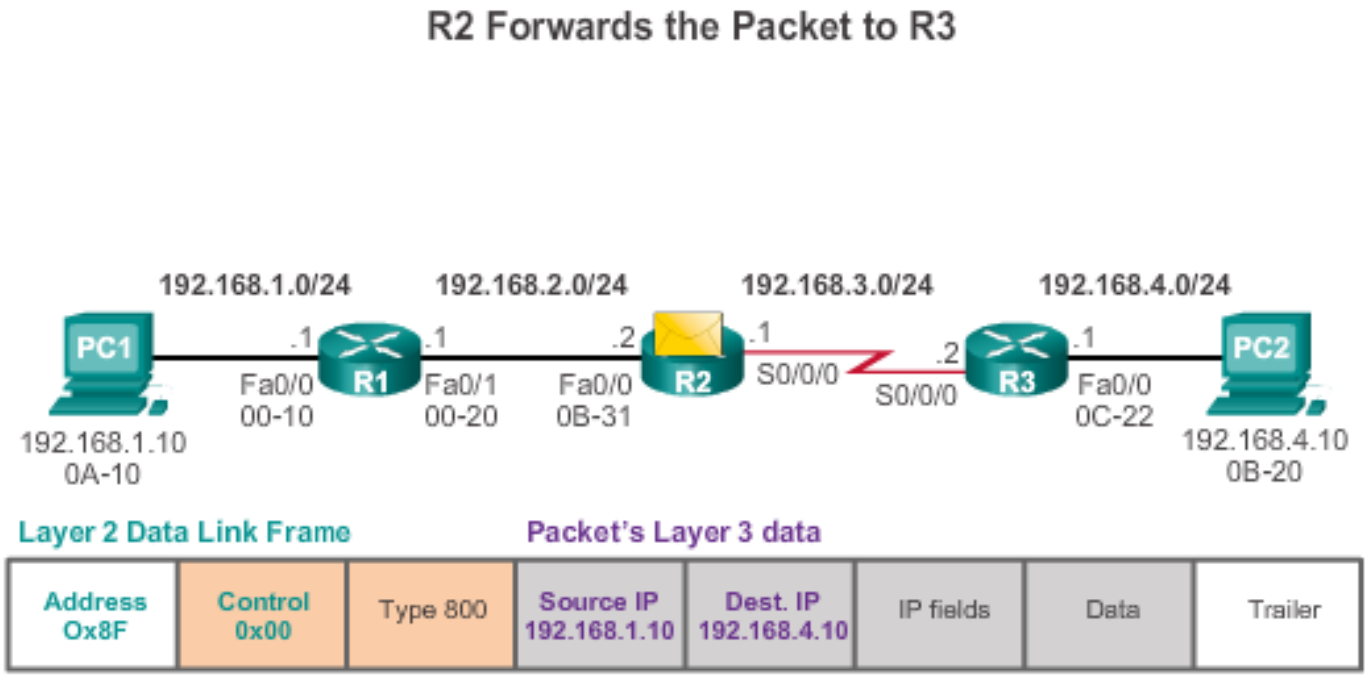


R1's Routing Table

Network	Hops	Next-hop-IP	Exit Interface
192.168.1.0/24	0	Dir. Connect.	Fa0/0
192.168.2.0/24	0	Dir. Connect.	Fa0/1
192.168.3.0/24	1	192.168.2.2	Fa0/1
192.168.4.0/24	2	192.168.2.2	Fa0/1

Routers (continued)

- Packet Routing



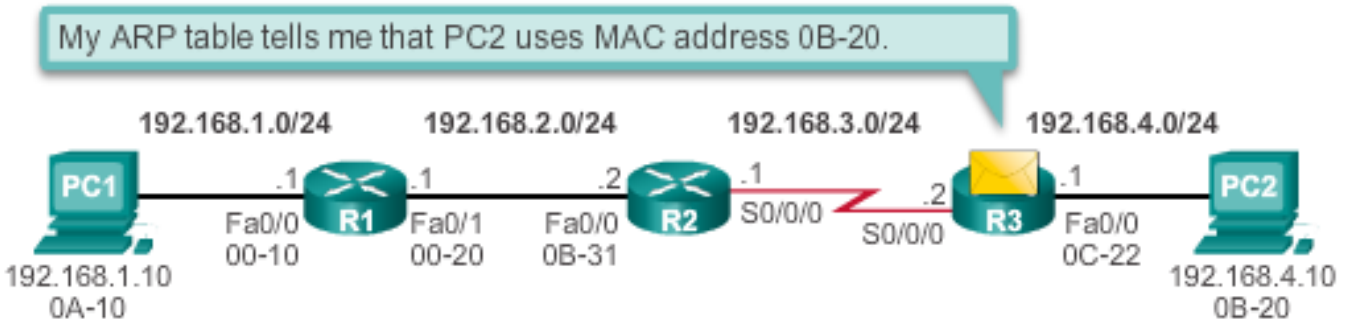
R2's Routing Table

Network	Hops	Next-hop-IP	Exit Interface
192.168.1.0/24	1	192.168.3.1	Fa/0/0
192.168.2.0/24	0	Dir. Connect.	Fa/0/0
192.168.3.0/24	0	Dir. Connect.	S0/0/0
192.168.4.0/24	1	192.162.3.2	S0/0/0

Routers (continued)

- Reach the Destination

R3 Forwards the Packet to PC2



Layer 2 Data Link Frame | **Packet's Layer 3 data**

Dest. MAC 0B-20	Source MAC 0C-22	Type 800	Source IP 192.168.1.10	Dest. IP 192.168.4.10	IP fields	Data	Trailer

R3's ARP Cache

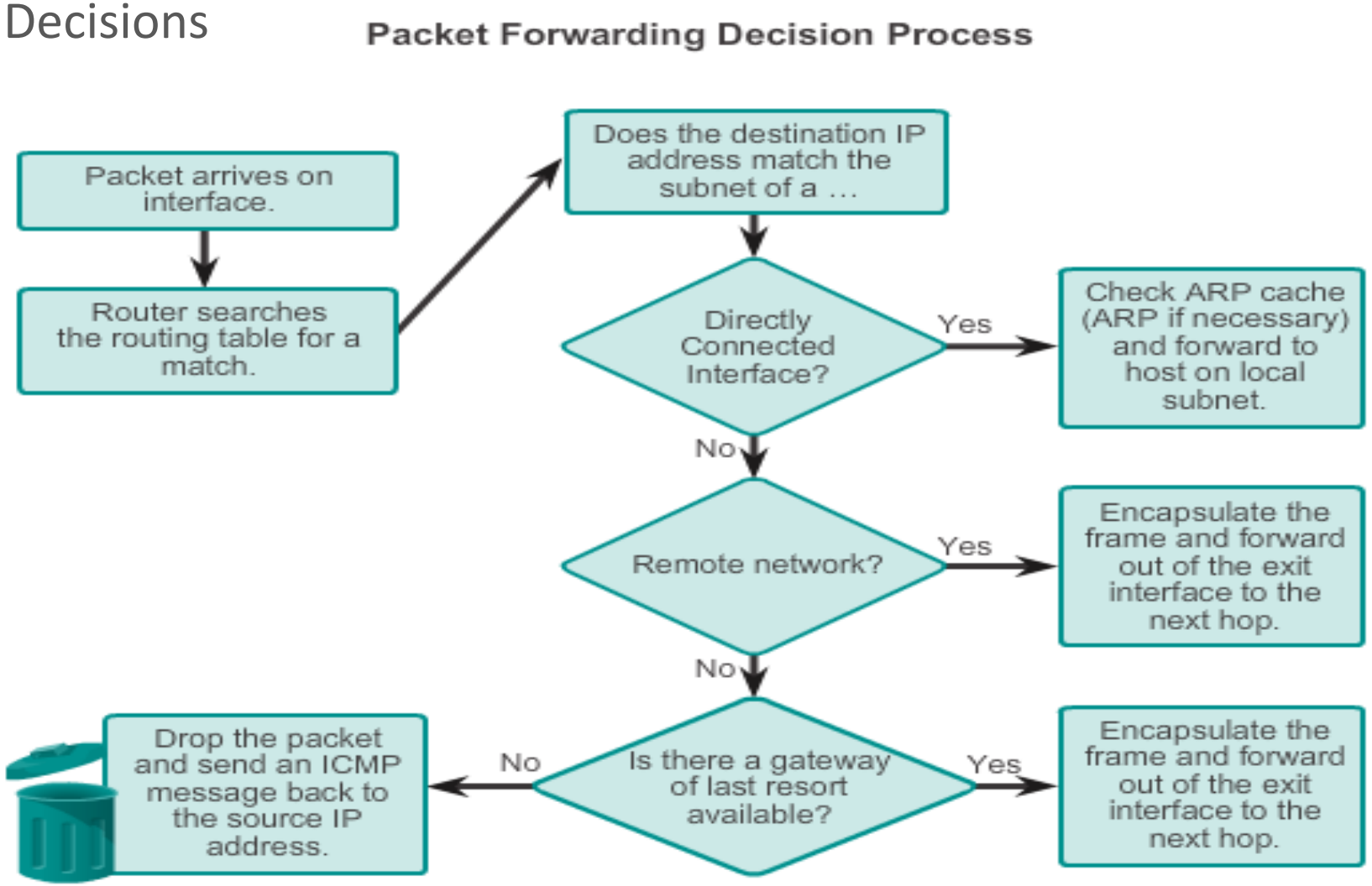
IP Address	MAC Address
192.168.4.10	0B-20

R3's Routing Table

Network	Hops	Next-hop-IP	Exit Interface
192.168.1.0/24v	2	192.168.3.1	S0/0/0
192.168.2.0/24	1	192.162.3.1	S0/0/0
192.168.3.0/24	0	Dir. Connect.	S0/0/0
192.168.4.0/24	0	Dir. Connect.	Fa0/0

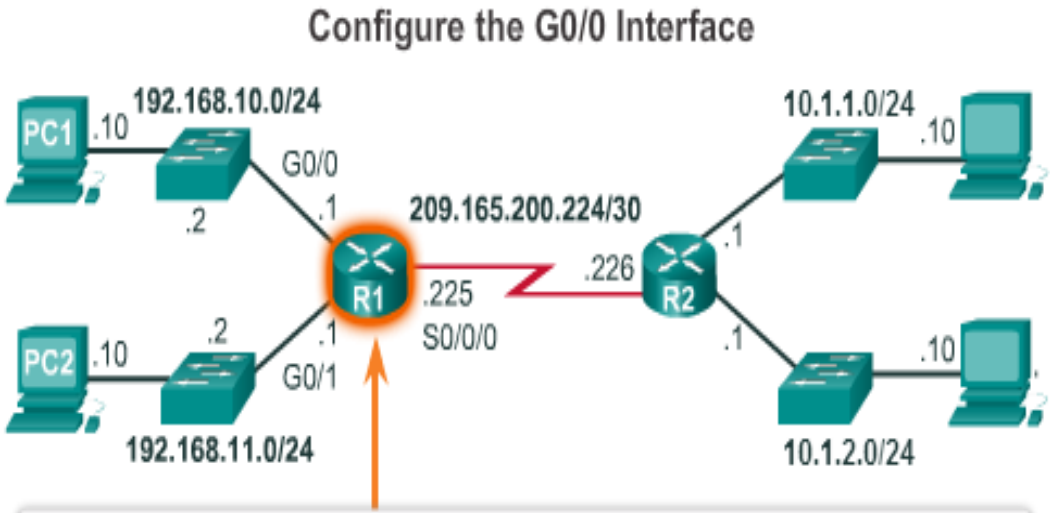
Routers (continued)

- Routing Decisions



Router Configuration

- Configure IPv4 Interface
  - Configured with an address and subnet mask
  - Must be activated using **no shutdown** command (by default LAN and WAN interfaces are not activated on routers)
  - Serial cable end labeled DCE must be configured with the clock rate command
  - Optional description can be included to help clarify the connections (important)



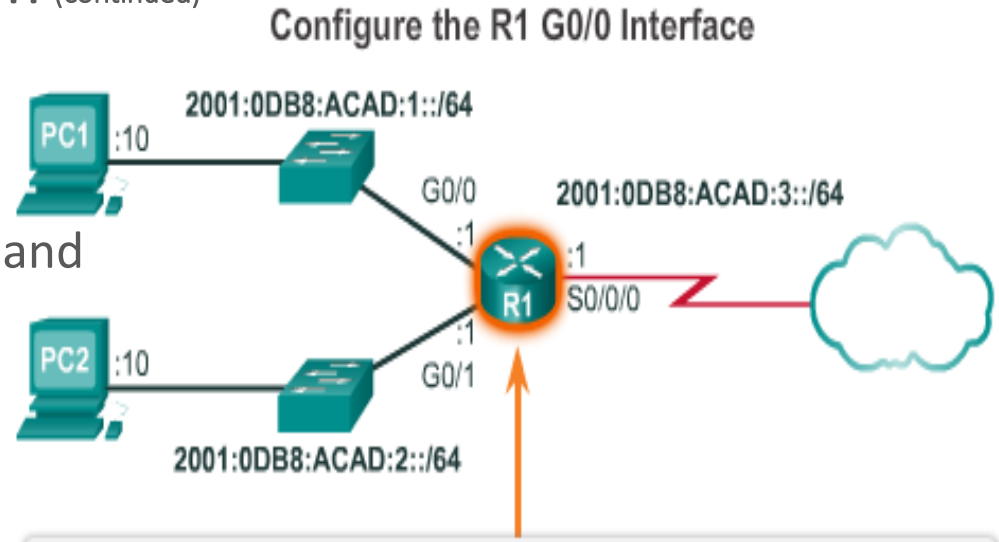

```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#description Link to LAN 1
R1(config-if)#ip address 192.168.10.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#
*Jan 30 22:04:47.551: %LINK-3-UPDOWN: Interface
GigabitEthernet0/0, changed state to down
R1(config)#
*Jan 30 22:04:50.899: %LINK-3-UPDOWN: Interface
GigabitEthernet0/0, changed state to up
*Jan 30 22:04:51.899: %LINEPROTO-5-UPDOWN: Line protocol on
Interface GigabitEthernet0/0, changed state to up
R1(config)#
```

Router Configuration (continued)

- Configure IPv6 Interface
  - Use the **ipv6 address ipv6-address/ipv6-length** [**link-local** | **eui-64**] interface configuration command
  - Activate using the no shutdown command

IPv6 interfaces can support more than one address:

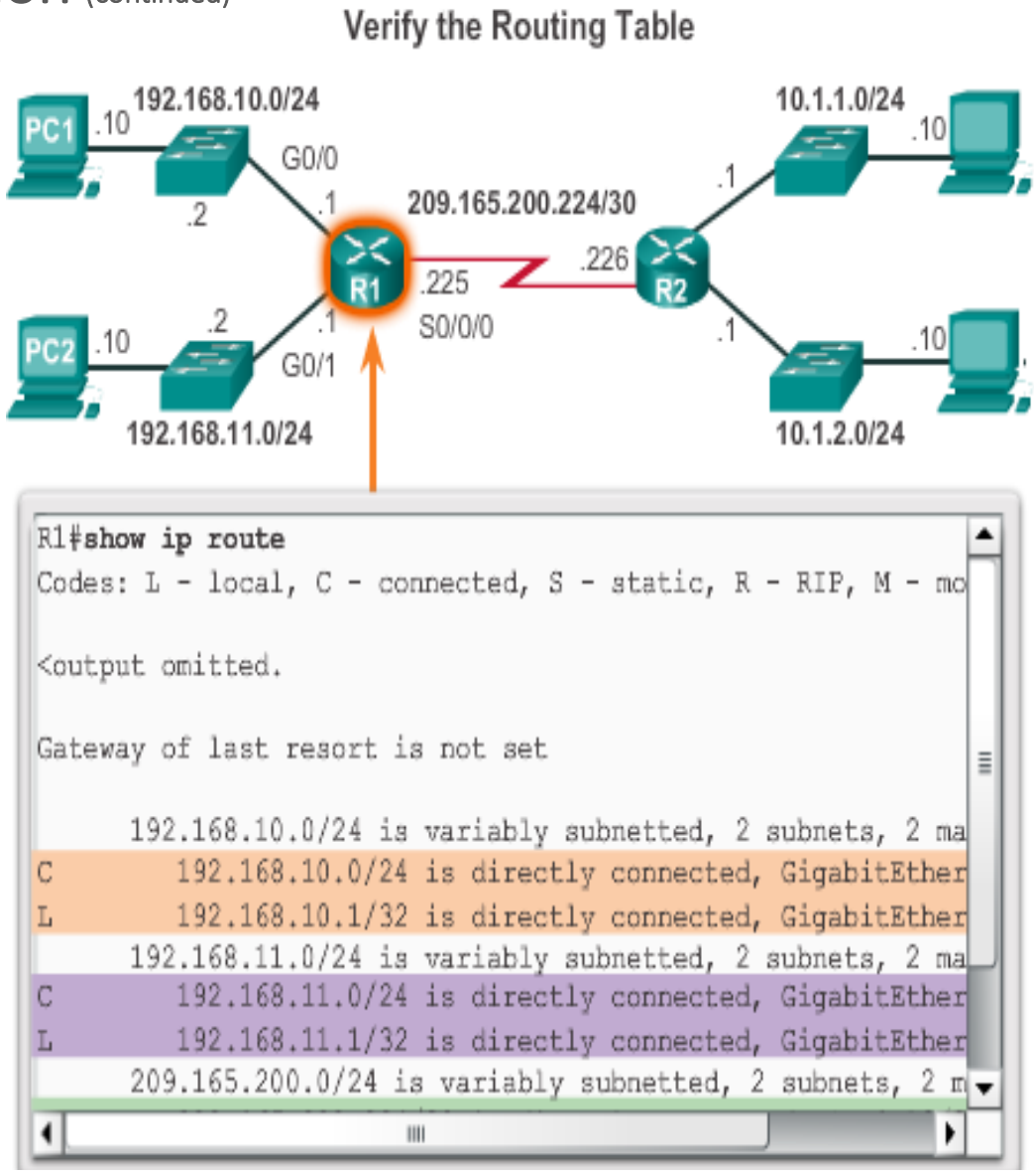
- Configure a specified **global unicast** – ipv6-address /ipv6-length
- Configure a global IPv6 address with an interface identifier (ID) in the low-order 64 bits - ipv6-address /ipv6-length **eui-64**
- Configure a link-local address - ipv6-address /ipv6-length link-local




```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#description Link to LAN 1
R1(config-if)#ipv6 address 2001:db8:acad:1::1/64
R1(config-if)#no shutdown
R1(config-if)#exit
R1(config)#
*Feb  3 21:38:37.279: %LINK-3-UPDOWN: Interface
GigabitEthernet0/0, changed state to down
*Feb  3 21:38:40.967: %LINK-3-UPDOWN: Interface
GigabitEthernet0/0, changed state to up
*Feb  3 21:38:41.967: %LINEPROTO-5-UPDOWN: Line protocol on
Interface GigabitEthernet0/0, changed state to up
R1(config)#
```

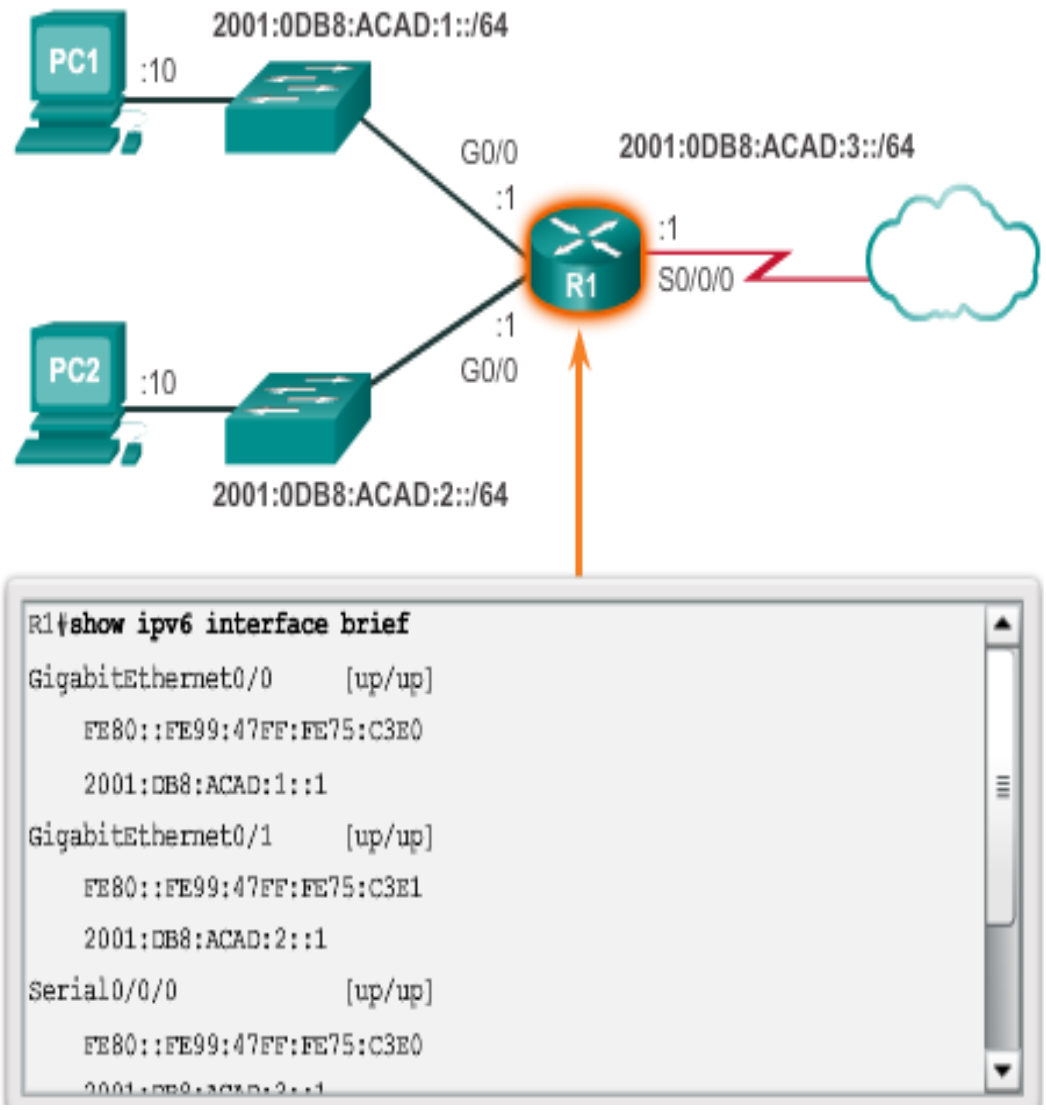
Router Configuration (continued)

- Verify Settings
  - Show commands are used to verify operation and configuration of interface:
    - **show ip interfaces brief**
    - **show ip route**
    - **show running-config**
  - Show commands are used to gather more detailed interface information:
    - **show interfaces**
    - **show ip interfaces**



Router Configuration (continued)

- Verify Interface Settings
  - Some of the common commands to verify the IPv6 interface configuration are:
    - **show ipv6 interface brief** – displays a summary for each of the I nterfaces
    - **show ipv6 interface gigabitethernet 0/0** - displays the interface status and all the IPv6 addresses for this interface
    - **show ipv6 route** - verifies that IPv6 networks and specific IPv6 interface addresses have been installed in the IPv6 routing table



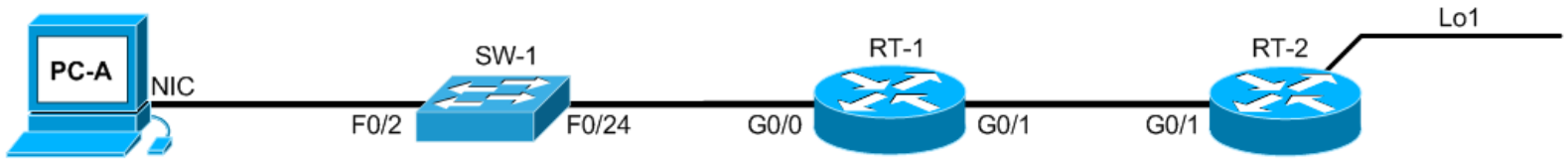
Router Configuration (continued)

- Filter, the **show** Command Output
  - Show command output can be managed using the following command and filters:
    - Use the **terminal length *number*** command to specify the number of lines to be displayed. A value of 0 (zero) prevents the router from pausing between screens of output (not available on PT)
    - To filter specific output of commands use the (**|**) **pipe character** after show command. Parameters that can be used after pipe include:
      - **section**, **include**, **exclude**, **begin**

```
R1#show ip interface brief
Interface                  IP-Address      OK? Method Status
Embedded-Service-Engine0/0 unassigned      YES unset  admini
GigabitEthernet0/0         192.168.10.1    YES manual up
GigabitEthernet0/1         192.168.11.1    YES manual up
Serial0/0/0                209.165.200.225 YES manual up
Serial0/0/1                unassigned      YES unset  admini

R1#show ip interface brief | exclude unassigned
Interface                  IP-Address      OK? Method Status
GigabitEthernet0/0         192.168.10.1    YES manual up
GigabitEthernet0/1         192.168.11.1    YES manual up
Serial0/0/0                209.165.200.225 YES manual up
```

```
R1#show ip interface brief
Interface                  IP-Address      OK? Method Status
Embedded-Service-Engine0/0 unassigned      YES unset  administ
GigabitEthernet0/0         192.168.10.1    YES manual up
GigabitEthernet0/1         192.168.11.1    YES manual up
Serial0/0/0                209.165.200.225 YES manual up
Serial0/0/1                unassigned      YES unset  administ
R1#
R1#show ip interface brief | include up
GigabitEthernet0/0         192.168.10.1    YES manual up
GigabitEthernet0/1         192.168.11.1    YES manual up
Serial0/0/0                209.165.200.225 YES manual up
R1#
```

Lab

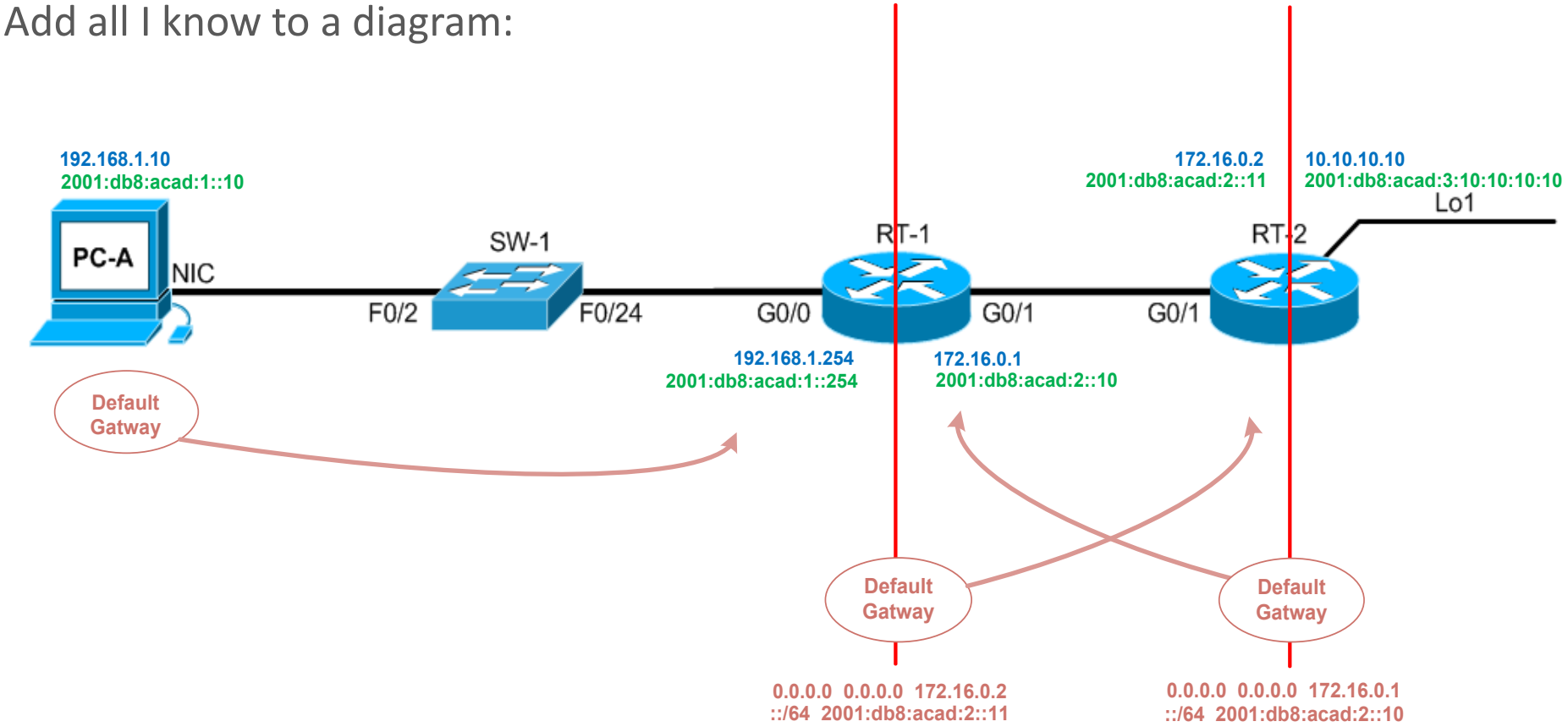


Device	interface	IPv4 Address IPv6 Address	Subnet Mask	Default Gateway	Static Routes
RT-1	G0/0	192.168.1.254	/24		
		2001:db8:acad:1::254	/64		::/64 2001:db8:acad:2::11
	G0/1	172.16.0.1	/30		0.0.0.0 0.0.0.0 172.16.0.2
		2001:db8:acad:2::10	/64		
RT-2	G0/1	172.16.0.2	/30		
		2001:db8:acad:2::11	/64		::/64 2001:db8:acad:2::10
	Lo1	10.10.10.10	/32		0.0.0.0 0.0.0.0 172.16.0.1
		2001:db8:acad:3:10:10:10:10	/64		
SW-1					
PC-A	NIC	192.168.1.10	/24	192.168.1.254	
		2001:db8:acad:1::10	/64	2001:db8:acad:1::254	

Maximum of 3 students per row!

Lab (continued)

- How I would proceed
  - Add all I know to a diagram:



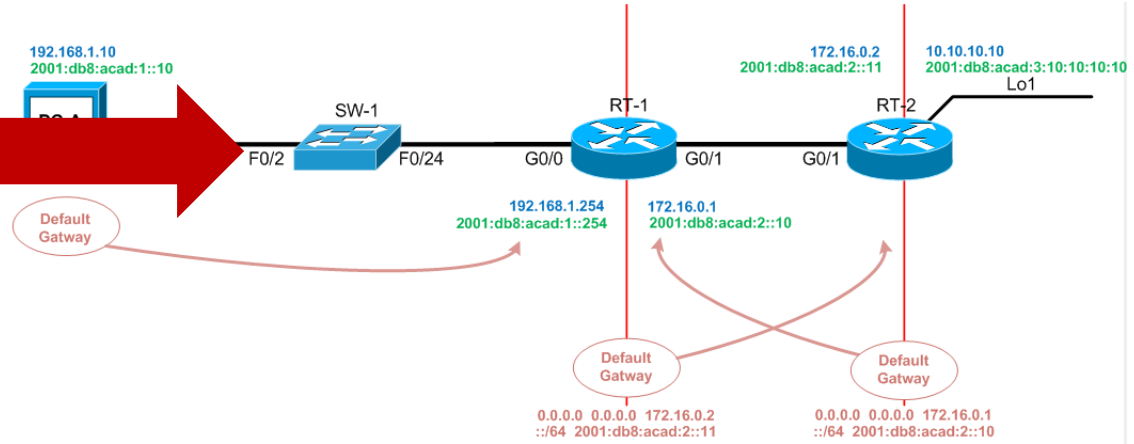
Lab (continued)

- How I would proceed (continued)

  Build scripts:

  Check that all the devices are clean!

  Copy in the basic config



RT-1

```
enable
clock set 12:10:00 14 May 2018
configure termnal
clock timezone EST -5
Hostna-neme RT-1
service password-encryption
enable secret class
no ip domain--lookup
ip domainname fanshawe.local
banner mo3d #
Unauthorized access is strictly prohibited. #
line con 0
 pasword cisco
 login
 logging synchronous
 exec-timeout 240
line vty 0 15
 pasword cisco
 login
 transport 1nput all
 exec-timeout 240
exit
```

RT-2

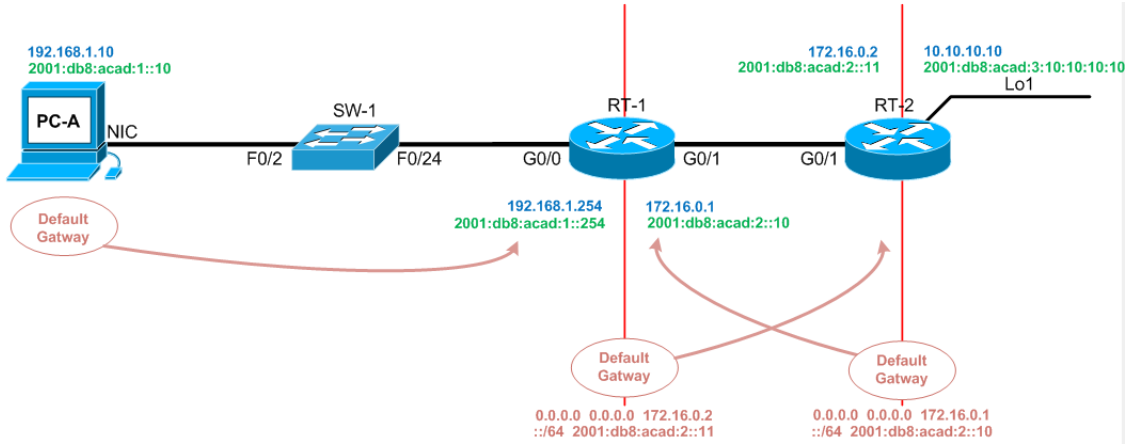
```
enable
clock set 12:10:00 14 May 2018
conf1gure terminal
clock timezone EST -5
hostname RT-2
service pasword-encryption
enable secret clas
no ip domain-lookup
ip domain-name fanshawe.local
baner motd #
Unauthorized access is strictly prohibited. #
line con 0
 pasword cisco
 login
 logging synchronous
 exec-timeout 240
line vty 0 15
 pasword cisco
 login
 transport input all
 exec-timeout 240
exit
```

Lab (continued)

- How I would proceed (continued)

  Build scripts:

Looking at the diagram, fill in what is needed in the text files for each router.



RT-1

```
ip6v unicast-routing
inter g0/0
 ip add 192.168.1.245 255.255.255.0
 ipv6 add 2001:bd8:acad:1::254/64
 no shut
inter g 0/1
 ip add 172.16.0.1 255.255.255.252
 ipv6 ad 2001:db8:acad:2::10/64
 no shut
exit
ip route 0.0.0.0 0.0.0.0 172.16.0.1
ipv6 route ::/0 2001:db8:acad:2::10
```

RT-2

```
ipv6 unicast-routing
inter lo1
 ip add 10.10.10.10 255.255.255.255
 ipv6 add 2001:db8:acad:3:10:10:10:10/62
 no shut
inter g 0/1
 ip add 172.61.0.2 255.255.255.252
  ipv6 add 2001:db8:acad:2::11/64
 on shut
exit
ip route 0.0.0.0 0.0.0.0 172.16.0.2
ipv6 route ::/0 2001:db8:acad:2::11
```

Lab (continued)

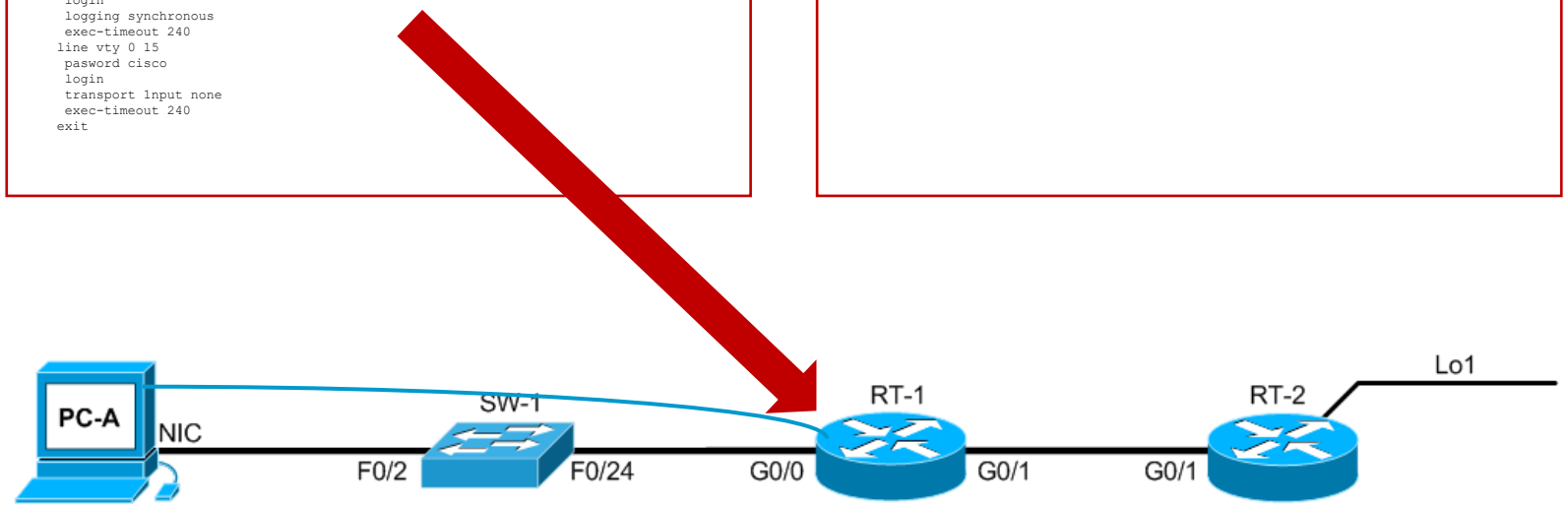
- How I would proceed (continued)

Copy scripts to devices:

RT-1

```
enable
clock set 12:10:00 14 May 2018
configure termnal
clock timezone EST -5
Hostna-neme RT-1
service password-encryption
enable secret class
no ip domain--lookup
ip domainname fanshawe.local
ip6v unicast-routing
inter g0/0
 ip add 192.681.1.235 255.255.255.0
 ipv6 add 2001:bd8:aacd:1::254/69
 no shut
inter g 0/1
 ip add 172.16.0.1 255.255.255.255
 ipv6 ad 2001:8db:cada:2::10/64
 no shut
exit
ip route 0.0.0.0 0.0.0.0 172.16.0.1
ipv6 route ::/0 2001:8db:acad:2::10
banner mo3d #
Unauthorized access is strictly prohibited. #
line con 0
 pasword cisco
 login
 logging synchronous
 exec-timeout 240
line vty 0 15
 pasword cisco
 login
 transport lnput none
 exec-timeout 240
exit
```

RT-2



Lab (continued)

- How I would proceed (continued)

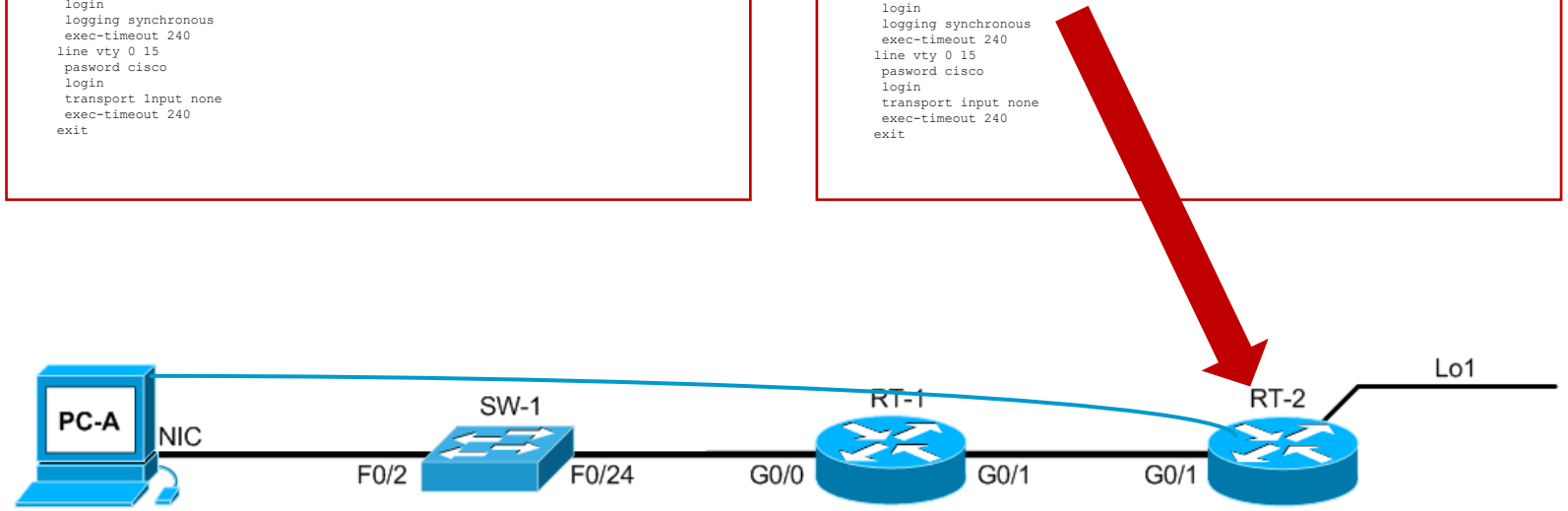
Copy scripts to devices:

RT-1

```
enable
clock set 12:10:00 14 May 2018
configure termnal
clock timezone EST -5
Hostna-neme RT-1
service password-encryption
enable secret class
no ip domain--lookup
ip domainname fanshawe.local
ip6v unicast-routing
inter g0/0
 ip add 192.681.1.235 255.255.255.0
 ipv6 add 2001:bd8:aacd:1::254/69
 no shut
inter g 0/1
 ip add 172.16.0.1 255.255.255.255
 ipv6 ad 2001:8db:cada:2::10/64
 no shut
exit
ip route 0.0.0.0 0.0.0.0 172.16.0.1
ipv6 route ::/0 2001:8db:acad:2::10
banner mo3d #
Unauthorized access is strictly prohibited. #
line con 0
 pasword cisco
 login
 logging synchronous
 exec-timeout 240
line vty 0 15
 pasword cisco
 login
 transport lnput none
 exec-timeout 240
exit
```

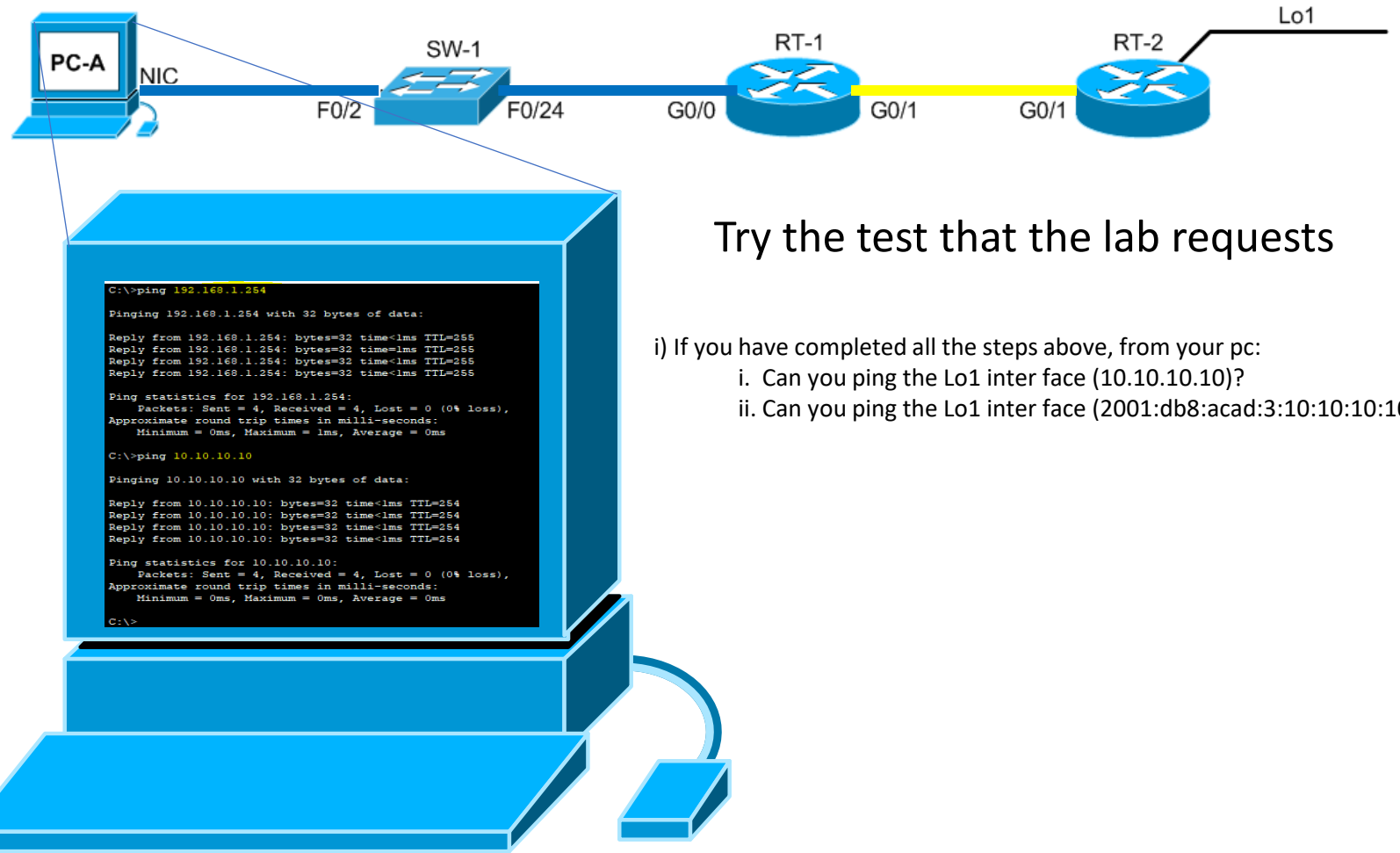
RT-2

```
enable
clock set 12:10:00 14 May 2018
conflgure terminal
clock timezone EST -5
hostname RT-66
service pasword-encryption
enable secret clas
no ip domain-lookup
ip domain-name fanshawe.local
ipv6 unicast-routing
inter lol
 ip add 10.10.10.10 255.255.255.255
 ipv6 add 2001:db8:acad:3:10:10:10:10/62
 no shut
inter g 0/1
 ip add 172.61.0.2 255.255.255.252
  ipv6 add 2001:8d:acad:2::11/64
 on shut
exit
ip route 0.0.0.0 0.0.0.0 172.16.0.2
ipv6 route ::/0 2001:8db:acad:2::11
baner motd #
Unauthorized access is strictly prohibited. #
line con 0
 pasword cisco
 login
 logging synchronous
 exec-timeout 240
line vty 0 15
 pasword cisco
 login
 transport input none
 exec-timeout 240
exit
```



Lab (continued)

- How I would proceed (continued)
  - Connect the needed ethernet cables:



Try the test that the lab requests

i) If you have completed all the steps above, from your pc:

i. Can you ping the Lo1 inter face (10.10.10.10)? **Yes**

ii. Can you ping the Lo1 inter face (2001:db8:acad:3:10:10:10:10)? **Yes**

Lab (continued)

- How I would proceed (continued)

Continue with the rest to the lab:

QUESTIONS