Computer Networks
Day 1
Routing

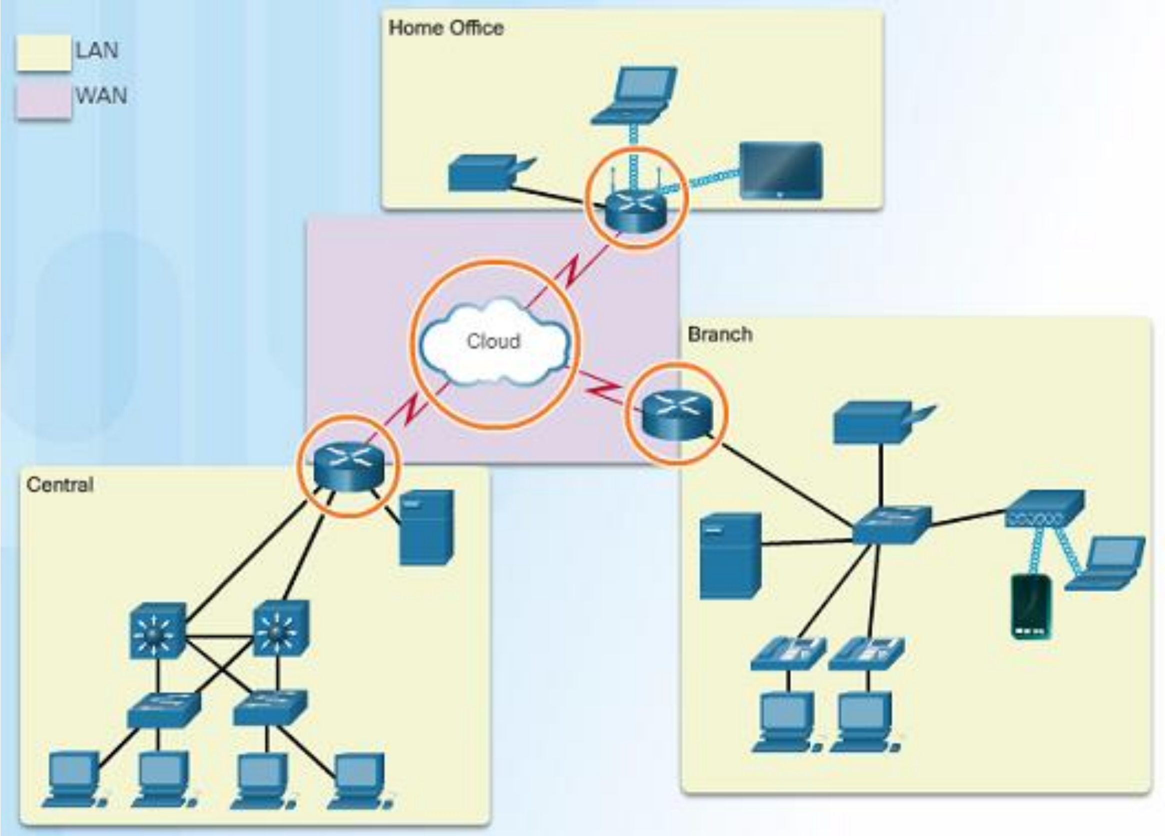
Outline

1. Routing Decisions
2. Static Routing
3. Dynamic Routing
4. Summary

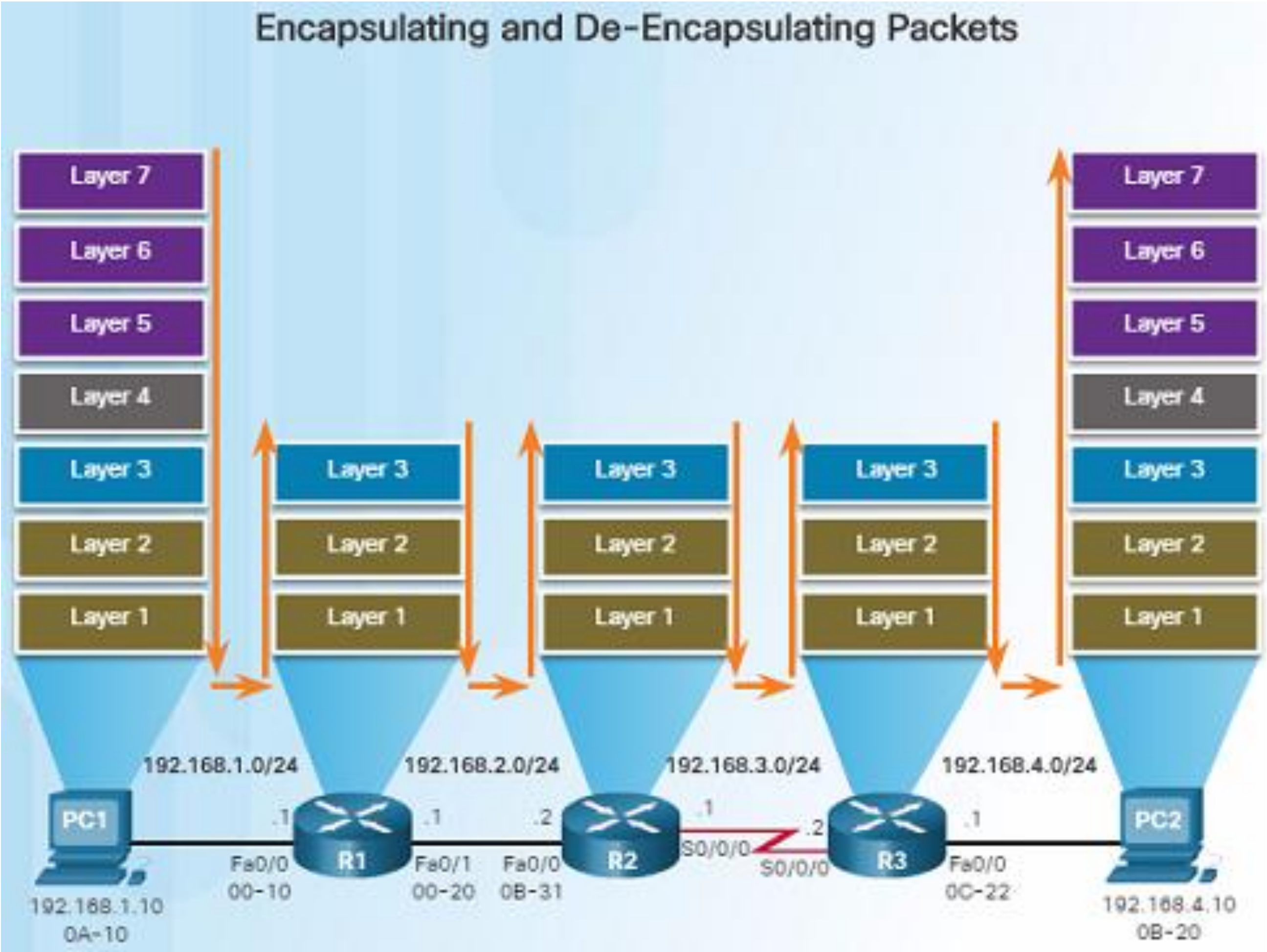
Routing Decisions

Why Routing?

- Router:
  - Connects one network to another network.
  - Determines the best route to the destination before forwarding traffic to the next router along the path.
  - Responsible for routing traffic between network.
  - Routing table used to determine the most efficient path to reach the destination.

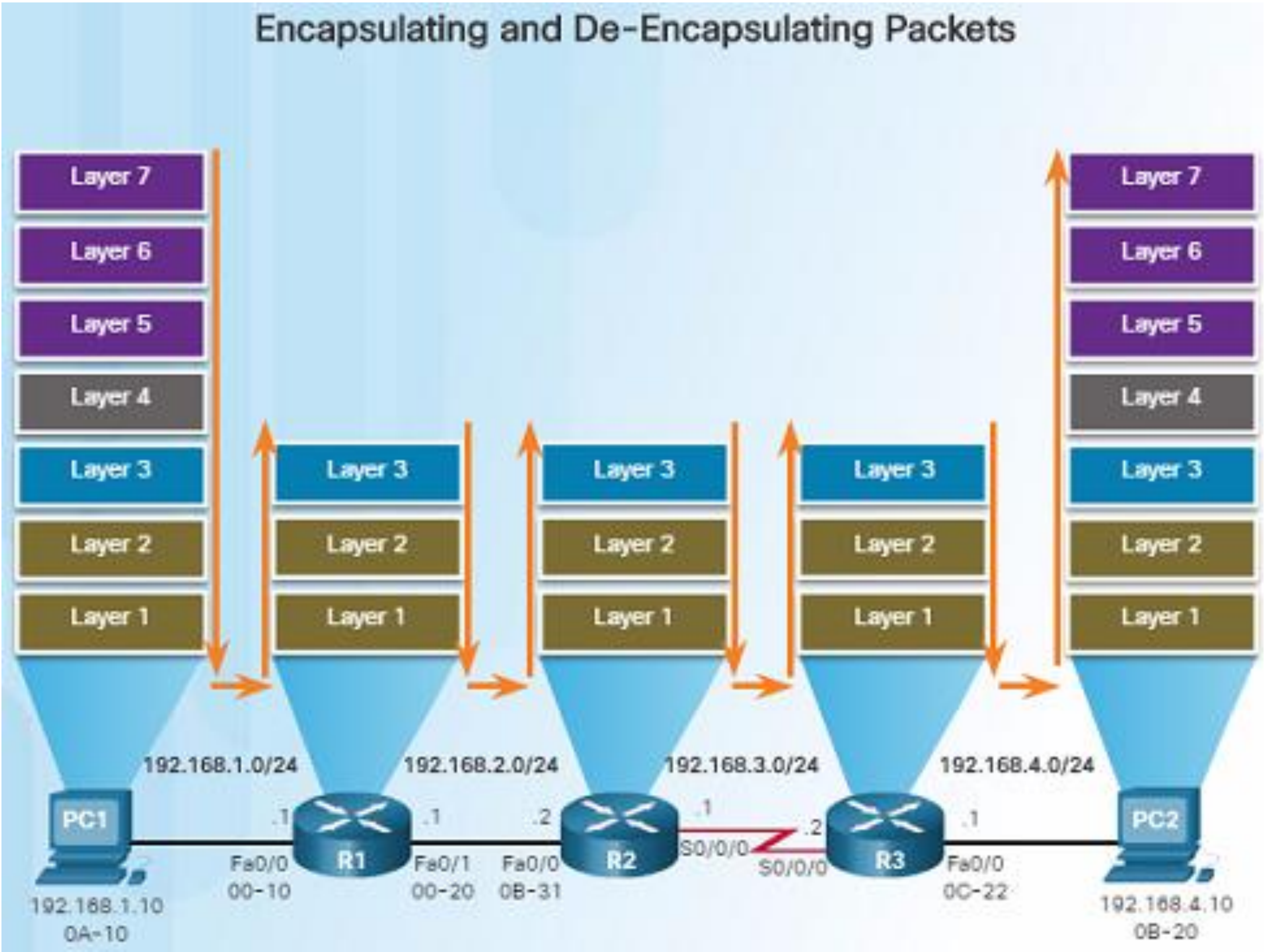


Router Switching Function



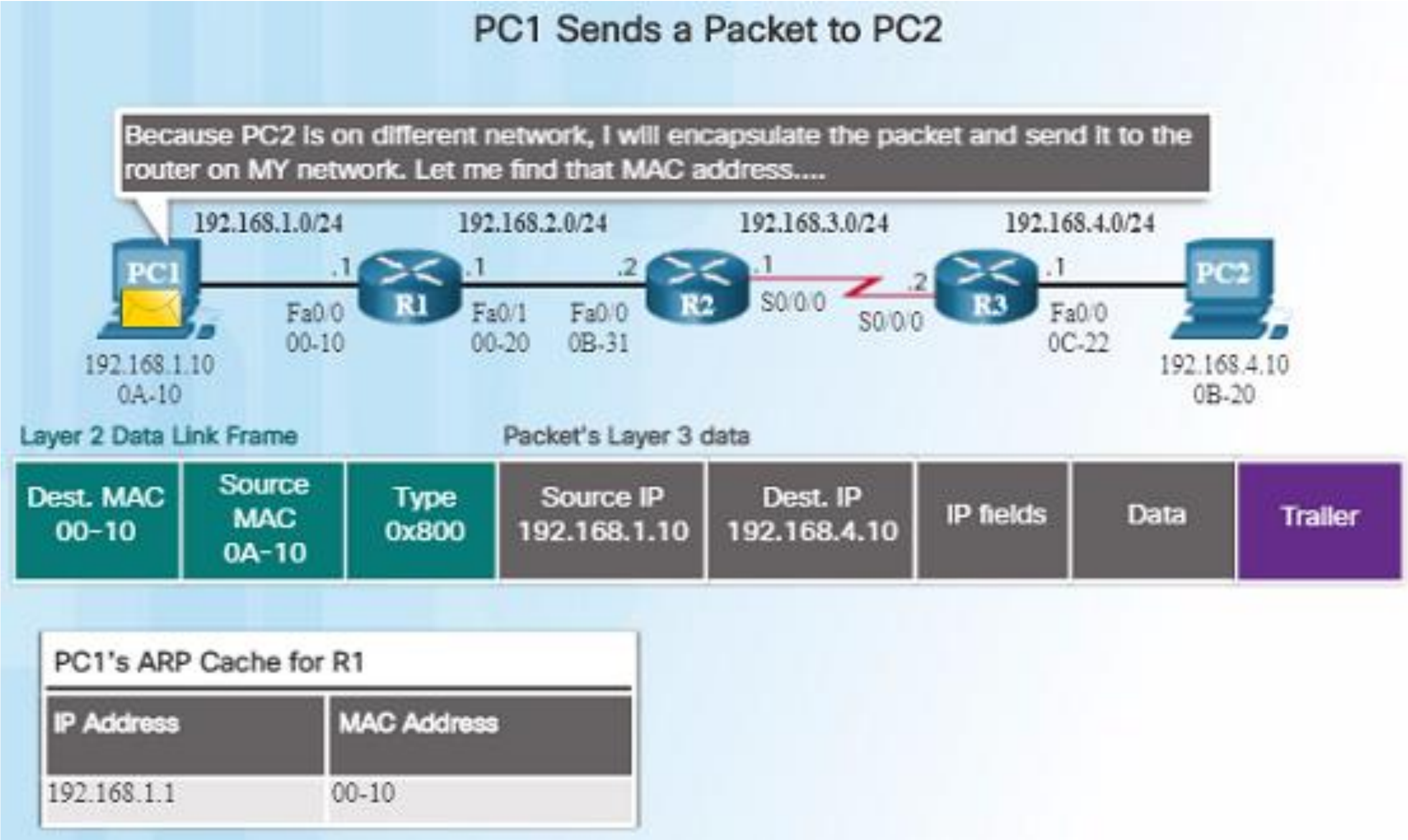
- The primary function of a router is to forward packets toward their destination.
  - Uses a switching function which is a process that accepts a packet on one interface and forwards it out of another interface. This is not to be confused with the function of a Layer 2 switch.
  - The switching function also encapsulates the packets in the appropriate data link frame type for the outgoing interface.

Router Switching Function (Cont.)



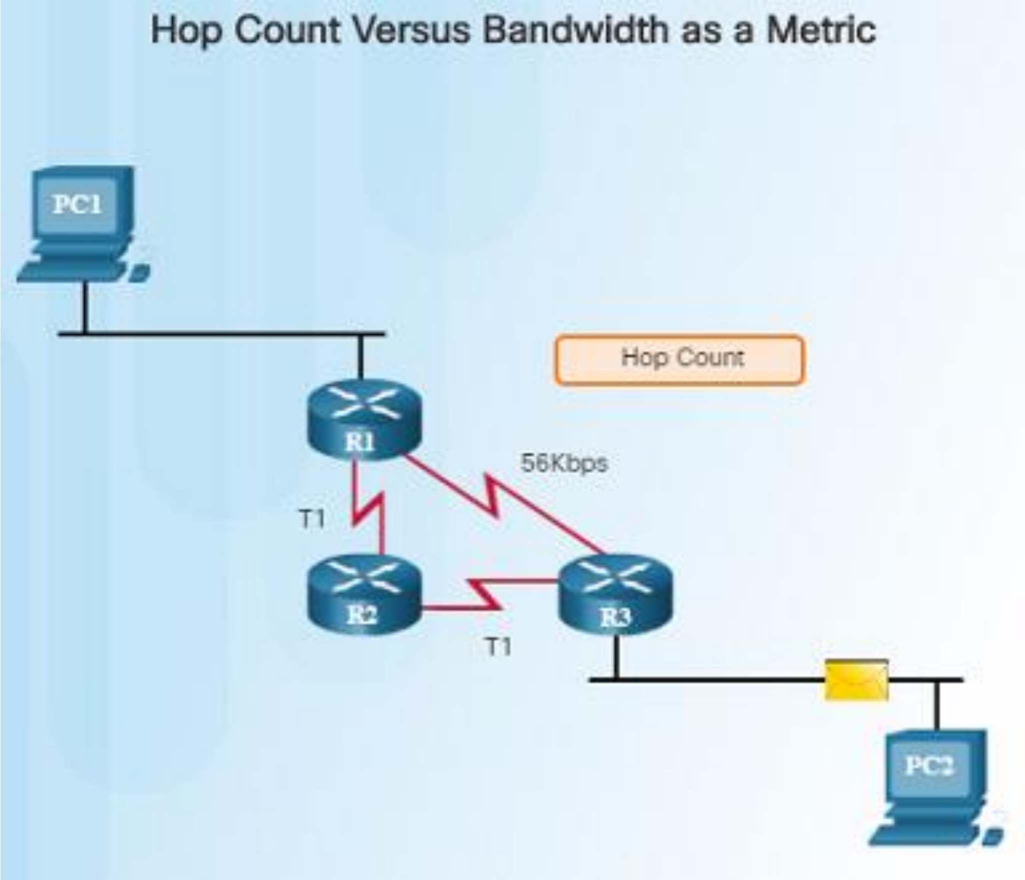
- When a router receives a packet from one network that is destined for another network, the router performs the following three steps:
  - Step 1. De-encapsulates the Layer 2 frame header and trailer to expose the Layer 3 packet.
  - Step 2. Examines the destination IP address of the IP packet to find the best path in the routing table.
  - Step 3. If the router finds a path to the destination, it encapsulates the Layer 3 packet into a new Layer 2 frame and forwards the frame out the exit interface.
- As a packet travels from the source device to the destination device, the Layer 3 IP addresses do not change. However, the Layer 2 data link addresses change at every hop as it is de-encapsulated and re-encapsulated.

Send a Packet



- For PC1 to send a packet to PC2, the following occurs:
  - PC1 must determine if the destination IPv4 address is on the same network. If it is on the same network, PC1 will obtain the destination MAC address from its ARP cache or use an ARP request.
  - Because the destination network is on a different network, PC1 forwards the packet to its default gateway.
  - To determine the MAC address of the default gateway, PC1 checks its ARP table for the IPv4 address of the default gateway and its corresponding MAC address. An ARP request is sent if it is not found.
  - When PC1 has the MAC address of Router R1, it can forward the packet.

Best Path



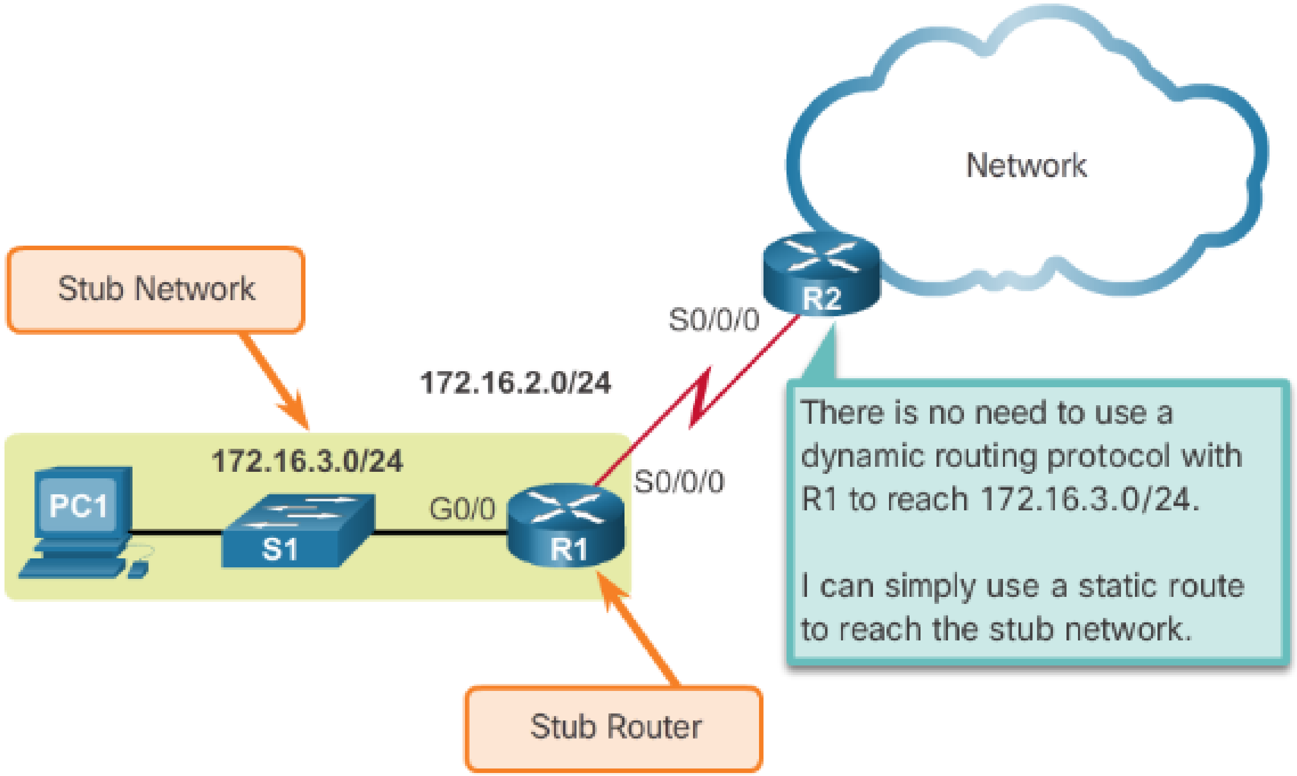
- Determining the best path to a destination network involves the evaluation of multiple paths and selecting the optimum or shortest path to reach that network.
- The best path is selected based on the metric or value that is used by the routing protocol.
- The best path to a network is the path with the lowest metric. A metric is a value that is used to measure the distance to a given network.
- Each dynamic routing protocols has their own rules and metrics to build and update routing tables. For example:
  - Routing Information Protocol (RIP) – Hop count
  - Open Shortest Path First (OSPF) – Cisco's cost based cumulative bandwidth from source to destination
  - Enhanced Interior Gateway Routing Protocol (EIGRP) – Bandwidth, delay, load, reliability

Static Routing Implementation

Types of Static Routes

Standard Static Route

Connecting to a Stub Network



Configure IPv4 Static Routes

ip route Command

```
Router(config)# ip route network-address subnet-mask
{ip-address | exit-intf}
```

Parameter	Description
network-address	Destination network address of the remote network to be added to the routing table
subnet-mask	• Subnet mask of the remote network to be added to the routing table • The subnet mask can be modified to summarize a group of networks
ip-address	• Commonly referred to as the next-hop router's IP address • Typically used when connecting to a broadcast media (i.e., Ethernet) • Commonly creates a recursive lookup
exit-intf	• Use the outgoing interface to forward packets to the destination network • Also referred to as a directly attached static route • Typically used when connecting in a point-to-point configuration
distance	• (Optional) Configures an administrative distance • Typically used to configure a floating static route

Next-Hop Options

The next hop can be identified by an IP address, exit interface, or both. How the destination is specified creates one of the three following route types:

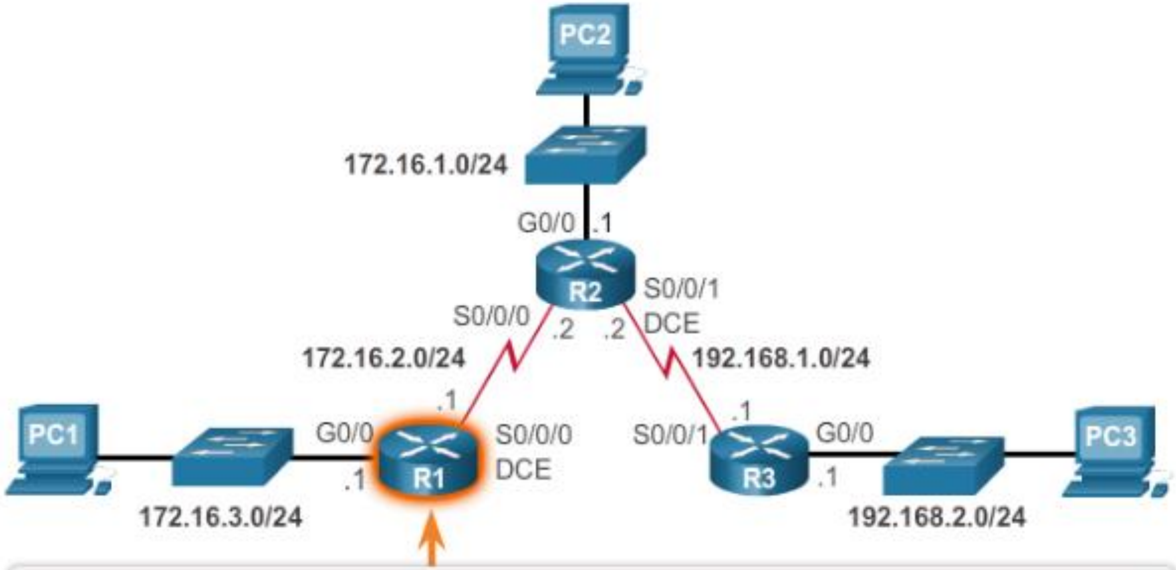
- **Next-hop route** - Only the next-hop IP address is specified.
- **Directly connected static route** - Only the router exit interface is specified.
- **Fully specified static route** - The next-hop IP address and exit interface are specified.

ROBERT GORDON UNIVERSITY ABERDEEN

Configure IPv4 Static Routes

Configure a Next-Hop Static Route

Configuring Next-Hop Static Routes on R1




```
R1(config)# ip route 172.16.1.0 255.255.255.0 172.16.2.2
R1(config)# ip route 192.168.1.0 255.255.255.0 172.16.2.2
R1(config)# ip route 192.168.2.0 255.255.255.0 172.16.2.2
R1(config)#
```

Configure IPv4 Static Routes

Default Static Route

Default Static Route Syntax

```
Router(config)#ip route 0.0.0.0 0.0.0.0 {ip-address | exit-intf}
```

Parameter	Description
0.0.0.0 0.0.0.0	Matches any network address.
ip-address	• Commonly referred to as the next-hop router's IP address. • Typically used when connecting to a broadcast media (i.e., Ethernet). • Commonly creates a recursive lookup.
exit-intf	• Use the outgoing interface to forward packets to the destination network. • Also referred to as a directly attached static route. • Typically used when connecting in a point-to-point configuration.

Dynamic Routing
RIP Protocol

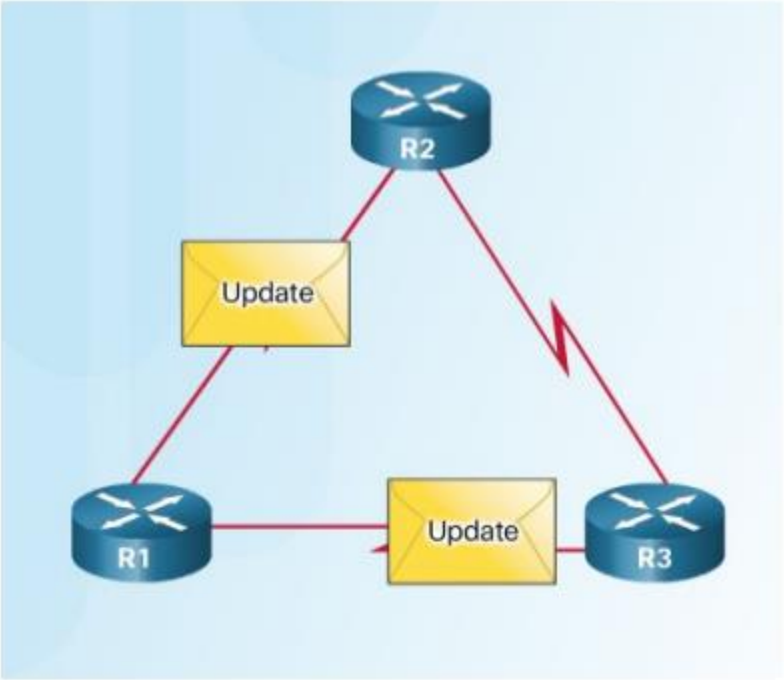
Dynamic Routing Protocol Overview

Dynamic Routing Protocols Components

Routing Protocols are used to facilitate the exchange of routing information between routers.

The purpose of dynamic routing protocols includes:

- Discovery of remote networks
- Maintaining up-to-date routing information
- Choosing the best path to destination networks
- Ability to find a new best path if the current path is no longer available



Dynamic verses Static Routing

Static Routing Advantages and Disadvantages

Advantages	Disadvantages
Easy to implement in a small network.	Suitable only for simple topologies or for special purposes such as a default static route.
Very secure. No advertisements are sent as compared to dynamic routing protocols.	Configuration complexity increases dramatically as network grows.
Route to destination is always the same.	Manual intervention required to re-route traffic.
No routing algorithm or update mechanism required; therefore, extra resources (CPU or RAM) are not required.	

Dynamic verses Static Routing

Dynamic Routing Advantages & Disadvantages

Advantages	Disadvantages
Suitable in all topologies where multiple routers are required.	Can be more complex to implement.
Generally independent of the network size.	Less secure. Additional configuration settings are required to secure.
Automatically adapts topology to reroute traffic if possible.	Route depends on the current topology.
	Requires additional CPU, RAM, and link bandwidth.

ROBERT GORDON UNIVERSITY ABERDEEN

Configuring the RIP Protocol

Router RIP Configuration Mode

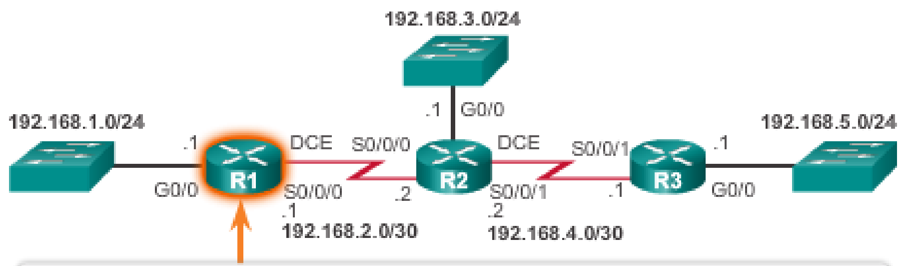
```
R1# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)# router rip
R1(config-router)#
```

Configuring the RIP Protocol

Router RIP Configuration Mode

- The **network network-address** router configuration mode command:
  - Enables RIP on all interfaces that belong to a specific network.
  - Advertises the network in RIP routing updates sent to other routers every 30 seconds.

Advertising the R1 Networks

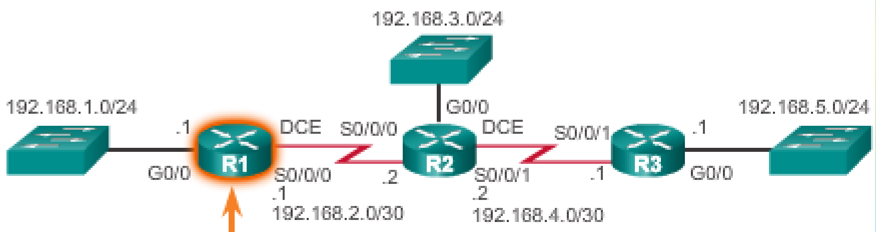



```
R1(config)#router rip
R1(config-router)#network 192.168.1.0
R1(config-router)#network 192.168.2.0
R1(config-router)#
```

Enable and Verify RIPv2

- Use the **version 2** router configuration mode command to enable RIPv2.
- Use **the show ip protocols** command to verify that RIPv2 is configured.
- Use the **show ip route** command to verify the RIPv2 routes in the routing table.

Enable and Verify RIPv2 on R1




```
R1(config)# router rip
R1(config-router)# version 2
R1(config-router)# ^Z
R1#
R1# show ip protocols | section Default
  Default version control: send version 2, receive version 2
    Interface             Send  Recv  Triggered RIP  Key-chain
    GigabitEthernet0/0    2     2
    Serial0/0/0           2     2
R1#
```

Configuring the RIP Protocol

Verify RIP Routing

show ip protocols – displays IPv4 routing protocols configured on the router.

Verifying RIP Routes on R1

```
R1# show ip route | begin Gateway
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        192.168.1.1/32 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, Serial0/0/0
L        192.168.2.1/32 is directly connected, Serial0/0/0
R     192.168.3.0/24 [120/1] via 192.168.2.2, 00:00:24, Serial0/0/0
R     192.168.4.0/24 [120/1] via 192.168.2.2, 00:00:24, Serial0/0/0
R     192.168.5.0/24 [120/2] via 192.168.2.2, 00:00:24, Serial0/0/0
R1#
```

Verifying RIP Settings on R1

```
R1# show ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 16 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip

  Default version control: send version 1, receive any version
    Interface             Send  Recv  Triggered RIP  Key-chain
    GigabitEthernet0/0    1     1 2
    Serial0/0/0           1     1 2

  Automatic network summarization is in effect
  Maximum path: 4
  Routing for Networks:
    192.168.1.0
    192.168.2.0

  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.2.2          120      00:00:15
  Distance: (default is 120)

R1#
```

Configuring the RIP Protocol

Disable Auto Summarization

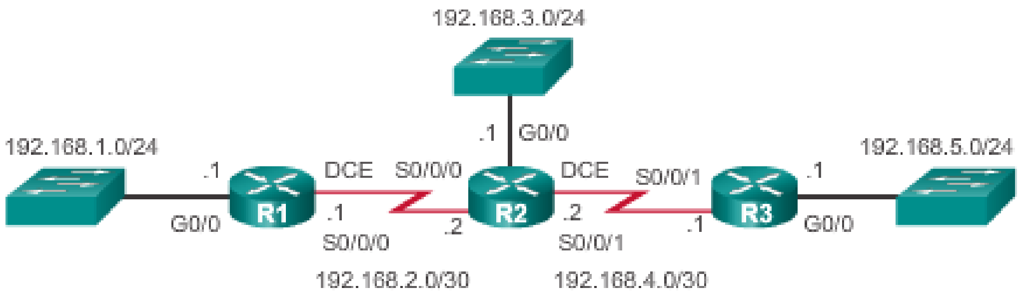
- Similarly to RIPv1, RIPv2 automatically summarizes networks at major network boundaries by default.
- To modify the default RIPv2 behavior of automatic summarization, use the **no auto-summary** router configuration mode command.
- This command has no effect when using RIPv1.
- When automatic summarization has been disabled, RIPv2 no longer summarizes networks to their classful address at boundary routers. RIPv2 now includes all subnets and their appropriate masks in its routing updates.
- The **show ip protocols** now states that automatic network summarization is not in effect.

Configuring the RIP Protocol

Configuring Passive Interfaces

- RIP updates are forwarded out all RIP-enabled interfaces by default.
- Sending out unneeded updates on a LAN impacts the network in three ways:
  - Wasted Bandwidth
  - Wasted Resources
  - Security Risk
- Use the passive-interface router configuration command to stop routing updates out the interface. Still allows that network to be advertised to other routers.

Configuring Passive Interfaces on R1



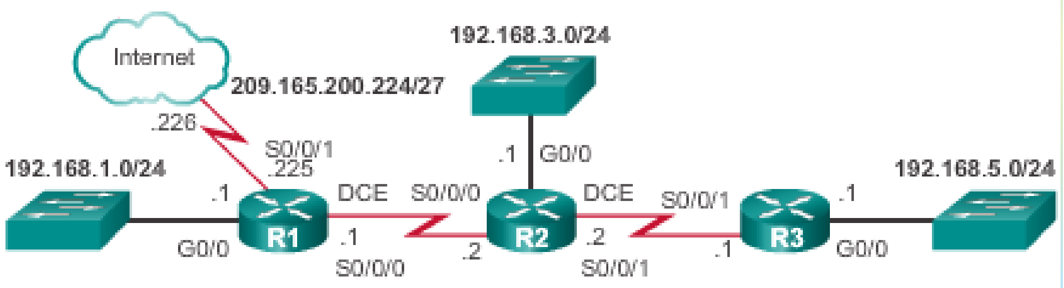

```
R1(config)# router rip
R1(config-router)# passive-interface g0/0
R1(config-router)# end
R1#
R1# show ip protocols | begin Default
  Default version control: send version 2, receive version 2
    Interface             Send  Recv  Triggered RIP  Key-chain
    Serial0/0/0           2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
    192.168.1.0
    192.168.2.0
  Passive Interface(s):
    GigabitEthernet0/0
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.2.2          120      00:00:06
  Distance: (default is 120)

R1#
```

Configuring the RIP Protocol

Propagate a Default Route

- In the diagram a default static route to the Internet is configured on R1.
- The **default-information originate** router configuration command instructs R1 to send the default static route information in the RIP updates.

Propagating a Default Route on R1




```
R1(config)# ip route 0.0.0.0 0.0.0.0 S0/0/1 209.165.200.226
R1(config)# router rip
R1(config-router)# default-information originate
R1(config-router)# ^Z
R1#
*Mar 10 23:33:51.801: %SYS-5-CONFIG_I: Configured from
console by console
R1# show ip route | begin Gateway
Gateway of last resort is 209.165.200.226 to network
0.0.0.0

S*    0.0.0.0/0 [1/0] via 209.165.200.226, Serial0/0/1
      192.168.1.0/24 is variably subnetted, 2 subnets, 2
masks
C        192.168.1.0/24 is directly connected,
GigabitEthernet0/0
L        192.168.1.1/32 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, Serial0/0/0
L        192.168.2.1/32 is directly connected, Serial0/0/0
R     192.168.3.0/24 [120/1] via 192.168.2.2, 00:00:08,
```

Parts of an IPv4 Route Entry

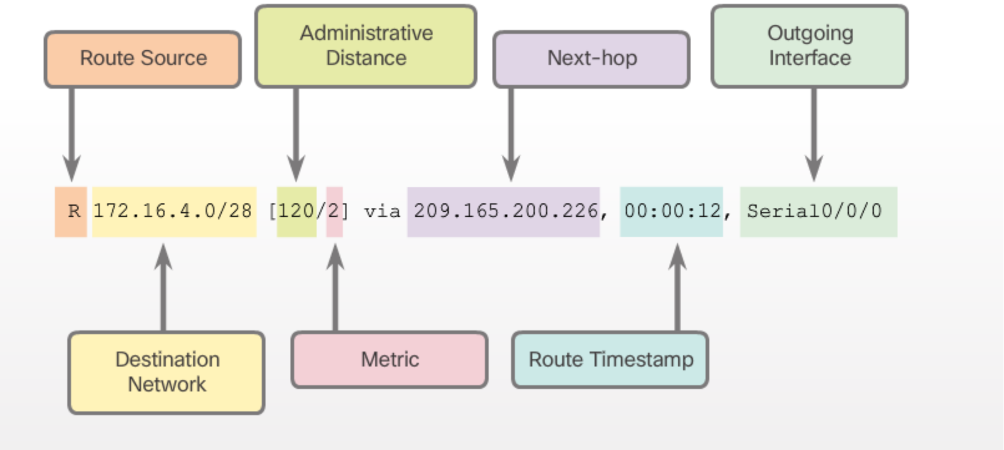
Routing Table Entries

Routing Table of R1

```
R1#show ip route | begin Gateway
Gateway of last resort is 209.165.200.234 to network 0.0.0.0

S* 0.0.0.0/0 [1/0] via 209.165.200.234, Serial0/0/1
                    is directly connected, Serial0/0/1
   172.16.0.0/16 is variably subnetted, 5 subnets, 3 masks
C     172.16.1.0/24 is directly connected, GigabitEthernet0/0
L     172.16.1.1/32 is directly connected, GigabitEthernet0/0
R     172.16.2.0/24 [120/1] via 209.165.200.226, 00:00:12, Serial0/0/0
R     172.16.3.0/24 [120/2] via 209.165.200.226, 00:00:12, Serial0/0/0
R     172.16.4.0/28 [120/2] via 209.165.200.226, 00:00:12, Serial0/0/0
R  192.168.0.0/16 [120/2] via 209.165.200.226, 00:00:03, Serial0/0/0
   209.165.200.0/24 is variably subnetted, 5 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
R     209.165.200.228/30 [120/1] via 209.165.200.226, 00:00:12,
                    Serial0/0/0
C     209.165.200.232/30 is directly connected, Serial0/0/1
L     209.165.200.233/30 is directly connected, Serial0/0/1
R1#
```

Parts of an IPv4 Route Entry

Remote Network Entries



- Routes to remote networks contain the following information:
  - Route source – how route was learned
  - Destination network
  - Administrative distance (AD) - trustworthiness of the route.
  - Metric – value assigned to reach the remote network. Lower is better.
  - Next hop – IPv4 address of the next router that the packet should be forwarded to.
  - Route timestamp – time since the route was updated.
  - Outgoing interface - the exit interface to use to forward the packet

Q&A