



Chapter 7: Routing Dynamically



Routing & Switching

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Chapter 7

- 7.1 Dynamic Routing Protocols
- 7.2 Distance Vector Dynamic Routing
- 7.3 RIP and RIPng Routing
- 7.4 Link-State Dynamic Routing
- 7.5 The Routing Table
- 7.6 Summary



Chapter 7: Objectives

- Explain the basic operation of dynamic routing protocols.
- Compare and contrast dynamic and static routing.
- Determine which networks are available during an initial network discovery phase.
- Define the different categories of routing protocols.
- Describe the process by which distance vector routing protocols learn about other networks.
- Identify the types of distance-vector routing protocols.
- Configure the RIP routing protocol.
- Configure the RIPng routing protocol.
- Explain the process by which link-state routing protocols learn about other networks.



Chapter 7: Objectives (cont.)

- Describe the information sent in a link-state update.
- Describe advantages and disadvantages of using link-state routing protocols.
- Identify protocols that use the link-state routing process. (OSPF, IS-IS)
- Determine the route source, administrative distance, and metric for a given route.
- Explain the concept of a parent/child relationship in a dynamically built routing table.
- Compare the IPv4 classless route lookup process and the IPv6 lookup process.
- Analyze a routing table to determine which route will be used to forward a packet.



Dynamic Routing Protocol Operation

The Evolution of Dynamic Routing Protocols

- Dynamic routing protocols used in networks since the late 1980s
- Newer versions support the communication based on IPv6

Routing Protocols Classification

	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector		Link-State		Path Vector
IPv4	RIPv2	EIGRP	OSPFv2	IS-IS	BGP-4
IPv6	RIPng	EIGRP for IPv6	OSPFv3	IS-IS for IPv6	BGP-MP



Dynamic Routing Protocol Operation

Purpose of Dynamic Routing Protocols

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 Routing Protocol Operation

Purpose of Dynamic Routing Protocols (cont.)

Main components of dynamic routing protocols include:

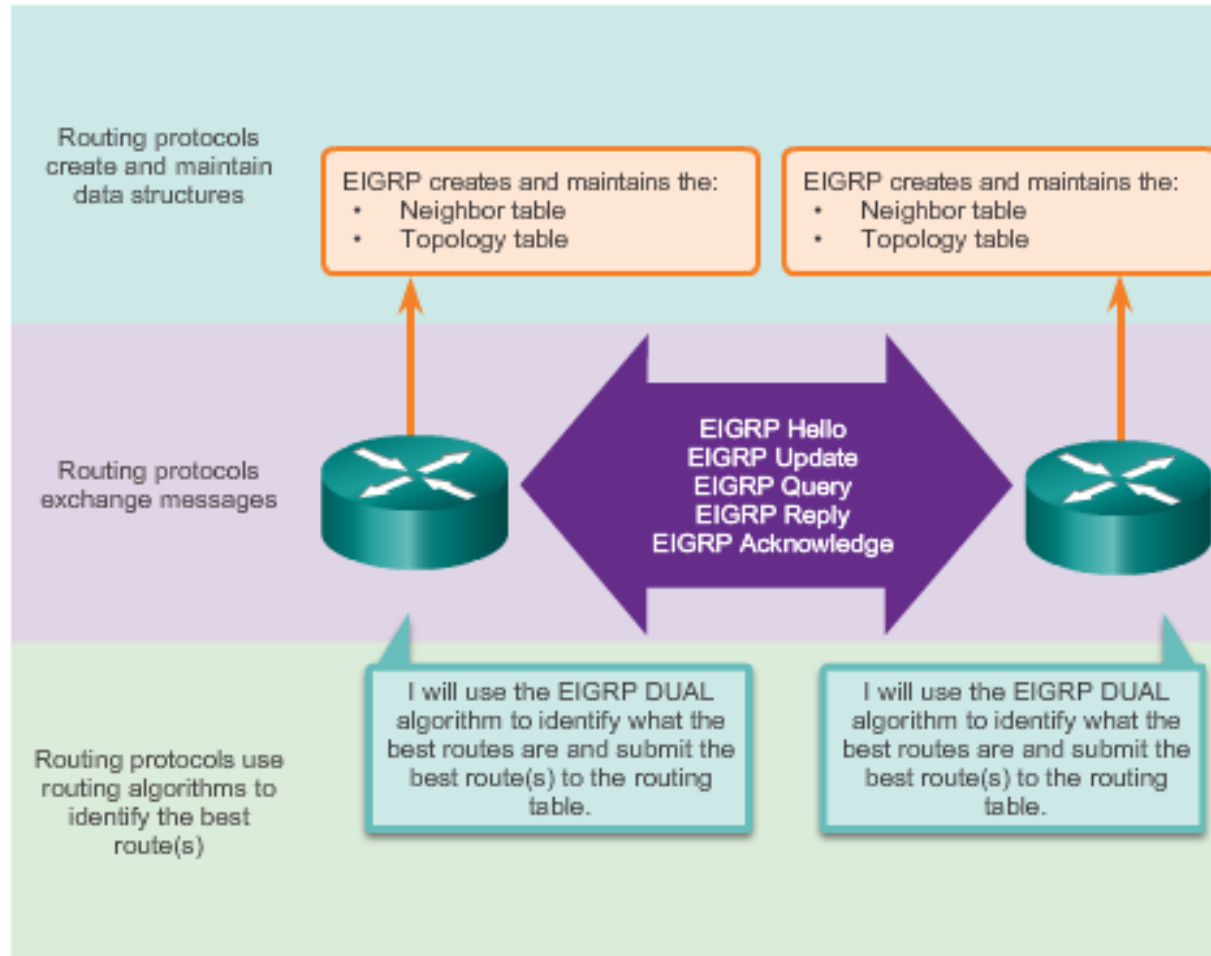
- **Data structures** - Routing protocols typically use tables or databases for its operations. This information is kept in RAM.
- **Routing protocol messages** - Routing protocols use various types of messages to discover neighboring routers, exchange routing information, and other tasks to learn and maintain accurate information about the network.
- **Algorithm** - Routing protocols use algorithms for facilitating routing information for best path determination.



Dynamic Routing Protocol Operation

Purpose of Dynamic Routing Protocols (cont.)

Components of Routing Protocols





Dynamic Routing Protocol Operation

The Role of Dynamic Routing Protocols

Advantages of dynamic routing include:

- Automatically share information about remote networks
- Determine the best path to each network and add this information to their routing tables
- Compared to static routing, dynamic routing protocols require less administrative overhead
- Help the network administrator manage the time-consuming process of configuring and maintaining static routes

Disadvantages of dynamic routing include:

- Part of a router's resources are dedicated for protocol operation, including CPU time and network link bandwidth
- Times when static routing is more appropriate



Dynamic verses Static Routing

Using Static Routing

Networks typically use a combination of both static and dynamic routing.

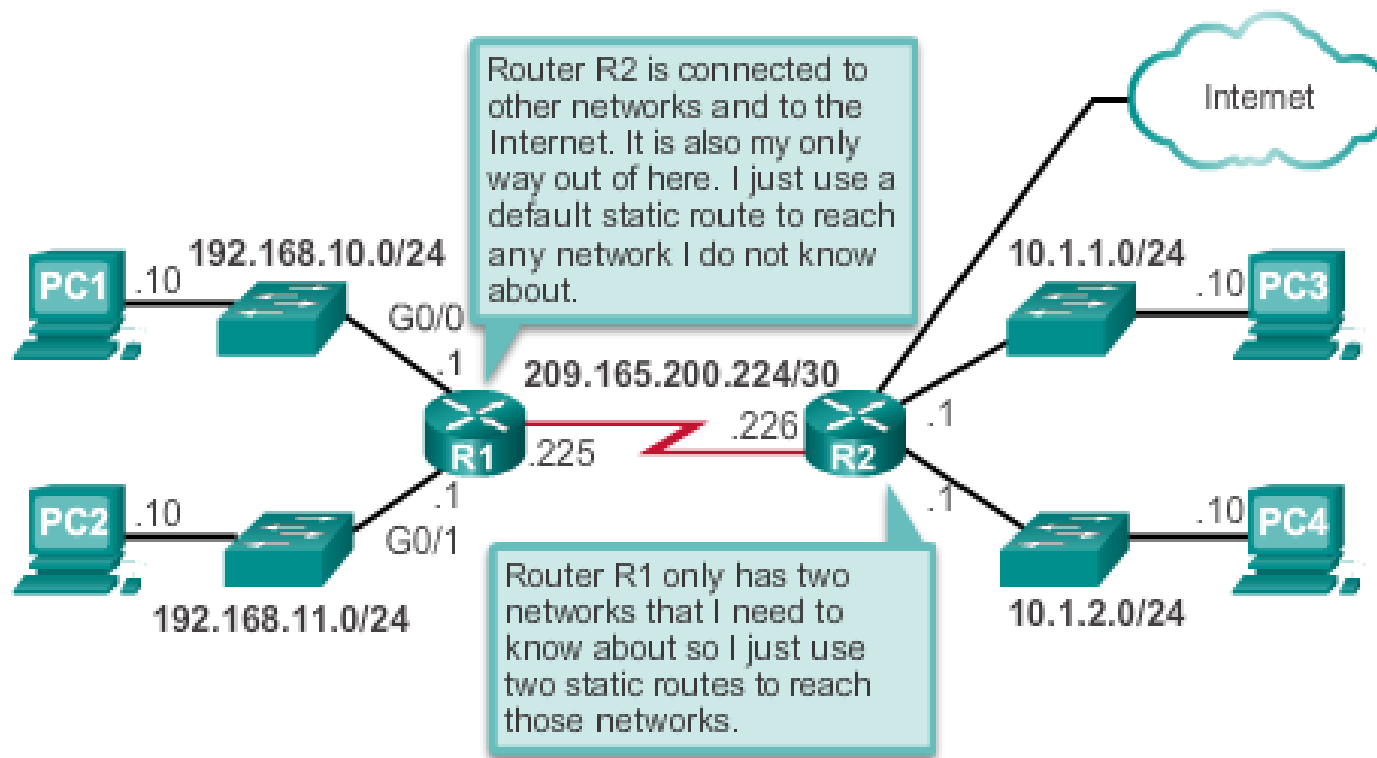
Static routing has several primary uses:

- Providing ease of routing table maintenance in smaller networks that are not expected to grow significantly.
- Routing to and from a stub network. A network with only one default route out and no knowledge of any remote networks.
- Accessing a single default router. This is used to represent a path to any network that does not have a match in the routing table.



Dynamic verses Static Routing

Using Static Routing (cont.)





Dynamic verses Static Routing

Static Routing Scorecard

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. Configuration complexity increases dramatically as network grows.
Very secure. No advertisements are sent as compared to dynamic routing protocols.	
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 Scorecard

Dynamic Routing Advantages and 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.



Routing Protocol Operating Fundamentals

Dynamic Routing Protocol Operation

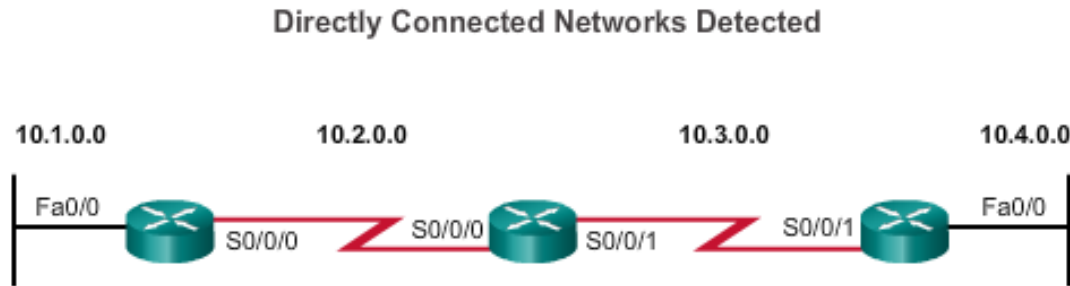
In general, the operations of a dynamic routing protocol can be described as follows:

1. The router sends and receives routing messages on its interfaces.
2. The router shares routing messages and routing information with other routers that are using the same routing protocol.
3. Routers exchange routing information to learn about remote networks.
4. When a router detects a topology change the routing protocol can advertise this change to other routers.



Routing Protocol Operating Fundamentals

Cold Start



Network	Interface	Hop
10.1.0.0	Fa0/0	0
10.2.0.0	S0/0/0	0

Network	Interface	Hop
10.2.0.0	S0/0/0	0
10.3.0.0	S0/0/1	0

Network	Interface	Hop
10.3.0.0	S0/0/1	0
10.4.0.0	Fa0/0	0

Routers running RIPv2

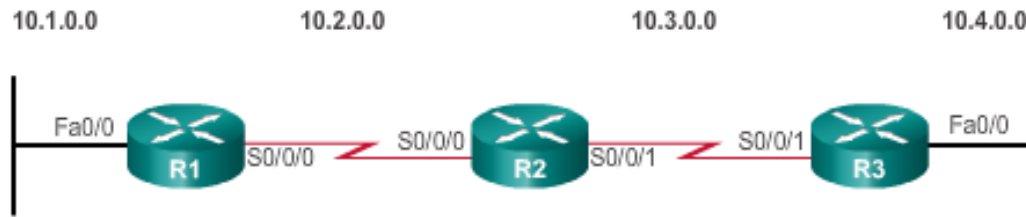
- R1 adds the 10.1.0.0 network available through interface FastEthernet 0/0 and 10.2.0.0 is available through interface Serial 0/0/0.
- R2 adds the 10.2.0.0 network available through interface Serial 0/0/0 and 10.3.0.0 is available through interface Serial 0/0/1.
- R3 adds the 10.3.0.0 network available through interface Serial 0/0/1 and 10.4.0.0 is available through interface FastEthernet 0/0.



Routing Protocol Operating Fundamentals

Network Discovery

Initial Exchange



Network	Interface	Hop	Network	Interface	Hop	Network	Interface	Hop
10.1.0.0	Fa0/0	0	10.2.0.0	S0/0/0	0	10.3.0.0	S0/0/0	0
10.2.0.0	S0/0/0	0	10.3.0.0	S0/0/1	0	10.4.0.0	Fa0/0	0
10.3.0.0	S0/0/0	1	10.1.0.0	S0/0/0	1	10.2.0.0	S0/0/1	1
			10.4.0.0	S0/0/1	1			

R1:

- Sends an update about network 10.1.0.0 out the Serial0/0/0 interface
- Sends an update about network 10.2.0.0 out the FastEthernet0/0 interface
- Receives update from R2 about network 10.3.0.0 with a metric of 1
- Stores network 10.3.0.0 in the routing table with a metric of 1

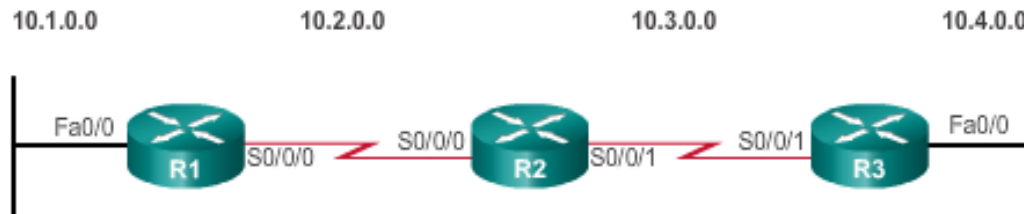
Routers running RIPv2



Routing Protocol Operating Fundamentals

Network Discovery (cont.)

Initial Exchange



Network	Interface	Hop	Network	Interface	Hop	Network	Interface	Hop
10.1.0.0	Fa0/0	0	10.2.0.0	S0/0/0	0	10.3.0.0	S0/0/0	0
10.2.0.0	S0/0/0	0	10.3.0.0	S0/0/1	0	10.4.0.0	Fa0/0	0
10.3.0.0	S0/0/0	1	10.1.0.0	S0/0/0	1	10.2.0.0	S0/0/1	1
			10.4.0.0	S0/0/1	1			

Routers running RIPv2

R2:

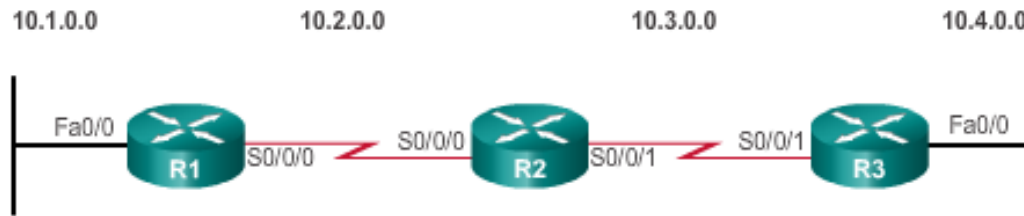
- Sends an update about network 10.3.0.0 out the Serial 0/0/0 interface
- Sends an update about network 10.2.0.0 out the Serial 0/0/1 interface
- Receives an update from R1 about network 10.1.0.0 with a metric of 1
- Stores network 10.1.0.0 in the routing table with a metric of 1
- Receives an update from R3 about network 10.4.0.0 with a metric of 1
- Stores network 10.4.0.0 in the routing table with a metric of 1



Routing Protocol Operating Fundamentals

Network Discovery (cont.)

Initial Exchange



Network	Interface	Hop	Network	Interface	Hop	Network	Interface	Hop
10.1.0.0	Fa0/0	0	10.2.0.0	S0/0/0	0	10.3.0.0	S0/0/0	0
10.2.0.0	S0/0/0	0	10.3.0.0	S0/0/1	0	10.4.0.0	Fa0/0	0
10.3.0.0	S0/0/0	1	10.1.0.0	S0/0/0	1	10.2.0.0	S0/0/1	1
			10.4.0.0	S0/0/1	1			

R3:

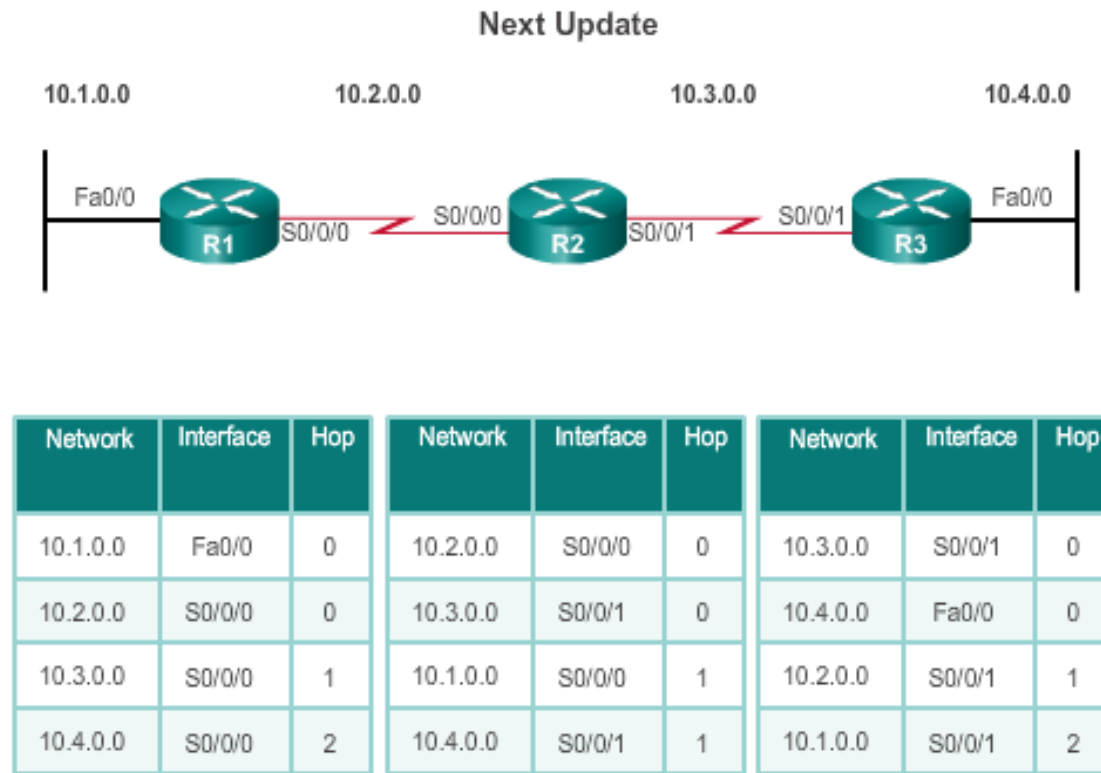
- Sends an update about network 10.4.0.0 out the Serial 0/0/1 interface
- Sends an update about network 10.3.0.0 out the FastEthernet0/0
- Receives an update from R2 about network 10.2.0.0 with a metric of 1
- Stores network 10.2.0.0 in the routing table with a metric of 1

Routers running RIPv2



Routing Protocol Operating Fundamentals

Exchanging the Routing Information



Routers running RIPv2

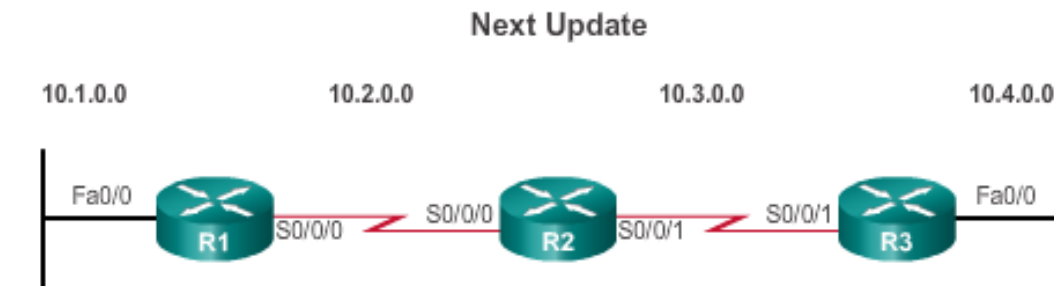
R1:

- Sends an update about network 10. 1. 0. 0 out the Serial 0/0/0 interface
- Sends an update about networks 10. 2. 0. 0 and 10. 3. 0. 0 out the FastEthernet0/0 interface
- Receives an update from R2 about network 10. 4. 0. 0 with a metric of 2
- Stores network 10. 4. 0. 0 in the routing table with a metric of 2
- Same update from R2 contains information about network 10. 3. 0. 0 with a metric of 1. There is no change; therefore, the routing information remains the same



Routing Protocol Operating Fundamentals

Exchanging the Routing Information (cont.)



Network	Interface	Hop	Network	Interface	Hop	Network	Interface	Hop
10.1.0.0	Fa0/0	0	10.2.0.0	S0/0/0	0	10.3.0.0	S0/0/1	0
10.2.0.0	S0/0/0	0	10.3.0.0	S0/0/1	0	10.4.0.0	Fa0/0	0
10.3.0.0	S0/0/0	1	10.1.0.0	S0/0/0	1	10.2.0.0	S0/0/1	1
10.4.0.0	S0/0/0	2	10.4.0.0	S0/0/1	1	10.1.0.0	S0/0/1	2

Routers running RIPv2

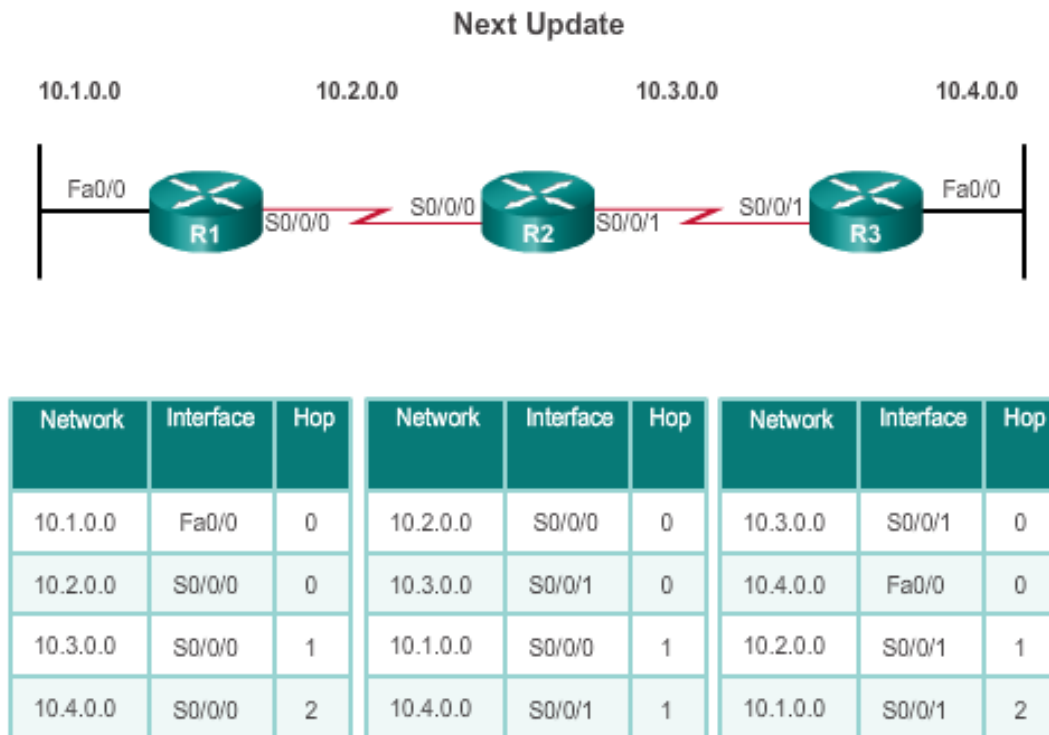
R2:

- Sends an update about networks 10. 3. 0. 0 and 10. 4. 0. 0 out of Serial 0/0/0 interface
- Sends an update about networks 10. 1. 0. 0 and 10. 2. 0. 0 out of Serial 0/0/1 interface
- Receives an update from R1 about network 10. 1. 0. 0. There is no change; therefore, the routing information remains the same.
- Receives an update from R3 about network 10. 4. 0. 0. There is no change; therefore, the routing information remains the same.



Routing Protocol Operating Fundamentals

Exchanging the Routing Information (cont.)



Routers running RIPv2

R3:

- Sends an update about network 10. 4. 0. 0 out the Serial 0/0/1 interface
- Sends an update about networks 10. 2. 0. 0 and 10. 3. 0. 0 out the FastEthernet0/0 interface
- Receives an update from R2 about network 10. 1. 0. 0 with a metric of 2
- Stores network 10. 1. 0. 0 in the routing table with a metric of 2
- Same update from R2 contains information about network 10. 2. 0. 0 with a metric of 1. There is no change; therefore, the routing information remains the same.



Routing Protocol Operating Fundamentals

Achieving Convergence

The network is converged when all routers have complete and accurate information about the entire network:

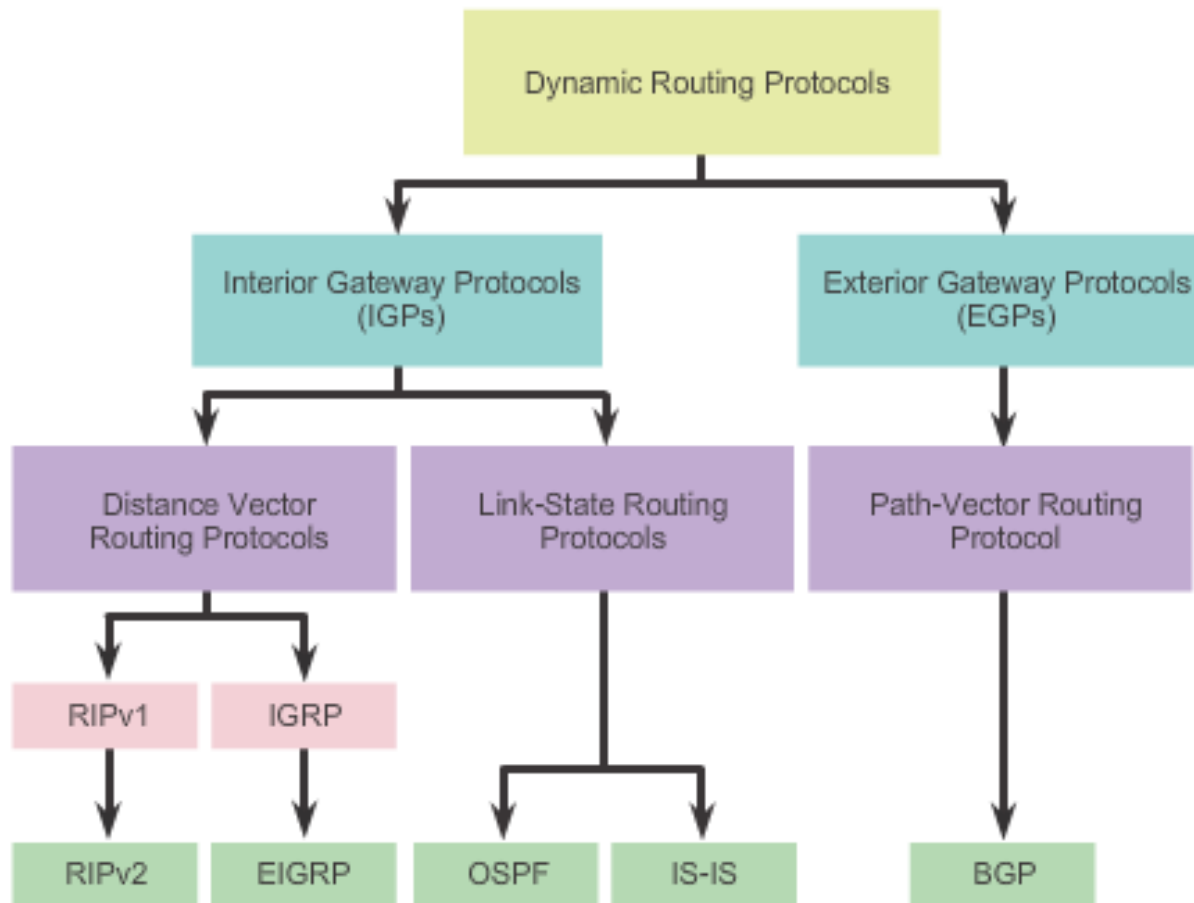
- Convergence time is the time it takes routers to share information, calculate best paths, and update their routing tables.
- A network is not completely operable until the network has converged.
- Convergence properties include the speed of propagation of routing information and the calculation of optimal paths. The speed of propagation refers to the amount of time it takes for routers within the network to forward routing information.
- Generally, older protocols, such as RIP, are slow to converge, whereas modern protocols, such as EIGRP and OSPF, converge more quickly.



Types of Routing Protocols

Classifying Routing Protocols

Routing Protocols Classification

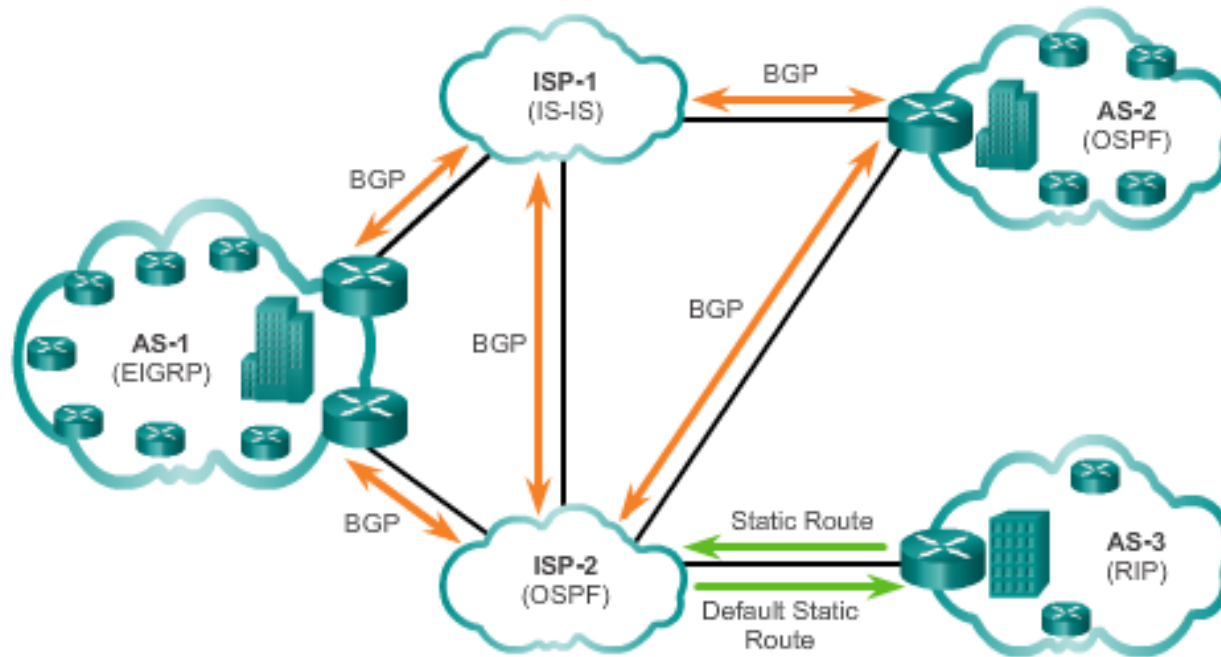




Types of Routing Protocols

IGP and EGP Routing Protocols

IGP versus EGP Routing Protocols



Interior Gateway Protocols (IGP) -

- Used for routing within an AS
- Include RIP, EIGRP, OSPF, and IS-IS

Exterior Gateway Protocols (EGP) -

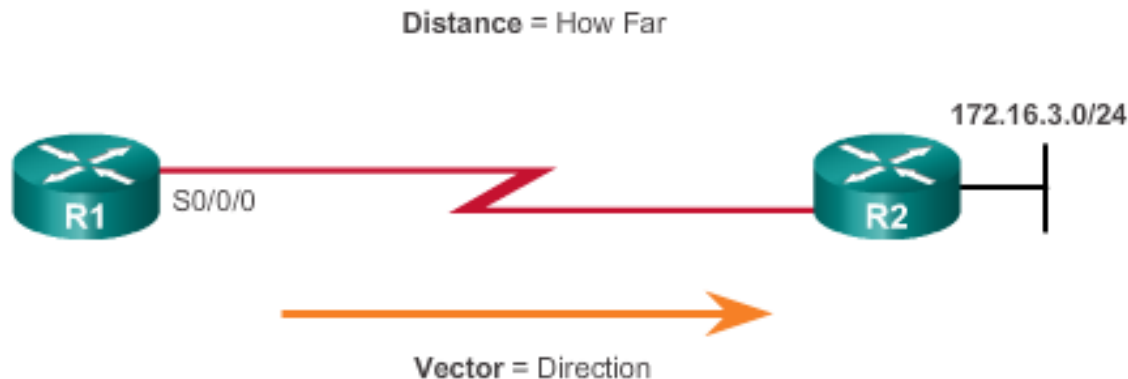
- Used for routing between AS
- Official routing protocol used by the Internet



Types of Routing Protocols

Distance Vector Routing Protocols

The Meaning of Distance Vector



For R1, 172.16.3.0/24 is one hop away (distance). It can be reached through R2 (vector).

Distance vector IPv4 IGPs:

- **RIPv1** - First generation legacy protocol
- **RIPv2** - Simple distance vector routing protocol
- **IGRP** - First generation Cisco proprietary protocol (obsolete)
- **EIGRP** - Advanced version of distance vector routing



Types of Routing Protocols

Distance Vector or Link-State Routing Protocols

Distance vector protocols use routers as sign posts along the path to the final destination.

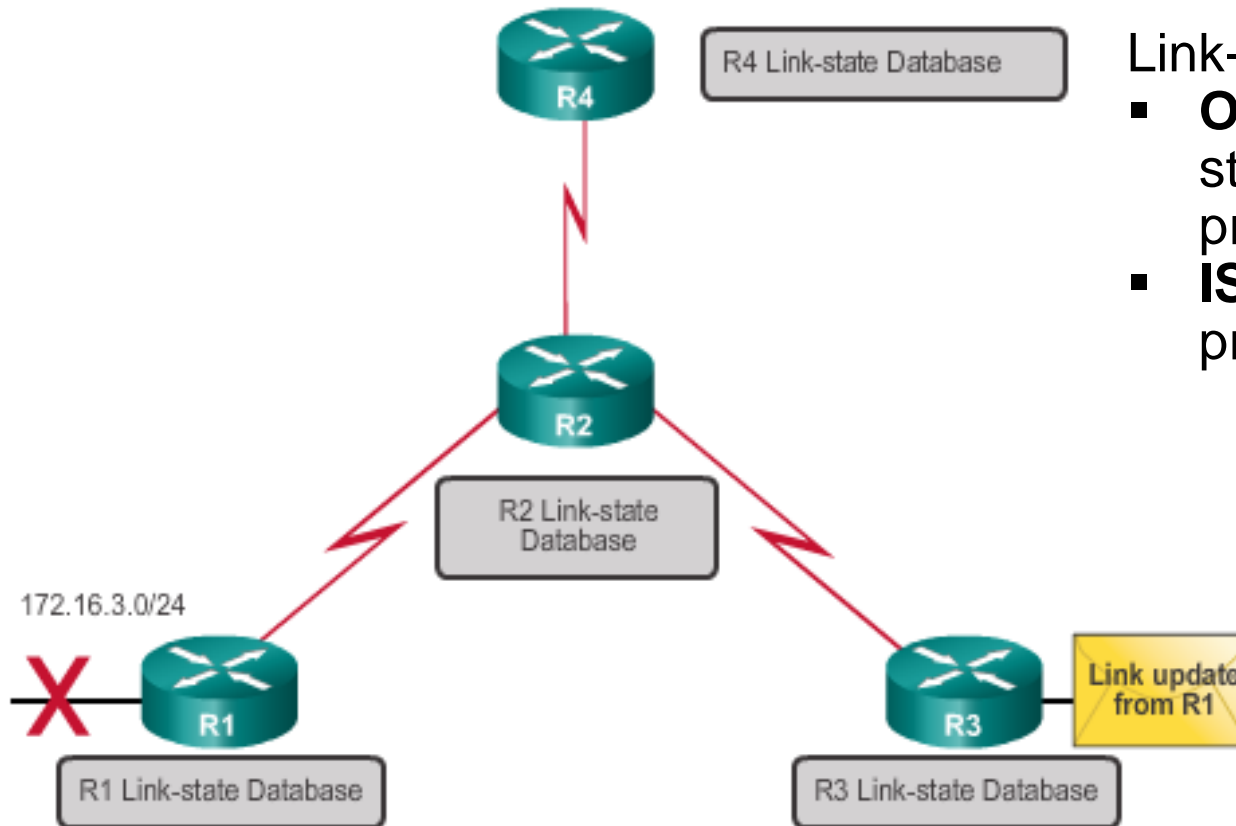
A link-state routing protocol is like having a complete map of the network topology. The sign posts along the way from source to destination are not necessary, because all link-state routers are using an identical map of the network. A link-state router uses the link-state information to create a topology map and to select the best path to all destination networks in the topology.



Types of Routing Protocols

Link-State Routing Protocols

Link-State Protocol Operation



Link-state protocols forward updates when the state of a link changes.

Link-state IPv4 IGPs:

- **OSPF** - Popular standards based routing protocol
- **IS-IS** - Popular in provider networks.



Types of Routing Protocols

Classful Routing Protocols

Classful routing protocols do not send subnet mask information in their routing updates:

- Only RIPv1 and IGRP are classful.
- Created when network addresses were allocated based on classes (class A, B, or C).
- Cannot provide variable length subnet masks (VLSMs) and classless interdomain routing (CIDR).
- Create problems in discontinuous networks.



Types of Routing Protocols

Classless Routing Protocols

Classless routing protocols include subnet mask information in the routing updates:

- RIPv2, EIGRP, OSPF, and IS-IS
- Support VLSM and CIDR
- IPv6 routing protocols



Types of Routing Protocols

Routing Protocol Characteristics

	Distance Vector				Link State	
	RIPv1	RIPv2	IGRP	EIGRP	OSPF	IS-IS
Speed Convergence	Slow	Slow	Slow	Fast	Fast	Fast
Scalability - Size of Network	Small	Small	Small	Large	Large	Large
Use of VLSM	No	Yes	No	Yes	Yes	Yes
Resource Usage	Low	Low	Low	Medium	High	High
Implementation and Maintenance	Simple	Simple	Simple	Complex	Complex	Complex



Types of Routing Protocols

Routing Protocol Metrics

A metric is a measurable value that is assigned by the routing protocol to different routes based on the usefulness of that route:

- Used to determine the overall “cost” of a path from source to destination.
- Routing protocols determine the best path based on the route with the lowest cost.

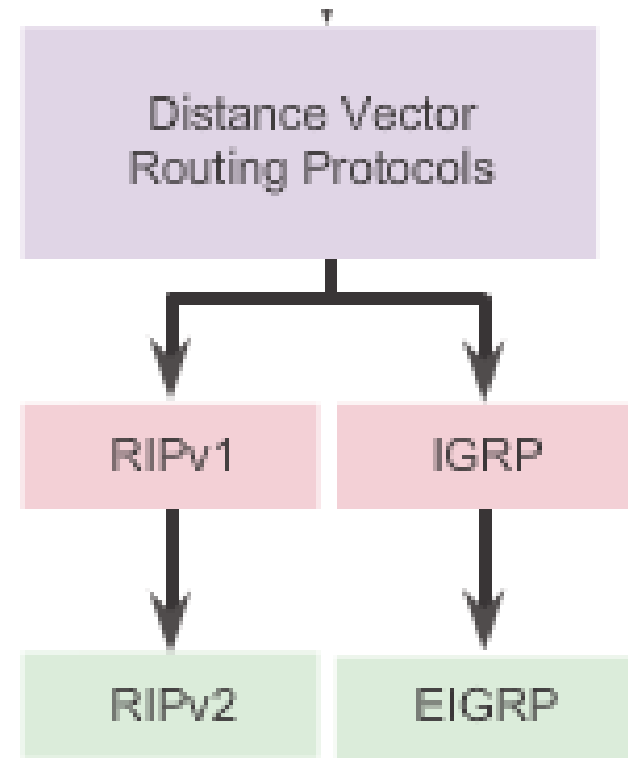


Distance Vector Routing Protocol Operation

Distance Vector Technologies

Distance vector routing protocols:

- Share updates between neighbors
- Not aware of the network topology
- Some send periodic updates to broadcast IP 255.255.255.255 even if topology has not changed
- Updates consume bandwidth and network device CPU resources
- RIPv2 and EIGRP use multicast addresses
- EIGRP will only send an update when topology has changed





Distance Vector Routing Protocol Operation

Distance Vector Algorithm

Purpose of Routing Algorithms

- Sending and receiving updates
- Calculate best path and install route
- Detect and react to topology changes



RIP uses the Bellman-Ford algorithm as its routing algorithm.

IGRP and EIGRP use the Diffusing Update Algorithm (DUAL) routing algorithm developed by Cisco.

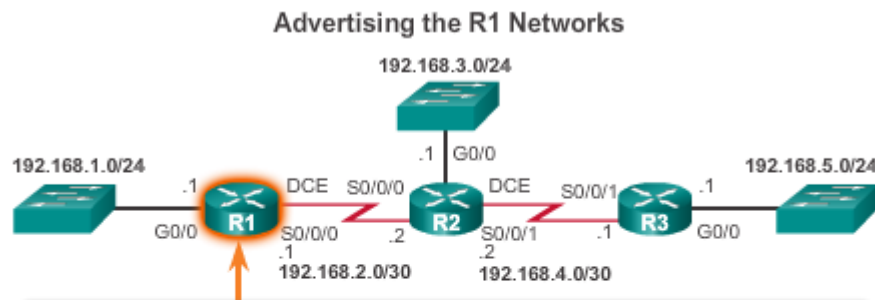


Configuring the RIP Protocol

Router RIP Configuration Mode

Advertising Networks

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



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



Configuring the RIP Protocol

Examining Default RIP Settings

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#
```

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#
```



Configuring the RIP Protocol

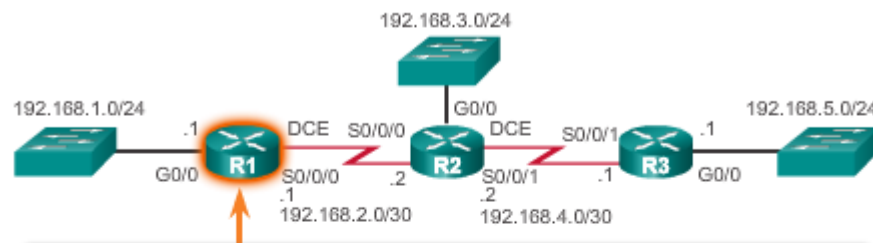
Enabling RIPv2

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
```

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

Disabling Auto Summarization

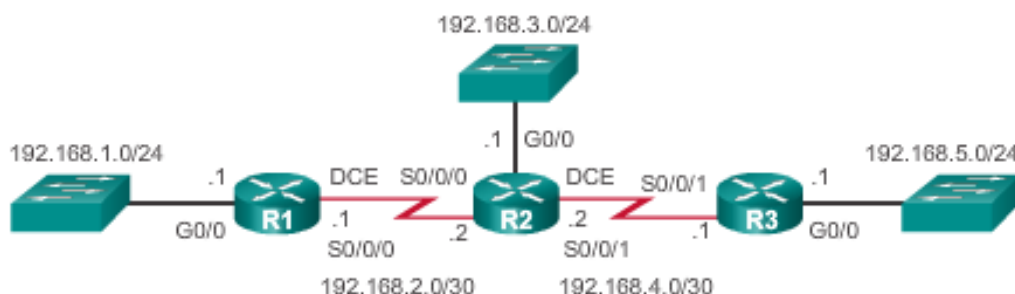
- Similarly to RIPv1, RIPv2 automatically summarizes networks at major network boundaries by default.
- To modify the default RIPv2 behavior of automatic summarization, use the **no auto-summary** router configuration mode command.
- This command has no effect when using RIPv1.
- When automatic summarization 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

Configuring Passive Interfaces on R1



Sending out unneeded updates on a LAN impacts the network in three ways:

- Wasted Bandwidth
- Wasted Resources
- Security Risk

```
R1(config)# router rip
R1(config-router)# passive-interface g0/0
R1(config-router)# end
R1#
```

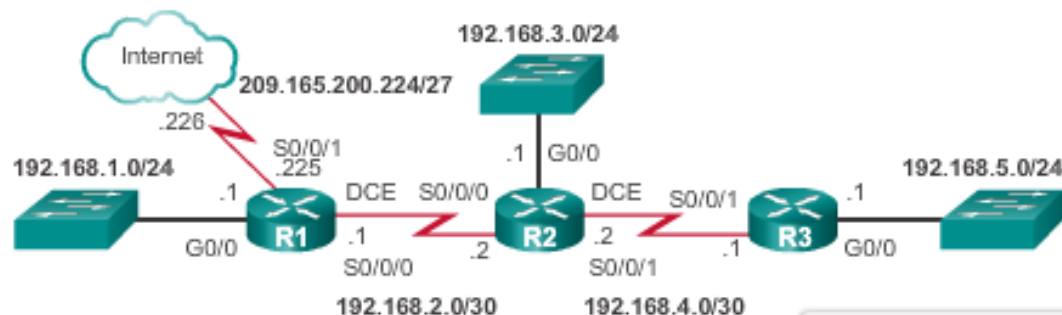
```
R1# show ip protocols | begin Default
Default version control: send version 2, receive version 2
Interface          Send Recv  Triggered RIP  Key-chain
Serial0/0/0         2      2
Automatic network summarization is not in effect
Maximum path: 4
Routing for Networks:
  192.168.1.0
  192.168.2.0
Passive 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

Propagating a Default Route

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,
```