Chapter 7: Enhanced Interior Gateway Protocol (EIGRP)

Scaling Networks

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Chapter 7

Chapter 7: Objectives

- Describe the features and operation of EIGRP.
- Examine the different EIGRP packet formats.
- Calculate the composite metric used by the Diffusing Update Algorithm (DUAL).
- Describe the concepts and operation of DUAL.
- Examine the commands to configure and verify basic EIGRP operations for IPv4 and IPv6.

7.1 Characteristics of EIGRP

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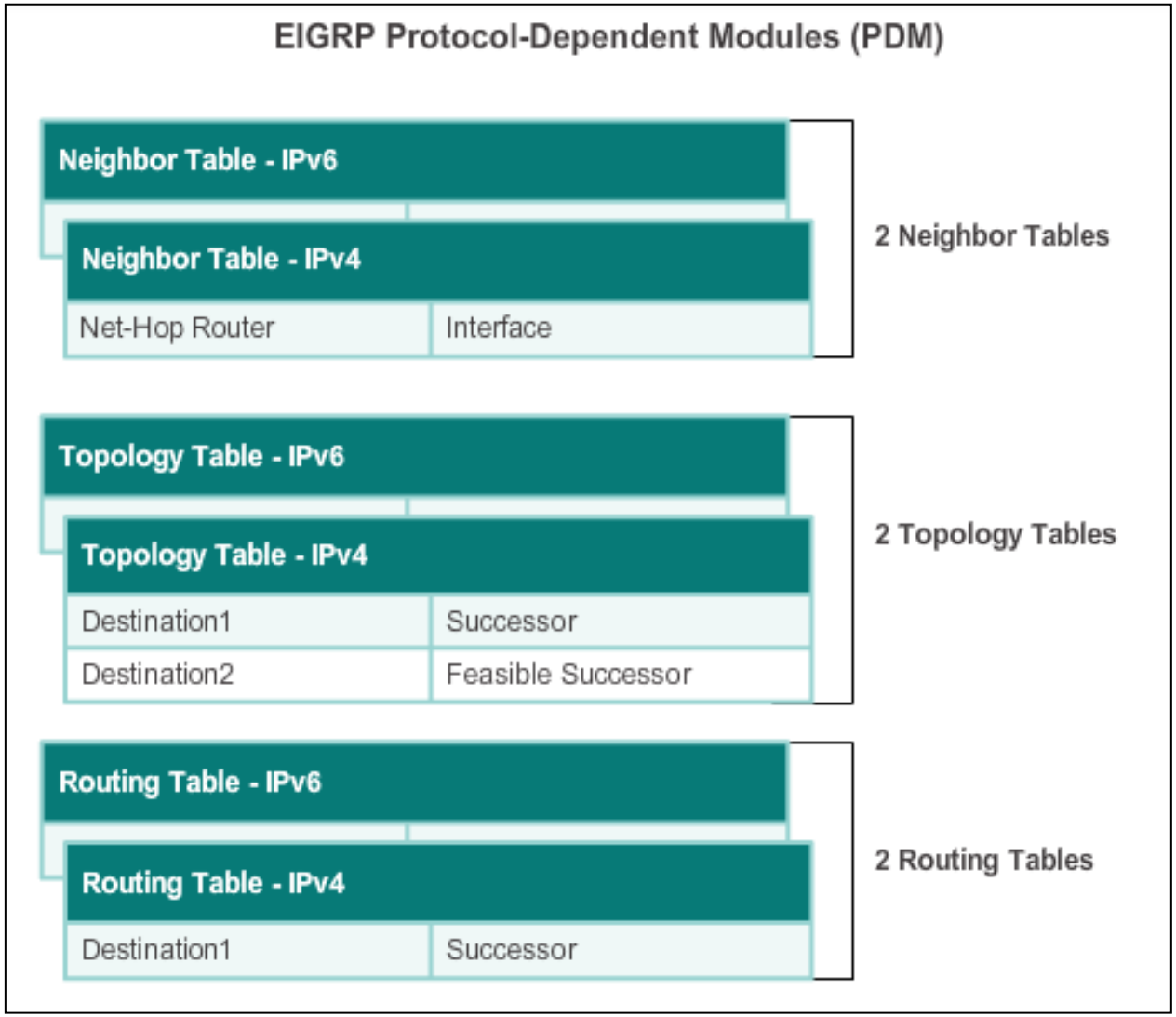
Features of EIGRP

- Released in 1992 as a Cisco proprietary protocol.
- 2013 basic functionality of EIGRP released as an open standard.
- Advanced Distance Vector routing protocol.
- Uses the Diffusing Update Algorithm (DUAL) to calculate paths and back-up paths.
- Establishes Neighbor Adjacencies.
- Uses the Reliable Transport Protocol to provide delivery of EIGRP packets to neighbors.
- Partial and Bounded Updates. Send updates only when there is a change and only to the routers that need the information.
- Supports Equal and Unequal Cost Load Balancing.

Basic Features of EIGRP

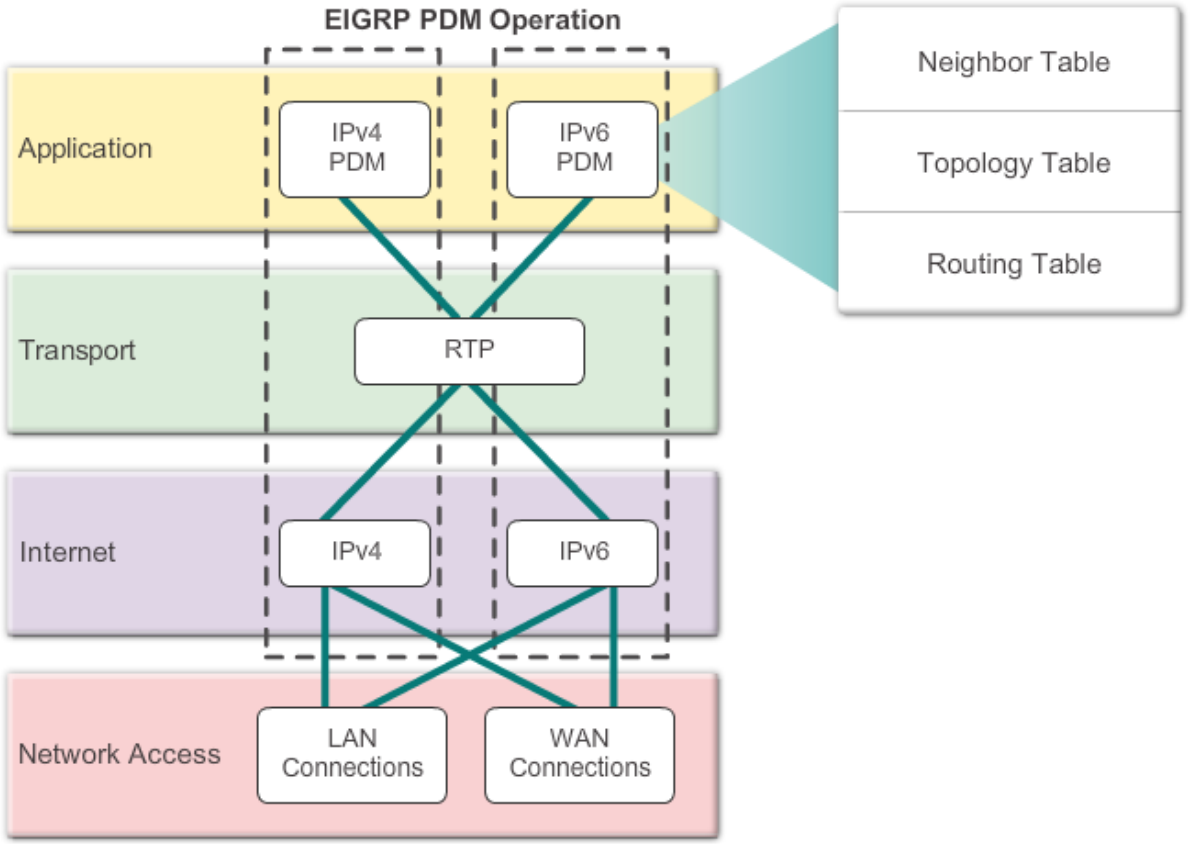
Protocol Dependent Modules



Basic Features of EIGRP

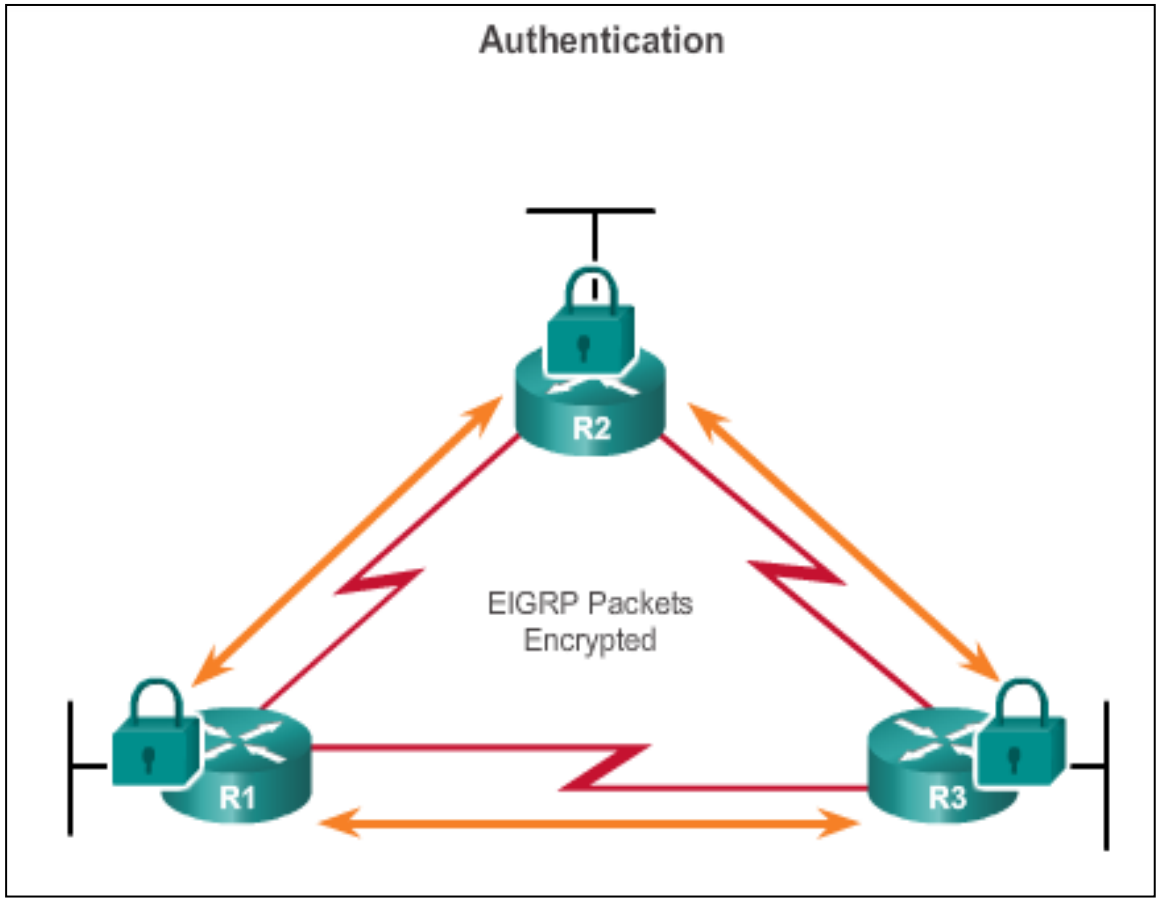
Reliable Transport Protocol

EIGRP Replaces TCP with RTP



Authentication

- EIGRP can be configured to authenticate routing information.
- Ensures routers only accept updates from routers that have been configured with the correct authentication information.



Types of EIGRP Packets

EIGRP Packet Types

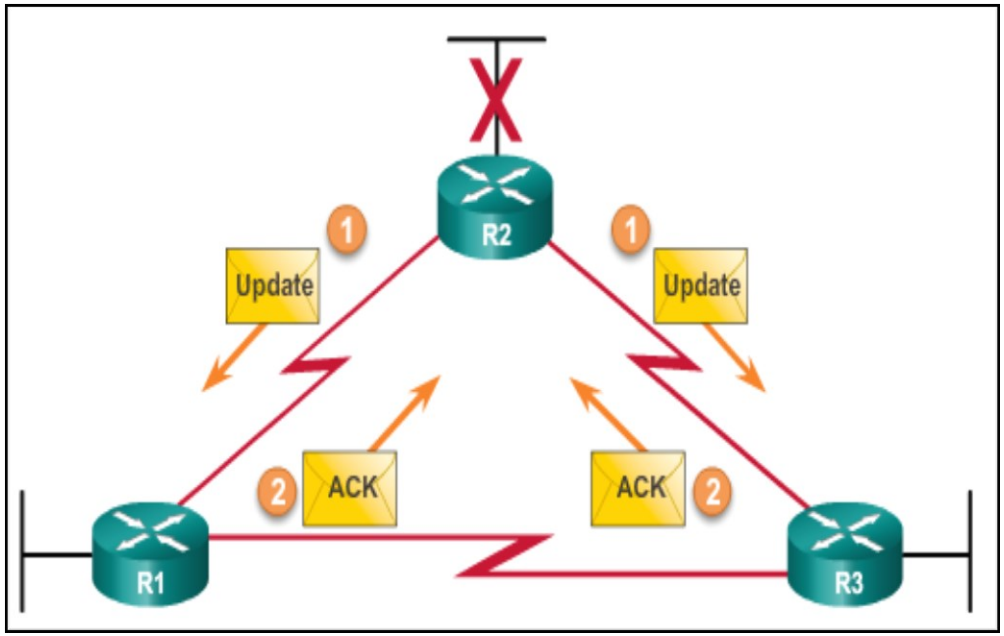
Packet Type	Description
Hello	Used to discover other EIGRP routers in the network.
Acknowledgement	Used to acknowledge the receipt of any EIGRP packet.
Update	Convey routing information to known destinations.
Query	Used to request specific information from a neighbor router.
Reply	Used to respond to a query.

EIGRP Hello Packets

- Used to discover EIGRP neighbors.
- Used to form and maintain EIGRP neighbor adjacencies.
- Sent as IPv4 or IPv6 multicasts.
- IPv4 multicast address 224.0.0.10.
- IPv6 multicast address FF02::A.
- Unreliable delivery.
- Sent every 5 seconds (every 60 seconds on low-speed NBMA networks).
- EIGRP uses a default Hold timer of three times the Hello interval before declaring neighbor unreachable.

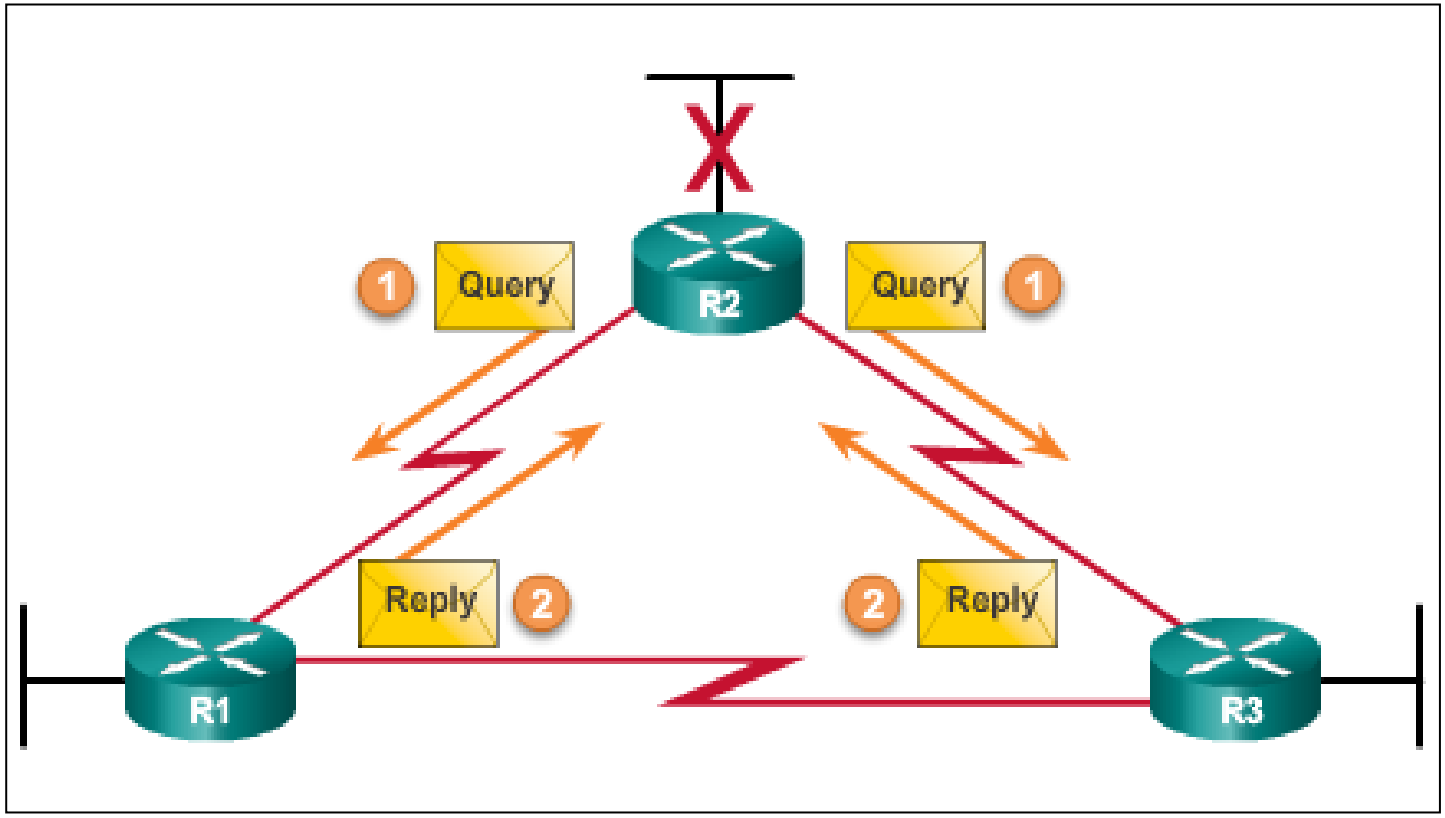
EIGRP Update & Acknowledgement Packets

- Update packets are sent to propagate routing information, only when necessary.
- Sends **Partial** updates – only contains information about route changes.
- Sends **Bounded** updates- sent only to routers affected by the change.
- Updates use reliable delivery, therefore, require an **acknowledgement**.

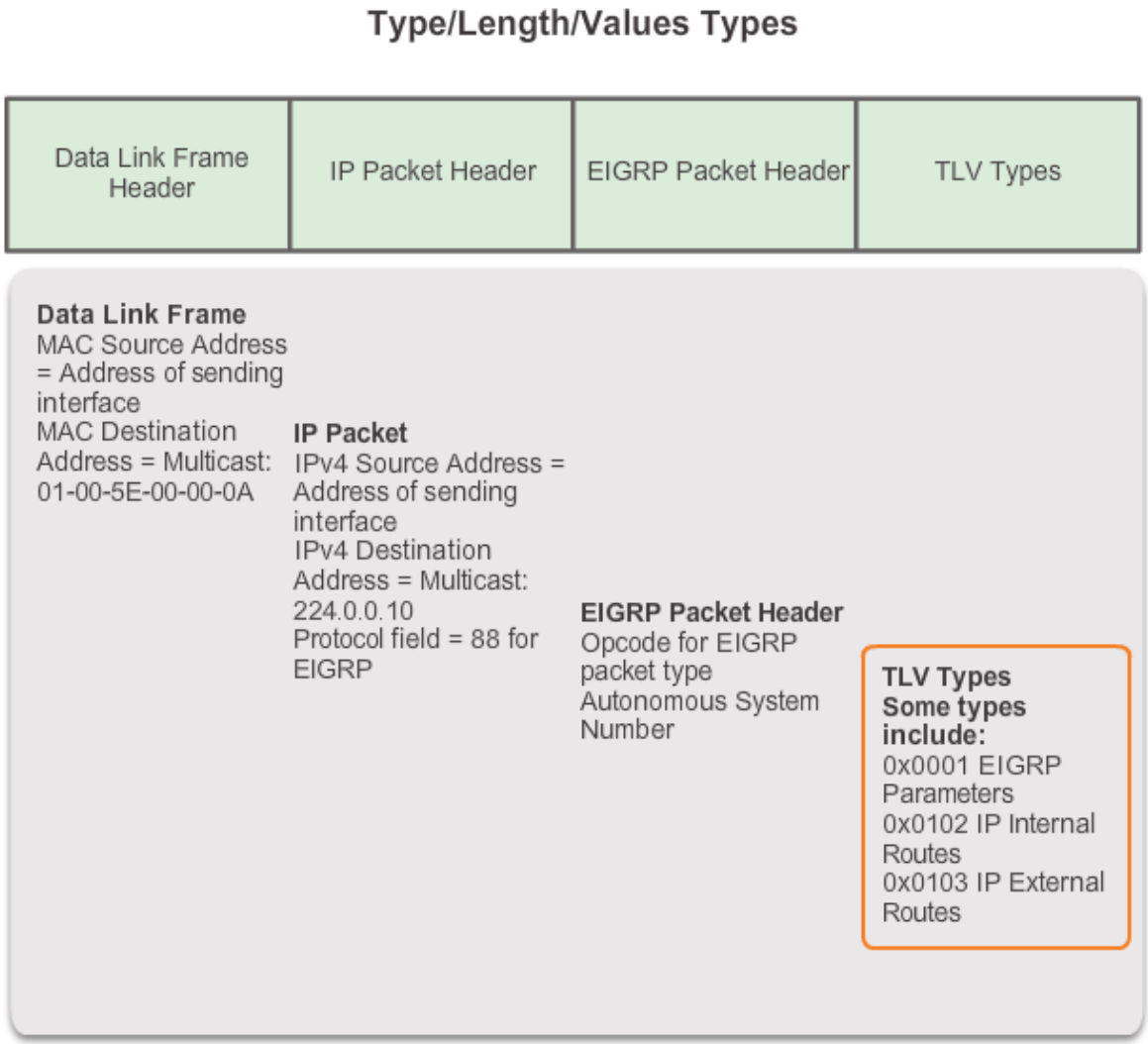


EIGRP Query and Reply Packets

- Used when searching for networks.
- Queries use reliable delivery, which can be multicast or unicast.
- Replies use reliable delivery.

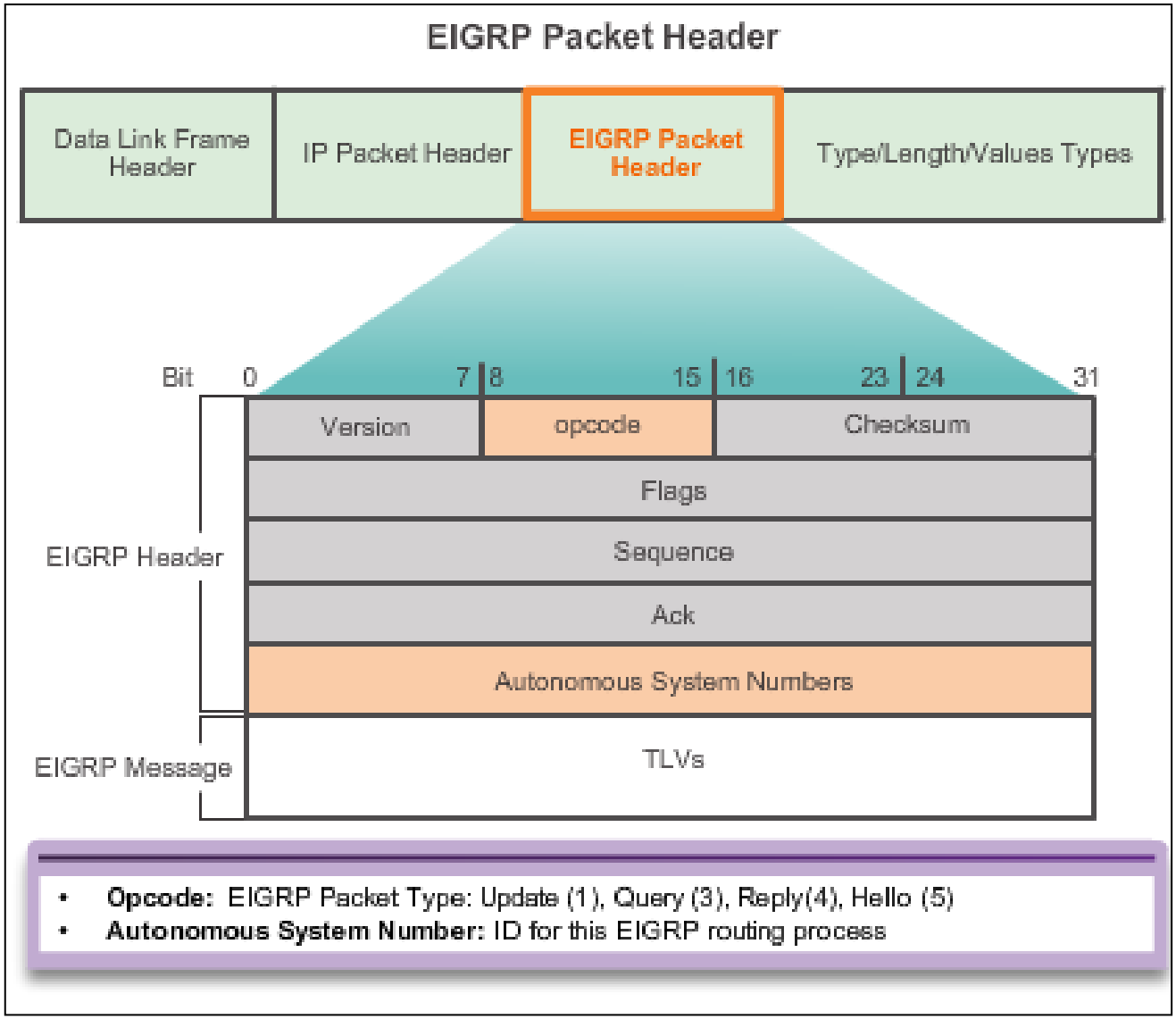


Encapsulating EIGRP Messages



EIGRP Messages

EIGRP Packet Header and TLV



7.2 Configuring EIGRP for IPv4

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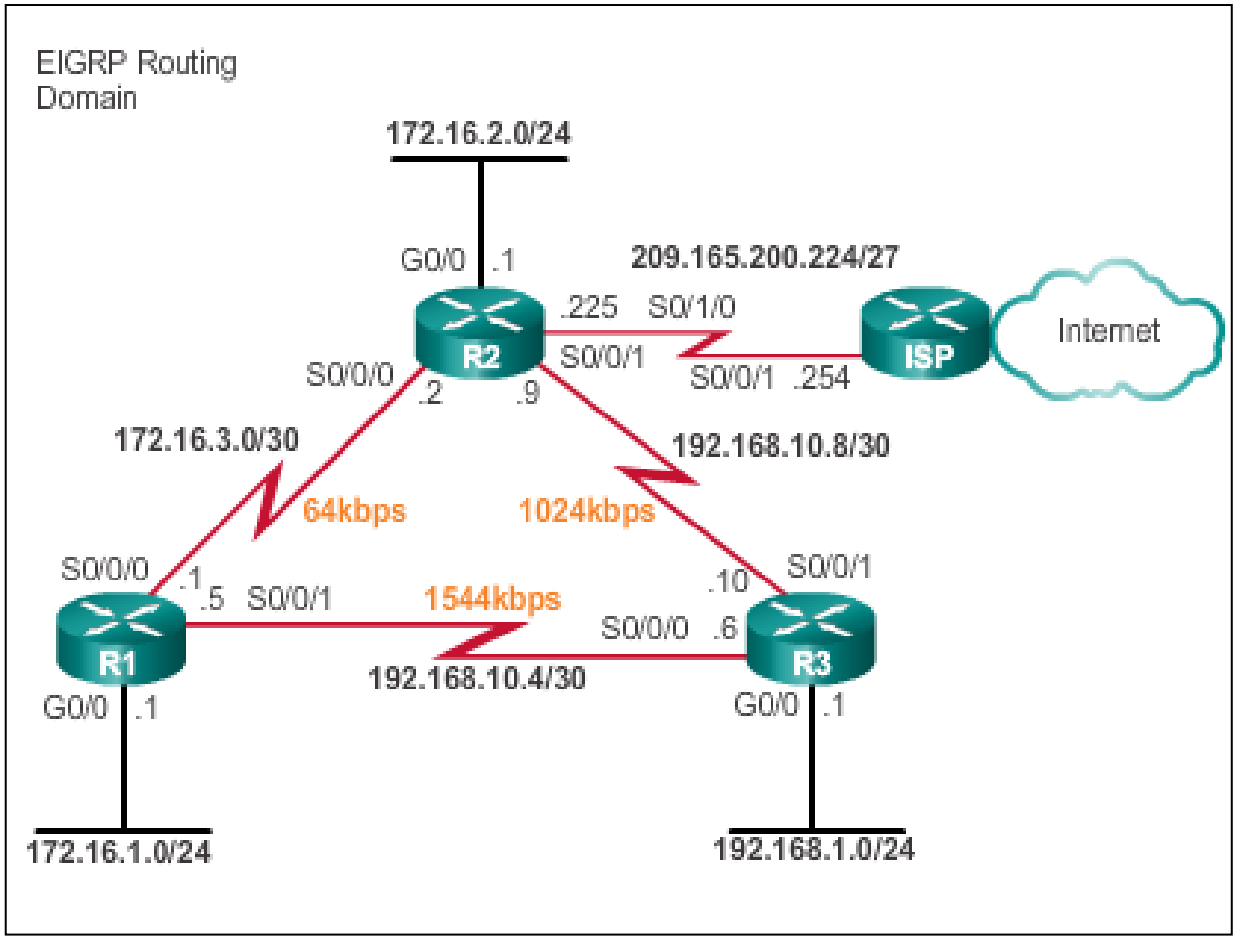
EIGRP Network Topology

This course uses the topology that configures EIGRP with IPv4.



Autonomous System Numbers

- The **`router eigrp`** *`autonomous-system`* command enables the EIGRP process.
- The autonomous system number is only significant to the EIGRP routing domain.
- The EIGRP autonomous system number is not associated with the Internet Assigned Numbers Authority (IANA) globally assigned autonomous system numbers used by external routing protocols.
- Internet Service Providers (ISPs) require an autonomous system number from IANA.
- ISPs often use the Border Gateway Protocol (BGP), which does use the IANA autonomous system number in its configuration.

Router EIGRP Command

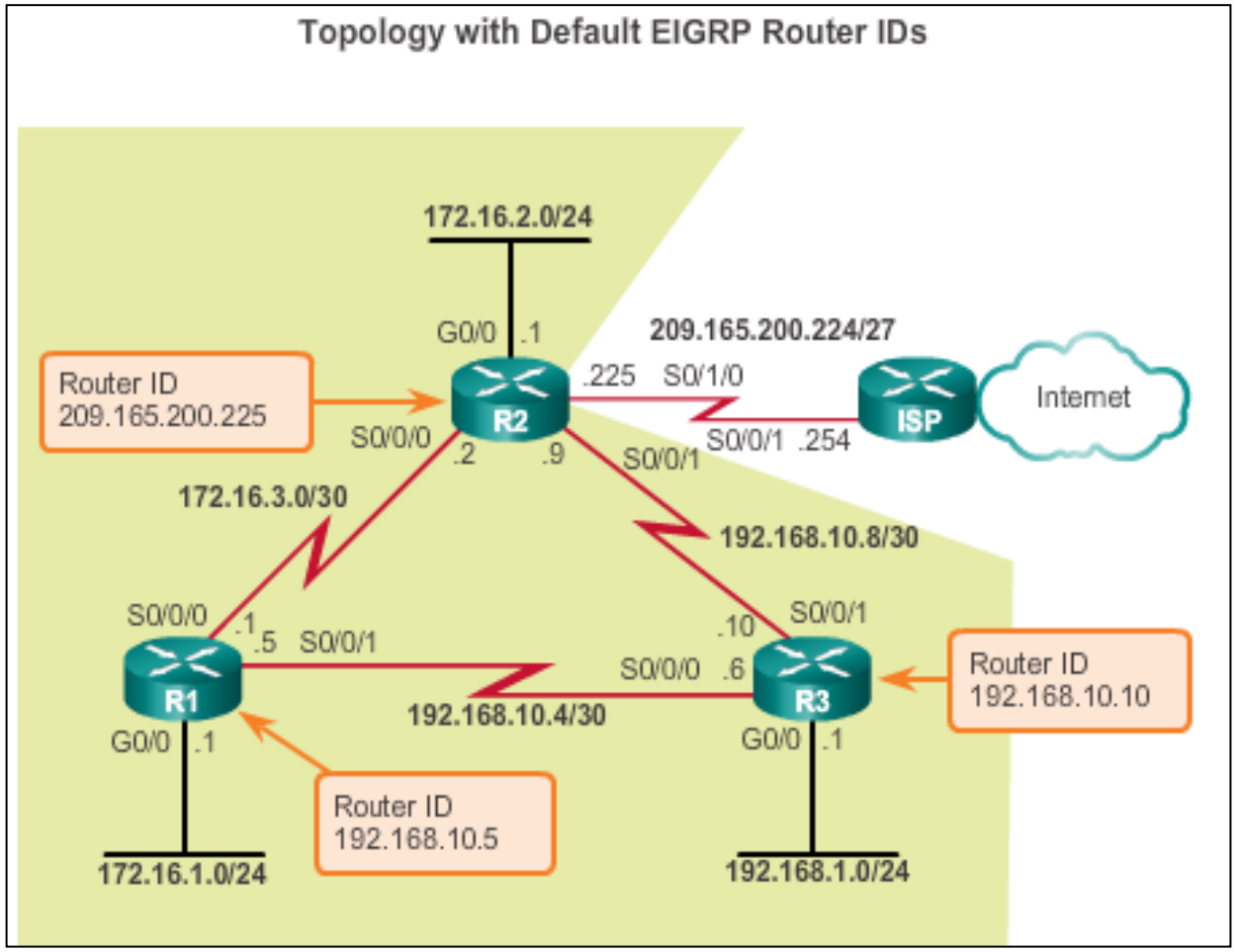
```
Router(config)# router eigrp autonomous-system
```

```
R1(config)#router eigrp 1
R1(config-router)#
```

To completely remove the EIGRP routing process from a device, use the **no router eigrp** *autonomous-system* command.

EIGRP Router ID

Used in both EIGRP and OSPF routing protocols, the router ID's role is more significant in OSPF.



Configuring the EIGRP Router ID

- Configuring the EIGRP router ID

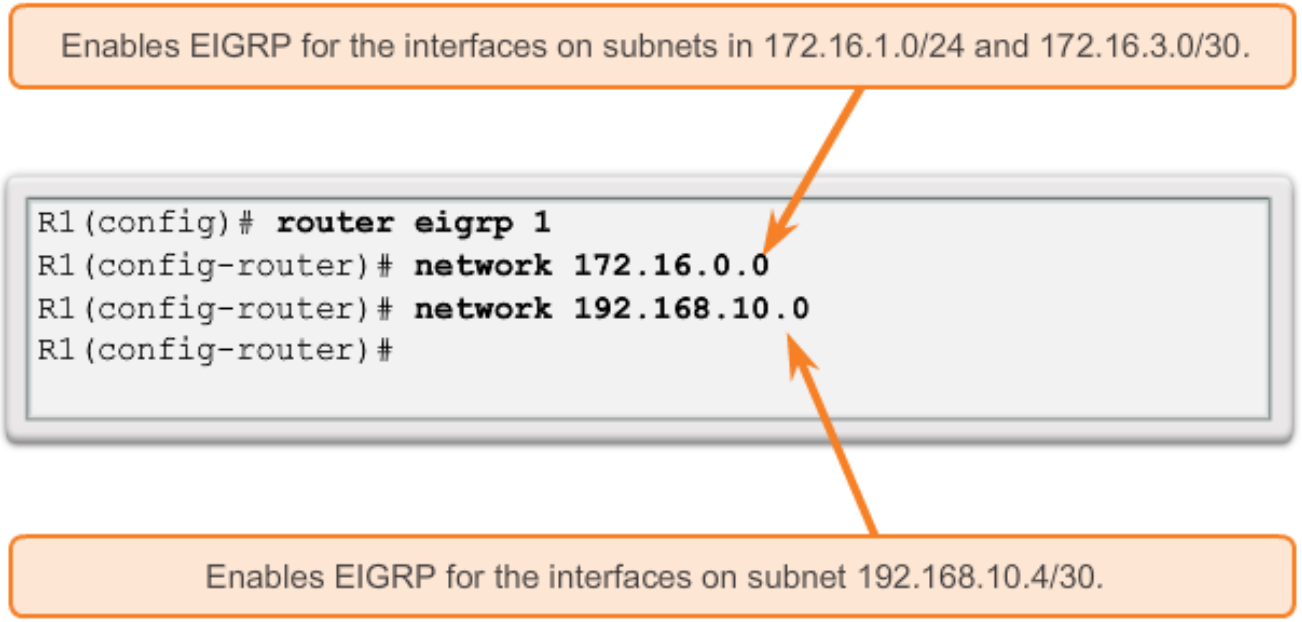
```
Router(config)# router eigrp autonomous-system
Router(config-router)# eigrp router-id ipv4-address
```

- The IPv4 loopback address can be used as the router ID.
- If the **eigrp** *router-id* value is not configured, the highest loopback address is selected as the router ID.
- Configuring a loopback interface

```
Router(config)# interface loopback number
Router(config-if)# ip addressipv4-address subnet-mask
```

Network Command

- Enables any interface on this router that matches the network address in the **network** router configuration mode command to send and receive EIGRP updates.
- These networks are included in EIGRP routing updates.



Network Command

The **`eigrp log-neighbor-changes`** router configuration mode

- On by default
- Displays changes in neighbor adjacencies
- Verifies neighbor adjacencies during configuration
- Indicates when any adjacencies have been removed

The Network Command and Wildcard Mask

- To configure EIGRP to advertise specific subnets only, use the *wildcard-mask* option with the **network** command.

```
Router(config-router)# network network
address [wildcard-mask]
```

- The wildcard mask is the inverse of the subnet mask.
- To calculate the wildcard mask, subtract the subnet mask from 255.255.255.255:

```
  255.255.255.255
--255.255.255.252
    0.   0.   0.   3   wildcard mask
```

- **Note**: Some IOS versions also let you enter the subnet mask instead of a wildcard mask.

Passive Interface

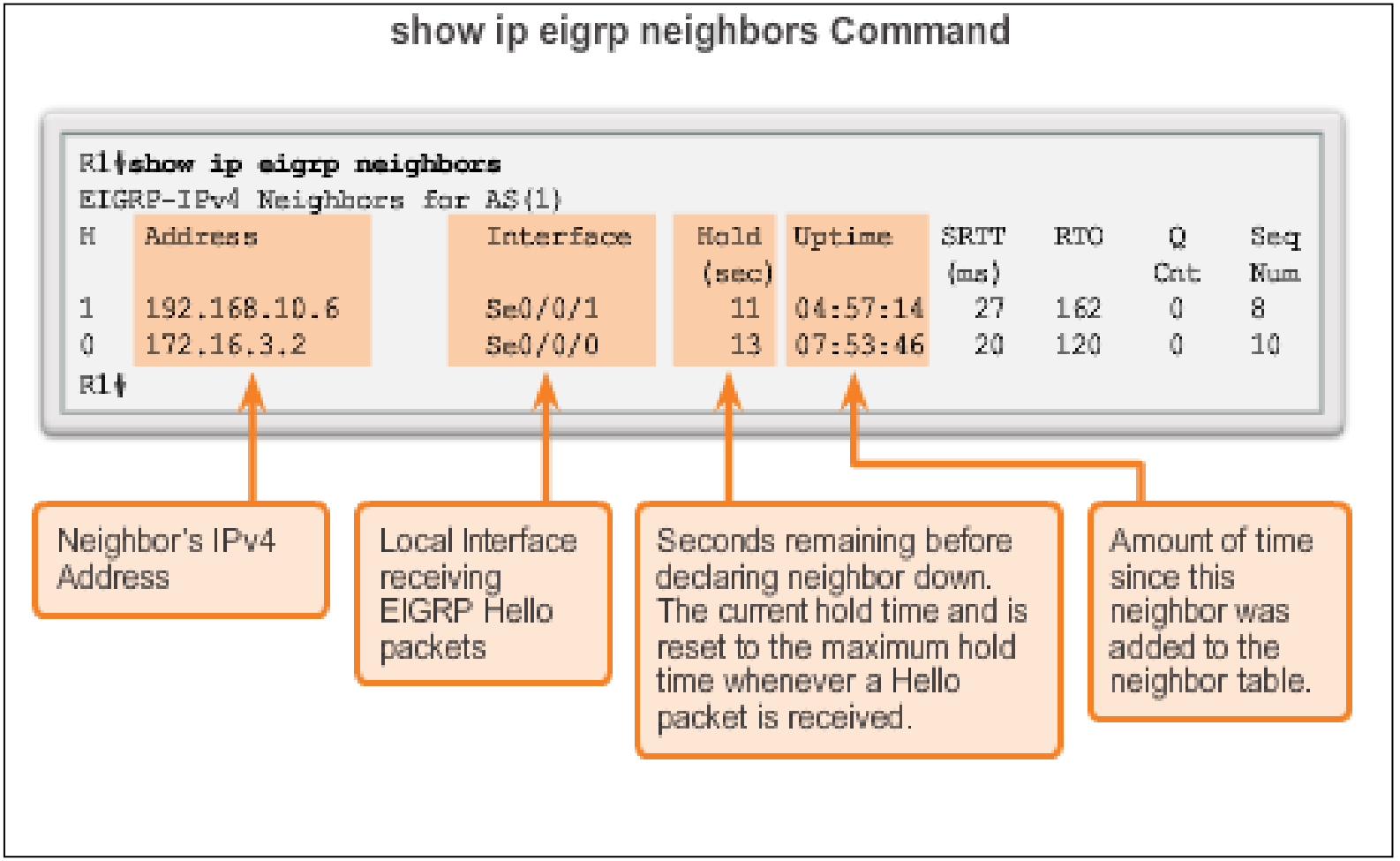
- Use the **passive-interface** command to:
  - Prevent neighbor adjacencies
  - Suppress unnecessary update traffic
  - Increase security controls, such as preventing unknown rogue routing devices from receiving EIGRP updates
- To configure:

```
Router(config)# router eigrp as-number
Router(config-router)# passive-interface interface-type interface-number
```

- To verify:

```
Router# show ip protocols
```

Verifying EIGRP: Examining Neighbors



Configuring EIGRP with IPv4

Verifying EIGRP: `show ip protocols` Command

`show ip protocols` Command

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

Routing Protocol is "eigrp 1"                          (1) Routing protocol and Process ID (AS Number)
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Default networks flagged in outgoing updates
  Default networks accepted from incoming updates
  EIGRP-IPv4 Protocol for AS(1)
    Metric weight K1=1, K2=0, K3=1, K4=0, K5=0
    NSF-aware route hold timer is 240
    Router-ID: 1.1.1.1                                 (2) EIGRP Router ID
    Topology : 0 (base)
      Active Timer: 3 min
      Distance: internal 90 external 170               (3) EIGRP Administrative Distances
      Maximum path: 4
      Maximum hopcount 100
      Maximum metric variance 1

  Automatic Summarization: disabled                    (4) EIGRP Automatic Summarization is disabled.
  Maximum path: 4
  Routing for Networks:
    172.16.0.0
    192.168.10.0
  Routing Information Sources:                         (5) EIGRP Routing Information Sources lists all the EIGRP routing sources the IOS uses to build its IPv4 routing table.
    Gateway         Distance      Last Update
    192.168.10.6         90       00:40:20
    172.16.3.2           90       00:40:20
  Distance: internal 90 external 170

R1#
```

Verifying EIGRP: Examine the IPv4 Routing Table

R1's IPv4 Routing Table

```
      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
D        172.16.2.0/24 [90/2170112] via 172.16.3.2,
00:14:35, Serial0/0/0
C        172.16.3.0/30 is directly connected, Serial0/0/0
L        172.16.3.1/32 is directly connected, Serial0/0/0
D     192.168.1.0/24 [90/2170112] via 192.168.10.6,
00:13:57, Serial0/0/1
      192.168.10.0/24 is variably subnetted, 3 subnets, 2
masks
C        192.168.10.4/30 is directly connected,
Serial0/0/1
L        192.168.10.5/32 is directly connected,
Serial0/0/1
D        192.168.10.8/30 [90/2681856] via 192.168.10.6,
00:50:42, Serial0/0/1
                         [90/2681856] via 172.16.3.2,
00:50:42, Serial0/0/0
R1#
```

7.3 Operation of EIGRP

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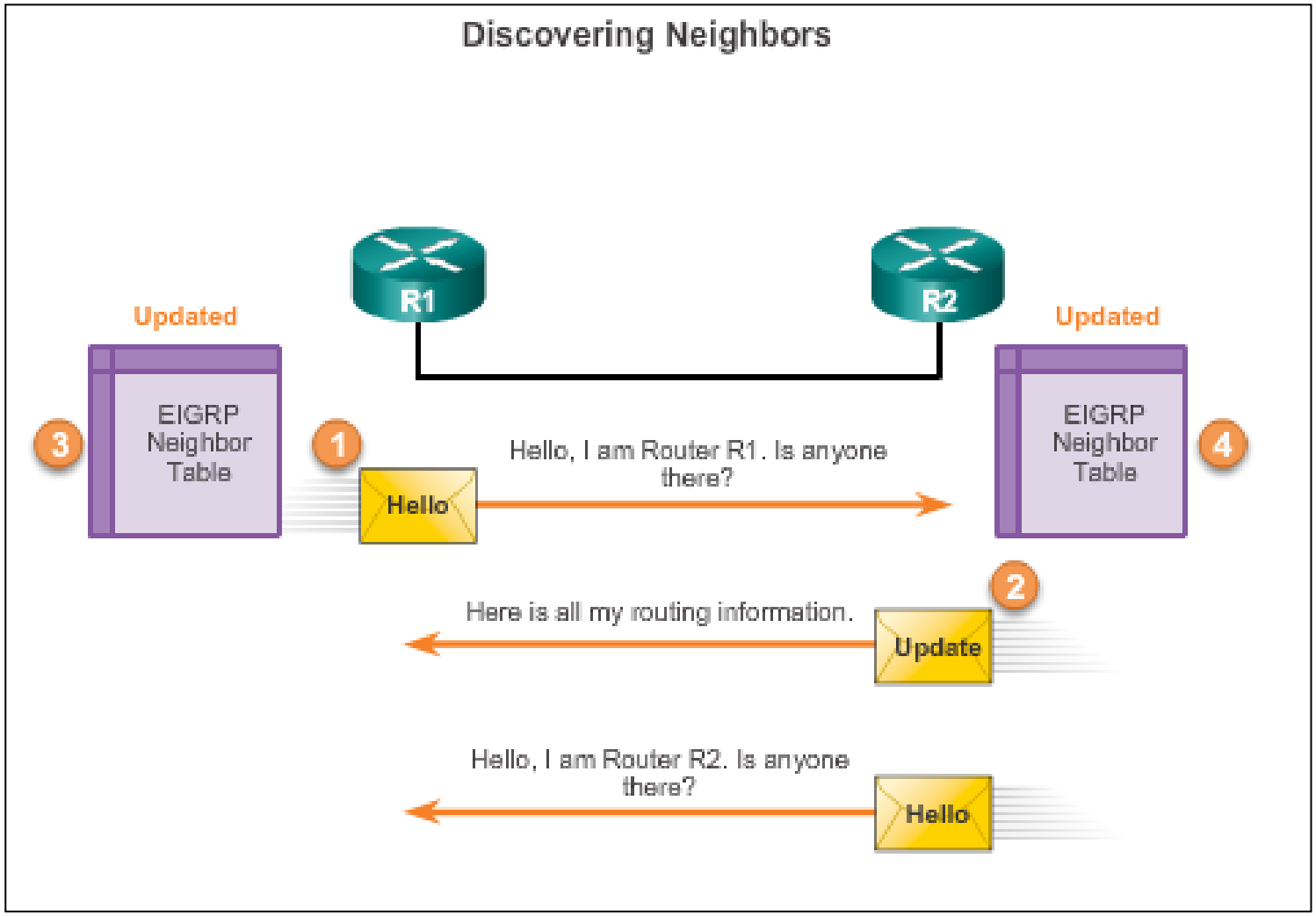
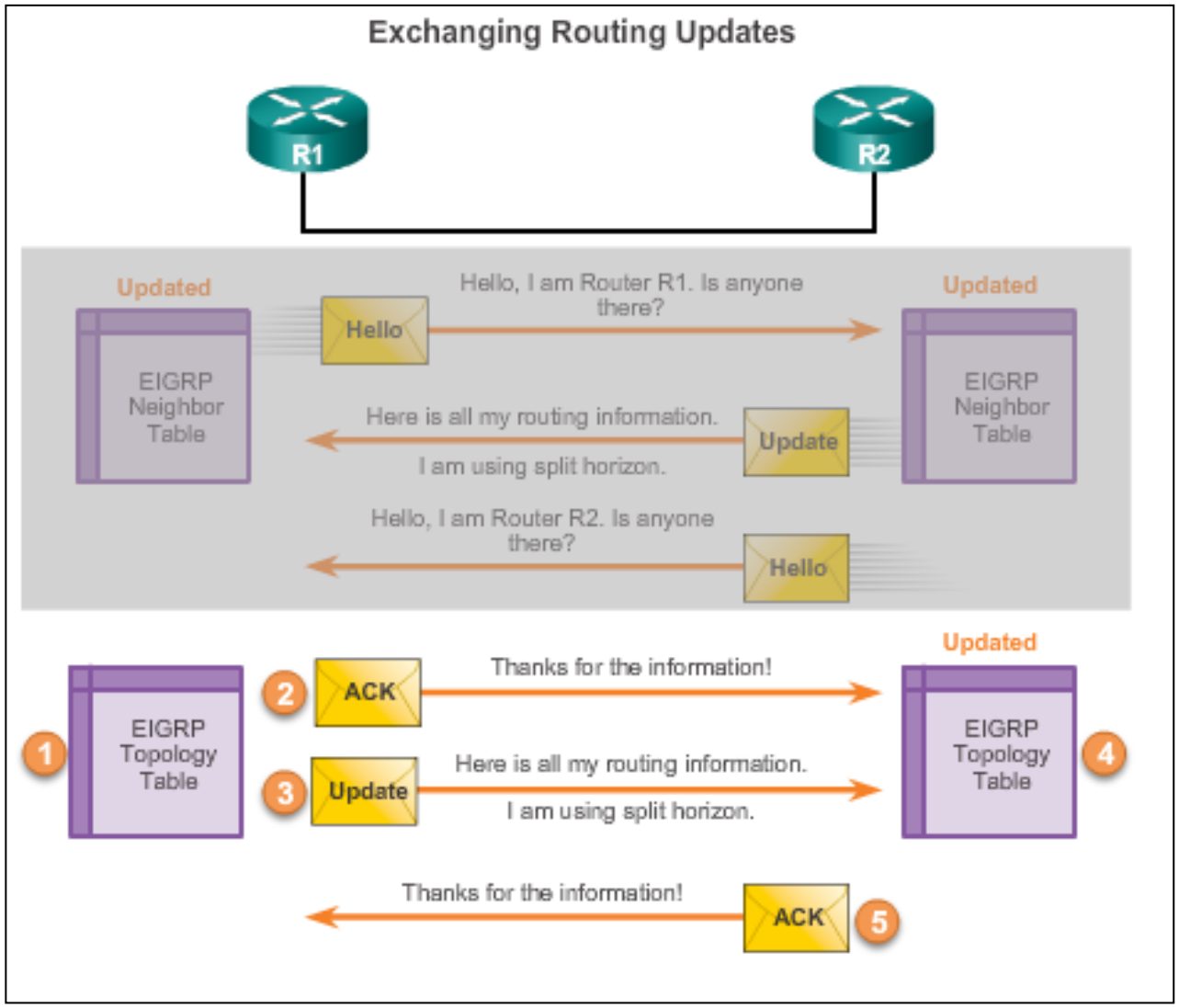
EIGRP Initial Route Discovery

EIGRP Neighbor Adjacency



EIGRP Initial Route Discovery

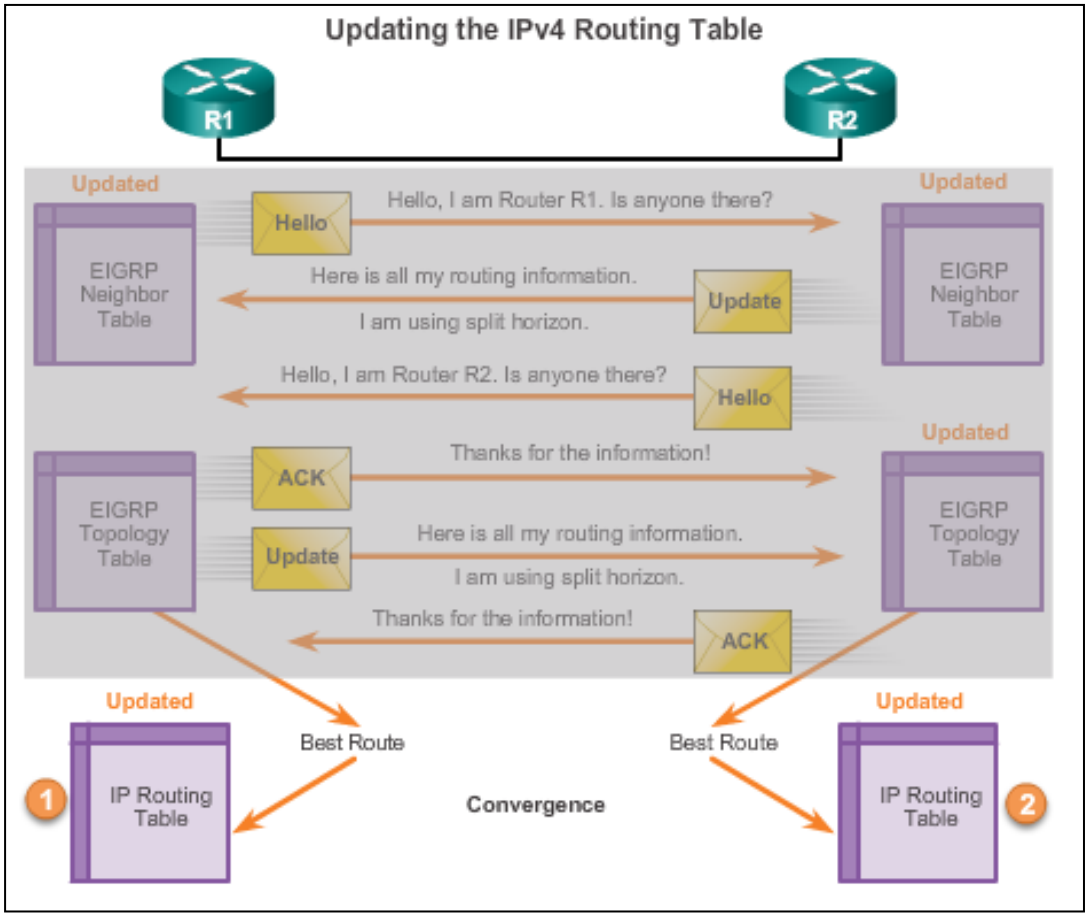
EIGRP Topology Table



EIGRP Initial Route Discovery

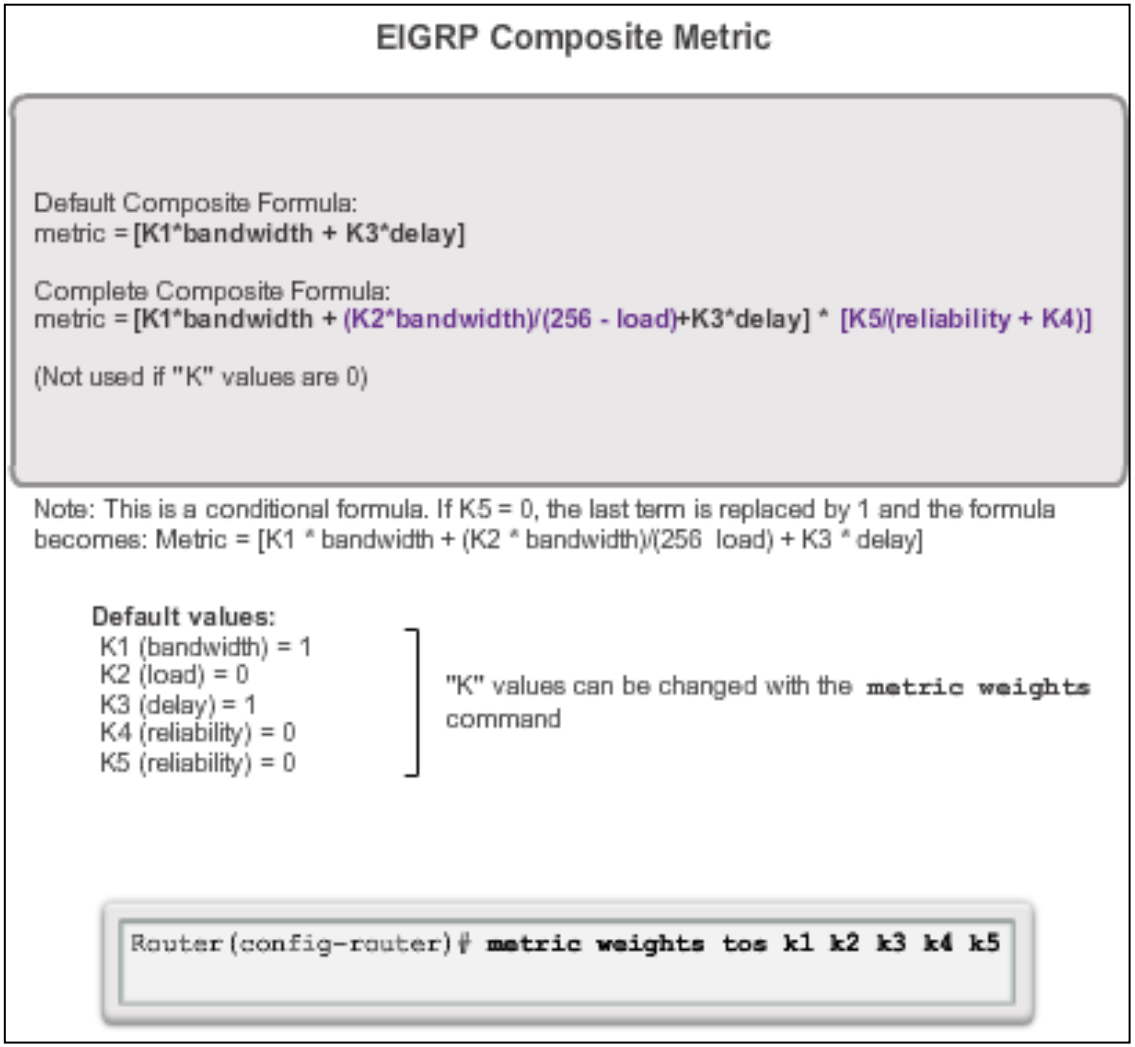
EIGRP Convergence

Convergence – All routers have the correct, most up-to-date information about the network.



Metrics

EIGRP Composite Metric



Examining Interface Values

- BW – Bandwidth of the interface (in Kilobits per second).
- DLY – Delay of the interface (microseconds).
- Reliability – Reliability of interface; by default, the value is not included in the computing metric.
- Txload, Rxload – By default, the value is not included in the computing metric.

```
R1#show interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
  Hardware is WIC MBRD Serial
  Internet address is 172.16.3.1/30
  MTU 1500 bytes, BW 1544 Kbit/sec, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
<Output omitted>
R1#

R1#show interface gigabitethernet 0/0
GigabitEthernet0/0 is up, line protocol is up
  Hardware is CN Gigabit Ethernet, address is fc99.4775.c3e0 (bia
fc99.4775.c3e0)
  Internet address is 172.16.1.1/24
  MTU 1500 bytes, BW 100000 Kbit/sec, DLY 100 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
<Output omitted>
R1#
```

Bandwidth Metric

- Use the **`show interfaces`** command to verify bandwidth.
- Most serial bandwidths are set to 1,544 kb/s (default).
- A correct value for bandwidth is very important in order to calculate the correct metric (both sides of link must have same bandwidth).

```
R1(config)# interface s 0/0/0
R1(config-if)# bandwidth 64
```

```
R1# show interface s 0/0/0
Serial0/0/0 is up, line protocol is up
  Hardware is WIC MBRD Serial
  Internet address is 172.16.3.1/30
  MTU 1500 bytes, BW 64 Kbit/sec, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
<Output omitted>
```

Delay Metric

Interface Delay Values

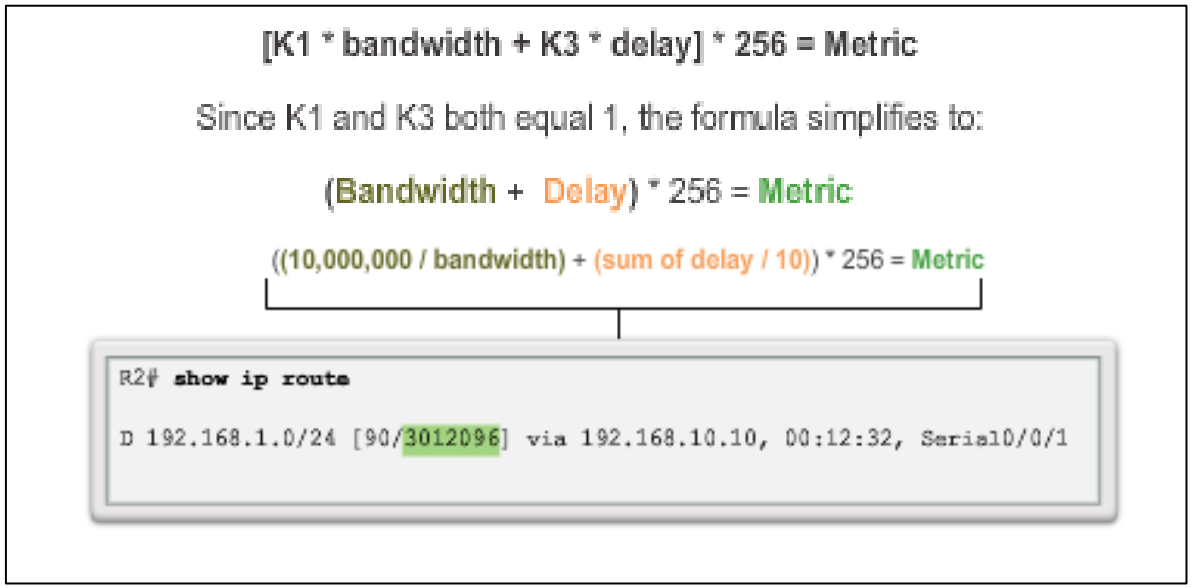
Media	Delay
Ethernet	1,000
Fast Ethernet	100
Gigabit Ethernet	10
16M Token Ring	630
FDDI	100
T1 (Serial Default)	20,000
DS0 (64 Kbps)	20,000
1024 Kbps	20,000
56 Kbps	20,000

Calculating the EIGRP Metric

Step 1. Determine the link with the slowest bandwidth. Use that value to calculate bandwidth (10,000,000/bandwidth).

Step 2. Determine the delay value for each outgoing interface on the way to the destination. Add the delay values and divide by 10 (sum of delay/10).

Step 3. Add the computed values for bandwidth and delay, and multiply the sum by 256 to obtain the EIGRP metric.

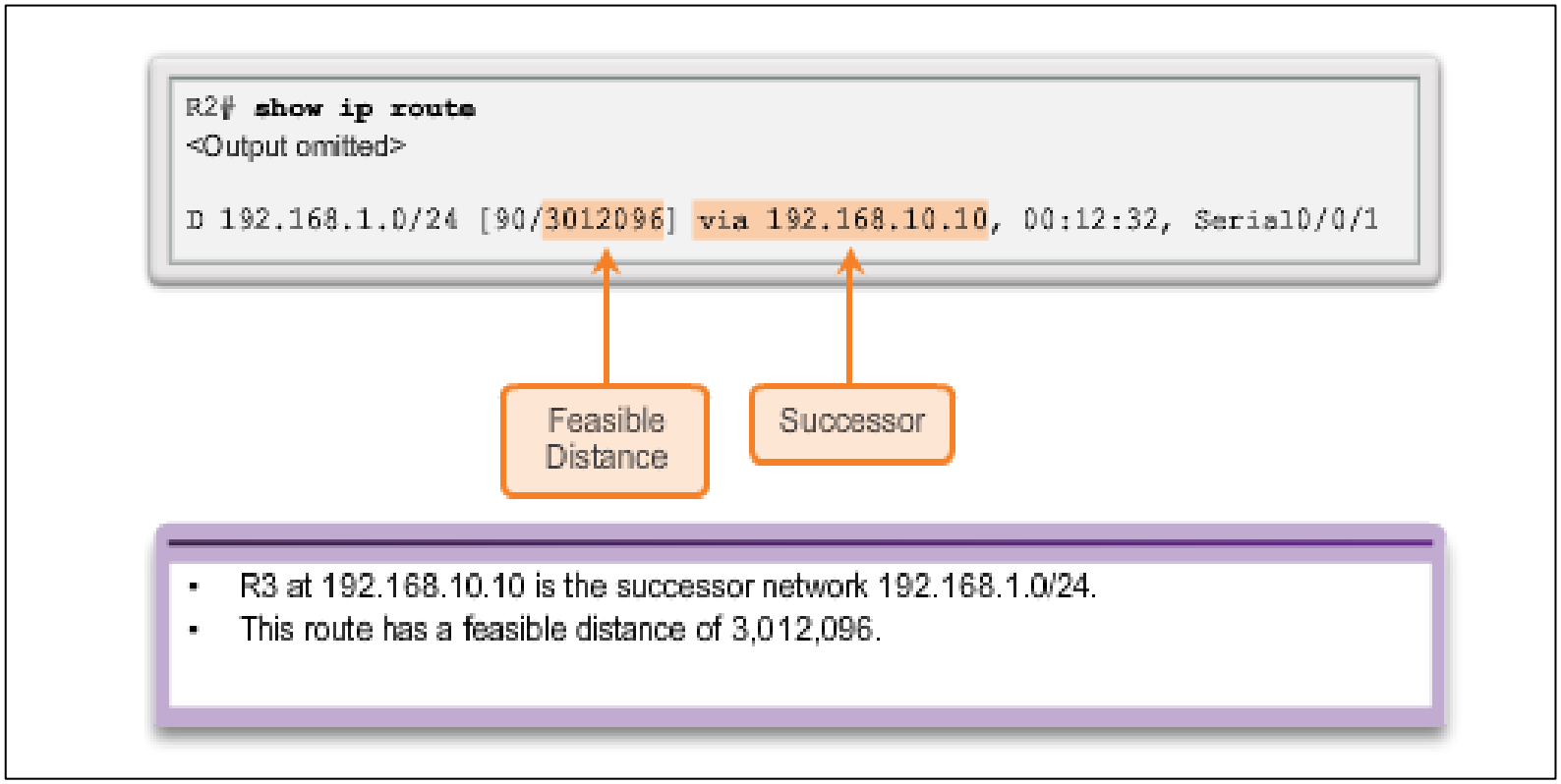


DUAL Concepts

- **Diffusing Update ALgorithm (DUAL)** provides the following:
  - Loop-free paths and loop-free backup paths
  - Fast convergence
  - Minimum bandwidth usage with bounded updates
- The decision process for all route computations is done by the **DUAL Finite State Machine (FSM)**
  - DUAL FSM tracks all routes.
  - Uses EIGRP metrics to select efficient, loop-free paths.
  - Identifies the routes with the least-cost path to be inserted into the routing table.
- EIGRP maintains a list of backup routes that DUAL has already determined that can be used immediately if the primary path fails.

Successor and Feasible Distance

- The **Successor** is the least-cost route to the destination network.
- The **Feasible Distance** (FD) is the lowest calculated metric to reach the destination network.



Feasible Successors, Feasibility Condition, and Reported Distance

- **Feasible Successor** (FS) is a neighbor that has a loop-free backup path to the same network as the successor, and it satisfies the Feasibility Condition (FC).
- **Feasibility Condition** (FC) is met when a neighbor's Reported Distance (RD) to a network is less than the local router's feasible distance to the same destination network.
- **Reported Distance** (RD) is an EIGRP neighbor's feasible distance to the same destination network.

Topology Table: `show ip eigrp` Command

```
R2#show ip eigrp topology
EIGRP-IPv4 Topology Table for AS(1)/ID(2.2.2.2)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

P 172.16.2.0/24, 1 successors, FD is 2816
        via Connected, GigabitEthernet0/0
P 192.168.10.4/30, 1 successors, FD is 3523840
        via 192.168.10.10 (3523840/2169856), Serial0/0/1
        via 172.16.3.1 (41024000/2169856), Serial0/0/0
P 192.168.1.0/24, 1 successors, FD is 3012096
        via 192.168.10.10 (3012096/2816), Serial0/0/1
        via 172.16.3.1 (41024256/2170112), Serial0/0/0
```

```
R2#show ip eigrp topology
<Output omitted>

P 192.168.1.0/24, 1 successors, FD is 3012096
        via 192.168.10.10 (3012096/2816), Serial0/0/1
        via 172.16.3.1 (41024256/2170112), Serial0/0/0
```

Feasible distance

Successor's (R3) Reported Distance

Next hop address of the successor

Outbound interface to reach this network

```
R2#show ip eigrp topology
<Output omitted>

P 192.168.1.0/24, 1 successors, FD is 3012096
        via 192.168.10.10 (3012096/2816), Serial0/0/1
        via 172.16.3.1 (41024256/2170112), Serial0/0/0
```

Feasible distance if the feasible successor (R1) was the successor

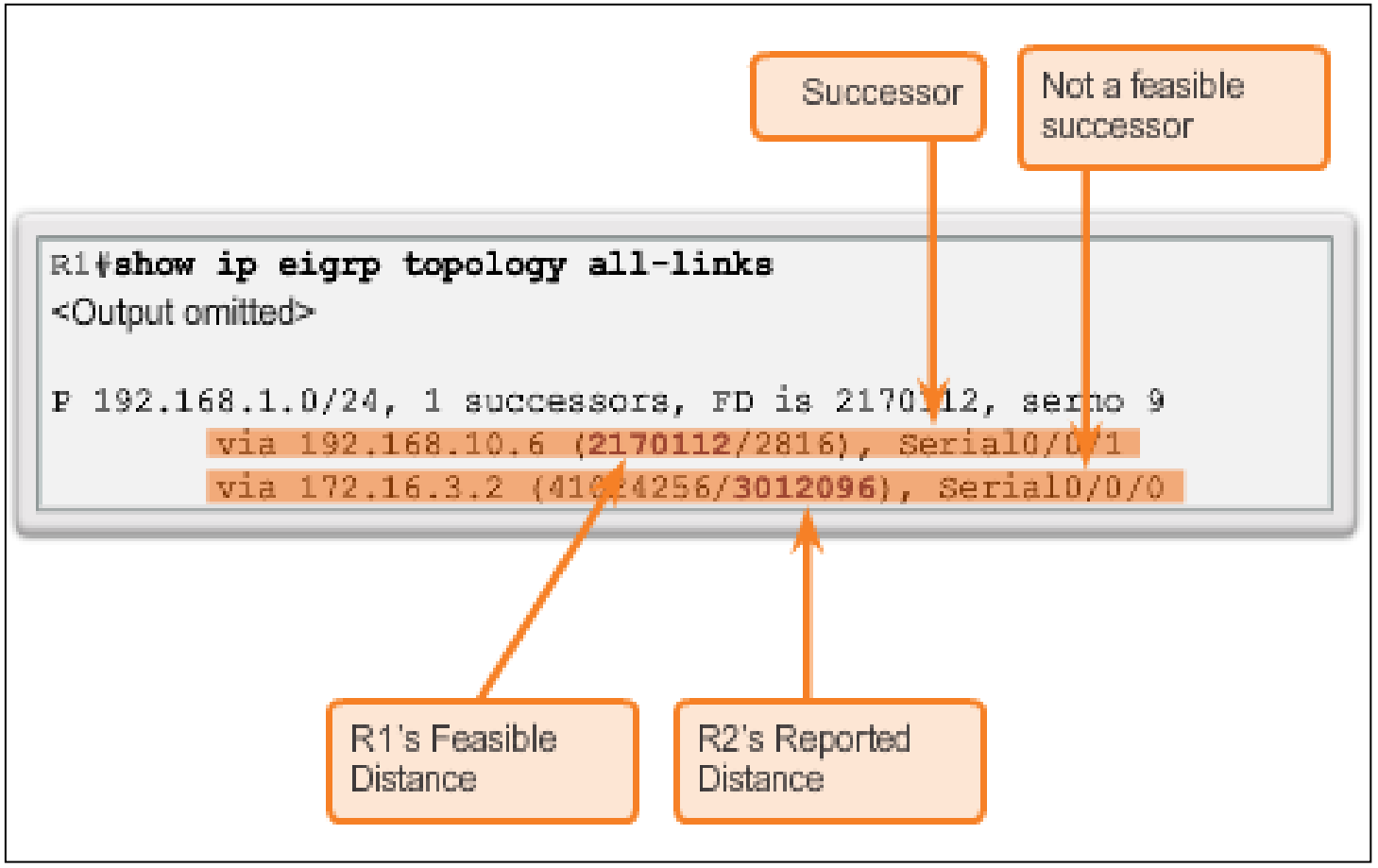
Outbound interface to reach this network

Next hop address of the feasible successor (R1)

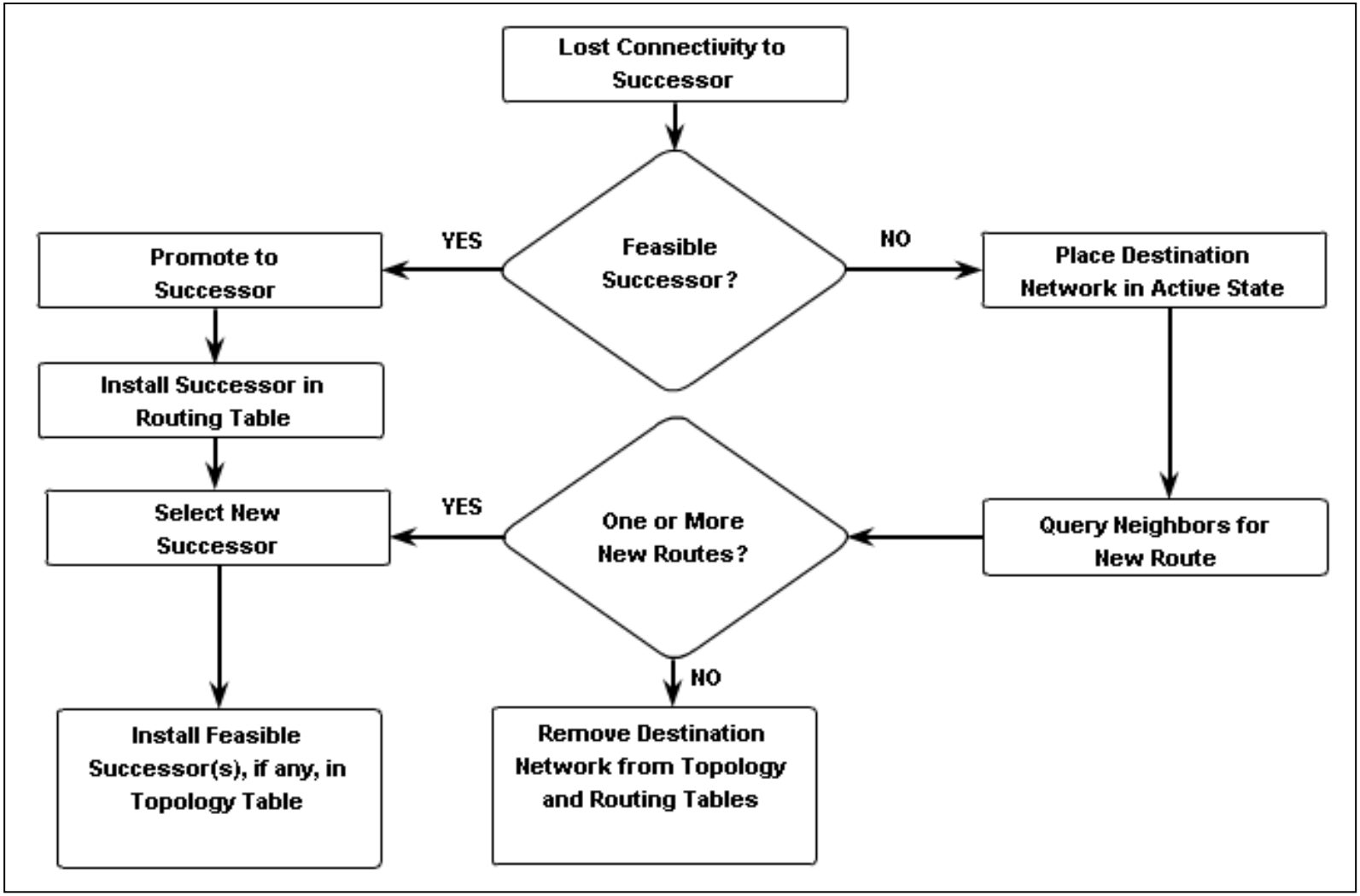
Feasible Successor's (R1) Reported Distance

DUAL and the Topology Table

Topology Table: No Feasible Successor



DUAL Finite State Machine (FSM)



DUAL: Feasible Successor

```
R2#debug eigrp fsm
EIGRP Finite State Machine debugging is on
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#interface s 0/0/1
R2(config-if)#shutdown
<Output omitted>
EIGRP-IPv4(1):Find FS for dest 192.168.1.0/24. FD is 3012096,
RD is 3012096 on tid 0
DUAL: AS(1) Removing dest 172.16.1.0/24, nexthop 192.168.10.10
DUAL: AS(1) RT installed 172.16.1.0/24 via 172.16.3.1
<Output omitted>
R2(config-if)#end
R2#undebug all
```

```
R2#show ip route
<Output omitted>

D 192.168.1.0/24 [90/41024256] via 172.16.3.1, 00:15:51,
Serial0/0/0
```

New Successor (R1)

DUAL and Convergence

DUAL: No Feasible Successor

```
R1#show ip eigrp topology
<Output omitted>

P 192.168.1.0/24, 1 successors, FD is 2170112
        via 192.168.10.6 (2170112/2816), Serial0/0/1
```

Successor (R3)

No feasible successor

```
R1#debug eigrp fsm
EIGRP Finite State Machine debugging is on
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#interface s 0/0/1
R1(config-if)#shutdown
<Output omitted>
EIGRP-IPv4(1): Find FS for dest 192.168.1.0/24. FD is 2170112,
RD is 2170112
DUAL: AS(1) Dest 192.168.1.0/24 entering active state for tid
0.
EIGRP-IPv4(1): dest(192.168.1.0/24) active
EIGRP-IPv4(1): rcvreply: 192.168.1.0/24 via 172.16.3.2 metric
41024256/3012096 EIGRP-IPv4(1): reply count is 1
EIGRP-IPv4(1): Find FS for dest 192.168.1.0/24. FD is
72057594037927935, RD is 72057594037927935
DUAL: AS(1) Removing dest 192.168.1.0/24, nexthop 192.168.10.6
DUAL: AS(1) RT installed 192.168.1.0/24 via 172.16.3.2
<Output omitted>
R1(config-if)#end
R1#undebug all
```

7.4 Configuration of EIGRP for IPv6

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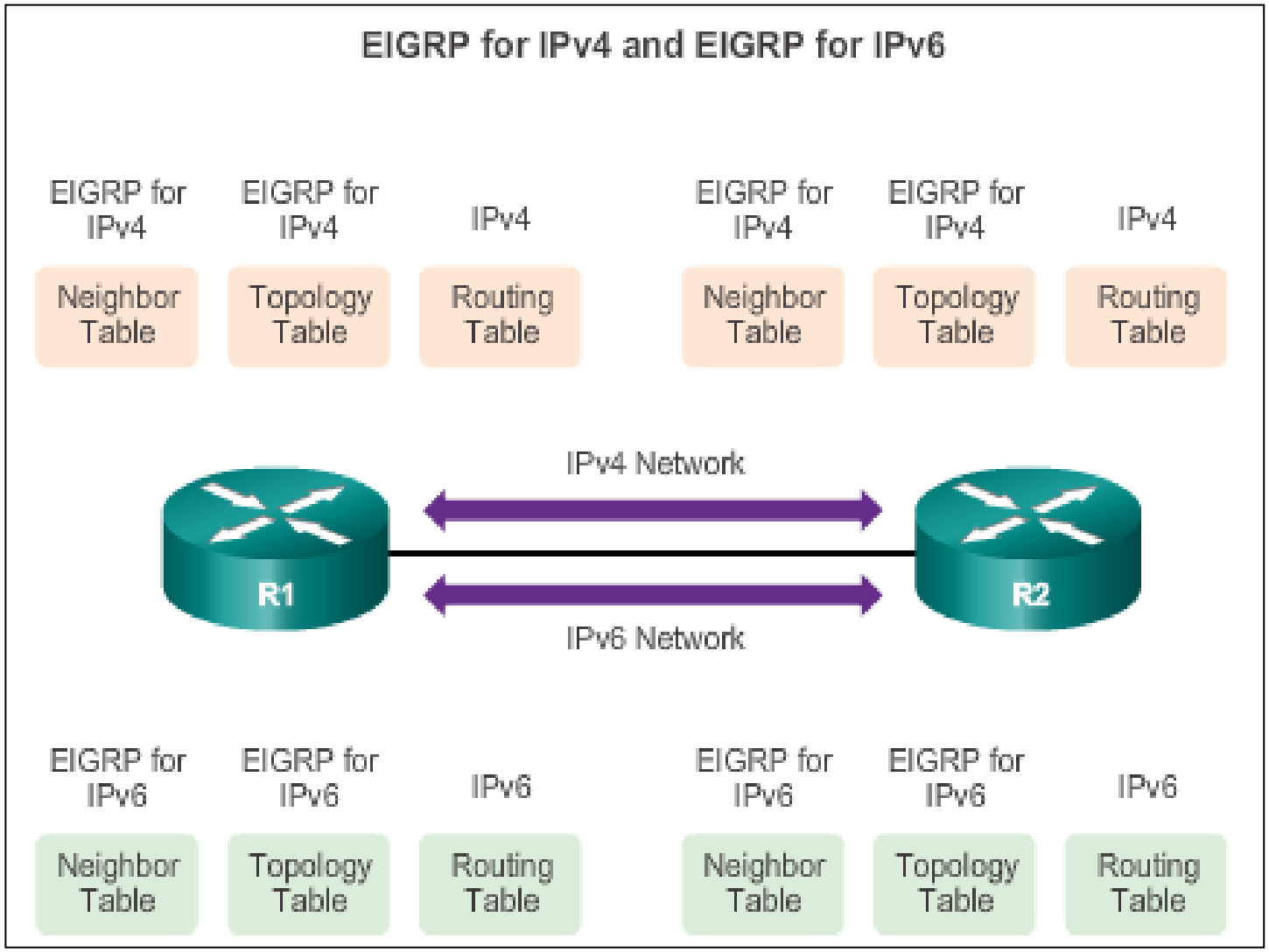
EIGRP for IPv4 vs. IPv6

EIGRP for IPv6

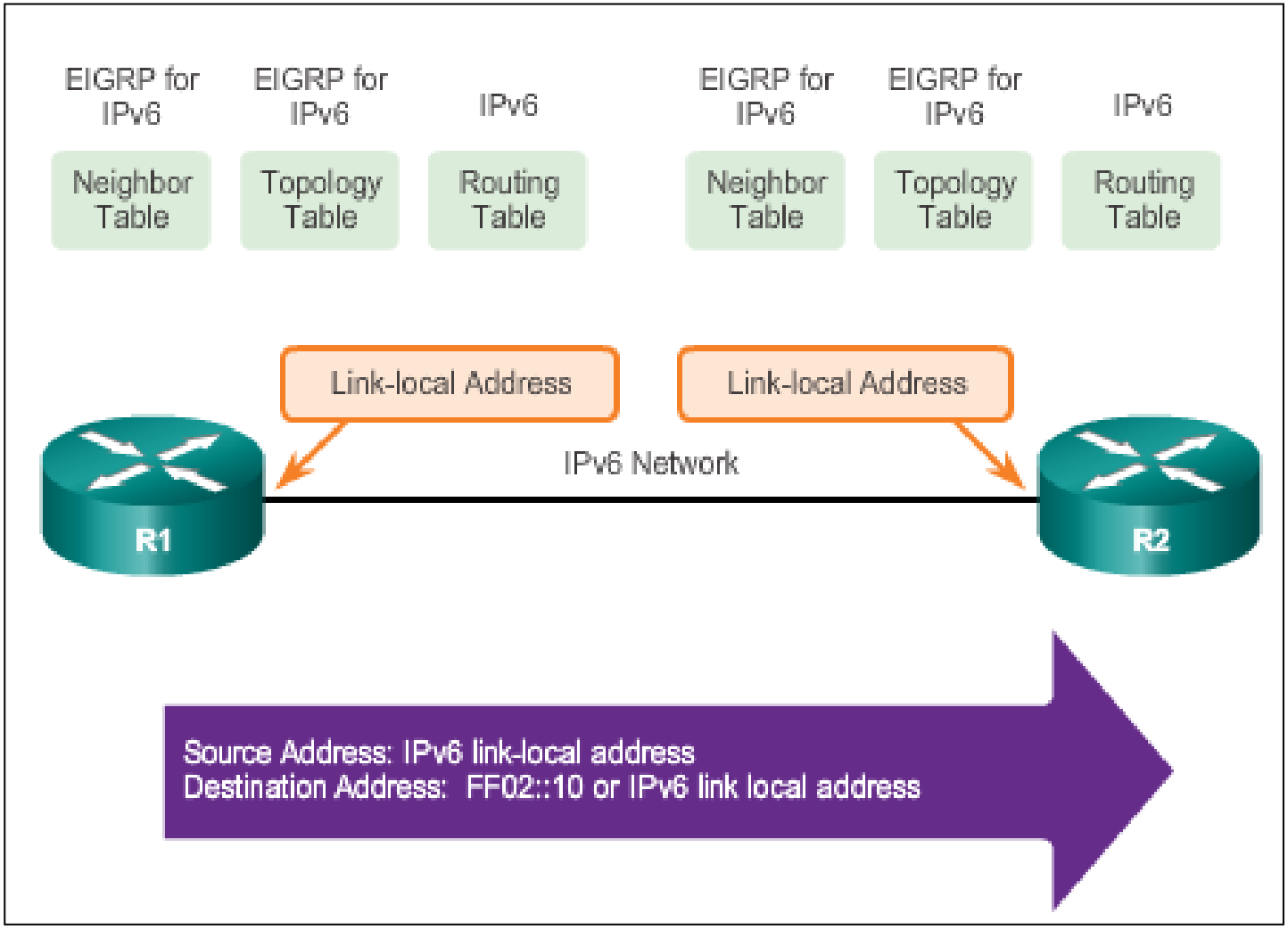


EIGRP for IPv4 vs. IPv6

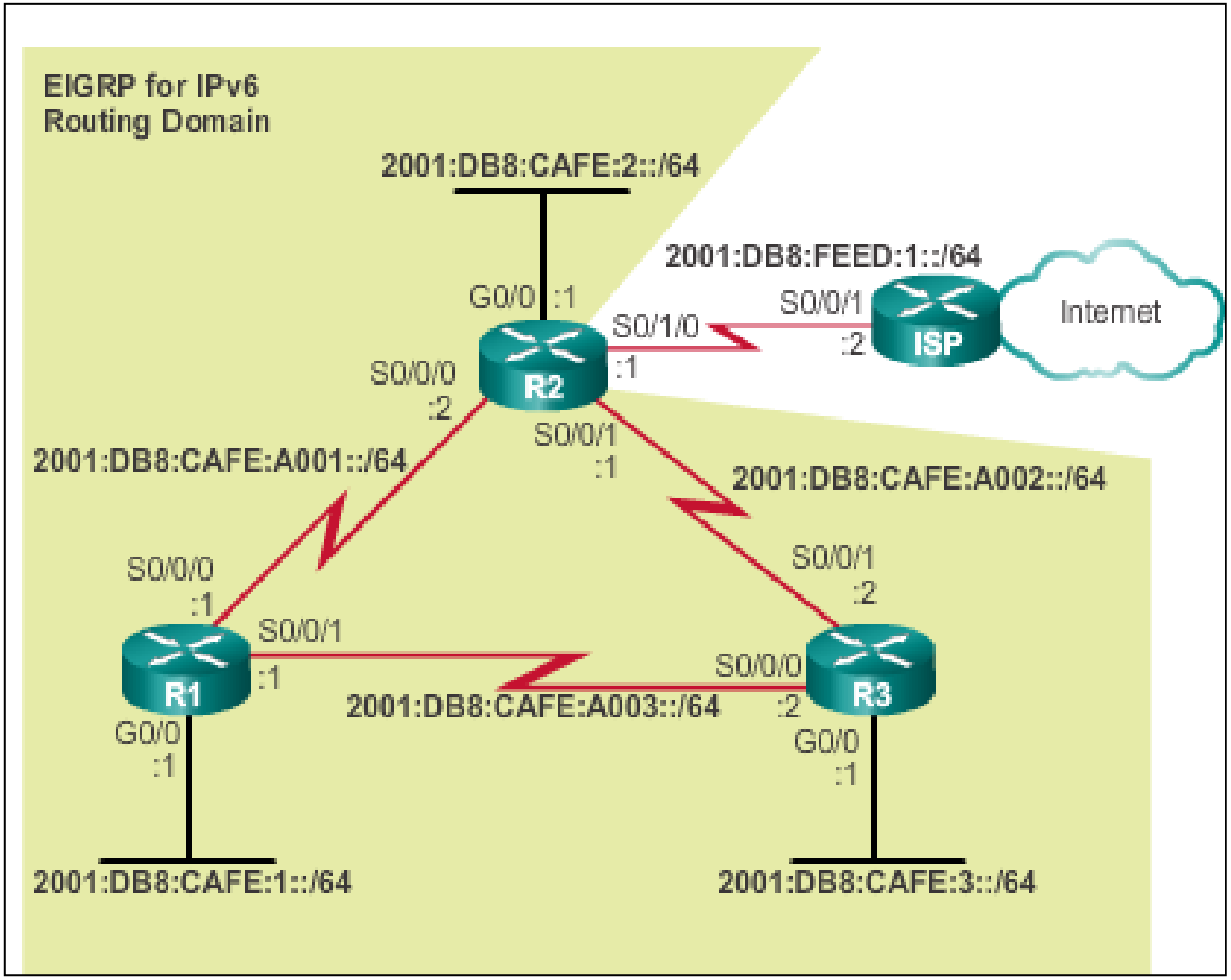
Comparing EIGRP for IPv4 and IPv6

	EIGRP for IPv4	EIGRP for IPv6
Advertised routes	IPv4 networks	IPv6 prefixes
Distance vector	Yes	Yes
Convergence technology	DUAL	DUAL
Metric	Bandwidth and delay by default, reliability and load are optional	Bandwidth and delay by default, reliability and load are optional
Transport protocol	RTP	RTP
Update messages	Incremental, partial and bounded updates	Incremental, partial and bounded updates
Neighbor discovery	Hello packets	Hello packets
Source and destination addresses	IPv4 source address and 224.0.0.10 IPv4 multicast destination address	IPv6 link-local source address and FF02::10 IPv6 multicast destination address
Authentication	Plain text and MD5	MD5
Router ID	32-bit router ID	32-bit router ID

IPv6 Link-local Addresses



EIGRP for IPv6 Network Topology



Configuring IPv6 Link-Local Addresses

Manually configuring link-local addresses

```
R1(config)#interface s 0/0/0
R1(config-if)#ipv6 address fe80::1 ?
  link-local  Use link-local address

R1(config-if)#ipv6 address fe80::1 link-local
R1(config-if)#exit
R1(config)#interface s 0/0/1
R1(config-if)#ipv6 address fe80::1 link-local
R1(config-if)#exit
R1(config)#interface g 0/0
R1(config-if)#ipv6 address fe80::1 link-local
R1(config-if)#
```

Verifying link-local addresses

```
R1#show ipv6 interface brief
GigabitEthernet0/0      [up/up]
    FE80::1
    2001:DB8:CAFE:1::1
Serial0/0/0             [up/up]
    FE80::1
    2001:DB8:CAFE:A001::1
Serial0/0/1             [up/up]
    FE80::1
    2001:DB8:CAFE:A003::1
R1#
```

Same IPv6 link-local address is configured on all interfaces.

Configuring EIGRP for the IPv6 Routing Process

- The **ipv6 unicast-routing** global configuration mode command is required to enable any IPv6 routing protocol.
- Configuring EIGRP for IPv6

```
R2(config)#ipv6 unicast-routing
R2(config)#ipv6 router eigrp 2
R2(config-rtr)#eigrp router-id 2.0.0.0
R2(config-rtr)#no shutdown
R2(config-rtr)#
```

- The **no shutdown** command and a router ID are required for the router to form neighbor adjacencies.

ipv6 eigrp interface Command

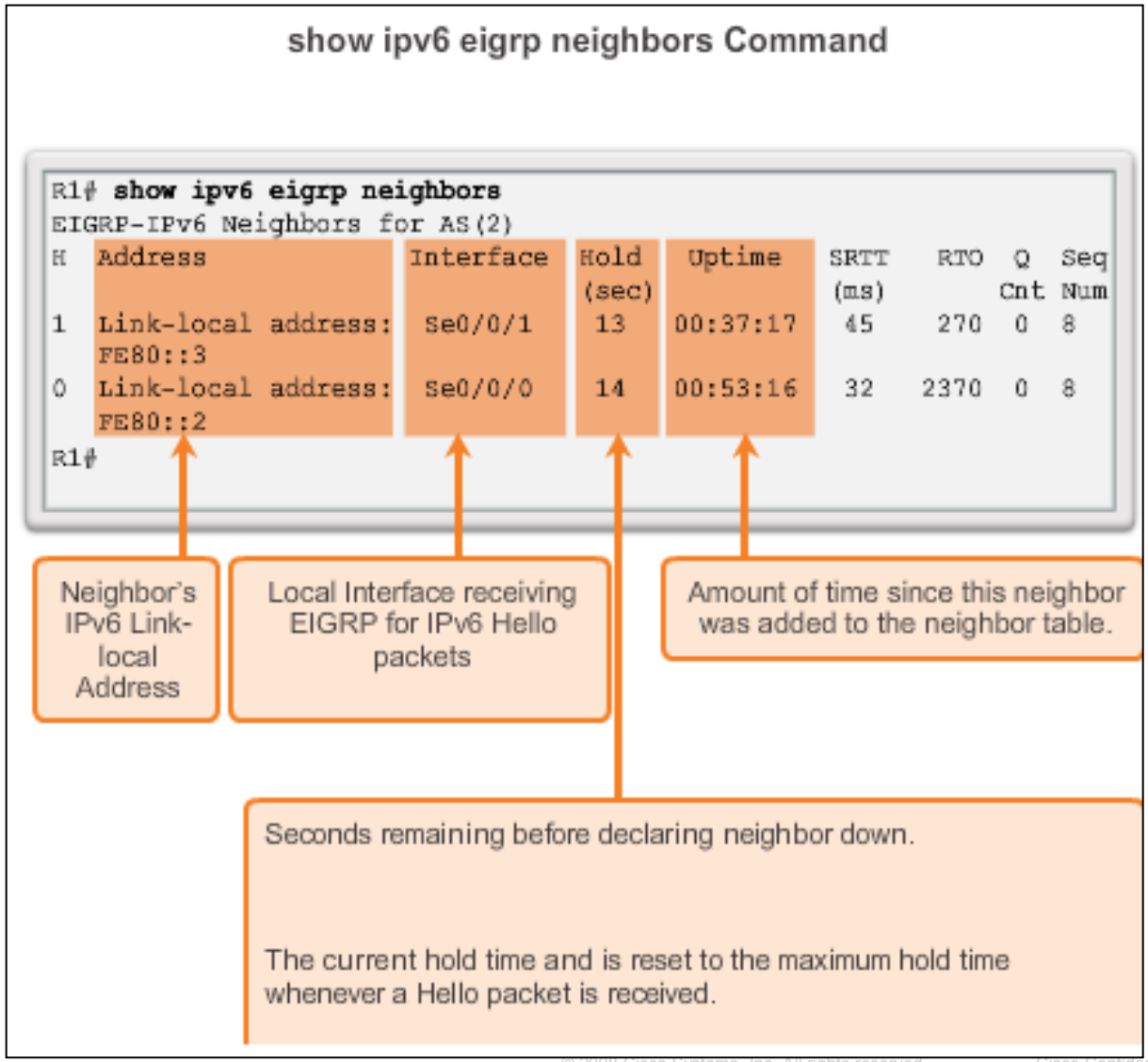
Enabling EIGRP of IPv6 on an Interface

```
R1(config)#interface g0/0
R1(config-if)#ipv6 eigrp 2
R1(config-if)#exit
R1(config)#interface s 0/0/0
R1(config-if)#ipv6 eigrp 2
R1(config-if)#exit
R1(config)#interface s 0/0/1
R1(config-if)#ipv6 eigrp 2
R1(config-if)#
```

```
R2(config)#interface g 0/0
R2(config-if)#ipv6 eigrp 2
R2(config-if)#exit
R2(config)#interface s 0/0/0
R2(config-if)#ipv6 eigrp 2
R2(config-if)#exit
%DUAL-5-NBRCHANGE: EIGRP-IPv6 2: Neighbor FE80::1
(Serial0/0/0) is up: new adjacency
R2(config)#interface s 0/0/1
R2(config-if)#ipv6 eigrp 2
R2(config-if)#
```

Verifying EIGRP for IPv6

Verifying EIGRP for IPv6: Examining Neighbors



Verifying EIGRP for IPv6: `show ip protocols` Command

```
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "eigrp 2"
EIGRP-IPv6 Protocol for AS(2)                    1  Routing protocol and Process ID (AS Number)

  Metric weight K1=1, K2=0, K3=1, K4=0, K5=0     2  K values used in composite metric

  NSF-aware route hold timer is 240
  Router-ID: 1.0.0.0                             3  EIGRP Router ID
  Topology : 0 (base)
    Active Timer: 3 min
    Distance: internal 90 external 170           4  EIGRP Administrative Distances
    Maximum path: 16
    Maximum hopcount 100
    Maximum metric variance 1

  Interfaces:                                    5  Interfaces enabled for this EIGRP for IPv6.
    GigabitEthernet0/0
    Serial0/0/0
    Serial0/0/1
  Redistribution:
    None
R1#
```

Verifying EIGRP for IPv6: Examine the Routing Table

Use the **`show ipv6 route`** command to examine the IPv6 routing table.

```
R1#show ipv6 route
 <Output omitted>
C   2001:DB8:CAFE:1::/64 [0/0]
     via GigabitEthernet0/0, directly connected
L   2001:DB8:CAFE:1::1/128 [0/0]
     via GigabitEthernet0/0, receive
D   2001:DB8:CAFE:2::/64 [90/3524096]
     via FE80::3, Serial0/0/1
D   2001:DB8:CAFE:3::/64 [90/2170112]
     via FE80::3, Serial0/0/1
C   2001:DB8:CAFE:A001::/64 [0/0]
     via Serial0/0/0, directly connected
L   2001:DB8:CAFE:A001::1/128 [0/0]
     via Serial0/0/0, receive
D   2001:DB8:CAFE:A002::/64 [90/3523840]
     via FE80::3, Serial0/0/1
C   2001:DB8:CAFE:A003::/64 [0/0]
     via Serial0/0/1, directly connected
L   2001:DB8:CAFE:A003::1/128 [0/0]
     via Serial0/0/1, receive
L   FF00::/8 [0/0]
     via Null0, receive
R1#
```

Chapter 7: Summary

- EIGRP is a classless, advanced distance vector routing protocol.
- EIGRP uses the source code of “D” for DUAL in the routing table.
- The default administrative distance of 90 is used for internal routes and 170 for routes imported from an external source.
- Advanced features include DUAL, establishing neighbor adjacencies, RTP, partial and bounded updates, and equal and unequal cost load balancing.
- PDMs give EIGRP the capability to support different Layer 3 protocols.
- EIGRP Hello packets are used to discover neighbors.
- The **`show ip eigrp neighbors`** command is used to view neighbor table and verify adjacencies.

Chapter 7: Summary (cont.)

- EIGRP sends partial bounded updates when a change occurs on network.
- EIGRP composite metric uses bandwidth, delay, reliability and load to determine the best path (by default, only bandwidth and delay are used).
- DUAL FSM is used to determine best path; Successor and potential backup path, FS to every destination network.