Enhanced Interior Gateway Routing Protocol - EIGRP

CCNP ROUTE: Implementing IP Routing

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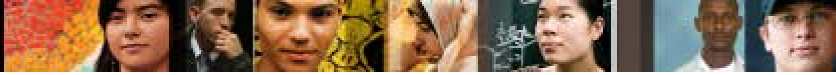
Objectives

- EIGRP Overview
- Terminology
- Key Technologies
- Packet Types
- DUAL Example
- Scalability
- Troubleshooting



EIGRP Capabilities and Attributes

- EIGRP is a Cisco-proprietary distance-vector protocol with link-state features.
- EIGRP features include:
  - Fast convergence
  - Partial updates
  - Multiple network layer support
  - Use of multicast and unicast communication
  - Variable-length subnet mask (VLSM) support
  - Seamless connectivity across all data link layer protocols and topologies
  - Performs automatic route summarization at major network boundaries (can be disabled) but can also be configured to summarize on interfaces.

EIGRP Terminology

- Tables:
  - Neighbor table
  - Topology table
  - Routing table
- Advertised Distance (AD)
- Feasible Distance (FD)
- Feasible Condition (FC)
- Successor
- Feasible successor (FS)
- Passive vs Active Routes

EIGRP Tables

- **Neighbor table**
  - Contains EIGRP neighbor addresses and the interface through which they can be reached.
- **Topology table**
  - Contains all destinations advertised by neighboring routers.
- **Routing table**
  - Contains EIGRP successor routes.

AD versus FD

- **Advertised Distance (AD)**
  - Advertised distance (AD), also referred to as the Reported Distance, is the cost between the next-hop router and the destination.
- **Feasible Distance (FD)**
  - Feasible distance (FD) is the cost between the local router and the next-hop router plus the next-hop router's AD to the destination network.
- **Feasibility Condition (FC)**
  - (FC) is met when a neighbor's Reported Distance (RD) to a network is less than the local router's feasible distance (FD) to the same destination network.

Successor and Feasible Successor

- **Successor**
  - A successor is a neighboring router that has a least-cost path to a destination (the lowest FD) that is guaranteed not to be part of a routing loop.
  - Successor routes are offered to the routing table to be used for forwarding packets.
  - Multiple successors can exist if they have the same FD.
- **Feasible successor (FS)**
  - A feasible successor is a neighbor that is closer to the destination than other routes, but it is not the least-cost path.
  - A feasible successor ensures a loop-free topology because it must have an AD less than the FD of the current successor route (Feasible Condition)
  - Feasible successors are selected at the same time as successors but are kept in the topology table as backups to the successor routes.
  - Inserted in the routing table when the successor fails.
  - The topology table can maintain multiple feasible successors for a destination.

Passive vs Active Routes

- **Passive Route**
  - A route is considered *passive* when the router is not performing recomputation on that route.
  - *Passive* is the operational, stable state.
- **Active route**
  - A route is *active* when it is undergoing recomputation.

Key EIGRP Technologies

- **Reliable Transport Protocol (RTP)**
  - Responsible for guaranteed, ordered delivery of EIGRP packets to all neighbors.
- **Neighbor discovery/recovery mechanism**
  - Enables EIGRP routers to dynamically learn when their neighbors become unreachable or inoperative by periodically sending small hello packets.
- **Protocol-dependent modules (PDMs)**
  - Responsible for network layer protocol-specific requirements such as IP, IPv6, AppleTalk, and Novell NetWare.
- **DUAL finite-state machine**
  - **Diffusing Update Algorithm (DUAL)** is the routing algorithm that tracks all routes advertised by all neighbors and uses the *distance* information, known as the composite metric, to select efficient, loop-free paths to all destinations.

Packet Types

Packet Type	Use
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 get specific information from a neighbor router.
Reply	Used to respond to a query.

Hello Packets

- EIGRP relies on Hello packets to discover, verify, and rediscover neighbor routers.
- EIGRP Hello packets are multicasts to 224.0.0.10.
- Hello packets are always sent unreliably and therefore do not require acknowledgment.

Hello Packets

- Hellos are sent at a fixed (and configurable) interval, called the Hello interval.
  - Hello/Hold timers do not need to match.
  - To reset the Hello interval: no ip hello-interval eigrp as#
- Default interval on point-to-point serial links, multipoint circuits with bandwidth greater than T1, and LANs
  - 5 seconds
- Default interval on T1 or less multipoint WAN circuits
  - 60 seconds

Hello Packets

- On hearing Hellos, a router creates a neighbor table and the continued receipt of Hellos maintains the table.
- Holdtime is the maximum amount of allowed time that Hellos are not heard from a neighbor.
  - Three times the Hello Interval:
    - High bandwidth (3 x 5 sec.) = 15 seconds
    - Low Bandwidth (3 x 60 sec.) = 180 seconds

Acknowledgement Packets

- Are used to indicate receipt of any EIGRP packet during a "reliable" (i.e., RTP) exchange.
  - To be reliable, a sender's message must be acknowledged by the recipient.
- Acknowledgment packets are:
  - Dataless Hello packets.
  - Unicast.

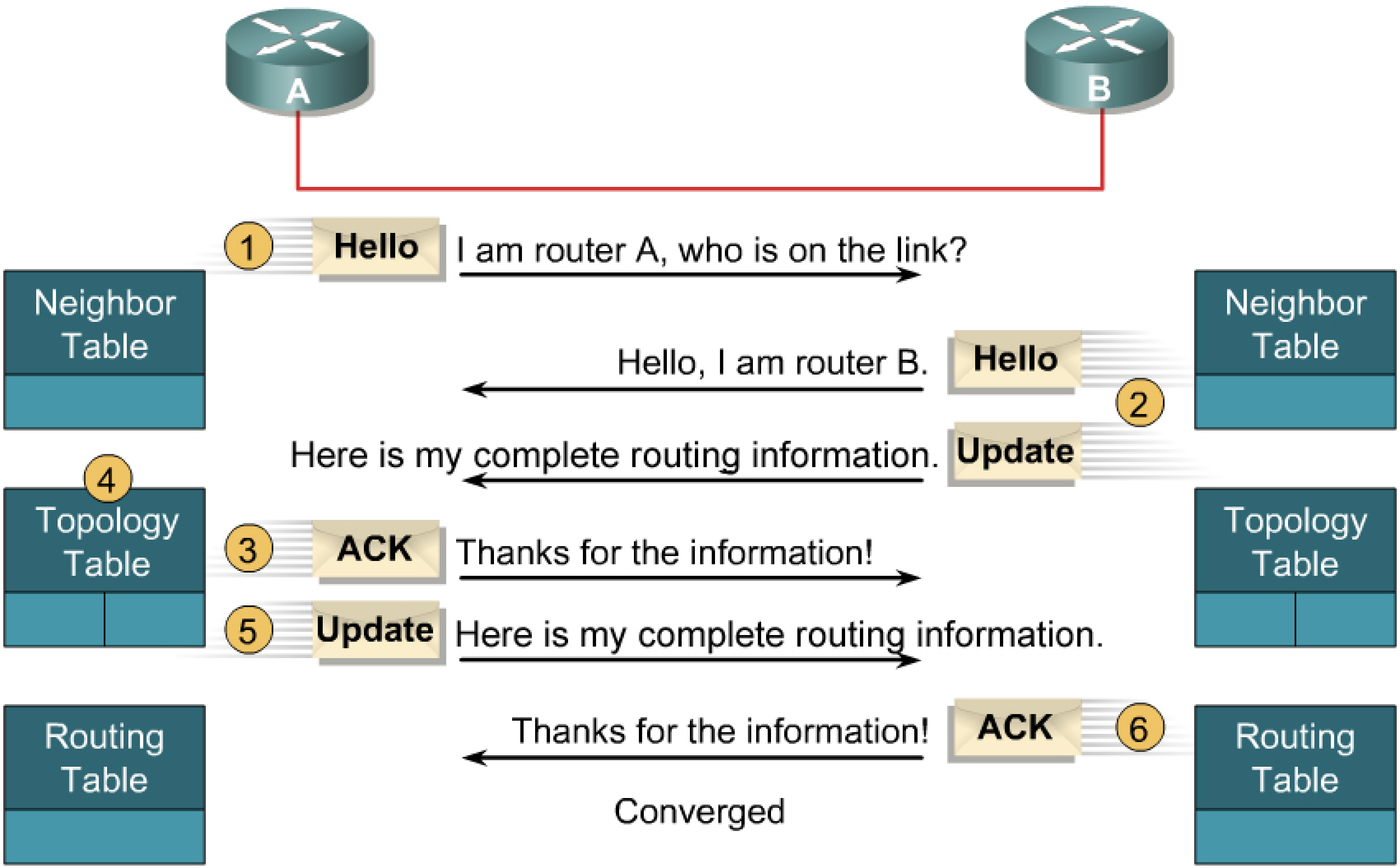
Update Packets

- After the local router discovers a new neighbor, update packets are sent to the new neighbor.
- Update packets are also used when a router detects a topology change.
  - The router sends a multicast Update packet to all neighbors, alerting them to the change.
- All Update packets are sent reliably.

Query and Reply Packets

- Query and Reply packets are sent when a destination has no feasible successors.
- Both packet types are sent reliably.
- A Query packet is multicasted to other EIGRP routers during the route re-computation process.
  - Query packets are always multicast.
- A Reply packet is used to respond to a query to instruct the originator not to recompute the route because feasible successors exist.
  - Reply packets are always unicast.

Initial Route Discovery



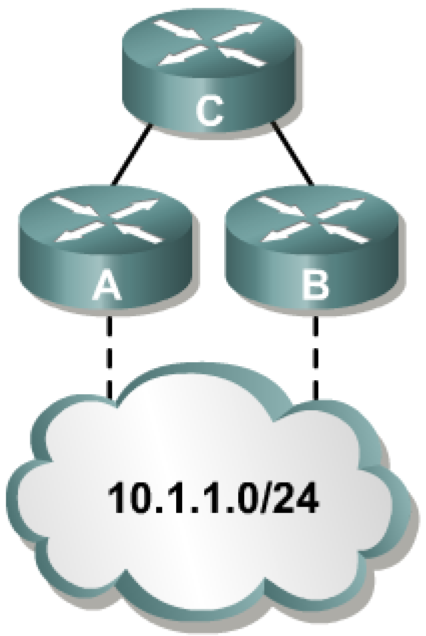
Example: EIGRP Tables

Router C's tables:

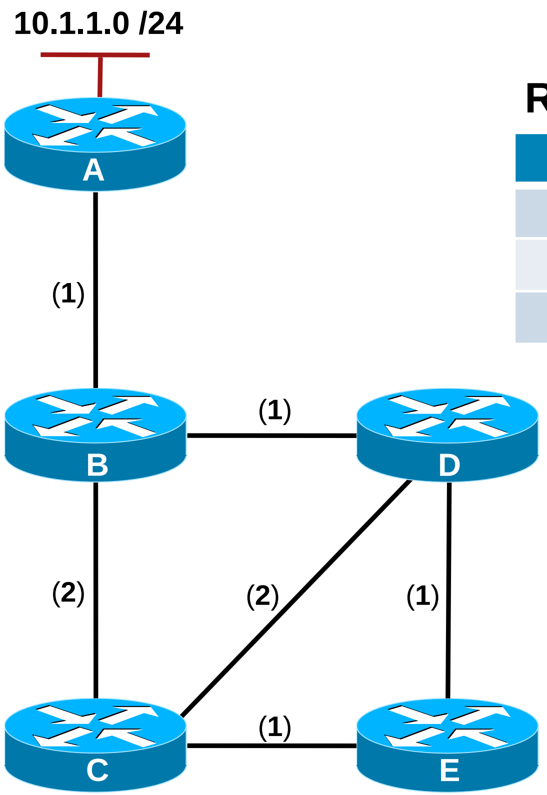
IP EIGRP Neighbor Table	
Next-Hop Router	Interface
Router A Router B	Ethernet 0 Ethernet 1

IP EIGRP Topology Table			
Network	Feasible Distance (EIGRP Metric)	Advertised Distance	EIGRP Neighbor
10.1.1.0 /24 10.1.1.0 /24	2000 2500	1000 1500	Router A (E0) Router B (E1)

The IP Routing Table			
Network	Metric (Feasible Distance)	Outbound Interface	Next Hop (EIGRP Neighbor)
10.1.1.0 /24	2000	Ethernet 0	Router A



DUAL Example



Router D

EIGRP	FD	AD	Topology
10.1.1.0 /24	2		***** Passive *****
via B	2	1	Successor
via C	5	3	

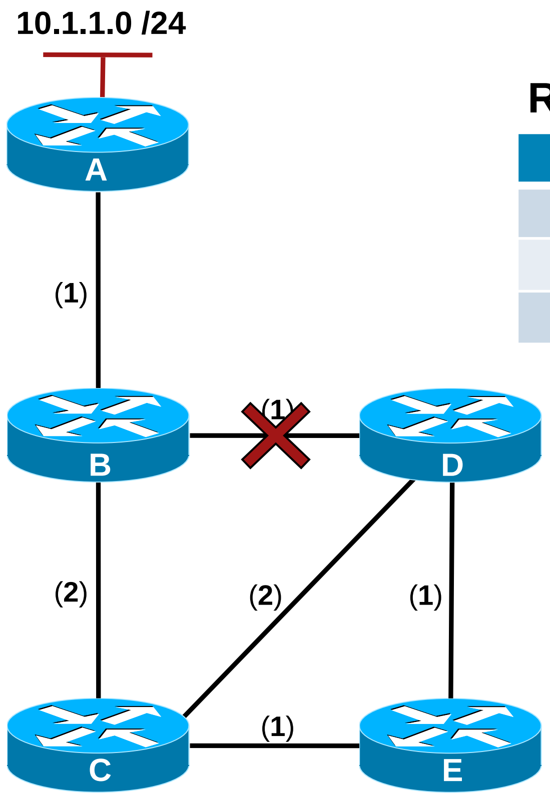
Router C

EIGRP	FD	AD	Topology
10.1.1.0 /24	3		***** Passive *****
via B	3	1	Successor
via D	4	2	Feasible Successor
via E	4	3	

Router E

EIGRP	FD	AD	Topology
10.1.1.0 /24	3		***** Passive *****
via D	3	2	Successor
via C	4	3	

DUAL Example



Router D

EIGRP	FD	AD	Topology
10.1.1.0 /24	2		***** Passive *****
~~via B~~	~~2~~	~~1~~	~~Successor~~
via C	5	3	

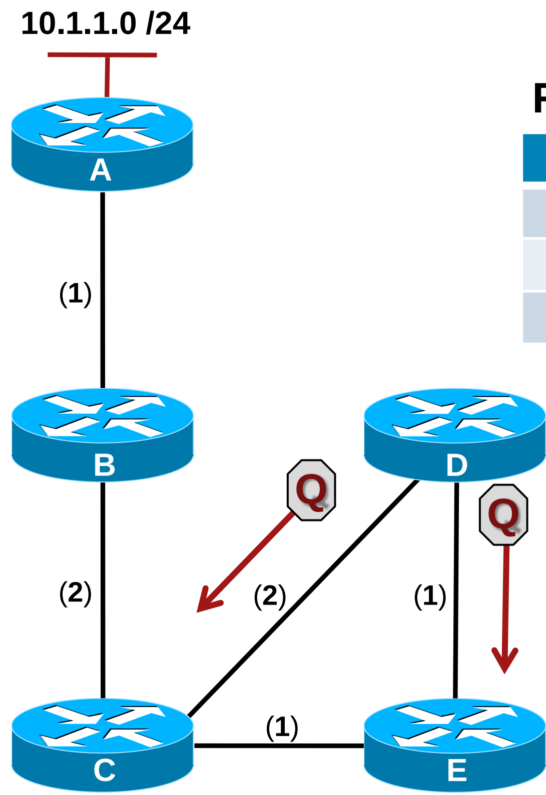
Router C

EIGRP	FD	AD	Topology
10.1.1.0 /24	3		***** Passive *****
via B	3	1	Successor
via D	4	2	Feasible Successor
via E	4	3	

Router E

EIGRP	FD	AD	Topology
10.1.1.0 /24	3		***** Passive *****
via D	3	2	Successor
via C	4	3	

DUAL Example



Router D

EIGRP	FD	AD	Topology
10.1.1.0 /24	-1		***** ACTIVE ******
via E			(Q) Query
via C	5	3	(Q) Query

= Query

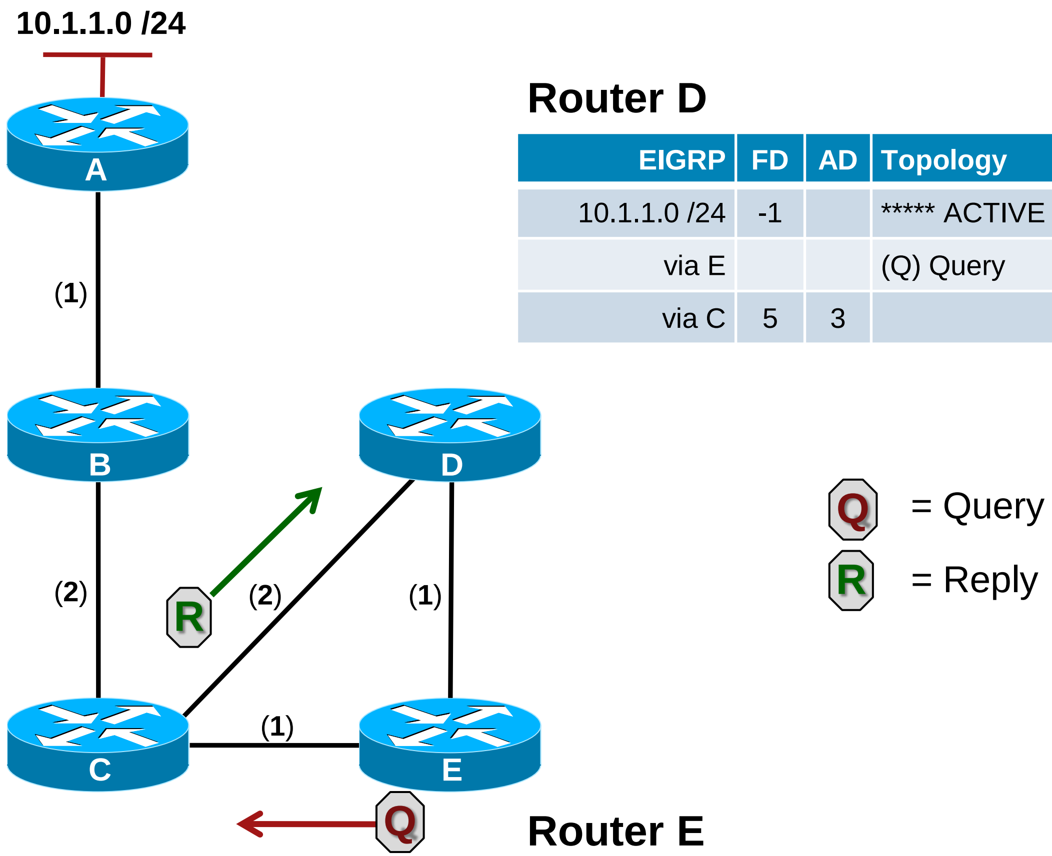
Router C

EIGRP	FD	AD	Topology
10.1.1.0 /24	3		***** Passive *****
via B	3	1	Successor
~~via D~~	~~4~~	~~2~~	~~Feasible Successor~~
via E	4	3	

Router E

EIGRP	FD	AD	Topology
10.1.1.0 /24	3		***** Passive *****
~~via D~~	~~3~~	~~2~~	~~Successor~~
via C	4	3	

DUAL Example



Router D

EIGRP	FD	AD	Topology
10.1.1.0 /24	-1		***** ACTIVE ******
via E			(Q) Query
via C	5	3	

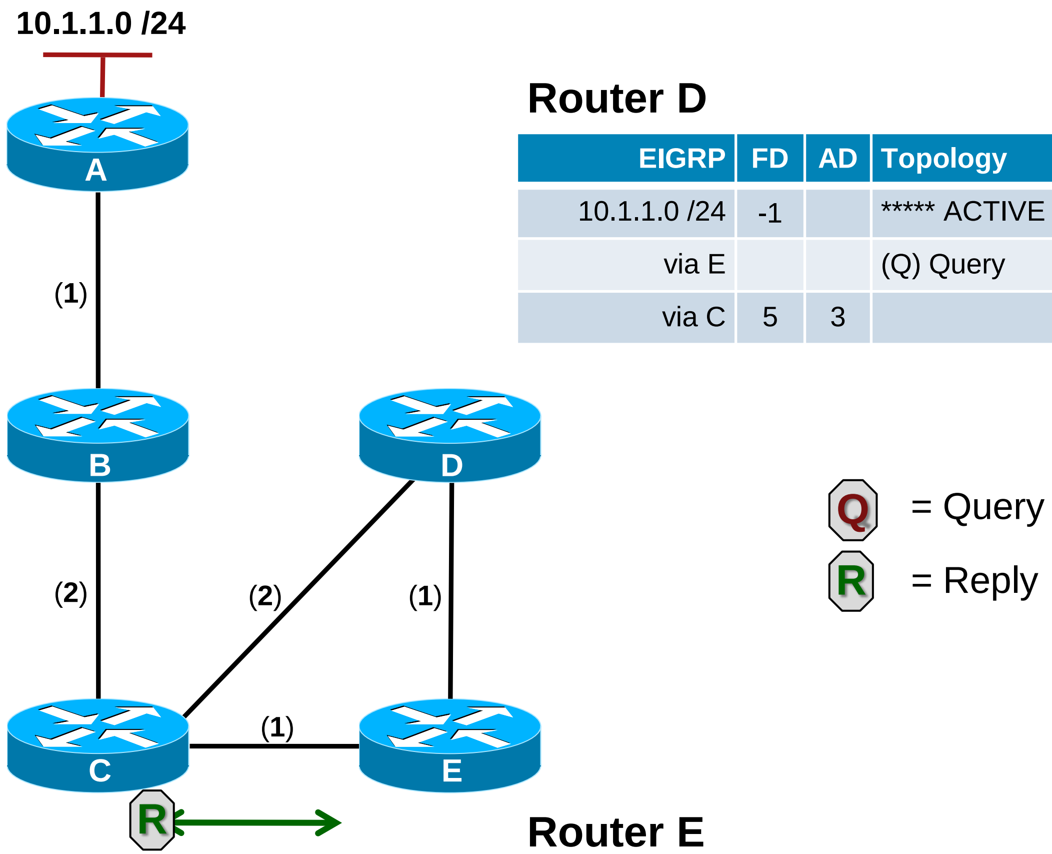
Router C

EIGRP	FD	AD	Topology
10.1.1.0 /24	3		***** Passive *****
via B	3	1	Successor
via D			
~~via E~~	~~4~~	~~3~~	

Router E

EIGRP	FD	AD	Topology
10.1.1.0 /24	-1		***** ACTIVE ******
via D			
via C	4	3	(Q) Query

DUAL Example



Router D

EIGRP	FD	AD	Topology
10.1.1.0 /24	-1		***** ACTIVE ******
via E			(Q) Query
via C	5	3	

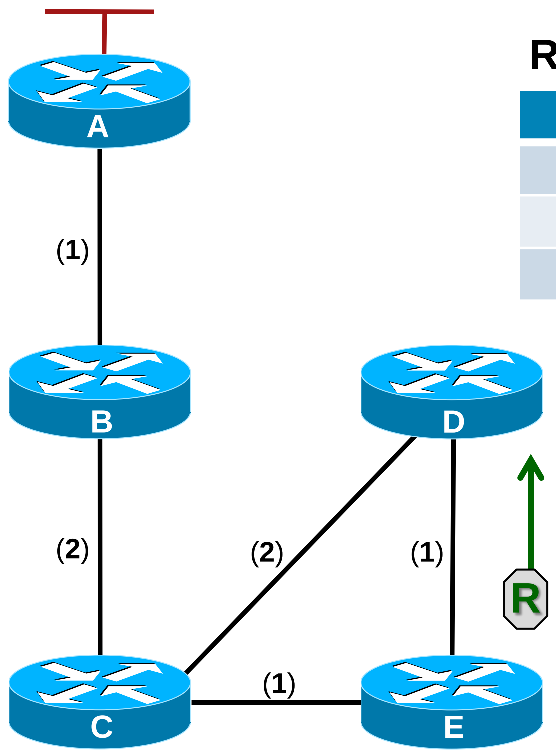
Router C

EIGRP	FD	AD	Topology
10.1.1.0 /24	3		***** Passive *****
via B	3	1	Successor
via D			
via E			

Router E

EIGRP	FD	AD	Topology
10.1.1.0 /24	4		***** Passive *****
via C	4	3	Successor
via D			

DUAL Example



Q = Query

R = Reply

Router D

EIGRP	FD	AD	Topology
10.1.1.0 /24	5		***** Passive *****
via C	5	3	Successor
via E	5	4	Successor

Router C

EIGRP	FD	AD	Topology
10.1.1.0 /24	3		***** Passive *****
via B	3	1	Successor
via D			
via E			

Router E

EIGRP	FD	AD	Topology
10.1.1.0 /24	4		***** Passive *****
via C	4	3	Successor
via D			

EIGRP Metric Calculation

- EIGRP uses a composite metric which can be based on the following metrics:
  - Bandwidth
  - Delay
  - Load
  - Reliability
- Only Bandwidth and Delay are used by default.

EIGRP MD5 Authentication

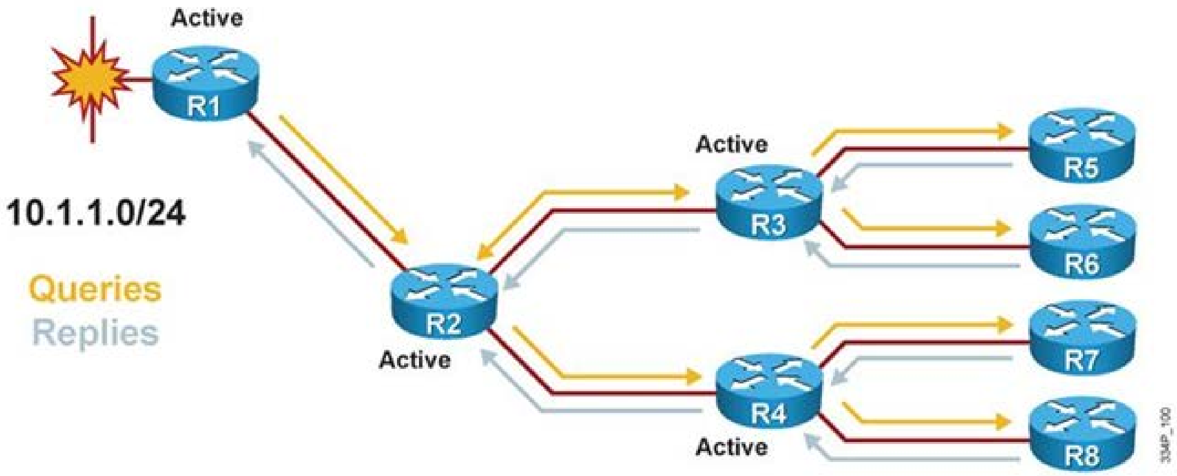
- EIGRP supports MD5 authentication.
- Router generates and checks every EIGRP packet. Router authenticates the source of each routing update packet that it receives.
- Configure a “key” (password) and key-id; each participating neighbor must have same key configured.

Factors That Influence EIGRP Scalability

- Quantity of routing information exchanged between peers: without proper route summarization, this can be excessive.
- Number of routers that must be involved when a topology change occurs.
- Depth of topology: the number of hops that information must travel to reach all routers
  - Increasing the convergence time.
- Number of alternate paths through the network
  - Redundant paths are important, but too much complexity will cause convergence problems and increase the queries.

Overwhelming EIGRP Query Process

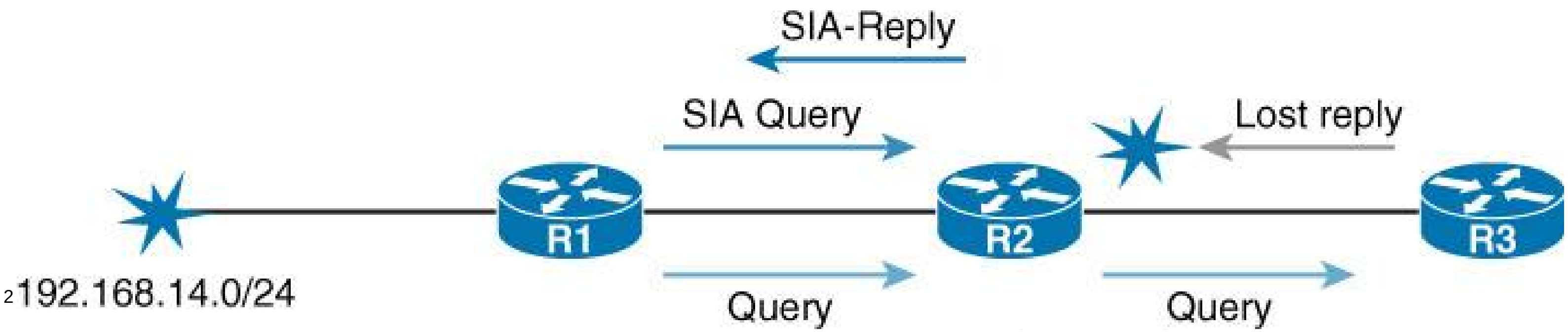
- In a large internetwork EIGRP queries can generate many resources.



- Several solutions exist to optimize the query propagation process and to limit the amount of unnecessary EIGRP load on the links, including:
  - Summarization
  - Redistribution
  - EIGRP stub routing feature.

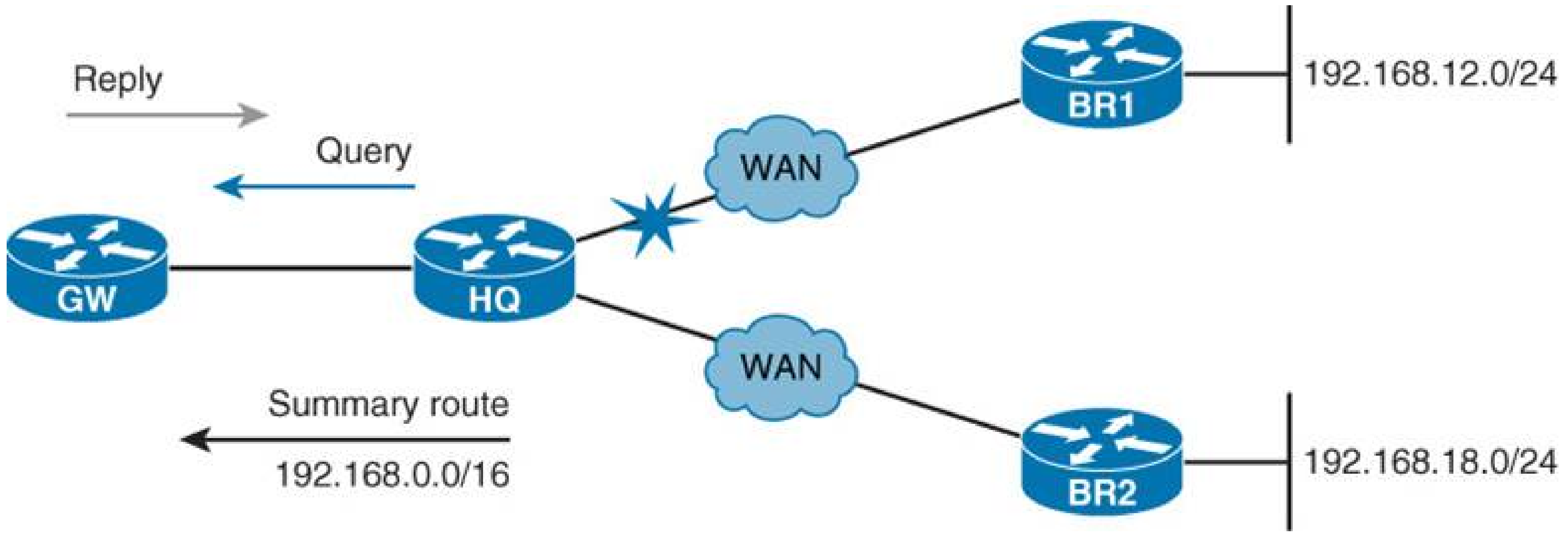
Stuck-in-Active

- If a router does not receive a reply to all the outstanding queries within default 3 minutes (180 seconds), the route goes into Stuck-in-Active (SIA) state.
- Common SIA reasons:
  - A router is too busy to answer the query.
  - A router cannot allocate the memory to process the query.
  - The circuit between the two routers is not reliable.
  - The router has unidirectional links.
- SIA solutions:
  - Redesign the network to limit the query range by route summarization and the **`ip summary-address eigrp`** command.
  - Configure the remote routers as stub EIGRP routers.



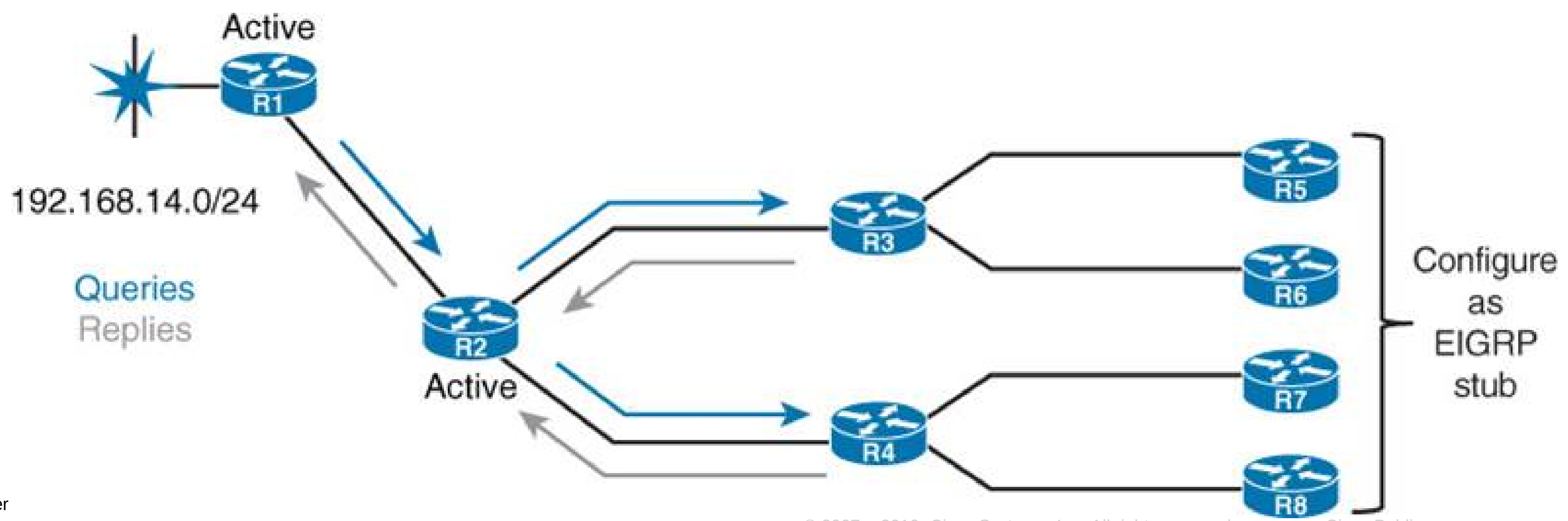
Route Summarization

- Implement route summarization to reduce the number of query messages
- A query for a specific network which is included in a summary route present in the routers routing table, will be replied without further forwarding the query packet
  - Reduces the number of queries sent and improves convergence time



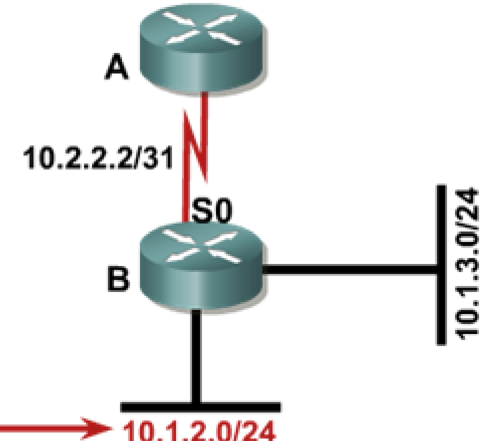
EIGRP Stub Routing

- Stub routing is commonly used in hub-and-spoke topology.
- Stub router sends a special peer information packet to all neighboring routers to report its status as a stub router.
  - Any neighbor that receives a packet informing it of the stub status does not query the stub router for any routes.
  - Stub routers are not queried and instead, hub routers connected to the stub router answer the query on behalf of the stub router.
- Only the remote routers are configured as stubs.



Example: EIGRP Stub Parameters

- If **`stub connected`** is configured:
  - B will advertise 10.1.2.0/24 to A.
  - B will not advertise 10.1.2.0/23, 10.1.3.0/23, or 10.1.4.0/24.
- If **`stub summary`** is configured:
  - B will advertise 10.1.2.0/23 to A.
  - B will not advertise 10.1.2.0/24, 10.1.3.0/24, or 10.1.4.0/24.



Router B

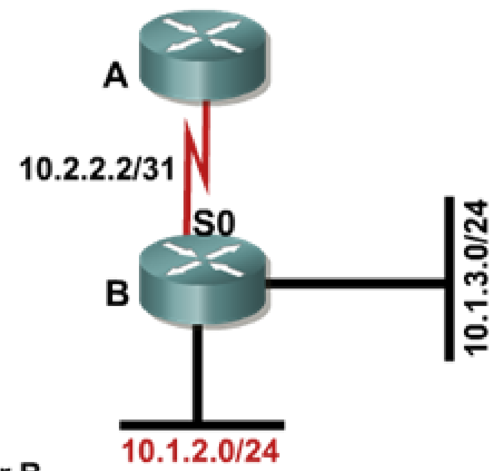
```
ip route 10.1.4.0 255.255.255.0 10.1.1.10
!
interface serial 0
ip summary-address eigrp 10.1.2.0 255.255.254.0
!
router eigrp 100
 redistribute static 1000 1 255 1 1500
 network 10.2.2.2 0.0.0.1
 network 10.1.2.0 0.0.0.255

 eigrp stub connected

 eigrp stub summary
```

Example: EIGRP Stub Parameters (Cont.)

- If **`stub static`** is configured:
  - B will advertise 10.1.4.0/24 to A.
  - B will not advertise 10.1.2.0/24, 10.1.2.0/23, or 10.1.3.0/24.
- If **`stub receive-only`** is configured:
  - B won’t advertise anything to A, so A needs to have a static route to the networks behind B to reach them.



Router B

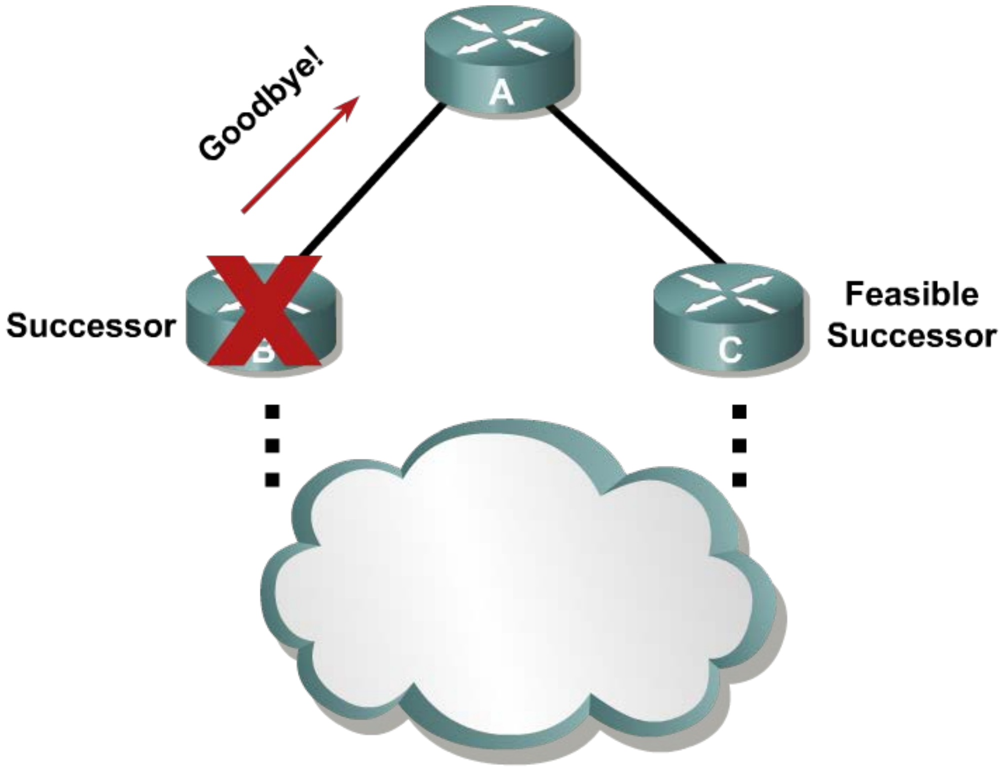
```
ip route 10.1.4.0 255.255.255.0 10.1.1.10
!
interface serial 0
ip summary-address eigrp 10.1.2.0 255.255.254.0
!
router eigrp 100
 redistribute static 1000 1 255 1 1500
 network 10.2.2.2 0.0.0.1
 network 10.1.2.0 0.0.0.255

 eigrp stub static

 eigrp stub summary
```

Graceful Shutdown

Sends a goodbye message to inform adjacent peers when an EIGRP routing process is shut down



Troubleshooting EIGRP - Routing Review

- To diagnose and resolve problems related to EIGRP, you must be able to do the following:
  - Apply your knowledge of EIGRP data structures to plan the gathering of necessary information as part of a structured approach to troubleshooting EIGRP routing problems
  - Apply your knowledge of the processes that EIGRP uses to exchange routing information to interpret and analyze the information that is gathered during an EIGRP troubleshooting process
  - Use IOS commands to gather information from the EIGRP data structures and track the flow of EIGRP routing information to troubleshoot EIGRP operation

Troubleshooting EIGRP - Routing Review

EIGRP stores its operational data, configured parameters, and statistics in three main data structures:

- Interface table
  - Lists all interfaces enabled for processing EIGRP packets (not passive interfaces)
- Neighbor table
  - To keep track of all active EIGRP neighbors
  - Built based on the reception of hello packets
- Topology table
  - All the routes received from neighboring routers
  - Used by DUAL to calculate best path

Monitoring EIGRP with show commands

- To gather information from the EIGRP data structures use the following **`show`** commands:
- **`show ip eigrp interfaces`**:
  - Displays the list of interfaces that have been activated for EIGRP processing.
- **`show ip eigrp neighbors:`**
  - Lists all neighbors that have been discovered by this router on its active EIGRP interfaces.
- **`show ip eigrp topology:`**
  - Displays the content of the EIGRP topology table. To select a specific entry from the table, the network and mask can be provided as an option to the command.

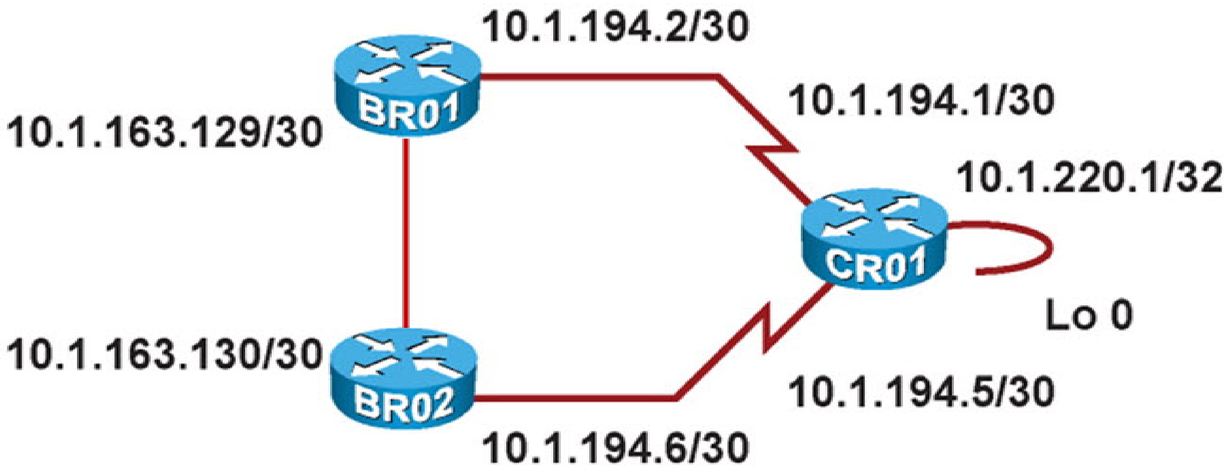
Monitoring EIGRP with debug Commands

To observe the real-time EIGRP information exchange use the following debug commands:

- **`debug ip routing`**:
  - Not specific to EIGRP.
  - Displays changes made to the routing table, such as installation or removal of routes.
  - Can be useful in diagnosing routing protocol instabilities.
- **`debug eigrp packets`**:
  - Displays the transmission and reception of EIGRP packets.
  - All packets can be displayed, or packets of a particular type, such as hellos, updates, queries, and replies can be selected.
- **`debug ip eigrp`**:
  - Displays EIGRP routing events, such as updates, queries, and replies sent to or received from neighbors.
- **`debug ip eigrp neighbor`** ***`as-number ip-address`***:
  - Limits output to information that is associated with the specified neighbor.
- **`debug ip eigrp`** ***`as-number network mask`***:
  - Limits output to information that is associated with the network specified by the network and mask options.

EIGRP Troubleshooting Example:

Packets from BR01 to CR01 Lo0 takes wrong path.




```
BRO1# traceroute 10.1.220.1

Type escape sequence to abort.
Tracing the route to cro1.mgmt.tshoot.local (10.1.220.1)

  1 10.1.163.130 0 msec 0 msec 0 msec
  2 10.1.194.5 12 msec 12 msec *

BRO1# ping 10.1.194.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.194.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/32 ms
```

EIGRP Troubleshooting Example – Cont.

EIGRP **show** commands indicate that there is only one BR01 topology entry for CR01 Lo0 and that BR01 and CR01 are not EIGRP neighbors.

```
BRO1# show ip eigrp topology 10.1.220.1 255.255.255.255
IP-EIGRP (AS 1): Topology entry for 10.1.220.1/32
  State is Passive, Query origin flag is 1, 1 Successor(s), FD is 40642560
  Routing Descriptor Blocks:
  10.1.163.130 (FastEthernet0/1), from 10.1.163.130, Send flag is 0x0
      Composite metric is (40642560/40640000), Route is Internal
      Vector metric:
        Minimum bandwidth is 64 Kbit
        Total delay is 25100 microseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1500
        Hop count is 2

BRO1# show ip eigrp neighbors
IP-EIGRP neighbors for process 1
H   Address                 Interface       Hold Uptime   SRTT   RTO  Q   Seq
                                             (sec)        (ms)       Cnt Num
0   10.1.163.130            Fa0/1          12 00:09:56    4    200  0   585
```

EIGRP Troubleshooting Example – Cont.

Only the BR01 Fa0/1 interface is participating in EIGRP. The **`show run`** command reveals that network statement for 10.1.194.1 is the problem.

```
BRO1# show ip eigrp interfaces
IP-EIGRP interfaces for process 1

                        Xmit Queue   Mean   Pacing Time   Multicast
Pending
Interface        Peers  Un/Reliable  SRTT   Un/Reliable   Flow Timer   Routes
Fa0/1           1        0/0         4       0/1           50           0


BRO1# show running-config | section router eigrp
router eigrp 1
 network 10.1.163.129 0.0.0.0
 network 10.1.194.1 0.0.0.0
 no auto-summary
```

Correct the problem:

```
BRO1(config-router)#
no network 10.1.194.1 0.0.0.0
network 10.1.194.2 0.0.0.0 (or 10.1.194.0 0.0.0.3)
```

EIGRP Troubleshooting Example – Cont.

After correcting the EIGRP **`network`** statement, both BR01 interfaces are participating in EIGRP and BR02 and CR01 are BR01 neighbors.

```
BRO1# show ip eigrp interfaces
IP-EIGRP interfaces for process 1

                        Xmit Queue   Mean   Pacing Time   Multicast    Pending
Interface         Peers Un/Reliable  SRTT   Un/Reliable   Flow Timer   Routes
Fa0/1            1       0/0          1      0/1            50           0
Se0/0/0         1        0/0       707     10/380       4592           0

BRO1# show ip eigrp neighbors
IP-EIGRP neighbors for process 1
H   Address                    Interface        Hold Uptime   SRTT   RTO  Q   Seq
                                                (sec)         (ms)       Cnt Num
1   10.1.194.1                 Se0/0/0        14 00:10:10  707   4242  0  783
0   10.1.163.130               Fa0/1           12 01:34:49    1   200  0  587
```

EIGRP Troubleshooting Example – Cont.

The new EIGRP Topology table after corrections were made.

```
BRO1# show ip eigrp topology 10.1.220.1 255.255.255.255
IP-EIGRP (AS 1): Topology entry for 10.1.220.1/32
  State is Passive, Query origin flag is 1, 1 Successor(s), FD is 40640000
  Routing Descriptor Blocks:
  10.1.194.1 (Serial0/0/0), from 10.1.194.1, Send flag is 0x0
      Composite metric is (40640000/128256), Route is Internal
      Vector metric:
        Minimum bandwidth is 64 Kbit
        Total delay is 25000 microseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1500
        Hop count is 1
  10.1.163.130 (FastEthernet0/1), from 10.1.163.130, Send flag is 0x0
      Composite metric is (40642560/40640000), Route is Internal
      Vector metric:
        Minimum bandwidth is 64 Kbit
        Total delay is 25100 microseconds
        Reliability is 255/255
        Load is 1/255
        Minimum MTU is 1500
        Hop count is 2
```

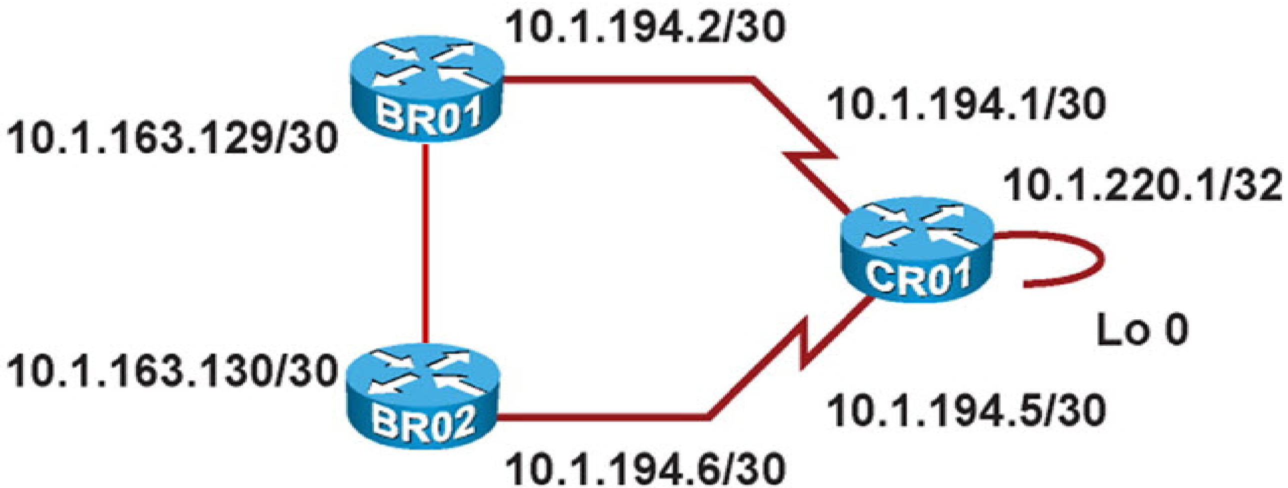
EIGRP Troubleshooting Example – Cont.

The IP routing table after corrections were made.

```
BRO1# show ip route 10.1.220.1 255.255.255.255
Routing entry for 10.1.220.1/32
  Known via "eigrp 1", distance 90, metric 40640000, type internal
  Redistributing via eigrp 1
  Last update from 10.1.194.1 on Serial0/0/0.111, 00:20:55 ago
  Routing Descriptor Blocks:
  * 10.1.194.1, from 10.1.194.1, 00:20:55 ago, via Serial0/0/0
      Route metric is 40640000, traffic share count is 1
      Total delay is 25000 microseconds, minimum bandwidth is 64 Kbit
      Reliability 255/255, minimum MTU 1500 bytes
      Loading 1/255, Hops 1
```

EIGRP Troubleshooting Example – Cont.

Traceroute to CR01 Lo0 now shows correct path.




```
BRO1# traceroute 10.1.220.1

Type escape sequence to abort.
Tracing the route to cro1.mgmt.tshoot.local (10.1.220.1)
  1 10.1.194.1 16 msec 12 msec *
```

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