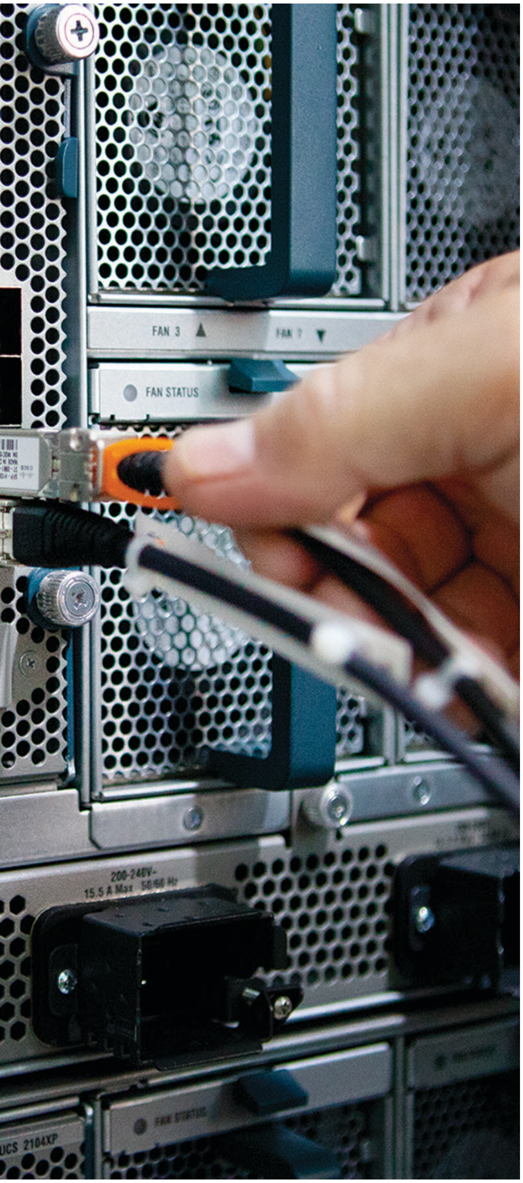


This chapter covers the following topics that you need to master for the CCNP ROUTE exam:

- **EIGRP Fundamentals:** This section reviews the EIGRP concepts, configuration, and verification commands covered in the CCNA curriculum.
- **EIGRP Neighborships:** This section discusses a variety of features that impact when a router attempts to form EIGRP neighbor relationships (neighborships), what must be true for those neighborships to work, and what might prevent those neighborships.
- **Neighborships over WANs:** This section examines the typical usage of EIGRP neighborships over various types of WAN technologies.

CHAPTER 4

Fundamental EIGRP Concepts

Enhanced Interior Gateway Routing Protocol (EIGRP) is configured with a few relatively simple commands. In fact, for most any size network, you could go to every router, enter the **router eigrp 1** command, followed by one or more **network** *net-id* subcommands (one for each classful network to which the router is connected), and EIGRP would likely work, and work very well, with no other configuration.

In spite of that apparent simplicity, here you sit beginning the first of four chapters of EIGRP coverage in this book. Many reasons exist for the amount of EIGRP material included here. First, EIGRP includes many optional configuration features that you need to both understand and master for the CCNP ROUTE exam. Many of these features require a solid understanding of EIGRP internals as well—a topic that can be conveniently ignored if you just do the minimal configuration, but something very important to planning, implementing, and optimizing a medium/large enterprise network.

Another reason for the depth of EIGRP coverage in this book is a fundamental change in the philosophy of the CCNP exams, as compared with earlier CCNP exam versions. Cisco has increased the focus on planning for the implementation and verification of new network designs. The bar has been raised, and in a way that is consistent with typical engineering jobs. Not only do you need to understand all the EIGRP features, but you also need to be able to look at a set of design requirements, and from that decide which EIGRP configuration settings could be useful—and which are not useful. You must also be able to direct others as to what verification steps would tell them if the implementation worked or not, rather than just relying on typing a **?** and looking around for that little piece of information you know exists somewhere.

This chapter begins with the "EIGRP Fundamentals" section, which is a review of the core prerequisite facts about EIGRP. Following the review, the chapter examines EIGRP neighbor relationships, including a variety of configuration commands that impact neighbor relationships, and the verification commands that you can use to confirm how well EIGRP neighbors work.

"Do I Know This Already?" Quiz

The "Do I Know This Already?" quiz enables you to assess whether you should read the entire chapter. If you miss no more than one of these seven self-assessment questions, you might want to move ahead to the "Exam Preparation Tasks" section. Table 4-1 lists the major headings in this chapter and the "Do I Know This Already?" quiz questions covering the material in those headings so that you can assess your knowledge of these specific areas. The answers to the "Do I Know This Already?" quiz appear in Appendix A.

Table 4-1 *"Do I Know This Already?" Foundation Topics Section-to-Question Mapping*

Foundation Topics Section	Questions
EIGRP Fundamentals	1, 2
EIGRP Neighborships	3–6
Neighborships over WANs	7

1. A router has been configured with the commands **router eigrp 9** and **network 172.16.1.0 0.0.0.255**. No other EIGRP-related commands have been configured. The answers list the IP addresses that could be assigned to this router's Fa0/0 interface. Which answers list an IP address/prefix length that would cause the router to enable EIGRP on Fa0/0? (Choose two answers.)

   a. 172.16.0.1/23

   b. 172.16.1.1/26

   c. 172.16.1.1/24

   d. 172.16.0.255/23

   e. None of the other answers are correct.

2. Router R1 has working interfaces S0/0, S0/1, and S0/2, with IP address/prefix combinations of 10.10.10.1/24, 10.10.11.2/24, and 10.10.12.3/22. R1's configuration includes the commands **router eigrp 9** and **network 10.0.0.0**. The **show ip eigrp interfaces** command lists S0/0 and S0/1 in the command output, but not S0/2. Which answer gives a possible reason for the omission?

   a. R1 has EIGRP neighbors reachable through S0/0 and S0/1, but not through S0/2, so it is not included.

   b. S0/2 might currently be in a state other than up/up.

   c. The **network 10.0.0.0** command requires the use of mask 255.0.0.0 because of EIGRP being classful by default.

   d. S0/2 might be configured as a passive interface.

3. Routers R1 and R2 are EIGRP neighbors using their Fa0/0 interfaces, respectively. An engineer adds the **ip hello-interval eigrp 9 6** command to R1's Fa0/0 configuration. Which of the following is true regarding the results from this change?

   a. The **show ip eigrp neighbors** command on R1 lists the revised Hello timer.

   b. The **show ip eigrp interfaces** command on R1 lists the revised Hello timer.

   c. The R1-R2 neighborship fails because of a Hello timer mismatch.

   d. The **show ip eigrp interfaces detail** command on R1 lists the revised Hello timer.

4. Router R1 has been configured with the commands **router eigrp 9** and network **172.16.2.0 0.0.0.255**, with no other current EIGRP configuration. R1's (working) Fa0/0 interface has been configured with IP address 172.16.2.2/26. R1 has found three EIGRP neighbors reachable through interface Fa0/0, including the router with IP address 172.16.2.20. When the engineer attempts to add the **neighbor 172.16.2.20 fa0/0** command in EIGRP configuration mode, which of the following occurs?

   a. Fa0/0 fails.

   b. The command is rejected.

   c. The existing three neighbors fail.

   d. The neighborship with 172.16.2.20 fails and then reestablishes.

   e. None of the other answers is correct.

5. Which of the following settings could prevent two potential EIGRP neighbors from becoming neighbors? (Choose two answers.)

   a. The interface used by one router to connect to the other router is passive in the EIGRP process.

   b. Duplicate EIGRP router IDs.

   c. Mismatched Hold Timers.

   d. IP addresses of 10.1.1.1/24 and 10.2.2.2/24, respectively.

6. An engineer has added the following configuration snippet to an implementation planning document. The configuration will be added to Router R1, whose Fa0/0 interface connects to a LAN to which Routers R2 and R3 also connect. R2 and R3 are already EIGRP neighbors with each other. Assuming that the snippet shows all commands on R1 related to EIGRP authentication, which answer lists an appropriate comment to be made during the implementation plan peer review?

```
key chain fred
key 3
key-string whehew
interface fa0/0
ip authentication key-chain eigrp 9 fred
```

   a. The configuration is missing one authentication-related configuration command.

   b. The configuration is missing two authentication-related configuration commands.

   c. Authentication type 9 is not supported; type 5 should be used instead.

   d. The key numbers must begin with key 1, so change the key 3 command to key 1.

7. A company has a Frame Relay WAN with one central-site router and 100 branch office routers. A partial mesh of PVCs exists: one PVC between the central site and each of the 100 branch routers. Which of the following could be true about the number of EIGRP neighborships?

a. A partial mesh totaling 100: one between the central-site router and each of the 100 branches.

b. A full mesh — (101 * 100) / 2 = 5050 — One neighborship between each pair of routers.

c. 101 — One between each router (including the central site) and its nearby PE router.

d. None of the answers is correct.

Foundation Topics

EIGRP Fundamentals

All the CCNP exams consider CCNA materials as prerequisites. So this book also assumes that the reader is already familiar with CCNA topics. However, the CCNP exams do test on features that overlap with CCNA. Additionally, most people forget some details along the way. Therefore, this section reviews the CCNA-level topics as a brief refresher.

To that end, this section begins with a review of EIGRP configuration using only the **router eigrp** and **network** commands. Following that, the next section details the key fields used to verify that EIGRP is working. Finally, the last part of this introduction summarizes the basic EIGRP internals behind this initial simple example.

Configuration Review

Cisco IOS uses the **router eigrp** *asn* command (where *asn* is an autonomous system number [ASN]), plus one or more **network** *net-id wildcard-mask* subcommands, to enable EIGRP on the router and on router interfaces. The rules for these commands are as follows:

Key Topic

1. Neighboring routers' **router eigrp** *asn* commands must be configured with the same ASN parameter to become neighbors.
2. Cisco IOS enables only EIGRP on interfaces matched by an EIGRP **network** command. When enabled, the router does the following:
   a. Attempts to discover EIGRP neighbors on that interface by sending multicast EIGRP Hello messages
   b. Advertises to other neighbors about the subnet connected to the interface
3. If no wildcard mask is configured on the EIGRP **network** command, the command's single parameter should be a classful network number (in other words, a class A, B, or C network number).
4. If no wildcard mask is configured on the EIGRP **network** command, the command enables EIGRP on all of that router's interfaces directly connected to the configured classful network.
5. If the **network** command includes a wildcard mask, the router performs access control list (ACL) logic when comparing the *net-id* configured in the **network** command with each interface's IP address, using the configured wildcard mask as an ACL wildcard mask.

Example 4-1 shows a sample configuration for each router in Figure 4-1, with several variations in the **network** commands to make the details in the preceding list more obvious.

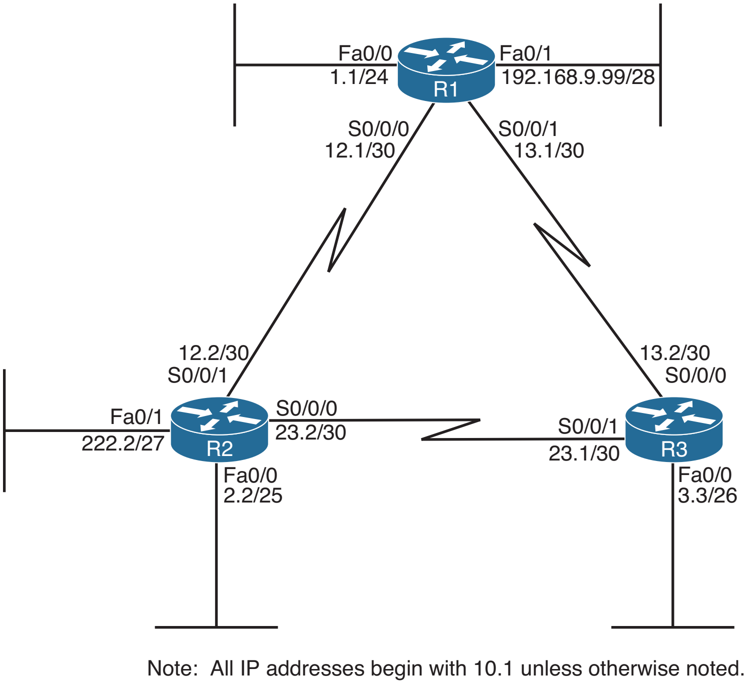


Figure 4-1 *Three-Router Internetwork*

Example 4-1 *EIGRP Configuration on Routers R1, R2, and R3*

```
! On Router R1: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
router eigrp 1
 network 10.0.0.0
 network 192.168.9.0
```

```
! On Router R2: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
router eigrp 1
 network 10.1.0.0 0.0.31.255
 network 10.1.2.2 0.0.0.0
```

```
! On Router R3: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
router eigrp 1
 network 10.1.0.0 0.0.255.255
```

First, note that all three routers use the **router eigrp 1** command, so all three routers' ASN values match.

Next, consider the two **network** commands on R1. The **network 10.0.0.0** command, without a *wildcard-mask* parameter, means that R1 matches all interfaces in class A network 10.0.0.0—which in this case means R1's Fa0/0, S0/0/0, and S0/0/1 interfaces. The **network 192.168.9.0** command, again without a wildcard mask, matches interface Fa0/1.

On R2, the **network 10.1.0.0 0.0.31.255** command requires a little more thought. The router uses the 0.0.31.255 value—the wildcard (WC) mask—just like an ACL WC mask. Cisco IOS compares the 10.1.0.0 value with each interface IP address, but only for the bit positions for which the WC mask lists a binary 0. For example, 0.0.31.255 represents 19 binary 0s, followed by 13 binary 1s. So, R2 would compare the first 19 bits of 10.1.0.0 with the first 19 bits of each interface's IP address.

Two features of the mechanics of the **network** command require a little extra attention. First, Cisco IOS might convert the address portion of the **network** *address wc-mask* command before putting the command into the running config. Just as Cisco IOS does for the address/WC mask combinations for the **access-list** command, Cisco IOS inverts the WC mask and then performs a Boolean AND of the address and mask. For example, if you type the **network 10.1.1.1 0.0.255.255** command, Cisco IOS inverts the WC mask (to 255.255.0.0) and ANDs this value with 10.1.1.1, resulting in 10.1.0.0. As a result, Cisco IOS stores the command **network 10.1.0.0 0.0.255.255**.

The second feature is that when you know for sure the values in the **network** command, you can easily find the range of interface addresses that match the address/WC mask combination in the **network** command. The low end of the range is the address as listed in the **network** command. To find the high end of the range, just add the address and WC mask together. For example, the **network 10.1.0.0 0.0.31.255** command has a range of 10.1.0.0 through 10.1.31.255.

Finally, on R3, the **network 10.1.0.0 0.0.255.255** command tells R3 to enable EIGRP on all interfaces whose IP addresses begin with 10.1, which includes all three interfaces on R3, as shown in Figure 4-1.

Taking a step back from the details, this config has enabled EIGRP, with ASN 1, on all three routers, and on all interfaces shown in Figure 4-1—except one interface. R2's Fa0/1 interface is not matched by any **network** commands on R2. So, EIGRP is not enabled on that interface. The next section reviews the commands that can be used to confirm that EIGRP is enabled, the interfaces on which it is enabled, the neighbor relationships that have been formed, and which EIGRP routes have been advertised and learned.

Verification Review

Even before starting to configure the routers, an engineer first considers all requirements. Those requirements lead to a design, which in turn leads to a chosen set of configuration commands. Then, the verification process that follows must consider the design requirements. The goal of verification is to determine that the internetwork works as designed, not just that some EIGRP routes have been learned.

For the purposes of this section, assume that the only design goal for the internetwork shown in Figure 4-1 is that EIGRP be used so that all routers have routes to reach all subnets shown in the figure.

To verify such a simple design, an engineer should start by confirming on which interfaces EIGRP has been enabled on each router. The next step should be to determine whether the EIGRP neighbor relationships that should occur are indeed up and working. Then, the EIGRP topology table should be examined to confirm that there is at least one entry for each subnet or network in the design. Finally, the IP routes on each router should be examined, confirming that all routes are known. To that end, Table 4-2 summarizes five key **show** commands that provide the information to answer these questions.

> **Note** The following table mentions some information that is covered later in this chapter (passive interfaces) or in other chapters (successor/feasible successors).

Example 4-2 shows samples of each command listed in Table 4-2. Note that the output highlights various samples of items that should be verified: the interfaces on which EIGRP is enabled, the known neighbors, the subnets in the topology table, and the EIGRP routes.

Key Topic

Table 4-2 *Key EIGRP Verification Commands*

Command	Key Information
show ip eigrp interfaces	Lists the working interfaces on which EIGRP is enabled (based on the **network** commands); it omits passive interfaces.
show ip protocols	Lists the contents of the **network** configuration commands for each routing process, and a list of neighbor IP addresses.
show ip eigrp neighbors	Lists known neighbors; does not list neighbors for which some mismatched parameter is preventing a valid EIGRP neighbor relationship.
show ip eigrp topology	Lists all successor and feasible successor routes known to this router. It does not list all known topology details. (See Chapter 5, "Advanced EIGRP Concepts," for more detail on successors and feasible successors.)
show ip route	Lists the contents of the IP routing table, listing EIGRP-learned routes with a code of D on the left side of the output.

Example 4-2 *EIGRP Verification on Routers R1, R2, and R3*

```
! On Router R1: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
R1# 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
Fa0/0          0        0/0            0       0/1             0               0
Se0/0/0        1        0/0           25       0/15          123               0
```

```
Se0/0/1        1        0/0           23       0/15         111              0
Fa0/1   0        0/0      0        0/1      0       0
```

```
! On Router R2: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
R2# show ip protocols
Routing Protocol is "eigrp 1"
  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 metric weight K1=1, K2=0, K3=1, K4=0, K5=0
  EIGRP maximum hopcount 100
  EIGRP maximum metric variance 1
  Redistributing: eigrp 1
  EIGRP NSF-aware route hold timer is 240s
  Automatic network summarization is in effect
  Maximum path: 4
  Routing for Networks:
    10.1.2.2/32
    10.1.0.0/19
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.1.12.1             90      00:19:36
    10.1.23.1             90      00:19:36
  Distance: internal 90 external 170
```

```
! On Router R3: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
R3# show ip eigrp neighbors
IP-EIGRP neighbors for process 1
H   Address                 Interface      Hold Uptime  SRTT  RTO  Q    Seq
                                           (sec)        (ms)      Cnt   Num
1   10.1.23.2               Se0/0/1        11 00:19:53   31   200   0    6
0   10.1.13.1               Se0/0/0        10 00:19:53   32   200   0    6
```

```
! On Router R2: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
R2# show ip eigrp topology
IP-EIGRP Topology Table for AS(1)/ID(10.1.222.2)

Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
      r - reply Status, s - sia Status

P 10.1.13.0/30, 2 successors, FD is 2681856
        via 10.1.23.1 (2681856/2169856), Serial0/0/0
        via 10.1.12.1 (2681856/2169856), Serial0/0/1
P 10.1.12.0/30, 1 successors, FD is 2169856
        via Connected, Serial0/0/1
```

```
P 10.1.3.0/26, 1 successors, FD is 2172416
        via 10.1.23.1 (2172416/28160), Serial0/0/0
P 10.1.2.0/25, 1 successors, FD is 28160
        via Connected, FastEthernet0/0
P 10.1.1.0/24, 1 successors, FD is 2172416
        via 10.1.12.1 (2172416/28160), Serial0/0/1
```

```
! On Router R3: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
R3# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

D    192.168.9.0/24 [90/2172416] via 10.1.13.1, 00:19:55, Serial0/0/0
     10.0.0.0/8 is variably subnetted, 6 subnets, 4 masks
C       10.1.13.0/30 is directly connected, Serial0/0/0
D       10.1.12.0/30 [90/2681856] via 10.1.23.2, 00:19:55, Serial0/0/1
                     [90/2681856] via 10.1.13.1, 00:19:55, Serial0/0/0
C       10.1.3.0/26 is directly connected, FastEthernet0/0
D       10.1.2.0/25 [90/2172416] via 10.1.23.2, 00:19:55, Serial0/0/1
D       10.1.1.0/24 [90/2172416] via 10.1.13.1, 00:19:55, Serial0/0/0
C       10.1.23.0/30 is directly connected, Serial0/0/1
```

To verify the interfaces on which EIGRP is enabled, both the **show ip eigrp interfaces** command (shown on R1) and the **show ip protocols** command (shown on R2) list the information. For this example, look at the list of interfaces in R2's **show ip protocols** command output: S0/0/0, S0/0/1, and FA0/0 are listed, but Fa0/1—unmatched by any of R2's network commands—is not.

In this design, each router should form a neighbor relationship with the other two routers, in each case over a point-to-point serial link. The **show ip eigrp neighbors** command (on R3) confirms R3's neighbors.

Finally, one design goal was for all routers to have routes for all subnets/networks. You could move on to the **show ip route** command or first look for all prefixes in the **show ip eigrp topology** command. With relatively general requirements, just looking at the IP routing table is fine. The example highlights R3's topology data and IP route for subnet 10.1.1.0/24. Of more interest might be the fact that the **show ip route** command output on R3 lists all subnet/network numbers except one: subnet 10.1.222.0/27. This subnet exists off R2's Fa0/1 interface (as seen in Figure 4-1), which is the interface on which EIGRP has not yet been enabled.

Internals Review

To complete the review of prerequisite CCNA-level EIGRP knowledge, this section looks at a few of the internals of EIGRP. Some of the facts listed here simply need to be memorized, whereas other topics will be discussed in more detail later.

EIGRP follows three general steps to add routes to the IP routing table, as follows:

Step 1. **Neighbor discovery:** EIGRP routers send Hello messages to discover potential neighboring EIGRP routers and perform basic parameter checks to determine which routers should become neighbors.

Step 2. **Topology exchange:** Neighbors exchange full topology updates when the neighbor relationship comes up, and then only partial updates as needed based on changes to the network topology.

Step 3. **Choosing routes:** Each router analyzes its respective EIGRP topology table, choosing the lowest-metric route to reach each subnet.

Because the majority of the rest of this chapter examines EIGRP neighborships, this review section skips any discussion of EIGRP neighbors, instead focusing on topology exchange and route selection.

Exchanging Topology Information

First, the EIGRP neighbor table lists the neighboring routers. Second, the EIGRP topology table holds all the topology information learned from EIGRP neighbors. Finally, EIGRP chooses the best IP routes, and those routes become candidates to be injected into the IP routing table. (Table 4-2, earlier in this chapter, lists the **show** commands that can be used to examine these tables.) EIGRP routers follow the process shown in Figure 4-2 to build the necessary information in these tables, with the end goal of populating the IP routing table.

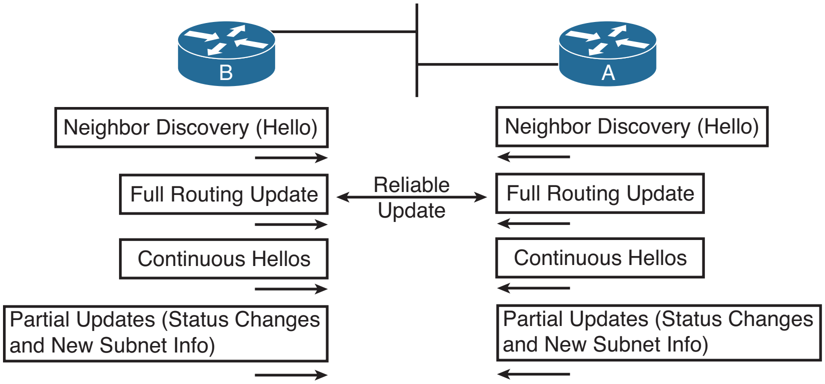

B
A
Neighbor Discovery (Hello)
Neighbor Discovery (Hello)
Full Routing Update
Reliable Update
Full Routing Update
Continuous Hellos
Continuous Hellos
Partial Updates (Status Changes and New Subnet Info)
Partial Updates (Status Changes and New Subnet Info)

Figure 4-2 *EIGRP Discovery and Update Process*

EIGRP uses Update messages to send topology information to neighbors. These Update messages can be sent to multicast IP address 224.0.0.10 if the sending router needs to update multiple routers on the same subnet. Unlike OSPF, there is no concept of a designated router (DR) or backup designated router (BDR), but the use of multicast packets on LANs allows EIGRP to exchange routing information with all neighbors on the LAN efficiently.

The update messages are sent using the *Reliable Transport Protocol (RTP)*. The significance of RTP is that, like OSPF, EIGRP resends routing updates that are lost in transit. By using RTP to guarantee delivery of the EIGRP messages, EIGRP can better avoid loops.

Note The acronym RTP also refers to a different protocol, Real-time Transport Protocol (RTP), which is used to transmit voice and video IP packets.

Neighbors use both full routing updates and partial updates, as depicted in Figure 4-2. A full update means that a router sends information about all known routes, whereas a partial update includes only information about recently changed routes. Full updates occur when neighbors first come up. After that, the neighbors send only partial updates in reaction to changes to a route.

Calculating the Best Routes for the Routing Table

EIGRP topology information includes the subnet number and mask, along with the components of the EIGRP composite metric. Each router then calculates an integer metric for each route, using the individual values of the EIGRP metric components listed in the EIGRP topology database. By default, EIGRP only uses the bandwidth and delay settings when calculating the metric. Optionally, the calculation can also include interface load and interface reliability, although Cisco recommends against using either.

Note Past documents and books often stated that EIGRP, and its predecessor IGRP, also could use Maximum Transmission Unit (MTU) as a part of the metric. However, MTU size is intended to be a tiebreaker if two paths have equal metrics but different MTU sizes. In such a case, the path with the higher MTU is selected. So, while MTU size is listed in EIGRP Update messages, it is not directly used in metric calculations.

EIGRP calculates the metric for each possible route by inserting the values of the composite metric into a formula. If the choice is made to just use the default parameters of bandwidth and delay, the formula is as follows:

$$\text{Metric} = \left(\left(\frac{10^7}{\text{least-bandwidth}}\right) + \text{cumulative-delay}\right) * 256$$

In this formula, the term *least-bandwidth* represents the lowest-bandwidth link in the route, using a unit of kilobits per second. For example, if the slowest link in a route is a 10-Mbps Ethernet link, the first part of the formula is $10^7 / 10^4$, because 10 Mbps equals

10,000 kbps, or 10^4 kbps. The *cumulative-delay* value used by the formula is the sum of all the delay values for all links in the route, with a unit of "tens of microseconds." So, if you add up all the delays (from the output of the **show interfaces** *type number* command) from all egress interfaces, you would take that number (which is in microseconds) and divide by 10 (to give you a unit of *tens of microseconds*) for use in the formula. You can set both bandwidth and delay for each link, using the **bandwidth** and **delay** interface subcommands.

Table 4-3 summarizes some of the key facts about EIGRP.

Key Topic

Table 4-3 *EIGRP Feature Summary*

Feature	Description
Transport	IP, protocol type 88 (does not use UDP or TCP).
Metric	Based on constrained bandwidth and cumulative delay by default, and optionally load and reliability.
Hello interval	Interval at which a router sends EIGRP Hello messages on an interface.
Hold Timer	Timer used to determine when a neighboring router has failed, based on a router not receiving any EIGRP messages, including Hellos, in this timer period.
Update destination address	Normally sent to 224.0.0.10, with retransmissions being sent to each neighbor's unicast IP address. Can also be sent to the neighbor's unicast IP address.
Full or partial updates	Full updates are used when new neighbors are discovered; otherwise, partial updates are used.
Authentication	Supports MD5 authentication only.
VLSM/classless	EIGRP includes the mask with each route, also allowing it to support discontiguous networks and VLSM.
Route tags	Allows EIGRP to tag routes as they are redistributed into EIGRP.
Next-hop field	Supports the advertisement of routes with a different next-hop router than the advertising router.
Manual route summarization	Allows route summarization at any point in the EIGRP network.
Automatic summarization	EIGRP supports, and defaults to use, automatic route summarization at classful network boundaries.
Multiprotocol	Supports the advertisement of IPX, AppleTalk, IP version 4, and IP version 6 routes.

This completes the CCNA-level EIGRP review. The rest of this chapter now examines EIGRP neighbor relationships.

EIGRP Neighborships

Like OSPF, EIGRP uses three major steps to achieve its goal of learning the best available loop-free routes:

Step 1. Establish EIGRP neighbor relationships—*neighborships*—with other routers that share a common subnet.

Step 2. Exchange EIGRP topology data with those neighbors.

Step 3. Calculate the currently best IP route for each subnet, based on the known EIGRP topology data, and add those best routes to the IP routing table.

This three-step process hinges on the first step—the successful creation of neighbor relationships between EIGRP routers. The basic EIGRP configuration described earlier in this chapter, particularly the **network** command, most directly tells EIGRP on which interfaces to dynamically discover neighbors. After EIGRP neighborships have been formed with neighboring routers that are reachable through those interfaces, the final two steps occur without any additional direct configuration.

EIGRP dynamically discovers neighbors by sending EIGRP Hello messages on each EIGRP-enabled interface. When two routers hear EIGRP Hello messages from each other, they check the EIGRP parameters listed in those messages and decide whether the two routers should or should not become neighbors.

The rest of this section focuses on topics related to EIGRP neighborship, specifically:

- Manipulating EIGRP Hello and Hold Timers
- Controlling whether routers become neighbors by using either passive interfaces or statically defined neighbors
- Examining configuration settings that can prevent EIGRP neighborships

Manipulating EIGRP Hello and Hold Timers

The word *convergence* defines the overall process by which routers notice internetwork topology changes, communicate about those changes, and change their routing tables to contain only the best currently working routes. EIGRP converges very quickly, even with all default settings.

One of the slower components of the EIGRP convergence process relates to the timers that EIGRP neighbors use to recognize that a neighborship has failed. If the interface over which the neighbor is reachable fails, and Cisco IOS changes the interface state to anything other than "up/up," a router immediately knows that the neighborship should fail. However, in some cases, an interface state might stay "up/up" during times when the link is not usable. In such cases, EIGRP convergence relies on the Hold Timer to expire, which by default, on LANs, means a 15-second wait. (The default EIGRP Hold time on interfaces/subinterfaces with a bandwidth of T1 or lower, with an encapsulation type of Frame Relay, is 180 seconds.)

The basic operation of these two timers is relatively simple. EIGRP uses the Hello messages in part as a confirmation that the link between the neighbors still works. If a router does not receive a Hello from a neighbor for one entire Hold time, that router considers the neighbor to be unavailable. For example, with a default LAN setting of Hello = 5 and Hold = 15, the local router sends Hellos every 5 seconds. The neighbor resets its downward-counting Hold Timer to 15 upon receiving a Hello from that neighbor. Under normal operation on a LAN, with defaults, the Hold Timer for a neighbor would vary from 15, down to 10, and then be reset to 15. However, if the Hellos were no longer received for 15 seconds, the neighborship would fail, driving convergence.

To optimize convergence, an engineer could simply reduce the Hello and Hold Timers, accepting insignificant additional overhead, in return for shorter convergence times. These settings can be made per interface/subinterface, and per EIGRP process.

Note Although expected to be outside the scope of CCNP, EIGRP can also use the Bi-directional Forwarding Detection (BFD) feature, which provides a means for subsecond detection of a failure in IP connectivity between two neighboring routers.

Configuring the Hello/Hold Timers

Most design engineers would normally choose Hello/Hold Timers that match on all router interfaces on a subnet. However, these settings do not have to match. Interestingly, by setting the Hello and Hold Timers to nondefault values, you can see some oddities with how EIGRP neighbors use these values.

For example, consider four WAN distribution routers, as shown in Figure 4-3. These routers might each have a number of Frame Relay PVCs to remote branches, or multiple MPLS VPN connections to branches. However, to communicate with each other and with data centers at the home office, these four routers connect through a core VLAN/subnet. Note that the design shows routers, rather than Layer 3 switches, but the concept is the same in either case.

A design that hoped to speed EIGRP convergence might call for setting the Hello and Hold Timers to 2 and 6, respectively. (The Hold Timer does not have to be three times the Hello Timer, but the 3:1 ratio is a reasonable guideline.) However, to make an important point about operation of the configuration commands, Example 4-3 sets only R1's Fa0/1 timers to the new values. Note that in this case, EIGRP has already been configured on all four routers, using ASN 9.

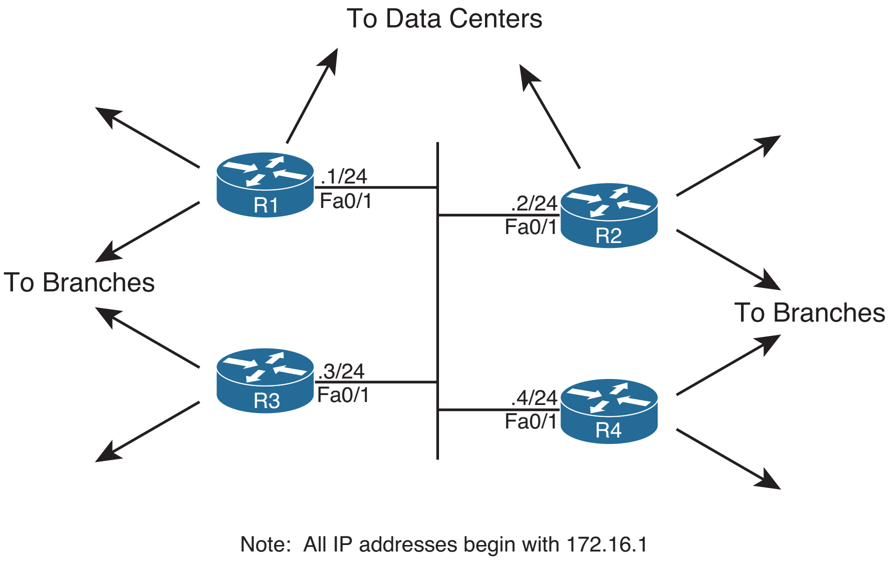


Figure 4-3 *Four WAN Distribution Routers on the Same VLAN/Subnet*

Example 4-3 *EIGRP Hello and Hold Timer Configuration—R1*

```
interface Fastethernet0/1
 ip hello-interval eigrp 9 2
 ip hold-time eigrp 9 6
```

A couple of interesting points can be made about the operation of these seemingly simple commands. First, these two settings can be made per interface/subinterface, but not per neighbor. In Figure 4-3, the Example 4-3 configuration then applies on R1 for all three neighbors reachable on interface Fa0/1.

The second interesting point about these commands is that one parameter (the Hello Interval) tells R1 what to do, whereas the other (the Hold Timer) actually tells the neighboring routers what to do. As shown in Figure 4-4, the **ip hello-interval eigrp 9 2** interface subcommand tells R1 to send Hellos every 2 seconds. However, the **ip hold-time eigrp 9 6** interface subcommand tells R1, again for the EIGRP process with ASN 9, to tell its neighbors to use a Hold Timer of 6 for their respective neighbor relationships with R1. In short, the EIGRP Hello message sent by R1 announces the Hold Timer that other routers should use in the neighbor relationship with R1. Figure 4-4 shows this idea in graphical form.

Note Cisco IOS does not prevent you from making the unfortunate configuration choice of setting the Hold Timer to a value smaller than the Hello interval. In such a case, the neighborship repeatedly fails and recovers, flapping routes in and out of the routing table.

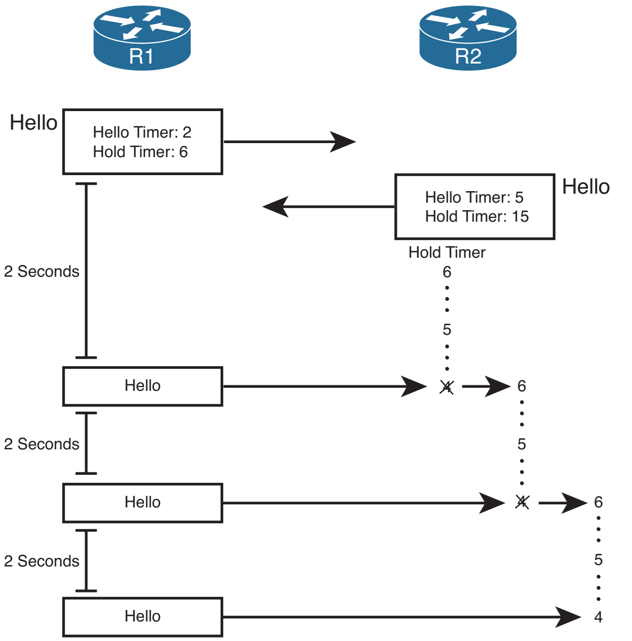


Figure 4-4 *R1 Announcing New Hello and Hold Timers*

Verifying the Hello/Hold Timers

To find the Hello interface and Hold time configured on a router's interface, you could of course look at a router's configuration, but the **show running-config** command might not be available to you on some question types on the ROUTE exam. However, if you have access to only user mode, you can issue the **show ip eigrp interfaces detail** *type number* command. It's important to note, however, that if you use that command on some older versions of Cisco IOS, the Hold time might not displayed.

Example 4-4 shows some sample command output from R1, R2, and R3. Note that the Hello and Hold Timer settings on R1 are all in the range of 10–15 seconds, because the timers on R2, R3, and R4 all still default to 5 and 15 seconds, respectively. R2's neighborship with R1 lists a Hold Timer of 4, which is within the expected range of 4–6 seconds remaining.

Example 4-4 *Demonstration that R2 and R3 Use R1's Configured Hold Timer*

```
! On Router R1: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
R1# show ip eigrp interfaces detail fa0/1

EIGRP-IPv4 Interfaces for AS(9)
                 Xmit Queue   PeerQ         Mean   Pacing Time   Multicast    Pending
Interface Peers  Un/Reliable  Un/Reliable   SRTT   Un/Reliable   Flow Timer   Routes
```

```
Fa0/1       3         0/0       0/0          535       0/1            50          0
  Hello-interval is 2, Hold-time is 6
  Split-horizon is enabled
  Next xmit serial <none>
  Packetized sent/expedited: 0/0
  Hello's sent/expedited: 102/1
  Un/reliable mcasts: 0/1  Un/reliable ucasts: 4/9
  Mcast exceptions: 1  CR packets: 1  ACKs suppressed: 1
  Retransmissions sent: 2  Out-of-sequence rcvd: 0
  Topology-ids on interface - 0
  Authentication mode is not set


R1# show ip eigrp neighbors
IP-EIGRP neighbors for process 9
H   Address             Interface  Hold Uptime         SRTT    RTO    Q     Seq
                                   (sec)               (ms)          Cnt    Num
2   172.16.1.4            Fa0/1        11 00:03:17      1596    5000   0     7
1   172.16.1.3            Fa0/1        11 00:05:21         1    200    0     5
0   172.16.1.2            Fa0/1        13 00:09:04         4    200    0     2
! On Router R2: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
R2# show ip eigrp neighbors
IP-EIGRP neighbors for process 9
H   Address             Interface  Hold Uptime         SRTT    RTO    Q     Seq
                                   (sec)               (ms)          Cnt    Num
2   172.16.1.4           Fa0/1       11 00:03:36         4     200    0     6
1   172.16.1.3           Fa0/1       11 00:05:40        12     200    0     4
0   172.16.1.1           Fa0/1        4 00:09:22         1     200    0     2
! On Router R3: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
R3# show ip eigrp neighbors
IP-EIGRP neighbors for process 9
H   Address             Interface  Hold Uptime         SRTT    RTO     Q     Seq
                                   (sec)               (ms)           Cnt    Num
2   172.16.1.4           Fa0/1         11 00:03:40       4      200     0     5
1   172.16.1.1           Fa0/1         5 00:05:44      1278     5000    0     4
0   172.16.1.2           Fa0/1         13 00:05:44     1277     5000    0     4
```

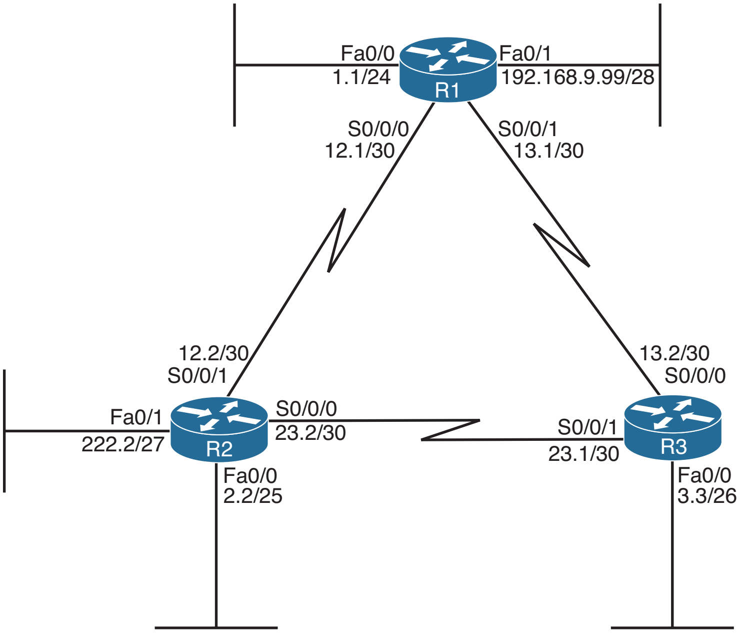
Preventing Unwanted Neighbors Using Passive Interfaces

When an EIGRP network configuration subcommand matches an interface, EIGRP on that router does two things:

Step 1. Attempts to find potential EIGRP neighbors by sending Hellos to the 224.0.0.10 multicast address

Step 2. Advertises the subnet connected to that interface

In some cases, however, no legitimate EIGRP neighbors might exist off an interface. For example, consider the small internetwork shown in Figure 4-5, with three routers, and with only one router connected to each LAN interface. Each router needs to advertise the subnets connected to their various FastEthernet interfaces, but at the same time, there is no benefit to multicast EIGRP Hellos on those interfaces, because only one router connects to each LAN.



Note: All IP addresses begin with 10.1 unless otherwise noted.

Figure 4-5 *LAN Interfaces That Benefit from the Passive Interface Feature*

The network designer can reasonably choose to limit EIGRP on those interfaces that have no legitimate EIGRP neighbors. However, the subnets connected to those same interfaces also typically need to be advertised by EIGRP. For example, subnet 10.1.1.0/24, off R1's Fa0/0 interface, still needs to be advertised by EIGRP, even though R1 should never find an EIGRP neighbor on that interface.

Given such a requirement—to advertise the subnet while disallowing EIGRP neighborships on the interface—an engineer has two main configuration options to choose from:

Key Topic

- Enable EIGRP on the interface using the EIGRP **network** command, but tell the router to not send any EIGRP messages on the interface by making the interface passive (using the **passive-interface** command).
- Do not enable EIGRP on the interface, and advertise the connected route using route redistribution (and the **redistribute connected** configuration command).

The first option relies on the passive interface feature—a feature specifically created with this design requirement in mind. When an interface is passive, EIGRP does not send any EIGRP messages on the interface—multicasts or EIGRP unicasts—and the router ignores any EIGRP messages received on the interface. However, EIGRP still advertises the connected subnets if matched with an EIGRP **network** command. As a result, the first option in the preceding list directly meets all the design requirements. It has the added advantage of being very secure in that no EIGRP neighborships are possible on the interface.

The second option—redistributing connected subnets—also works, but frankly it is the less preferred option in this case. Specifically, the passive interface option clearly meets the design requirements, while the redistribution option causes the connected route to be advertised as an external EIGRP route. This could cause problems in some cases with multiple redistribution points between routing domains (as discussed in Chapter 10, “Route Redistribution”).

The configuration of the passive interface itself is fairly straightforward. To configure the passive interface option, these three routers could be configured as shown in Example 4-5.

Example 4-5 *Configuration of* **passive-interface** *Commands on R1, R2, and R3*

```
! On Router R1: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
router eigrp 1
 passive-interface fastethernet0/0
 passive-interface fastethernet0/1
 network 10.0.0.0
 network 192.168.9.0

! On Router R2: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
router eigrp 1
 passive-interface default
 no passive-interface serial0/0/0
 no passive-interface serial0/0/1
 network 10.0.0.0

! On Router R3: !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
router eigrp 1
 passive-interface fastethernet0/0
 network 10.0.0.0
```

R1’s configuration lists two **passive-interface** commands, one per LAN interface. As a result, R1 no longer sends EIGRP messages on these two interfaces, including the multicast EIGRP Hellos used to discover neighbors.

R2’s configuration uses a slightly different option: the **passive-interface default** command. This command essentially changes the default for an interface from not being passive to instead being passive. Then, to make an interface not passive, you have to use a **no** version of the **passive-interface** command for those interfaces.

Two commands help to verify that the passive interface design is working properly. First, the **show ip eigrp interfaces** command omits passive interfaces, listing the nonpassive interfaces matched by a **network** command. Alternatively, the **show ip protocols** command explicitly lists all passive interfaces. Example 4-6 shows samples of both commands on R2.

Example 4-6 *Verifying the Results of* **passive-interface** *on R2*

```
R2# 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
Se0/0/0          1         0/0         32          0/15              159       0
Se0/0/1          1         0/0       1290          0/15             6443       0
R2# show ip protocols
Routing Protocol is "eigrp 1"
  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 metric weight K1=1, K2=0, K3=1, K4=0, K5=0
  EIGRP maximum hopcount 100
  EIGRP maximum metric variance 1
  Redistributing: eigrp 1
  EIGRP NSF-aware route hold timer is 240s
  Automatic network summarization is in effect
  Maximum path: 4
  Routing for Networks:
    10.0.0.0
  Passive Interface(s):
    FastEthernet0/0
    FastEthernet0/1
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.1.12.1             90      00:00:39
    10.1.23.1             90      00:00:39
  Distance: internal 90 external 170
```

Controlling Neighborships with Static Configuration

EIGRP supports the ability to statically define neighbors instead of dynamically discovering neighbors.

Although seldom used, you can use this feature to reduce the overhead associated with EIGRP multicast messages. Frame Relay WANs in particular might benefit from the static neighbor definitions, because to support multicasts and broadcasts over Frame Relay, a router must replicate a frame and send a copy over every PVC associated with the interface or subinterface. For example, if a multipoint subinterface has ten PVCs associated with it, but only two of the remote routers used EIGRP, without static neighbors, all ten routers would be sent a copy of the EIGRP multicast Hello packets. With static neighbor definitions for the two routers, EIGRP messages would be sent as unicasts to each of the two neighbors, with no EIGRP messages sent to the eight non-EIGRP routers, reducing overhead.

The configuration seems simple, but it has a few subtle caveats. This section examines the straightforward configuration first and then examines the caveats.

Configuring Static EIGRP Neighbors

To define a neighbor, both routers must configure the **neighbor** *ip-address outgoing-interface* EIGRP router subcommand. The IP address is the interface IP address of the neighboring router. Also, the configured IP address must be from the subnet connected to the interface listed in the **neighbor** command; otherwise, the command is rejected. Also, note that the EIGRP configuration still needs a **network** command that matches the interface referenced by the **neighbor** command.

For example, consider Figure 4-6, which adds a new router (R5) to the internetwork of Figure 4-3. R1 and R5 have a PVC connecting them, with IP addresses and subinterface numbers shown.

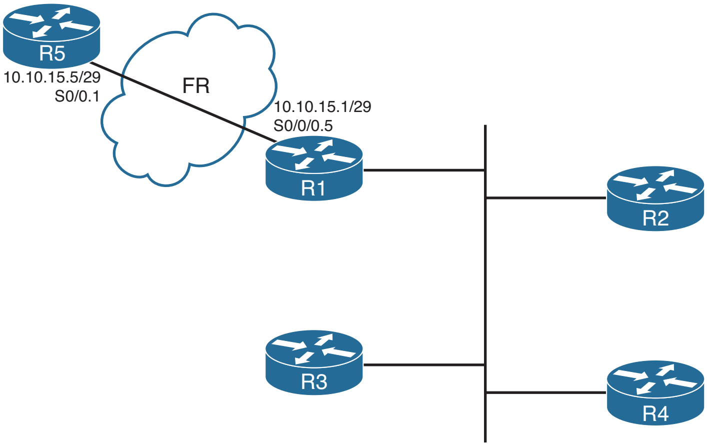


Figure 4-6 *Adding a Branch, with a Static EIGRP Neighbor*

Example 4-7 shows the configuration on both R1 and R5 to use static neighbor definitions. Of note, R1's neighbor command refers to R5's IP address on their common subnet (10.10.15.5), with R1's local interface (S0/0/0.5). R5 lists the reverse, with R1's 10.10.15.1 IP address and R5's local S0/0.1 interface. Also note that both routers have a **network** command that references network 10.0.0.0, and both routers do advertise subnet 10.10.15.0/29.

The **show ip eigrp neighbors** command does not identify a neighbor as static, but the **show ip eigrp neighbors detail** command does. Example 4-7 shows the more detailed output near the end, with the designation of 10.10.15.5 (R5) as a static neighbor.

Example 4-7 *Static EIGRP Neighborship Between R1 and R5*

```
! New configuration on router R1
R1# show running-config
! lines omitted
router eigrp 9
 network 172.16.0.0
 network 10.0.0.0
 no auto-summary
 neighbor 10.10.15.5 Serial0/0/0.5
! Back to R1
R1# show ip eigrp neighbors detail
IP-EIGRP neighbors for process 9
H   Address                 Interface    Hold Uptime  SRTT  RTO      Q       Seq
                                            (sec)     (ms)          Cnt      Num
3   10.10.15.5              Se0/0/0.5   10 00:00:51     15  200      0        2
   Static neighbor
   Version 12.4/1.2, Retrans: 0, Retries: 0
2   172.16.1.2              Fa0/1       11 00:02:57     3  200       0       25
   Version 12.4/1.2, Retrans: 1, Retries: 0
1   172.16.1.3              Fa0/1        10 00:03:45    5  200       0       21
   Version 12.4/1.2, Retrans: 0, Retries: 0
0   172.16.1.4              Fa0/1        13 00:03:45    5  200       0       18
```

```
! R5's new config added to support the neighbor
R5# show running-config
! lines omitted
router eigrp 9
 network 10.0.0.0
 no auto-summary
 neighbor 10.10.15.1 Serial0/0.1
```

Caveat When Using EIGRP Static Neighbors

Cisco IOS changes how it processes EIGRP packets on any interface referenced by an EIGRP **neighbor** command. Keeping in mind the design goal for this feature—to reduce multicasts—Cisco IOS disables all EIGRP multicast packet processing on an interface when an EIGRP **neighbor** command has been configured. For example, in Example 4-7, R1's S0/0/0.5 subinterface will not process EIGRP multicast packets any more as a result of R1's **neighbor 10.10.15.5 Serial0/0/0.5** EIGRP subcommand.

Because of the operation of the EIGRP **neighbor** command, if at least one EIGRP static neighbor is defined on an interface, no dynamic neighbors can be either discovered or continue to work if already discovered. For example, again in Figure 4-6 and Example 4-7, if R1 added a **neighbor 172.16.1.5 FastEthernet0/1** EIGRP subcommand, R1 would lose its current neighborships with Routers R2, R3, and R4.

Configuration Settings That Could Prevent Neighbor Relationships

Some of the configuration settings already mentioned in this chapter, when configured incorrectly, might prevent EIGRP neighborships. This section summarizes those settings, and introduces a few other configuration settings that can prevent neighbor relationships. The list of items that must match—and that do not have to match—can be a useful place to start troubleshooting neighbor initialization problems in real life, and to troubleshoot neighborship problems for simulation questions on the CCNP ROUTE exam.

Table 4-4 lists the neighbor requirements for both EIGRP and Open Shortest Path First (OSPF). (OSPF is included here just as a frame of reference for those more familiar with OSPF; this information will be repeated in Chapter 7, "Fundamental OSPF Concepts," which discusses OSPF neighborship requirements.) Following the table, the next few pages examine some of these settings for EIGRP.

Key Topic

Table 4-4 *Neighbor Requirements for EIGRP and OSPF*

Requirement	EIGRP	OSPF
The routers must be able to send/receive IP packets to one another.	Yes	Yes
Interfaces' primary IP addresses must be in same subnet.	Yes	Yes
Must not be passive on the connected interface.	Yes	Yes
Must use the same ASN (EIGRP) or process-ID (OSPF) in the router configuration command.	Yes	No
Hello interval/timer, plus either the Hold (EIGRP) or Dead (OSPF) timer, must match.	No	Yes
Must pass neighbor authentication (if configured).	Yes	Yes
Must be in same area.	N/A	Yes
IP MTU must match.	No	Yes
K-values (used in metric calculation) must match.	Yes	—
Router IDs must be unique.	No[1]	Yes

[1] Duplicate EIGRP RIDs do not prevent routers from becoming neighbors, but it can cause problems when adding external EIGRP routes to the IP routing table.

Going through Table 4-4 sequentially, the first two items relate to IP connectivity. Two routers must be able to send and receive IP packets with each other. Additionally, the primary IP address on the interfaces—in other words, the IP address configured without the **secondary** keyword on the **ip address** command—must be in the same subnet.

Note It should not matter for CCNP ROUTE, but possibly for CCIE R/S: EIGRP's rules about neighbor IP addresses being in the same subnet are less exact than OSPF. OSPF requires matching subnet numbers and masks. EIGRP just asks the question of whether the neighbor's IP address is in the range of addresses for the subnet as known to the local router. For example, two routers with addresses of 10.1.1.1/24 (range 10.1.1.1–10.1.1.254) and 10.1.1.2/30 (range 10.1.1.1–10.1.1.2) would actually allow EIGRP neighborship, because each router believes the neighbor's IP address to be in the same subnet as the local router.

The next three items in Table 4-4—passive interfaces, matching the EIGRP ASN number, and allowing mismatching Hello/Hold Timers—have already been covered in this chapter.

The next item, authentication, is discussed in detail in Chapter 17, "Routing Protocol Authentication."

The next two items in the table—matching the IP MTU and matching OSPF areas—do not prevent EIGRP neighborships. These topics, are requirements for OSPF neighborship and will be discussed in Chapter 7.

Finally, the last two items in the table (K-values and router IDs) each require more than a cursory discussion for EIGRP and will be explained in the upcoming pages.

Configuring EIGRP Metric Components (K-values)

EIGRP calculates its integer metric, by default, using a formula that uses constraining bandwidth and cumulative delay. You can change the formula to use link reliability and link load, and even disable the use of bandwidth and/or delay. To change the formula, an engineer can configure five weighting constants, called K-values, which are represented in the metric calculation formula as constants K1, K2, K3, K4, and K5.

From a design perspective, Cisco strongly recommends against using link load and link reliability in the EIGRP metric calculation. Most shops that use EIGRP never touch the K-values at all. However, in labs, it can be useful to disable the use of bandwidth from the metric calculation, because that simplifies the metric math and makes it easier to learn the concepts behind EIGRP.

The **metric weights** command sets five variables (K1 through K5), each of which weights the metric calculation formula more or less heavily for various parts of the formula. Mismatched K-value settings prevent two routers from becoming neighbors. Thankfully, determining whether such a mismatch exists is easy. When a router receives an EIGRP Hello with mismatched K-values (as compared to itself), the router issues a log message stating that a K-value mismatch exists. You can also examine the values either by looking at the running configurations or by looking for the K-values listed in the output of the **show ip protocols** command, as shown in Example 4-8.

Note In the command **metric weights 0 1 0 1 1 0**, the first number (that is, the leftmost 0) represents the Type of Service (ToS) value with which EIGRP packets should be marked. This is a Quality of Service (QoS) setting. It equals 0 and cannot be changed to a different value. The remaining five numbers are the K-values: K1, K2, K3, K4, and K5, respectively.

Example 4-8 *Mismatched K-values*

```
R2(config)# router eigrp 1
R2(config-router)# metric weights 0 1 0 1 1 0
R2(config-router)# end
Feb 23 18:48:21.599: %DUAL-5-NBRCHANGE: IP-EIGRP(0) 1: Neighbor 10.1.12.1
(Serial0/0/1) is down: metric changed
R2#
Feb 23 18:48:24.907: %DUAL-5-NBRCHANGE: IP-EIGRP(0) 1: Neighbor 10.1.12.1
(Serial0/0/1) is down: K-value mismatch
R2# show ip protocols
Routing Protocol is "eigrp 1"
  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 metric weight K1=1, K2=0, K3=1, K4=1, K5=0
! lines omitted for brevity
```

EIGRP Router ID

EIGRP uses a concept of a representing each router with a router ID (RID). The EIGRP RID is a 32-bit number, represented in dotted decimal. Each router determines its RID when the EIGRP process starts, using the same general rules as does OSPF for determining the OSPF RID, as follows:

Key Topic

Step 1. Use the configured value (using the **eigrp router-id** *a.b.c.d* EIGRP subcommand).

Step 2. Use the highest IPv4 address on an up/up loopback interface.

Step 3. Use the highest IPv4 address on an up/up nonloopback interface.

Although EIGRP does require each router to have an RID, the actual value is of little practical importance. The EIGRP **show** commands seldom list the RID value, and unlike OSPF RIDs, engineers do not need to know each router's EIGRP RID to interpret the EIGRP topology database. Additionally, although it is best to make EIGRP RIDs unique, duplicate RIDs do not prevent routers from becoming neighbors.

The only time the value of EIGRP RIDs matters is when injecting external routes into EIGRP. In that case, the routers injecting the external routes must have unique RIDs to avoid confusion.

Neighborship over WANs

EIGRP configuration and neighborship rules do not differ when comparing typical LAN and typical WAN technologies. However, some design and operational differences exist, particularly regarding which routers become neighbors with which other routers. This short section closes the EIGRP neighbor discussion with a brief look at Frame Relay, MPLS VPNs, and Metro Ethernet as implemented with Virtual Private LAN Service (VPLS).

Neighborship on Frame Relay

Frame Relay provides a Layer 2 WAN service. Each router connects to the service using a physical serial link, called a Frame Relay access link. The provider then creates logical connections, called *permanent virtual circuits (PVC)*, which are logical paths between pairs of routers connected to a Frame Relay service. Any pair of routers that connect to the ends of a Frame Relay PVC can send Frame Relay frames to each other. Therefore, they can send IP packets and become EIGRP neighbors. Figure 4-7 shows a typical case, with R1 as a central-site router, and R2, R3, and R4 acting as branch routers.

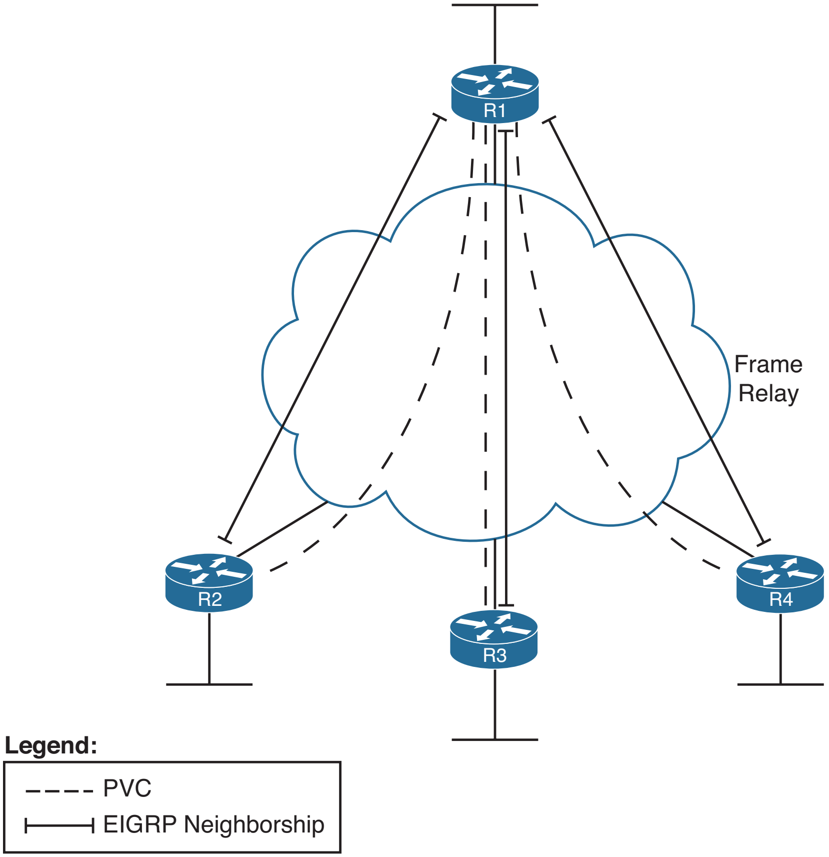


Figure 4-7 *EIGRP Neighborships over Frame Relay*

Figure 4-7 shows EIGRP neighborships, but note that all routers can learn all routes in the internetwork, even though not all routers become neighbors. The neighborships can only form when a PVC exists between the two routers.

Neighborship on MPLS VPN

Multiprotocol Label Switching (MPLS) Virtual Private Networks (VPN) create a WAN service that has some similarities but many differences when compared to Frame Relay. The customer routers connect to the service, often with serial links but at other times with Frame Relay PVCs or with Ethernet. The service itself is a Layer 3 service, forwarding IP packets through a cloud. As a result, no predefined PVCs need to exist between the customer routers. Additionally, the service uses routers at the edge of the service provider cloud—generically called *provider edge (PE)* routers—and these routers are Layer 3 aware.

That Layer 3 awareness means that the *customer edge (CE)* routers form an EIGRP neighborship with the PE router on the other end of their local access link, as shown in Figure 4-8. The PE routers exchange their routes, typically using Multiprotocol BGP (MP-BGP), a topic outside the scope of this book. However, all the CE routers then learn routes from each other, although each CE router has only one EIGRP neighborship for each of its connections into the MPLS VPN cloud.

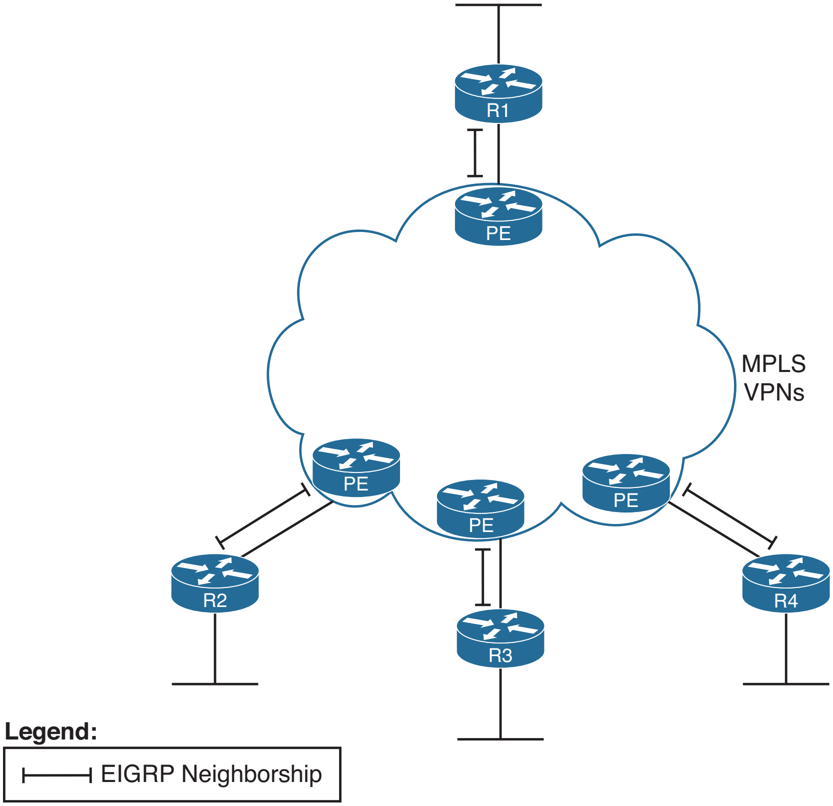


Figure 4-8 *EIGRP Neighborships over MPLS VPN*

Neighborship on Metro Ethernet

The term *Metropolitan Ethernet (MetroE)* represents a range of Layer 2 WAN services in which the CE device connects to the WAN service using some form of Ethernet. Because MetroE provides a Layer 2 Ethernet service, the service delivers an Ethernet frame sent by one customer router to another customer router (for unicast frames), or to many other routers (for multicast or broadcast frames).

MetroE encompasses several underlying technologies to create the service. Of note for the purposes of this book are the Virtual Private Wire Service (VPWS) and the Virtual Private LAN Service (VPLS). Both technical specifications allow for connections using Ethernet links, with the service forwarding Ethernet frames. VPWS focuses on point-to-point topologies, whereas VPLS supports multipoint, approximating the concept of the entire WAN service acting like one large Ethernet switch. Because it is a Layer 2 service, MetroE does not have any Layer 3 awareness, and customer routers (typically referenced with the more general service provider term *customer premises equipment*, or *CPE*) see the MetroE service as a VLAN. Because the customer routers connect to the service as a VLAN, all the routers connected to the service can become EIGRP neighbors, as shown in Figure 4-9.

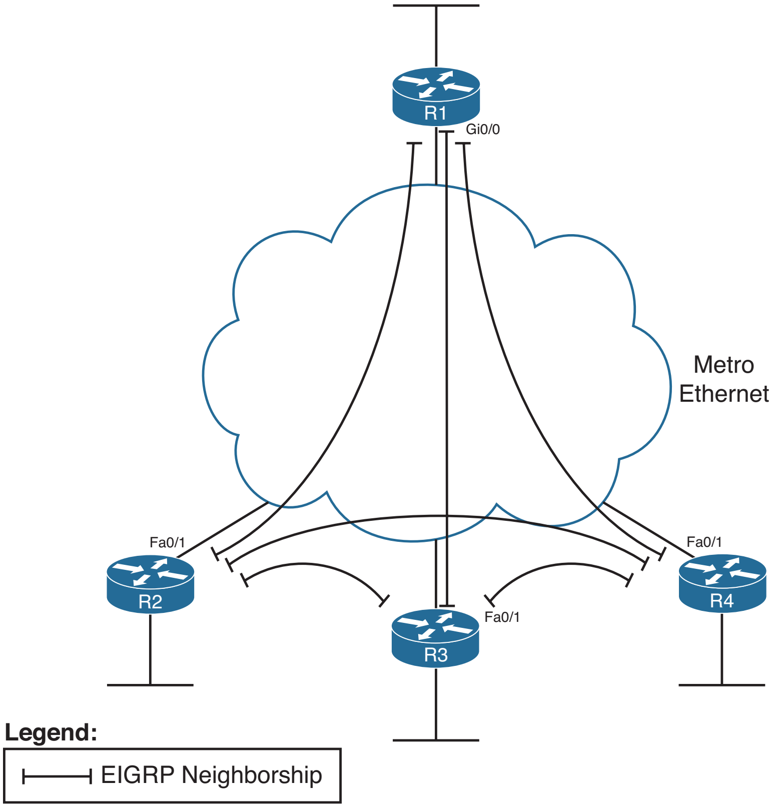


Figure 4-9 *EIGRP Neighborships over Metro Ethernet*

Exam Preparation Tasks

Planning Practice

The CCNP ROUTE exam expects test takers to be able to review design documents, create implementation plans, and create verification plans. This section provides some exercises that can help you to take a step back from the minute details of the topics in this chapter, so that you can think about the same technical topics from the planning perspective.

For each planning practice table, simply complete the table. Note that any numbers in parentheses represent the number of options listed for each item in the solutions in Appendix F, "Completed Planning Practice Tables," which you can find on the CD-ROM accompanying this book.

Design Review Table

Table 4-5 lists several design goals related to this chapter. If these design goals were listed in a design document, and you had to take that document and develop an implementation plan, what implementation options come to mind? For any configuration items, a general description can be used, without any concern about the specific parameters.

Table 4-5 *Design Review*

Design Goal	Possible Implementation Choices Covered in This Chapter
Improve EIGRP convergence.	
Implement EIGRP on each router so that neighborships are formed (2).	
Limit neighborship formation on interfaces matched with an EIGRP **network** command (3).	

Implementation Plan Peer Review Table

Table 4-6 shows a list of questions that others might ask, or that you might think about, during a peer review of another network engineer's implementation plan. Complete the table by answering the questions.

Table 4-6 *Notable Questions from This Chapter to Consider During an Implementation Plan Peer Review*

Question	Answer
What happens on a router interface on which an EIGRP **network** command matches the interface? (2)	
What configuration settings prevent EIGRP neighbor discovery on an EIGRP-enabled interface? (2)	
What configuration settings prevent any neighborships on an EIGRP-enabled interface?	
What settings do potential neighbors check before becoming EIGRP neighbors? (5)	
What settings that you might think would impact EIGRP neighbor relationships actually do not prevent neighborship? (3)	

Create an Implementation Plan Table

To practice skills useful when creating your own EIGRP implementation plan, list in Table 4-7 configuration commands related to the configuration of the following features. You might want to record your answers outside the book, and set a goal to complete this table (and others like it) from memory during your final reviews before taking the exam.

Table 4-7 *Implementation Plan Configuration Memory Drill*

Feature	Configuration Commands/Notes
Enabling EIGRP on interfaces	
Setting Hello and Hold Timers	
Passive interfaces	
Static EIGRP neighbors	
K-values	
EIGRP router ID	

Choose Commands for a Verification Plan Table

To practice skills useful when creating your own EIGRP verification plan, list in Table 4-8 all commands that supply the requested information. You might want to record your answers outside the book, and set a goal to complete this table (and others like it) from memory during your final reviews before taking the exam.

Table 4-8 *Verification Plan Memory Drill*

Information Needed	Command
Routes that have been added to the IP routing table by EIGRP.	
All routes in a router's routing table.	
The specific route for a single destination address or subnet.	
A listing of all (both statically configured and dynamically discovered) EIGRP neighbors.	
Notation as to whether a neighbor was dynamically discovered or statically configured.	
A listing of statistics regarding the numbers of EIGRP messages sent and received by a router.	
A listing of interfaces on which EIGRP has been enabled (by virtue of the EIGRP **network** command).	
A listing of the number of EIGRP peers known through a particular interface.	
The elapsed time since a neighborship was formed.	
The parameters of any EIGRP **network** commands.	
The configured Hello Timer for an interface.	
The configured Hold Timer for an interface.	
The current actual Hold Timer for a neighbor.	
A router's EIGRP ASN.	
A list of EIGRP passive interfaces.	
A list of nonpassive EIGRP interfaces.	
A listing of EIGRP K-values.	
A listing of traffic statistics about EIGRP.	
A router's EIGRP Router ID.	

Review All the Key Topics

Review the most important topics from inside the chapter, noted with the Key Topic icon in the outer margin of the page. Table 4-9 lists a reference of these key topics and the page numbers on which each is found.

Key Topic

Table 4-9 *Key Topics for Chapter 4*

Key Topic Element	Description	Page Number
List	Configuration step review for basic EIGRP configuration	125
Table 4-2	Key EIGRP verification commands	128
Table 4-3	Summary of EIGRP features and facts	133
List	Methods of disallowing EIGRP neighborships on an interface, while still advertising the connected subnet	139
Table 4-4	List of items that can impact the formation of EIGRP neighborships	144
List	Rules for choosing an EIGRP Router ID	146

Complete the Tables and Lists from Memory

Print a copy of Appendix D, "Memory Tables," (found on the CD), or at least the section for this chapter, and complete the tables and lists from memory. Appendix E, "Memory Tables Answer Key," also on the CD, includes completed tables and lists to check your work.

Define Key Terms

Define the following key terms from this chapter, and check your answers in the glossary:

K-value, neighborship, Hello interval, Hold Timer, passive interface