The University of Jordan, Comp. Eng. Dept.
Networks Lab: Handout: Experiment 6
Enhanced Interior Gateway Routing Protocol (Theory and Practice)

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Parts Included: Enhanced Interior Gateway Routing Protocol (EIGRP), EIGRP Configuration Commands, Practical Problems, and Manual Summarization.

Part I. Enhanced Interior Gateway Routing Protocol (EIGRP)

This protocol has the following characteristics:

- Is a unique Cisco innovation.
- A classless version of IGRP.
- EIGRP includes several features that are not commonly found in other distance vector routing protocols like RIP (RIPv1 and RIPv2) and IGRP.
- **These features include:**
  - **Reliable Transport Protocol (RTP)**
  - **Bounded Updates**
  - **Diffusing Update Algorithm (DUAL)**
  - **Establishing Adjacencies, through the use of Hello and Update packets. By forming adjacencies, EIGRP routers do the following:**
    - **Dynamically learn of new routes that join their network**
    - **Identify routers that become either unreachable or inoperable**
    - **Rediscover routers that had previously been unreachable**
  - **Neighbor and Topology Tables, will be explained shortly when discussing EIGRP matric calculation.**
- Although EIGRP may act like a link-state routing protocol, it is still a distance vector routing protocol.
- The term hybrid routing protocol is sometimes used to define EIGRP. However, this term is misleading because EIGRP is not a hybrid between distance vector and link-state routing protocols. It is solely a distance vector routing protocol. Therefore, Cisco is no longer using this term to refer to EIGRP.

- The AD distance of EIGRP is 90. The AD value is the first value in the brackets for a routing table entry. Notice, through Figures 1 and 2, that R2 has a route to the 192.168.6.0/24 network with an AD value of 90.

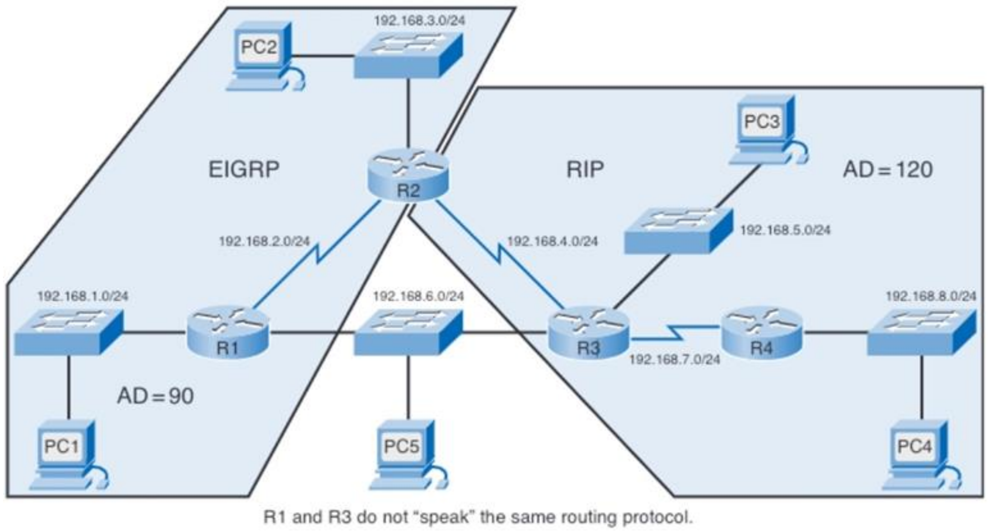


Figure 1. Different administrative distances on R2.

```
R2# show ip route

<output omitted>

Gateway of last resort is not set

D     192.168.1.0/24 [90/2172416] via 192.168.2.1, 00:00:24, Serial0/0
C     192.168.2.0/24 is directly connected, Serial0/0/0
C     192.168.3.0/24 is directly connected, FastEthernet0/0
C     192.168.4.0/24 is directly connected, Serial0/0/1
R     192.168.5.0/24 [120/1] via 192.168.4.1, 00:00:08, Serial0/0/1
D     192.168.6.0/24 [90/2172416] via 192.168.2.1, 00:00:24, Serial0/0/0
R     192.168.7.0/24 [120/1] via 192.168.4.1, 00:00:08, Serial0/0/1
R     192.168.8.0/24 [120/2] via 192.168.4.1, 00:00:08, Serial0/0/1
```

Figure 2. Routing Table of R2

A. Path Determination and Convergence

Protocols, such as RIP and IGRP, age out individual routing entries, and therefore need to periodically send routing table updates. EIGRP uses the diffusing update algorithm. As a result, EIGRP does not send periodic updates and route entries do not age out. Instead, EIGRP uses a lightweight Hello protocol to monitor connection status with its neighbors. Only changes in the routing information, such as a new link or a link becoming unavailable cause a routing update to occur.

Traditional distance vector routing protocols such as RIP and IGRP keep track of only the preferred routes; the best path to a destination network. If the route becomes unavailable, the router waits for another routing update with a path to this remote network. **EIGRP's DUAL maintains a topology table separate from the routing table, including both the best path to a destination network and any backup paths that DUAL has determined to be loop-free.** If a route becomes unavailable, DUAL will search its topology table for a valid backup path. If one exists, that route is immediately entered into the routing table. **If one does not exist, DUAL performs a network discovery process (re-computation) to see if there happens to be a backup path that meets the requirement of the feasibility condition.**

Traditional distance vector routing protocols such as RIP and IGRP use periodic updates. Due to the unreliable nature of periodic updates, traditional distance vector routing protocols are prone to routing loops and count-to-infinity problem. RIP and IGRP use several mechanisms to help avoid these problems including holddown timers, which cause long convergence times. **EIGRP does not use holddown timers. Instead, loop-free paths are achieved through a system of route calculations (diffusing computations) that are performed in a coordinated fashion among the routers.**

B. EIGRP Features

The EIGRP has the following features:

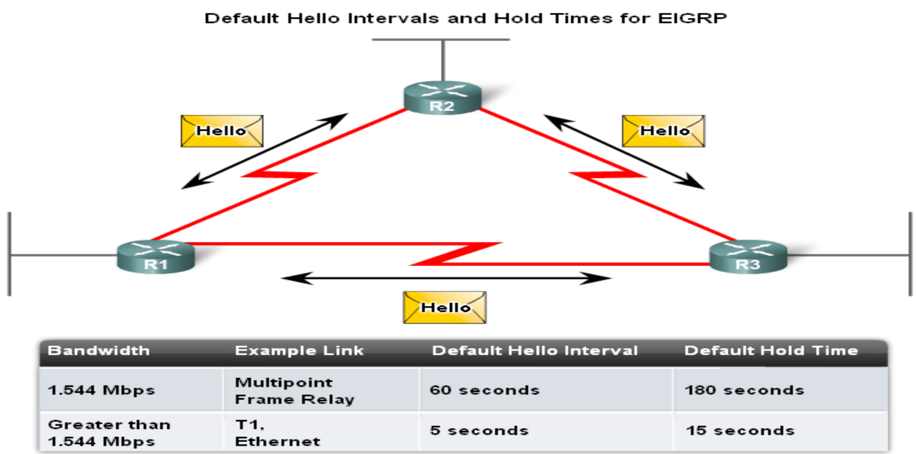
1) Reliable Transport Protocol (RTP)

Reliable Transport Protocol (RTP) is the protocol used by EIGRP for the delivery and reception of EIGRP packets. Reliable RTP requires an acknowledgement to be returned by the receiver to the sender. An unreliable RTP packet does not require an acknowledgement. **RTP can send packets either as a unicast or a multicast.**

Interestingly, EIGRP uses five different packet types, some in pairs.

- ***Hello packets,*** are used by EIGRP to discover neighbors and to form adjacencies with those neighbors. EIGRP hello packets are multicasts and use unreliable delivery, as shown in Figure 3.
  - ✓ On most networks, EIGRP Hello packets are sent every 5 seconds.
  - ✓ On multipoint nonbroadcast multi-access networks (NBMA) such as X.25, Frame Relay, and ATM interfaces with access links of T1 (1.544 Mbps) or slower, Hellos are unicast every 60 seconds.
  - ✓ An EIGRP router assumes that as long as it is receiving Hello packets from a neighbor, the neighbor and its routes remain viable.
  - ✓ Holdtime tells the router the maximum time the router should wait to receive the next Hello before declaring that neighbor as unreachable.
  - ✓ By default, the hold time is three times the Hello interval, or 15 seconds on most networks and 180 seconds on low speed NBMA networks. If the hold time expires, EIGRP will declare the route as down and DUAL will search for a new path by sending out queries.
- ***Update packets,*** are used by EIGRP to propagate routing information. Unlike RIP, EIGRP does not send periodic updates. Update packets are sent only when necessary. EIGRP updates contain only the routing information needed and are sent only to those routers that require it. EIGRP update packets use reliable delivery. Update packets are sent as a multicast when required by multiple routers, or as a unicast when required by only a single router. In Figure 4, because the links are point-to-point, the updates are sent as unicasts.

- ***Acknowledgement (ACK) packets***, are sent by EIGRP when reliable delivery is used. RTP uses reliable delivery for EIGRP update, query, and reply packets. In Figure 4, R2 has lost connectivity to the LAN attached to its FastEthernet interface. R2 immediately sends an Update to R1 and R3 noting the downed route. R1 and R3 respond with an acknowledgement.
- ***Query and reply packets,*** are used by DUAL when searching for networks and other tasks. Queries and replies use reliable delivery. Queries can use multicast or unicast, whereas replies are always sent as unicast. In Figure 5, R2 has lost connectivity to the LAN and it sends out queries (as no backup route is available) to all EIGRP neighbors searching for any possible routes to the LAN. Because queries use reliable delivery, the receiving router must return an EIGRP acknowledgement. All neighbors must send a reply regardless of whether or not they have a route to the downed network. Because replies also use reliable delivery, routers such as R2, must send an acknowledgement. It is good to mention that to keep this example simple, acknowledgements were omitted in the graphic.



Bandwidth	Example Link	Default Hello Interval	Default Hold Time
1.544 Mbps	Multipoint Frame Relay	60 seconds	180 seconds
Greater than 1.544 Mbps	T1, Ethernet	5 seconds	15 seconds

Figure 3. EIGRP Hello Packets

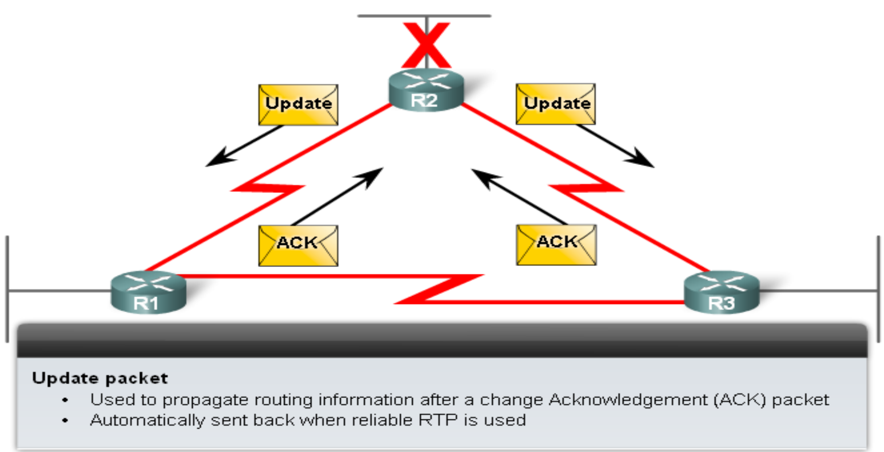


Figure 4. EIGRP Update Packets

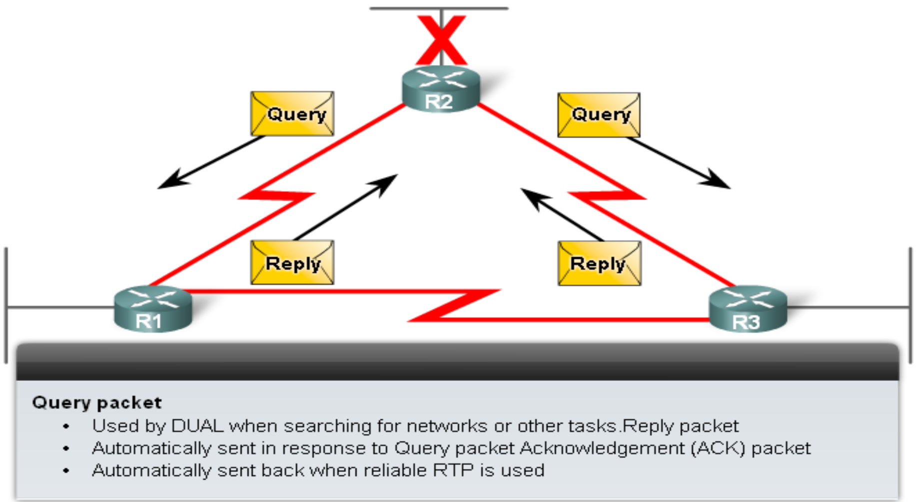


Figure 5. EIGRP Query and Reply Packets

2) Bounded Updates

- EIGRP uses the term partial and bounded when referring to its update packets.
- Unlike RIP, EIGRP does not send periodic updates. Instead, EIGRP sends its updates only when the metric for a route changes.
- The term partial means that the update only includes information about the route changes. EIGRP sends these incremental updates when the state of a destination changes, instead of sending the entire contents of the routing table.
- The term bounded refers to the propagation of partial updates sent only to those routers that are affected by the change. The partial update is automatically "bounded" so that only those routers that need the information are updated. By sending only the routing information that is needed and only to those routers that need it, EIGRP minimizes the bandwidth required to send EIGRP packets.

3) **Diffusing Update Algorithm (DUAL)**

DUAL provides loop-free paths. In additional, it provides loop-free backup paths which can be used immediately. It also provides fast convergence. It also guarantees minimum bandwidth usage with bonded updates. Interestingly, DUAL uses several terms which will be discussed in more detail:

- Successor, is a neighboring router that is used for packet forwarding and is the least-cost route to the destination network. The IP address of a successor is shown in a routing table entry right after the word via, as shown in Figure 6.
- Feasible Distance (FD), is the lowest calculated metric to reach the destination network. FD is the metric listed in the routing table entry as the second number inside the brackets, as shown in Figure 6. As with other routing protocols this is also known as the metric for the route.
- Feasible Successor (FS), One of the reasons DUAL can converge quickly after a change in the topology is because it can use backup paths to other routers known as feasible successors without having to recompute DUAL. A feasible successor (FS) is a neighbor

who has a loop-free backup path to the same network as the successor by satisfying the feasibility condition.

- Reported Distance (RD) or Advertised Distance (AD), is simply an EIGRP neighbor's feasible distance to the same destination network. In other words, it is the metric that a router reports to a neighbor about its own cost to that network, as shown in Figure 7. In particular, In Figure 7, R1 is reporting to R2 that its feasible distance to 192.168.1.0/24 is 2172416. From R2's perspective, 2172416 is R1's reported distance. From R1's perspective, 2172416 is its feasible distance.
- Feasible Condition or 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. Referring to Figure 7, R2 examines the reported distance (RD) of 2172416 from R1. Because the reported distance (RD) of R1 is less than R2's own feasible distance (FD) of 3014400, R1 meets the feasibility condition. R1 is now a feasible successor for R2 to the 192.168.1.0/24 network. Therefore, this backup route will be stored in the topology table. In fact, this condition guarantees having loop-free.

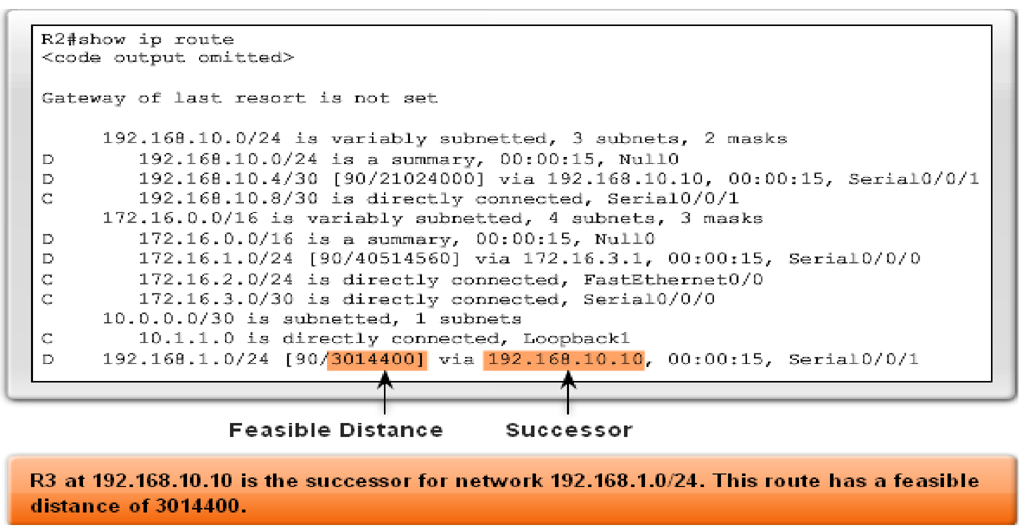


Figure 6. EIGRP Successor and Feasible Distance

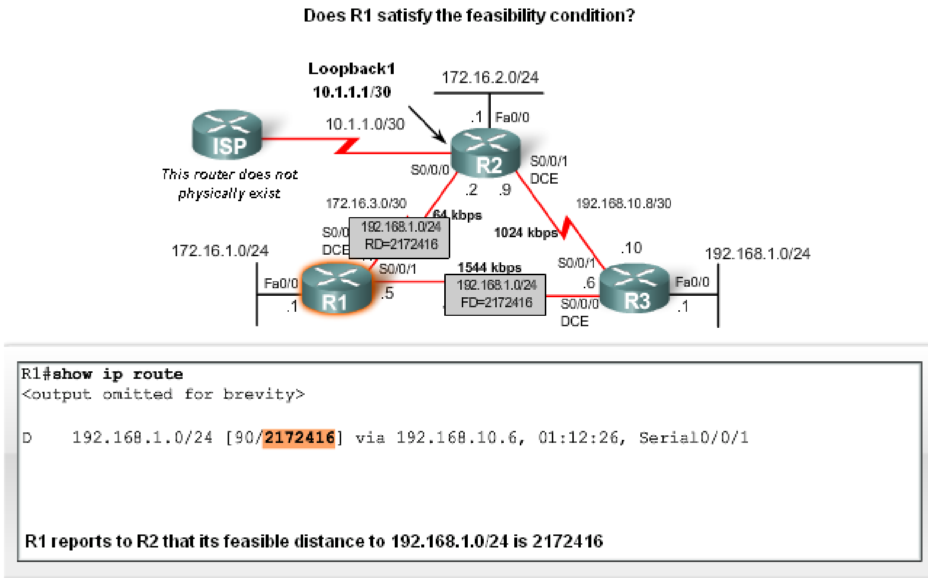


Figure 7. EIGRP Reported Distance and Feasibility Condition

C. EIGRP Metric calculation

EIGRP uses the following values in its composite metric to calculate the preferred path to a network: 1) Bandwidth, 2) Delay, 3) Reliability, 4) Load. By default, only bandwidth and delay are used to calculate the metric. Cisco recommends that reliability and load are not used unless the administrator has an explicit need to do so. Most serial interfaces use the default bandwidth value of 1544 Kbit or 1,544,000 bps (1.544 Mbps). This is the bandwidth of a T1 connection. Delay is a measure of the time it takes for a packet to traverse a route. The delay (DLY) metric is a static value based on the type of link to which the interface is connected and is expressed in microseconds. Delay is not measured dynamically. In other words, the router does not actually track how long packets are taking to reach the destination. The delay value, much like the bandwidth value, is a default value that can be changed by the network administrator. Table 1 shows the default delay values for various interfaces. Notice that the default value is 20,000 microseconds for Serial interfaces and 100 microseconds for FastEthernet interfaces.

Table 1. Default delay values for various interfaces

Media	Delay
100M ATM	100 µS
Fast Ethernet	100 µS
FDDI	100 µS
1HSSI	20,000 µS
16M Token Ring	630 µS
Ethernet	1,000 µS
T1 (Serial Default)	20,000 µS
512K	20,000 µS
DS0	20,000 µS
56K	20,000 µS

It is good to mention that metric calculation is detailed in Figure 8.

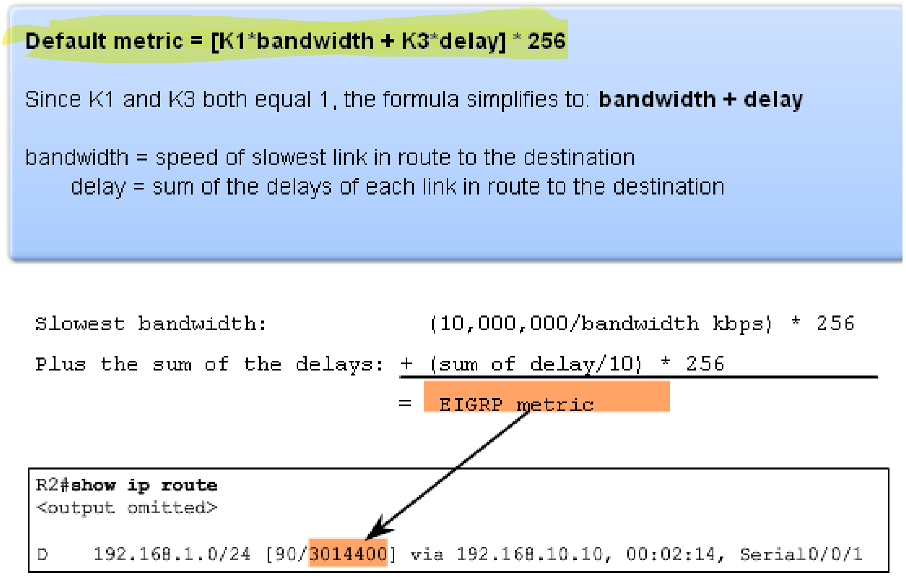


Figure 8. Matric Calculation

1) **Example:** When considering Figure 9(a), imagine that R2 wants to find a route to 192.168.1.0/24 to be stored in its routing table and further a backup route to be stored in its topology table. In this case, the EIGRP DUAL will be used to figure this out. At first, it is required to change the bandwidth of the interfaces as mentioned in Figure 9 (a). Now, Figure 9 (b) shows the procedure of setting up the new bandwidths. To verify this, Figure 9 (c) is provided. Then, as there are two possible paths to192.168.1.0/24 from R2, it is required to find the best feasible distance (i.e., the minimum one).

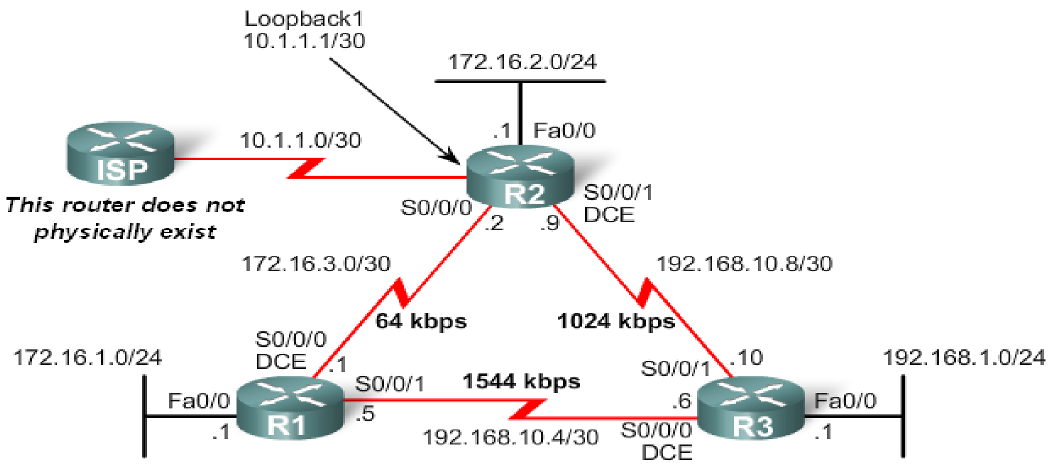


Figure 9 (a). Matric Calculation Example

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

```
R2(config)#inter s 0/0/0
R2(config-if)#bandwidth 64
R2(config)#inter s 0/0/1
R2(config-if)#bandwidth 1024
```

```
R3(config)#inter s 0/0/1
R3(config-if)#bandwidth 1024
```

Note: The actual bandwidth of the link between R1 and R3 matches the default value for serial interfaces (1544 kbps).

Figure 9 (b). Changing metrics – bandwidth

```
R2#show interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
  Hardware is PowerQUICC Serial
  Internet address is 172.16.3.2/30
  MTU 1500 bytes, BW 64 Kbit, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
<some output omitted>

R2#show interface serial 0/0/1
Serial0/0/1 is up, line protocol is up
  Hardware is PowerQUICC Serial
  Internet address is 192.168.10.9/30
  MTU 1500 bytes, BW 1024 Kbit, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
```

Figure 9 (c). Changing metrics – bandwidth – verification

The feasible distance can be found as follows:

$$FD = \left\lfloor \frac{10^7\,kbps}{BW_{slowest}(kbps)} \right\rfloor \times 256 + \frac{Delay_{sum}(\mu s)}{10\mu s} \times 256. \qquad (1)$$

As mentioned earlier, there are two routes from R2 to 192.168.1.0/24 (we call it N), namely, R2-R3-N and R2-R1-R3-N. Therefore, two FDs have to be computed as follows (kindly refer to Table 1 for finding the delay of various interfaces):

$$\begin{aligned} FD_{R2-R3-N} &= \left\lfloor \frac{10^7\,kbps}{1024kbps} \right\rfloor \times 256 + \frac{20100\mu s}{10\mu s} \times 256 \\ &= (9765 \times 256) + (2010 \times 256) \\ &= 2499840 + 514560 \\ &= 3014400 \end{aligned}$$

$$FD_{R2\text{-}R1\text{-}R3\text{-}N} = \left\lfloor \frac{10^7\,kbps}{64kbps} \right\rfloor \times 256 + \frac{40100\mu s}{10\mu s} \times 256$$
$$= (156250 \times 256) + (4010 \times 256)$$
$$= 40000000 + 1026560$$
$$= 41026560$$

Based on the FDs obtained, the R2-R3-N path will be chosen. Therefore, the successor will be **192.168.10.10**, as shown in Figures 17 and 21. Now, to figure out if there is any feasible successor to be stored in the topology table, we will examine the feasibility condition, as shown below:

$$RD_{R1-R2} < FD_{R2-R3-N}\ ?\ \text{which is also equivalent to } FD_{R1-R3-N} < FD_{R2-R3-N}$$

$RD_{R1-R2} = FD_{R1-R3-N} = \left\lfloor \frac{10^7\,kbps}{1544kbps} \right\rfloor \times 256 + \frac{20100\mu s}{10\mu s} \times 256 = 1657856 + 514560 = 2172416$, as shown in Figure 7.

Now, 2172416< 3014400, which means that there is a feasible successor, which is **172.16.3.1,** as shown in Figure 10. **It is good to mention that the topology table usually stores both successors and feasible successor as shown in Figure 10. It is further important to note that the code "P", shown in the topology table (Figure 10), means that this route is in the passive state. When DUAL is not performing its diffusing computations to determine a new path for a network, the route will be in a stable mode, known as the passive state. If DUAL is recalculating or searching for a new path, the route will be in an active state. In other words, if an EIGRP router loses its successor and cannot find a feasible successor for a route, DUAL places the route in the active state. All routes in the topology table should be in the passive state for a stable routing domain.**

Based on the earlier discussion, we can find out this time the routing table and topology table of R1 (not R2) easily, as shown in both Figures 11 (a), 11 (b) and 11 (c). Why isn't R2 listed as a feasible successor? R2 is not a feasible successor because it does not meet the feasibility condition.

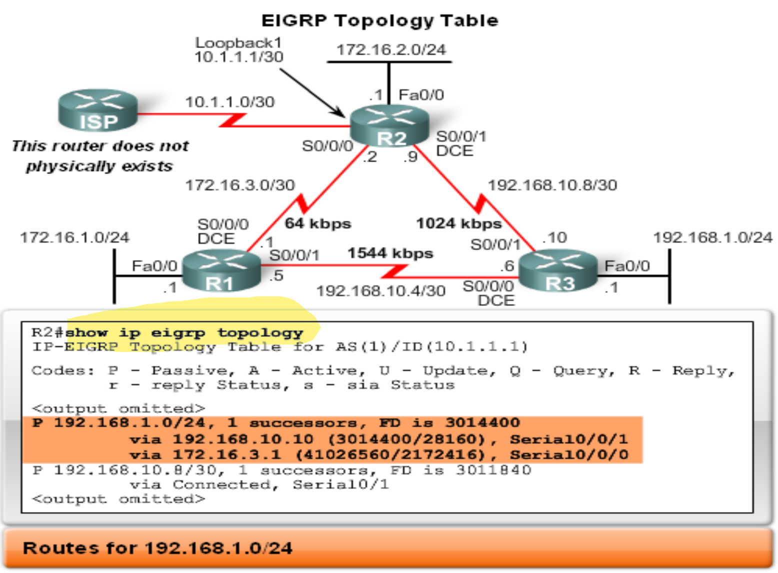


Figure 10. R2 topology table

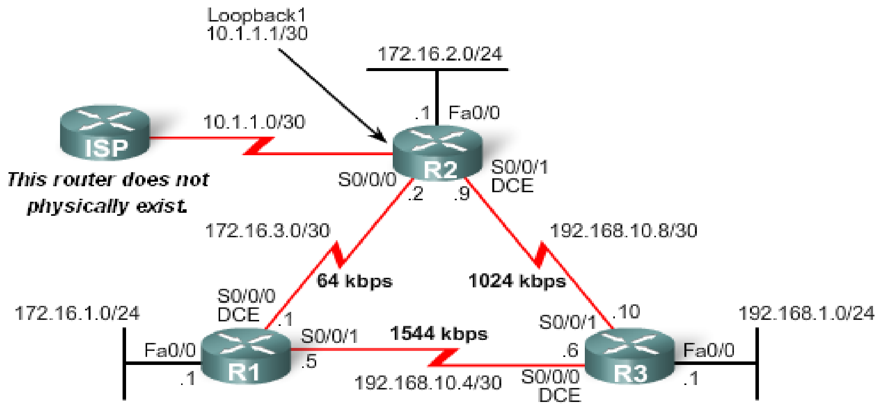


Figure 11 (a). Finding Path from R1 to 192.168.1.0/24

```
R1#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       <output omitted>

Gateway of last resort is not set

     192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
D       192.168.10.0/24 is a summary, 00:45:09, Null0
C       192.168.10.4/30 is directly connected, Serial0/0/1
D       192.168.10.8/30 [90/3523840] via 192.168.10.6, 00:44:56, Serial0/0/1
     172.16.0.0/16 is variably subnetted, 4 subnets, 3 masks
D       172.16.0.0/16 is a summary, 00:46:10, Null0
C       172.16.1.0/24 is directly connected, FastEthernet0/0
D       172.16.2.0/24 [90/40514560] via 172.16.3.2, 00:45:09, Serial0/0/0
C       172.16.3.0/30 is directly connected, Serial0/0/0
D    192.168.1.0/24 [90/2172416] via 192.168.10.6, 00:44:55, Serial0/0/1
```

Figure 11 (b). R1 Routing Table

```
R1#show ip eigrp topology
IP-EIGRP Topology Table for AS(1)/ID(192.168.10.5)

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

P 192.168.10.0/24, 1 successors, FD is 2169856
        via Summary (2169856/0), Null0
P 192.168.10.4/30, 1 successors, FD is 2169856
        via Connected, Serial0/0/1
P 192.168.1.0/24, 1 successors, FD is 2172416
        via 192.168.10.6 (2172416/28160), Serial0/0/1
P 192.168.10.8/30, 1 successors, FD is 3523840
        via 192.168.10.6 (3523840/3011840), Serial0/0/1
<output omitted>
```

Figure 11 (c). R1 Topology Table

D. EIGRP - The Null0 summary route

It is important to mention that the EIGRP uses the Null0 interface to discard any packets that match the parent route but do not match any of the child routes. For example, as shown in Figure 12, R1 will discard any packets that match the parent 172.16.0.0/16 classful

network but do not match one of the child routes 172.16.1.0/24, 172.16.2.0/24 or 172.16.3.0/30. For example, a packet to 172.16.4.10 would be discarded. Even if a default route was configured, R1 would still discard the packet because it matches the Null0 summary route to 172.16.0.0/16.

EIGRP **automatically includes a null0 summary route** as a child route whenever both of following conditions exist: 1) There is at least one subnet that was learned via EIGRP, 2) Automatic summarization is enabled (by default).

```
R1#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

     192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
D       192.168.10.0/24 is a summary, 00:45:09, Null0
C       192.168.10.4/30 is directly connected, Serial0/0/1
D       192.168.10.8/30 [90/3523840] via 192.168.10.6, 00:44:56, Serial0/0/1
     172.16.0.0/16 is variably subnetted, 4 subnets, 3 masks
D       172.16.0.0/16 is a summary, 00:46:10, Null0
C       172.16.1.0/24 is directly connected, FastEthernet0/0
D       172.16.2.0/24 [90/40514560] via 172.16.3.2, 00:45:09, Serial0/0/0
C       172.16.3.0/30 is directly connected, Serial0/0/0
D    192.168.1.0/24 [90/2172416] via 192.168.10.6, 00:44:55, Serial0/0/1
```

EIGRP installs a Null0 summary route for each parent route.
Packets matching the Null0 summary route are discarded.

Figure 12. R1 Routing Table - The Null0 Summary Route

The bottom-line here why do some routing protocols insert a summary route to null0 on the local router when doing route summarization? Kindly consider Figure 13 and consequently imagine what happens if R1 wants to send a packet to 2.2.2.7. The summary route advertised from R2 is 2.2.2.0/29, which means that the summary covers the range 2.2.2.1 – 2.2.2.7. However, R2 does not have a route for 2.2.2.7. It just does have a default-route. What we have there is a recipe for disaster in the form of a routing loop. R1 will send the packet to R2. R2 won't have a route for 2.2.2.7 and will default route it back to R1. This will continue until the IP TTL expires.

Interestingly, if we were running a routing protocol that implements the summary route to null0 feature, our problem would be solved. Now, R1 wants to reach 2.2.2.7. It has a summary route for 2.2.2.0/29 learned from R2 so it sends the packet to R2. R2 still doesn't have a specific route for 2.2.2.7, but it DOES have a more general route for 2.2.2.0/29 that matches. Because of that, R2 routes the packet to a black hole called null0 and the packet is stopped and dropped instead of causing a routing loop!

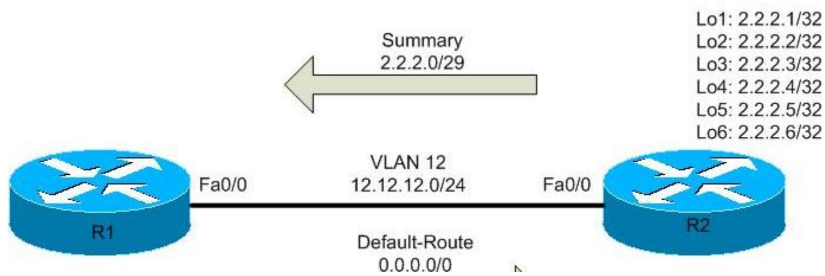


Figure 13. Need for Null0 Summary Route

It is good to stress on the point that the automatic summarization can be disabled on any router using the no auto-summary command where its effect is shown in Figure 14.

```
R3#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       <output omitted>

Gateway of last resort is not set

     192.168.10.0/30 is subnetted, 2 subnets
C       192.168.10.4 is directly connected, Serial0/0/0
C       192.168.10.8 is directly connected, Serial0/0/1
     172.16.0.0/16 is variably subnetted, 3 subnets, 2 masks
D       172.16.1.0/24 [90/2172416] via 192.168.10.5, 00:00:11, Serial0/0/0
D       172.16.2.0/24 [90/3014400] via 192.168.10.9, 00:00:12, Serial0/0/1
D       172.16.3.0/30 [90/41024000] via 192.168.10.5, 00:00:12, Serial0/0/0
                      [90/41024000] via 192.168.10.9, 00:00:12, Serial0/0/1
C    192.168.1.0/24 is directly connected, FastEthernet0/0
```

Figure 14. Routing table on R3 with no auto summary

E. EIGRP Default Route

The "quad zero" (0.0.0.0/0) static default route can be used with any currently supported routing protocols. **The static default route is usually configured on the router that has a connection to a network outside the EIGRP routing domain, for example, to an ISP.** EIGRP requires the use of the redistribute static command to include this static default route with its EIGRP routing updates. **In fact, the redistribute static command tells EIGRP to include this static route in its EIGRP updates to other routers.** Figure 15 shows the use of EIGRP default route in R1. Kindly note the following symbols along with their meaning:

- D - This static route was learned from an EIGRP routing update.
- * - The route is a candidate for a default route.
- EX - The route is an external EIGRP route, in this case a static route outside of the EIGRP routing domain.
- 170 - This is the administrative distance of an external EIGRP route.

```
R1#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 192.168.10.6 to network 0.0.0.0

     192.168.10.0/30 is subnetted, 2 subnets
C       192.168.10.4 is directly connected, Serial0/0/1
D       192.168.10.8 [90/3523840] via 192.168.10.6, 01:06:01, Serial0/0/1
     172.16.0.0/16 is variably subnetted, 3 subnets, 2 masks
C       172.16.1.0/24 is directly connected, FastEthernet0/0
D       172.16.2.0/24 [90/3526400] via 192.168.10.6, 01:05:39, Serial0/0/1
C       172.16.3.0/30 is directly connected, Serial0/0/0
D*EX 0.0.0.0/0 [170/3651840] via 192.168.10.6, 00:02:14, Serial0/0/1
D    192.168.0.0/22 [90/2172416] via 192.168.10.6, 01:05:38, Serial0/0/1
```

Figure 15. EIGRP Default Route

F. EIGRP Neighbor Table

The structure of the neighbor table is shown in Figure 16.

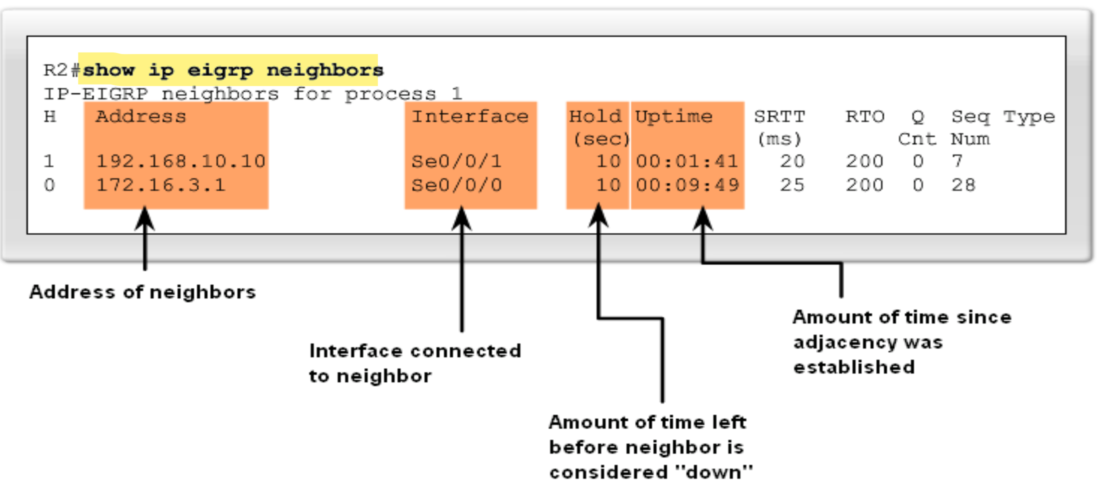


Figure 16. Neighbor Table Structure

Kindly pay attention to the meaning and description of the following fields:

1) Hold - The current hold time. Whenever a Hello packet is received, this value is reset to the maximum hold time for that interface and then counts down to zero. If zero is reached, the neighbor is considered "down".
2) Queue Count - Should always be zero. If more than zero, then EIGRP packets are waiting to be sent.
3) Sequence Number - Used to track updates, queries, and reply packets.
4) SRTT (Smooth Round Trip Timer) and RTO (Retransmit Interval) where they are used by RTP to manage reliable EIGRP packets bearing in mind that:

Retransmit timeout = 6 $\times$ SRTT
Min (RTO) = 200 ms and Max (RTO) = 5000 ms.

Once the current routes and backup routes are gone (due to link failures), DUAL re-computations will occur through getting advantage of QUERY and REPLY control packets. In other words, the current router will send a QUERY packet to its neighbors asking for help to reach the network wherein the available routes got broken.

To make it clearer, imagine we sent a QUERY packet and did not receive a REPLY packet. How does the protocol act?

Answer: It should wait 16 times 1.5 backoff RTO.

1	2	3	4	----- 16 times
200ms	300ms	450ms	675ms	----- 5000ms

Worst Case: initially RTO starts with 5000 ms

1	2	3	4	----- 16 times
5000ms	5000ms	5000ms	5000ms	----- 5000ms

Overall waiting time = 16 $\times$ 5000ms (5sec) =80 sec.

G. Question, how does the feasibility condition maintain loop-free topology?

Referring to Figure 17, R1 is our router which has a route to R5. Suppose the path through R2 is better (the lowest FD), so R2 is becoming our Successor for that route. Now R1 has to decide if R3 will become a Feasible Successor or not. Let's split this into 2 cases.

1) Suppose R1's distance to R5 (which is FD) is 100, whereas R3's distance to R5 through R4 is 120 (which is RD). Let's violate the feasibility condition and choose R3 as a Feasible Successor. What happens when we configure unequal load balancing? R1 sends some IP packets to R5 through R3. When a packet comes to the next hop, R3 thinks "I need to send it towards R5, so let's consult my routing table". And guess what? The routing table will tell R3 to send the packet back to R1 because R1 is the Successor for that route, in R3's point of view (remember that distance on the left is 100+X, and 120 on the right; X is distance between R1 and R3 which may easily be less than 20). So we have a loop, as the packet can bounce between R1 and R3 never going to other routers.

2) Suppose R1's distance to R5 (which is FD) is 100, whereas R3's distance to R5 through R4 is 95 (which is RD). Now whatever distance X is between R1 and R3, 100+X always greater than 95, so R3 will never route through R1. This is why it's a loop free path.

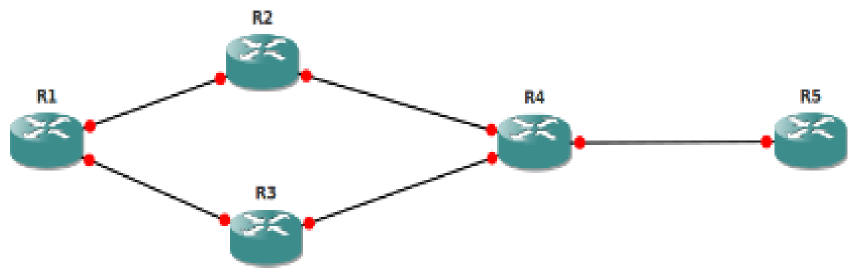


Figure 17. EIGRP – loop-free

H. EIGRP Router ID

The EIGRP router ID is used to uniquely identify each router in the EIGRP routing domain. The router ID is used in the EIGRP and OSPF routing protocols, although the function of this router ID is more important in OSPF. In IPv4 EIGRP implementations, the use of the router ID is not so obvious. EIGRP for IPv4 uses the 32-bit router ID to identify the source router for redistribution of external routes. Route redistribution allows routes from one routing protocol to be advertised in another routing protocol. You must be careful when redistributing routes into another protocol because you may inadvertently create routing loops or suboptimal routes. Additionally, different routing protocols use different metrics, so you must take this into account when advertising one protocol into another. However, the need for a router ID is most evident in the EIGRP analysis for IPv6.

Cisco routers derive the router ID based on three criteria, in the following precedence:

- Use the IPv4 address configured with the **eigrp router-id** in the router configuration mode command.
- If the router ID is not configured, the router chooses the highest IPv4 address of any of its loopback interfaces. **Loopback interface is a virtual interface and is automatically in the up state when configured.**
- **If no loopback interfaces are configured, the router chooses the highest active IPv4 address of any of its physical interfaces.**

It is worth mentioning that if the network administrator does not explicitly configure a router ID by using the eigrp router id command, EIGRP generates its own router ID from a loopback address or a physical IPv4 address.

- *Configuring the EIGRP Router ID:*
  - ✓ The **eigrp router-id** command is used to configure the EIGRP router ID and takes precedence over any loopback address or IPv4 physical interface address.
  - ✓ The router ID can be configured with any IPv4 address, with two exceptions: 0.0.0.0 and 255.255.255.255. The router ID must be a unique 32-bit number in the EIGRP routing domain; otherwise, routing inconsistencies may occur.
  - ✓ Example of the EIGRP router ID settings on R1 router are shown below:

```
Router (config) # router eigrp 1
```

```
Router (config-router) # eigrp router-id 1.1.1.1
```

- *Use of loopback address as Router ID:*
  - ✓ Another option to specify the EIGRP router ID is to use an IPv4 loopback address. The advantage of using a loopback interface instead of the IPv4 address of a physical interface is that, unlike physical interfaces, it cannot fail.
  - ✓ There are no real adjacent cables or devices on which the loopback interface depends to be in the up state. Therefore, **using a loopback address as a router ID can provide a more consistent router ID than using an interface address**.
  - ✓ If the eigrp router-id command is not used and there are loopback interfaces configured, EIGRP chooses the highest IPv4 address of any of the loopback interfaces.
  - ✓ The following commands are used to enable and configure a **loopback interface**:

```
Router (config) # interface loopback number
Router (config-if) # ip address ipv4-address subnet-mask
```

- Note: The EIGRP router ID does not change, unless the EIGRP process is removed with the no router eigrp command, or the router ID is manually configured with the eigrp router-id command.

I. Wildcard Mask

It is quite similar to subnet mask (except that the ones and zeros are flipped). **In other words, everything done through the subnet mask can be done through the wildcard mask.** It is worth mentioning that to convert between subnet mask and wildcard masks, **we simply have to subtract each octet from 255, as shown in Figure 18 (a).** The wildcard mask is simply the inverse of subnet mask. Kindly pay attention that the /21, /27, and /20 are the CIDR notations. To consider one of its functions, which is examining whether any two IP addresses belong to (or are in) the same subnet, as shown in Figure 18 (b). Firstly, to examine this using the subnet mask, there should a perfect match in all columns of the two IP addresses **along all 1's of subnet mask**. If it is so, then they are in the same subnet. This is clearly shown in Figure 18 (c). Secondly, to examine that using the wildcard mask, there should a perfect match in all columns of the two IP addresses **along all 0's of wildcard mask**. Unfortunately, this is not the case, as shown in Figure 18 (d). Interestingly, we repeat the same process (examinations) over two different IP addresses and ultimately find out that all columns of the new IP addresses perfectly match **all 1's of subnet mask and further all 0's of wildcard mask**, as shown in Figures 29 (e) and (f), respectively.

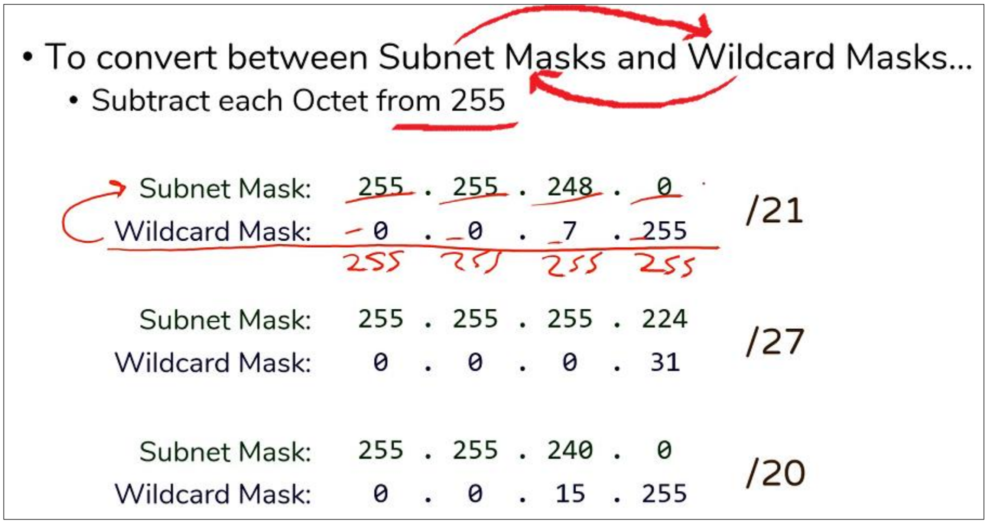


Figure 18 (a). Comparing Wildcard Masks with Subnet Masks

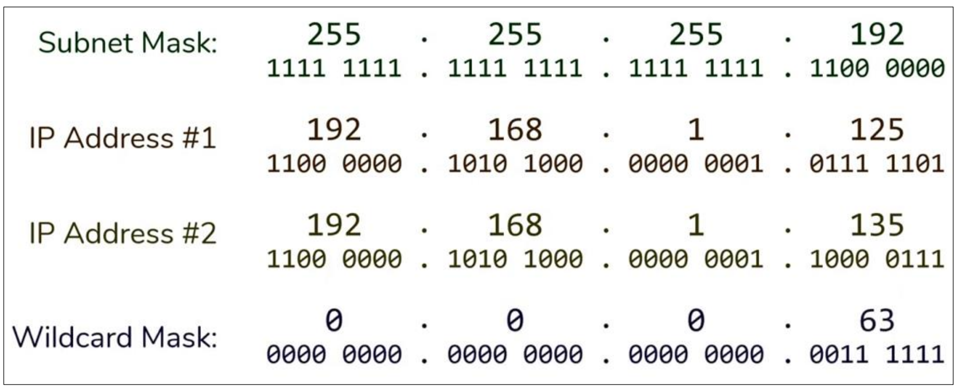


Figure 18 (b). Are the two IP addresses in the same subnet?

Figure 18 (c). Examining using subnet mask

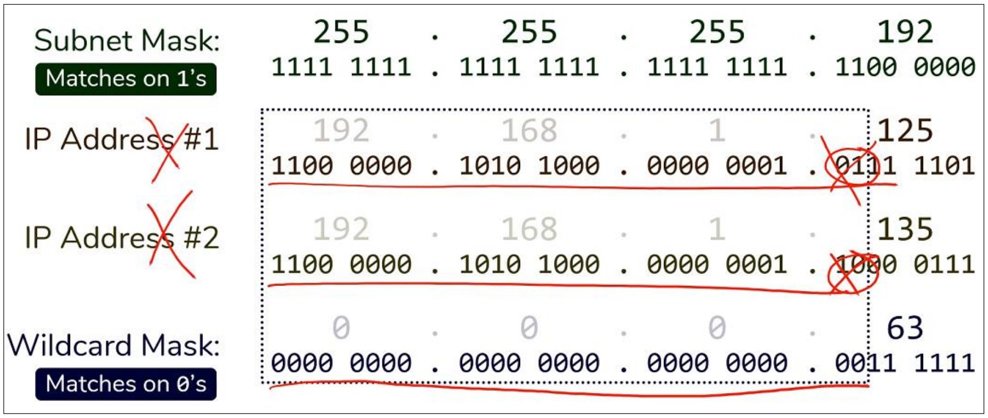


Figure 18 (d). Examining using wildcard mask

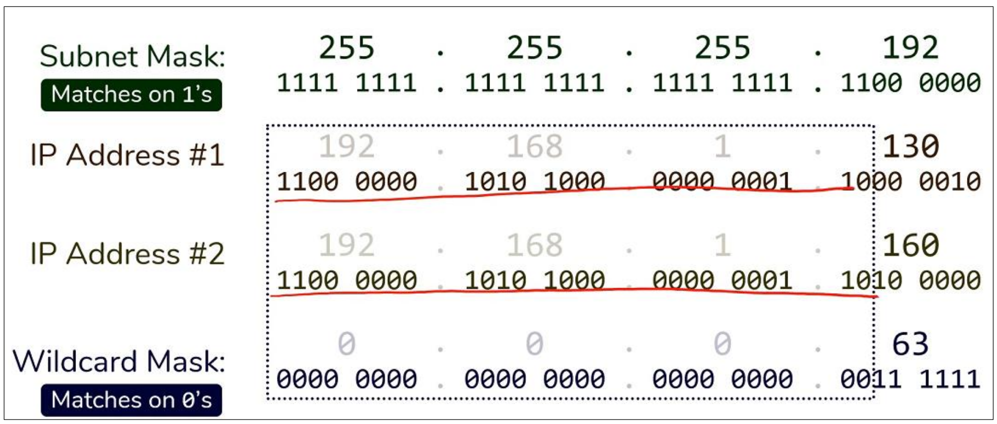


Figure 18 (e). Examining using wildcard mask – different IP addresses

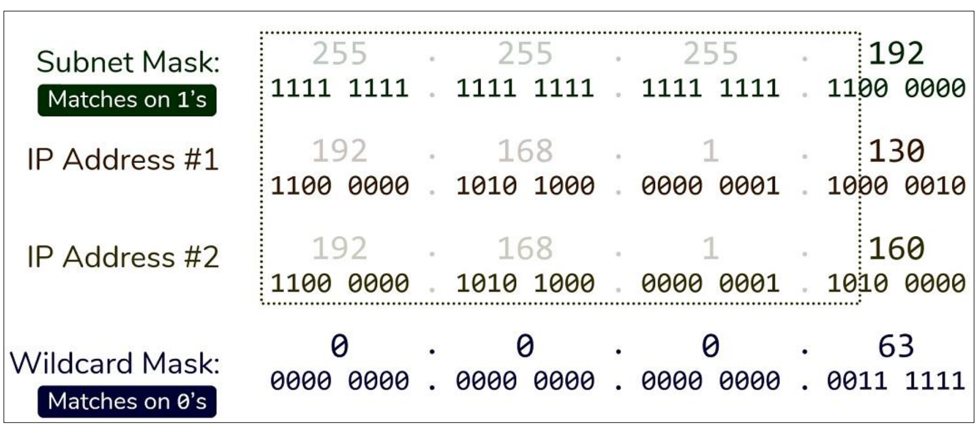


Figure 18 (f). Examining using subnet mask – different IP addresses

Part II: EIGRP Commands:

The EIGRP commands are discussed for both IPv4 and IPv6 as shown below:

A. EIGRP commands for IPv4:

- EIGRP configuration is straightforward. **It is a two-step process**. In the first step, we enable EIGRP. In the second step, we provide the required details to the EIGRP. Let's discuss both steps in detail.

  - **Enabling EIGRP:** To enable EIGRP, we use the following command in global configuration mode.

```
Router(config)# router eigrp [AS_number]
```

The above command enables EIGRP and puts us in EIGRP configuration mode. It needs only one parameter, an **AS number**. You can choose any number from the range 1 to 65535 as an AS number. After selecting a number, you have to use the same number on all routers. If two routers belong to different AS, they will not share routing information.

  - **Customizing EIGRP:** In EIGRP configuration mode, we use the following command to include the network in the EIGRP operation.

```
Router(config-router)# network [network_address] [wildcard_mask]
```

The above command needs two parameters: a network address and wildcard mask of the network. The network address is the network ID of the subnet that you want to include in the EIGRP operation. The wildcard mask is the range of addresses that you want to include in the operation. Each time this command will add only one network. To add more networks, you can use the same command again and again. For example, if you want to add three networks, you have to use this command three times.

- The **passive-interface command** allows a router to receive routing updates on an interface but not send updates via that interface.

```
Router(config-router) # passive-interface {interface name}
```

- **To avoid automatic summarization** on routing table, we will add no auto-summary command.

```
Router(config-router) # no auto-summary
```

- **The redistribute static command** propagates the static default route in EIGRP updates.

```
Router(config-router) # redistribute static
```

- Use the default routes when you want to draw all traffic to unknown destinations to a default route at the core of the network. This method is effective for advertising connections to the Internet, but will redistribute all static routes into EIGRP.

```
Router(config)# ip route 0.0.0.0 0.0.0.0 x.x.x.x (next hop)
```

```
Router(config)#router eigrp 100
Router(config-router)#redistribute static
```

- EIGRP metric values: Figure 19, below, shows the interface information about EIGRP metrics values.

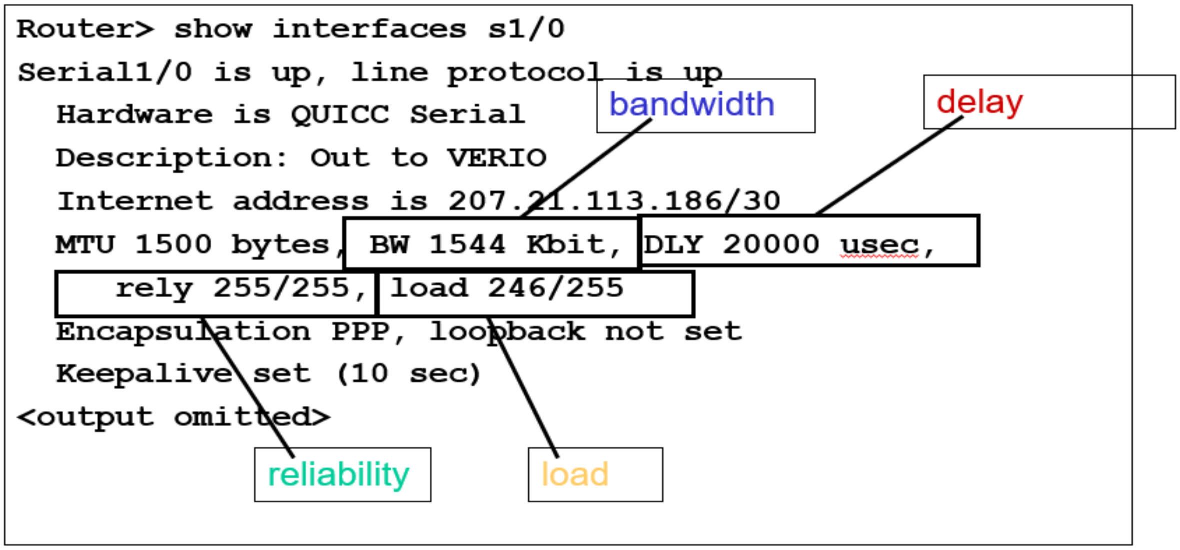


Figure 19. EIGRP metrics values

1) **Bandwidth, which is detailed as shown in the following bullets:**
   - Expressed in kilobits (show interface)
   - This is a static number and used for metric calculations only.
   - Does not necessarily reflect the actual bandwidth of the link.
   - It is an information parameter only.
   - You cannot adjust the actual bandwidth on an interface with this command.
   - Use the show interface command to display the raw value.
   - Default bandwidth of a Cisco interface depends on the type of interface.
   - Default bandwidth of a Cisco serial interface is 1544 kilobits or 1,544,000 bps (T1), whether that interface is attached to a T1 line (1.544 Mbps) or a 56K line.
   - IGRP/EIGRP metric uses the slowest bandwidth of all of the outbound interfaces to the destination network.
   - **To configure the correct value for bandwidth,** you should use bandwidth command on the router interface that are attached to this slow links. This action is very important to the accuracy of routing information. This command is configured in the interface mode.

```
Router(config-if) # bandwidth kilobits
```

   - **To restore the default value: Router(config-if)# no bandwidth**

2) **Delay, which is detailed as shown in the following bullets:**
   - Like bandwidth, delay it is a static number.

- Expressed in microseconds, millionths of a second.
- Use the show interface command to display the raw value
- It is an information parameter only.
- The default delay value of a Cisco interface depends upon the type of interface.
- **Default delay of a Cisco serial interface is 20,000 microseconds, that of a T1 line.**
- IGRP/EIGRP metric uses the sum of all of the delays of all of the outbound interfaces to the destination network.
- **Changing the delay informational parameter:**

```
Router(config-if)#  delay tens-of-µs(microseconds)
```

- **Example of changing the delay on a serial interface to 30,000 microseconds:**

```
Router(config-if)# delay 3000
```

- **To restore the 20,000 microsecond default value:**

```
Router(config-if)# no delay
```

3) K values, which are detailed as shown in the following bullets:

- **Default: k1=k3=1 and k2=k4=k5=0)**
- You may change the k values to change what you want to give more or less weight to.
- **k1 for bandwidth**, k2 for load, **k3 for delay**, k4 and k5 for Reliability
- Higher the k value, the more that part of the metric is used to calculate the overall EIGRP metric. The command to adjust the k values is:

```
Router(config-router)# metric weights tos k1 k2
k3 k4 k5
```

- The *tos* is always set to 0; at one time it was Cisco's intent to use it, but it was never implemented

4) Hello intervals and Hold times: Hello intervals are configurable on a per-interface basis and do not have to match with other EIGRP routers to establish adjacencies. The seconds value for hello and intervals can range from 1 to 65,535. **If you change the hello interval, make sure that the hold time value equal to or greater than the hello interval. Otherwise, neighbor adjacency will go down after the hold time expires and before the next hello interval.**

```
Router(config-if)#ip hello-interval eigrp AS {seconds}
```

5) Verifying EIGRP configuration: You verify EIGRP configuration in two ways:

- **By testing end-to-end connectivity:** To test connectivity between two devices, we use the **ping** command. This command sends dummy data packets to the destination device and tracks the response. If it receives replies from the destination device, it lists the replies on the console. A successful reply verifies that the source and the destination have proper connectivity.

- **By listing EIGRP routes on the router,** using the following commands listed in Table 2.1:

Table 2.1. Verifying EIGRP configuration commands

Command	Key Information
show ip route	Lists the contents of a router's IP routing table, with EIGRP-learned routes appearing with a code of D on the left side of the output.
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 interfaces	Lists the working interfaces on which EIGRP is enabled (based on the **network** commands), omitting passive interfaces.
show ip eigrp neigbors	Lists known EIGRP neighbors, excluding adjacent EIGRP-speaking routers with a mismatched parameter preventing the establishment of an EIGRP neighborship.
show ip eigrp topology [**all-links**]	Lists all successor and feasible successor routes known to the router. The addition of the **all-links** keyword causes the output to include any additional known routes that are neither successor nor feasible successor routes.
show ip eigrp traffic [as-number]	Displays the number of EIGRP packets sent and recieved. Command output can be filtered by including an optional AS number.
debug eigrp fsm	This command helps in observing EIGRP feasible successor activity and to determine whether route updates are being installed and deleted by the routing process.
debug eigrp packet	The output of the command shows transmission and receipt of EIGRP packets. These packet types may be hello, update, request, query, or reply packets. The sequence and acknowledgment numbers by the EIGRP reliable transport algorithm are shown in the output.

B. EIGRP commands for IPv6

Kindly consider the following bullets while configuring EIGRP for IPv6:

- The **ipv6 unicast-routing** global configuration command must be configured to enable the router to forward IPv6 packets (i.e., packet forwarding).

```
Router(config)# ipv6 unicast-routing
```

- The **"ipv6 router eigrp AS-number"** command is used to create an EIGRP IPv6 routing process. eigrp router-id **"eigrp router-id"** command is used to configure the router ID. EIGRP for IPv6 uses a 32 bit value for the router ID. The router ID should be a unique 32-bit number in the EIGRP for IP routing domain; otherwise, routing inconsistencies can occur. By default, the EIGRP for IPv6 process is in a shutdown state. The **"no shutdown"** command is required to activate the EIGRP for IPv6 process. **Both the "no**

shutdown" command and a router ID are required for the router to form neighbor adjacencies, as shown in Figure 2.1.

```
R1(config)# ipv6 router eigrp 2
R1(config-rtr)# eigrp router-id 1.0.0.0
R1(config-rtr)# no shutdown
R1(config-rtr)#
```

Figure 2.1. IPv6 EIGRP commands

- EIGRP for IPv6 uses a different method to enable an interface for EIGRP. Instead of using the network command to specify matching interface addresses, the following command **"ipv6 eigrp AS_number"** is used to enable EIGRP for IPv6 directly on the interface, The AS value must be the same as the autonomous system number used to enable the EIGRP routing process as shown in Figure 2.2:

```
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)#
```

Figure 2.2. Enabling IPv6 EIGRP commands on interfaces

- As mentioned earlier, the **"eigrp router-id"** command is used to configure the EIGRP router ID and takes precedence over any loopback address or IPv4 physical interface address. The syntax of the command in IPV6 is:

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

- **The following commands are used to enable and configure a loopback interface:**

```
Router (config) # interface loopback number
Router (config-if) # ip address ipv4-address subnet-mask
```

- Commands used to verify the EIGRP for IPV6 is the same command that are used to verify the IPv4, but use **ipv6** instead of **ip** in all commands.
- The **"show ipv6 eigrp neighbors"** command is used to **view the neighbor table** and verify that EIGRP for IPv6 has established an adjacency with its neighbors.
- The **"show ipv6 protocols"** command **is used to display the parameters about the state of any active IPv6 routing protocol processes configured on the router.**

- The "show ipv6 route" command is used to examine the IPv6 routing table. EIGRP for IPv6 routes are denoted in the routing table with a D.
- Table 2.2 presents a EIGRP Routing protocol configuration commands summary.

Table 2.2 Summary of IPv4 and IPv6 EIGRP configuration commands

Command	Description
Router(config)# router eigrp AS_number	Enable IPv4 EIGRP routing protocol
Router(config)#no router eigrp AS_number	Disable IPv4 EIGRP routing protocol
Router(config-router)#network a.b.c.d [wildcard_mask]	Add a.b.c.d network with wild mask in IPv4 EIGRP routing advertisement
Router(config-router)#no network a.b.c.d [wildcard_mask]	Remove a.b.c.d network from IPv4 EIGRP routing advertisement
Router(config-if)#bandwidth kilobits	Set the bandwidth for the interface
Router(config-router)#no auto-summary	By default IPv4 EIGRP automatically summarize networks in their default classful boundary. This command will turn it off.
Router(config-router)#passive-interface s0/0/0	IPv4 EIGRP will not broadcast routing update from this interface
Router(config-router) # redistribute static	propagate the static default route in IPv4 EIGRP updates.
Router(config-router)# eigrp router-id router-id	Enables the use of a fixed router ID in IPv4.
Router(config)# ipv6 unicast-routing	Enable the router to forward IPv6 packets
Router(config)# ipv6 router eigrp AS_number	Enter router configuration mode and creates an EIGRP IPv6 routing process.
Router(config-rtr)# eigrp router-id router-id	Enables the use of a fixed router ID in IPv6.
Router(config-rtr)# no shutdown	Enables no shut mode so the routing process can start running.
Router (config)#interface g0/0	Enter the interface mode
Router (config-if)#ipv6 eigrp AS_number	Enable an EIGRP IPv6 routing process in the interface.

Part III: Configuring EIGRP for IPv4 and IPv6 (Practical part):

A. IPv4 EIGRP Configuration (Packet Tracer)

- Consider the following scenario in Figure 2.3, which helps you practice configuring IPv4 EIGRP on routers. Suppose the PCs, server, and routers' interfaces are configured in the same manner as mentioned in the previous section. Now routers have information about the direct networks that they have on their own interfaces. Routers will not exchange this information between themselves. We need to implement the EIGRP routing protocol, which will insist they share this information.

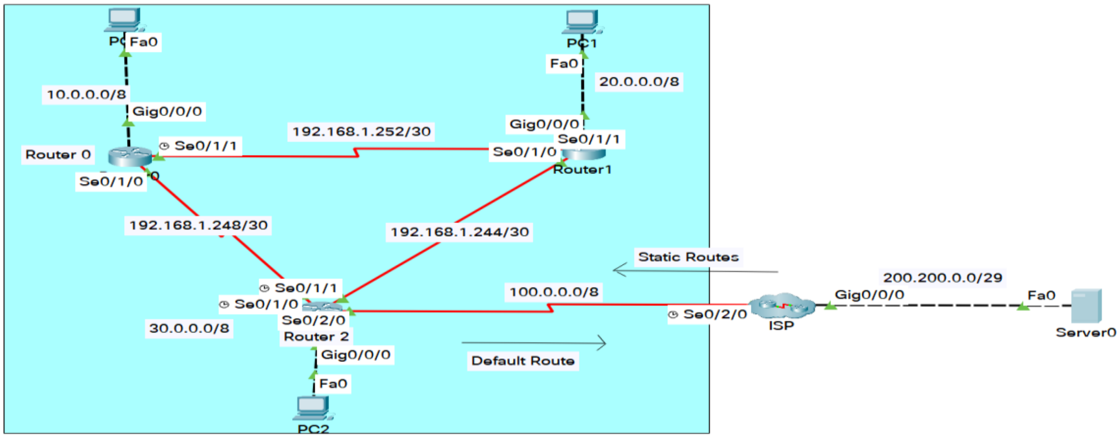


Figure 2.3. The network topology to be configured using IPv4 EIGRP.

1. Configure the EIGRP routing protocol

Configuration of the EIGRP protocol is much easier than you think. It requires only five steps to configure the EIGRP routing on Router 0, Router 1, and Router 2.

- Enable the EIGRP routing protocol from global configuration mode.
- Set the AS number to a specific value (suppose it in our example is set to 20).
- Tell the EIGRP routing protocol which networks you want to advertise.
- Disable the summarization of networks.
- Configure the LAN interface that contains no routers so that it does not send out any routing information (i.e., passive interface).

Only for router 2, we add two extra commands because it is connected to the ISP router:

- Use the appropriate command to create a static default route on router 2 for all Internet traffic to exit the network through Serial0/2/0.
- Advertise the default route configured in the previous step with other EIGRP routers using the "**redistribute static**" command.

The ISP router is configured with a summarized static route and LAN static routes.

Let's configure it in Router0:

```
Router0(config)#router eigrp 20
Router0(config-router)# network 10.0.0.0 0.255.255.255
Router0(config-router)# network 192.168.1.252 0.0.0.3
Router0(config-router)# network 192.168.1.248 0.0.0.3
Router0(config-router)# no auto-summary
Router0(config-router)# passive-interface g0/0/0
```

That's all we need to configure the EIGRP. Follow the same steps on remaining routers.

Let's configure it in Router1:

```
Router1(config)#router eigrp 20
Router1(config-router)# network 20.0.0.0 0.255.255.255
Router1(config-router)# network 192.168.1.244 0.0.0.3
Router1(config-router)# network 192.168.1.252 0.0.0.3
Router1(config-router)# no auto-summary
```

```
Router1(config-router)# passive-interface g0/0/0
```

Let's configure it in Router2:

- Note: This router is connected directly to the ISP router, so we need to add two extra commands, which are colored in red.

```
Router2(config)# router eigrp 20
Router2(config-router)# network 30.0.0.0 0.255.255.255
Router2(config-router)# network 192.168.1.248 0.0.0.3
Router2(config-router)# network 192.168.1.244 0.0.0.3
Router2(config-router)# no auto-summary
Router2(config-router)# passive-interface g0/0/0
Router2(config-router)# redistribute static
Router2(config-router)#exit
Router2(config)#ip route 0.0.0.0 0.0.0.0 Serial0/2/0
```

Let's configure it in ISP:

- Note: This router uses static routing; we add the remote summarized networks and other remote networks (i.e., which are not summarized).

```
ISP>
ISP > enable
ISP # conf t
ISP (config)#ip route 192.168.1.240 255.255.255.240 s0/2/0
ISP (config)#ip route 10.0.0.0 255.0.0.0 s0/2/0
ISP (config)#ip route 20.0.0.0 255.0.0.0 s0/2/0
ISP (config)#ip route 30.0.0.0 255.0.0.0 s0/2/0
```

That's it. Our network is ready to take advantage of EIGRP routing.

2. **Verify the configurations**

To verify the setup, we will use the "**ping**" command to test the connectivity between two devices.

Step 1: View the routing tables of Router 0, Router 1, Router 2, and the ISP.

- Use the appropriate command to show the routing table of **Router 2**. EIGRP (D) now appears with connected (C) and local (L) routes in the routing table, as shown in Figure 2.4. All networks have an entry. You also see a default route listed (S*).

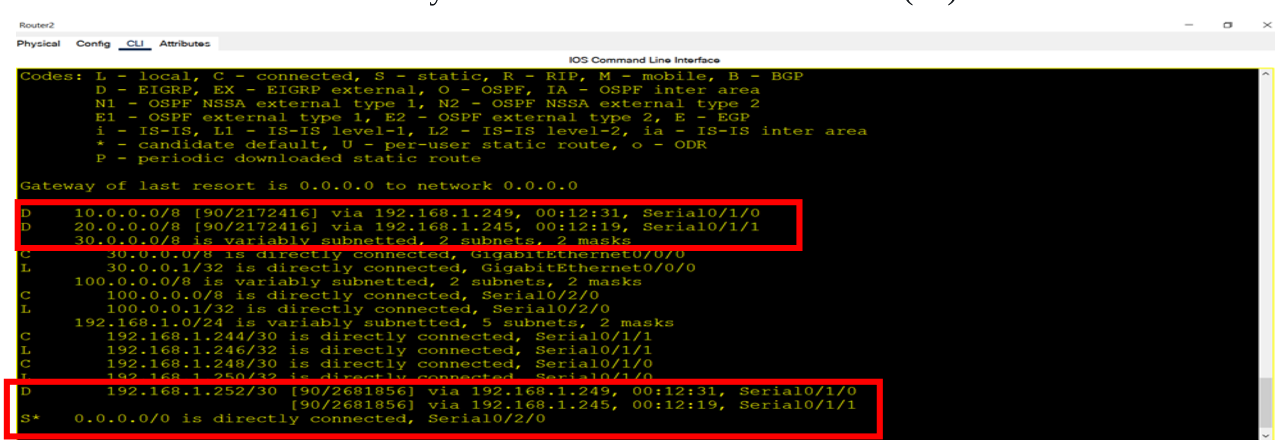


Figure 2.4. Routing table of Router 2 after configuring the EIGRP networks and static defaults routes.

- View the routing tables for **Router 0**. Notice that, as presented in Figure 2.5, Router 0 has a full listing of all the directly connected networks, which are denoted by the symbol ″D″, which indicates the use of EIGRP, and a default route, which is represented by the symbol ″D*EX″ to indicates the use of external EIGRP since it comes from the ″**redistribute static**″ command.

```
Router0#show ip eigrp neighbors
IP-EIGRP neighbors for process 20
H    Address          Interface        Hold Uptime    SRTT   RTO   Q    Seq
                                       (sec)          (ms)         Cnt  Num
0    192.168.1.253    Se0/1/1          14   00:27:18  40     1000  0    11
1    192.168.1.250    Se0/1/0          11   00:25:05  40     1000  0    15
Router0#show ip eigrp interfaces
IP-EIGRP interfaces for process 20

                        Xmit Queue   Mean   Pacing Time   Multicast    Pending
Interface        Peers  Un/Reliable  SRTT   Un/Reliable   Flow Timer   Routes
Se0/1/1            1        0/0      1236       0/10           0           0
Se0/1/0            1        0/0      1236       0/10           0           0
Router0#show ip route eigrp
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
D    20.0.0.0/8 [90/2172416] via 192.168.1.253, 00:31:17, Serial0/1/1
D    30.0.0.0/8 [90/2172416] via 192.168.1.250, 00:29:03, Serial0/1/0
     192.168.1.0/24 is variably subnetted, 5 subnets, 2 masks
D       192.168.1.244/30 [90/2681856] via 192.168.1.253, 00:31:17, Serial0/1/1
                         [90/2681856] via 192.168.1.250, 00:28:51, Serial0/1/0
D*EX 0.0.0.0/0 [170/7289856] via 192.168.1.250, 00:20:35, Serial0/1/0
Router0#show ip protocols
Routing Protocol is "eigrp  20 "
  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 20
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
     10.0.0.0
     192.168.1.252/30
     192.168.1.248/30
  Passive Interface(s):
    GigabitEthernet0/0/0
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.1.253   90            87933997
    192.168.1.250   90            88067022
  Distance: internal 90 external 170

Router0#
```

Figure 2.5. Verifying the EIGRP configuration using different show commands

Step 2: Verify full connectivity to all destinations.

- Every device should now be able to ping every other device inside the network. In addition, all devices should be able to ping the Web Server, as shown in Figure 2.6.

Fire	Last Status	Source	Destination	Type	Color	Time(se	Periodic	Num	Edit
	Successful	PC0	PC1	ICMP		0.000	N	0	(edit)
	Successful	PC0	PC2	ICMP		0.000	N	1	(edit)
	Successful	PC0	Server0	ICMP		0.000	N	2	(edit)

Fire	Last Status	Source	Destination	Type	Color	Time(se	Periodic	Num	Edit
	Successful	PC1	PC0	ICMP		0.000	N	0	(edit)
	Successful	PC1	PC2	ICMP		0.000	N	1	(edit)
	Successful	PC1	Server0	ICMP		0.000	N	2	(edit)

Fire	Last Status	Source	Destination	Type	Color	Time(se	Periodic	Num	Edit
	Successful	PC2	PC0	ICMP		0.000	N	0	(edit)
	Successful	PC2	PC1	ICMP		0.000	N	1	(edit)
	Successful	PC2	Server0	ICMP		0.000	N	2	(edit)

Fire	Last Status	Source	Destination	Type	Color	Time(se	Periodic	Num	Edit
	Successful	Server0	PC0	ICMP		0.000	N	0	(edit)
	Successful	Server0	PC1	ICMP		0.000	N	1	(edit)
	Successful	Server0	PC2	ICMP		0.000	N	2	(edit)

Figure 2.6. The successful ping results for each device in the network.

B. Configuring IPv6 EGRP (Practical part):

- Consider the following scenario, as demonstrated in Figure 2.7, which helps you practice configuring IPv6 EIGRP on routers, followed by the addressing table for each interface, as shown in Table 2.3.

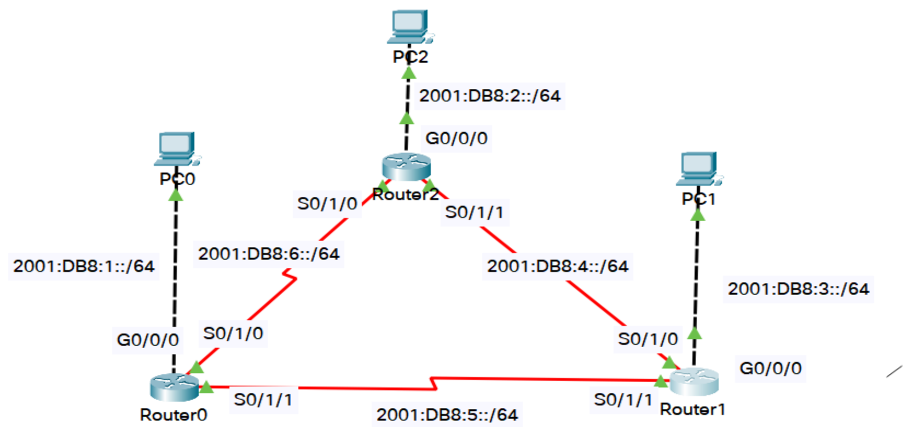


Figure 2.7. The network topology for IPv6 EIGRP.

Table 2.3. Initial IPv6 configuration

Device	Interface	IP configuration	Connected with	Default gateway
PC0	Fa 0	2001:DB8:1::2/64	Router0' G0/0/0	FE80::1
PC1	Fa 0	2001:DB8:3::2/64	Router1' G0/0/0	FE80::2
PC2	Fa 0	2001:DB8:2::2/64	Router2' G0/0/0	FE80::3
Router 0	G0/0/0	2001:DB8:1::1/64	PC0' Fa0	N/A
	S0/1/0	2001:DB8:6::1/64	Router 2' S0/1/0	N/A
	S0/1/1	2001:DB8:5::1/64	Router 1's S0/1/1	N/A
	Link-local	FE80::1	-	N/A
Router 1	G0/0/0	2001:DB8:3::1/64	PC1's Fa0	N/A
	S0/1/0	2001:DB8:4::1/64	Router'2 S0/1/1	N/A
	S0/1/1	2001:DB8:5::2/64	Router0' S0/1/1	N/A
	Link-local	FE80::2	-	N/A
Router 2	G0/0/0	2001:DB8:3::1/64	PC2's Fa0	N/A
	S0/1/0	2001:DB8:6::2/64	Router 0' S0/1/0	N/A
	S0/1/1	2001:DB8:4::2/64	Router 1' S0/1/0	N/A
	Link-local	FE80::3	-	N/A

1. Assign IP addresses to PCs and server

Double-click on **each PC**, click the **Desktop** menu item, and click **IP Configuration**. Assign IPv6 addresses and the default gateway for each PC, as shown in the addressing table (Table 2.3).

2. Assign IP address to interfaces of routers

Double-click Router1 and click CLI, then press the Enter key to access the command prompt for Router1. We need to enable IPv6 on the route, configure IPv6 addresses on interfaces, and enable them before we can actually use them for routing. Interface mode is used to assign IPv6 addresses, which can be accessed from the global configuration mode. **<u>These steps are repeated for all routers.</u>**

```
Router1>enable
Router1# configure terminal
Router1(config)#ipv6 unicast-routing

Router1(config)#interface GigabitEthernet0/0/0
Router1(config-if)#ipv6 address 2001:DB8:3::1/64
Router1(config-if)#no shutdown
Router1(config-if)#exit

Router1(config)#
Router1(config)#interface s0/1/0
Router1(config-if)#ipv6 address 2001:DB8:4::1/64
Router1(config-if)#no shutdown
Router1(config-if)#exit

Router1(config)#interface Serial0/1/1
Router1(config-if)#ipv6 address 2001:DB8:5::2/64
Router1(config-if)#no shutdown
Router1(config-if)#ipv6 address FE80::2 link-local
Router1(config-if)#exit
```

Now routers have information about the networks that they have on their own interfaces. Routers will not exchange this information between them on their own. We need to implement the EIGRP routing protocol, which will insist them to share this information.

3. Configure the IPv6 EIGRP routing protocol

Configuration of the IPv6 EIGRP protocol is much easier than you think. It requires enabling EIGRP in IPv6 with an AS number, assigning a router ID, and enabling it with the **"no shutdown"** command. It is worth mentioning that you can use any value for the AS number and router ID, or as required by you in the question. After that, we must enter each interface and enable IPv6 EIGRP with the same AS number assigned to the EIGRP in the global configuration mode. The following are the exact steps needed to configure EIGRP on Router 0, Router 1, and Router 2.

Let's configure it in Router0:

```
Router0(config)#ipv6 router eigrp 10

Router0(config-rtr)#router eigrp router-id 1.1.1.1
Router0(config-rtr)#no shutdown

Router0(config-rtr)#exit
Router0(config)# interface g0/0/0
Router0(config-if)#ipv6 eigrp 10

Router0(config)# interface s0/1/0
Router0(config-if)#ipv6 eigrp 10

Router0(config)# interface s0/1/1
Router0(config-if)#ipv6 eigrp 10
```

That's all we need to configure the IPv6 EIGRP. Follow same steps on remaining routers.

Let's configure it in Router1:

```
Router1(config)#ipv6 router eigrp 10
```

```
Router1(config-rtr)#router eigrp router-id 2.2.2.2
Router1(config-rtr)#no shutdown

Router1(config-rtr)#exit
Router1(config)# interface g0/0/0
Router1(config-if)#ipv6 eigrp 10

Router1(config)# interface s0/1/0
Router1(config-if)#ipv6 eigrp 10

Router1(config)# interface s0/1/1
Router1(config-if)#ipv6 eigrp 10
```

Let's configure it in Router2:

```
Router2(config)# ipv6 router eigrp 10

Router2(config-rtr)#router eigrp router-id 3.3.3.3
Router2(config-rtr)#no shutdown

Router2(config-rtr)#exit
Router2(config)# interface g0/0/0
Router2(config-if)#ipv6 eigrp 10

Router2(config)# interface s0/1/0
Router2(config-if)#ipv6 eigrp 10

Router2(config)# interface s0/1/1
Router2(config-if)#ipv6 eigrp 10
```

To verify the routing table, we can use the show IPv6 commands mentioned in the IPV6 EIGRP commands section.

Part IV: Manual Summarization: Deep Dive

The configuration of interfaces using manual summarization is shown in the following Figure:

```
Router(config-if)# ip summary-address eigrp
             [as-number]
             [network-address]
             [subnet-mask]
```

Figure 2.8. Manual Summarization: Interface Configuration

Figures 2.9-2.11 provide an example of how to configure interfaces utilizing manual summarization taking into account that the three networks (192.168.1.0/24, 192.168.2.0/24, and 192.168.3.0/24), which are directly connected to R3, will be configured at R3 interfaces, namely, S0/0/0 and S0/0/1 to be then summarized to R1 and R2, respectively.

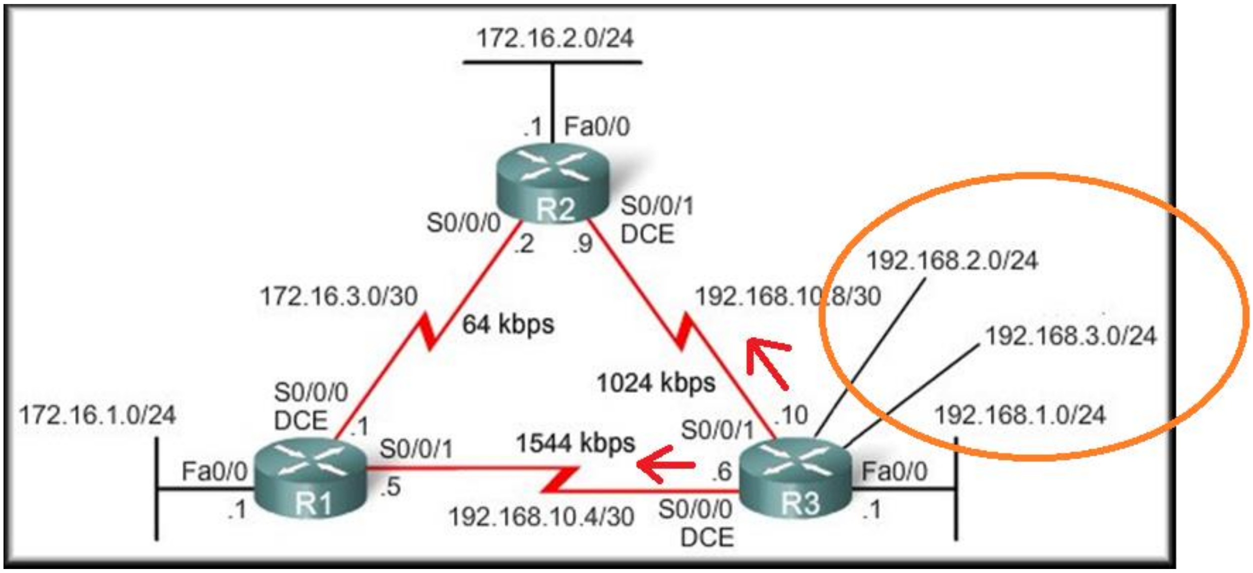


Figure 2.9. Manual Summarization: Example 1

192.168.1.0:	11000000	.	10101000	.	00000001	.	00000000
192.168.2.0:	11000000	.	10101000	.	00000010	.	00000000
192.168.3.0:	11000000	.	10101000	.	00000011	.	00000000

Figure 2.10. Manual Summarization: Three Routes Summarization (/22 or 255.255.252.0)

```
R3(config)# interface serial 0/0/0
R3(config-if)# ip summary-address eigrp 1 192.168.0.0 255.255.252.0
R3(config-if)# interface serial 0/0/1
R3(config-if)# ip summary-address eigrp 1 192.168.0.0 255.255.252.0
```

Figure 2.11. Manual Summarization: Interface Configuration

Another example, in Figure 2.12, Router "Two" summarizes 192.168.1.0/24, 192.168.2.0/24, and 192.168.3.0/24 into the CIDR block 192.168.0.0/22.

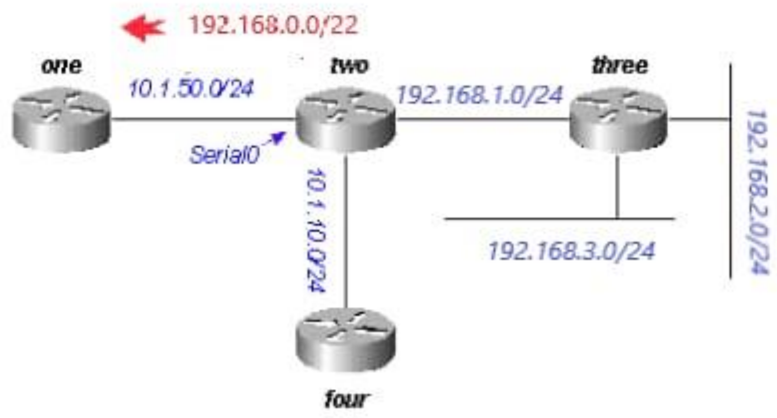


Figure 2.12. Manual Summarization Example 2

The configuration on Router "Two" is shown:

```
two#show running-config
....
!
interface Serial0
 ip address 10.1.50.1 255.255.255.0
 ip summary-address eigrp 2000 192.168.0.0 255.255.252.0
!
....
```

```
two#show ip eigrp topology
IP-EIGRP Topology Table for process 2000

Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
      r - Reply status

P 10.1.10.0/24, 1 successors, FD is 45842176
        via Connected, Loopback0
P 10.1.50.0/24, 1 successors, FD is 2169856
        via Connected, Serial0
P 192.168.1.0/24, 1 successors, FD is 10511872
        via Connected, Serial1
P 192.168.0.0/22, 1 successors, FD is 10511872
        via Summary (10511872/0), Null0
P 192.168.3.0/24, 1 successors, FD is 10639872
        via 192.168.1.1 (10639872/128256), Serial1
P 192.168.2.0/24, 1 successors, FD is 10537472
        via 192.168.1.1 (10537472/281600), Serial1
```

Look at the **ip summary-address eigrp** command under interface Serial0 and the summary route via Null0. On Router One, this is seen as an internal route:

```
one#show ip eigrp topology
IP-EIGRP Topology Table for process 2000

Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - Reply status

P 10.1.10.0/24, 1 successors, FD is 46354176
         via 10.1.50.1 (46354176/45842176), Serial0
P 10.1.50.0/24, 1 successors, FD is 2169856
         via Connected, Serial0
P 192.168.0.0/22, 1 successors, FD is 11023872
         via 10.1.50.1 (11023872/10511872), Serial0
```

Important Note: Some parts of this handout have been collected from several trustable sites, books, and published slides and the other parts have been prepared and written by the instructors. As a matter of fact, this handout is made to be so straight forward, understandable, and so attractive whereas the students can do the required activities and solve the problems in a systematic and easy way, but still the instructors are expected to discuss some important material during the labs' sessions.