Chapter 9

Enhanced Interior Gateway Routing Protocol (EIGRP)

Part I

Note for Instructors

- These presentations are the result of a collaboration among the instructors at St. Clair College in Windsor, Ontario.
- Thanks must go out to Rick Graziani of Cabrillo College. His material and additional information was used as a reference in their creation.
- If anyone finds any errors or omissions, please let me know at:
  - tdame@stclaircollege.ca.

EIGRP

DUAL

DUAL provides:

- Loop-free paths
- Loop-free backup paths which can be used immediately
- Fast convergence
- Minimum bandwidth usage with bounded updates

DUAL Concepts

- Diffusing Update ALgorithm (DUAL) provides the following:
  - Loop-free paths.
  - Loop-free backup paths which can be used immediately.
  - Fast convergence.
  - Minimum bandwidth usage with bounded updates.

DUAL Concepts

- Diffusing Update ALgorithm (DUAL) uses several terms that we will discuss in more detail throughout this section:
  - Successor.
  - Feasible distance.
  - Feasible successor.
  - Reported distance or advertised distance.
  - Feasible condition or feasibility condition.

Successor and Feasible Distance

```
R2# show ip route
<output omitted>
D       192.168.1.0/24 [90/3014400] via 192.168.10.10, 00:00:15, S0/0/1
```

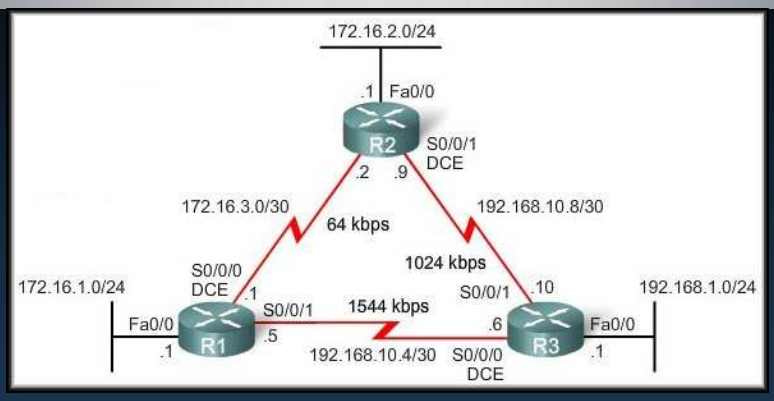
- A successor is:
  - A neighboring router that is used for packet forwarding.
  - The least-cost route to the destination network.
- The IP address of a successor is shown in a routing table entry right after the word *via*.

Successor and Feasible Distance

```
R2# show ip route
<output omitted>
D       192.168.1.0/24 [90/3014400] via 192.168.10.10, 00:00:15, S0/0/1
```

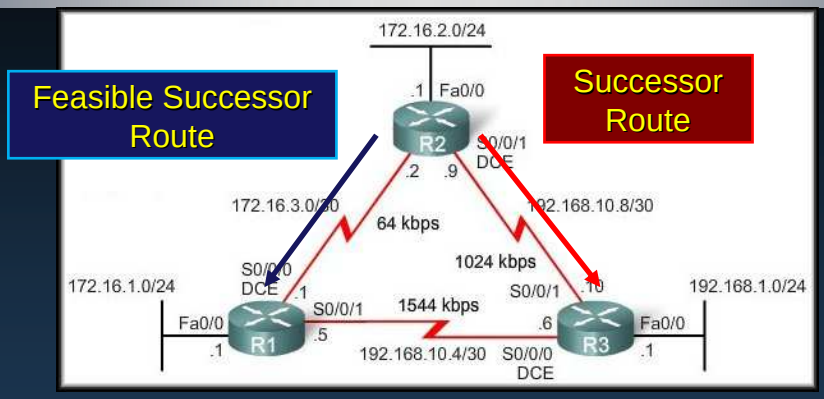
- Feasible Distance (FD):
  - Is the lowest calculated metric to reach the destination network.
  - Feasible Distance is listed in the routing table entry as the second number inside the brackets.
  - As with other routing protocols, this is the metric for the route.

Feasible Successors



- 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 re-compute DUAL.

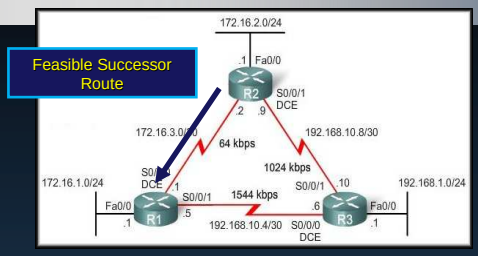
Feasible Successors



- A Feasible Successor (FS) is a neighbor who has a loop-free backup path to the same network as the successor.

Feasibility Condition and Reported Distance

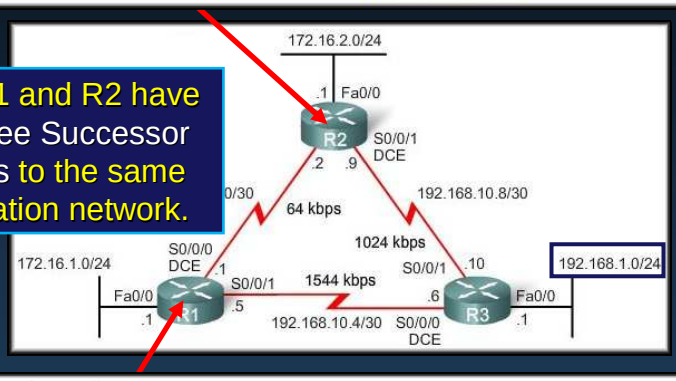
- How does a route become a Feasible Successor?
  - It must meet the Feasibility Condition.



- Feasibility Condition (FC):
  - The FC is met when a neighbor's Reported Distance to a network is less than the local router's Feasible Distance to the same destination network.

Feasibility Condition and Reported Distance

```
R2# show ip route
<output omitted>
D       192.168.1.0/24 [90/3014400] via 192.168.10.10, 00:00:15, S0/0/1
```

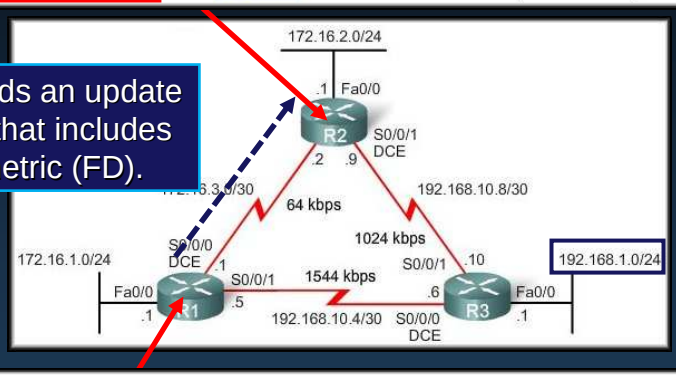


Both R1 and R2 have loop-free Successor Routes to the same destination network.

```
R1# show ip route
<output omitted>
D 192.168.1.0/24 [90/2172416] via 192.168.10.6, 01:12:26, Serial0/0/1
```


Feasibility Condition and Reported Distance

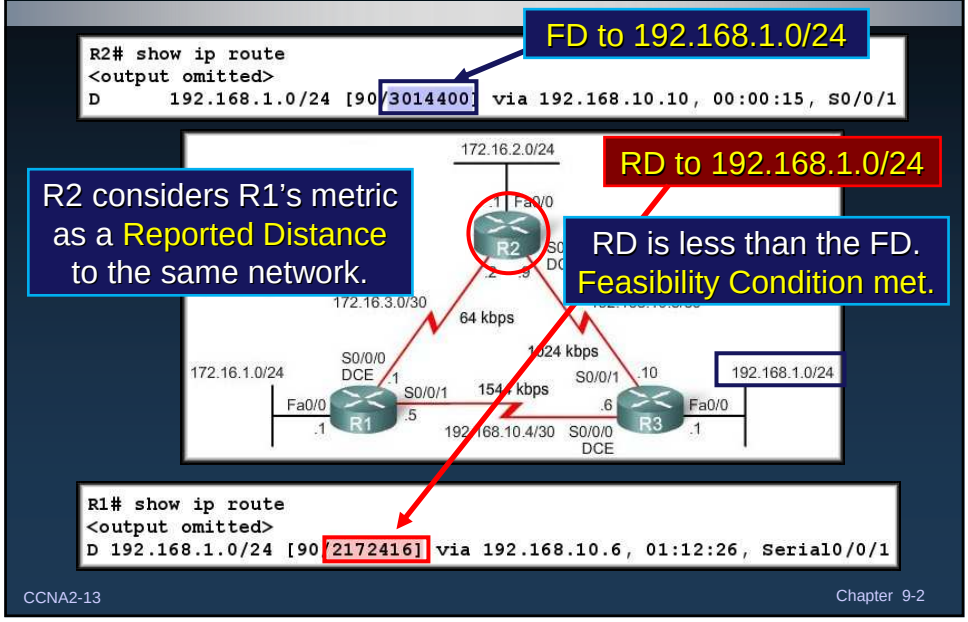
```
R2# show ip route
<output omitted>
D       192.168.1.0/24 [90/3014400] via 192.168.10.10, 00:00:15, S0/0/1
```



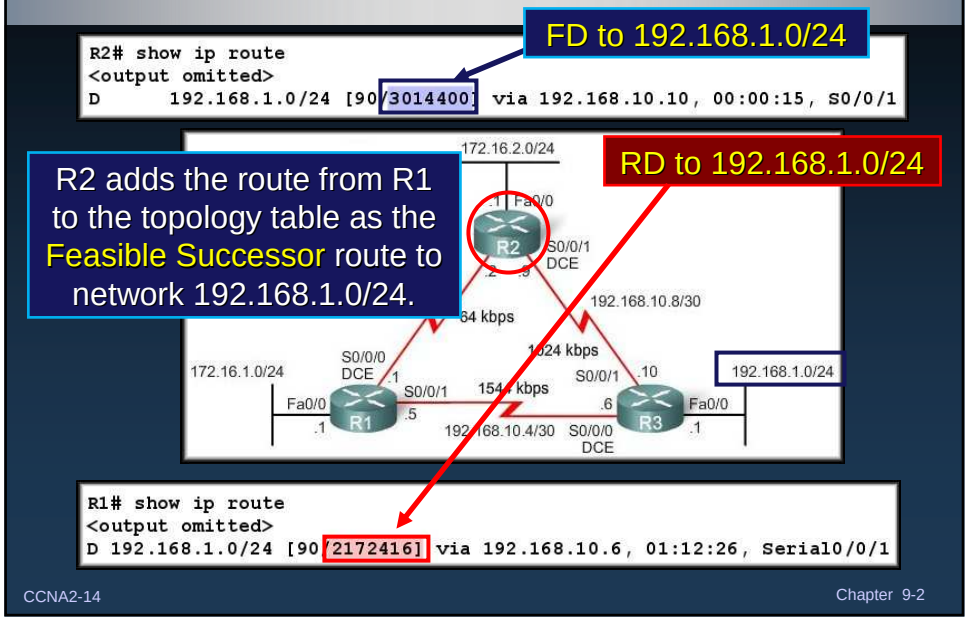
R1 sends an update to R2 that includes its metric (FD).

```
R1# show ip route
<output omitted>
D 192.168.1.0/24 [90/2172416] via 192.168.10.6, 01:12:26, Serial0/0/1
```

Feasibility Condition and Reported Distance



Feasibility Condition and Reported Distance



Topology Table

```
R2# show ip eigrp topology
IP-EIGRP Topology Table for AS(1)/ID(10.1.1.1)
 Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
r - reply Status, s - sia Status
<output omitted>

P 192.168.1.0/24, 1 successors, FD is 3014400
          via 192.168.10.10 (3014400/28160), Serial0/0/1
          via 172.16.3.1 (41026560/2172416), Serial0/0/0
P 192.168.10.8/30, 1 successors, FD is 3011840
          via Connected, Serial0/1
<output omitted>
```

- Successor and Feasible Successor:
  - The Successor, Feasible Distance, and any Feasible Successors with their Reported Distances are kept by a router in its EIGRP topology table.

Topology Table: Successor

Two States:
Active (A): Being recalculated by DUAL.
Passive (P): A stable successor route.

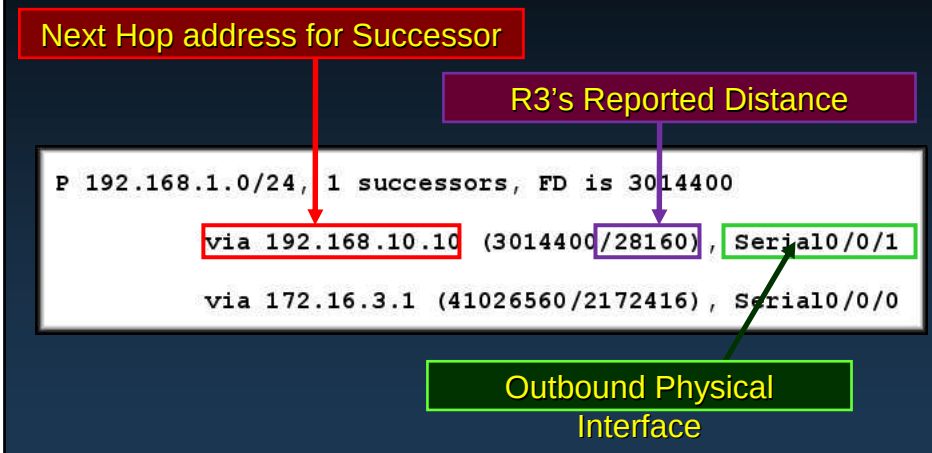
```
P 192.168.1.0/24, 1 successors, FD is 3014400
          via 192.168.10.10 (3014400/28160), Serial0/0/1
          via 172.16.3.1 (41026560/2172416), Serial0/0/0
```

Destination Network

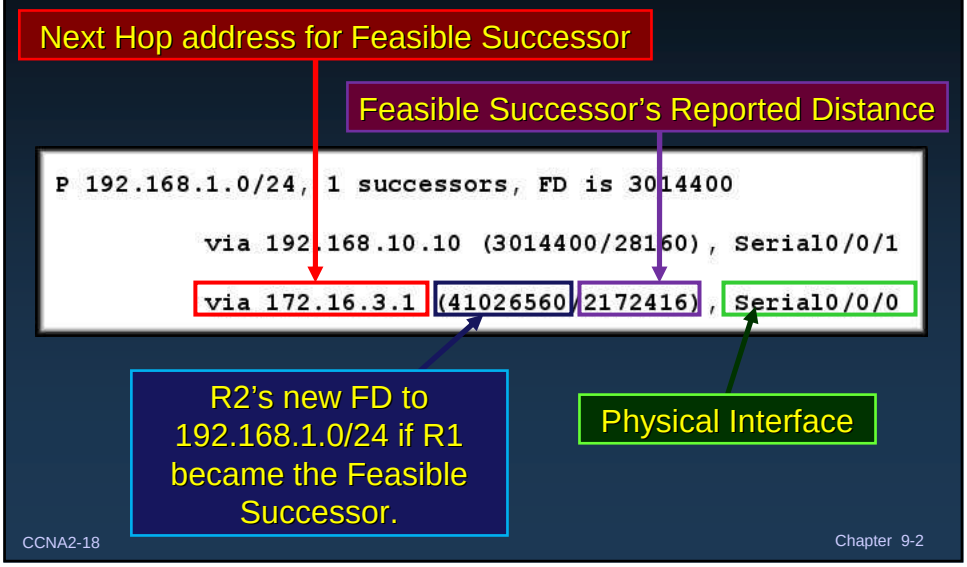
Number of Successors

Feasible Distance to Successor

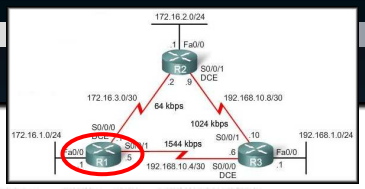
Topology Table: Successor



Topology Table: Feasible Successor



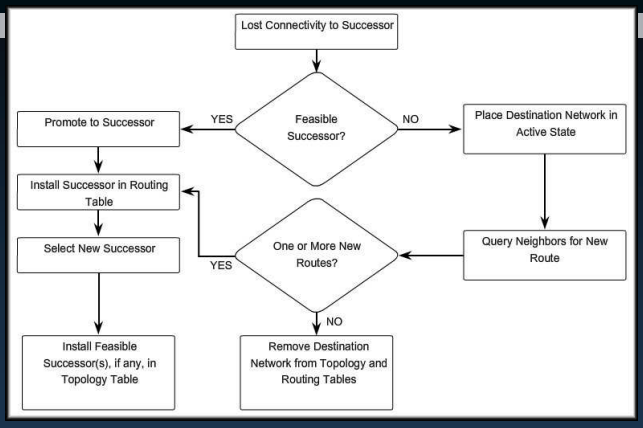
Topology Table: NO Feasible Successor




```
R1# show ip eigrp topology
<output omitted>
P 192.168.1.0/24, 1 successors, FD is 2172416
        via 192.168.10.6 (2172416/28160), Serial0/0/1
<output omitted>
```

- The above is a portion of R1's topology table that shows its link to network 192.168.1.0/24.
  - Why has R2's route NOT become the feasible successor for R1?
    - It does not meet the Feasibility Condition.
- EIGRP is a distance vector routing protocol and only knows about remote network information through its neighbors.

Finite State Machine (DUAL FSM)



- The centerpiece of EIGRP is DUAL and its EIGRP route-calculation engine – the Finite State Machine.
- This FSM contains all the logic used to calculate and compare routes in an EIGRP network.

Finite State Machine (DUAL FSM)

- What is FSM?
  - An FSM is an abstract machine, not a mechanical device with moving parts.
  - FSMs define a set of possible states something can go through, what events causes those states, and what events result from those states.
  - Designers use FSMs to describe how a device, computer program, or routing algorithm will react to a set of input events.

EIGRP

More EIGRP Configurations

Null0 Summary Route

Disable Automatic Summarization

Manual Summarization

EIGRP Default Route

The Null0 Summary Route

```
R1# show ip route
<output omitted>

   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, S0/0/0
C     172.16.3.0/30 is directly connected, Serial0/0/0

<output omitted>
```

- EIGRP automatically includes a Null0 summary route as a child route whenever both of the following conditions exist:
  - There is at least one subnet that was learned via EIGRP.
  - Automatic summarization is enabled (default).
- R1 will discard any packets that match the parent classful network but do not match one of the child routes.

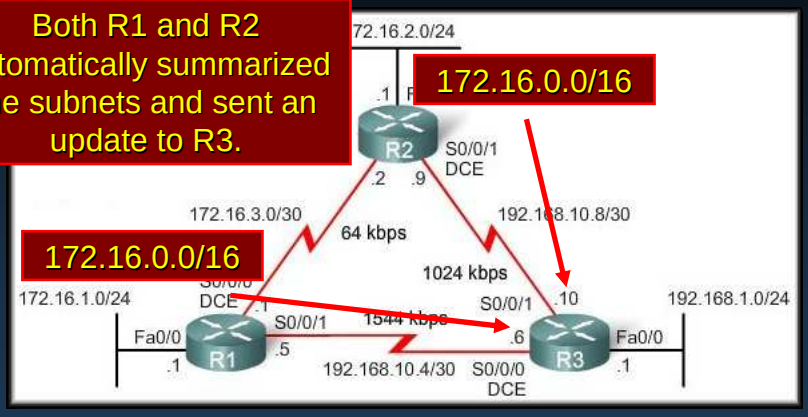
The Null0 Summary Route

```
R1# show ip route
<output omitted>

   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, S0/0/0
C     172.16.3.0/30 is directly connected, Serial0/0/0

<output omitted>
```

- You might think that if you configure classless routing behavior with the **ip classless** command, EIGRP would not discard that packet but would continue looking for a default or supernet route.
- This Null0 summary route is a child route that will match any possible packets of the parent route regardless of the **ip classless** / **no ip classless** command.

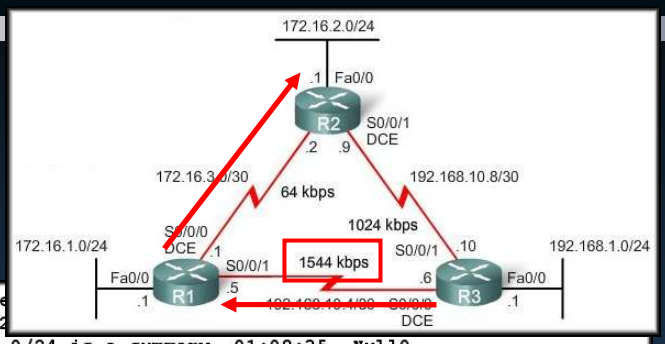
Disabling Automatic Summarization

Both R1 and R2 automatically summarized the subnets and sent an update to R3.



- Like RIP, EIGRP automatically summarizes at major network boundaries using the default **`auto-summary`** command.

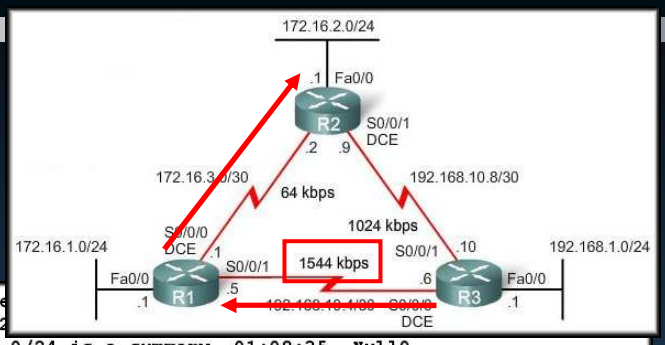
Disabling Automatic Summarization




```
R3# show ip route
    192.168.10.0/2
D      192.168.10.0/24 is a summary, 01:08:35, Null0
C      192.168.10.4/30 is directly connected, Serial0/0/0
C      192.168.10.8/30 is directly connected, Serial0/0/1
D    172.16.0.0/16 [90/2172416] via 192.168.10.5, 01:08:30, Serial0/0/0
C    192.168.1.0/24 is directly connected, FastEthernet0/0
```

- The result is that R3 has one route to 172.16.0.0/16 through R1.
- R1 is the successor because of the difference in bandwidth.

Disabling Automatic Summarization

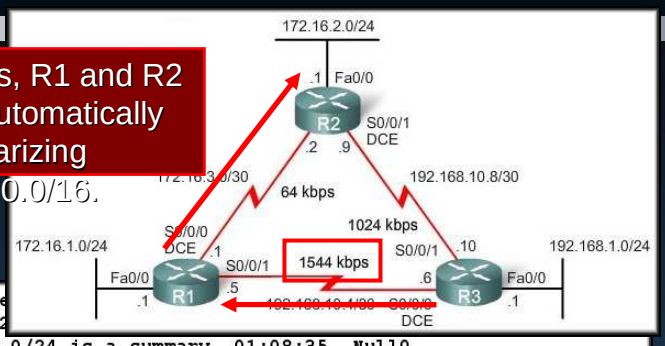



```
R3# show ip route
    192.168.10.0/2
D      192.168.10.0/24 is a summary, 01:08:35, Null0
C      192.168.10.4/30 is directly connected, Serial0/0/0
C      192.168.10.8/30 is directly connected, Serial0/0/1
D    172.16.0.0/16 [90/2172416] via 192.168.10.5, 01:08:30, Serial0/0/0
C    192.168.1.0/24 is directly connected, FastEthernet0/0
```

- R3 will route all packets destined for 172.16.2.0 through R1.
- R3 does not know that R1 will then have to route these packets across a very slow link to R2 (64 Kbps).

Disabling Automatic Summarization

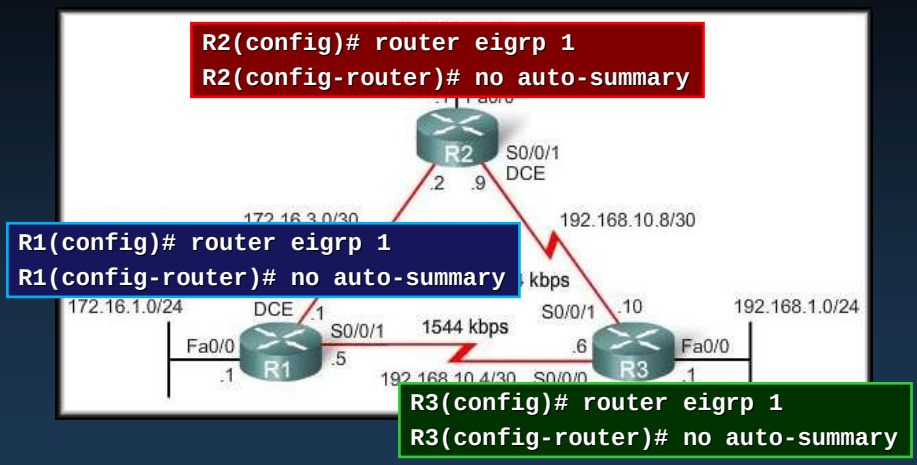
In other words, R1 and R2 must stop automatically summarizing 172.16.0.0/16.




```
R3# show ip route
    192.168.10.0/2
D      192.168.10.0/24 is a summary, 01:08:35, Null0
C      192.168.10.4/30 is directly connected, Serial0/0/0
C      192.168.10.8/30 is directly connected, Serial0/0/1
D    172.16.0.0/16 [90/2172416] via 192.168.10.5, 01:08:30, Serial0/0/0
C    192.168.1.0/24 is directly connected, FastEthernet0/0
```

- The only way R3 can learn about this slow bandwidth is if R1 and R2 send individual routes for each of the 172.16.0.0/16 subnets.

Disabling Automatic Summarization



- Automatic summarization can be disabled with the **`no auto-summary`** command.

Disabling Automatic Summarization

Before

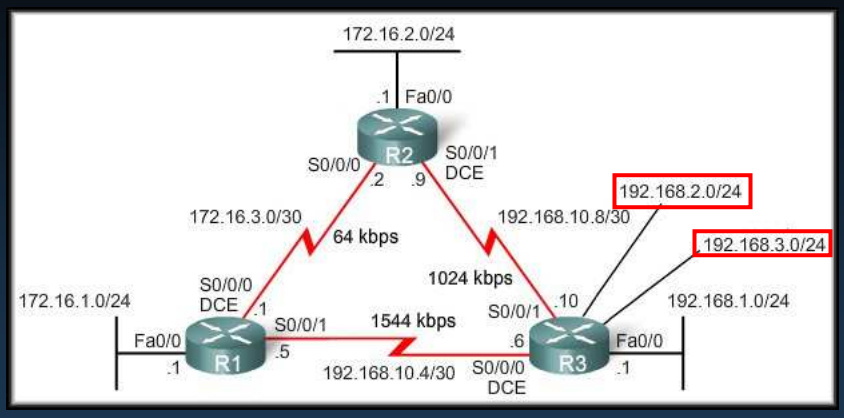
```
R3# show ip route
    192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
C       192.168.10.0/24 is a summary, 01:08:35, Null0
C       192.168.10.4/30 is directly connected, Serial0/0/0
C       192.168.10.8/30 is directly connected, Serial0/0/1
D   172.16.0.0/16 [90/2172416] via 192.168.10.5, 01:08:30, Serial0/0/0
C   192.168.1.0/24 is directly connected, FastEthernet0/0
```

After

```
R3# show ip route

    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, S0/0/0
D       172.16.2.0/24 [90/3014400] via 192.168.10.9, 00:00:12, S0/0/1
D       172.16.3.0/30 [90/41024000] via 192.168.10.5, 00:00:12, S0/0/0
                      [90/41024000] via 192.168.10.9, 00:00:12, S0/0/1
C   192.168.1.0/24 is directly connected, FastEthernet0/0
```

- Without automatic summarization, R3's routing table now includes the three subnets.

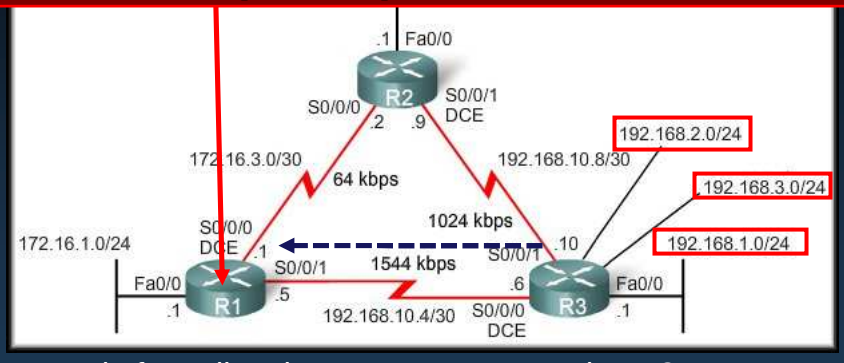
Manual Summarization



- EIGRP can be configured to summarize routes, whether or not automatic summarization is enabled.
  - Modify the topology to add two more networks to R3.

Manual Summarization

```
R1# show ip route
D   192.168.1.0/24 [90/2172416] via 192.168.10.6, 02:07:38, S0/0/1
D   192.168.2.0/24 [90/2297856] via 192.168.10.6, 00:00:34, S0/0/1
D   192.168.3.0/24 [90/2297856] via 192.168.10.6, 00:00:18, S0/0/1
```



- Instead of sending three separate networks, R3 can summarize the 192.168.1.0/24, 192.168.2.0/24, and 192.168.3.0/24 networks as a single route.

Manual Summarization

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

- Write out the networks that you want to summarize in binary.
- Find the matching bits.
- Count the number of leftmost matching bits, which in this example is **22**.
- This number becomes your subnet mask for the summarized route **(/22 or 255.255.252.0)** .
- To find the network address for summarization, copy the matching 22 bits and add all 0 bits to the end to make 32 bits.
- The result is the summary network address and mask for **192.168.0.0/22**

Configure EIGRP Manual Summarization

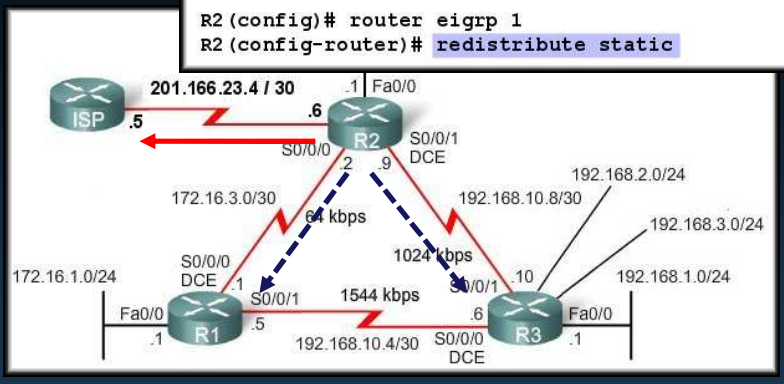
```
Router(config-if)# ip summary-address eigrp
                   [as-number]
                   [network-address]
                   [subnet-mask]
```

```
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
```

- Because R3 has two EIGRP neighbours, EIGRP manual summarization is configured on both serial interfaces and will be propagated to the neighbours.

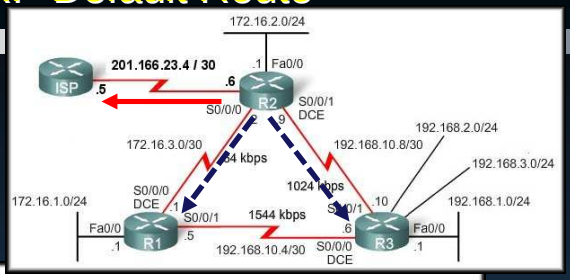
EIGRP Default Route

```
R2(config)# ip route 0.0.0.0 0.0.0.0 201.166.23.5

R2(config)# router eigrp 1
R2(config-router)# redistribute static
```



- Using a static route to 0.0.0.0/0 as a default route is not routing protocol dependent.
- EIGRP requires the use of the **`redistribute static`** command to include this static default route with its updates.

EIGRP Default Route




```
R1# show ip route
Gateway of last resort is 192.168.10.6 to network 0.0.0.0

D*EX   0.0.0.0/0 [170/3651840] via 192.168.10.6, 00:02:14, S0/0/1
```

```
R2# show ip route
Gateway of last resort is 0.0.0.0 to network 0.0.0.0

S*    0.0.0.0/0 is directly connected, 201.166.23.5
```

```
R3# show ip route
Gateway of last resort is 192.168.10.9 to network 0.0.0.0

D*EX   0.0.0.0/0 [170/3139840] via 192.168.10.9, 00:01:25, S0/0/1
```

EIGRP Default Route

```
R3# show ip route
Gateway of last resort is 192.168.10.9 to network 0.0.0.0

D*EX   0.0.0.0/0 [170/3139840] via 192.168.10.9, 00:01:25, S0/0/1
```

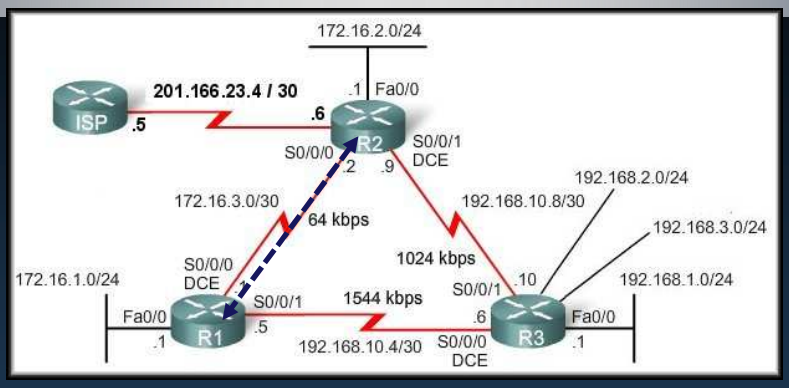
- In the routing tables for R1 and R3, notice the routing source and AD for the new static default route.
  - **D** - This static route was learned from an EIGRP routing update.
  - ***** - The route is a candidate for a default route.
  - **EX** - The route is an external EIGRP route, in this case a static route outside of the EIGRP routing domain.
  - **170** - This is the AD of an external EIGRP route.

Fine-Tuning EIGRP

```
Router(config-if)# ip bandwidth-percent eigrp
                        [as-number]
                        [percent]
```

- By default, EIGRP uses only up to 50 percent of the bandwidth of an interface for EIGRP information.
- This prevents the EIGRP process from over-utilizing a link and not allowing enough bandwidth for the routing of normal traffic.
- The **ip bandwidth-percent eigrp** command can be used to configure the percentage of bandwidth that may be used by EIGRP on an interface.

Fine-Tuning EIGRP



- We can limit EIGRP to no more than 50 percent of the 64 Kbps link's bandwidth by configuring the following on R1 and R2.

```
Router(config-if)# ip bandwidth-percent eigrp 1 50
```


Hello Intervals and Hold times

```
Router(config-if)# ip hello-interval eigrp
                    [as-number]
                    [seconds]
```

```
Router(config-if)# ip hold-time eigrp
                    [as-number]
                    [seconds]
```

- Hello intervals and hold times are configurable on a per-interface basis and do not have to match with other EIGRP routers to establish adjacencies.
  - The seconds value for both hello and holdtime intervals can range from 1 to 65,535
- If you change the hello interval, make sure that you also change the hold time to a 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.