EIGRP

Routing Protocols and Concepts – Chapter 9

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Objectives

- Describe the background and history of Enhanced Interior Gateway Routing Protocol (EIGRP).
- Examine the basic EIGRP configuration commands and identify their purposes.
- Calculate the composite metric used by EIGRP.
- Describe the concepts and operation of DUAL.
- Describe the uses of additional configuration commands in EIGRP.

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Introduction

In this chapter, you will learn to:

- Describe the background and history of EIGRP.
- Describe the features and operation of EIGRP.
- Examine the basic EIGRP configuration commands and identify their purposes.
- Calculate the composite metric used by EIGRP.
- Describe the concepts and operation of DUAL.
- Describe the uses of additional configuration commands in EIGRP.

	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector Routing Protocols		Link State Routing Protocols		Path Vector
Classful	RIP	IGRP			EGP
Classless	RIPv2	EIGRP	OSPFv2	IS-IS	BGPv4
	RIPng	EIGRP for IPv6	OSPFv3	IS-IS for IPv6	BGPv4 for IPv6

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EIGRP

- Roots of EIGRP: IGRP
  - -Developed in 1985 to overcome RIPv1's limited hop count
  - -Distance vector routing protocol
  - -Metrics used by IGRP
    - bandwidth (used by default)
    - Delay (used by default)
    - reliability
    - load
  - -Discontinued support starting with IOS 12.2(13)T & 12.2(R1s4)S

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EIGRP

EIGRP Message Format

- EIGRP Header
  - Data link frame header - contains source and destination MAC address
  - IP packet header - contains source & destination IP address
  - EIGRP packet header - contains AS number
  - Type/Length/Field - data portion of EIGRP message

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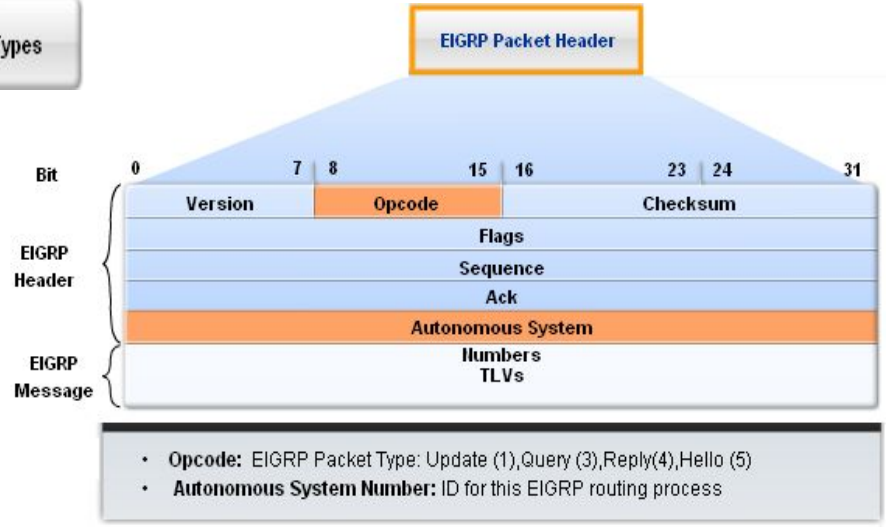
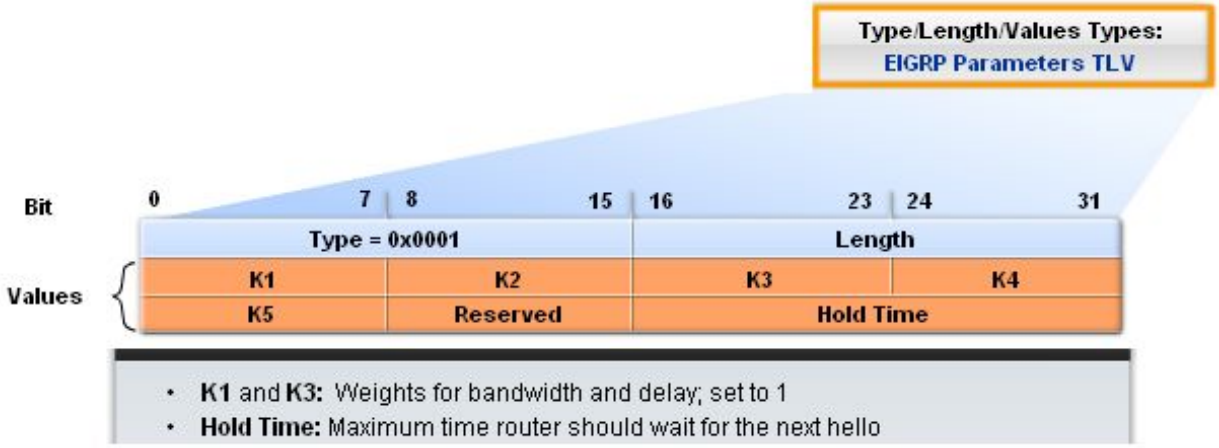
EIGRP

- **EIGRP packet header** contains
  - **Opcode field**
  - **Autonomous System number**
- **EIGRP Parameters** contains
  - **Weights**
  - **Hold time**





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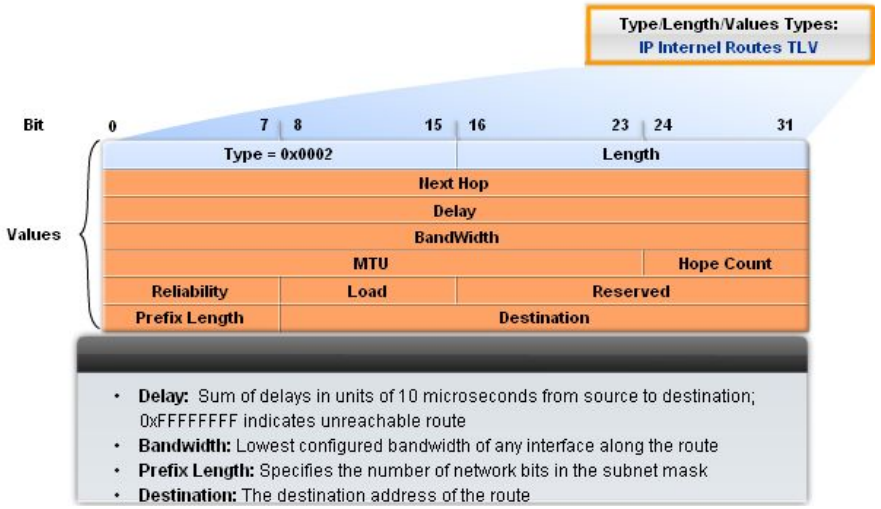
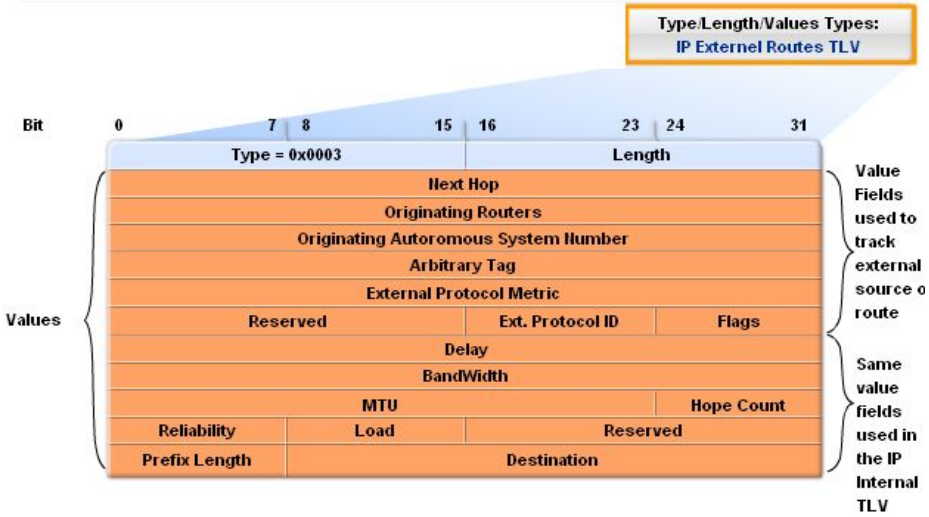
EIGRP

- **TLV: IP internal** contains
  - Metric field
  - Subnet mask field
  - Destination field
- **TLV: IP external** contains
  - Fields used when external routes are imported into EIGRP routing process





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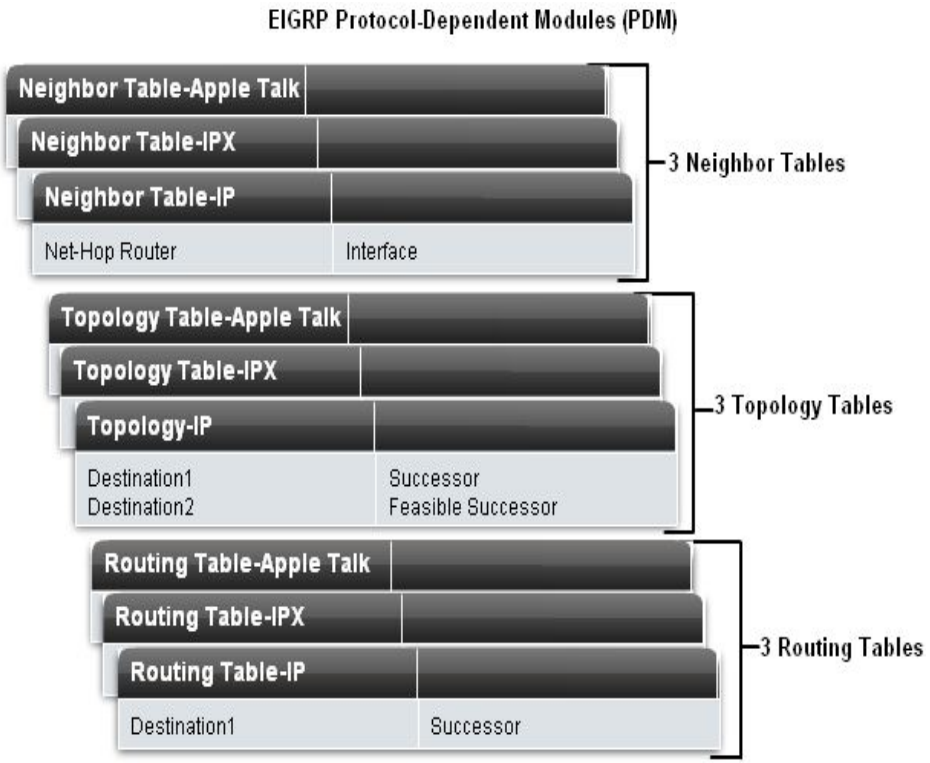
EIGRP

Protocol Dependent Modules (PDM)

- EIGRP uses PDM to route several different protocols i.e. IP, IPX & AppleTalk
- PDMs are responsible for the specific routing task for each network layer protocol



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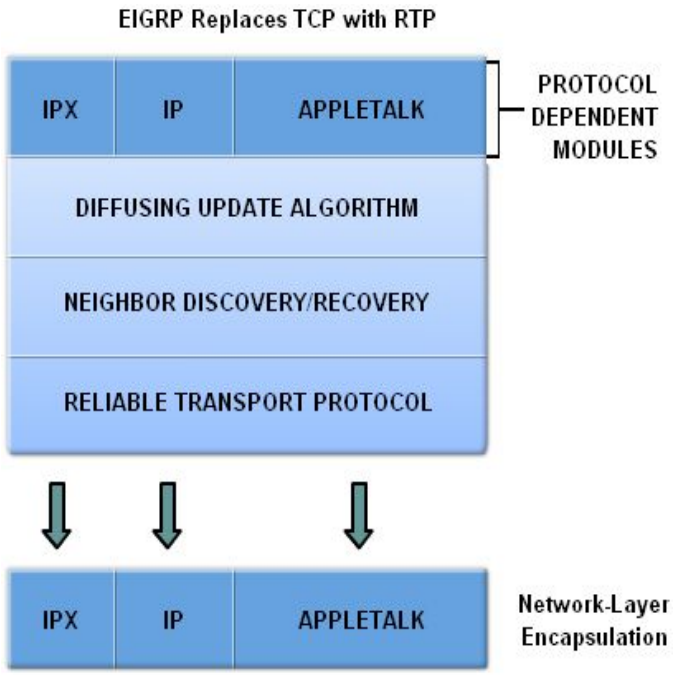
EIGRP

Reliable Transport Protocol (RTP)

- **Purpose of RTP**
  - Used by EIGRP to transmit and receive EIGRP packets
- **Characteristics of RTP**
  - Involves both reliable & unreliable delivery of EIGRP packet
    - Reliable delivery requires acknowledgment from destination
    - Unreliable delivery does not require an acknowledgement from destination
  - Packets can be sent
    - Unicast
    - Multicast
      - Using address 224.0.0.10



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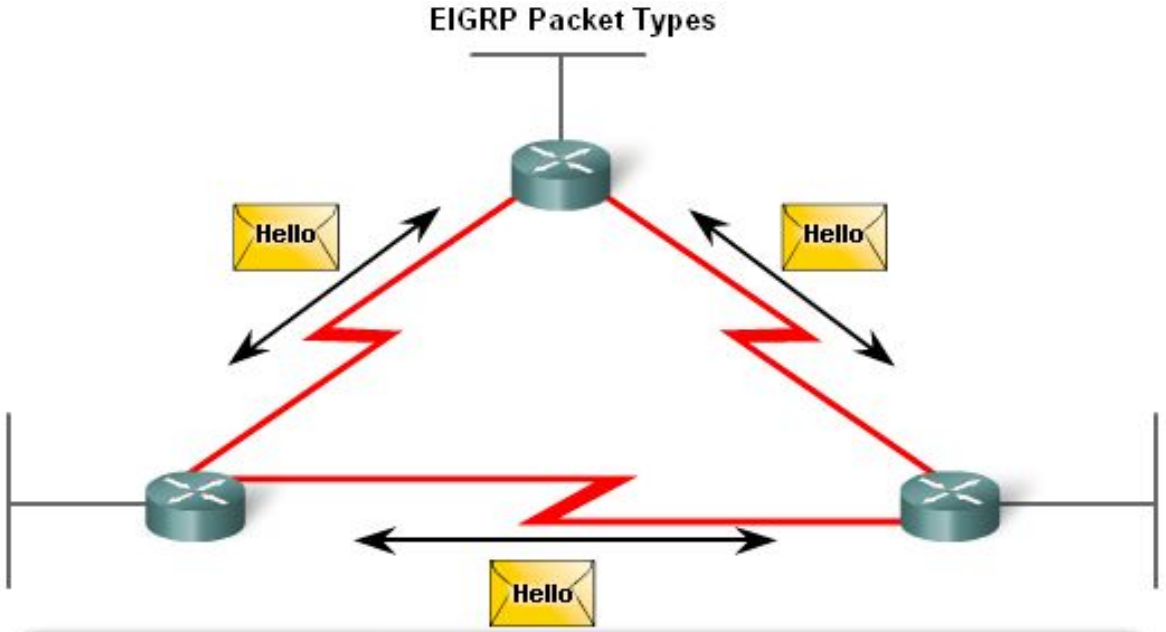
EIGRP

EIGRP's 5 Packet Types

- **Hello packets**
  - Used to discover & form adjacencies with neighbors



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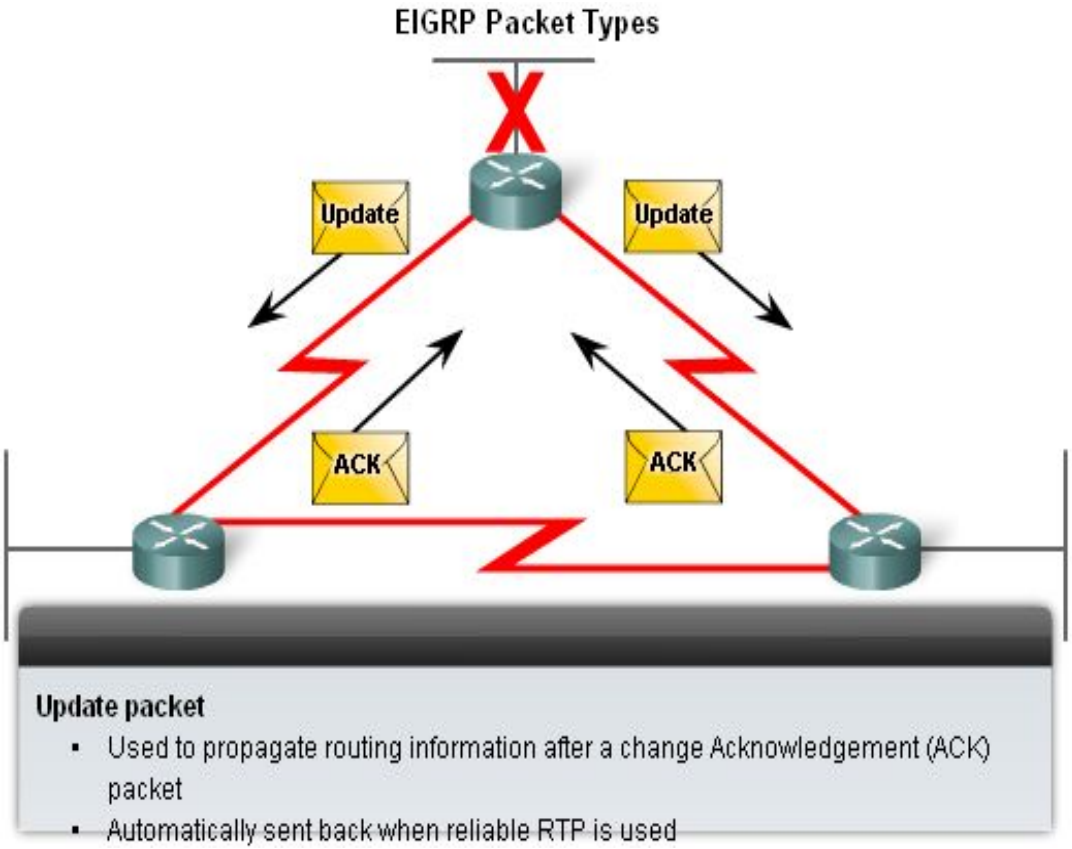
EIGRP

- **Update packets**
  - –Used to propagate routing information
- **Acknowledgement packets**
  - –Used to acknowledge rec of update, query & reply packets



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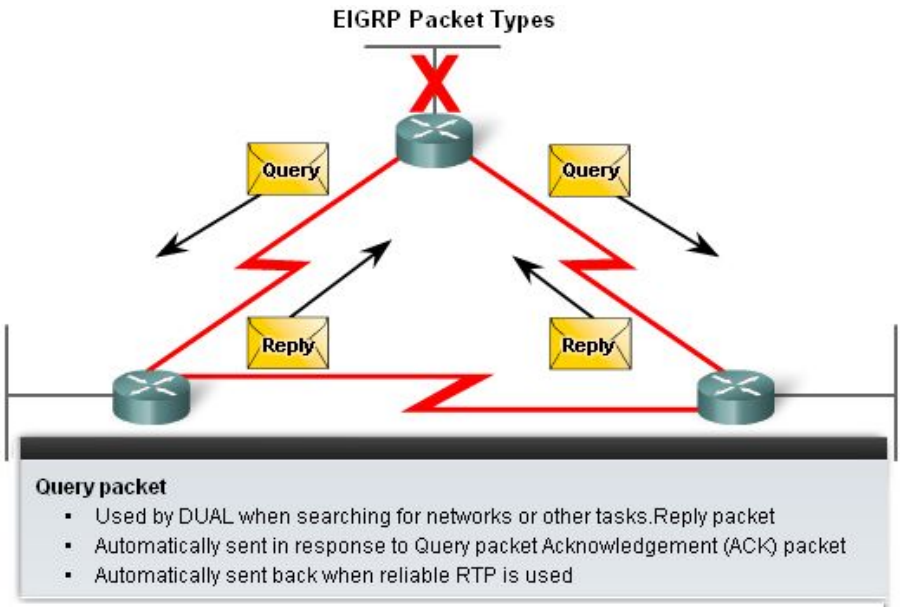
EIGRP

- **Query & Reply packets**
  - Used by DUAL for searching for networks
  - Query packets
    - -Can use
      - Unicast
      - Multicast
  - Reply packet
    - -Use only
      - unicast



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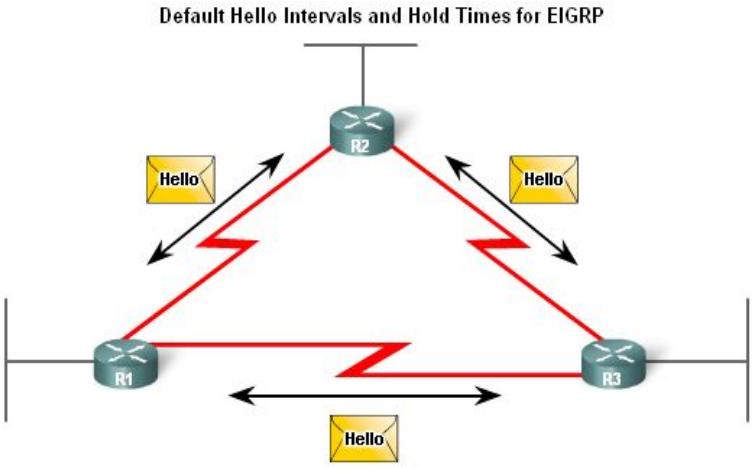
EIGRP

- **Purpose of Hello Protocol**
  - To discover & establish adjacencies with neighbor routers
- **Characteristics of hello protocol**
  - Time interval for sending hello packet
    - Most networks it is every 5 seconds
    - Multipoint non broadcast multi-access networks
      - Unicast every 60 seconds

-Holdtime

- This is the maximum time router should wait before declaring a neighbor down
- Default holdtime
  - 3 times hello interval



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

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EIGRP

EIGRP Bounded Updates

- EIGRP only sends update when there is a change in route status
- Partial update
  - A partial update includes only the route information that has changed – the whole routing table is NOT sent
- Bounded update
  - When a route changes, only those devices that are impacted will be notified of the change
- EIGRP's use of partial bounded updates minimizes use of bandwidth

EIGRP Updates

EIGRP Updates are partial and bounded:
Partial because the update only includes information about route changes.
Bounded because only those routers affected by the change will receive the update.

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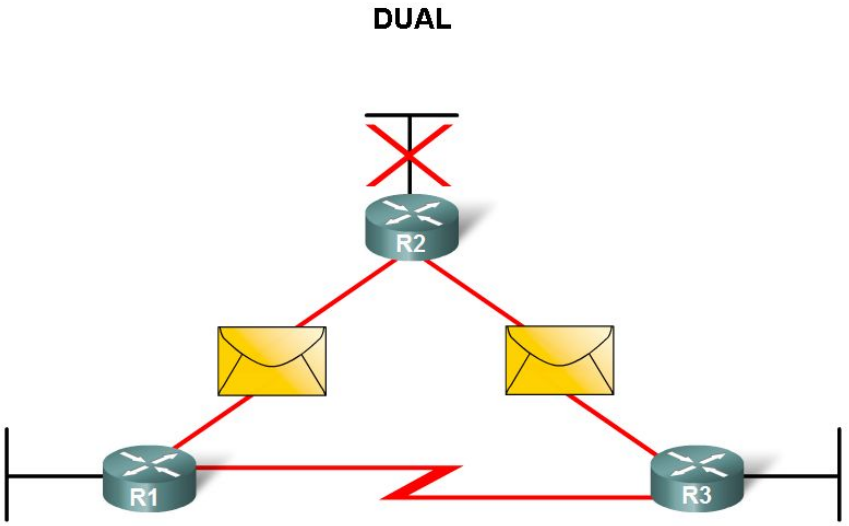
EIGRP

Diffusing **U**pdate **Al**gorithm (DUAL)

- Purpose
  - EIGRP's primary method for preventing routing loops
- Advantage of using DUAL
  - Provides for fast convergence time by keeping a list of loop-free backup routes



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EIGRP

- Administrative Distance (AD)
  - Defined as the trustworthiness of the source route
- EIGRP default administrative distances
  - Summary routes = 5
  - Internal routes = 90
  - Imported routes = 170

Default Administrative Distances

Route Source	Administrative Distance
Connected	0
Static	1
EIGRP summary route	5
External BGP	20
Internal EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
RIP	120
External EIGRP	170
Internal BGP	200

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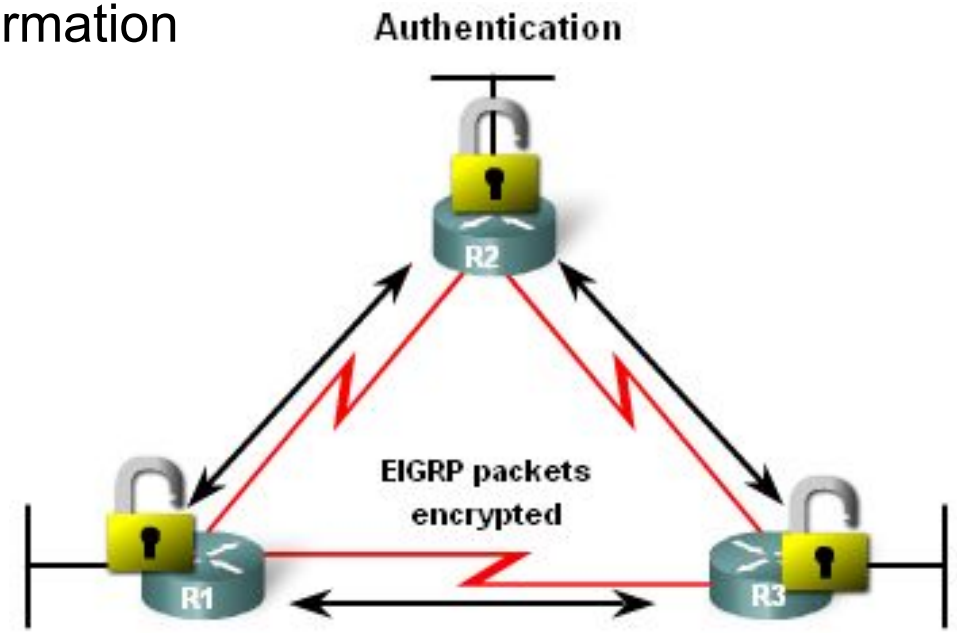
EIGRP

Authentication

- EIGRP can
  - Encrypt routing information
  - Authenticate routing information



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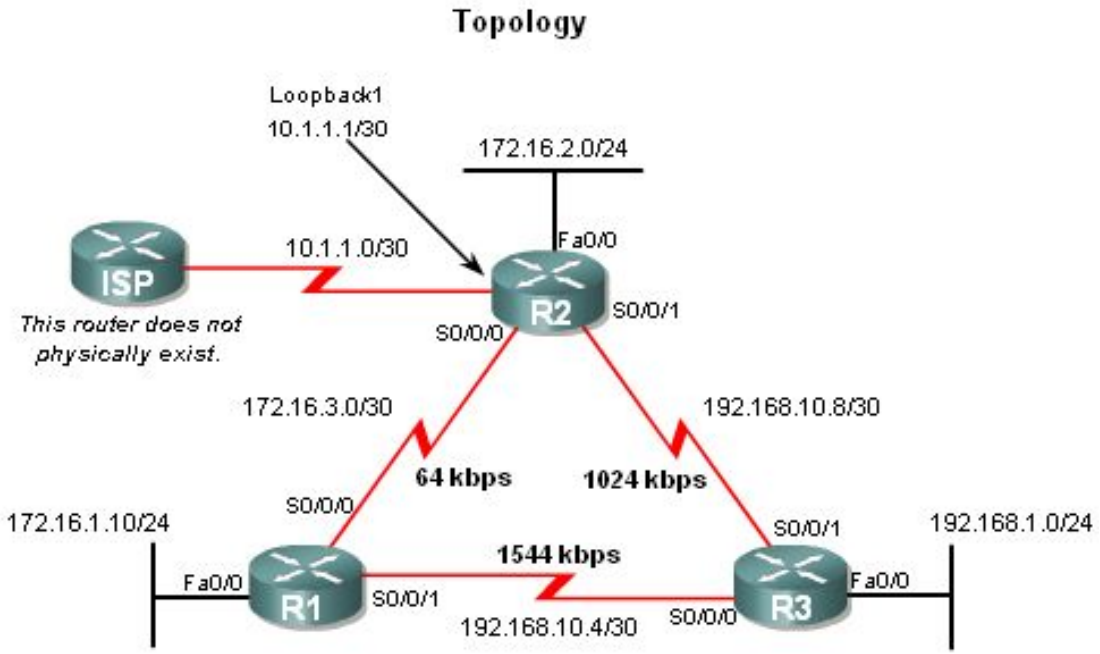
EIGRP

Network Topology

- Topology used is the same as previous chapters with the addition of an ISP router



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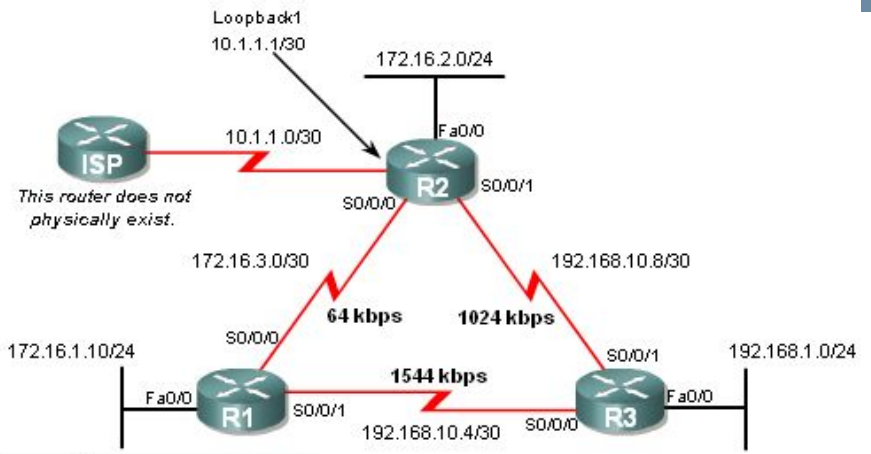
EIGRP

- EIGRP will automatically summarize routes at classful boundaries

Topology



Addressing Table

Device	Interface	IP Address	Subnet Mask
R1	Fa0/0	172.16.1.1	255.255.255.0
	S0/0/0	172.16.3.1	255.255.255.252
	S0/0/1	192.168.10.5	255.255.255.252
R2	Fa0/0	172.16.2.1	255.255.255.0
	S0/0/0	172.16.3.2	255.255.255.252
	S0/0/1	192.168.10.9	255.255.255.252
	Lo1	10.1.1.1	255.255.255.252
R3	Fa0/0	192.168.1.1	255.255.255.0
	S0/0/0	192.168.10.6	255.255.255.252
	S0/0/1	192.168.10.10	255.255.255.252

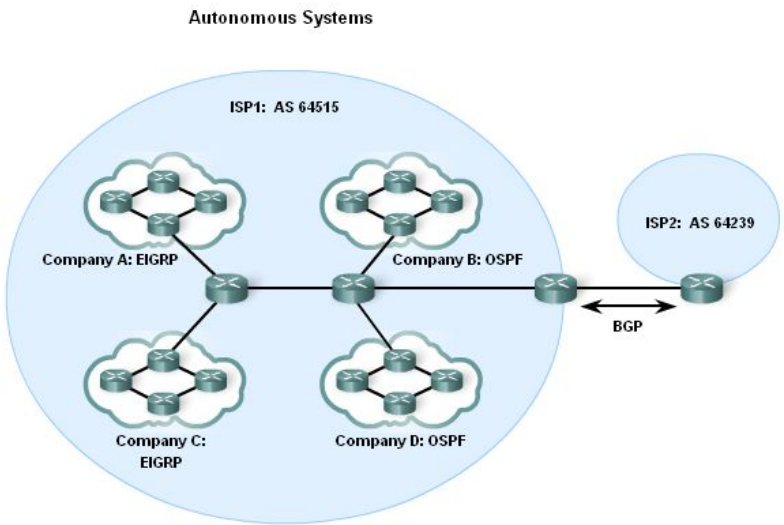
```
R1#show startup-config

<some output omitted>
!
hostname R1
!
interface FastEthernet0/0
 ip address 172.16.1.1 255.255.255.0
!
interface Serial0/0/0
 ip address 172.16.3.1 255.255.255.252
 clock rate 64000
!
interface Serial0/0/1
 description Link to R3
 ip address 192.168.10.5 255.255.255.252
!
end
```

```
R2#show startup-config

<some output omitted>
!
hostname R2
!
interface Loopback1
 ip address 10.1.1.1 255.255.255.252
 description Simulated ISP
!
interface FastEthernet0/0
 ip address 172.16.2.1 255.255.255.0
!
interface Serial0/0/0
 ip address 172.16.3.2 255.255.255.252
!
interface Serial0/0/1
 ip address 192.168.10.9 255.255.255.252
 clockrate 64000
```

```
R3#show startup-config

<some output omitted>
!
hostname R3
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.0
!
interface Serial0/0/0
 ip address 192.168.10.6 255.255.255.252
 clockrate 64000
!
interface Serial0/0/1
 ip address 192.168.10.10 255.255.255.252
!
```

Basic EIGRP Configuration

- Autonomous System (AS) & Process IDs
  - This is a collection of networks under the control of a single authority (reference RFC 1930)
  - AS Numbers are assigned by IANA
  - Entities needing AS numbers
    - ISP
    - Internet Backbone prodiers
    - Institutions connecting to other institutions using AS numbers

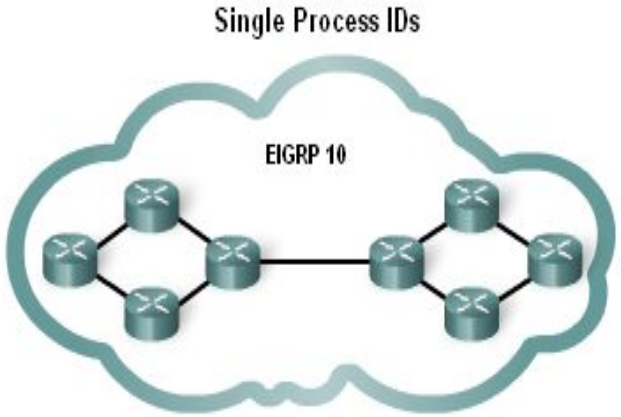


Basic EIGRP Configuration

- EIGRP autonomous system number actually functions as a process ID
- Process ID represents an instance of the routing protocol running on a router
- Example

Router(config)#router

eigrp *autonomous-system*




```
R1(config)#router eigrp ?
  <1-65535>  Autonomous system number
R1(config)#router eigrp 10
```

Although the Cisco IOS refers to the router eigrp parameter as an "Autonomous system number", this parameter configures an EIGRP process-an instance of EIGRP running on the router-and has nothing to do with AS configurations in ISP routers.

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Basic EIGRP Configuration

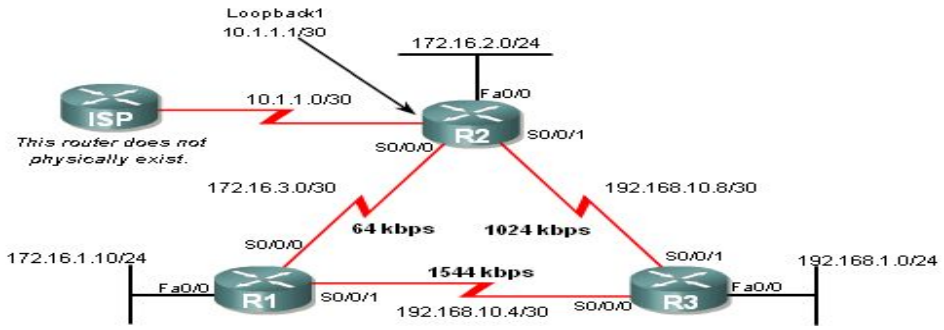
The *router eigrp* command

- The global command that enables eigrp is

  router eigrp autonomous-system

  -All routers in the EIGRP routing domain must use the same process ID number (autonomous-system number)

Enabling EIGRP Routing

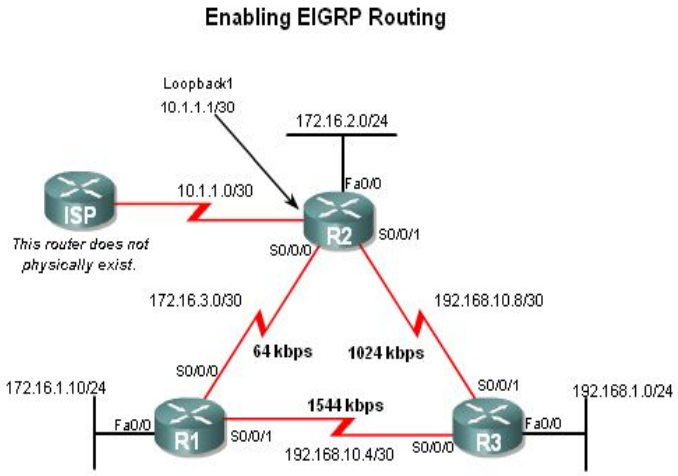



```
R1(config)#router eigrp 1
R1(config-router)#

R2(config)#router eigrp 1
R2(config-router)#

R3(config)#router eigrp 1
R3(config-router)#
```

Basic EIGRP Configuration

The Network Command

- Functions of the network command
  - Enables interfaces to transmit & receive EIGRP updates
  - Includes network or subnet in EIGRP updates
- Example
  - Router(config-router)#network *n*




```
R1(config)#router eigrp 1
R1(config-router)#network 172.16.0.0
R1(config-router)#network 192.168.10.0
```

```
R2(config)#router eigrp 1
R2(config-router)#network 172.16.0.0
%DUAL-5-NBRCHANGE: IP-EIGRP 1: Neighbor 172.16.3.1 (Serial0/0/0) is up: new adjacency
```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Basic EIGRP Configuration

- The network Command with a Wildcard Mask

  -This option is used when you want to configure EIGRP to advertise specific subnets

  -Example

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

```
R1(config)#router eigrp 1
R1(config-router)#network 172.16.0.0
R1(config-router)#network 192.168.10.0
```

```
R2(config)#router eigrp 1
R2(config-router)#network 172.16.0.0
%DUAL-5-NBRCHANGE: IP-EIGRP 1: Neighbor 172.16.3.1 (Serial0/0/0) is up: new adjacency
R2(config-router)#network 192.168.10.8 0.0.0.3
```

```
R3(config)#router eigrp 1
R3(config-router)#network 192.168.10.0
%DUAL-5-NBRCHANGE: IP-EIGRP 1: Neighbor 192.168.10.5 (Serial0/0/0) is up: new adjacency
R3(config-router)#
%DUAL-5-NBRCHANGE: IP-EIGRP 1: Neighbor 192.168.10.9 (Serial0/0/1) is up: new adjacency
R3(config-router)#network 192.168.1.0
```


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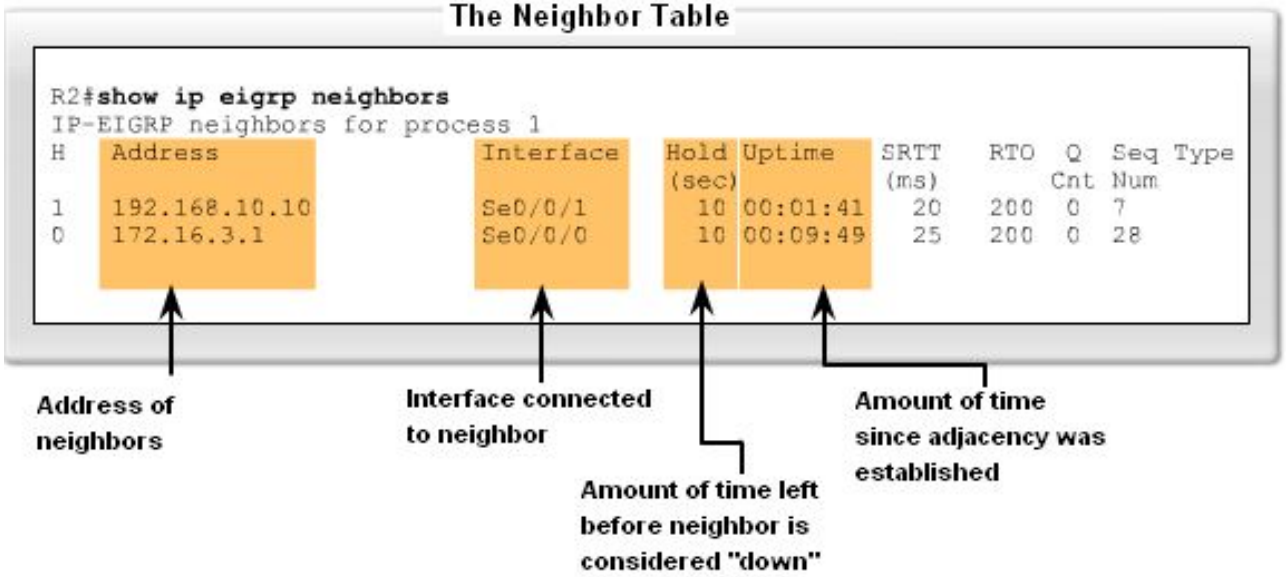
Basic EIGRP Configuration

Verifying EIGRP

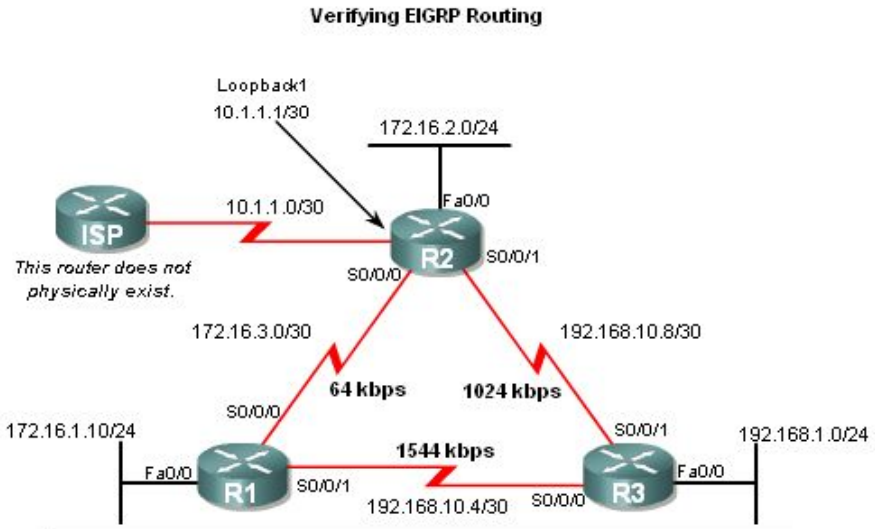
- EIGRP routers must establish adjacencies with their neighbors before any updates can be sent or received
- Command used to view neighbor table and verify that EIGRP has established adjacencies with neighbors is

show ip eigrp neighbors



EIGRP

- The ***show ip protocols*** command is also used to verify that EIGRP is enabled




```
R1#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
  Automatic network summarization is in effect
  Automatic address summarization:
    192.168.10.0/24 for FastEthernet0/0, Serial0/0/0
      Summarizing with metric 2169856
    172.16.0.0/16 for Serial0/0/1
      Summarizing with metric 28160
  Maximum path: 4
  Routing for Networks:
    172.16.0.0
    192.168.10.0
  Routing Information Sources:
    Gateway         Distance      Last Update
    (this router)         90      00:03:29
    192.168.10.6          90      00:02:09
    Gateway         Distance      Last Update
    172.16.3.2            90      00:02:12
  Distance: internal 90 external 170
```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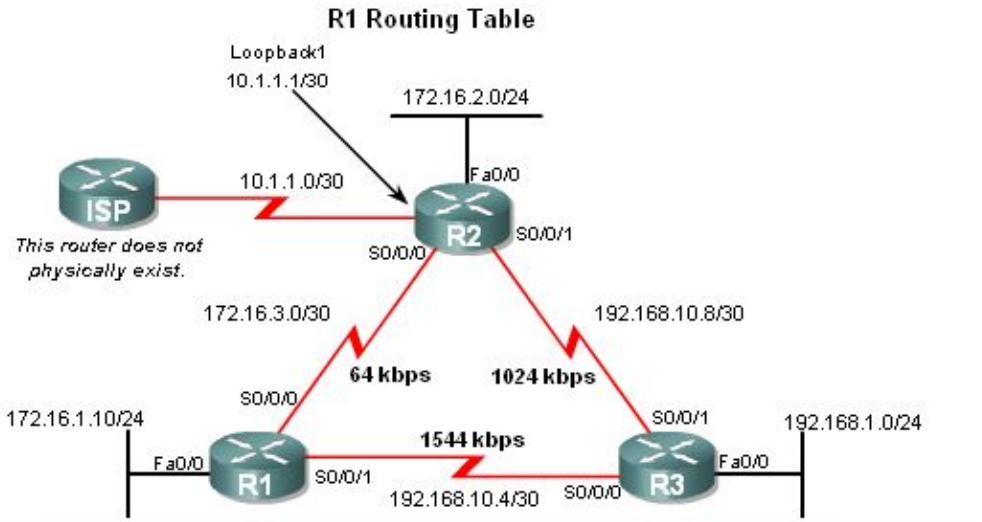
Basic EIGRP Configuration

Examining the Routing Table

- The **show ip route** command is also used to verify EIGRP
- EIGRP routes are denoted in a routing table by the letter "**D**"
- By default , EIGRP automatically summarizes routes at major network boundary




```
R1#show ip route
Codes: C - connected, S - static, I - IGRP, 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
<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, 00:03:50, Null0
C       192.168.10.4/30 is directly connected, Serial0/0/1
D       192.168.10.8/30 [90/2681856] via 192.168.10.6, 00:02:43, Serial0/0/1
     172.16.0.0/16 is variably subnetted, 4 subnets, 3 masks
D       172.16.0.0/16 is a summary, 00:10:52, Null0
C       172.16.1.0/24 is directly connected, FastEthernet0/0
D       172.16.2.0/24 [90/2172416] via 172.16.3.2, 00:10:47, 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, 00:02:31, Serial0/0/1
```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Basic EIGRP Configuration

- **Introducing the Null0 Summary Route**
  - Null0 is not a physical interface
  - In the routing table summary routes are sourced from Null0
    - Reason: routes are used for advertisement purposes
  - EIGRP will automatically include a null0 summary route as child route when 2 conditions are met
    - At least one subnet is learned via EIGRP
    - Automatic summarization is enabled

R2 Routing Table

```
R2#show ip route
<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, 00:04:13, Null0
D       192.168.10.4/30 [90/2681856] via 192.168.10.10, 00:03:05, Serial0/0/1
C       192.168.10.8/30 is directly connected, Serial0/0/1
     172.16.0.0/16 is variably subnetted, 4 subnets, 3 masks
D       172.16.0.0/16 is a summary, 00:04:07, Null0
D       172.16.1.0/24 [90/2172416] via 172.16.3.1, 00:11:11, Serial0/0/0
C       172.16.2.0/24 is directly connected, FastEthernet0/0
C       172.16.3.0/30 is directly connected, Serial0/0/0
     10.0.0.0/30 is subnetted, 1 subnets
C       10.1.1.0 is directly connected, Loopback1
D    192.168.1.0/24 [90/2172416] via 192.168.10.10, 00:02:54, Serial0/0/1
```

Summary Routes to Null0

Summary Routes to Null0

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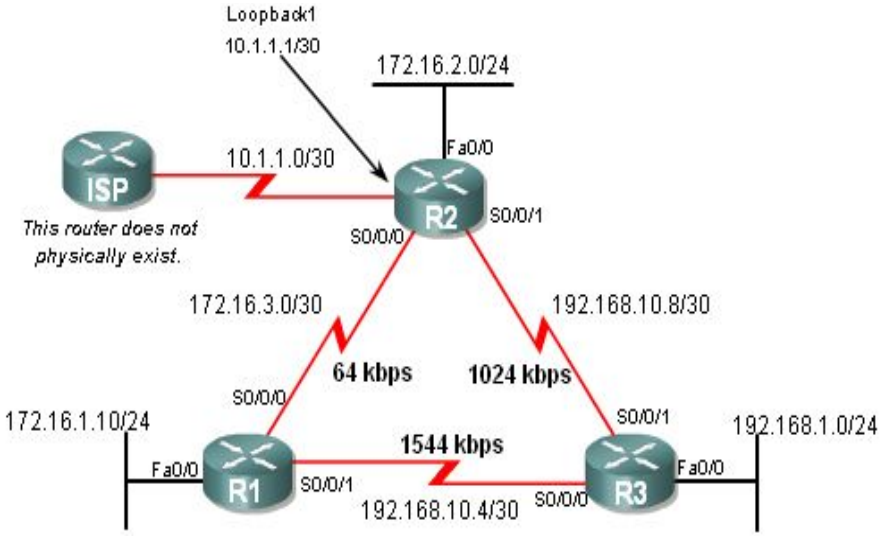
Basic EIGRP Configuration

- R3's routing table shows that the 172.16.0.0/16 network is automatically summarized by R1 & R3



R3 Routing Table

```
R3#show ip route
<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, 00:03:11, 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, 00:03:23, Serial0/0/0
                   [90/2172416] via 192.168.10.9, 00:03:23, Serial0/0/1
C    192.168.1.0/24 is directly connected, FastEthernet0/0
```

Equal cost routes to 172.16.0.0/16

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EIGRP Metric Calculation

EIGRP Composite Metric & the K Values

- EIGRP uses the following values in its composite metric
  - -Bandwidth, delay, reliability, and load
- The composite metric used by EIGRP
  - formula used has values K1 – K5
    - K1 & K3 = 1
    - all other K values = 0

EIGRP Composite Metric

Default Composite Formula:
metric = **[K1*bandwidth + K3*delay]**

Complete Composite Formula:
metric = **[K1*bandwidth + (K2*bandwidth)/(256 - load) + K3*delay] * [K5/(reliability + K4)]**
(Not used if "K" values are 0)

Default values:
K1 (bandwidth) = 1
K2 (load) = 0
K3 (delay) = 1
K4 (reliability) = 0
K5 (reliability) = 0

"K" values can be changed with the **metric weights** command.

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


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EIGRP Metric Calculation

- Use the **sh ip protocols** command to verify the K values

```
R1#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
  Automatic network summarization is in effect
  Automatic address summarization:
    192.168.10.0/24 for FastEthernet0/0, Serial0/0/0
      Summarizing with metric 2169856
    172.16.0.0/16 for Serial0/0/1
      Summarizing with metric 28160
  Maximum path: 4
  Routing for Networks:
    172.16.0.0
    192.168.10.0
  Routing Information Sources:
    Gateway         Distance      Last Update
    (this router)           90      00:03:29
    192.168.10.6            90      00:02:09
    Gateway         Distance      Last Update
    172.16.3.2              90      00:02:12
  Distance: internal 90 external 170
```


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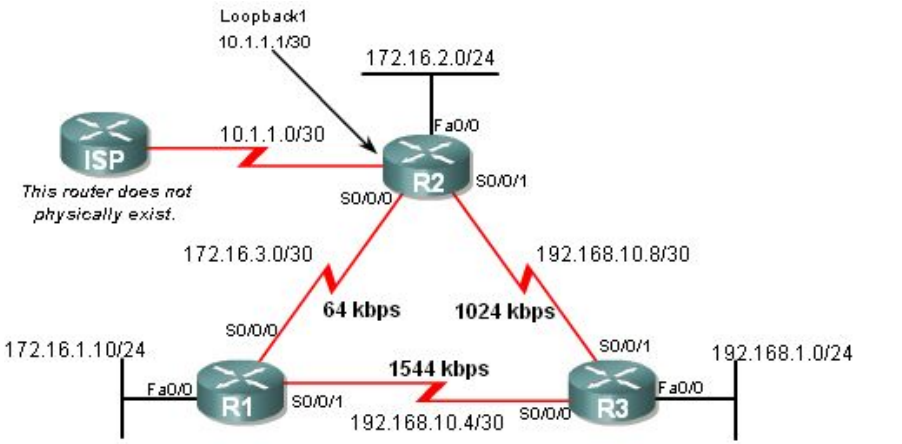
EIGRP Metric Calculation

EIGRP Metrics

- Use the **show interfaces** command to view metrics
- EIGRP Metrics

  Bandwidth – EIGRP uses a static bandwidth to calculate metric

  Most serial interfaces use a default bandwidth value of 1.544Mbos (T1)




```
R1#show interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
  Hardware is GT96K Serial
  Description: Link to R2
  Internet address is 172.16.3.1/30
  MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
  Keepalive set (10 sec)
  Last input 00:00:00, output 00:00:01, output hang never
  Last clearing of "show interface" counters 3d22h
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue: 0/40 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     112522 packets input, 7303722 bytes, 0 no buffer
     Received 40016 broadcasts, 0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
     112601 packets output, 7280131 bytes, 0 underruns
     0 output errors, 0 collisions, 2 interface resets
     0 output buffer failures, 0 output buffers swapped out
     12 carrier transitions
     DCD=up  DSR=up  DTR=up  RTS=up  CTS=up
```

usec = microsecond or 1 millionth of a second

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EIGRP Metric Calculation

EIGRP Metrics

- **Delay** is the defined as the measure of time it takes for a packet to traverse a route

  -it is a static value based on link type to which interface is connected

Delay Values in Microseconds

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
DSO	20,000 µS
56K	20,000 µS

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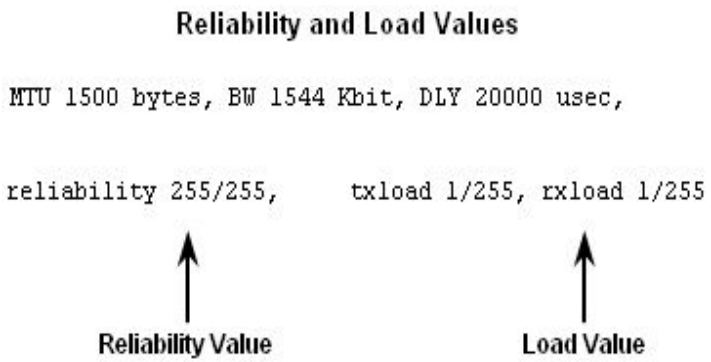
EIGRP Metric Calculation

- **Reliability** (not a default EIGRP metric)
  - -A measure of the likelihood that a link will fail
  - -Measure dynamically & expressed as a fraction of 255
    - the higher the fraction the better the reliability
- **Load** (not a default EIGRP metric)
  - A number that reflects how much traffic is using a link
  - Number is determined dynamically and is expressed as a fraction of 255
    - The lower the fraction the less the load on the link



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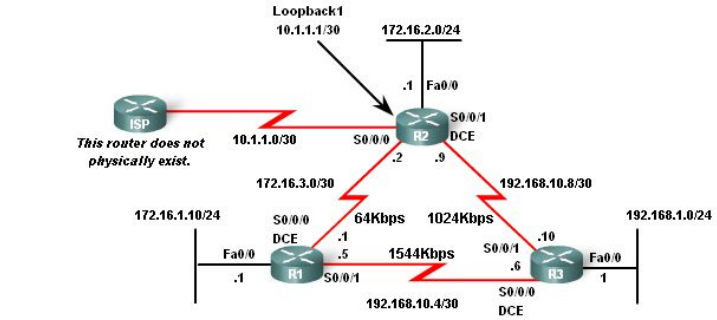
EIGRP Metric Calculation

Using the Bandwidth Command

- Modifying the interface bandwidth
  - -Use the ***bandwidth*** command
  - -Example
    - Router(config-if)#*bandwidth* kilobits
- Verifying bandwidth
  - –Use the ***show interface*** command
- Note – bandwidth command **does not change** the link's physical bandwidth



The bandwidth Command

```
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
```

Verifying Bandwidth Value

```
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>
```

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

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EIGRP Metric Calculation

- The EIGRP metric can be determined by examining the bandwidth delay

Calculating the EIGRP Default Metric

Default metric = [K1*bandwidth + K3*delay]

Since K1 and K3 both equal 1, the formula simplifies to: **bandwidth + delay**

bandwidth = speed of slowest link in route to the destination
delay = sum of the delays of each link in route to the destination

```
Slowest bandwidth:              (10,000,000/bandwidth kbps) * 256
Plus the sum of the delays    + (sum of delay/10) * 256
                              = EIGRP metric
```

```
R2#show ip route
<output omitted>
D    192.168.1.0/24 [90/3014400] via 192.168.10.10, 00:02:14, Serial0/0/1
```


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EIGRP Metric Calculation

- EIGRP uses the lowest bandwidth (BW)in its metric calculation

  Calculated BW = reference BW / lowest BW(kbps)

- Delay – EIGRP uses the cumulative sum of all outgoing interfaces

  Calculated Delay = the sum of outgoing interface delays

- EIGRP Metric = calculated BW + calculated delay

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EIGRP Metric Calculation

Finding the Slowest Bandwidth

```
R2#show inter ser 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,
<remaining output omitted>
```

```
R3#show inter fa 0/0
FastEthernet0/0 is up, line protocol is up
  Hardware is AmdFE, address is 0002.b9ee.5ee0 (bia 0002.b9ee.5ee0)
  Internet address is 192.168.1.1/24
  MTU 1500 bytes, BW 100000 Kbit, DLY 100 usec,
<remaining output omitted>
```

bandwidth = (10,000,000/1024) = 9765 * 256 = 2499840

Summing the Delays

```
R2#show inter ser 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,
<remaining output omitted>

<remaining output omitted>
```

```
R3#show inter fa 0/0
FastEthernet0/0 is up, line protocol is up
  Hardware is AmdFE, address is 0002.b9ee.5ee0 (bia 0002.b9ee.5ee0)
  Internet address is 192.168.1.1/24
  MTU 1500 bytes, BW 100000 Kbit, DLY 100 usec,
<remaining output omitted>
```

delay = [(20000/10) + (100/10)] * 256 = 514560

EIGRP Metric = bandwidth + delay = 2499840 + 514560 = 3014400

```
R2#show ip route
<code 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, 00:00:15, Null0
D       192.168.10.4/30 [90/21024000] via 192.168.10.10, 00:00:15, Serial0/0/1
C       192.168.10.8/30 is directly connected, Serial0/0/1
     172.16.0.0/16 is variably subnetted, 4 subnets, 3 masks
D       172.16.0.0/16 is a summary, 00:00:15, Null0
D       172.16.1.0/24 [90/40514560] via 172.16.3.1, 00:00:15, Serial0/0/0
C       172.16.2.0/24 is directly connected, FastEthernet0/0
C       172.16.3.0/30 is directly connected, Serial0/0/0
     10.0.0.0/30 is subnetted, 1 subnets
C       10.1.1.0 is directly connected, Loopback1
D    192.168.1.0/24 [90/3014400] via 192.168.10.10, 00:00:15, Serial0/0/1
```


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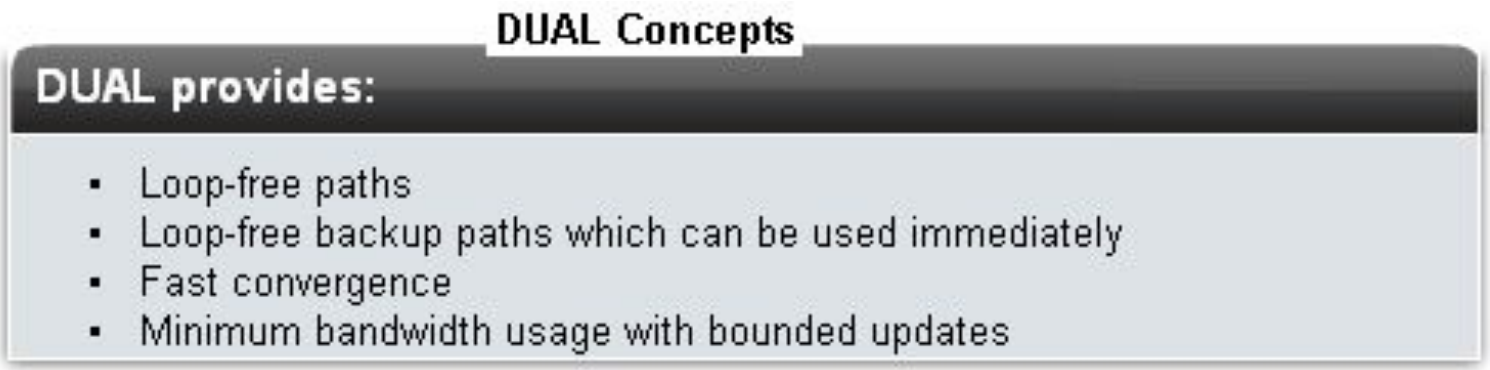
DUAL Concepts

- The **D**iffusing **U**pdate **Al**gorithm (DUAL) is used to prevent looping



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DUAL Concepts

- Successor

  The best least cost route to a destination found in the routing table

- Feasible distance

  The lowest calculated metric along a path to a destination network

Feasible Distance and Successor

```
R2#show ip route
<code 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, 00:00:15, Null0
D       192.168.10.4/30 [90/21024000] via 192.168.10.10, 00:00:15,
Serial0/0/1
C       192.168.10.8/30 is directly connected, Serial0/0/1
     172.16.0.0/16 is variably subnetted, 4 subnets, 3 masks
D       172.16.0.0/16 is a summary, 00:00:15, Null0
D       172.16.1.0/24 [90/40514560] via 172.16.3.1, 00:00:15, Serial0/0/0
C       172.16.2.0/24 is directly connected, FastEthernet0/0
C       172.16.3.0/30 is directly connected, Serial0/0/0
     10.0.0.0/30 is subnetted, 1 subnets
C       10.1.1.0 is directly connected, Loopback1
D    192.168.1.0/24 [90/3014400] via 192.168.10.10, 00:00:15, Serial0/0/1
```

feasible distance — successor

R3 at 192.168.10.10 is the successor for network 192.168.1.0/24. This route has a feasible distance of 3014400.

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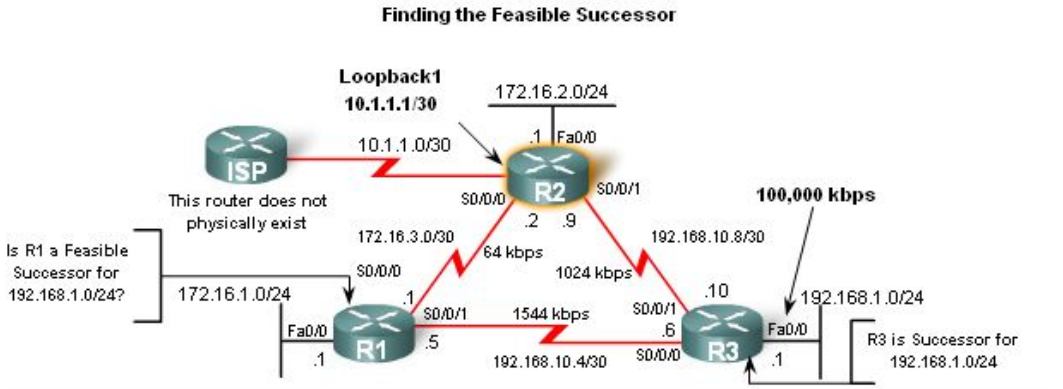
DUAL Concepts

Feasible Successors, Feasibility Condition & Reported Distance

- Feasible Successor

  -This is a loop free backup route to same destination as successor route




```
R2#show ip route
<code 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, 00:00:15, Null0
D       192.168.10.4/30 [90/21024000] via 192.168.10.10, 00:00:15, Serial0/0/1
C       192.168.10.8/30 is directly connected, Serial0/0/1
     172.16.0.0/16 is variably subnetted, 4 subnets, 3 masks
D       172.16.0.0/16 is a summary, 00:00:15, Null0
D       172.16.1.0/24 [90/40514560] via 172.16.3.1, 00:00:15, Serial0/0/0
C       172.16.2.0/24 is directly connected, FastEthernet0/0
C       172.16.3.0/30 is directly connected, Serial0/0/0
     10.0.0.0/30 is subnetted, 1 subnets
C       10.1.1.0 is directly connected, Loopback1
D    192.168.1.0/24 [90/3014400] via 192.168.10.10, 00:00:15, Serial0/0/1
```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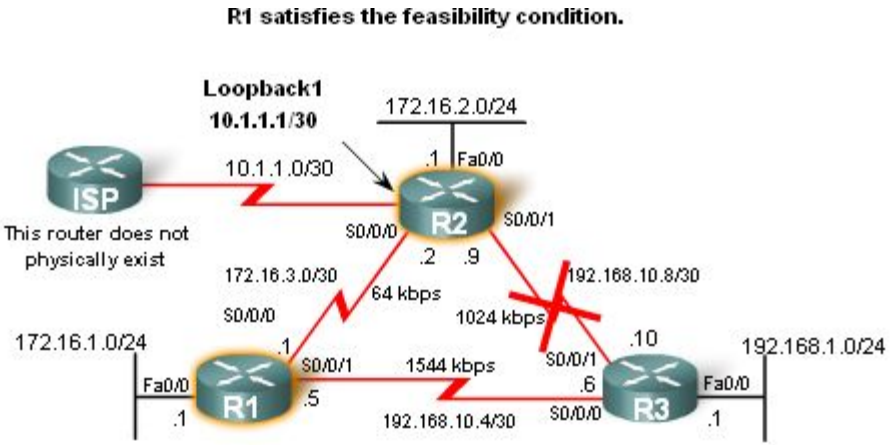
DUAL Concepts

Feasible Successors, Feasibility Condition & Reported Distance

- Reported distance (RD)
  - -The metric that a router reports to a neighbor about its own cost to that network




```
R2#show ip route
<output omitted for brevity>

D    192.168.1.0/24 [90/3014400] via 192.168.10.10, 00:00:15, Serial0/0/1
----------------------------------------------------------------------------

R1#show ip route
<output omitted for brevity>

D    192.168.1.0/24 [90/2172416] via 192.168.10.6, 01:12:26, Serial0/0/1
```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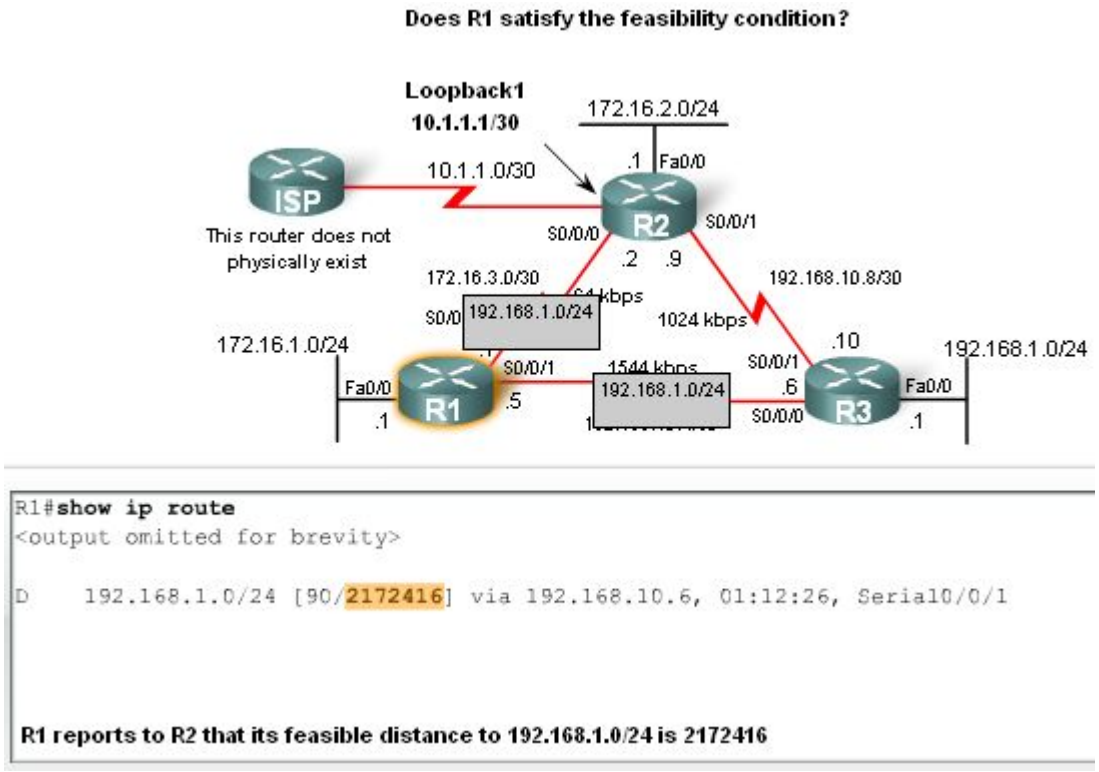
DUAL Concepts

- Feasibility Condition (FC)

  -Met when a neighbor's RD is less than the local router's FD to the same destination network



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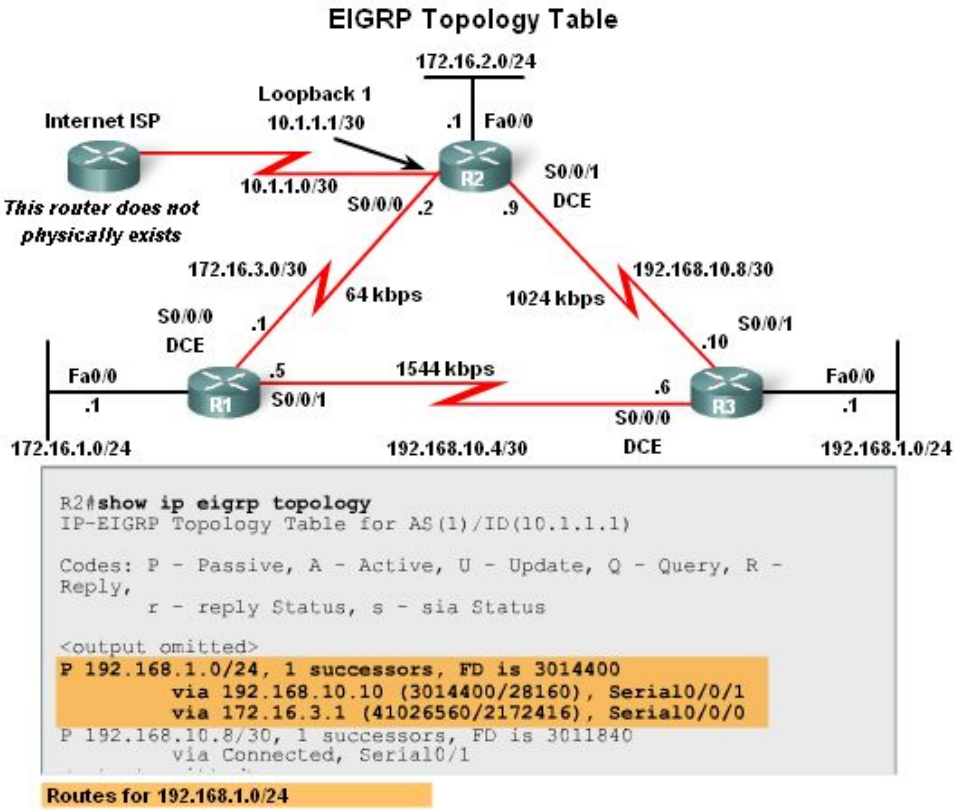
DUAL Concepts

- Topology Table: Successor & Feasible Successor
- EIGRP Topology table
  - Viewed using the *show ip eigrp topology* command
    - Contents of table include:
      - all successor routes
      - all feasible successor routes



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DUAL Concepts

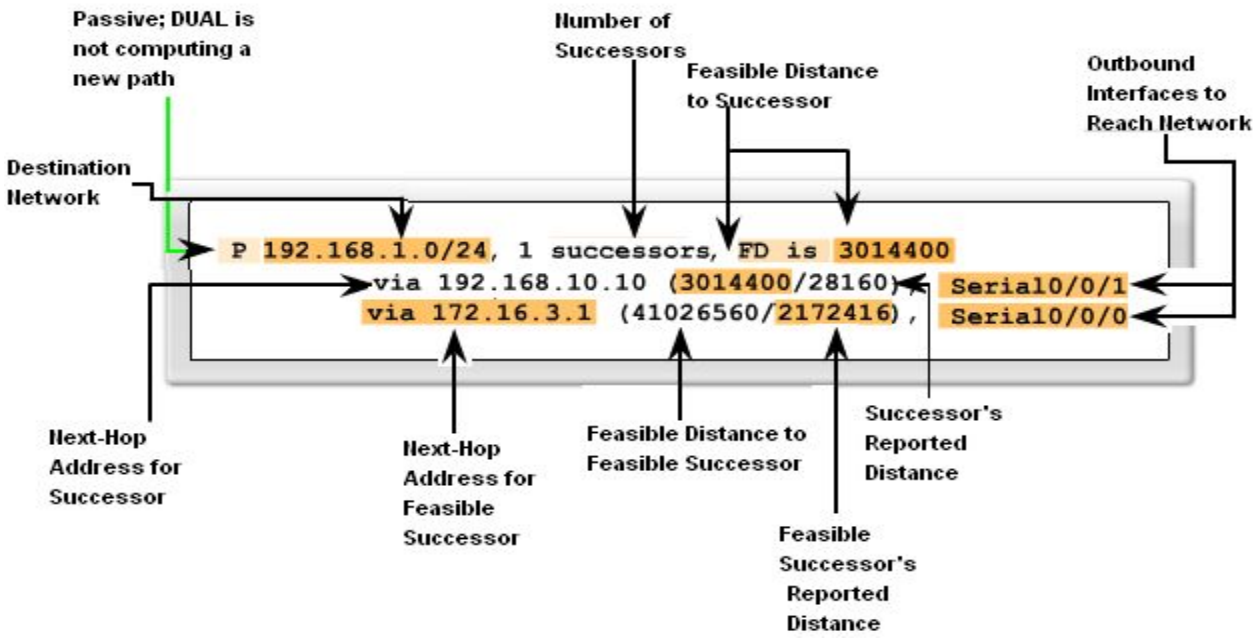
- EIGRP Topology Table dissected

```
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
```

Table Entry for 192.168.1.0/24

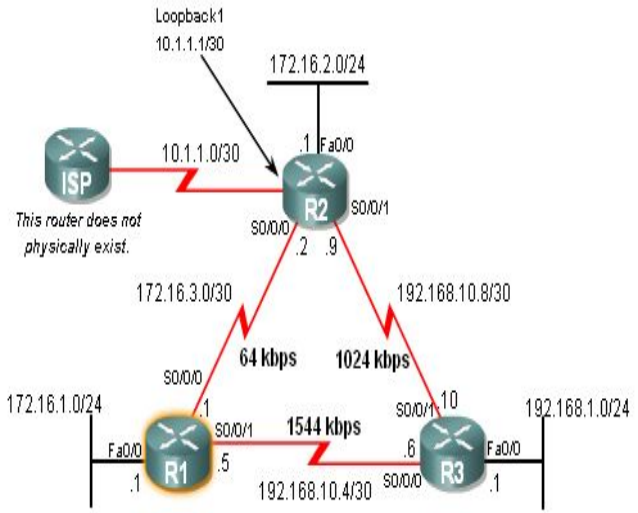


DUAL Concepts

Topology Table: **No Feasible Successor**

- A feasible successor may not be present because the feasibility condition may not be met

  -In other words, the reported distance of the neighbor is greater than or equal to the current feasible distance



No Feasible Successor

```
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>
```

```
R1#show ip eigrp topology all-links
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, serno 3
        via Summary (2169856/0), Null0
        via 172.16.3.2 (41024000/3011840), Serial0/0/0
P 192.168.10.4/30, 1 successors, FD is 2169856, serno 1
        via Connected, Serial0/0/1
P 192.168.1.0/24, 1 successors, FD is 2172416, serno 5
        via 192.168.10.6 (2172416/28160), Serial0/0/1
        via 172.16.3.2 (41026560/3014400), Serial0/0/0
P 192.168.10.8/30, 1 successors, FD is 3523840, serno 11
        via 192.168.10.6 (3523840/3011840), Serial0/0/1
<output omitted>
```

RD from R2 is higher than FD to R1.

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DUAL Concepts

- Finite Sate Machine (FSM)
  - An abstract machine that defines a set of possible states something can go through, what event causes those states and what events result form those states
  - FSMs are used to describe how a device, computer program, or routing algorithm will react to a set of input events

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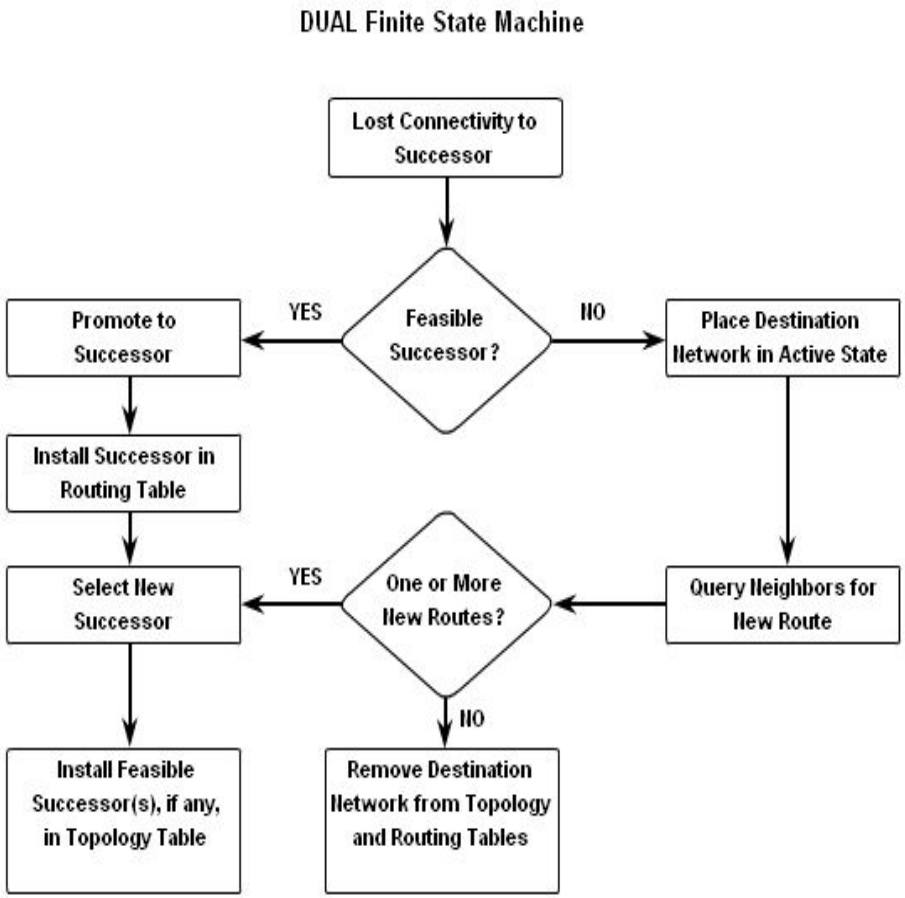
DUAL Concepts

- **DUAL FSM**
  - Selects a best loop-free path to a destination
  - Selects alternate routes by using information in EIGRP tables



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DUAL Concepts

Finite State Machines (FSM)

- To examine output from EIGRP's finite state machine us the ***debug eigrp fsm*** command

```
R2#debug eigrp fsm
EIGRP FSM Events/Actions debugging is on
R2#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)#int s0/0/1
R2(config-if)#shutdown
<some debug output omitted>

DUAL: Find FS for dest 192.168.1.0/24. FD is 3014400, RD is 3014400
DUAL: 192.168.10.10 metric 4294967295/4294967295
DUAL: 172.16.3.1 metric 41026560/2172416 found Dmin is 41026560
DUAL: Removing dest 192.168.1.0/24, nexthop 192.168.10.10
DUAL: RT installed 192.168.1.0/24 via 172.16.3.1

R2(config-if)#end
R2#undebug all
All possible debugging has been turned off

R2#show ip route
<some output omitted>

D    192.168.1.0/24 [90/41026560] via 172.16.3.1, 00:08:58, Serial0/0
```


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More EIGRP Configurations

The Null0 Summary Route

- By default, EIGRP uses the Null0 interface to discard any packets that match the parent route but do not match any of the child routes
- EIGRP automatically includes a null0 summary route as a child route whenever both of the following conditions exist
  - One or subnets exists that was learned via EIGRP
  - Automatic summarization is enabled

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More EIGRP Configurations

The Null0 Summary 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 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.

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More EIGRP Configurations

Disabling Automatic Summarization

- The ***auto-summary*** command permits EIGRP to automatically summarize at major network boundaries
- The ***no auto-summary*** command is used to disable automatic summarization
  - This causes all EIGRP neighbors to send updates that will not be automatically summarized
    - this will cause changes to appear in both

      -routing tables

      -topology tables

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More EIGRP Configurations

Manual Summarization

- Manual summarization can include supernets

  Reason: EIGRP is a classless routing protocol & include subnet mask in update

- Command used to configure manual summarization
  - Router(config-if)#ip summary-address eigrp as-number network-address subnet-mask

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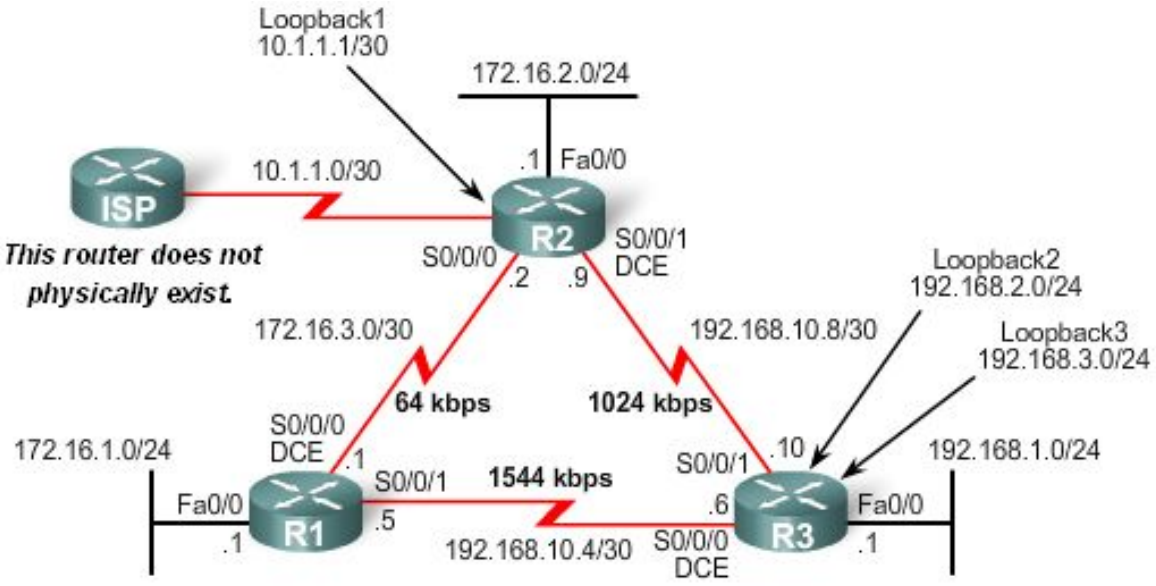
More EIGRP Configurations

- Configuring a summary route in EIGRP




```
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
```

Configure the summary route on all interfaces that send EIGRP packets.

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More EIGRP Configurations

EIGRP Default Routes

- "quad zero" static default route

  -Can be used with any currently supported routing protocol

  -Is usually configured on a router that is connected a network outside the EIGRP domain

- EIGRP & the "Quad zero" static default route
  - Requires the use of the redistribute static command to disseminate default route in EIGRP updates

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More EIGRP Configurations

Fine-Tuning EIGRP

- EIGRP bandwidth utilization

  -By default, EIGRP uses only up to 50% of interface bandwidth for EIGRP information

  -The command to change the percentage of bandwidth used by EIGRP is

  Router(config-if)#*ip bandwidth-percent eigrp as-number percent*

EIGRP Bandwidth Utilization

```
R1(config)#interface serial 0/0/0
R1(config-if)#bandwidth 64
R1(config-if)#ip bandwidth-percent eigrp 1 50
```

```
R2(config)#interface serial 0/0/0
R2(config-if)#bandwidth 64
R2(config-if)#ip bandwidth-percent eigrp 1 50
```


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More EIGRP Configurations

- Configuring Hello Intervals and Hold Times

  -Hello intervals and hold times are configurable on a per-interface basis

  -The command to configure hello interval is

  Router(config-if)#*ip hello-interval eigrp as-number seconds*

- Changing the hello interval also requires changing the hold time to a value greater than or equal to the hello interval

  -The command to configure hold time value is

  Router(config-if)#*ip hold-time eigrp as-number seconds*

```
R1(config)#int s0/0/0
R1(config-if)#ip hello-interval eigrp 1 60
R1(config-if)#ip hold-time eigrp 1 180
R1(config-if)#end
```

```
R2(config)#int s0/0/0
R2(config-if)#ip hello-interval eigrp 1 60
R2(config-if)#ip hold-time eigrp 1 180
R2(config-if)#end
```


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Summary

- **Background & History**
  - EIGRP is a derivative of IGRP
    - EIGRP is a Cisco proprietary distance vector routing protocol released in 1994
- **EIGRP terms and characteristics**
  - EIGPR uses RTP to transmit & receive EIGRP packets
  - EIGRP has 5 packet type:
    - Hello packets
    - Update packets
    - Acknowledgement packets
    - Query packets
    - Reply packets
  - Supports VLSM & CIDR

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Summary

- **EIGRP terms and characteristics**
  - EIGRP uses a hello protocol
    - Purpose of hello protocol is to discover & establish adjacencies
  - EIGRP routing updates
    - Aperiodic
    - Partial and bounded
    - Fast convergence

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Summary

- **EIGRP commands**
  - The following commands are used for EIGRP configuration
    - RtrA(config)#router eigrp [autonomous-system #]
    - RtrA(config-router)#network *network-number*
  - The following commands can be used to verify EIGRP
    - Show ip protocols
    - Show ip eigrp neighbors
    - Show ip route

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Summary

- **EIGRP metrics include**
  - Bandwidth (default)
  - Delay (default)
  - Reliability
  - Load

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Summary

- **DUAL**
  - Purpose of DUAL
    - To prevent routing loops
  - Successor
    - Primary route to a destination
  - Feasible successor
    - Backup route to a destination
  - Feasible distance
    - Lowest calculated metric to a destination
  - Reported distance
    - The distance towards a destination as advertised by an upstream neighbor

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Summary

- **Choosing the best route**
  - After router has received all updates from directly connected neighbors, it can calculate its DUAL
    - 1st metric is calculated for each route
    - 2nd route with lowest metric is designated successor & is placed in routing table
    - 3rd feasible successor is found
      - Criteria for feasible successor: it must have lower reported distance to the destination than the installed route's feasible distance
      - Feasible routes are maintained in topology table

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Summary

- **Automatic summarization**
  - On by default
  - Summarizes routes on classful boundary
  - Summarization can be disabled using the following command
    - RtrA(config-if)#no auto-summary

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