Configuration and Management of Networks

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Network Layer - Routing

- **Static:** The router learns routes when an administrator manually configures the static route. The administrator must manually update this static route entry whenever an internetwork topology change requires an update.

- **Dynamic:** The router dynamically learns routes after an administrator configures a routing protocol that helps determine routes.

Routing protocol

describe the following information:

- How updates are conveyed
- What knowledge is conveyed
- When to convey the knowledge
- How to locate recipients of the updates

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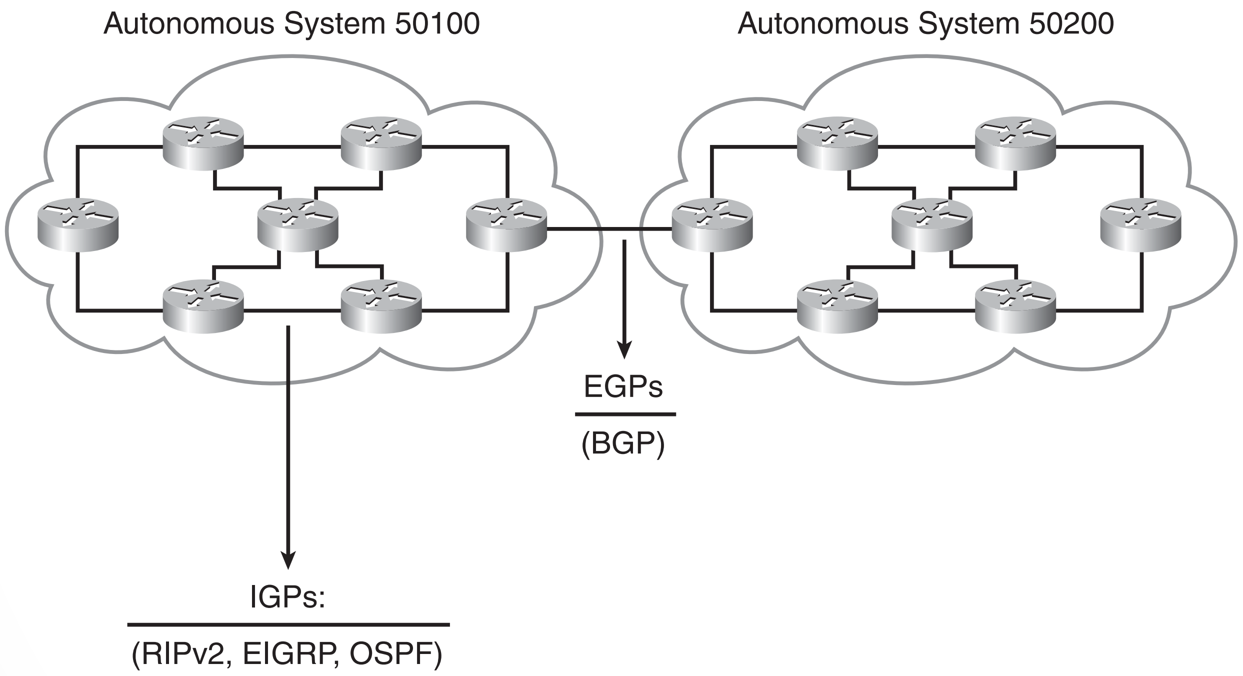
Network Layer – IGP and EGP

IGP Versus EGP



Network Layer – IGP and EGP

- **Distance vector:** The distance vector routing approach determines the direction (vector) and distance (such as hops) to any link in the internetwork.

- **Link-state:** The link-state approach, which utilizes the shortest path first (SPF) algorithm, creates an abstraction of the exact topology of the entire internetwork, or at least of the partition in which the router is situated.

- **Advanced distance vector:** The advanced distance vector approach combines aspects of the link-state and distance vector algorithms. This is also sometimes referred to as a hybrid routing protocol.

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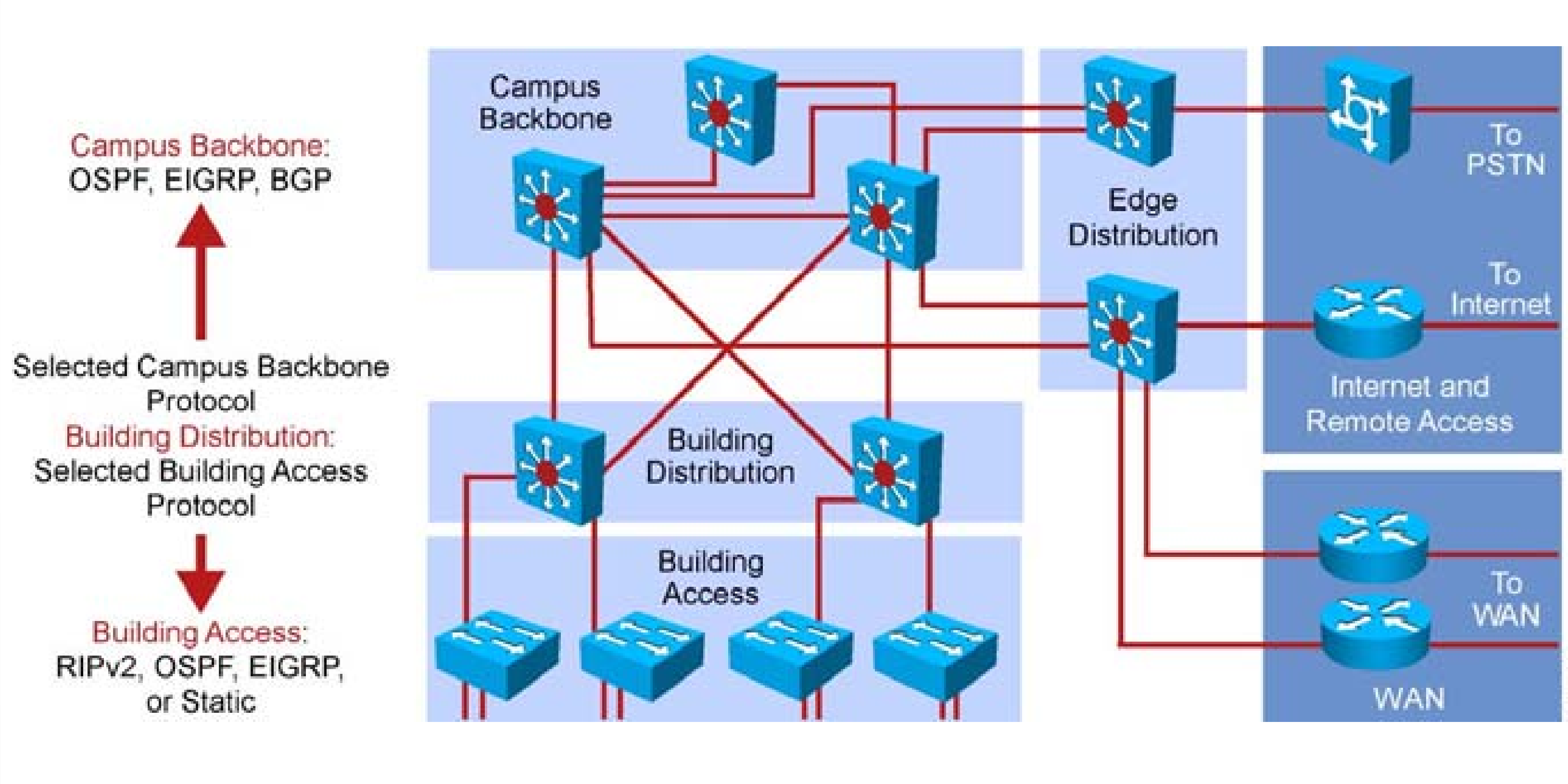
Routing protocols in the Network



Configuration and Management of Networks

Distance Vector protocols

Periodicaly advertise routes as vectors, where distance is a metric (or cost) such as hop count, and vector is the next-hop router's IP used to reach the destination

- Distance: The distance is the route metric to reach the network.
- Vector: The vector is the interface or direction to reach the network.

Routers determine least cost path (distance vector protocols implement a distributed Bellman-Ford algorithm) and advertise only those to neighbors

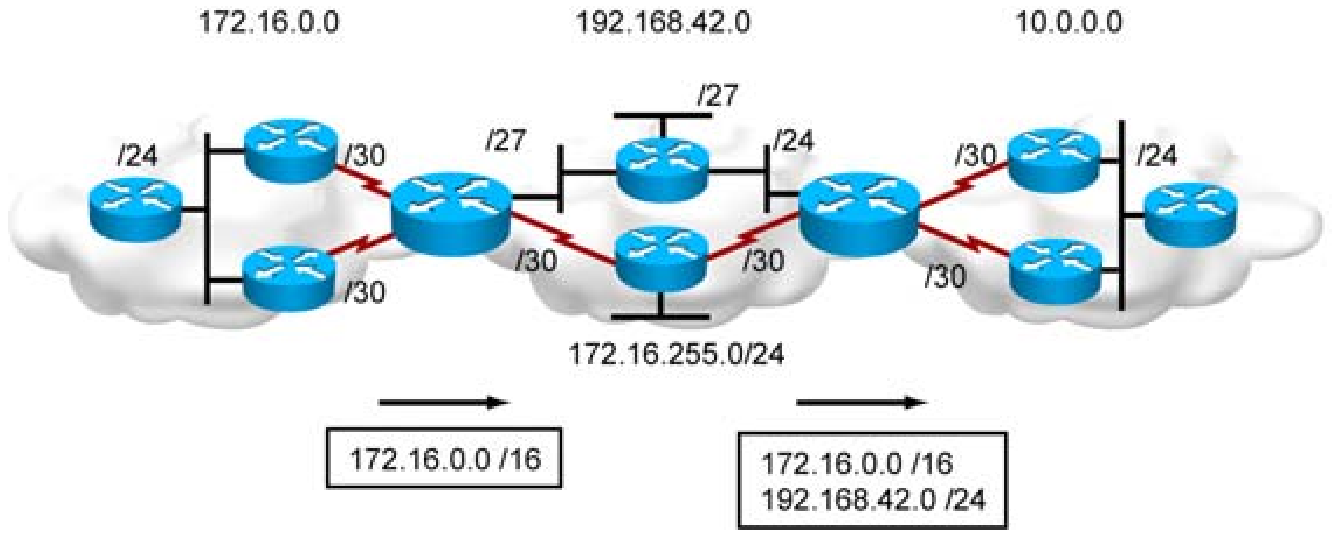
Configuration and Management of Networks

Distance Vector protocols - EIGRP

Non- Distance Vector Characterisitcs:

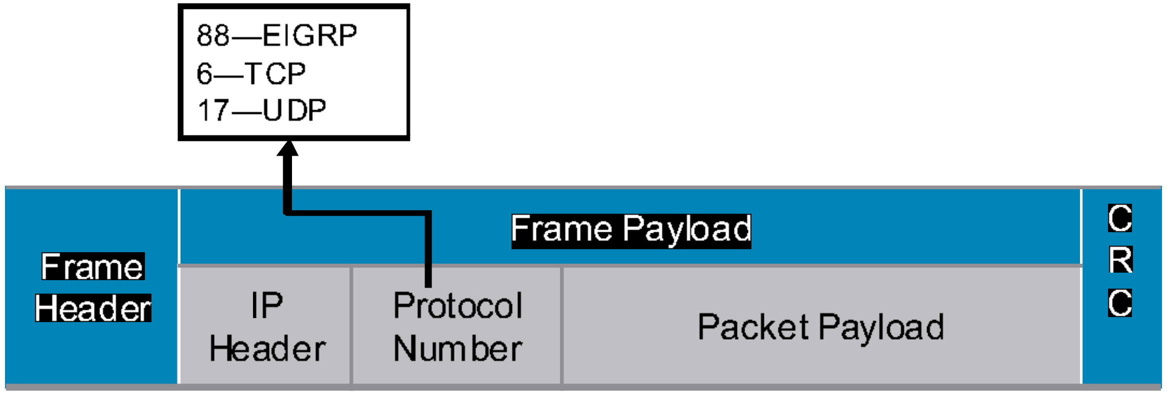
- Support for VLSM and discontiguous subnets
- Load balancing across equal- and unequal-cost pathways
- Easy configuration for WANs and LANs
- Manual summarization at any point
- Sophisticated metric

updates through neighbour relationships only when there is a change in the network



EIGRP – Key technologies

- EIGRP
  - Runs directly above the IP layer
- Neighbor discovery and recovery
  - Uses Hello packets between neighbors
- Reliable Transport Protocol
  - Guaranteed, ordered EIGRP packet delivery to all neighbors
  - Used for flooding



EIGRP – Packets

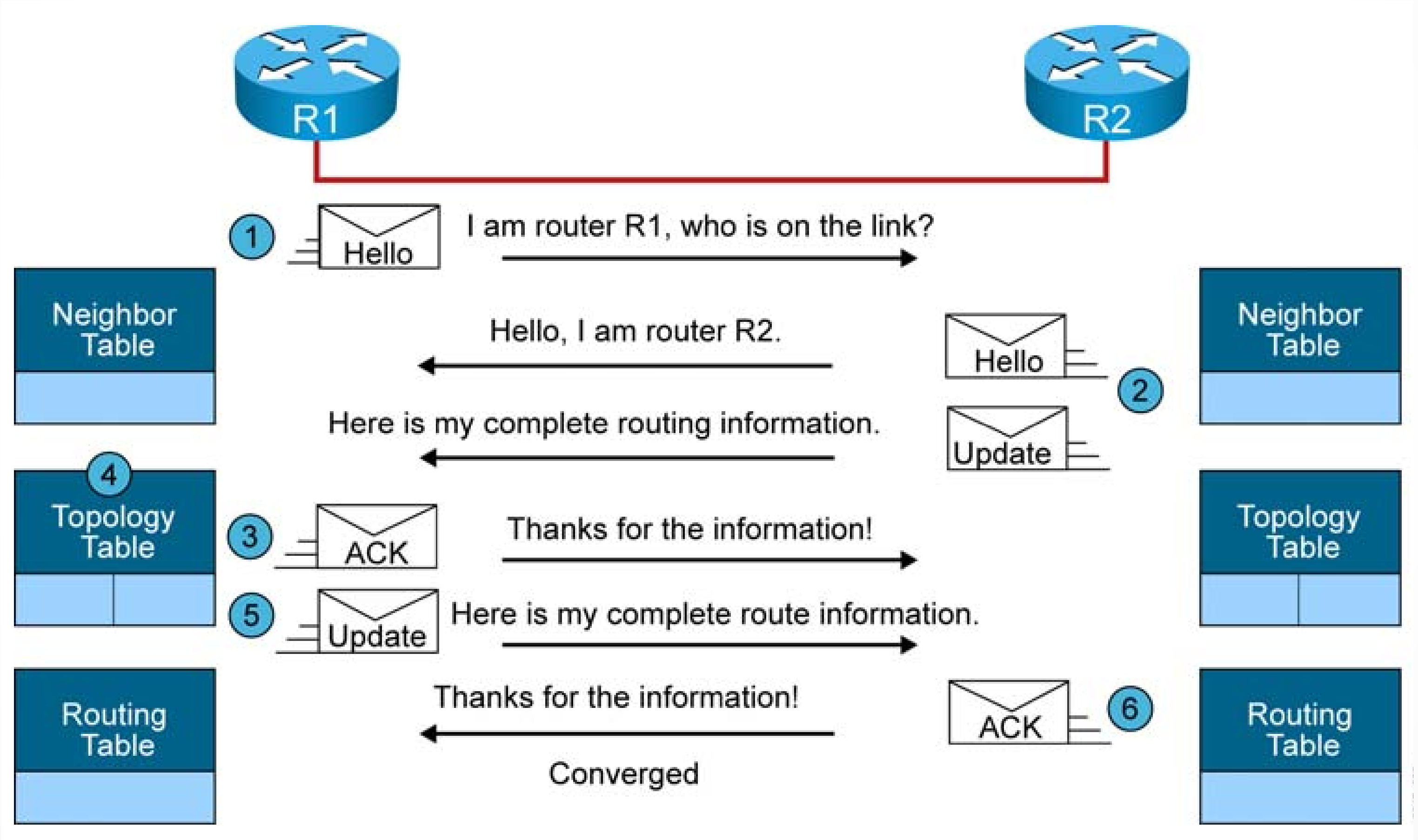
- Hello: Establish neighbor relationships
- Update: Send routing updates
- Query: Ask neighbors about routing information
- Reply: Respond to query about routing information
- ACK: Acknowledge a reliable packet

```
<omitted>
EIGRP: Enqueueing UPDATE on Ethernet0 iidbQ un/rely 0/1 serno 683-683
EIGRP: Sending UPDATE on Ethernet0
  AS 1, Flags 0x0, Seq 624/0 idbQ 0/0 iidbQ un/rely 0/0 serno 683-683<output
omitted>
```

```
<omitted>
EIGRP: Enqueueing QUERY on Ethernet0 iidbQ un/rely 0/1 serno 699-699
EIGRP: Sending QUERY on Ethernet0
  AS 1, Flags 0x0, Seq 650/0 idbQ 0/0 iidbQ un/rely 0/0 serno 699-699
<omitted>
```

```
<omitted>
DUAL: dual_rcvreply(): 10.1.4.0/24 via 10.1.2.1 metric 4294967295/4294967295
<omitted>
```

EIGRP – Initial Route Discovery



EIGRP – Neighbour Table

- The list of directly connected routers running EIGRP with which this router has an adjacency

IP EIGRP Neighbor Table	
Next-Hop Router	Interface

```
R1#show ip eigrp neighbor
IP-EIGRP neighbors for process 1
H   Address       Interface      Hold Uptime    SRTT   RTO   Q   Seq
                                 (sec)          (ms)         Cnt Num
2   10.1.115.5    Se0/0/0.4        11 00:17:16  1239   5000  0   3
1   10.1.112.2    Se0/0/0.1        12 00:17:25   538   3228  0   14
0   172.30.13.3   Fa0/0            13 00:17:31   416   2496  0   13
```

EIGRP – Topology table

- The list of all routes learned from each EIGRP neighbor
- The source for the topology table: IP EIGRP Neighbor Table

IP EIGRP Topology Table	
Destination 1	FD and AD via Each Neighbor

```
R1#show ip eigrp topology
IP-EIGRP Topology Table for AS(1)/ID(172.30.13.1)

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

P 192.168.1.0/24, 1 successors, FD is 2297856
        via 10.1.115.5 (2297856/128256), Serial0/0/0.4
P 192.168.2.0/24, 1 successors, FD is 2297856
        via 10.1.115.5 (2297856/128256), Serial0/0/0.4
P 192.168.3.0/24, 1 successors, FD is 2297856
        via 10.1.115.5 (2297856/128256), Serial0/0/0.4
P 10.1.115.0/24, 1 successors, FD is 2169856
        via Connected, Serial0/0/0.4
<output omitted>
```

EIGRP – IP routing table

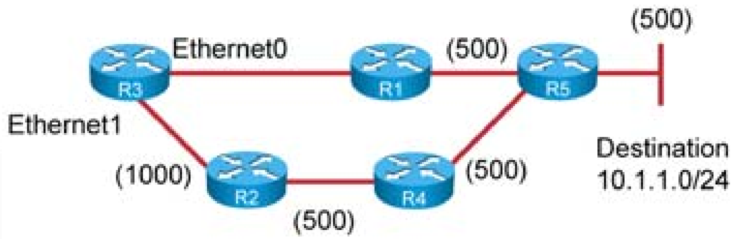
- The list of all best routes from the EIGRP topology table and other routing processes
- The source for the EIGRP routes in an IP routing table: IP EIGRP Topology Table

The IP Routing Table	
Destination 1	Best Route

```
R1#show ip route eigrp
<output omitted>
172.30.0.0/24 is subnetted, 2 subnets
D       172.30.24.0 [90/2172416] via 10.1.112.2, 04:13:27, Serial0/0/0.1
     10.0.0.0/24 is subnetted, 3 subnets
D       10.1.134.0 [90/2172416] via 172.30.13.3, 04:13:27, FastEthernet0/0
D    192.168.1.0/24 [90/2297856] via 10.1.115.5, 04:13:19, Serial0/0/0.4
D    192.168.2.0/24 [90/2297856] via 10.1.115.5, 04:13:19, Serial0/0/0.4
D    192.168.3.0/24 [90/2297856] via 10.1.115.5, 04:13:19, Serial0/0/0.4
<output omitted>
```

EIGRP – Tables Example

Example: EIGRP Tables



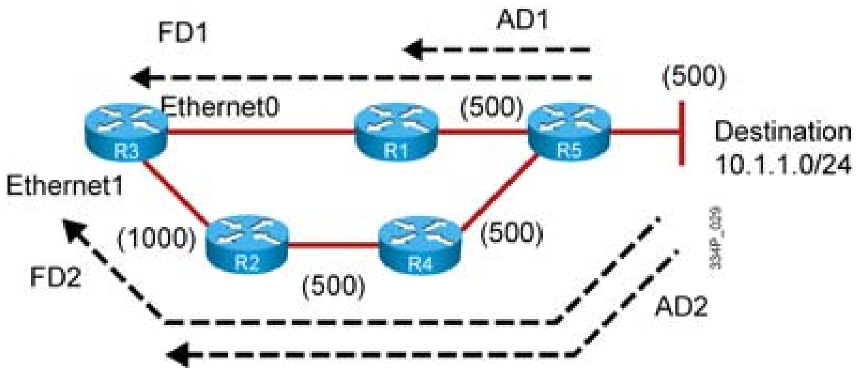
IP EIGRP Neighbor Table	
Next-Hop Router	Interface
Router R1	Ethernet 0
Router R2	Ethernet 1

IP EIGRP Topology Table			
Network	Feasible Distance (EIGRP Metric)	Advertised Distance	EIGRP Neighbor
10.1.1.0 /24	2000	1000	Router R1 (E0)
10.1.1.0 /24	2500	1500	Router R2 (E1)

The IP Routing Table			
Network	Metric (Feasible Distance)	Outbound Interface	Next Hop (EIGRP Neighbor)
10.1.1.0 /24	2000	Ethernet 0	Router R1

EIGRP – DUAL

- Upstream and downstream router
- Selects lowest-cost loop-free paths to each destination
  - Advertised Distance (AD) = next-hop router-destination
  - Feasible Distance (FD) = local router cost + AD
  - Lowest-cost = lowest FD
  - (Current) successor = next-hop router with the lowest-FD-cost loop-free path
  - Feasible successor = backup router with loop-free path (its AD < current successor FD)

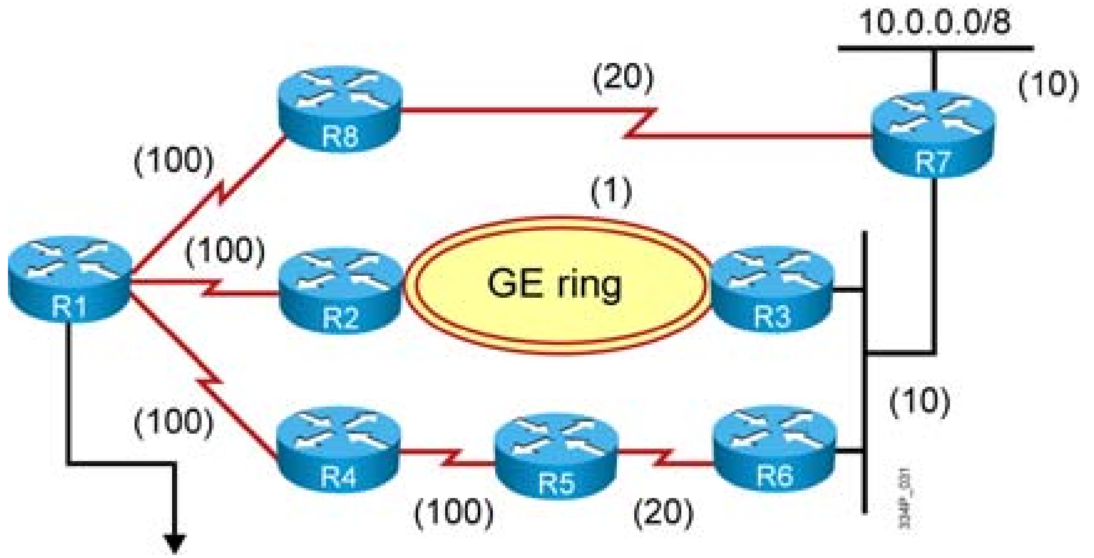


EIGRP – DUAL

- The topology table is changed when:
  - The cost or state of a directly connected link changes
  - An EIGRP packet (update, query, reply) is received
  - A neighbor is lost
- DUAL computes an alternate path if the primary (successor) is lost
  - Local computation: a feasible successor is present in the topology—the route is passive
  - DUAL recomputation: no feasible successor is present in the topology—the route is active

EIGRP – Example

- Advertised distance is the distance (metric) to a destination as advertised by an upstream neighbor



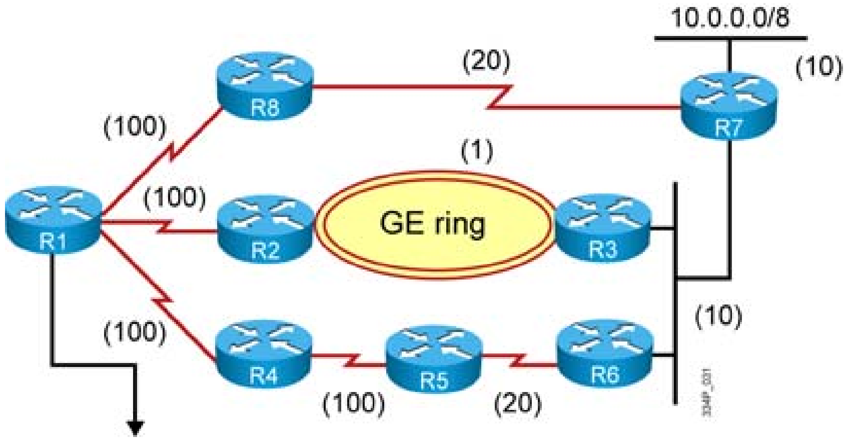
EIGRP – Example

Topology Table

Destination	Advertised Distance (AD)	Neighbor
10.0.0.0/8	20+10=30	R8
10.0.0.0/8	1+10+10=21	R2
10.0.0.0/8	100+20+10+10=140	R4

Destination	Feasible Distance (FD)	Neighbor
10.0.0.0/8	100+20+10=130	R8
10.0.0.0/8	100+1+10+10=121	R2
10.0.0.0/8	100+100+20+10+10=240	R4

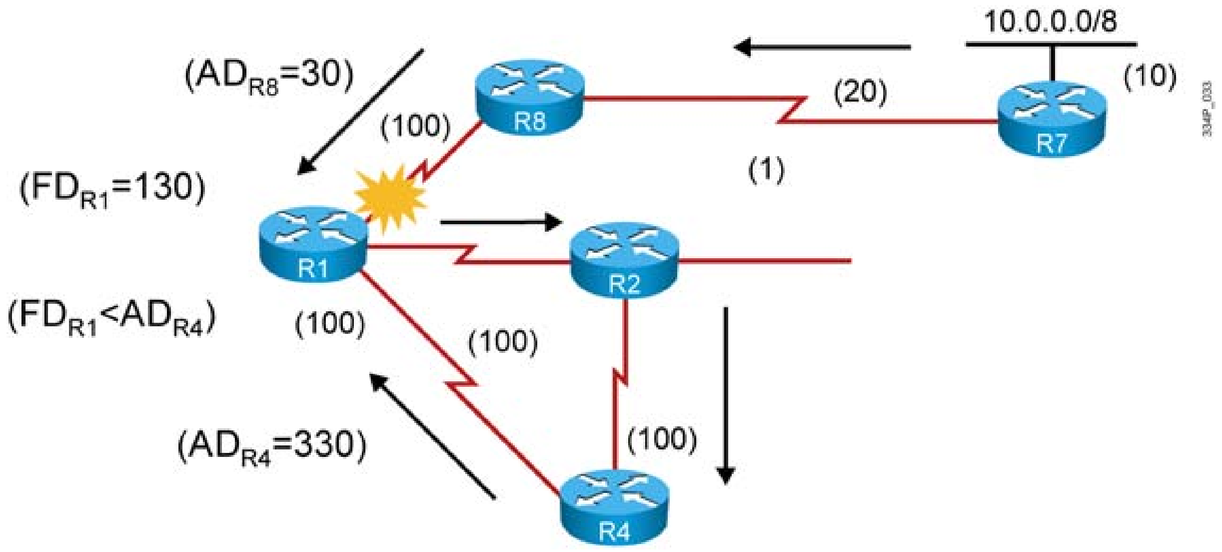
EIGRP – Successor and Feasible Successor



Destination	AD	FD	Neighbor	Status
10.0.0.0/8	30	130	R8	FS
10.0.0.0/8	21	121	R2	S
10.0.0.0/8	140	240	R4	

EIGRP – Successor and Feasible Successor

- R1 receives information about 10.0.0./8 from R8 and R4
- FD on R1 is smaller than AD from R4 and the update from R4 is not FS



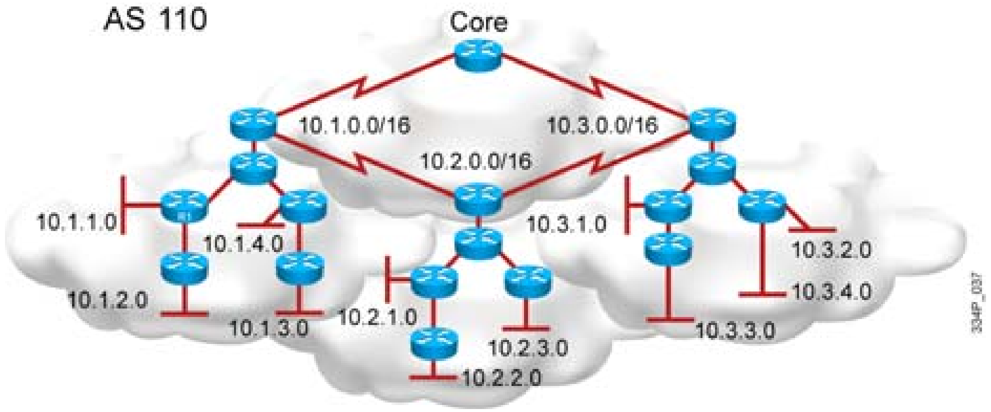
EIGRP – Metrics

- The use of metric components is represented by K values
- Metric components are:
  - Bandwidth (K1)
  - Delay (K3)
  - Reliability (K4 and K5)
  - Loading (K2)
- MTU is included in the update but not used for metric calculation

EIGRP – Planning

- Verify and configure IP addressing
- Enable EIGRP using the correct AS number
- Define networks to include per router
- Define a special metric to influence path selection

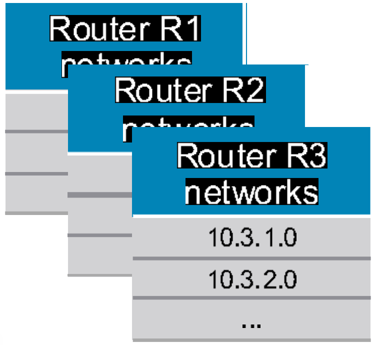
Router R1 Networks
10.1.1.0



Router	Link	Metric
R1	Fa0	Bandwidth = 10 Mb/s

EIGRP – Documenting

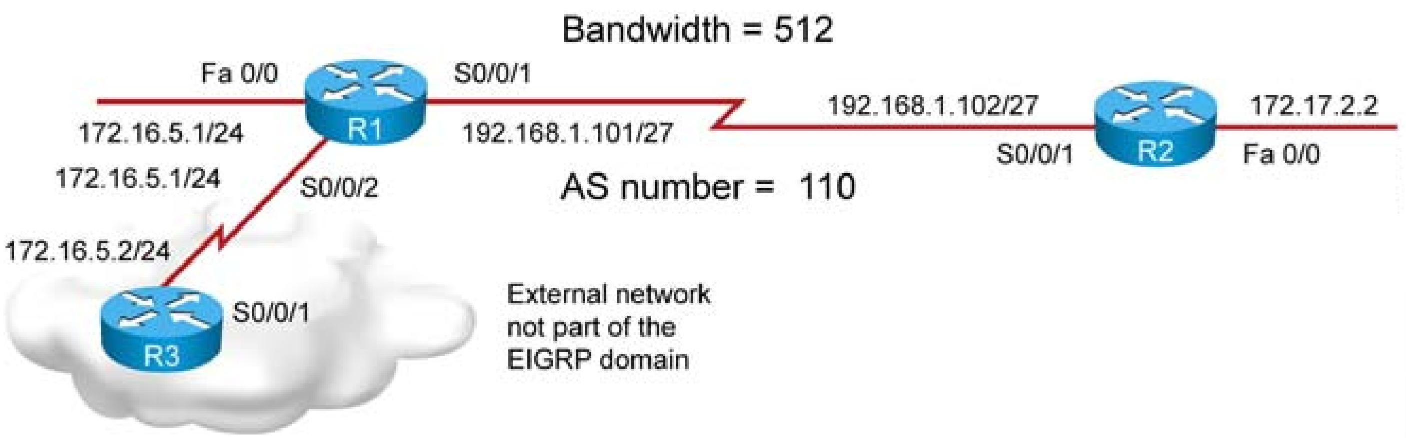
- Documenting EIGRP
  - Topology—use topology map
  - AS numbering and IP addressing
  - Networks included in EIGRP per routers
  - Non-default metric applied



Router	Link	Metric
R1	Fa0	Bandwidth = 10 Mb/s
R2	Serial1	Delay = 100
R2	Serial2	Delay = 200
R2	Tunnel	Bandwidth = 2 Mb/s

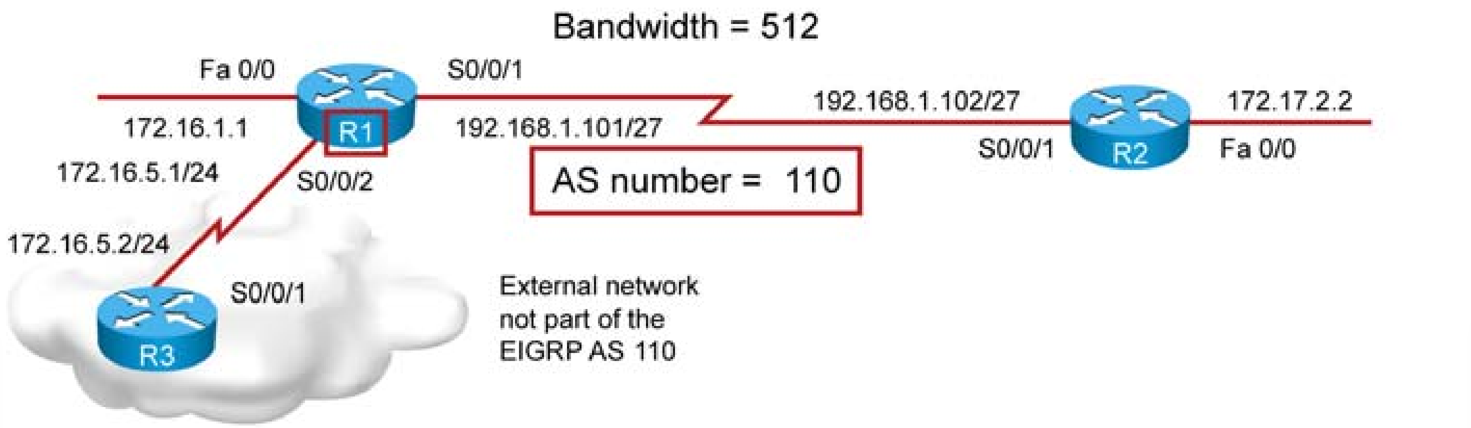
EIGRP – Requirements

- EIGRP routing protocol AS number
- Interfaces for EIGRP neighbor relationship
- Networks participating in EIGRP
- Interface bandwidth



EIGRP – Configuring

- Define EIGRP as the routing protocol
- All routers in the internetwork that must exchange EIGRP routing updates must have the same autonomous system number

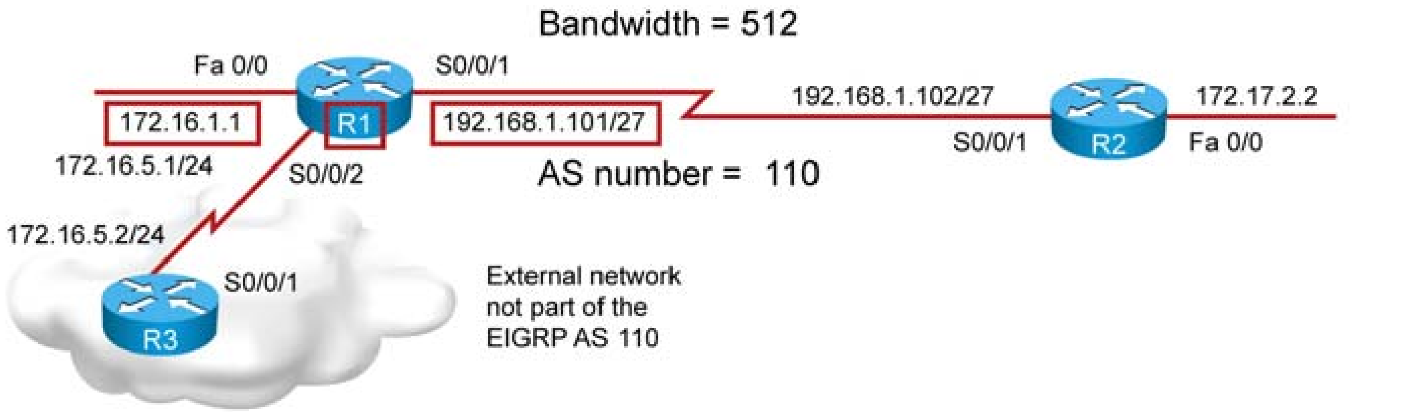


R1 (config-if) #

```
router eigrp 110
```

EIGRP – Configuring

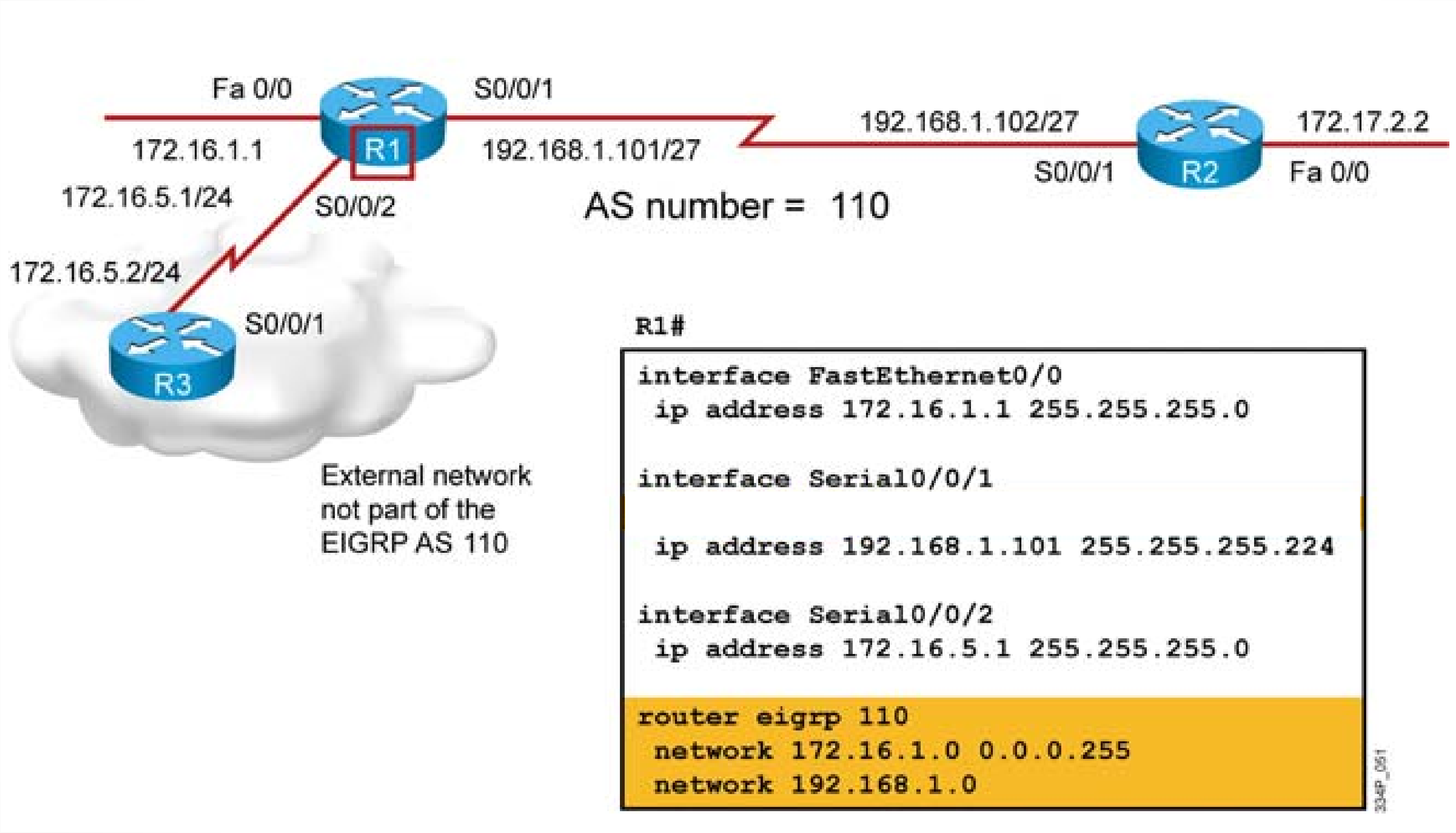
- Define the attached networks participating in EIGRP
- The wildcard-mask is an inverse mask used to determine how to interpret the address. The mask has wildcard bits, where 0 is a match and 1 is “do not care.”



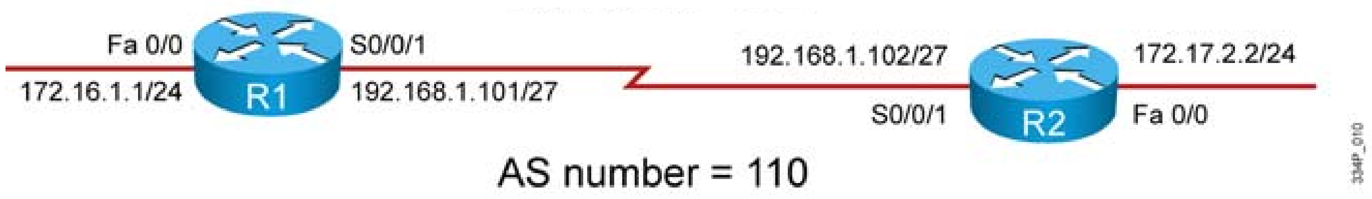
R1 (config-router) #

```
network 172.16.1.00.0.0.255
network 192.168.1.0
```

EIGRP – Configuring



EIGRP – Configuring



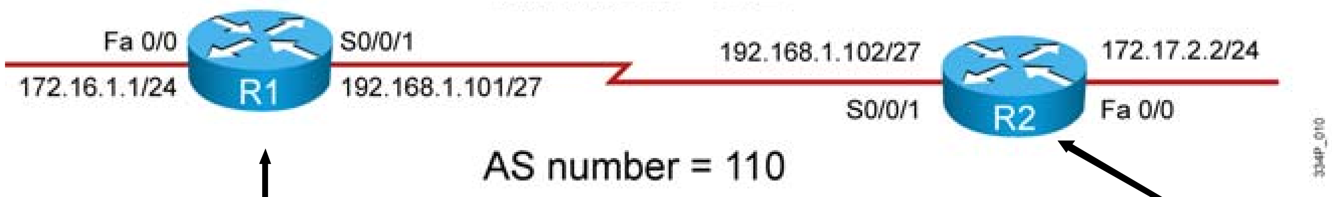
R1#

```
interface FastEthernet0/0
  ip address 172.16.1.1 255.255.255.0
!
interface Serial0/0/1

 ip address 192.168.1.101 255.255.255.224
!
router eigrp 110
 network 172.16.1.0 0.0.0.255
 network 192.168.1.0
```

R2#

```
interface FastEthernet0/0
  ip address 172.17.2.2 255.255.255.0
!
interface Serial0/0/1

 ip address 192.168.1.102 255.255.255.224
!
router eigrp 110
 network 172.17.2.0 0.0.0.255
 network 192.168.1.0
```

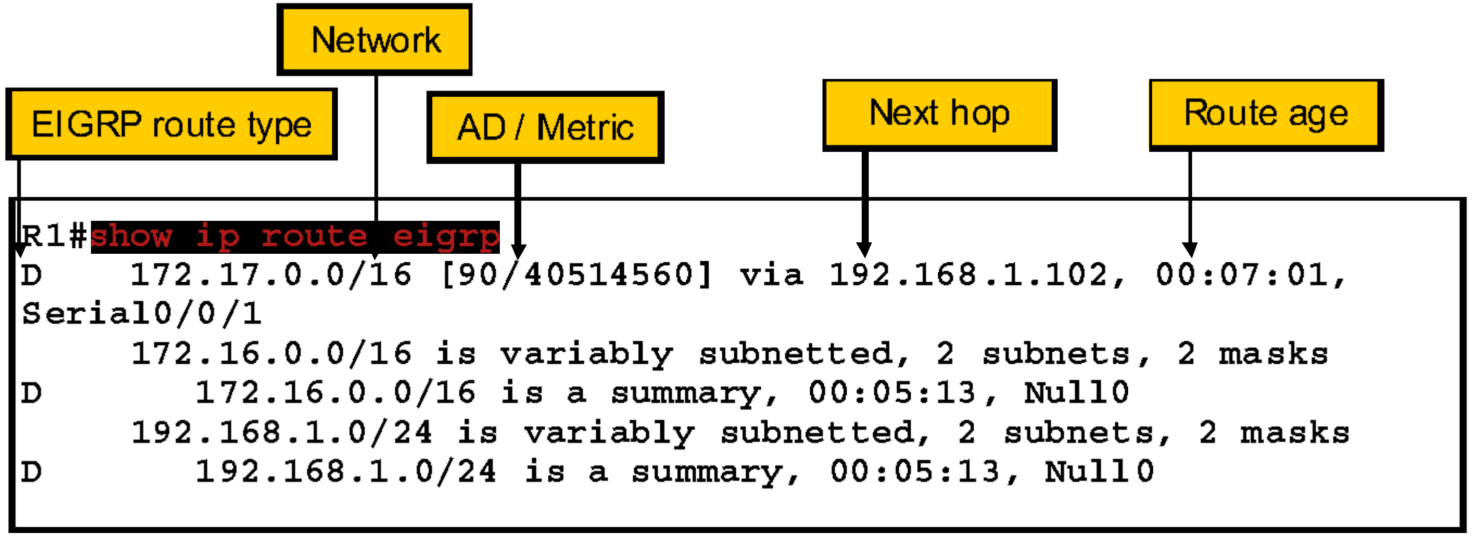
EIGRP – verifying



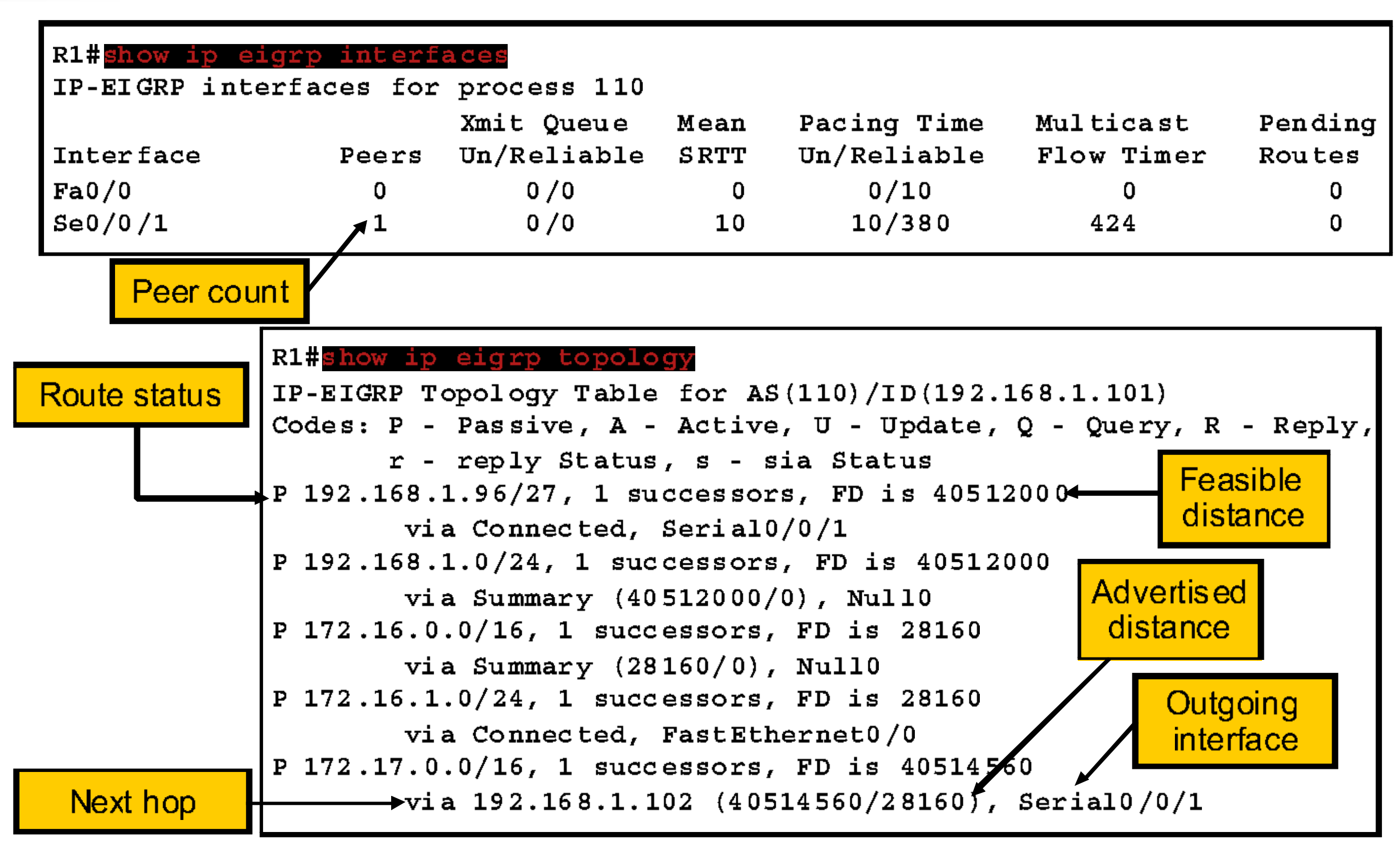

```
R1#show ip eigrp neighbors
IP-EIGRP neighbors for process 110
H   Address          Interface     Hold  Uptime     SRTT    RTO   Q   Seq
                                   (sec)            (ms)         Cnt  Num
0   192.168.1.102    Se0/0/1       10    00:07:22    10     2280  0   5
```

```
R2#show ip eigrp neighbors
IP-EIGRP neighbors for process 110
H   Address          Interface     Hold  Uptime     SRTT    RTO   Q   Seq
                                   (sec)            (ms)         Cnt  Num
0   192.168.1.101    Se0/0/1       10    00:17:02    10     1380  0   5
```

EIGRP – Verifying EIGRP Routes

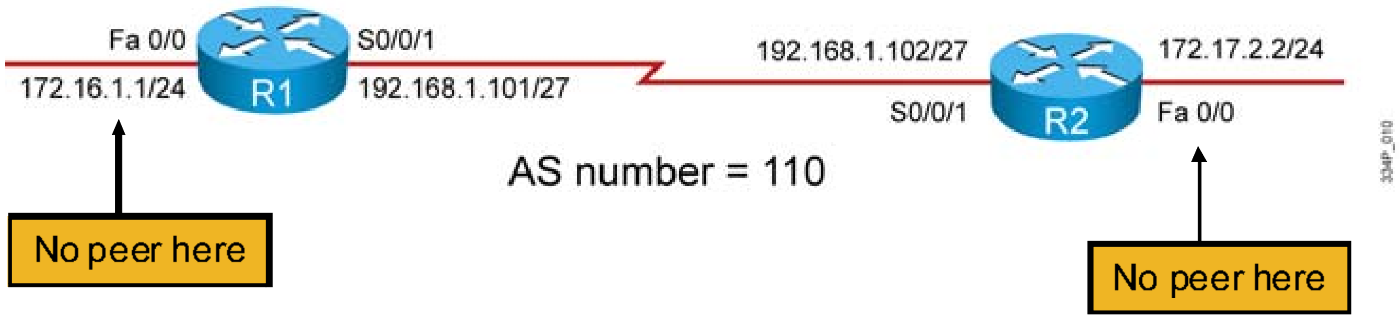


EIGRP – Verification



EIGRP – Passive Interfaces

- EIGRP announces the directly connected network of an interface
- EIGRP does not try to form neighbor relationships over the interface where only the host is connected
  - Reduces traffic overhead



R1#

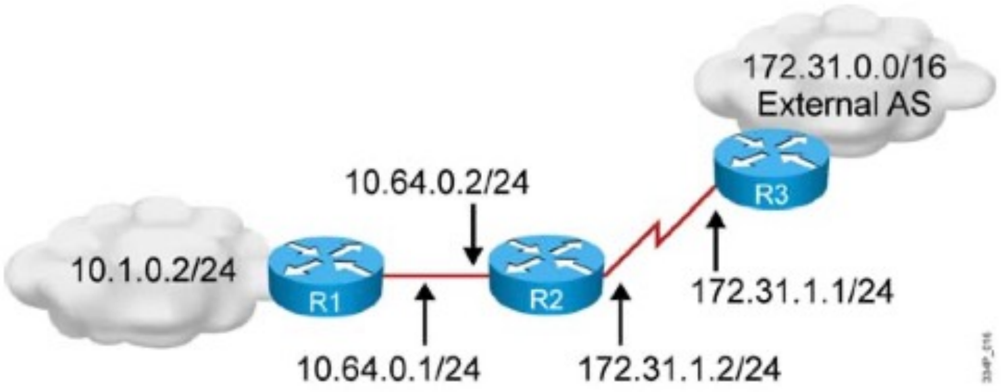
```
router eigrp 110
 passive-interface FastEthernet0/0
 network 172.16.1.0 0.0.0.255
 network 192.168.1.0
```

R2#

```
router eigrp 110
 passive-interface FastEthernet0/0
 network 172.17.2.0 0.0.0.255
 network 192.168.1.0
```

EIGRP – Default routes

- Default routes decrease the size of the routing table
- Multiple candidates:
  - 0.0.0.0 is statically set or advertised by the routing protocol

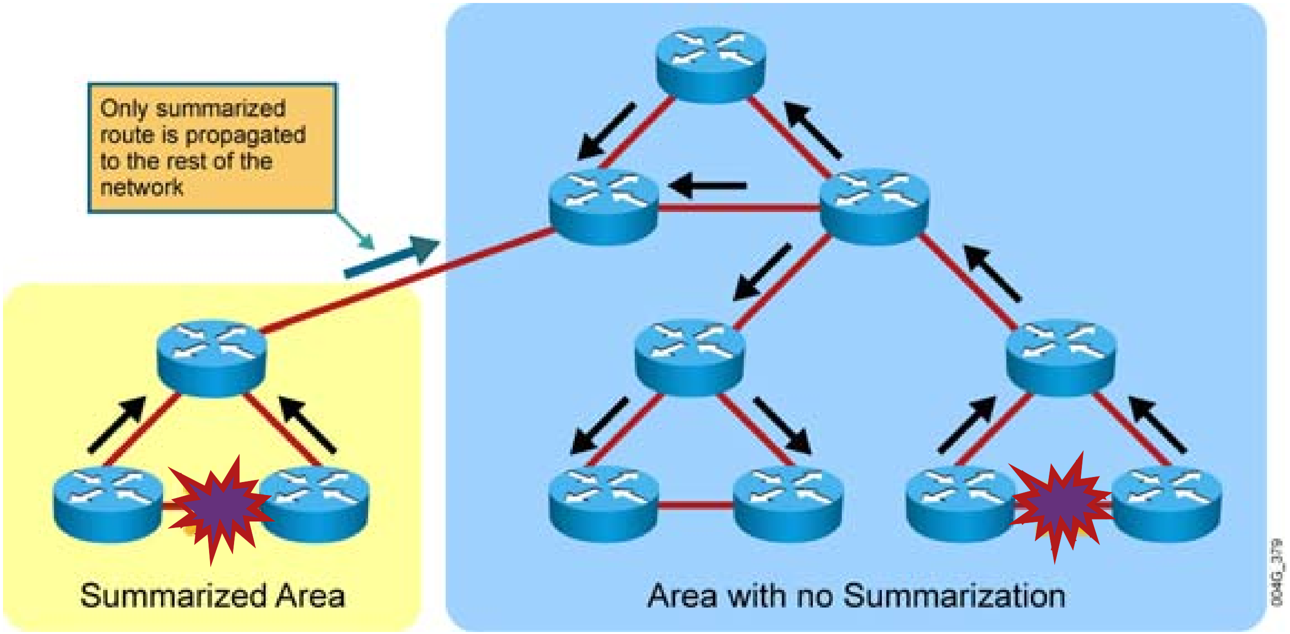


EIGRP: Use Default Route and Redistribution

```
R2(config)#ip route 0.0.0.0 0.0.0.0 172.31.1.2
R2(config)#router eigrp 110
R2(config-router)#redistribute static
```

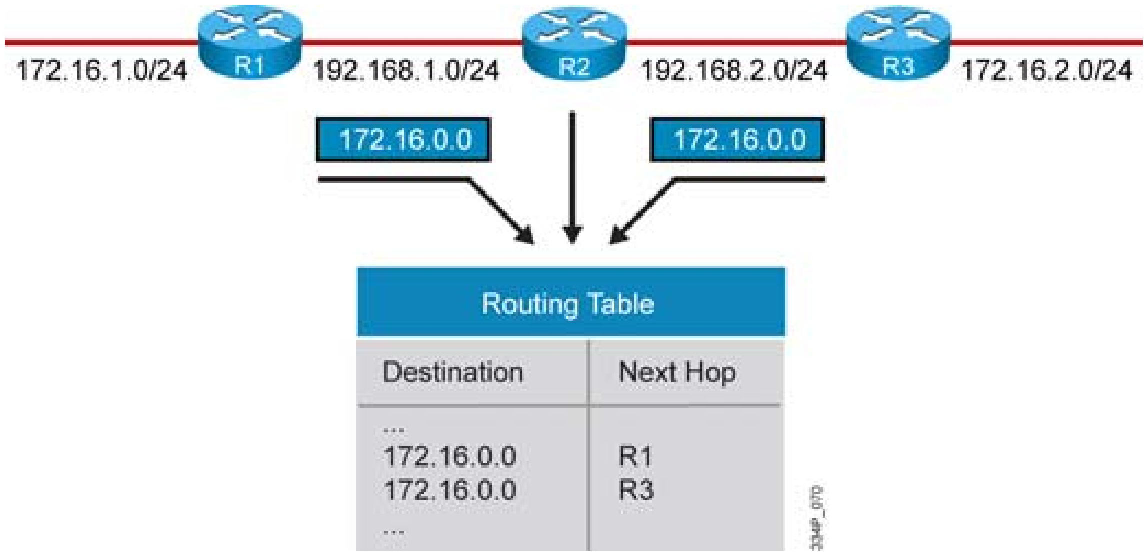
EIGRP – Route Summarization

- Improves network scalability
  - Smaller routing tables
  - Fewer updates
- Should follow IP addressing



EIGRP – Automatic Route Summarization

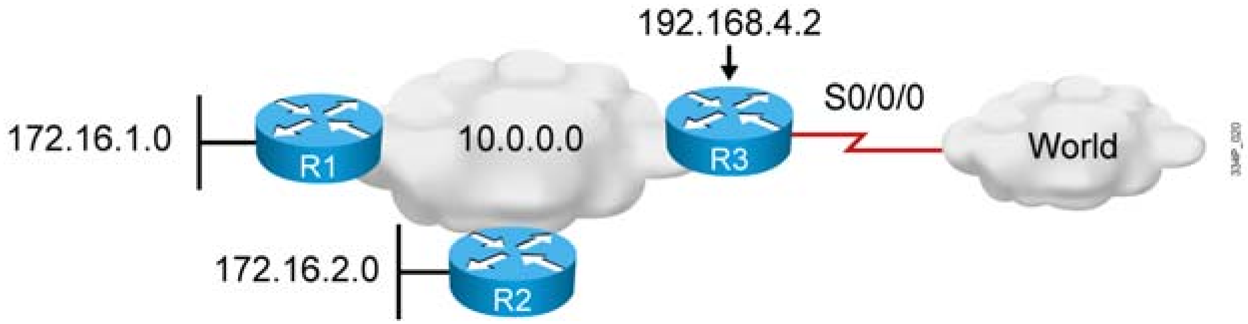
- Performed on major network boundaries
  - Subnetworks are summarized to a single classful (major) network.
  - Automatic summarization occurs by default.
- Could result in routing issues—disable auto summarization



Destination	Next Hop
...	
172.16.0.0	R1
172.16.0.0	R3
...	

EIGRP – Manual Route Summarization

Creating a summary route for 172.16.0.0/16



R1(config)#

```
router eigrp 110
 network 10.0.0.0
 network 172.16.0.0
 no auto-summary
```

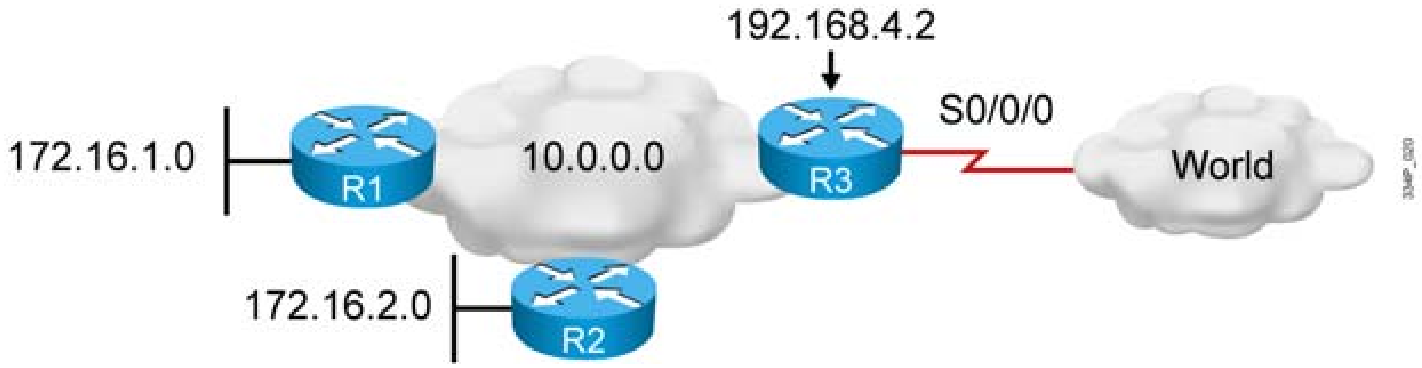
R2(config)#

```
router eigrp 110
 network 10.0.0.0
 network 172.16.0.0
 no auto-summary
```

R3(config)#

```
interface Serial0/0/0
 ip address 192.168.4.2 255.255.255.0
 ip summary-address eigrp 110 172.16.0.0 255.255.0.0
!
router eigrp 110
 network 10.0.0.0
 network 192.168.4.0
 no auto-summary
```

EIGRP – Route Summarization




```
R3#show ip route
<output omitted>
Gateway of last resort is not set
     172.16.0.0/16 is variably subnetted, 3 subnets, 2 masks
D       172.16.0.0/16 is a summary, 00:00:04, Null0
D       172.16.1.0/24 [90/156160] via 10.1.1.2, 00:00:04, FastEthernet0/0
D       172.16.2.0/24 [90/20640000] via 10.2.2.2, 00:00:04, Serial0/0/1
C    192.168.4.0/24 is directly connected, Serial0/0/0
     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C       10.2.2.0/24 is directly connected, Serial0/0/1
<output omitted>
```

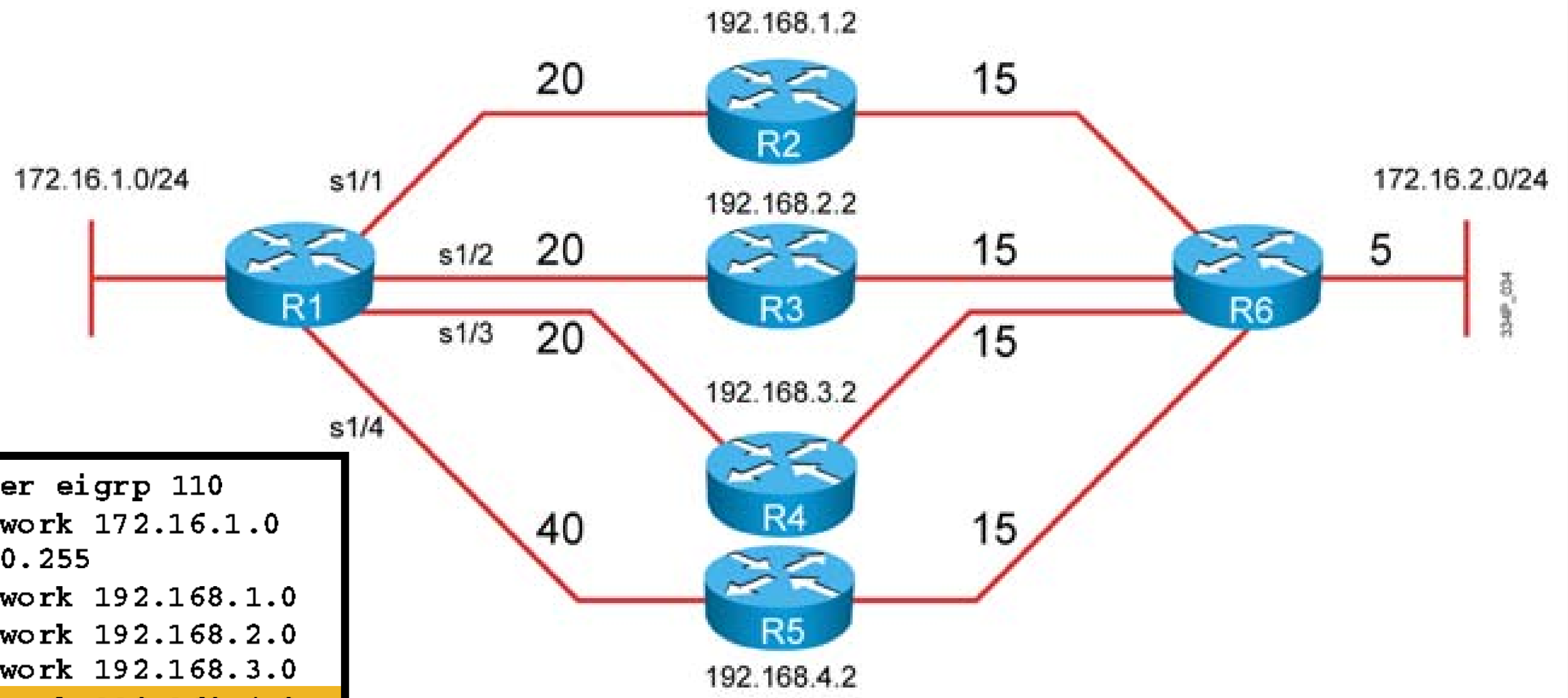
EIGRP – Load Balancing

- Routes with a metric equal to the minimum metric are installed in the routing table - equal-metric load balancing
- Up to 16 entries can be in the routing table for the same destination (default is 4)
  - Maximum number is configurable
  - To disable load balancing, set the value to one

```
R1(config)#
router eigrp 110
 maximum-paths 2
```

- To control the maximum number of parallel routes that an IP routing protocol can support

EIGRP – Load Balancing



R1#

```
router eigrp 110
 network 172.16.1.0
0.0.0.255
 network 192.168.1.0
 network 192.168.2.0
 network 192.168.3.0
 network 192.168.4.0
 maximum-paths 3
```

```
R1#show ip route eigrp
<output omitted>
 172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
D    172.16.2.0/24 [90/2809856] via 192.168.1.2, 00:07:01, Serial1/1
                   [90/2809856] via 192.168.2.2, 00:07:01, Serial1/2
                   [90/2809856] via 192.168.3.2, 00:07:01, Serial1/3
<output omitted>
```

EIGRP – Load Balancing Unequal-Cost

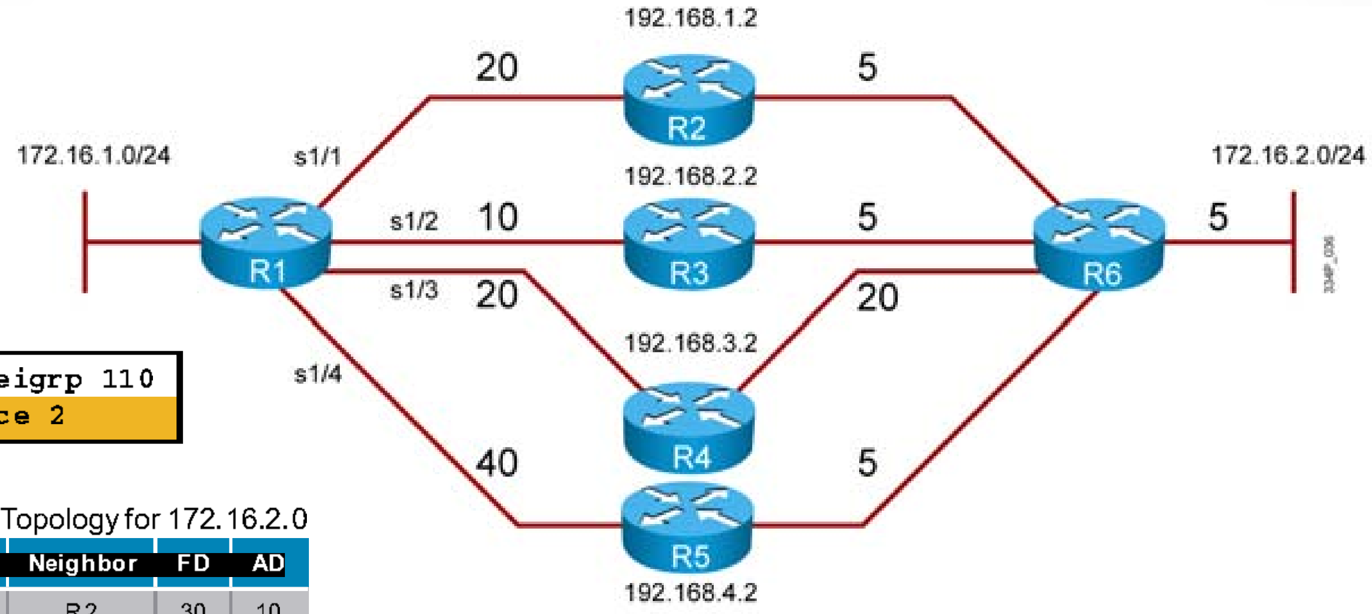
- The router can balance traffic across multiple routes that have different metrics to a destination
  - Successor is always used
  - Feasible successors are used if the cost is less than (minimum cost * variance)
    - Variance is only a multiplier, not a max-path parameter
  - The maximum number of paths is limited by the **maximum–paths** command
    - Variance opens the gate for unequal-cost load balancing

R1(config)#

```
router eigrp 110
 variance 2
```

- To control load balancing in an internetwork based on EIGRP

EIGRP – Load Balancing Unequal-Cost



R1#
```
router eigrp 110
 variance 2
```

R1 EIGRP Topology for 172.16.2.0

Network	Neighbor	FD	AD
172.16.2.0	R2	30	10
	R3	20	10
	R4	45	25
	R5	50	10

- AD(R4)>FD(R3)
- Variance: 50(FD)>2*20(FD,Successor)

```
R1#show ip route eigrp
<output omitted>
 172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
D    172.16.2.0/24 [90/10665472] via 192.168.2.2, 00:07:01, Serial1/2
                   [90/11151872] via 192.168.1.2, 00:07:01, Serial1/1
<output omitted>
```