Learning Routes

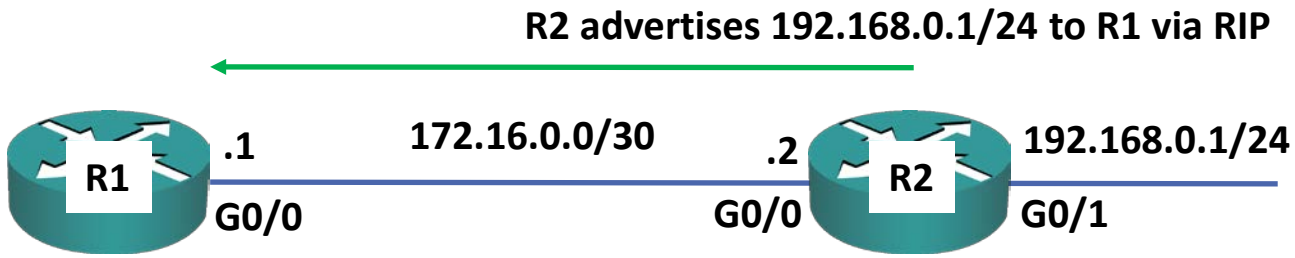
- Routers learn routes by:
- An administrator configuring IP addresses on its interfaces (Connected and Local routes)
- An administrator configuring Static routes on that router
- Receiving them via routing protocols from neighbor routers

Learning Routes (Cont.)

```
R1(config)#interface g0/0
R1(config-if)#ip address 172.16.0.1 255.255.255.252

R1(config)#ip route 192.168.100.0 255.255.255.0 172.16.0.2
```

- RIP is also enabled between R1 and R2.



The Routing Table

```
R1#sh ip route
Codes: L - local, 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, H - NHRP, l - LISP
       a - application route
       + - replicated route, % - next hop override, p - overrides from PfR

Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        172.16.0.0/30 is directly connected, GigabitEthernet0/0
L        172.16.0.1/32 is directly connected, GigabitEthernet0/0
R     192.168.0.0/24 [120/1] via 172.16.0.2, 00:00:04, GigabitEthernet0/0
S     192.168.100.0/24 [1/0] via 172.16.0.2
```

Route Precedence

- A router's main job is to forward packets received towards their destination, based on the packet's destination IP address
- It decides where to forward a packet based on the routes it has learned
- The best route for a packet decision is based on:
  1. Longest prefix (most specific)
  2. AD Administrative Distance
  3. Metric

Route Precedence (Cont.)

- If a router learns multiple routes for the **exact same** network and prefix it must decide which is the best route
- For example these routes are for the exact same network and prefix:

  192.168.0.0/24 received via EIGRP from R2

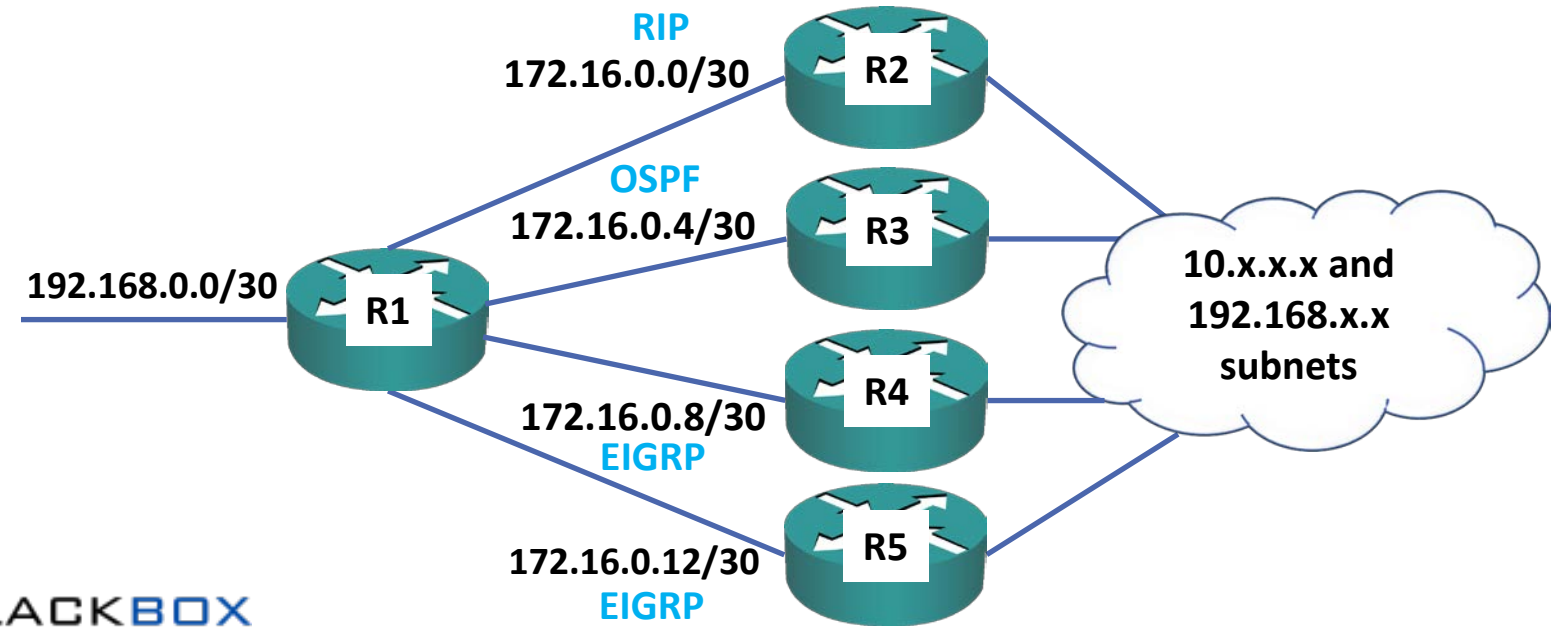
  192.168.0.0/24 received via OSPF from R3

Route Precedence (Cont.)

- Only the best route for each learned network/prefix makes it into the routing table and is used to forward packets
- Criteria for which is the best route to the exact same network/prefix:
  1. Administrative Distance (lower value is better.) If there is a tie:
  2. Metric (lower value is better)
- If there are multiple best routes with the same Administrative Distance and Metric, they will all enter the routing table and the router will perform Equal Cost Load Balancing over them

Route Precedence Example Topology

- The following examples are based on the network topology below
- The point of this video is purely to explain how R1 decides between learned routes. This network design would never be used in the real world



Example 1

R1 learns these routes:

- 10.0.0.0/24 via RIP (AD 120) from R2, Metric 5
- 10.0.0.0/24 via OSPF (AD 110) from R3, Metric 2
- 10.0.0.0/24 via EIGRP (AD 90) from R4, Metric 3072
- 10.0.0.0/24 via EIGRP (AD 90) from R5, Metric 6144

Example 1 (Cont.)

- EIGRP has a better Administrative Distance than RIP and OSPF
- The route via R4 has a better metric than the route via R5
- The EIGRP route from R4 wins and is inserted into R1's routing table.
- If R1 receives a packet with a destination address of 10.0.0.1– 10.0.0.255 it will be forwarded to R4 at 172.16.0.10

```
R1#sh ip route
! truncated

      10.0.0.0/24 is subnetted, 1 subnets
D        10.0.0.0 [90/3072] via 172.16.0.10, 00:00:18, GigabitEthernet0/2
      172.16.0.0/16 is variably subnetted, 8 subnets, 2 masks
C        172.16.0.0/30 is directly connected, GigabitEthernet0/0
L        172.16.0.1/32 is directly connected, GigabitEthernet0/0
C        172.16.0.4/30 is directly connected, GigabitEthernet0/1
L        172.16.0.5/32 is directly connected, GigabitEthernet0/1
C        172.16.0.8/30 is directly connected, GigabitEthernet0/2
L        172.16.0.9/32 is directly connected, GigabitEthernet0/2
C        172.16.0.12/30 is directly connected, GigabitEthernet0/3
L        172.16.0.13/32 is directly connected, GigabitEthernet0/3
```

Example 2

R1 learns these routes:

- 10.0.1.0/24 via RIP (AD 120) from R2, Metric 5
- 10.0.1.0/24 via OSPF (AD 110) from R3, Metric 2
- 10.0.1.0/24 via EIGRP (AD 90) from R4, Metric 3072
- 10.0.1.0/24 via EIGRP (AD 90) from R5, Metric 3072

Example 2 (Cont.)

- EIGRP has a better Administrative Distance than RIP and OSPF
- The routes via R4 and R5 have the same Administrative Distance and metric
- The EIGRP routes from R4 and R5 win and both are inserted into R1's routing table.
- If R1 receives packets with a destination address of 10.0.1.1– 10.0.1.255 they will be load balanced over R4 at 172.16.0.10 and R5 at 172.16.0.14

```
R1#sh ip route
! truncated

 10.0.0.0/24 is subnetted, 2 subnets
D        10.0.0.0 [90/3072] via 172.16.0.10, 00:04:14, GigabitEthernet0/2
D        10.0.1.0 [90/3072] via 172.16.0.14, 00:00:06, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:00:06, GigabitEthernet0/2
      172.16.0.0/16 is variably subnetted, 8 subnets, 2 masks
C        172.16.0.0/30 is directly connected, GigabitEthernet0/0
L        172.16.0.1/32 is directly connected, GigabitEthernet0/0
C        172.16.0.4/30 is directly connected, GigabitEthernet0/1
L        172.16.0.5/32 is directly connected, GigabitEthernet0/1
C        172.16.0.8/30 is directly connected, GigabitEthernet0/2
L        172.16.0.9/32 is directly connected, GigabitEthernet0/2
C        172.16.0.12/30 is directly connected, GigabitEthernet0/3
L        172.16.0.13/32 is directly connected, GigabitEthernet0/3
```

Example 3

R1 learns these routes:

- 192.168.0.0/30 as a Connected Route (AD 0) on its interface G0/4
- 192.168.0.0/24 via RIP (AD 120) from R2, Metric 1
- 192.168.0.0/16 via OSPF (AD 110) from R3, Metric 11
- 192.168.0.0/26 via EIGRP (AD 90) from R4, Metric 3072
- 192.168.0.0/28 via EIGRP (AD 90) from R5, Metric 3072

Example 3 (Cont.)

- They are all best, **different** routes so they are all inserted into R1's routing table

```
R1#sh ip route
! Truncated
! 172.16.0.x routes are hidden

 10.0.0.0/24 is subnetted, 2 subnets
D        10.0.0.0 [90/3072] via 172.16.0.14, 00:18:50, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:18:50, GigabitEthernet0/2
D        10.0.1.0 [90/3072] via 172.16.0.14, 00:02:44, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:02:44, GigabitEthernet0/2
O     192.168.0.0/16 [110/11] via 172.16.0.6, 00:09:24, GigabitEthernet0/1
      192.168.0.0/24 is variably subnetted, 5 subnets, 5 masks
R        192.168.0.0/24 [120/1] via 172.16.0.2, 00:00:12, GigabitEthernet0/0
D        192.168.0.0/26
           [90/3072] via 172.16.0.10, 00:00:06, GigabitEthernet0/2
D        192.168.0.0/28
           [90/3072] via 172.16.0.14, 00:02:00, GigabitEthernet0/3
C        192.168.0.0/30 is directly connected, GigabitEthernet0/4
L        192.168.0.1/32 is directly connected, GigabitEthernet0/4
```

Example 3 (Cont.)

- 192.168.0.0/30 matches destination addresses 192.168.0.1 – 192.168.0.3
- 192.168.0.0/28 matches destination addresses 192.168.0.1 – 192.168.0.15
- 192.168.0.0/26 matches destination addresses 192.168.0.1 – 192.168.0.63
- 192.168.0.0/24 matches destination addresses 192.168.0.1 – 192.168.0.255
- 192.168.0.0/16 matches destination addresses 192.168.0.1 – 192.168.255.255

Example 3 (Cont.)

- A packet with destination address 192.168.0.2 matches all the highlighted routes
- The longest prefix match is the Connected route so the packet is forwarded out interface G0/4

```
R1#sh ip route
! Truncated
! 172.16.0.x routes are hidden

 10.0.0.0/24 is subnetted, 2 subnets
D        10.0.0.0 [90/3072] via 172.16.0.14, 00:18:50, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:18:50, GigabitEthernet0/2
D        10.0.1.0 [90/3072] via 172.16.0.14, 00:02:44, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:02:44, GigabitEthernet0/2
O     192.168.0.0/16 [110/11] via 172.16.0.6, 00:09:24, GigabitEthernet0/1
      192.168.0.0/24 is variably subnetted, 5 subnets, 5 masks
R        192.168.0.0/24 [120/1] via 172.16.0.2, 00:00:12, GigabitEthernet0/0
D        192.168.0.0/26
           [90/3072] via 172.16.0.10, 00:00:06, GigabitEthernet0/2
D        192.168.0.0/28
           [90/3072] via 172.16.0.14, 00:02:00, GigabitEthernet0/3
C        192.168.0.0/30 is directly connected, GigabitEthernet0/4
L        192.168.0.1/32 is directly connected, GigabitEthernet0/4
```

Example 3 (Cont.)

- A packet with destination address 192.168.0.5 matches all the highlighted routes
- The longest prefix match is the EIGRP route from R5 so the packet is forwarded to 172.16.0.14

```
R1#sh ip route
! Truncated
! 172.16.0.x routes are hidden

 10.0.0.0/24 is subnetted, 2 subnets
D        10.0.0.0 [90/3072] via 172.16.0.14, 00:18:50, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:18:50, GigabitEthernet0/2
D        10.0.1.0 [90/3072] via 172.16.0.14, 00:02:44, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:02:44, GigabitEthernet0/2
O     192.168.0.0/16 [110/11] via 172.16.0.6, 00:09:24, GigabitEthernet0/1
      192.168.0.0/24 is variably subnetted, 5 subnets, 5 masks
R        192.168.0.0/24 [120/1] via 172.16.0.2, 00:00:12, GigabitEthernet0/0
D        192.168.0.0/26
           [90/3072] via 172.16.0.10, 00:00:06, GigabitEthernet0/2
D        192.168.0.0/28
           [90/3072] via 172.16.0.14, 00:02:00, GigabitEthernet0/3
C        192.168.0.0/30 is directly connected, GigabitEthernet0/4
L        192.168.0.1/32 is directly connected, GigabitEthernet0/4
```

Example 3 (Cont.)

- A packet with destination address 192.168.0.20 matches all the highlighted routes
- The longest prefix match is the EIGRP route from R4 so the packet is forwarded to 172.16.0.10

```
R1#sh ip route
! Truncated
! 172.16.0.x routes are hidden

 10.0.0.0/24 is subnetted, 2 subnets
D        10.0.0.0 [90/3072] via 172.16.0.14, 00:18:50, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:18:50, GigabitEthernet0/2
D        10.0.1.0 [90/3072] via 172.16.0.14, 00:02:44, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:02:44, GigabitEthernet0/2
O     192.168.0.0/16 [110/11] via 172.16.0.6, 00:09:24, GigabitEthernet0/1
      192.168.0.0/24 is variably subnetted, 5 subnets, 5 masks
R        192.168.0.0/24 [120/1] via 172.16.0.2, 00:00:12, GigabitEthernet0/0
D        192.168.0.0/26
           [90/3072] via 172.16.0.10, 00:00:06, GigabitEthernet0/2
D        192.168.0.0/28
           [90/3072] via 172.16.0.14, 00:02:00, GigabitEthernet0/3
C        192.168.0.0/30 is directly connected, GigabitEthernet0/4
L        192.168.0.1/32 is directly connected, GigabitEthernet0/4
```

Example 3 (Cont.)

- A packet with destination address 192.168.0.120 matches all the highlighted routes
- The longest prefix match is the RIP route from R1 so the packet is forwarded to 172.16.0.2
- **The RIP route is preferred over the (better AD) OSPF route because of longest prefix match**

```
R1#sh ip route
! Truncated
! 172.16.0.x routes are hidden

 10.0.0.0/24 is subnetted, 2 subnets
D        10.0.0.0 [90/3072] via 172.16.0.14, 00:18:50, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:18:50, GigabitEthernet0/2
D        10.0.1.0 [90/3072] via 172.16.0.14, 00:02:44, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:02:44, GigabitEthernet0/2
O     192.168.0.0/16 [110/11] via 172.16.0.6, 00:09:24, GigabitEthernet0/1
      192.168.0.0/24 is variably subnetted, 5 subnets, 5 masks
R        192.168.0.0/24 [120/1] via 172.16.0.2, 00:00:12, GigabitEthernet0/0
D        192.168.0.0/26
           [90/3072] via 172.16.0.10, 00:00:06, GigabitEthernet0/2
D        192.168.0.0/28
           [90/3072] via 172.16.0.14, 00:02:00, GigabitEthernet0/3
C        192.168.0.0/30 is directly connected, GigabitEthernet0/4
L        192.168.0.1/32 is directly connected, GigabitEthernet0/4
```

Example 3 (Cont.)

- A packet with destination address 192.168.1.5 matches only the highlighted route
- The longest prefix match is the OSPF route from R3 so the packet is forwarded to 172.16.0.6

```
R1#sh ip route
! Truncated
! 172.16.0.x routes are hidden

 10.0.0.0/24 is subnetted, 2 subnets
D        10.0.0.0 [90/3072] via 172.16.0.14, 00:18:50, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:18:50, GigabitEthernet0/2
D        10.0.1.0 [90/3072] via 172.16.0.14, 00:02:44, GigabitEthernet0/3
                  [90/3072] via 172.16.0.10, 00:02:44, GigabitEthernet0/2
O     192.168.0.0/16 [110/11] via 172.16.0.6, 00:09:24, GigabitEthernet0/1
      192.168.0.0/24 is variably subnetted, 5 subnets, 5 masks
R        192.168.0.0/24 [120/1] via 172.16.0.2, 00:00:12, GigabitEthernet0/0
D        192.168.0.0/26
           [90/3072] via 172.16.0.10, 00:00:06, GigabitEthernet0/2
D        192.168.0.0/28
           [90/3072] via 172.16.0.14, 00:02:00, GigabitEthernet0/3
C        192.168.0.0/30 is directly connected, GigabitEthernet0/4
L        192.168.0.1/32 is directly connected, GigabitEthernet0/4
```

Example 3 (Cont.) – show ip route < address >

```
R1#show ip route 192.168.1.5
Routing entry for 192.168.0.0/16, supernet
  Known via "ospf 1", distance 110, metric 11, type intra area
  Last update from 172.16.0.6 on GigabitEthernet0/1, 00:50:27 ago
  Routing Descriptor Blocks:
  * 172.16.0.6, from 172.16.0.6, 00:50:27 ago, via GigabitEthernet0/1
      Route metric is 11, traffic share count is 1
```

Practice Question

R1 learns these routes:

- 10.0.0.0/28 via EIGRP from R2, Metric 9
- 10.0.0.0/28 via RIP from R3, Metric 5
- 10.0.0.0/28 via OSPF from R4, Metric 7
- 10.0.0.0/16 via OSPF from R5, Metric 6
- 10.0.0.0/16 via RIP from R6, Metric 4
- 10.0.0.0/16 via EIGRP from R7, Metric 8
- 10.0.0.0/16 via OSPF from R8, Metric 9

Which router will R1 forward a received packet with destination IP address 10.0.0.16 to?

Practice Question - Answer

R1 learns these routes:

- 10.0.0.0/28 via EIGRP from R2, Metric 9
- 10.0.0.0/28 via RIP from R3, Metric 5
- 10.0.0.0/28 via OSPF from R4, Metric 7
- 10.0.0.0/16 via OSPF from R5, Metric 6
- 10.0.0.0/16 via RIP from R6, Metric 4
- **10.0.0.0/16 via EIGRP from R7, Metric 8**
- 10.0.0.0/16 via OSPF from R8, Metric 9

10.0.0.0/28 matches 10.0.0.1 – 10.0.0.15

EIGRP has a better Administrative Distance (90) than OSPF (110) and RIP (120)