



CCNA

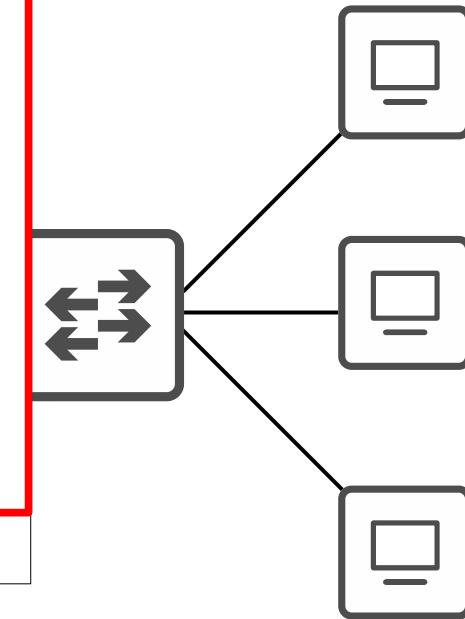


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3.0 IP Connectivity

- 3.1 Interpret the components of routing table
 - 3.1.a Routing protocol code
 - 3.1.b Prefix
 - 3.1.c Network mask
 - 3.1.d Next hop
 - 3.1.e Administrative distance
 - 3.1.f Metric
 - 3.1.g Gateway of last resort
- 3.2 Determine how a router makes a forwarding decision by default
 - 3.2.a Longest match
 - 3.2.b Administrative distance
 - 3.2.c Routing protocol metric
- 3.3 Configure and verify IPv4 and IPv6 static routing
 - 3.3.a Default route
 - 3.3.b Network route
 - 3.3.c Host route
 - 3.3.d Floating static
- 3.4 Configure and verify single area OSPFv2
 - 3.4.a Neighbor adjacencies
 - 3.4.b Point-to-point
 - 3.4.c Broadcast (DR/BDR selection)
 - 3.4.d Router ID
- 3.5 Describe the purpose of first hop redundancy protocol

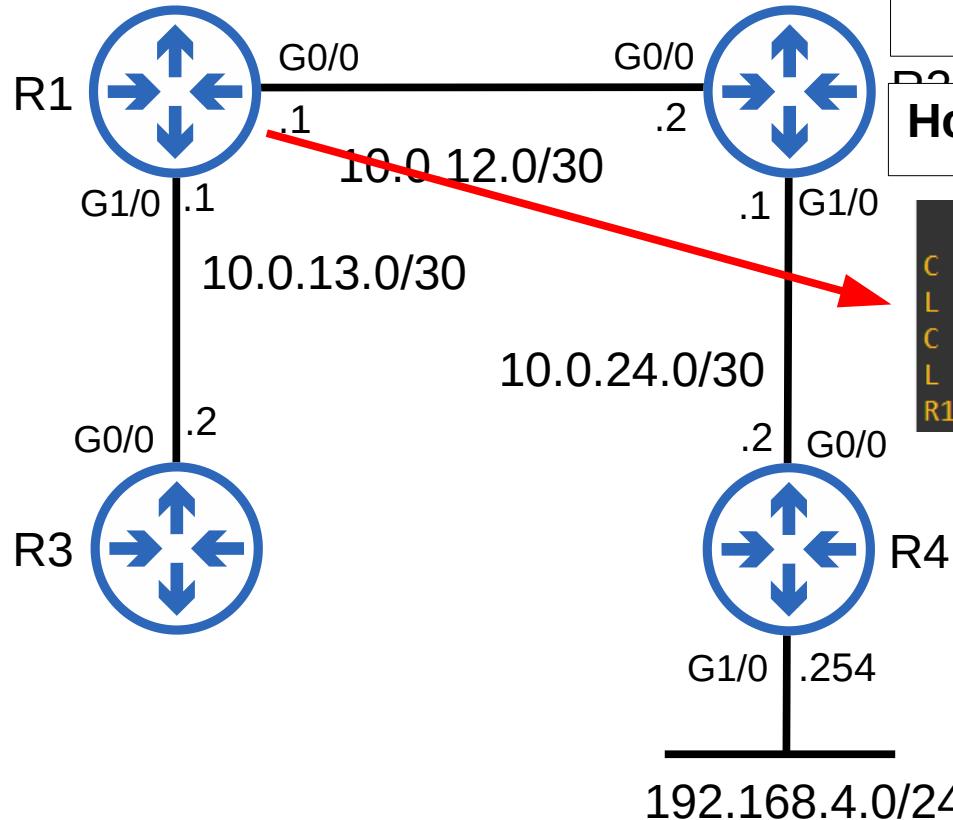
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Things we'll cover

- Introduction to dynamic routing protocols
- Types of dynamic routing protocols
- Dynamic routing protocol metrics
- Administrative distance

Dynamic Routing



Network route: A route to a network/subnet (mask length < /32)

Host route: A route to a specific host (/32 mask)

```
10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C 10.0.12.0/30 is directly connected, GigabitEthernet0/0
C 10.0.12.1/32 is directly connected, GigabitEthernet0/0
C 10.0.13.0/30 is directly connected, GigabitEthernet1/0
C 10.0.13.1/32 is directly connected, GigabitEthernet1/0
R1#
```

3.3 Configure and verify IPv4 and IPv6 static routing

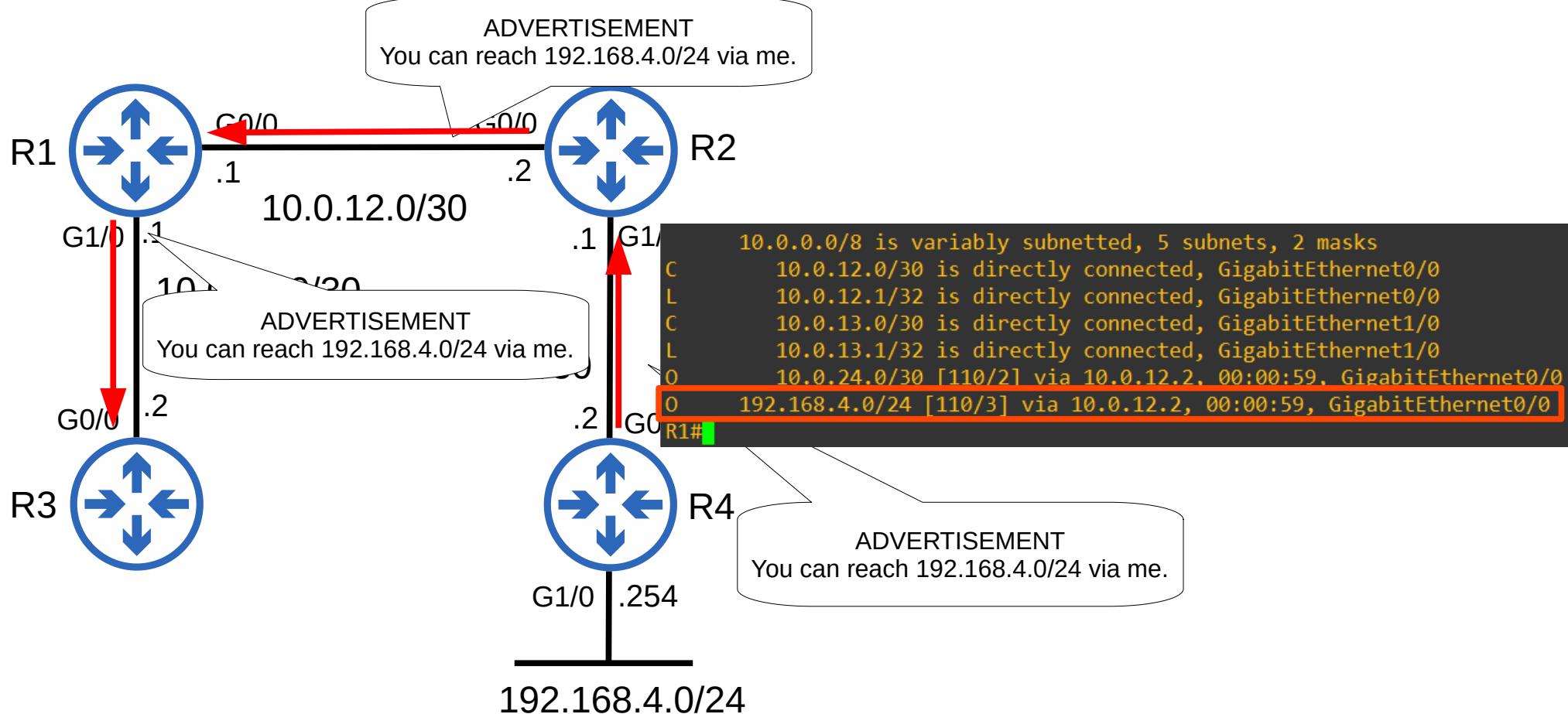
3.3.a Default route

3.3.b Network route

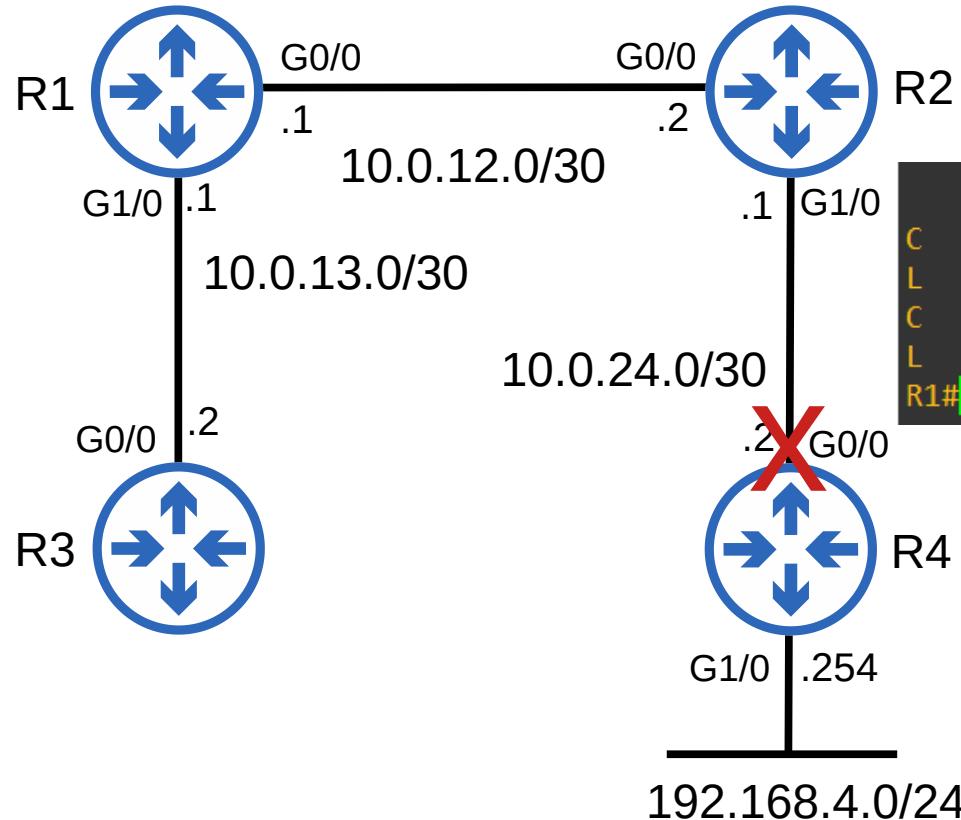
3.3.c Host route

3.3.d Floating static

Dynamic Routing

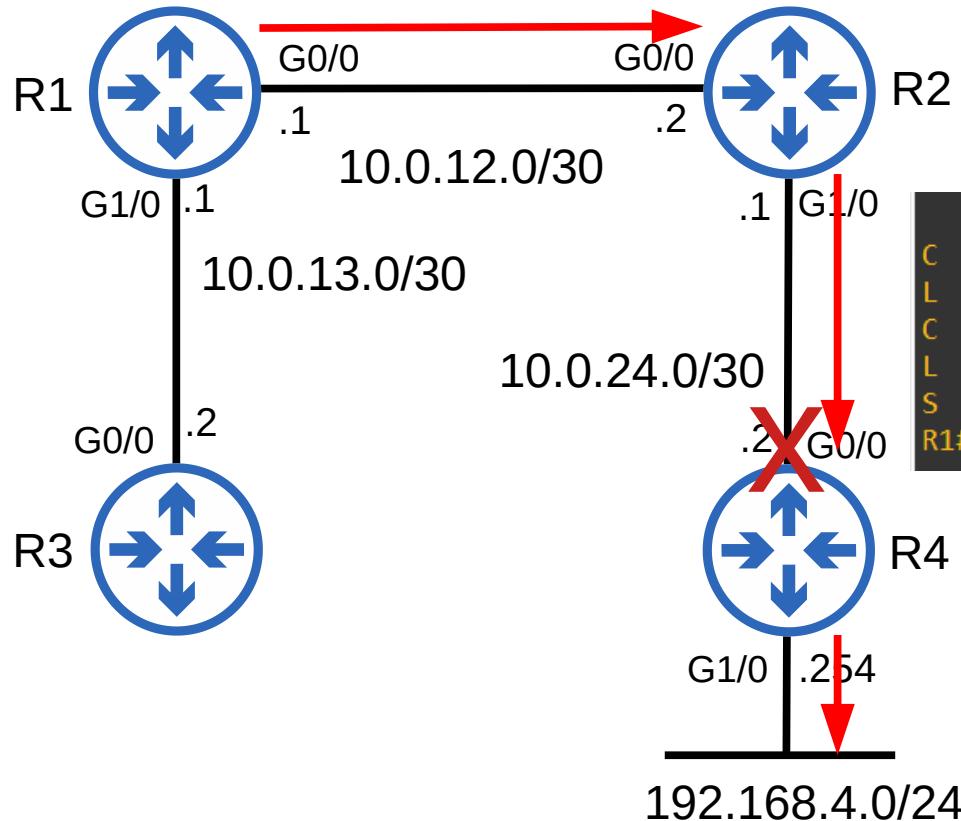


Dynamic Routing



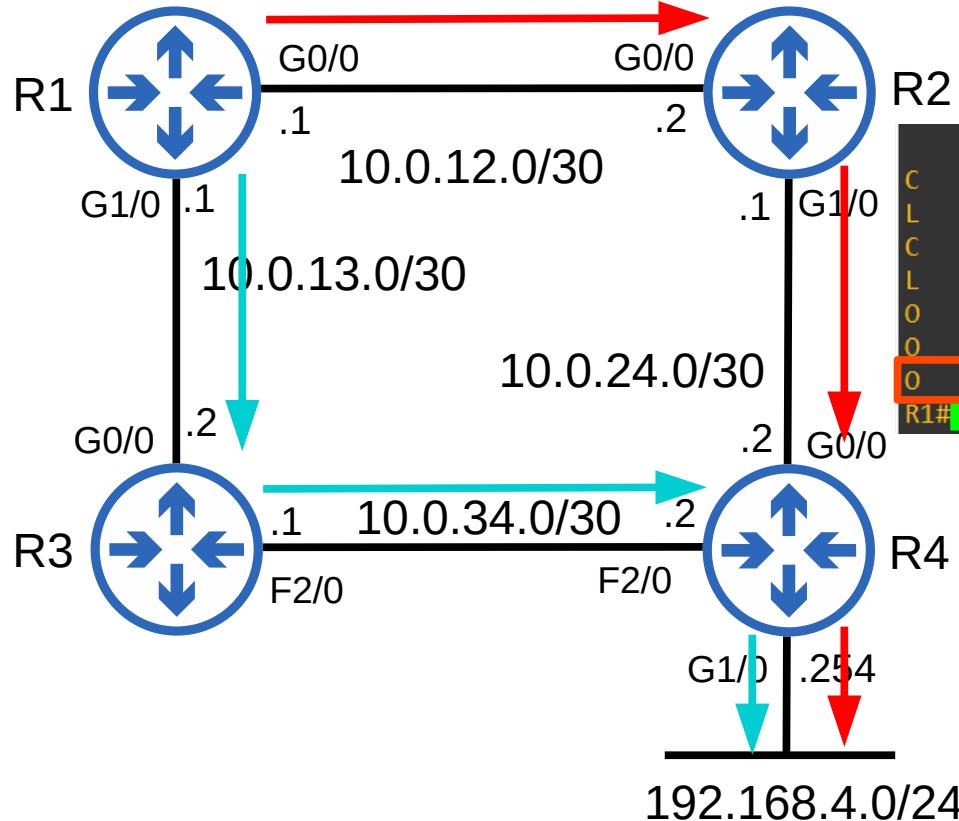
10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C 10.0.12.0/30 is directly connected, GigabitEthernet0/0
L 10.0.12.1/32 is directly connected, GigabitEthernet0/0
C 10.0.13.0/30 is directly connected, GigabitEthernet1/0
L 10.0.13.1/32 is directly connected, GigabitEthernet1/0
R1#

Static Routing



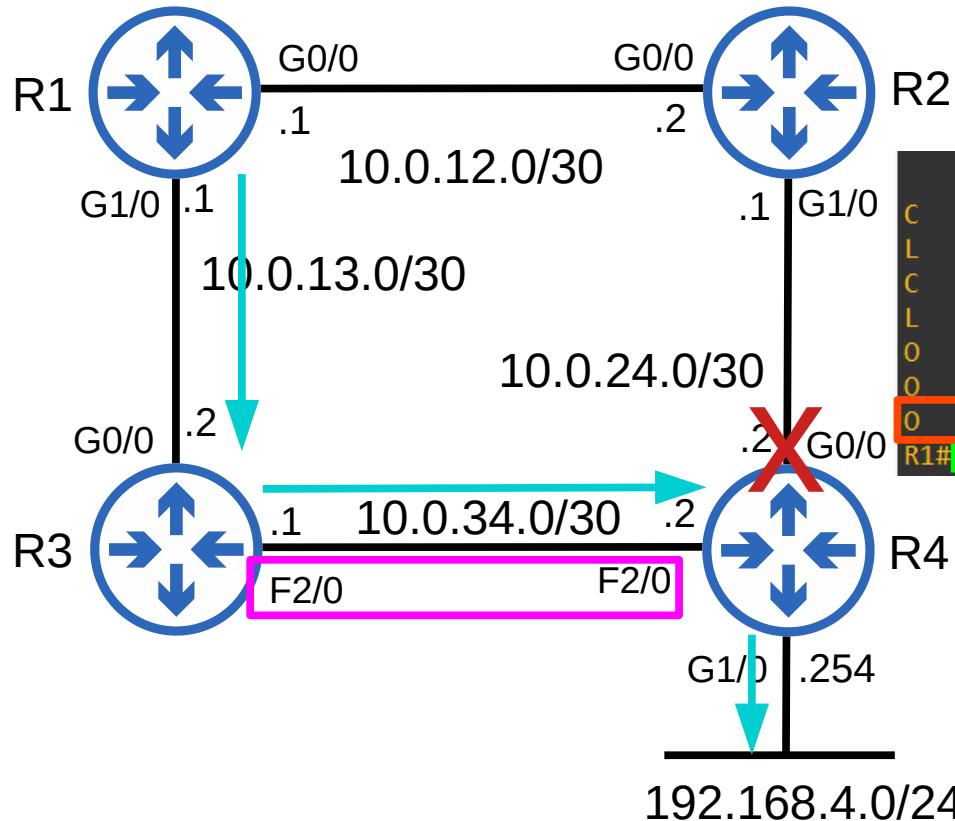
```
10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C   10.0.12.0/30 is directly connected, GigabitEthernet0/0
C   10.0.12.1/32 is directly connected, GigabitEthernet0/0
C   10.0.13.0/30 is directly connected, GigabitEthernet1/0
C   10.0.13.1/32 is directly connected, GigabitEthernet1/0
S   192.168.4.0/24 [1/0] via 10.0.12.2
R1#
```

Dynamic Routing



```
10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C   10.0.12.0/30 is directly connected, GigabitEthernet0/0
C   10.0.12.1/32 is directly connected, GigabitEthernet0/0
C   10.0.13.0/30 is directly connected, GigabitEthernet1/0
C   10.0.13.1/32 is directly connected, GigabitEthernet1/0
O   10.0.24.0/30 [110/2] via 10.0.12.2, 00:04:48, GigabitEthernet0/0
O   10.0.34.0/30 [110/11] via 10.0.13.2, 00:00:41, GigabitEthernet1/0
R1# 192.168.4.0/24 [110/3] via 10.0.12.2 00:04:48, GigabitEthernet0/0
```

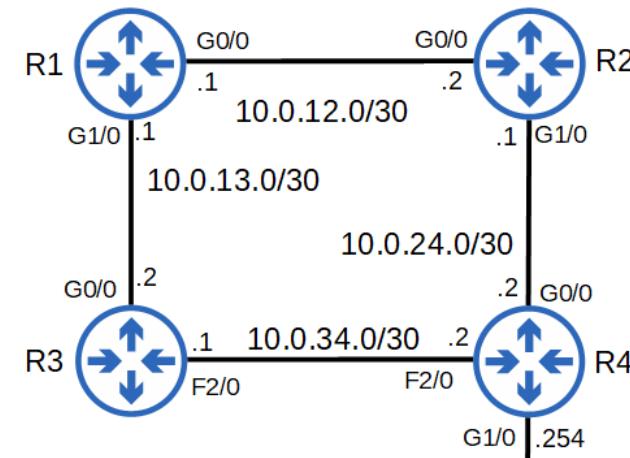
Dynamic Routing



```
10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C   10.0.12.0/30 is directly connected, GigabitEthernet0/0
L   10.0.12.1/32 is directly connected, GigabitEthernet0/0
C   10.0.13.0/30 is directly connected, GigabitEthernet1/0
L   10.0.13.1/32 is directly connected, GigabitEthernet1/0
O   10.0.24.0/30 [110/2] via 10.0.12.2, 00:01:20, GigabitEthernet0/0
O   10.0.34.0/30 [110/11] via 10.0.13.2, 00:13:33, GigabitEthernet1/0
R1# 192.168.4.0/24 [110/12] via 10.0.13.2 00:01:52, GigabitEthernet1/0
```

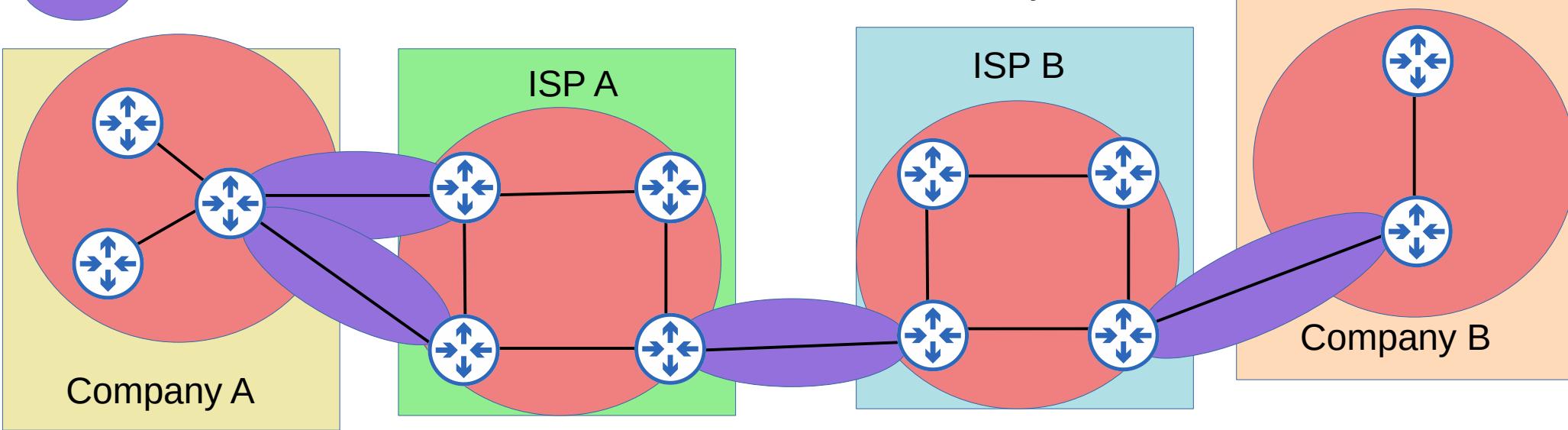
Dynamic Routing

- Routers can use dynamic routing protocols to advertise information about the routes they know to other routers.
- They form ‘adjacencies’ / ‘neighbor relationships’ / ‘neighborships’ with adjacent routers to exchange this information.
- If multiple routes to a destination are learned, the router determines which route is superior and adds it to the routing table. It uses the ‘metric’ of the route to decide which is superior (lower metric = superior).

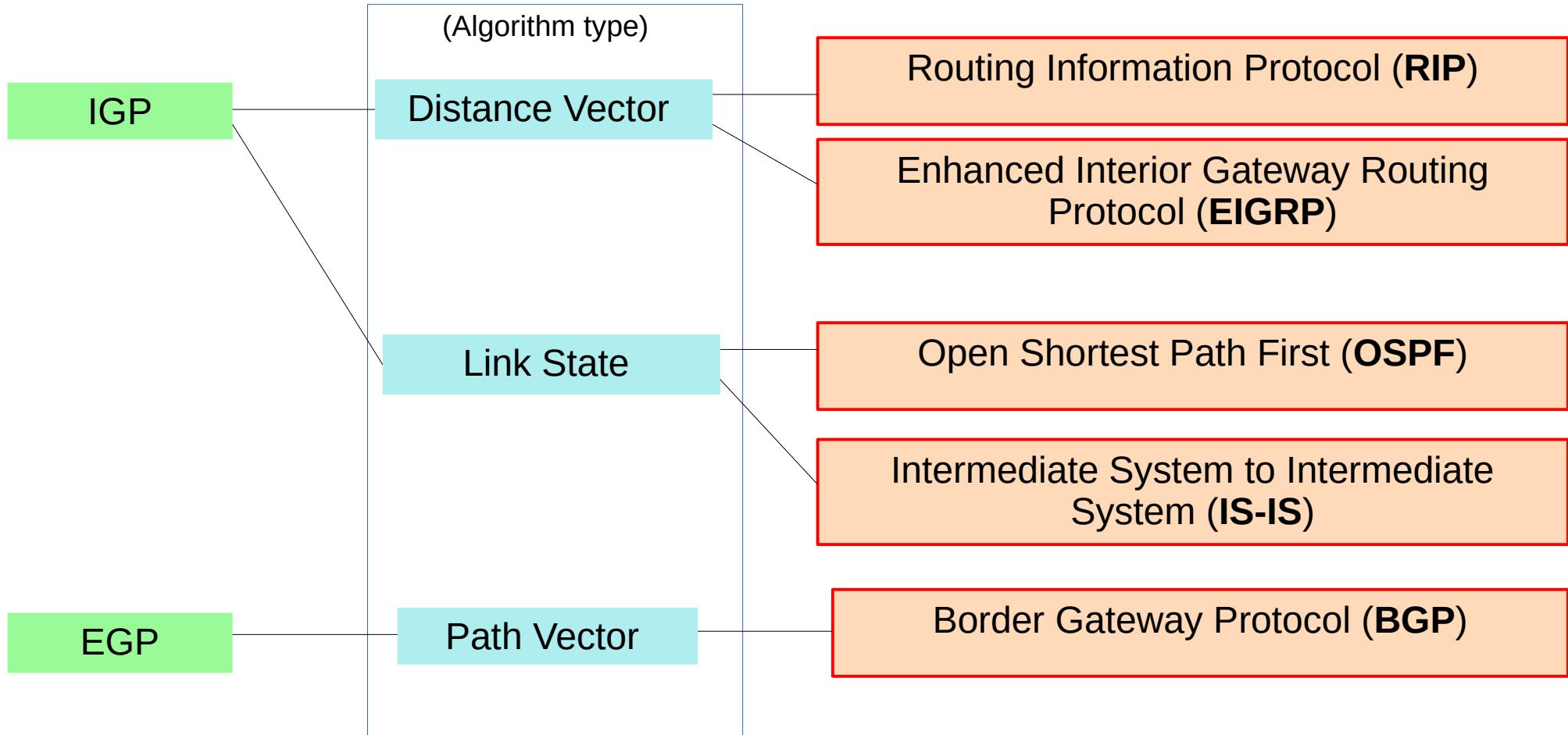


Types of Dynamic Routing Protocols

- Dynamic routing protocols can be divided into two main categories:
IGP (Interior Gateway Protocol)
EGP (Exterior Gateway Protocol).
- IGP = used to share routes within a single *autonomous system* (AS), which is a single organization (ie. a company)
- EGP = used to share routes *between* different autonomous systems



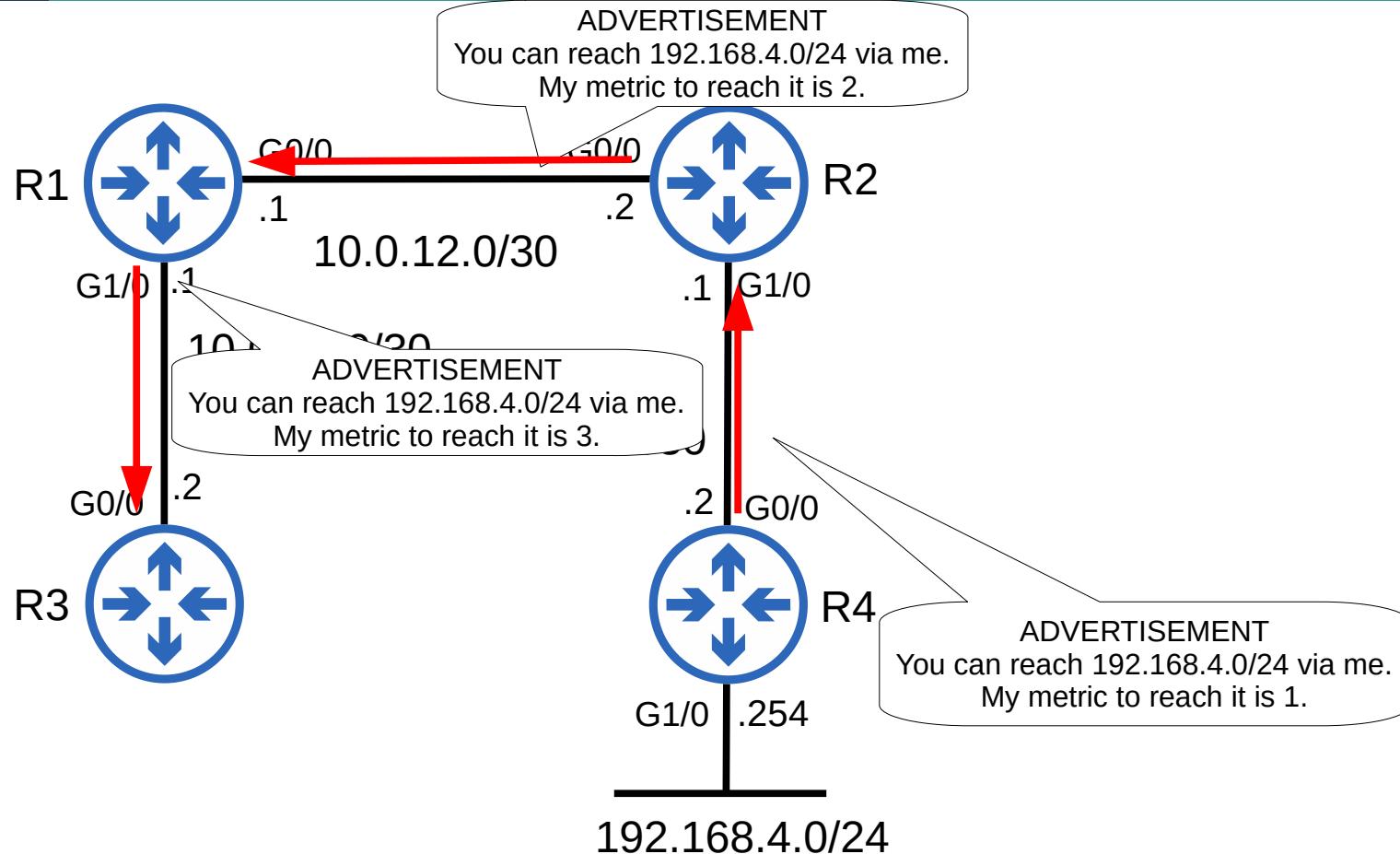
Types of Dynamic Routing Protocols



Distance Vector Routing Protocols

- Distance vector protocols were invented before link state protocols.
- Early examples are **RIPv1** and Cisco's proprietary protocol **IGRP** (which was updated to **EIGRP**)
- Distance vector protocols operate by sending the following to their directly connected neighbors:
 - their known destination networks
 - their metric to reach their known destination networks
- This method of sharing route information is often called 'routing by rumor'
- This is because the router doesn't know about the network beyond its neighbors. It only knows the information that its neighbors tell it.
- Called 'distance vector' because the routers only learn the 'distance' (metric) and 'vector' (direction, the next-hop router) of each route.

Distance Vector Routing Protocols



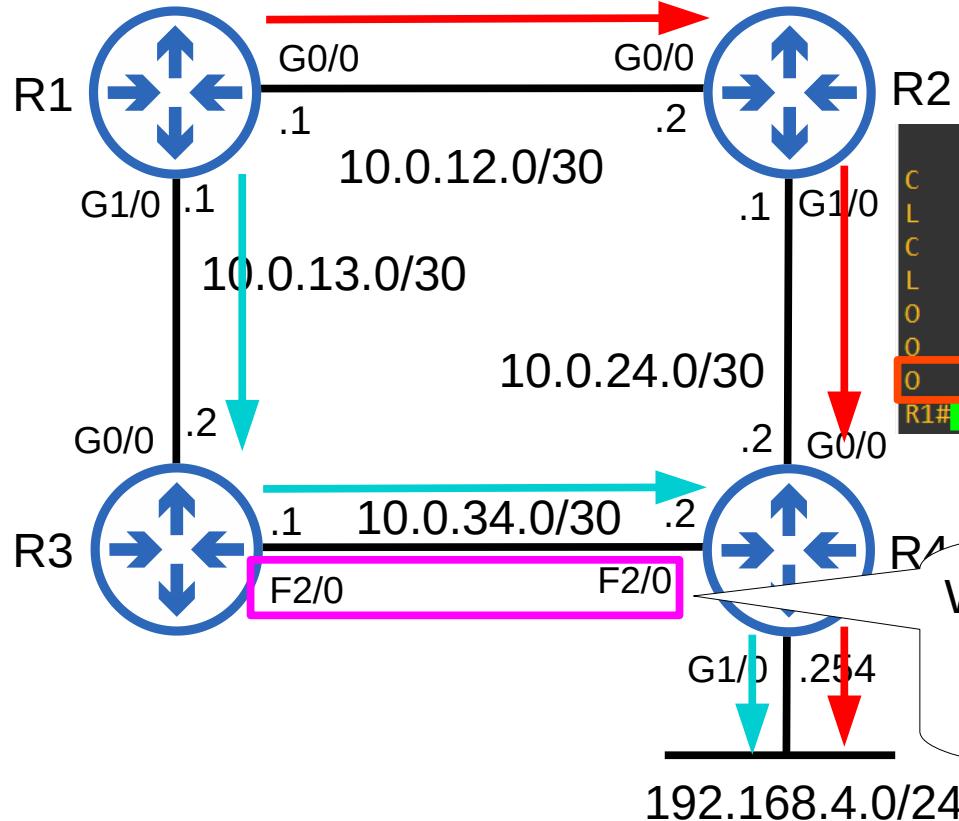
Link State Routing Protocols

- When using a **link state** routing protocol, every router creates a ‘connectivity map’ of the network.
- To allow this, each router advertises information about its interfaces (connected networks) to its neighbors. These advertisements are passed along to other routers, until all routers in the network develop the same map of the network.
- Each router independently uses this map to calculate the best routes to each destination.
- Link state protocols use more resources (CPU) on the router, because more information is shared.
- However, link state protocols tend to be faster in reacting to changes in the network than distance vector protocols.

Dynamic Routing Protocol Metrics

- A router's route table contains the best route to each destination network it knows about.
- If a router using a dynamic routing protocol learns two different routes to the same destination, how does it determine which is 'best'?
- It uses the **metric** value of the routes to determine which is best. A lower metric = better.
- Each routing protocol uses a different metric to determine which route is the best.

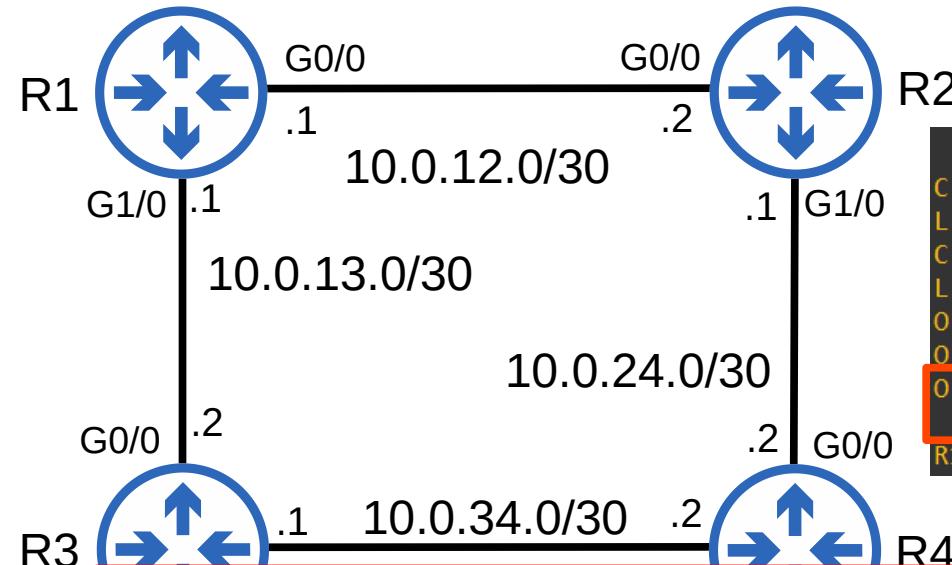
Dynamic Routing Protocol Metrics



```
10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C   10.0.12.0/30 is directly connected, GigabitEthernet0/0
C   10.0.12.1/32 is directly connected, GigabitEthernet0/0
C   10.0.13.0/30 is directly connected, GigabitEthernet1/0
C   10.0.13.1/32 is directly connected, GigabitEthernet1/0
O   10.0.24.0/30 [110/2] via 10.0.12.2, 00:04:48, GigabitEthernet0/0
O   10.0.34.0/30 [110/11] via 10.0.13.2, 00:00:41, GigabitEthernet1/0
R1# 192.168.4.0/24 [110/3] via 10.0.12.2 00:04:48, GigabitEthernet0/0
```

What if this was also a gigabit Ethernet connection?
Both routes would have the same metric, so
which route would be added to the route table?

Dynamic Routing Protocol Metrics



```
R1# show ip route
C 10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C   10.0.12.0/30 is directly connected, GigabitEthernet0/0
C   10.0.12.1/32 is directly connected, GigabitEthernet0/0
C   10.0.13.0/30 is directly connected, GigabitEthernet1/0
C   10.0.13.1/32 is directly connected, GigabitEthernet1/0
O   10.0.24.0/30 [110/2] via 10.0.12.2, 00:00:09, GigabitEthernet0/0
O   10.0.34.0/30 [110/2] via 10.0.13.2, 00:00:09, GigabitEthernet1/0
O   192.168.4.0/24 [110/3] via 10.0.13.2, 00:00:09, GigabitEthernet1/0
O   192.168.4.0/24 [110/3] via 10.0.12.2, 00:00:09, GigabitEthernet0/0
```

If a router learns two (or more) routes via the **same routing protocol** to the **same destination** (same network address, same subnet mask) with the **same metric**, both will be added to the routing table. Traffic will be load-balanced over both routes.

Dynamic Routing Protocol Metrics

```
R1#show 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, J - L2TP
      C - Connected, S - Static, R - RIP, B - BGP, E1 - EIGRP External, E2 - EIGRP External, O - OSPF, OI - OSPF Inter-Area, N1 - OSPF NSSA External, N2 - OSPF NSSA External, E1 - OSPF External, E2 - OSPF External, i - IS-IS, si - 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, ODR - ODR, PDR - Periodic Downloaded Static Route, H - NHRP, J - L2TP, C - Connected, S - Static, R - RIP, B - BGP, E1 - EIGRP External, E2 - EIGRP External, O - OSPF, OI - OSPF Inter-Area, N1 - OSPF NSSA External, N2 - OSPF NSSA External, E1 - OSPF External, E2 - OSPF External, i - IS-IS, si - 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, ODR - ODR, PDR - Periodic Downloaded Static Route, H - NHRP, J - L2TP
```

ECMP (Equal Cost Multi-Path)

Gateway of last resort is not set

```
10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C        10.0.12.0/30 is directly connected, GigabitEthernet0/0
L        10.0.12.1/32 is directly connected, GigabitEthernet0/0
C        10.0.13.0/30 is directly connected, GigabitEthernet1/0
L        10.0.13.1/32 is directly connected, GigabitEthernet1/0
O        10.0.24.0/30 [110/2] via 10.0.12.2, 00:00:09, GigabitEthernet0/0
O        10.0.34.0/30 [110/2] via 10.0.13.2, 00:00:09, GigabitEthernet1/0
[0]      192.168.4.0/24 [110/3] via 10.0.13.2, 00:00:09, GigabitEthernet1/0
                  [110/3] via 10.0.12.2, 00:00:09, GigabitEthernet0/0
```

R1#

ECMP with Static Routes

```
R1(config)#ip route 192.168.4.0 255.255.255.0 10.0.12.2
R1(config)#ip route 192.168.4.0 255.255.255.0 10.0.13.2
R1(config)#do show 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
        + - replicated route, % - next hop override

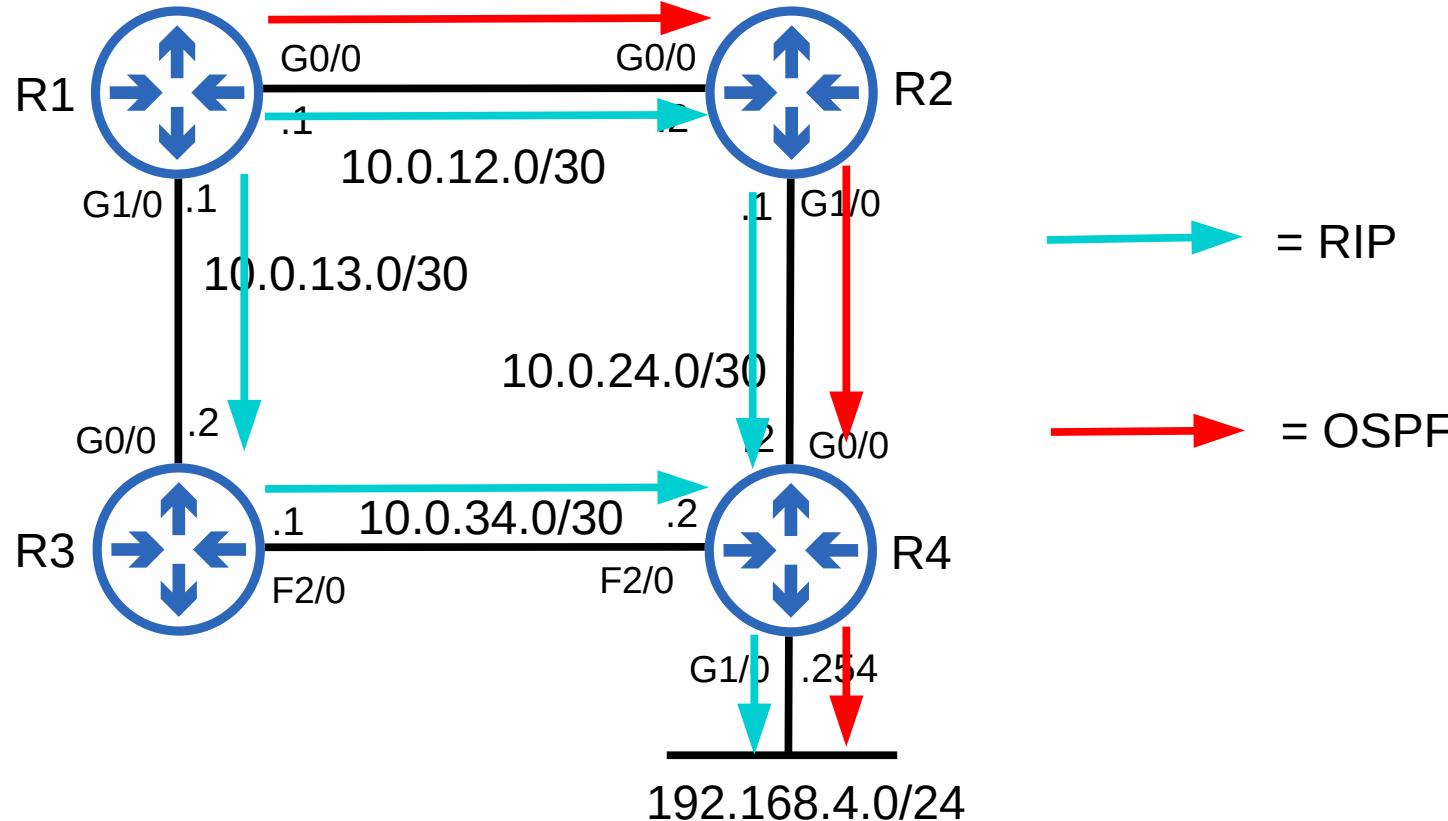
Gateway of last resort is not set

    10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C        10.0.12.0/30 is directly connected, GigabitEthernet0/0
L        10.0.12.1/32 is directly connected, GigabitEthernet0/0
C        10.0.13.0/30 is directly connected, GigabitEthernet1/0
L        10.0.13.1/32 is directly connected, GigabitEthernet1/0
S        192.168.4.0/24 [1/0] via 10.0.13.2
                  [1/0] via 10.0.12.2
R1(config)#[
```

Dynamic Routing Protocol Metrics

IGP	Metric	Explanation
RIP	Hop count	Each router in the path counts as one 'hop'. The total metric is the total number of hops to the destination. Links of all speeds are equal.
EIGRP	Metric based on bandwidth & delay (by default)	Complex formula that can take into account many values. By default, the bandwidth of the slowest link in the route and the total delay of all links in the route are used.
OSPF	Cost	The cost of each link is calculated based on bandwidth. The total metric is the total cost of each link in the route.
IS-IS	Cost	The total metric is the total cost of each link in the route. The cost of each link is not automatically calculated by default. All links have a cost of 10 by default.

Dynamic Routing Protocol Metrics



Administrative Distance

- In most cases a company will only use a single IGP – usually OSPF or EIGRP.
- However, in some rare cases they might use two. For example, if two companies connect their networks to share information, two different routing protocols might be in use.
- Metric is used to compare routes learned via the same routing protocol.
- Different routing protocols use totally different metrics, so they cannot be compared.
- For example, an OSPF route to 192.168.4.0/24 might have a metric of 30, while an EIGRP route to the same destination might have a metric of 33280. Which route is better? Which route should the router put in the route table?
- The **administrative distance** (AD) is used to determine which routing protocol is preferred.
- A lower AD is preferred, and indicates that the routing protocol is considered more ‘trustworthy’ (more likely to select good routes).

Administrative Distance

Route protocol/type	AD
Directly connected	0
Static	1
External BGP (eBGP)	20
EIGRP	90
IGRP	100
OSPF	110

Route protocol/type	AD
IS-IS	115
RIP	120
EIGRP (external)	170
Internal BGP (iBGP)	200
Unusable route	255

If the administrative distance is 255, the router does not believe the source of that route and does not install the route in the routing table.

Administrative Distance

- The following routes to the destination network 10.1.1.0/24 are learned:
 - next hop 192.168.1.1, learned via RIP, metric 5
 - next hop 192.168.2.1, learned via RIP, metric 3
 - next hop 192.168.3.1, learned via OSPF, metric 10

Which route to 10.1.1.0/24 will be added to the route table?

- Metric is used to compare routes learned from the same routing protocol.
- However, before comparing metrics, AD is used to select the best route.
- The OSPF route will always take precedence over the RIP routes, because it has a lower AD.

Administrative Distance

```
R1(config)#ip route 192.168.4.0 255.255.255.0 10.0.12.2
R1(config)#ip route 192.168.4.0 255.255.255.0 10.0.13.2
R1(config)#do show 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
        + - replicated route, % - next hop override
```

Gateway of last resort is not set

```
10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C      10.0.12.0/30 is directly connected, GigabitEthernet0/0
L      10.0.12.1/32 is directly connected, GigabitEthernet0/0
C      10.0.13.0/30 is directly connected, GigabitEthernet1/0
L      10.0.13.1/32 is directly connected, GigabitEthernet1/0
S      192.168.4.0/24 [1/0] via 10.0.13.2
                  [1/0] via 10.0.12.2
```

```
R1(config)#[
```

Administrative Distance

```
R1#show 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
      + - replicated route, % - next hop override
```

Gateway of last resort is not set

```
10.0.0.0/8 is variably subnetted, 6 subnets, 2 masks
C    10.0.12.0/30 is directly connected, GigabitEthernet0/0
L    10.0.12.1/32 is directly connected, GigabitEthernet0/0
C    10.0.13.0/30 is directly connected, GigabitEthernet1/0
L    10.0.13.1/32 is directly connected, GigabitEthernet1/0
O    10.0.24.0/30 [110/2] via 10.0.12.2, 00:00:09, GigabitEthernet0/0
O    10.0.34.0/30 [110/2] via 10.0.13.2, 00:00:09, GigabitEthernet1/0
O    192.168.4.0/24 [110/3] via 10.0.13.2, 00:00:09, GigabitEthernet1/0
                                [110/3] via 10.0.12.2, 00:00:09, GigabitEthernet0/0
```

R1#

Administrative Distance

- You can change the AD of a routing protocol (I will demonstrate this when we cover OSPF configuration in a later video).
- You can also change the AD of a static route:

```
R1(config)#ip route 10.0.0.0 255.0.0.0 10.0.13.2 ?
<1-255>    Distance metric for this route
multicast    multicast route
name         Specify name of the next hop
permanent    permanent route
tag          Set tag for this route
track        Install route depending on tracked item
<cr>
```

```
R1(config)#ip route 10.0.0.0 255.0.0.0 10.0.13.2
```

Administrative Distance

```
R1(config)#ip route 10.0.0.0 255.0.0.0 10.0.13.2 100
R1(config)#do show 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
      + - replicated route, % - next hop override
```

Gateway of last resort is not set

```
10.0.0.0/8 is variably subnetted, 6 subnets, 3 masks
S    10.0.0.0/8 [100/0] via 10.0.13.2
C    10.0.12.0/30 is directly connected, GigabitEthernet0/0
L    10.0.12.1/32 is directly connected, GigabitEthernet0/0
C    10.0.13.0/30 is directly connected, GigabitEthernet1/0
L    10.0.13.1/32 is directly connected, GigabitEthernet1/0
D    10.0.24.0/30 [90/3072] via 10.0.12.2, 00:06:35, GigabitEthernet0/0
R1(config)#

```

Floating Static Routes

- By changing the AD of a static route, you can make it less preferred than routes learned by a dynamic routing protocol to the same destination (make sure the AD is higher than the routing protocol's AD!).
- This is called a 'floating static route'.
- The route will be inactive (not in the routing table) unless the route learned by the dynamic routing protocol is removed (for example, the remote router stops advertising it for some reason, or an interface failure causes an adjacency with a neighbor to be lost).

3.3 Configure and verify IPv4 and IPv6 static routing

3.3.a Default route

3.3.b Network route

3.3.c Host route

3.3.d Floating static

Things we covered

- Introduction to dynamic routing protocols
- Types of dynamic routing protocols
- Dynamic routing protocol metrics
- Administrative distance

QUIZ

Quiz 1

R1 learns four routes to 192.168.1.0/24 through multiple routing protocols: RIP, EIGRP, OSPF, and IS-IS. Which route/routes will be added to the route table?

- a) RIP route only
- b) EIGRP route only
- c) OSPF route only
- d) IS-IS route only
- e) RIP and EIGRP routes, because both are distance vector protocols.
- f) OSPF and IS-IS routes, because both are link state protocols.
- g) All four routes will be added.

Quiz 2

Which type of routing protocol is also known as 'routing by rumor'?

- a) Link state protocols
- b) Path vector protocols
- c) Distance vector protocols
- d) Interior gateway protocols

Quiz 3

R1 learns two routes to 172.16.0.0/16 via RIP, one via 10.0.0.1 and the other via 10.1.0.1. Both routes are 5 hops away. Which route/routes will be entered into the routing table?

- a) Both routes
- b) Only the route via 10.0.0.1
- c) Only the route via 10.1.0.1
- d) Neither route will be added because RIP's AD value is too high.