CCNP-RS ROUTE v2.0

CCNP-RS ROUTE Timetable

Day	AM	Lunch	PM
1	EIGRP	--	*IGP EIGRP Lab*
2	OSPF	--	*IGP OSPF Lab*
3	Redistribution & Path Control	--	*IGP Redistribution Lab*
4	BGP	--	*BGP Lab*
5	IPv6 Routing	--	*IGP IPv6 Lab, Full Scale Lab*

Chapter 1:

Routing Services

- CCNP-RS ROUTE

Chapter 1 Objectives

- Describe common enterprise traffic requirements and network design models.
- Describe how to create a plan for implementing routing services in an enterprise network.
- Review the fundamentals of routing and compare various routing protocols.

IP Routing Overview

Routing

- This section addresses the ways in which routers learn about networks and how routers can incorporate static and dynamic routes.
- A router can be made aware of remote networks in two ways:
  - An administrator can manually configure the information (static routing)
  - The router can learn from other routers (dynamic routing).
- A routing table can contain both static and dynamically recognized routes.

Static Routes

- A static route can be used in the following circumstances:
  - To have absolute control of routes used by the router.
  - When a backup to a dynamically recognized route is necessary.
  - When it is undesirable to have dynamic routing updates forwarded across slow bandwidth links.
  - To reach a stub network.

Static Routing

- Configure a static route with the `ip route` command.

```
Router(config)#
```

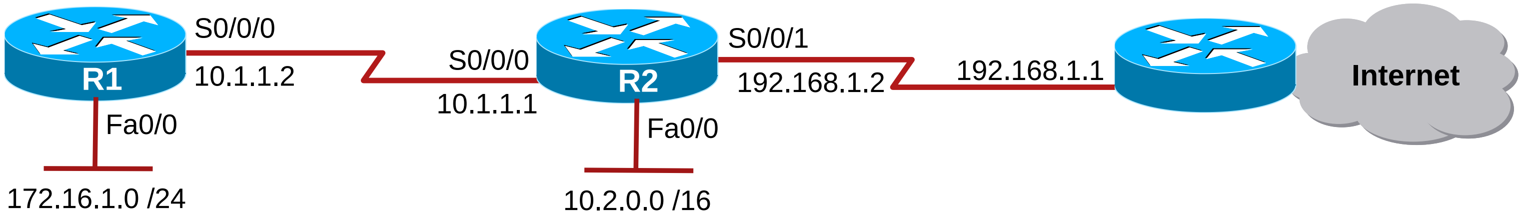
ip route *prefix mask address interface* **dhcp** *distance* **name** *next-hop-name* **permanent track** *number* **tag** *tag*

Parameter	Description
prefix mask	The IP network and subnet mask for the remote network to be entered into the IP routing table.
address	The IP address of the next hop that can be used to reach the destination network.
interface	The local router outbound interface to be used to reach the destination network.
dhcp	(Optional) Enables a Dynamic Host Configuration Protocol (DHCP) server to assign a static route to a default gateway (option 3).
distance	(Optional) The administrative distance to be assigned to this route.
name *next-hop-name*	(Optional) Applies a name to the specified route.
permanent	(Optional) Specifies that the route will not be removed from the routing table even if the interface associated with the route goes down.
track *number*	(Optional) Associates a track object with this route. Valid values for the number argument range from 1 to 500.
tag *tag*	(Optional) A value that can be used as a match value in route maps.

Configuring a Default Static Route

- R2 is configured with a static route to the R1 LAN and a default static route to the Internet.
- R1 is configured with a default static route.

```
R2(config)# ip route 172.16.1.0 255.255.255.0 S0/0/0
R2(config)# ip route 0.0.0.0 0.0.0.0 192.168.1.1
```




```
R1(config)# ip route 0.0.0.0 0.0.0.0 10.1.1.1
R1(config)# exit
R1# show ip route

<output omitted>
Gateway of last resort is not set
C    172.16.1.0 is directly connected, FastEthernet0/0
C    10.1.1.0 is directly connected, Serial0/0/0
S*   0.0.0.0/0 [1/0] via 10.1.1.1
R1#
```

Dynamic Routing

- Dynamic routing (RIPv1, RIPv2, EIGRP, OSPF, and IS-IS) allows the network to adjust to changes in the topology automatically, without administrator involvement.
- The information exchanged by routers includes the metric or cost to each destination (this value is sometimes called the distance).
  - Different routing protocols base their metric on different measurements, including hop count, interface speed, or more-complex metrics.

Distance Vector Versus Link-State

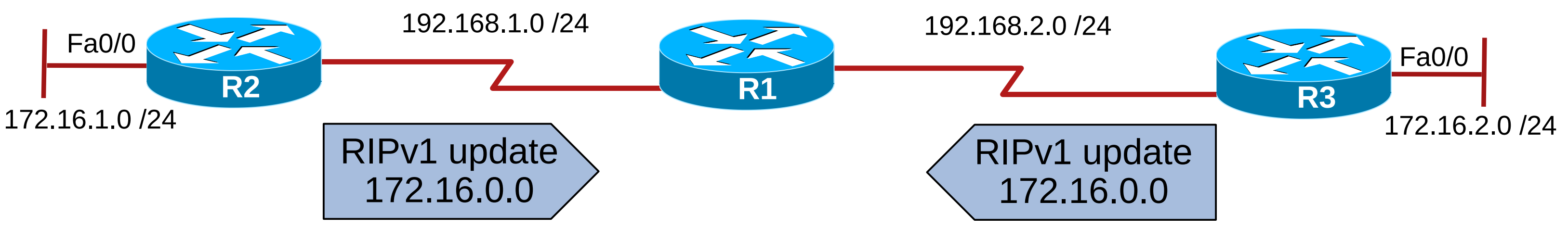
- **Distance vector:**
  - All the routers periodically send their routing tables (or a portion of their tables) to only their neighboring routers.
  - Routers use the received information to determine whether any changes need to be made to their own routing table.
- **Link-state routing protocol:**
  - Each router sends the state of its own interfaces (links) to all other routers in an area only when there is a change.
  - Each router uses the received information to recalculate the best path to each network and then saves this information in its routing table.

Classful Versus Classless Routing

- **Classful Routing Protocol:**
  - Does not support VLSM.
  - Routing updates sent do not include the subnet mask.
  - Subnets are not advertised to a different major network.
  - Discontiguous subnets are not visible to each other.
  - RIP Version 1 (RIPv1) is a classful routing protocol.
- **Classless Routing Protocol:**
  - Supports VLSM.
  - Routing updates sent include the subnet mask.
  - Subnets are advertised to a different major network.
  - Discontiguous subnets are visible to each other.
  - RIPv2, EIGRP, OSPF, IS-IS, and BGP are classless routing protocols.

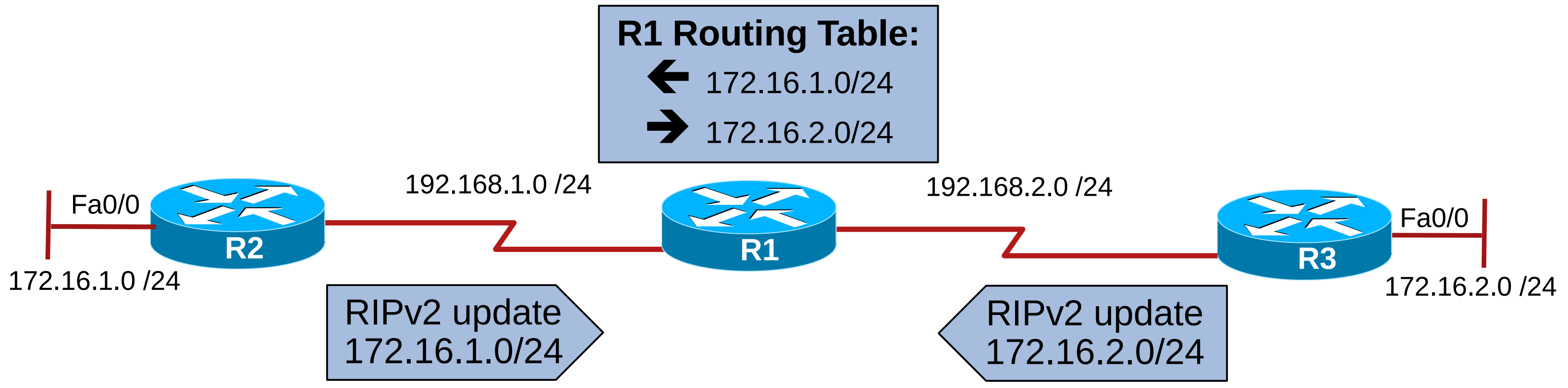
Discontiguous Subnets - Classful Routing

- Classful routing protocols do not support discontiguous networks.
- Discontiguous subnets are subnets of the same major network that are separated by a different major network.
  - For example, RIPv1 has been configured on all three routers.
  - Routers R2 and R3 advertise 172.16.0.0 to R1.
    - They cannot advertise the 172.16.1.0 /24 and 172.16.2.0 /24 subnets across a different major network because RIPv1 is classful.
  - R1 therefore receives routes about 172.16.0.0 /16 from two different directions and it might make an incorrect routing decision.



Discontiguous Subnets - Classless Routing

- Classless routing protocols support discontiguous networks.
  - For example, RIPv2 has been configured on all three routers.
  - Because of RIPv2, routers R2 and R3 can now advertise the 172.16.1.0 /24 and 172.16.2.0 /24 subnets across a different major network.
  - R1 therefore receives routes with valid subnet information and can now make a correct routing decision.



ip classless Command

- The behavior of a classful routing protocol changes when the **`ip classless`** global config command is used.
- Classful protocols assume that if the router knows some of the subnets of a classful network (e.g. 10.0.0.0), then it must know all that network's existing subnets.
  - If a packet arrives for an unknown destination on the 10.0.0.0 subnet and:
    - **`ip classless`** is *not* enabled, the packet is dropped.
    - **`ip classless`** is enabled, then the router will follow the best supernet route or the default route.
- Since IOS release 12.0, **`ip classless`** is enabled by default and should not be disabled.

Automatic Route Summarization

- Classful routing automatically summarize to the classful network boundary at major network boundaries.
- Classless routing protocols either do not automatically summarize or automatically summarize but this feature can be disabled.
  - OSPF , IS-IS and new EIGRP do not support automatic network summarization.
  - RIPv2 and old version of EIGRP perform automatic network summarization to maintain backward compatibility with RIPv1 and IGRP.
  - However, automatic summarization can be disabled in RIPv2 and old version of EIGRP by using the **`no auto-summary`** router config command.

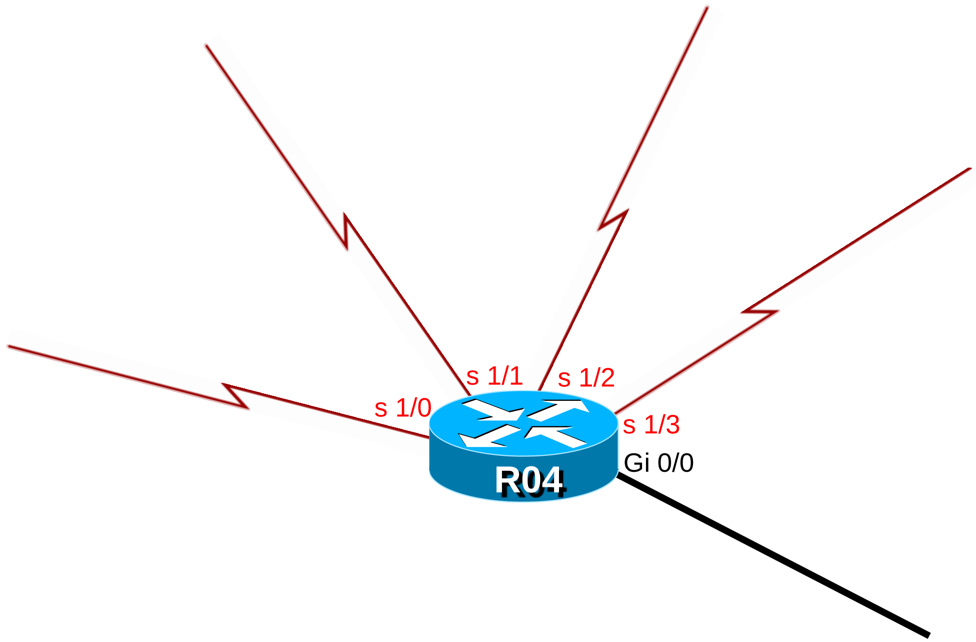
Characteristics of Routing Protocols

Characteristics	RIPv1	RIPv2	EIGRP	IS-IS	OSPF	BGP
Distance vector	✓	✓	✓			✓
Link-state				✓	✓	
Classless		✓	✓	✓	✓	✓
VLSM support		✓	✓	✓	✓	✓
Automatic route summarization	✓	✓ (can be disabled using `no auto-summary`)	✓			✓
Manual route summarization		✓	✓	✓	✓	✓
Hierarchical topology required				✓	✓	
Size of network	Small	Small	Large	Large	Large	Very large
Metric	Hops	Hops	Composite metric	Metric	Cost	Path attributes
Convergence time	Slow	Slow	Very fast	Fast	Fast	Slow

Routing Protocol Specifics

Routing Protocol	Protocol Number	Port Number	Admin Distance
RIP	17	UDP 520	120
IGRP	9	IGRP	100
EIGRP	88	EIGRP	90 Summary Routes – 5 Redistributed Routes – 170
OSPF	89	OSPF	110
IS-IS	124	IS-IS	115
BGP	6	TCP 179	eBGP – 20 iBGP – 200

Routing Table Criteria



Routing Table Criteria

Packet wants to reach 1.1.1.1

```
R04#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
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is 192.168.24.2 to network 0.0.0.0

R        0.0.0.0/0 [120/4] via 192.168.24.2, 00:00:20, Serial1/0
S        1.0.0.0/8 [1/0] via 192.168.14.1, 00:00:07, GigabitEthernet0/0
D        1.1.0.0/16 [90/216549] via 192.168.45.5, 00:00:11, Serial1/2
O        1.1.1.0/24 [110/65] via 192.168.34.3, 00:00:18, Serial1/1
i        1.1.1.0/28 [115/20] via 192.168.46.6, 00:00:07, Serial1/3

R04#
```

Routing Table Criteria

Packet wants to reach 1.1.1.1

```
R04#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
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is 192.168.24.2 to network 0.0.0.0

R         0.0.0.0/0 [120/4] via 192.168.24.2, 00:00:20, Serial1/0
S         1.0.0.0/8 [1/0] via 192.168.14.1, 00:00:07, GigabitEthernet0/0
D         1.1.0.0/16 [90/216549] via 192.168.45.5, 00:00:11, Serial1/2
O         1.1.1.0/24 [110/65] via 192.168.34.3, 00:00:18, Serial1/1
i         1.1.1.0/28 [115/20] via 192.168.46.6, 00:00:07, Serial1/3

R04#
```

Longest Prefix Match (LPM)

Routing Table Criteria

Packet wants to reach 1.1.1.1

```
R04#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
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is 192.168.24.2 to network 0.0.0.0

R         0.0.0.0/0 [120/4] via 192.168.24.2, 00:00:20, Serial1/0
S         1.0.0.0/8 [1/0] via 192.168.14.1, 00:00:07, GigabitEthernet0/0
D         1.1.1.0/24 [90/216549] via 192.168.45.5, 00:00:11, Serial1/2
O         1.1.1.0/24 [110/65] via 192.168.34.3, 00:00:18, Serial1/1

R04#
```

Routing Table Criteria

Packet wants to reach 1.1.1.1

```
R04#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
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is 192.168.24.2 to network 0.0.0.0

R        0.0.0.0/0 [120/4] via 192.168.24.2, 00:00:20, Serial1/0
S        1.0.0.0/8 [1/0] via 192.168.14.1, 00:00:07, GigabitEthernet0/0
D        1.1.1.0/24 [90/216549] via 192.168.45.5, 00:00:11, Serial1/2
O        1.1.1.0/24 [110/65] via 192.168.34.3, 00:00:18, Serial1/1

R04#
```

Lowest Administrative Distance

Administrative Distance

- Cisco routers use a value called administrative distance to select the best path when they learn of two or more routes to the same destination with the same prefix from different routing protocols.
- Administrative distance rates a routing protocol's *believability*.
- Cisco has assigned a default administrative distance value to each routing protocol supported on its routers.
  - Each routing protocol is prioritized in the order of most to least believable.

Administrative Distances

Route Source	Default Distance	Routing Table Entry
Connected interface	0	C
Static route to a next-hop address	1	S
EIGRP summary route	5	D
External BGP	20	B
Internal EIGRP	90	D
IGRP	100	I
OSPF	110	O
IS-IS	115	i
RIPv1, RIPv2	120	R
Exterior Gateway Protocol (EGP)	140	E
ODR	160	O
External EIGRP	170	D EX
Internal BGP	200	B
Unknown	255	

Routing Table Criteria

Packet wants to reach 1.1.1.1

```
R04#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
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is 192.168.24.2 to network 0.0.0.0

R         0.0.0.0/0 [120/4] via 192.168.24.2, 00:00:20, Serial1/0
S         1.0.0.0/8 [1/0] via 192.168.14.1, 00:00:07, GigabitEthernet0/0
O         1.1.1.0/24 [110/129] via 192.168.45.5, 00:00:11, Serial1/2
O         1.1.1.0/24 [110/65] via 192.168.34.3, 00:00:18, Serial1/1

R04#
```

Routing Table Criteria

Packet wants to reach 1.1.1.1

```
R04#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
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is 192.168.24.2 to network 0.0.0.0

R         0.0.0.0/0 [120/4] via 192.168.24.2, 00:00:20, Serial1/0
S         1.0.0.0/8 [1/0] via 192.168.14.1, 00:00:07, GigabitEthernet0/0
O         1.1.1.0/24 [110/129] via 192.168.45.5, 00:00:11, Serial1/2
O         1.1.1.0/24 [110/65] via 192.168.34.3, 00:00:18, Serial1/1

R04#
```

Lowest Metric

Routing Metric

The following are metrics, used in determining the best path for a routing protocol:

Bandwidth – Throughput speed in bits per second

Delay – Network latency caused by such factors as distance or congestion

Load – Measurement of traffic that flows through a router

MTU – The largest unit size allowed to be transmitted on all routes from source to destination

Reliability – Represents the amount of network downtime, that is, how reliable a network path is)

Hop Count – The number of routers (hops) a packets passes through to its destination

Cost – An arbitrary value assigned by an administrator for the intersecting of networks

Ticks – Measurement of delay, where is tick is 1/18 of a second.

Routing Metric

The following are metrics used in which routing protocol:

Bandwidth – EIGRP

Delay – EIGRP

Load – EIGRP

MTU – EIGRP

Reliability – EIGRP

Hop Count – RIPv1, RIPv2, EIGRP, *BGP* *(mostly)*

Cost – OSPFv2, OSPFv3, IS-IS

Ticks – IPX RIP

Routing Table Criteria

Packet wants to reach 1.1.1.1

```
R04#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
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is 192.168.24.2 to network 0.0.0.0

R        0.0.0.0/0 [120/4] via 192.168.24.2, 00:00:20, Serial1/0
S        1.0.0.0/8 [1/0] via 192.168.14.1, 00:00:07, GigabitEthernet0/0
O        1.1.1.0/24 [110/65] via 192.168.45.5, 00:00:11, Serial1/2
O        1.1.1.0/24 [110/65] via 192.168.34.3, 00:00:18, Serial1/1

R04#
```

Routing Table Criteria

Packet wants to reach 1.1.1.1

```
R04#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
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is 192.168.24.2 to network 0.0.0.0

R         0.0.0.0/0 [120/4] via 192.168.24.2, 00:00:20, Serial1/0
S         1.0.0.0/8 [1/0] via 192.168.14.1, 00:00:07, GigabitEthernet0/0
O         1.1.1.0/24 [110/65] via 192.168.45.5, 00:00:11, Serial1/2
                     [110/65] via 192.168.34.3, 00:00:18, Serial1/1

R04#
```

Equal Cost Path Load Balance

Routing Table Criteria

- The best route selected from various routing protocols for a specific destination is chosen by considering the following four criteria:
  - O 1.1.1.0/24 [110/65] via 192.168.45.5, 00:07:22, Serial1/0
- Valid next-hop IP address {IF}

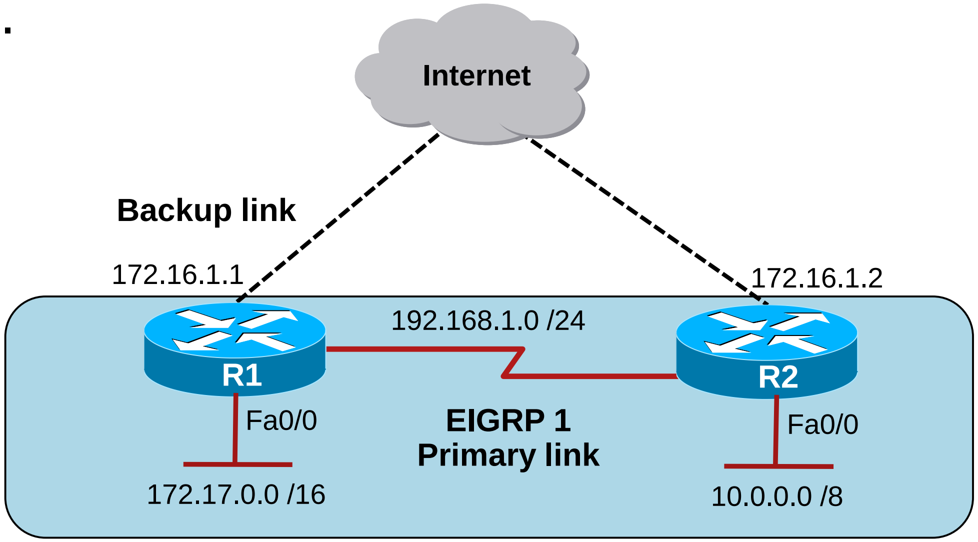
1. **Longest Prefix Match (LPM)**
2. **Lowest Administrative Distance**
3. **Lowest Metric**
4. **Equal Cost Path Load Balance**

Floating Static Route

- Routers believe static routes over any dynamically learned route.
- To change this default behavior and make a static route appear in the routing table only when the primary route goes away, create a **floating static** route.
  - The administrative distance of the static route is configured to be higher than the administrative distance of the primary route and it “floats” above the primary route, until the primary route fails.
- To configure a static route use the **`ip route`** command with the *distance* parameter.

Configuring a Floating Static Route

- Create floating static routes on R1 and R2 that floats above the EIGRP learned routes.




```
R1(config)# ip route 10.0.0.0 255.0.0.0 172.16.1.2 100
R1(config)# router eigrp 1
R1(config-router)# network 172.17.0.0
R1(config-router)# network 192.168.1.0
```

```
R2(config)# ip route 172.17.0.0 255.255.0.0 172.16.1.1 100
R2(config)# router eigrp 1
R2(config-router)# network 10.0.0.0
R2(config-router)# network 192.168.1.0
```

Routing Within the ECNM

- The Enterprise Composite Network Model can assist in determining where each routing protocol is implemented, where the boundaries between protocols are, and how traffic flows between them will be managed.

Routing Within the ECNM

- Routing protocols are an integral part of any network.
  - When designing a network routing protocol, selection and planning are among the design decisions to be made.
- Although the best practice is to use one IP routing protocol throughout the enterprise if possible, in some cases multiple routing protocols might be required.

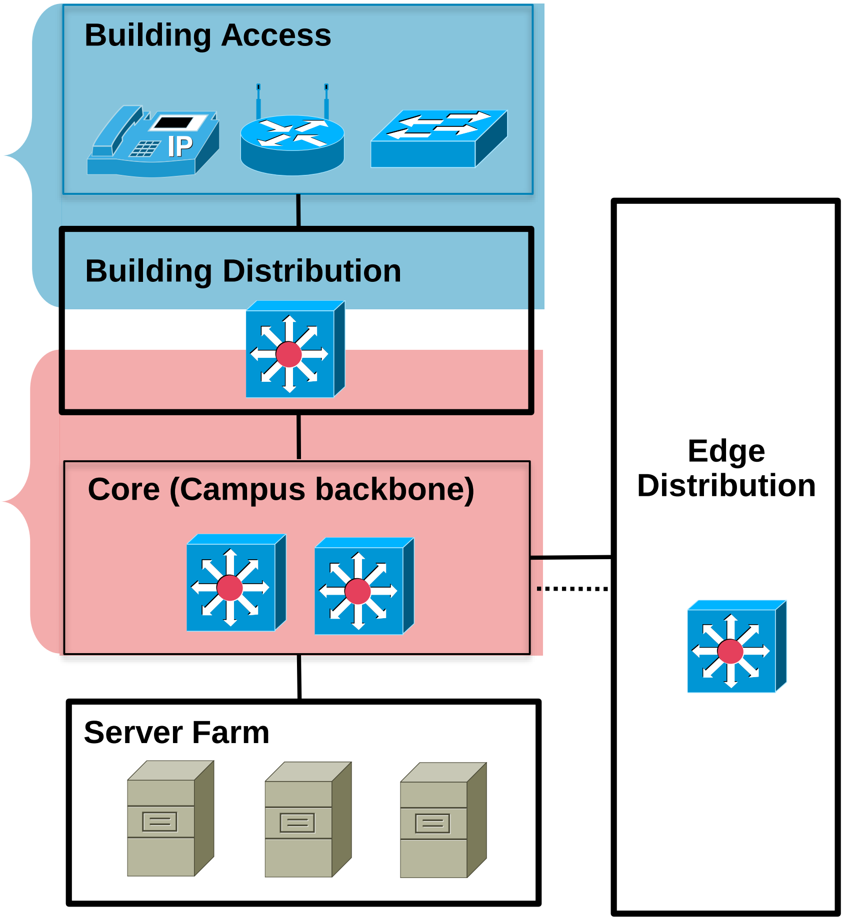
Suggested Routing Protocols Used

Between Building Access and Building Distribution:

RIPv2, OSPF, EIGRP, Static routes

Between Building Distribution and Core:

OSPF, EIGRP, IS-IS and BGP



Chapter 1 Summary

- Static routing characteristics and configuration.
- Dynamic routing protocol characteristics, including:
  - The metric, a value (such as path length) that routing protocols use to measure paths to a destination.
  - Configuration, using the **router** *protocol* global configuration command.
  - Distance vector routing, in which all the routers periodically send their routing tables (or a portion of their tables) to only their neighboring routers.
  - Link-state routing, in which each of the routers sends the state of its own interfaces (its links) to all other routers (or to all routers in a part of the network, known as an area) only when there is a change.
  - Hybrid routing, in which routers send only changed information when there is a change (similar to link-state protocols) but only to neighboring routers (similar to distance vector protocols).
  - Classful routing protocol updates, which do not include the subnet mask. Classful protocols do not support VLSM or discontiguous subnets and must automatically summarize across the network boundary to the classful address.
  - Classless routing protocol updates, which do include the subnet mask. Classless protocols do support VLSM and discontiguous subnets, and do not have to summarize automatically across network boundaries.
- The process that Cisco routers use to populate their routing tables includes a valid next-hop IP address, Administrative distance, metric, and prefix.

Chapter 1 Labs

- **IGP-LAB-1.1 for Tcl Script Reference and Demonstration**

Q&A