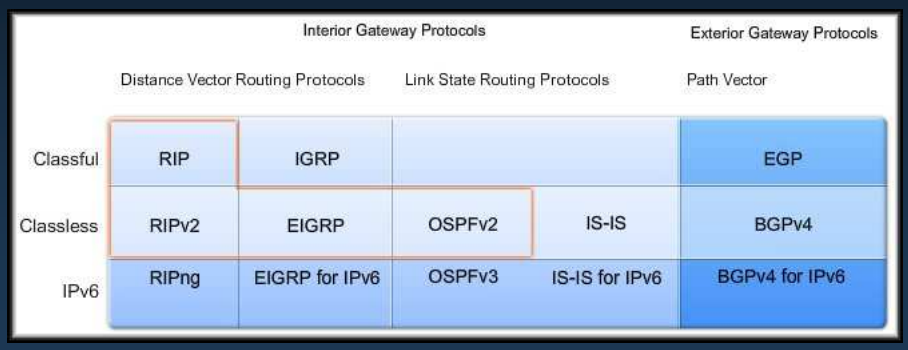
Chapter 3

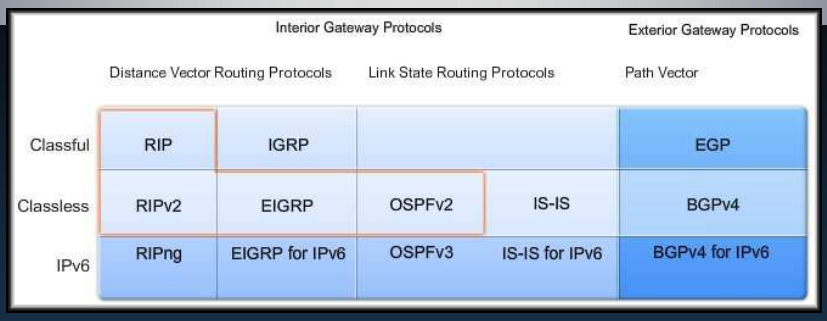
Introduction to Dynamic Routing Protocols

Note for Instructors

- These presentations are the result of a collaboration among the instructors at St. Clair College in Windsor, Ontario.
- Thanks must go out to Rick Graziani of Cabrillo College. His material and additional information was used as a reference in their creation.
- If anyone finds any errors or omissions, please let me know at:
  - tdame@stclaircollege.ca.

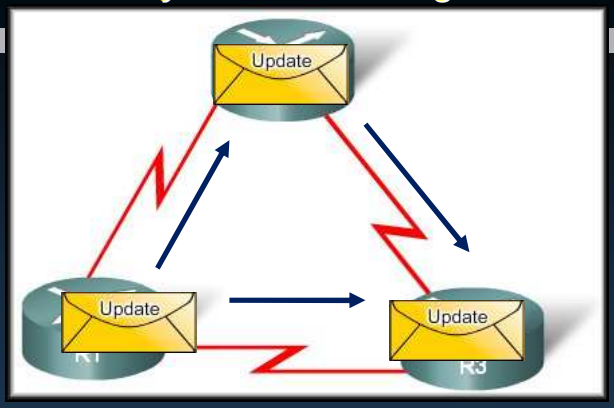
Introduction to Dynamic Routing Protocols





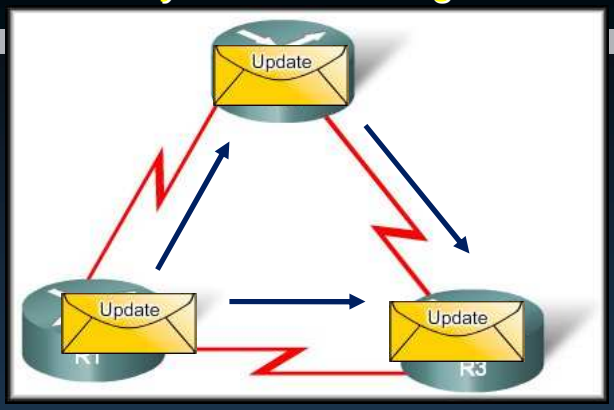
- Dynamic routing protocols have evolved over several years.
- As networks have evolved and become more complex, new routing protocols have emerged.
- The first version of RIP was released in 1982, but some of the basic algorithms within the protocol were used on the ARPANET as early as 1969.

Role of Dynamic Routing Protocol



- Exchange of routing information between routers.
  - Dynamically learn information about remote networks and add routes to routing tables.
  - Determines the best path to each network.
  - Automatically finds alternate paths if needed.

Role of Dynamic Routing Protocol



- Advantages over Static Routes:
  - Less administrative overhead.
  - Scales better.
  - Less prone to configuration errors.

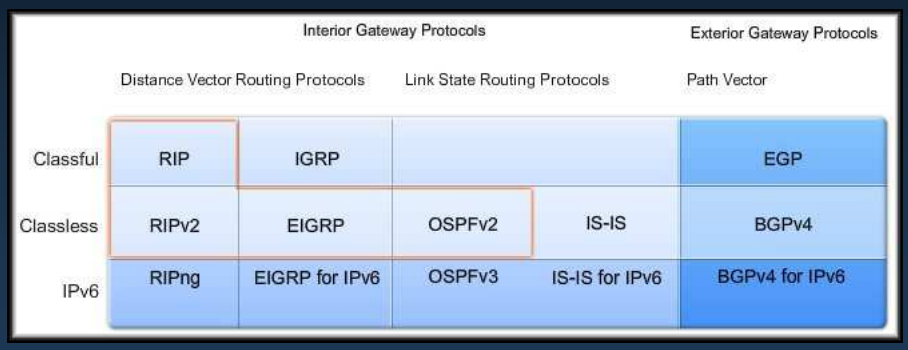
Network Discovery and Routing Table

- Components of Dynamic Routing Protocols:
  - Data Structures:
    - Tables or databases for their operations, kept in RAM.
  - Algorithm:
    - An algorithm is a finite list of steps used in accomplishing a task.
    - Used for processing routing information and for best-path determination.
  - Routing Protocol Messages:
    - Discover neighboring routers.
    - Exchange, learn and maintain accurate network routing information.

Dynamic Routing vs Static Routing

	Dynamic routing	Static routing
Configuration Complexity	Generally independent of the network size	Increases with network size
Required administrator knowledge	Advanced knowledge required	No extra knowledge required
Topology changes	Automatically adapts to topology changes	Administrator intervention required
Scaling	Suitable for simple and complex topologies	Suitable for simple topologies
Security	Less secure	More secure
Resource usage	Uses CPU, memory, link bandwith	No extra resources needed
Predictability	Route depends on the current topology	Route to destination is always the same

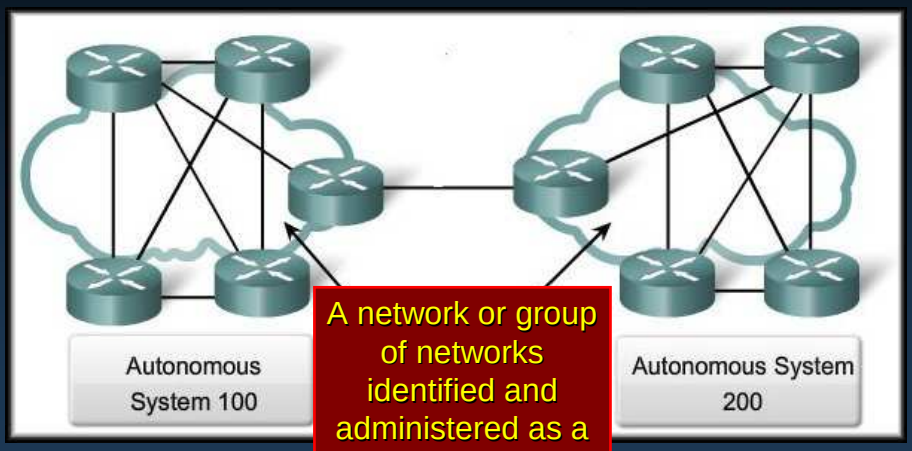
Classifying Dynamic Routing Protocols



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

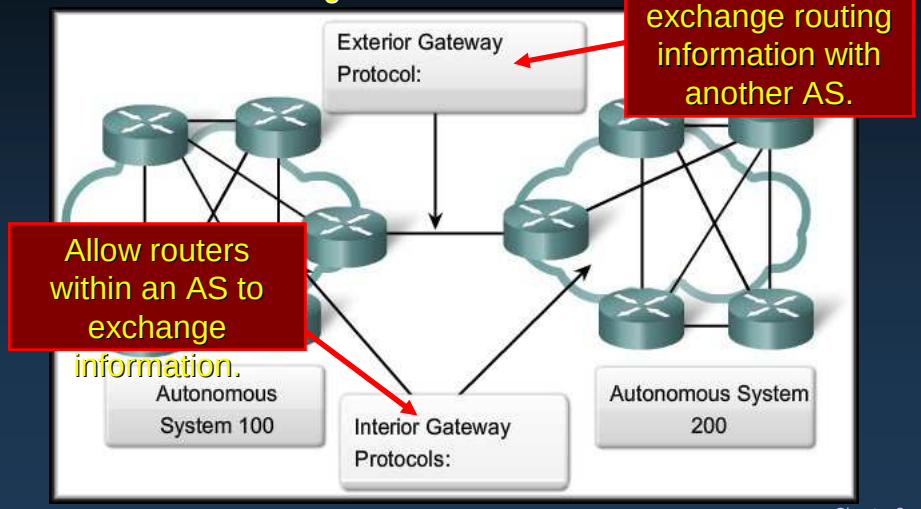
Classifying Dynamic Routing Protocols

- Concept of Autonomous Systems (AS):



Classifying Dynamic Routing Protocols

- IGP vs. EGP Routing Protocols:



Classifying Dynamic Routing Protocols

	Interior Gateway				Exterior Gateway
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IPv6	RIPng	EIGRP for IPv6	OSPFv3	IS-IS for IPv6	BGPv4 for IPv6

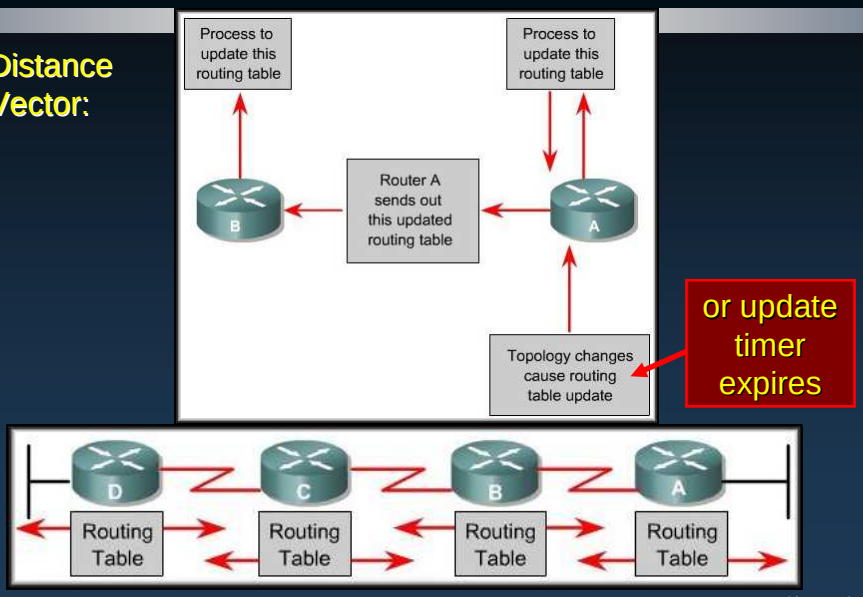
Distance Vector and Link State

- Distance Vector:
  - Routes are advertised as vectors of distance and direction.
    - Distance:
      - Is defined in terms of a metric.
        - Hop Count: The number of routers between the source and destination networks.
    - Direction:
      - Is simply the next-hop router or exit interface.
  - *Routing updates usually consist of periodic updates of the entire routing table.*

  (e.g.. Routing Information Protocol - RIP – every 30 seconds)

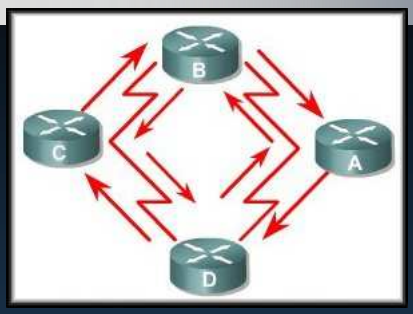
Distance Vector and Link State

- Distance Vector:



Distance Vector and Link State

- Distance Vector:
  - The network is simple and flat and does not require a hierarchical design.
  - The administrators do not have enough knowledge to configure and troubleshoot link-state protocols.
  - Specific types of networks, such as hub-and-spoke networks, are being implemented.
  - Worst-case convergence times in a network are not a concern.



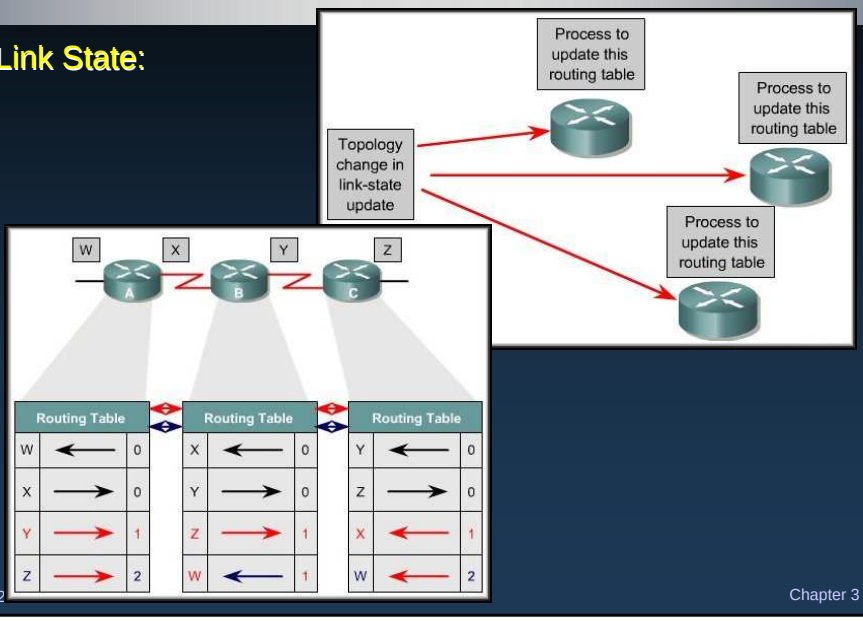
Distance Vector and Link State

- Link State:
  - A Link State routing protocol can create a complete map of the network topology.
  - A link-state router:
    - Receives an update.
    - Builds a topology database.
    - Uses a Shortest Path First (SPF) algorithm to create its view of the network.
    - Builds the routing table.
  - *Routing updates (not the entire table) are only sent to neighbouring routers when the topology changes.*

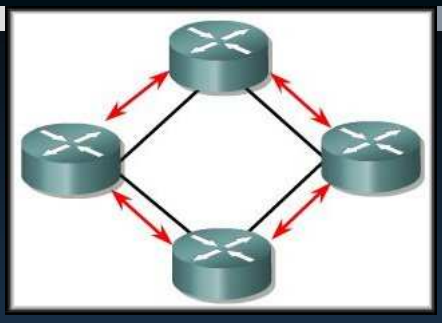
    (e.g.. Open Shortest Path First - OSPF)

Distance Vector and Link State

- Link State:



Distance Vector and Link State



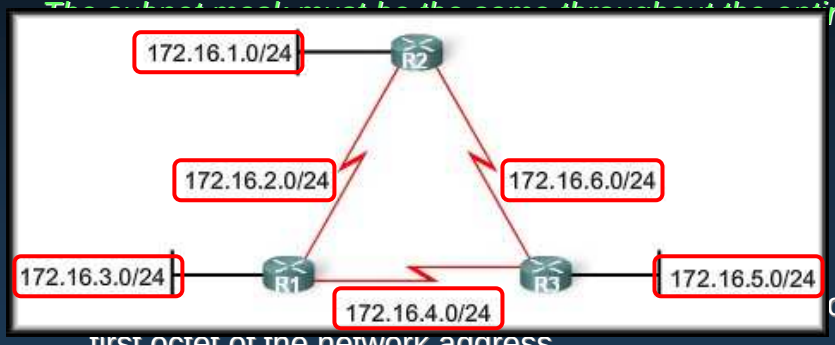
- **Link State:**
  - The network design is hierarchical, usually occurring in large networks.
  - The administrators have a good knowledge of the implemented link-state routing protocol.
  - **Fast convergence** of the network is crucial.

Classifying Dynamic Routing Protocols

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

Classful and Classless

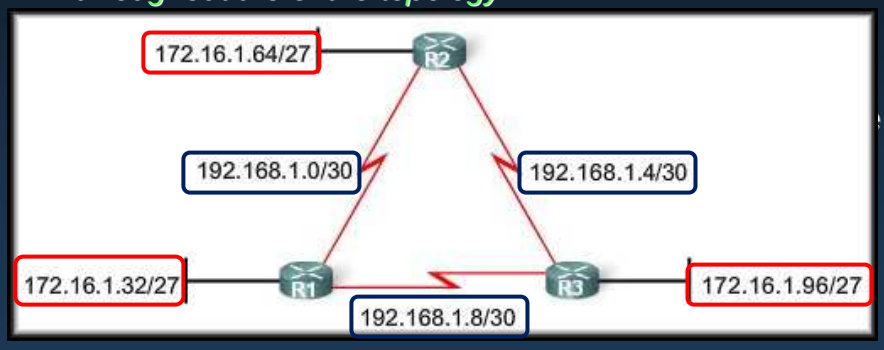
- Classful Protocols:
  - *Do not send subnet mask information in routing updates.*
  - *The subnet mask must be the same throughout the entire*



of first octet of the network address.
  - VLSM and CIDR are not possible.

Classful and Classless

- Classless Protocols:
  - *Include subnet mask information in routing updates.*
  - *The subnet mask does not have to be the same throughout the entire topology.*



  - VLSM and CIDR are possible.

Classifying Dynamic Routing Protocols

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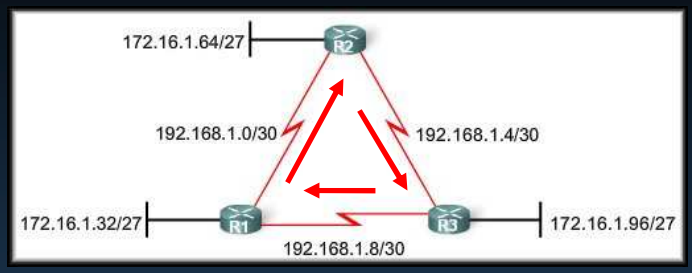
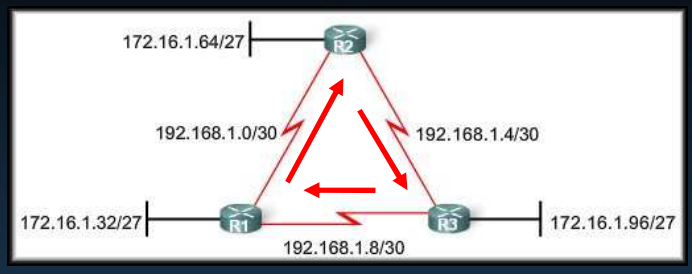
Dynamic Routing Protocols and Convergence



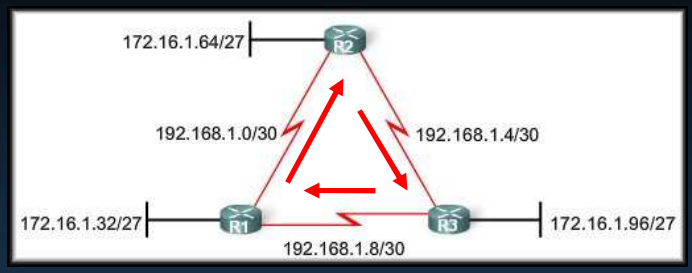
- Convergence:
  - *The network has converged when all routers have complete and accurate information about the network.*
  - The speed of convergence is an important characteristic of a network.

Dynamic Routing Protocols and Convergence



- Convergence:
  - The routers must:
    - Share routing information.
    - Calculate the best path to a destination.
    - Update their routing tables.

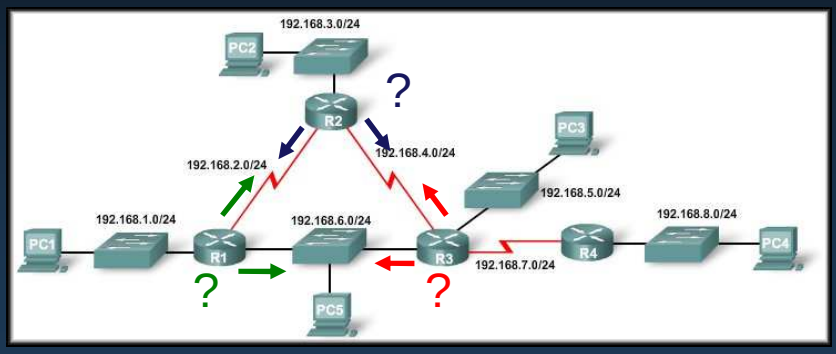
Dynamic Routing Protocols and Convergence



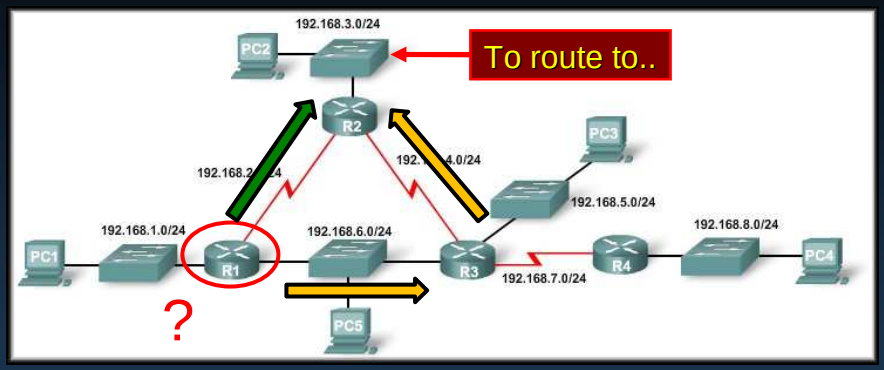
- Convergence:
  - Generally:
    - Slower Convergence: RIP
    - Faster Convergence: EIGRP and OSPF

Introduction to Dynamic Routing Protocols

Metrics

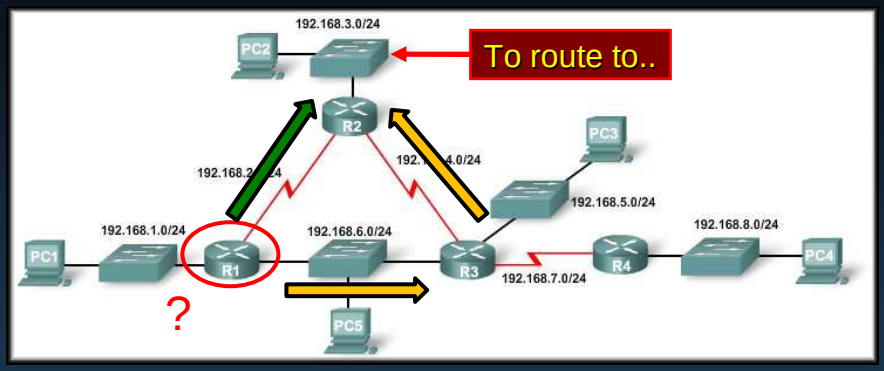


Purpose of a Metric



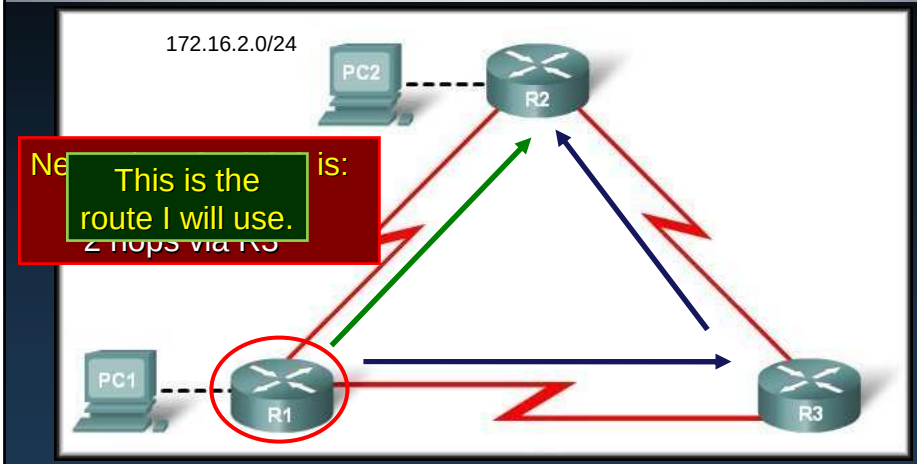
- There are times when a router will have multiple paths to the same destination.
- **Metrics** are a way to **measure and/or compare** routes to determine which route is the best path.

Purpose of a Metric



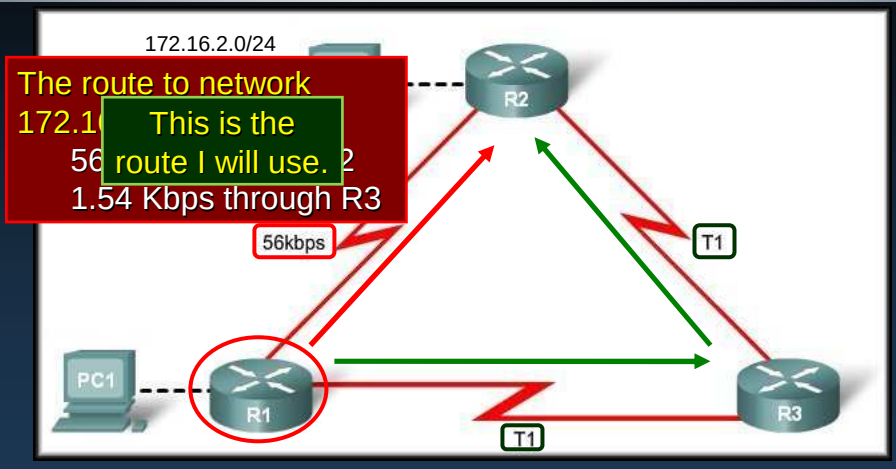
- The route chosen will depend on two things:
  - The routing protocol in use.
  - The metric used by the routing protocol.

Metrics and Routing Protocols



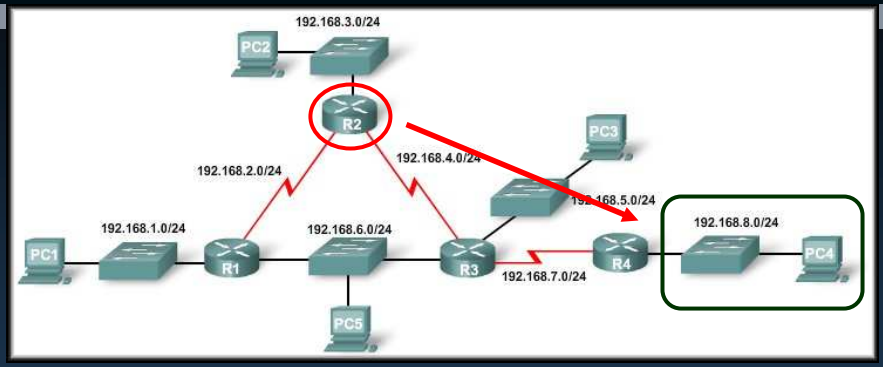
- **Routing Information Protocol (RIP):**
  - Uses **hop count** as its metric. Lower is better.

Metrics and Routing Protocols



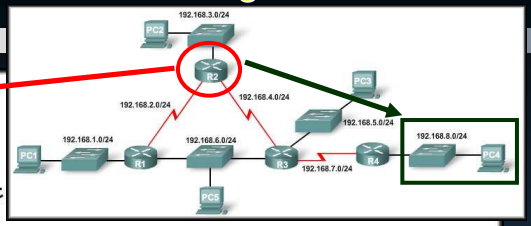
- Open Shortest Path First (OSPF):
  - Uses bandwidth as its metric. Faster is better.

Metric Filed in the Routing Table



- The routing table displays the metric for each dynamic and static route.
  - Dynamic routes with the lowest metric are installed by routing protocols.
  - Static routes always have a metric of 0.

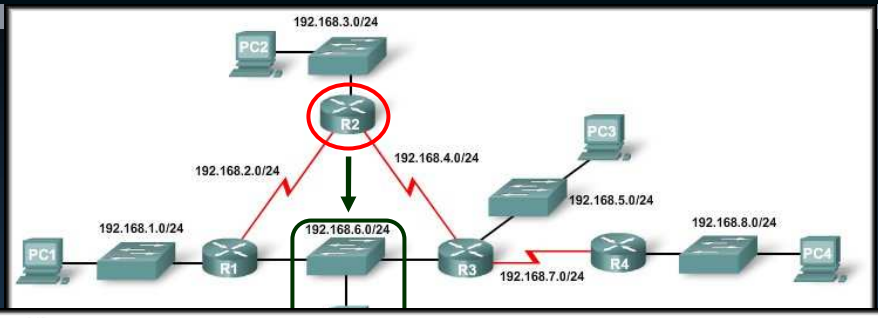
Metric Field in the Routing Table




```
R2# show ip route

<output omitted>

Gateway of last resort is not

R    192.168.1.0/24 [120/1] via 192.168.2.1, 00:00:24, Serial0/0/0
C    192.168.2.0/24 is directly connected, Serial0/0/0
C    192.168.3.0/24 is directly connected, FastEthernet0/0
C    192.168.4.0/24 is directly connected, Serial0/0/1
R    192.168.5.0/24 [120/1] via 192.168.4.1, 00:00:26, Serial0/0/1
R    192.168.6.0/24 [120/1] via 192.168.2.1, 00:00:24, Serial0/0/0
                    [120/1] via 192.168.4.1, 00:00:26, Serial0/0/1
R    192.168.7.0/24 [120/1] via 192.168.4.1, 00:00:26, Serial0/0/1
R    192.168.8.0/24 [120/2] via 192.168.4.1, 00:00:26, Serial0/0/1
```

- All routers are running RIP.
- R2 has a route to 192.168.8.0 and is **2 hops away**.

Load Balancing




```
R2# show ip route
<output omitted>
R    192.168.6.0/24 [120/1] via 192.168.2.1, 00:00:24, Serial0/0/0
                    [120/1] via 192.168.4.1, 00:00:26, Serial0/0/1
```

- What happens when **two or more routes** to the same destination have **identical metric** values?
- The router **load balances** among all equal-cost paths.

Introduction to Dynamic Routing Protocols

Administrative Distance

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

Purpose of Administrative Distance (AD)

- Routers learn about adjacent networks that are directly connected and about remote networks by using static routes and dynamic routing protocols.
- A router might learn of a route to the same network from more than one source.

Purpose of Administrative Distance (AD)

- Routers learn about adjacent networks that are **directly connected** and about remote networks by using **static routes and dynamic** routing protocols.
- A router might learn of a route to the **same network** from **more than one source**.
- Three types of **Routing Sources**.
  - Direct Connect
  - Static
  - Dynamic Routing Protocol

Route Source	AD
Direct Connect	0
Static	1
EIGRP Summary	5
External BGP	20
Internal EIGRP	90
OSPF	110
IS-IS	115
RIP	120
External EIGRP	170
Internal BGP	200

Purpose of Administrative Distance (AD)

- **Administrative Distance** *is used to determine which route is to be installed in the routing table.*
- The route that has the **lower AD** will be **preferred** over the route with the higher AD and will be added to the routing table.
- The term **trustworthy** is commonly used when defining administrative distance.
  - The lower the administrative distance value, the more "trustworthy" the route.

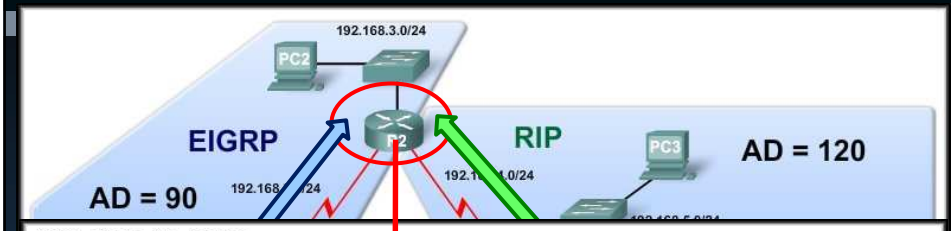
Route Source	AD
Direct Connect	0
Static	1
EIGRP Summary	5
External BGP	20
Internal EIGRP	90
OSPF	110
IS-IS	115
RIP	120
External EIGRP	170
Internal BGP	200

Multiple Routing Sources

- For Example:
  - A route to a network is learned by the configuration of a static route.
  - Another route (or the same route) to the same network is learned when OSPF is enabled on the router.
    - Static Route AD = 1
    - OSPF AD = 110
  - The static route will be added to the routing table and the route learned from OSPF will be ignored.

Route Source	AD
Direct Connect	0
Static	1
EIGRP Summary	5
External BGP	20
Internal EIGRP	90
OSPF	110
IS-IS	115
RIP	120
External EIGRP	170
Internal BGP	200

Multiple Routing Sources




```
R2# show ip route
<output omitted>
Gateway of last resort is not set
D     192.168.1.0/24 [90/2172416] via 192.168.2.1, 00:00:24, Serial0/0
C     192.168.2.0/24 is directly connected, Serial0/0/0
C     192.168.3.0/24 is directly connected, FastEthernet0/0
C     192.168.4.0/24 is directly connected, Serial0/0/1
R     192.168.5.0/24 [120/1] via 192.168.4.1, 00:00:08, Serial0/0/1
D     192.168.6.0/24 [90/2172416] via 192.168.2.1, 00:00:24, Serial0/0/0
R     192.168.7.0/24 [120/1] via 192.168.4.1, 00:00:08, Serial0/0/1
R     192.168.8.0/24 [120/2] via 192.168.4.1, 00:00:08, Serial0/0/1
```

- The route learned from EIGRP will be installed in the routing table.

Verifying Administrative Distance (AD)

- **show ip route**

```
R2# show ip route
<output omitted>
Gateway of last resort is not set
D    192.168.1.0/24 [90/2172416] via 192.168.2.1, 00:00:24, Serial0/0
C    192.168.2.0/24 is directly connected, Serial0/0
C    192.168.3.0/24 is directly connected, FastEthernet0/0
C    192.168.4.0/24 is directly connected, Serial0/0/1
R    192.168.5.0/24 [120/1] via 192.168.4.1, 00:00:08, Serial0/0/1
D    192.168.6.0/24 [90/2172416] via 192.168.2.1, 00:00:24, Serial0/0/0
R    192.168.7.0/24 [120/1] via 192.168.4.1, 00:00:08, Serial0/0/1
R    192.168.8.0/24 [120/2] via 192.168.4.1, 00:00:08, Serial0/0/1
```

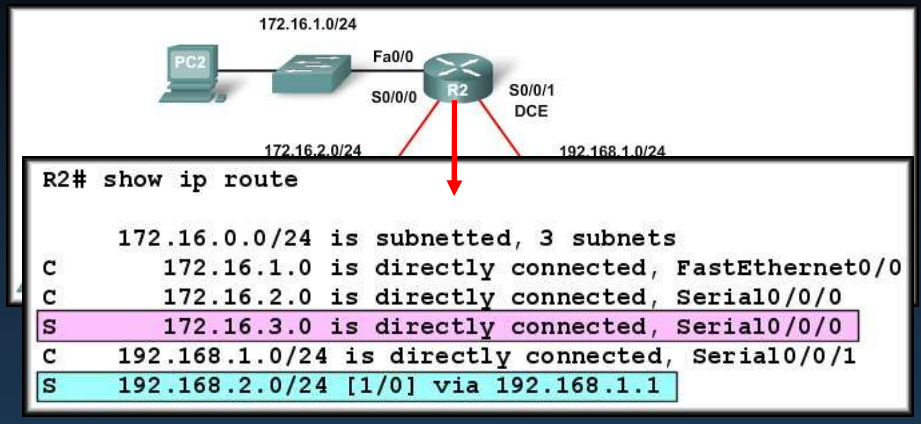
AD = 0

Verifying Administrative Distance (AD)

- **show ip protocols**

```
R2# show ip protocols
Routing Protocol is "eigrp 100 "

<output omitted>

  Automatic address summarization:
  Maximum path: 4
  Routing for Networks:
     192.168.2.0
     192.168.3.0
     192.168.4.0
Routing Information Sources:
  Gateway         Distance      Last Update
  192.168.2.1     90            2366569
Distance: internal 90 external 170
Routing Protocol is "rip"

<output omitted>

  Automatic network summarization is in effect
  Maximum path: 4
  Routing for Networks:
    192.168.3.0
    192.168.4.0
  Passive Interface(s):
  Routing Information Sources:
     Gateway         Distance      Last Update
     192.168.4.1     120
  Distance: (default is 120)
```

Static Routes and Administrative Distance




```
R2# show ip route

     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
S       172.16.3.0 is directly connected, Serial0/0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
S    192.168.2.0/24 [1/0] via 192.168.1.1
```

- Static Route AD = 1
  - After directly connected networks (AD = 0), static routes are the most preferred route source.

Static Routes and Administrative Distance

Exit Interface:

```
ip route 172.16.3.0 255.255.255.0 serial 0/0/0
```

```
R2# show ip route

     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
S       172.16.3.0 is directly connected, Serial0/0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
S    192.168.2.0/24 [1/0] via 192.168.1.1
```

Next-hop Address:

```
ip route 172.16.3.0 255.255.255.0 192.168.1.1
```

- Routing table display depends on how you issued the command. The AD for both of these is 1!

Directly Connected and Administrative Distance

```
R2# show ip route

     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
S       172.16.3.0 is directly connected, Serial0/0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
S    192.168.2.0/24 [1/0] via 192.168.1.1
```

- Appear in the routing table as soon as the interface is active with an IP address and subnet mask ("up" and "up").
  - AD = 0 is the most preferred route.
    - Cannot be changed
    - No other type of route can have AD = 0.
- There is no better route for a router than having one of its interfaces directly connected to that network.

Directly Connected and Administrative Distance

```
R2# show ip route 172.16.3.0
Routing entry for 172.16.1.0/24
Known via "connected", distance 0, metric 0 (connected, via interface)
   Routing Descriptor Blocks:
   * directly connected, via FastEthernet0/0
      Route metric is 0, traffic share count is 1
```

- To see the AD value of any network, use the command **`show ip route [route]`** option.
  - Directly Connected
  - Static
  - Dynamic Routing Protocol