

DYNAMIC / DISTANCE VECTOR ROUTING

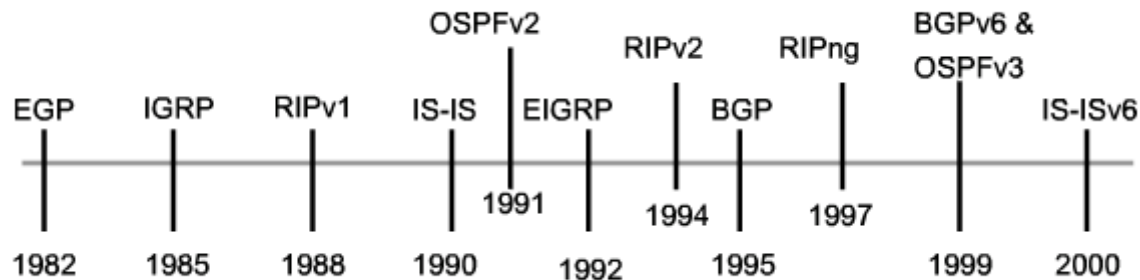
Mohammad S. Hasan

Types of Routing Protocols

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- Use different methods for updating and maintaining routing tables

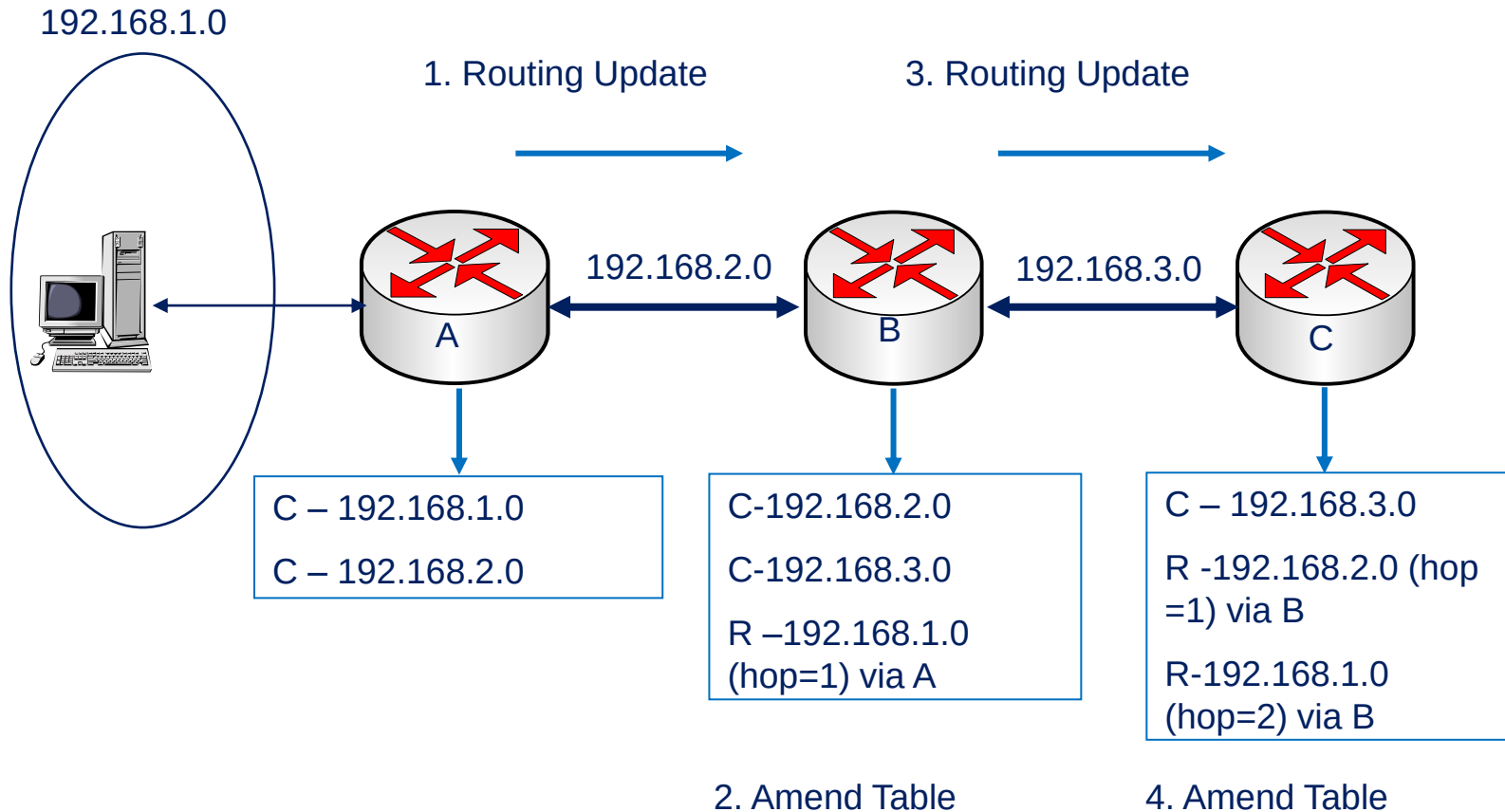
	Distance Vector Routing Protocols	Link State Routing Protocols		Path Vector
Classful	RIP	IGRP		EGP
Classless	RIPv2	EIGRP	OSPFv2	IS-IS
IPv6	RIPng	EIGRP for IPv6	OSPFv3	IS-IS for IPv6



Distance Vector Routing

Dynamic Routing Operation

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Distance Vector Routing

Dynamic vs. Static Routes

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□ Static Routing

- ▣ A network administrator enters route into the router's configuration.
- ▣ The administrator must manually update this static route entry if there is any change in the network topology.
- ▣ Static routing reduces overhead
- ▣ Better security
- ▣ Used in Stub Networks

□ Dynamic routing

- ▣ Route knowledge is updated automatically by a routing process whenever new information is received from the network.
- ▣ Router CPU resources are utilised to maintain dynamic routing tables.
- ▣ Less secure

The Purpose of Dynamic Routing Protocols

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- A routing protocol is a set of processes, algorithms, and messages that are used to exchange routing information and populate a routing table (list of known destination networks with the routing protocol's choice of best paths).
- The purpose of a routing protocol includes:
 - ▣ Discovery of remote networks.
 - ▣ Maintaining up-to-date routing information.
 - ▣ Choosing the best path to destination networks.
 - ▣ Ability to find a new best path if the current path is no longer available.

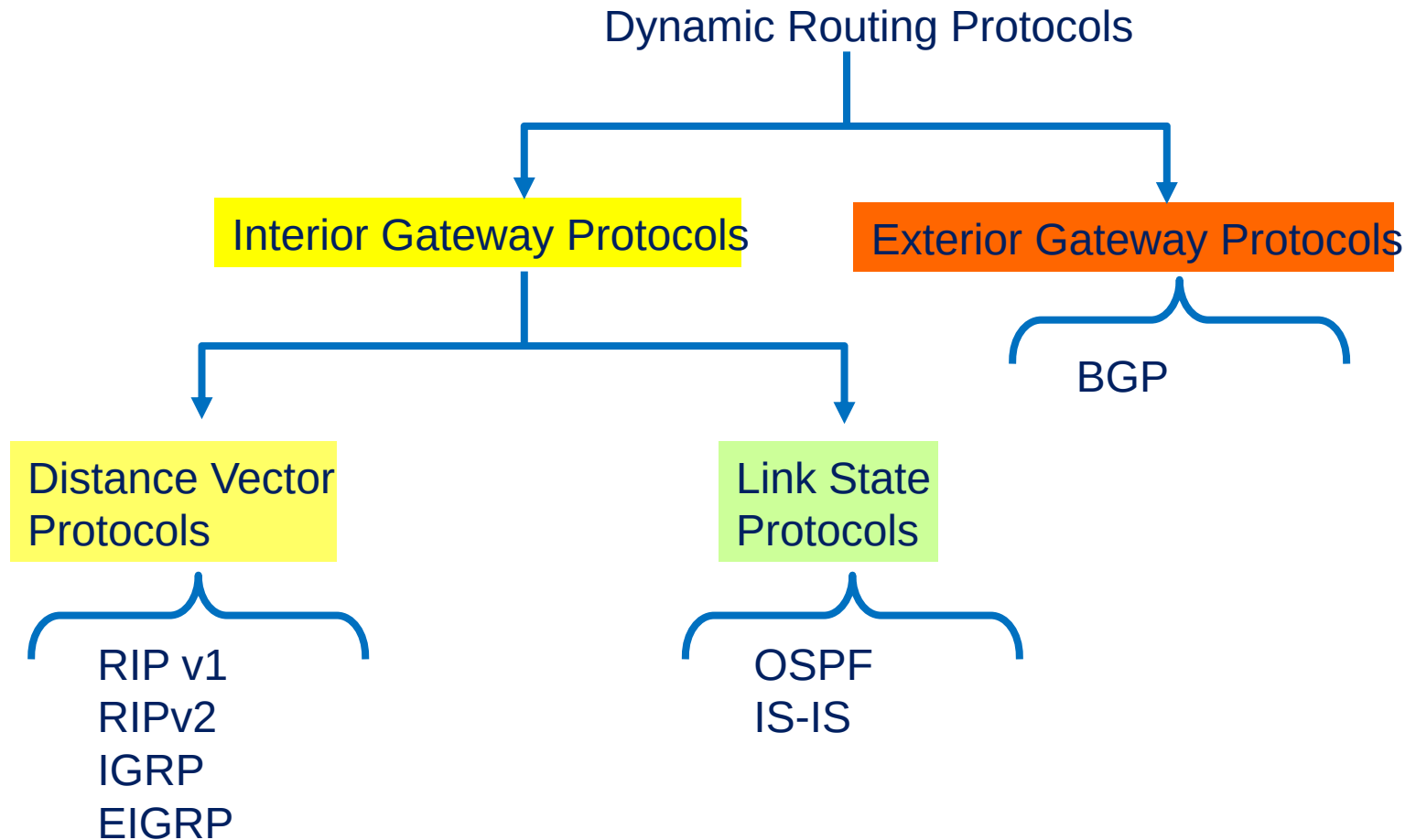
Components of Dynamic Routing Protocols

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- Data structures - Some routing protocols use tables and/or databases for its operations. This information is kept in RAM.
- Algorithm - An algorithm is a finite list of steps used in accomplishing a task. Routing protocols use algorithms for facilitating routing information and for best path determination.
- Routing protocol messages - Routing protocols use various types of messages to discover neighboring routers, exchange routing information, and other tasks to learn and maintain accurate information about the network.

Classifying Routing Protocols

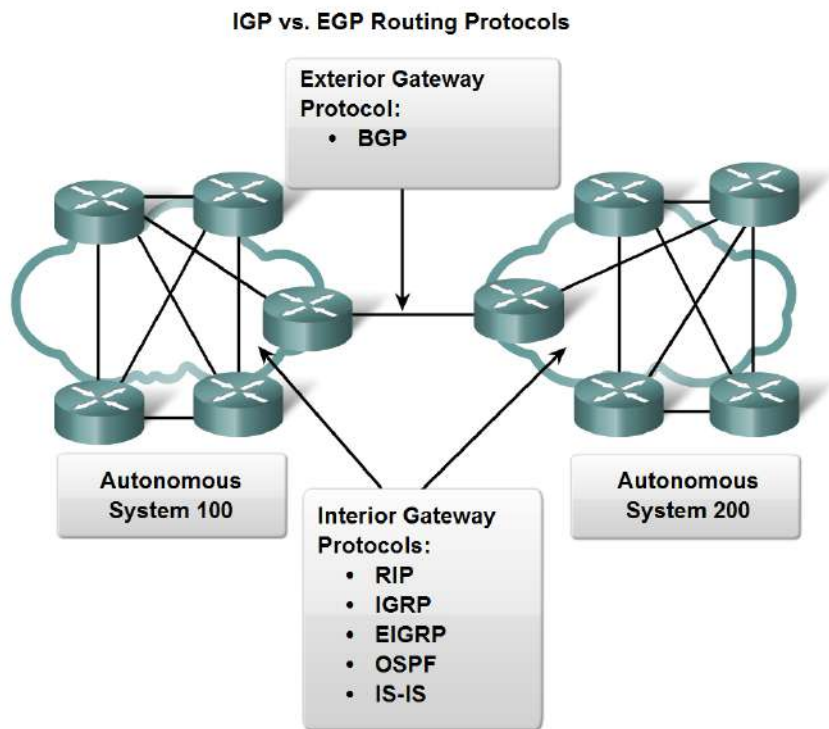
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Distance Vector Routing

Autonomous Systems (AS)

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- An autonomous system (AS) or a routing domain
 - ▣ a collection of routers under a common administration.

Autonomous Systems and Routing

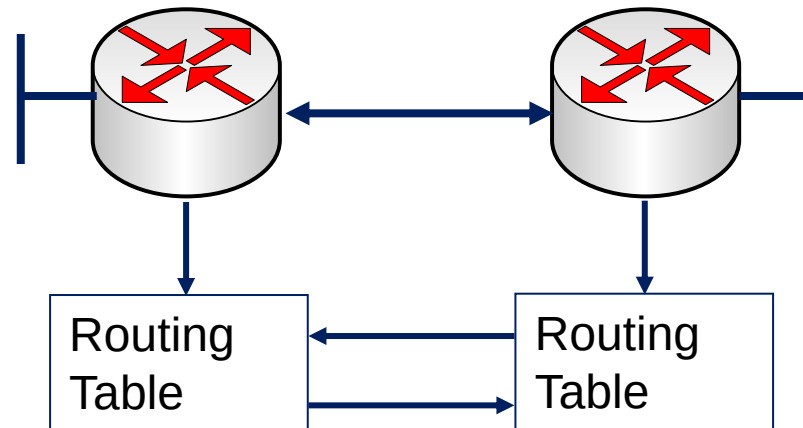
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- The Internet is based on the AS concept.
 - ▣ Thus two types of routing protocols are required
- Interior Gateway Protocols (IGP)
 - ▣ used for intra-AS routing or routing inside an AS
- Exterior Gateway Protocols (EGP)
 - ▣ used for inter-AS routing or routing between AS

Distance Vector Routing

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- Distance vector routing protocols do NOT have an actual map of the network topology.



Distance Vector Routing

Application of Distance Vector Routing

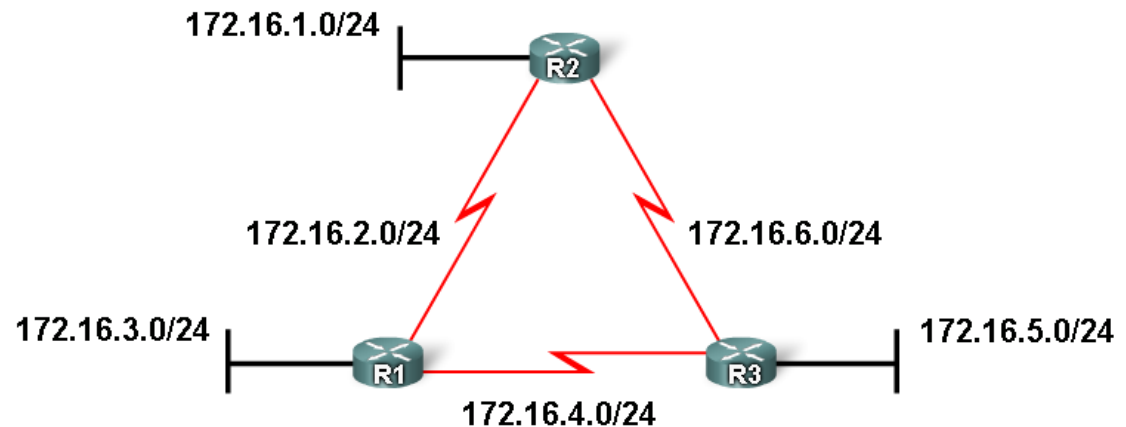
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- The network is simple, small and flat and does NOT require a special hierarchical design.
- The administrators do NOT have enough knowledge to configure and troubleshoot link-state protocols.
- Specific types of networks, such as hub-and-spoke networks,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

Classful Routing Protocols

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- Classful routing protocols do not send subnet mask in routing updates.
- The first routing protocols e.g. RIP, were classful
 - ▣ Based on class A, B, or C network address.
- Classful Routing Protocols do NOT support VLSM known as CIDR.

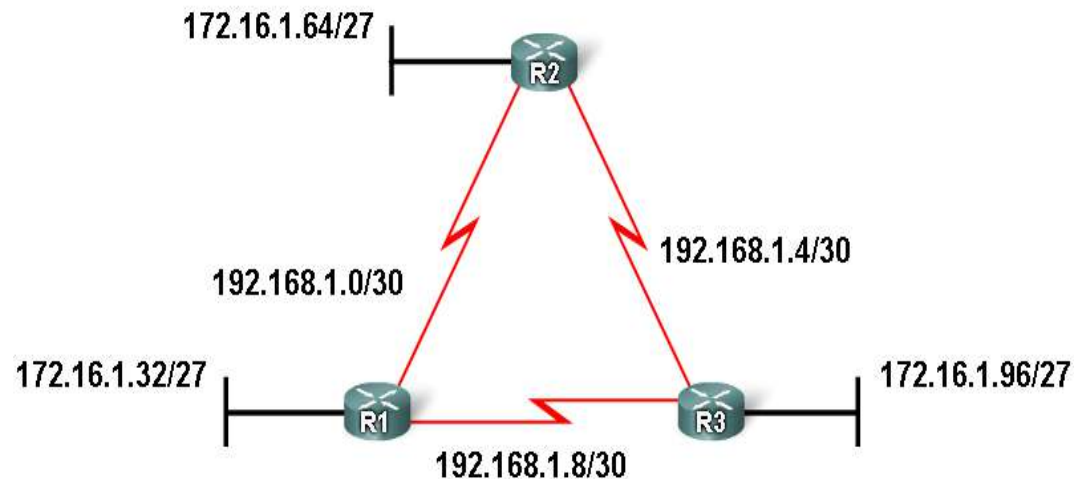


Distance Vector Routing

Classless Routing Protocols or VLSM

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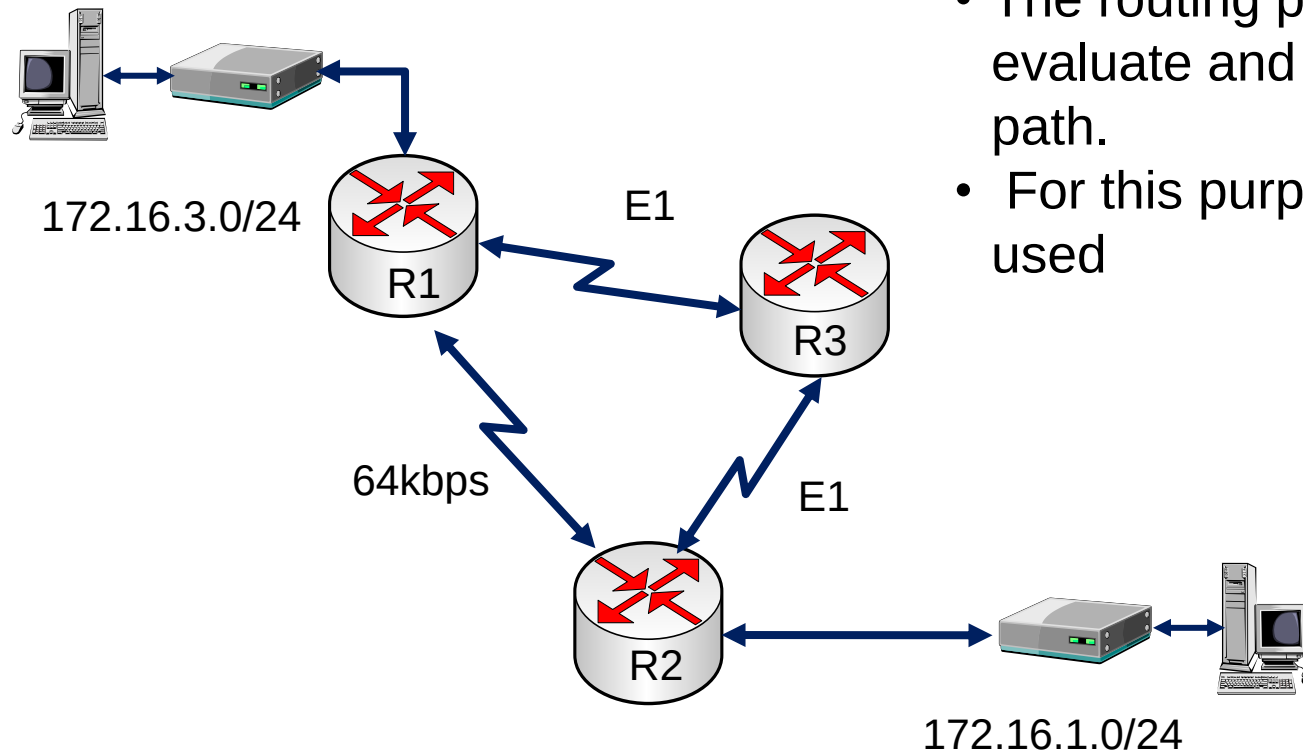
- Classless routing protocols include the subnet mask with the network address in routing updates.
- Classless routing protocols are required in most networks today because they support VLSM and discontinuous networks.



Distance Vector Routing

Best Path & Metric

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- Possibility of more than one route to the same destination.
- The routing protocol must evaluate and select the best path.
- For this purpose a metric is used

Distance Vector Routing

Metrics used in Routing Protocols

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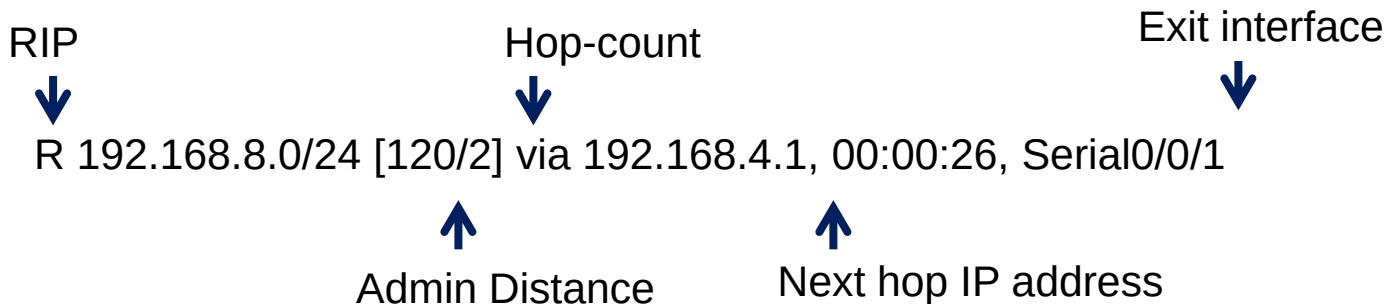
- Hop count - the number of routers a packet must traverse
- Bandwidth - Influences path selection by preferring the path with the highest bandwidth
- Load - Considers the traffic utilization of a certain link
- Delay - Considers the time a packet takes to traverse a path
- Reliability - Assesses the probability of a link failure, calculated from the interface error count or previous link failures
- Cost - A value determined either by the IOS or by the network administrator to indicate preference for a route. Cost can represent a metric, a combination of metrics or a policy.

Routing Protocol Metrics

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- RIP: Hop count - Best path is chosen by the route with the lowest hop count.
- IGRP and EIGRP: Bandwidth, Delay, Reliability, and Load - Best path is chosen by the route with the smallest composite metric value calculated from these multiple parameters. By default, only bandwidth and delay are used.
- IS-IS and OSPF: Cost - Best path is chosen by the route with the lowest cost. Cisco's implementation of OSPF uses bandwidth

Routing Table extract:

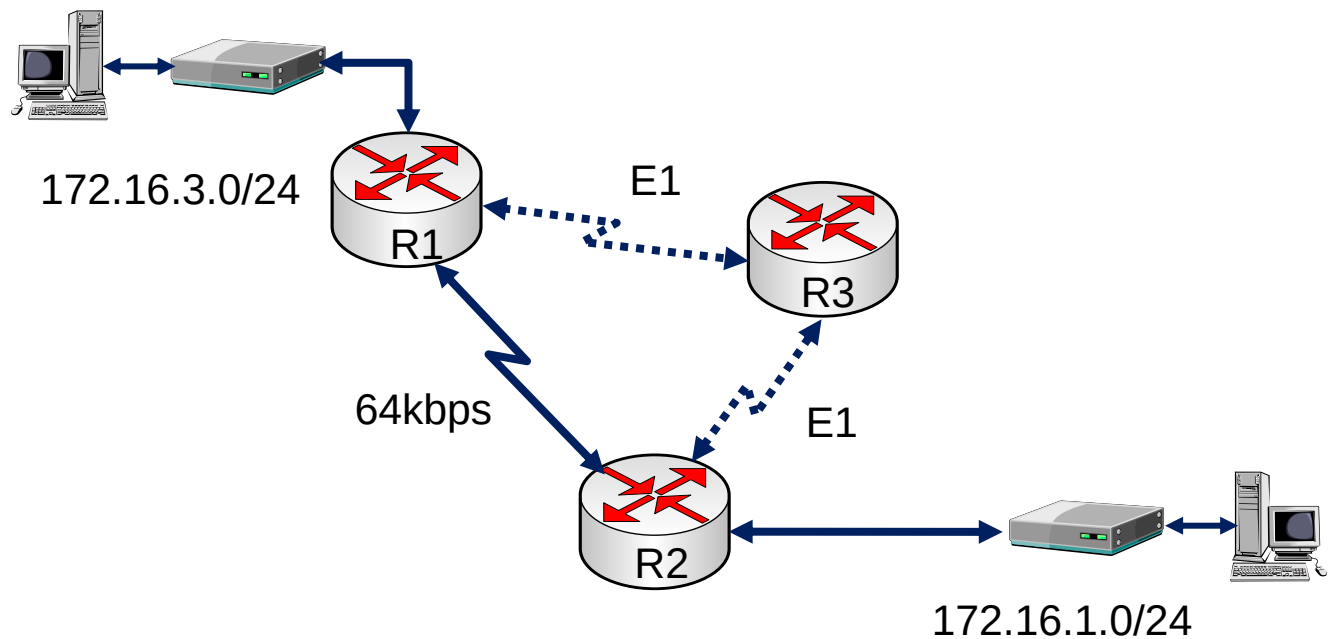


Distance Vector Routing

Routing Information Protocol (RIP) - Best Path & Metric

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- RIP uses hop-count as a metric, and would take the shortest path to a destination, not necessarily the fastest.

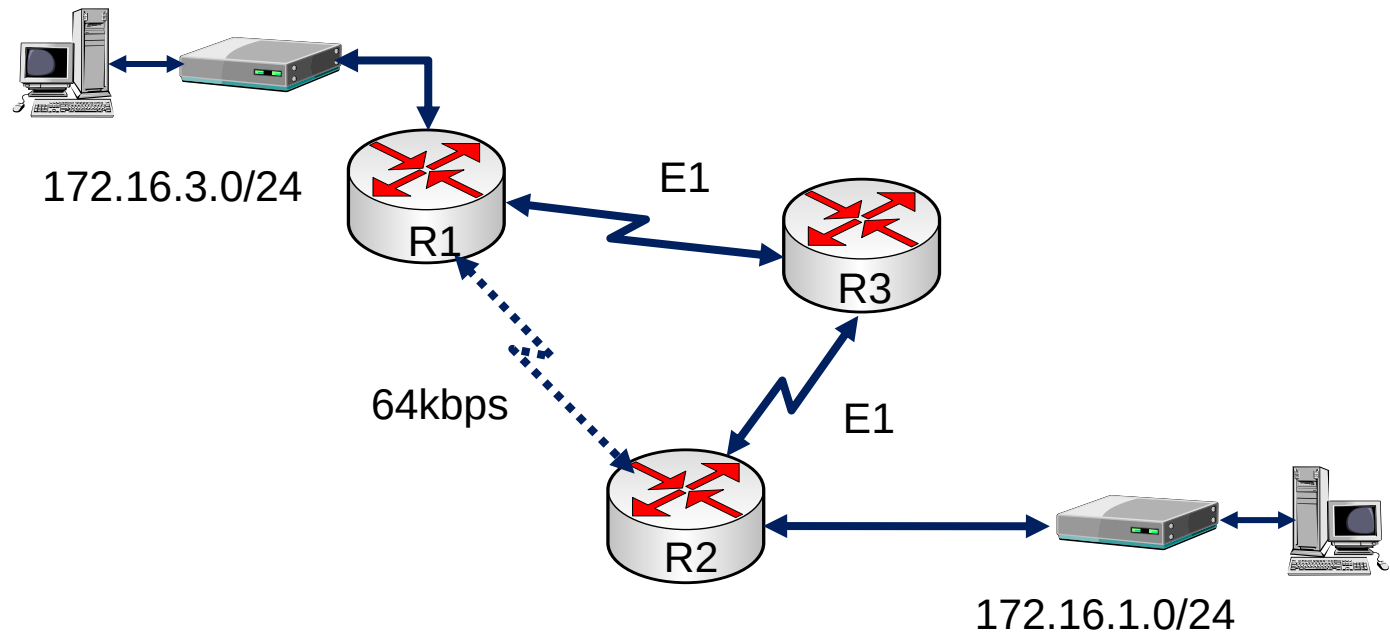


Distance Vector Routing

Open Shortest Path First (OSPF) - Best Path & Metric

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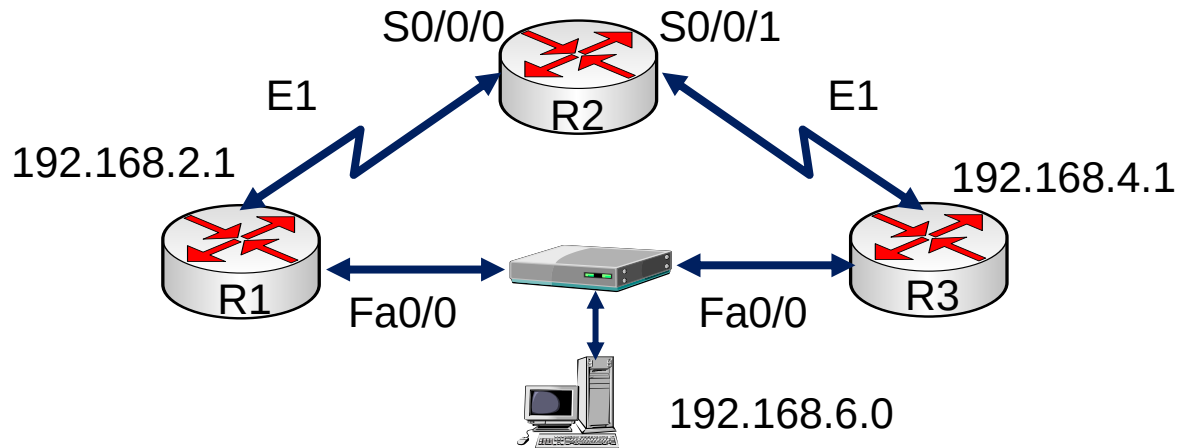
- OSPF uses bandwidth as a metric, and would take the fastest path to a destination, not necessarily the shortest.



Distance Vector Routing

Equal Cost Load Balancing

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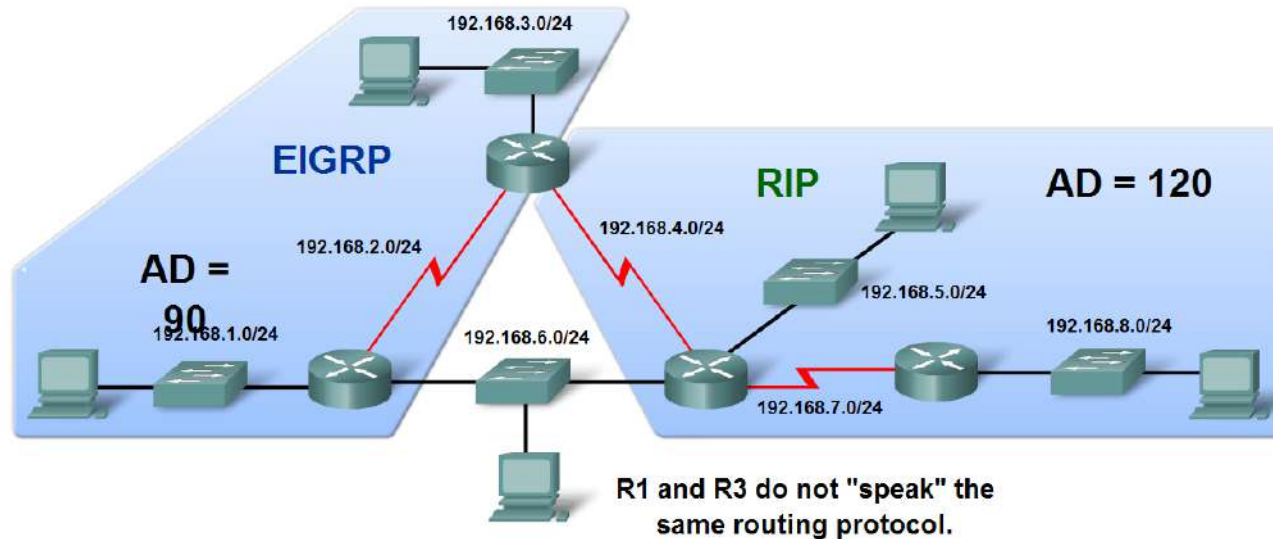
- If two or more routes have the same metric values, the router does not choose only one route.
- Instead, the router "load balances" between these equal cost paths.

Routing Table extract:

```
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
```

Administrative Distance (AD) of a Route

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- AD defines the preference of a routing source for routing protocols, static routes, and even directly connected networks.
- Cisco routers use the AD feature to select the best path when it learns about the same destination network from two or more different routing sources.

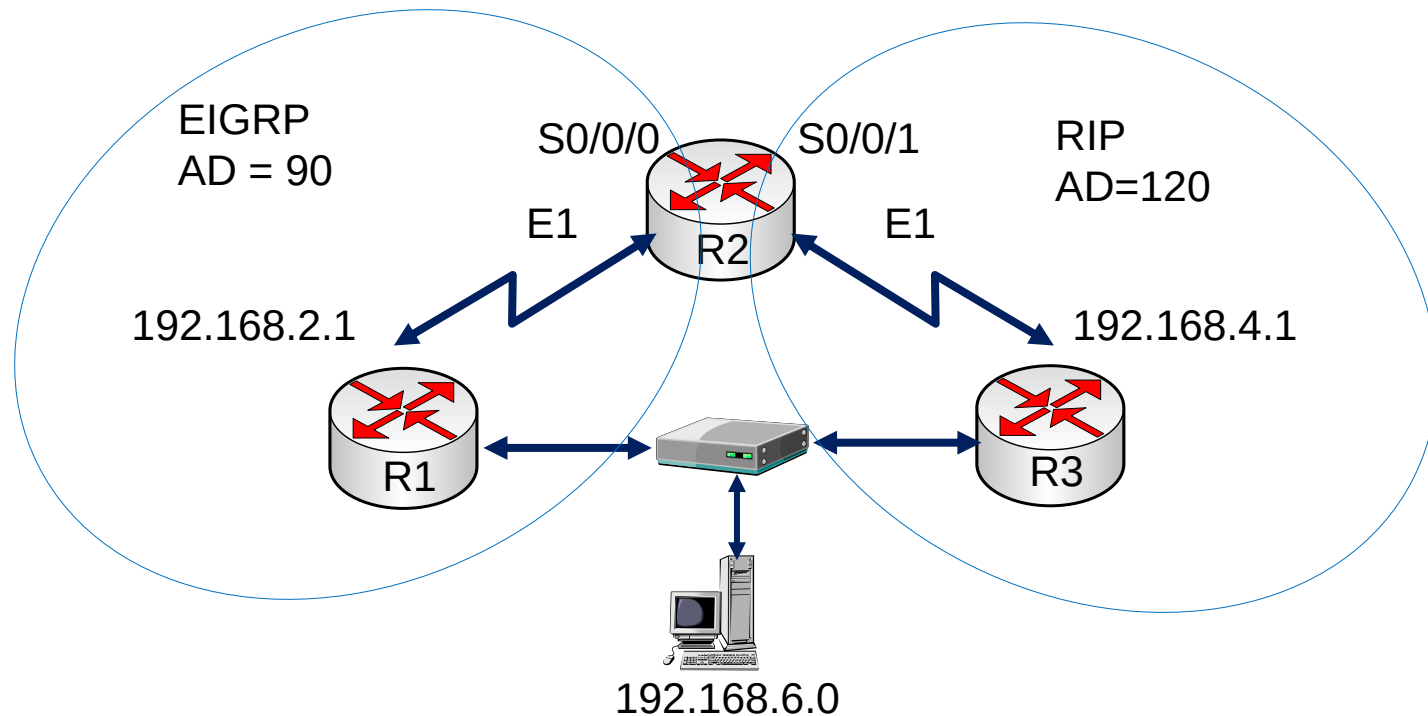
Administrative Distance (AD) of a Route

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- AD is an integer value from 0 to 255. The lower the value the more preferred the route source.
 - ▣ Only a directly connected network has an administrative distance of 0, which cannot be changed.
- It is possible to modify the administrative distance for static routes and dynamic routing protocols. This is discussed in CCNP.
- An administrative distance of 255 means the router will not believe the source of that route and it will not be installed in the routing table.
- Note: The term trustworthiness is commonly used when defining administrative distance.

Administrative Distance (AD) of a Route

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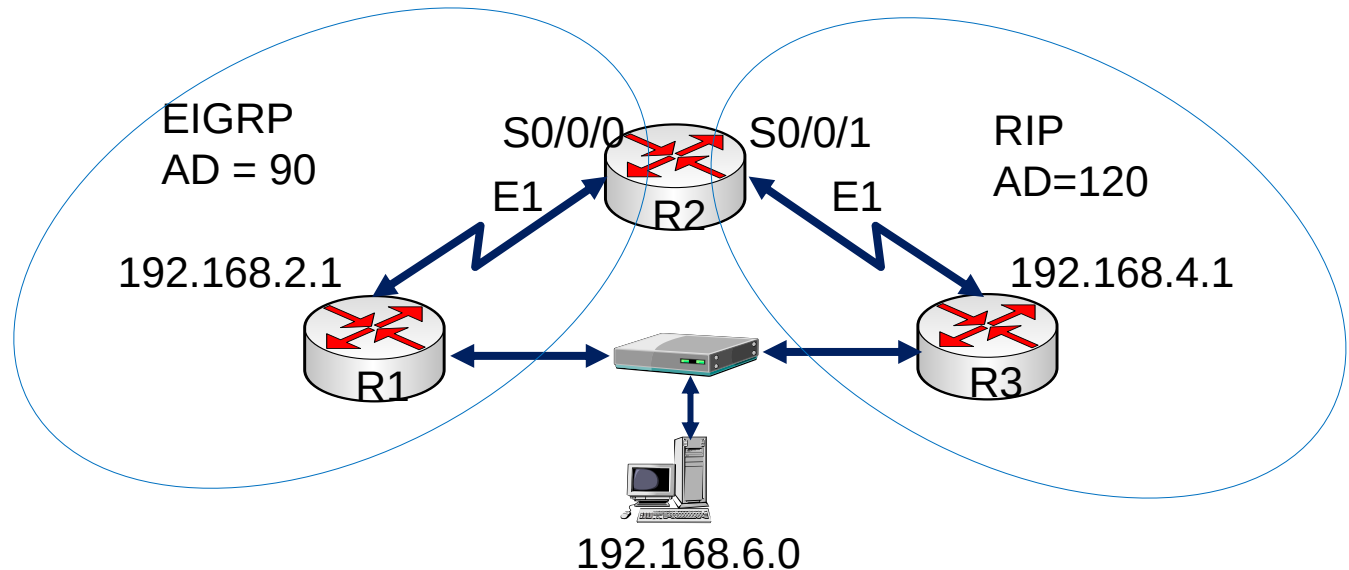


R2 learns about network 192.168.6.0 from via EIGRP and RIP – which route is installed in R2 routing table?

Distance Vector Routing

Administrative Distance (AD) of a Route

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```
R2#show ip route  
<output omitted>
```

Gateway of last resort is not set

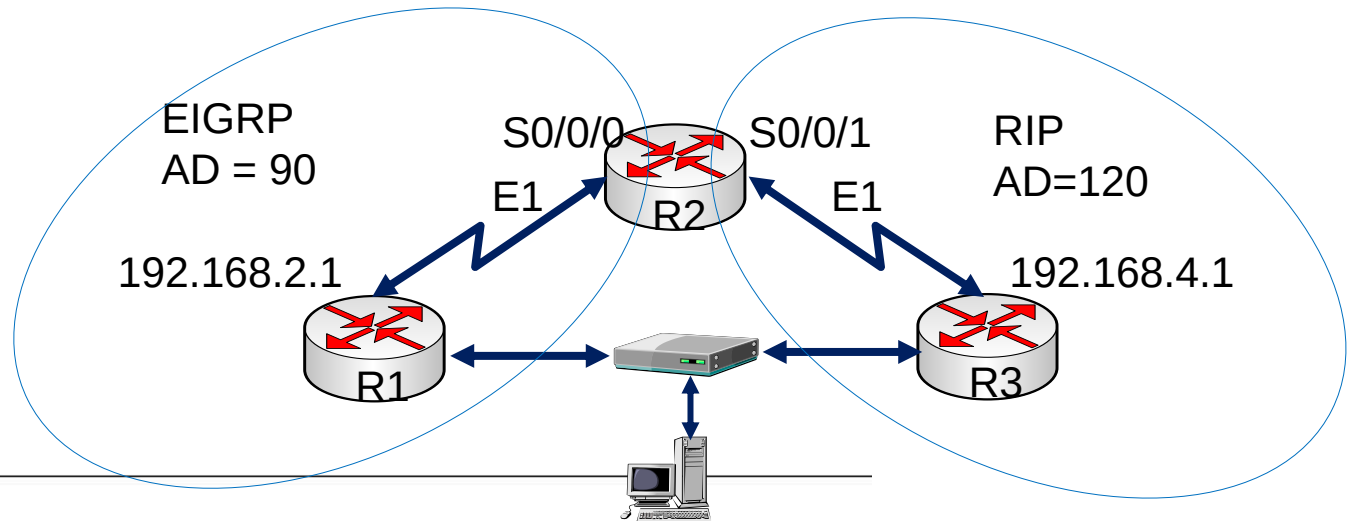
```
D    192.168.1.0/24 [90/2172416] via 192.168.2.1, 00:00:24, Serial0/0/0  
C    192.168.2.0/24 is directly connected, Serial0/0/0  
C    192.168.3.0/24 is directly connected, FastEthernet0/0  
C    192.168.4.0/24 is directly connected, Serial0/0/1  
R    192.168.5.0/24 [120/1] via 192.168.4.1, 00:00:08, 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
```

AD of EIGRP is 90 which is lower than the AD of RIP (120), So EIGRP route is installed.

Distance Vector Routing

Administrative Distance (AD) of a Route

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```
R2#show ip rip database
```

```
192.168.3.0/24    directly connected, FastEthernet0/0
192.168.4.0/24    directly connected, Serial0/0/1
192.168.5.0/24
  [1] via 192.168.4.1, Serial0/0/1
192.168.6.0/24
  [1] via 192.168.4.1, Serial0/0/1
192.168.7.0/24
  [1] via 192.168.4.1, Serial0/0/1
192.168.8.0/24
  [2] via 192.168.4.1, Serial0/0/1
```

R2 stores the route to 192.168.6.0 in its RIP database, in case the route learnt via EIGRP fails.

Administrative Distance (AD) of a Route

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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

AD of Static Routes

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```
R2#show ip route
<output omitted>

Gateway of last resort is not set

    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
```

- A static route has a default AD value of 1. When a static route is configured with an exit interface, the output shows the network as directly connected via that interface, with no AD displayed:

- Use sh ip route to discover 'hidden' AD:

```
R2#show ip route 172.16.3.0
Routing entry for 172.16.3.0/24
Known via "static", distance 1, metric 0 (connected)
Routing Descriptor Blocks:
* directly connected, via Serial0/0/0
  Route metric is 0, traffic share count is 1
```

AD of Directly Connected Interfaces

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- Directly connected networks appear in the routing table as soon as the IP address on the interface is configured and the interface is enabled and operational.
- The AD of a directly connected network cannot be changed and no other route source can have an AD of 0.

```
R2#show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
       i - IS-IS, 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

Gateway of last resort is not set

    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
```

Routing Information Protocol (RIP)

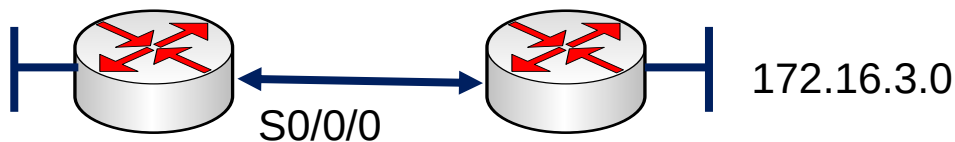
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- ❑ Originally specified in RFC 1058. It has the following key characteristics:
 - ▣ Hop count is used as the metric for path selection.
 - ▣ If the hop count for a network is greater than 15, RIP cannot supply a route to that network.
 - ▣ Routing updates are broadcast or multicast every 30 seconds, by default.

Distance Vector Technology

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- A router using a distance vector routing protocol does not have the knowledge of the entire path to a destination network. Instead the router knows only:
 - ▣ The direction (vector) or interface in which packets should be forwarded.
 - ▣ The distance or how far it is to the destination network.

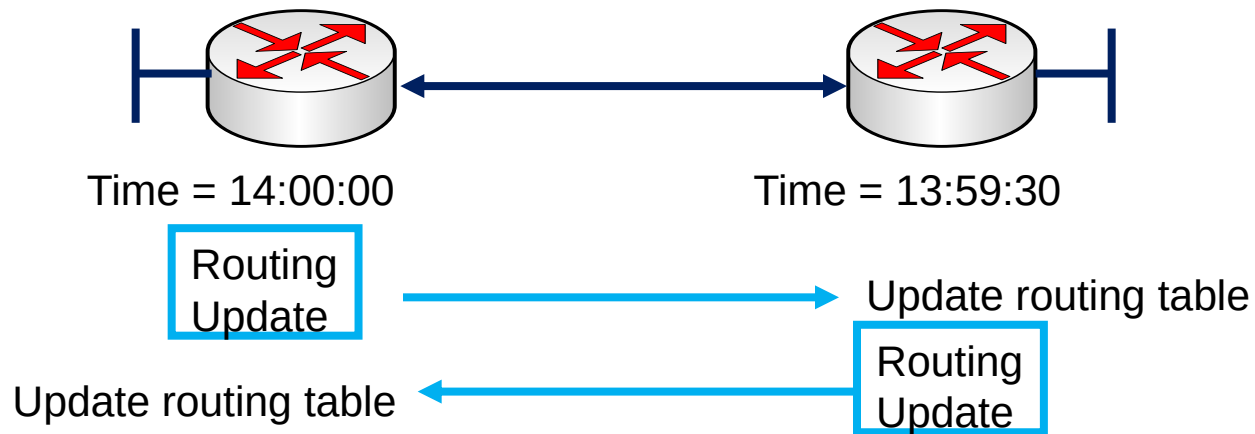


Where is network 172.16.3.0?
Distance = 1 hop
Direction = S0/0/0

Routing Table Update timing

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- Some distance vector routing protocols periodically broadcast the entire routing table to each of its neighbours.
 - ▣ Waste of CPU power and Network bandwidth
- Periodic Updates are sent at regular intervals even NO change in the topology
 - ▣ 30 seconds for RIP and 90 seconds for IGRP)



Distance Vector Routing

Routing Protocol Algorithms

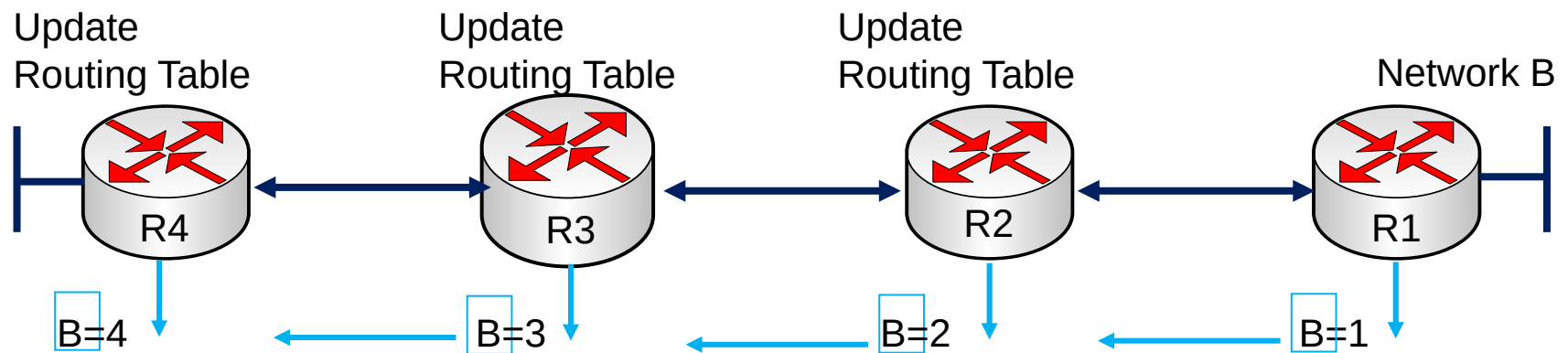
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- Different routing protocols use different algorithms to install routes in the routing table, send updates to neighbors, and make path determination decisions.
- The algorithm used for the routing protocols defines the following processes:
 - ▣ Mechanism for sending and receiving routing information.
 - ▣ Mechanism for calculating the best paths and installing routes in the routing table.
 - ▣ Mechanism for detecting and reacting to topology changes.

Distance Vector Routing Operations

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- Distance vector routing protocols receive a routing table update from a neighbour.
- Each router increments the hop count of all available networks by 1 prior to transmission.

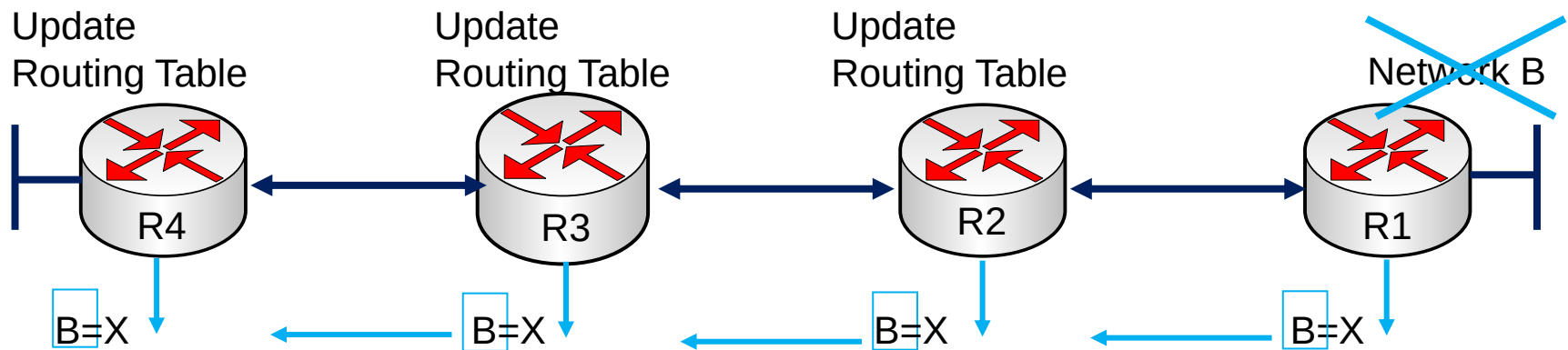


Distance Vector Routing

Distance Vector Routing Operations – Failed Network

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- If a network fails, this information is forwarded in an update, and the routers will remove the route to the failed network from their routing tables.



Distance Vector Routing

Routing Protocol Characteristics

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- Time to Convergence - how quickly the routers in the network share routing info and reach a state of consistent knowledge. Routing loops can occur when inconsistent routing tables are not updated due to slow convergence in a changing network.
- Scalability - how large a network can become based on the routing protocol. The larger the network is, the more scalable the routing protocol needs to be.
- Classless or Classful - Classless routing protocols include the subnet mask in the updates, and support VLSM, whereas classful routing protocols do not include the subnet mask and cannot support VLSM.
- Resource Usage – how powerful router hardware is needed to support the routing protocol.
- Implementation and Maintenance - the level of knowledge that is required for a network administrator to implement and maintain the routing protocol.

Pros and cons of Distance Vector Routing Protocols

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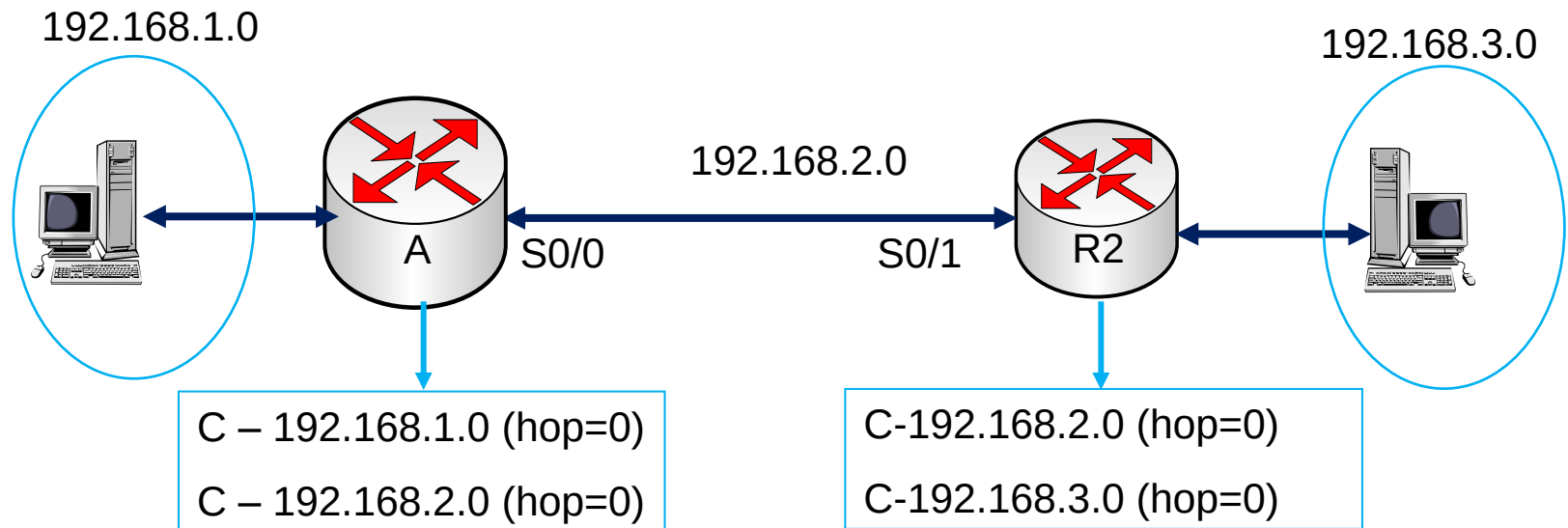
Advantages & Disadvantages of Distance Vector Routing Protocols

Advantages:	Disadvantages:
Simple implementation and maintenance. The level of knowledge required to deploy and later maintain a network with distance vector protocol is not high.	Slow convergence. The use of periodic updates can cause slower convergence. Even if some advanced techniques are used, like triggered updates which are discussed later, the overall convergence is still slower compared to link state routing protocols.
Low resource requirements. Distance vector protocols typically do not need large amounts of memory to store the information. Nor do they require a powerful CPU. Depending of the network size and the IP addressing implemented they also typically do not require a high level of link bandwidth to send routing updates. However, this can become an issue if you deploy a distance vector protocol in a large network.	Limited scalability. Slow convergence may limit the size of the network because larger networks require more time to propagate routing information.
	Routing loops. Routing loops can occur when inconsistent routing tables are not updated due to slow convergence in a changing network.

Exchange of Routing Information – Phase 1

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- After a cold start, the routers initially discover their own directly connected networks and subnet masks. This information is added to their routing tables.

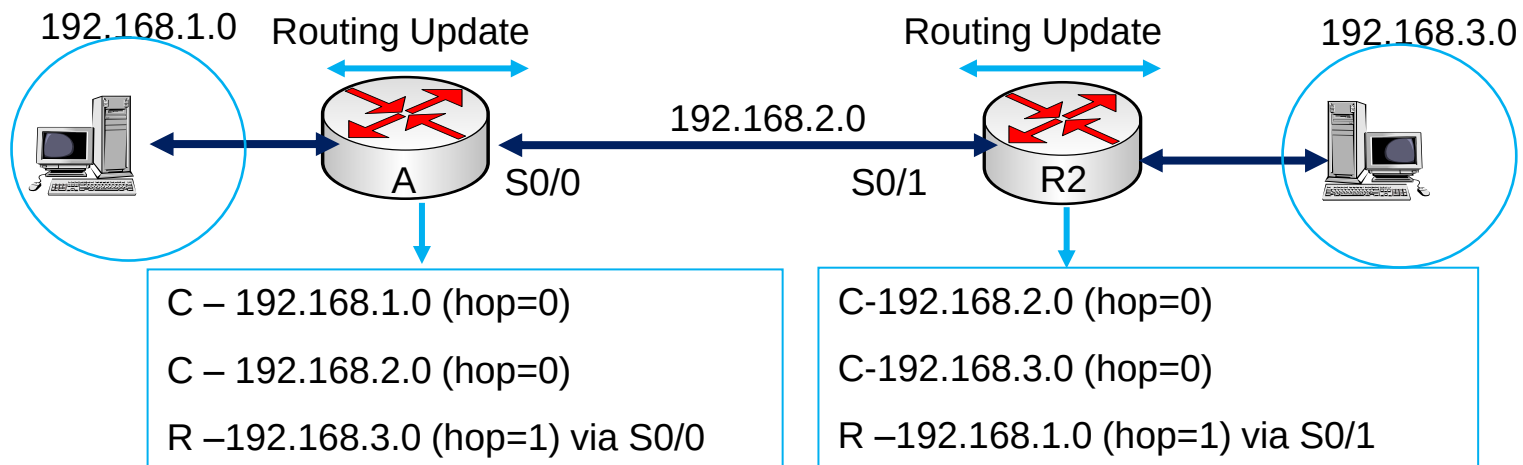


Distance Vector Routing

Exchange of Routing Information – Phase 2

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- If a routing protocol is configured, the routers begin exchanging routing updates. Initially, these updates only include information about their directly connected networks.
- Upon receiving an update, the router checks it for new information. Any routes that are not currently in its routing table are added.

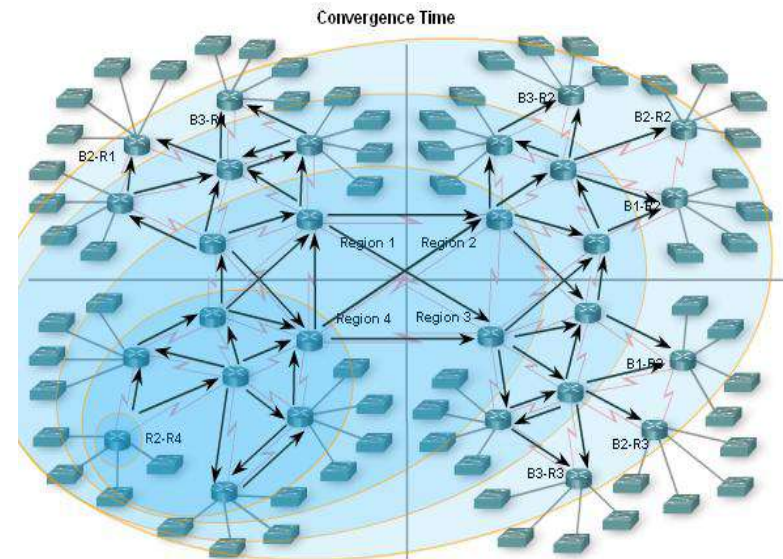


Distance Vector Routing

Convergence

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- The convergence time is directly proportional to the size of the network.
- The speed of achieving convergence consists of:
 - How quickly the routers propagate a change in the topology in a routing update to its neighbors.
 - The speed of calculating best path routes using the new routing information collected.
- A network is not completely operable until it has converged, therefore, network administrators prefer routing protocols with shorter convergence times.



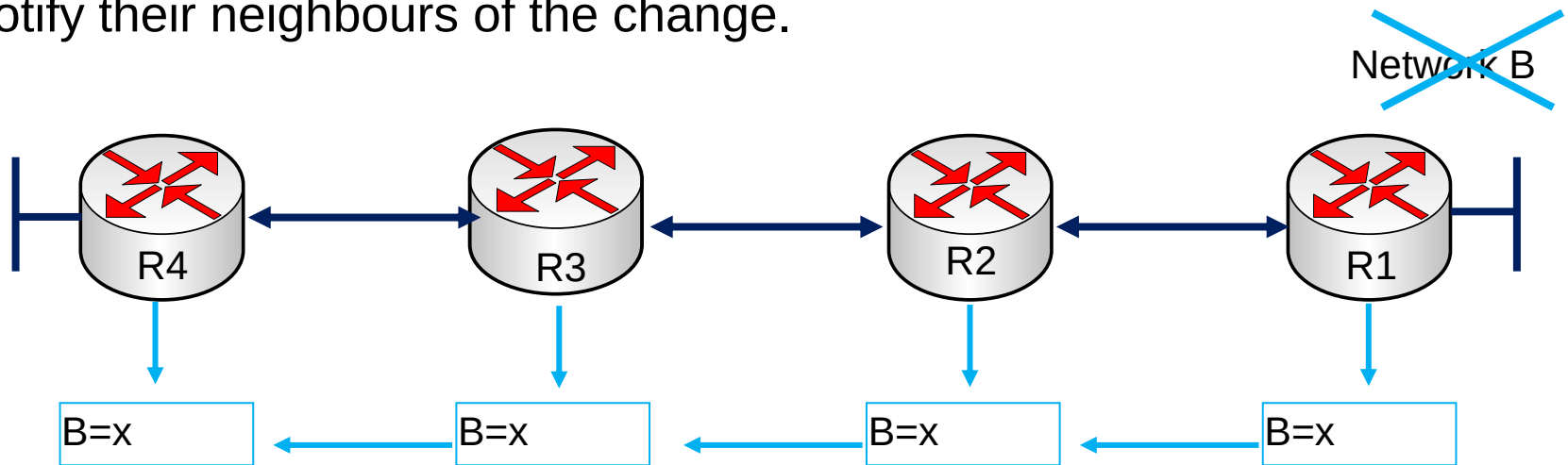
Distance Vector Routing

Triggered Updates

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To speed up the convergence when there is a topology change, RIP uses triggered updates. A triggered update is a routing table update that is sent immediately in response to a routing change.

Triggered updates do not wait for update timers to expire. The detecting router immediately sends an update message to adjacent routers. The receiving routers, in turn, generate triggered updates that notify their neighbours of the change.

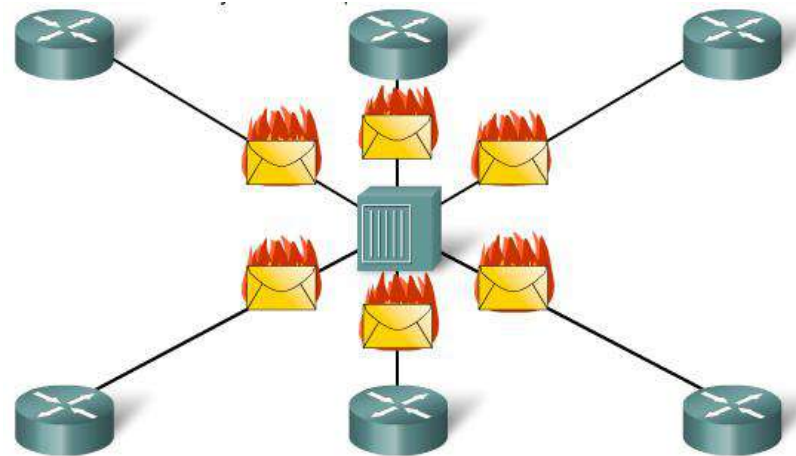


Distance Vector Routing

Random Jitter

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- Sending updates at the same time is known as the synchronization of updates. Synchronisation can become a problem with distance vector routing protocols due to their usage of periodic updates.
- As more routers' timers become synchronized, more collisions of updates and more delays occur in the network.
- Solution - the Cisco IOS uses a random variable, called RIP_JITTER, which subtracts a variable amount of time to the update interval for each router in the network.



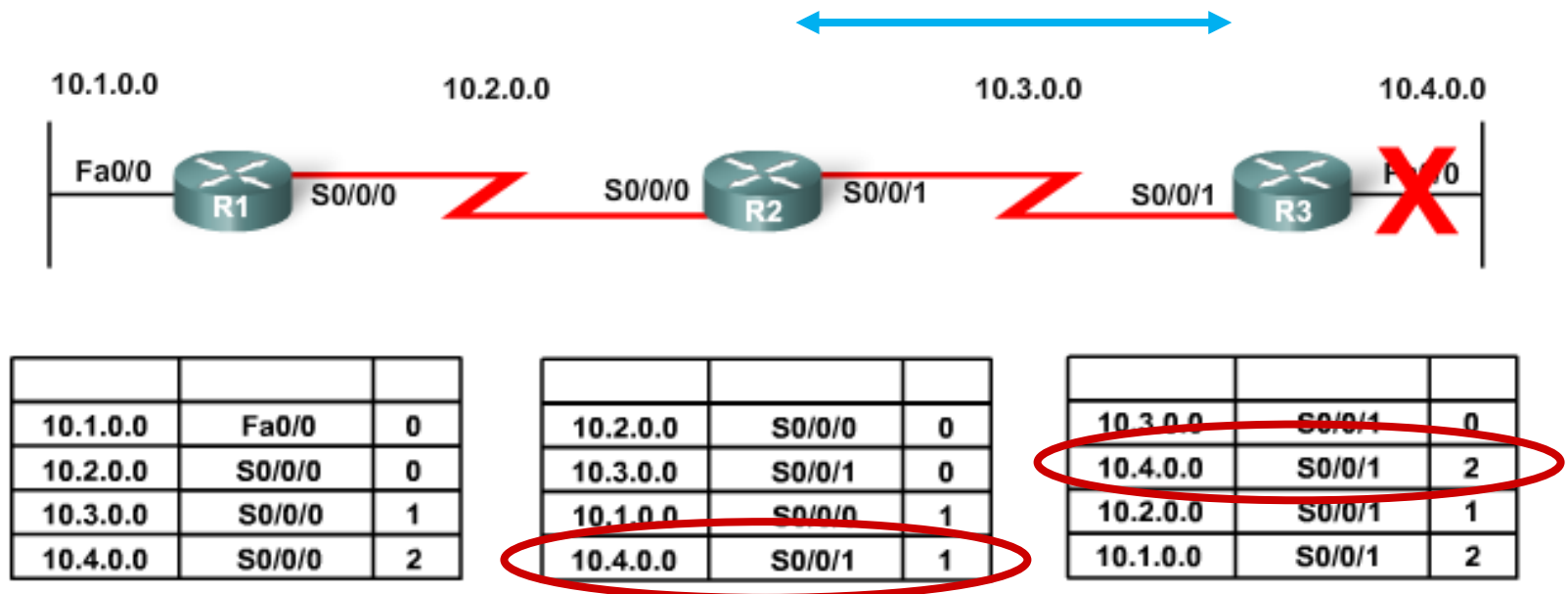
Distance Vector Routing

Routing Loops

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- Routing loops can occur when inconsistent routing tables are not updated due to slow convergence in a changing network.
- Data packets will circulate continuously between the routers in the loop.

Packets for 10.4.0.0 will loop between R2 and R3



Distance Vector Routing

Routing Loops - Problems

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- ❑ Waste of link bandwidth by the looping traffic.
- ❑ A router's CPU will be strained due to looping packets.
- ❑ A router's CPU will be burdened with useless packet forwarding that will negatively impact the convergence of the network.
- ❑ Routing updates may get lost or not be processed in a timely manner. These conditions would introduce additional routing loops, making the situation even worse.
- ❑ Packets may get lost in "black holes."

Routing Loops - Prevention

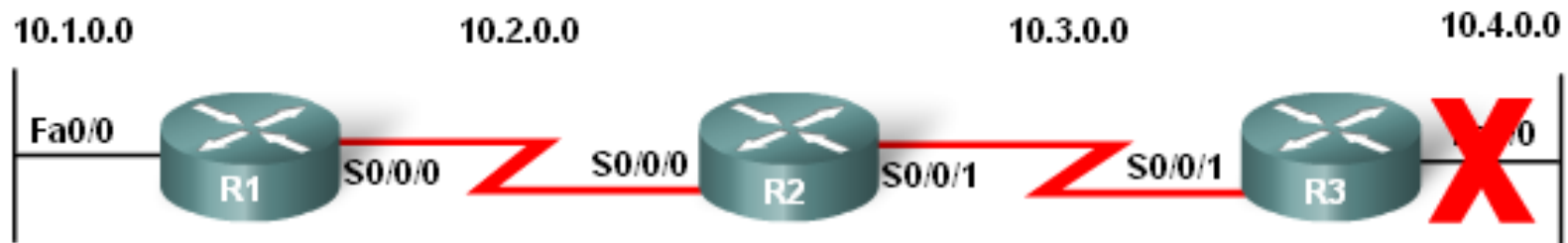
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- There are a number of mechanisms to prevent routing loops in distance vector routing protocols.
 - ▣ Defining a maximum metric to prevent count to infinity
 - ▣ Hold-down timers
 - ▣ Split horizon
 - ▣ Route poisoning or poison reverse
 - ▣ Triggered updates

Counting to Infinity Problem

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The problem exists when inaccurate routing updates increase the metric value to "infinity" for a network that is no longer reachable.



Network	Interface	Hop
10.1.0.0	Fa0/0	0
10.2.0.0	S0/0/0	0
10.3.0.0	S0/0/0	1
10.4.0.0	S0/0/0	16

Network	Interface	Hop
10.2.0.0	S0/0/0	0
10.3.0.0	S0/0/1	0
10.1.0.0	S0/0/0	1
10.4.0.0	S0/0/1	16

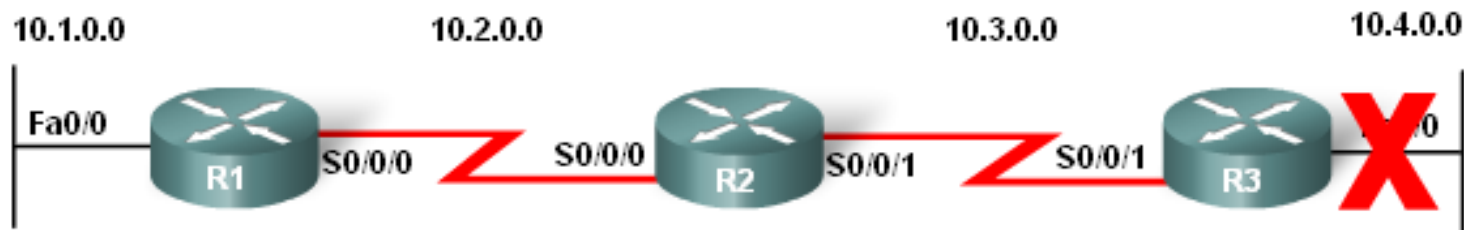
Network	Interface	Hop
10.3.0.0	S0/0/1	0
10.4.0.0	S0/0/1	16
10.2.0.0	S0/0/1	1
10.1.0.0	S0/0/1	2

Distance Vector Routing

Defining a Maximum for Infinity

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- To eventually stop the incrementing of the metric, "infinity" is defined by setting a maximum metric value.
- For example, RIP defines infinity as 16 hops - an "unreachable" metric. Once the routers "count to infinity," they mark the route as unreachable.



Network	Interface	Hop
10.1.0.0	Fa0/0	0
10.2.0.0	S0/0/0	0
10.3.0.0	S0/0/0	1
10.4.0.0	S0/0/0	16

Network	Interface	Hop
10.2.0.0	S0/0/0	0
10.3.0.0	S0/0/1	0
10.1.0.0	S0/0/0	1
10.4.0.0	S0/0/1	16

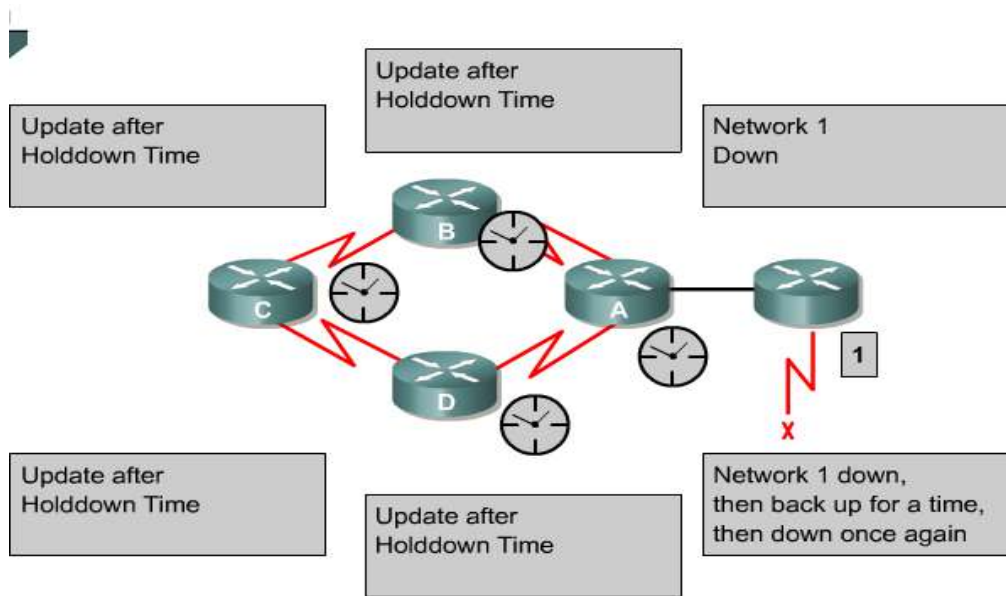
Network	Interface	Hop
10.3.0.0	S0/0/1	0
10.4.0.0	S0/0/1	16
10.2.0.0	S0/0/1	1
10.1.0.0	S0/0/1	2

Distance Vector Routing

Hold-down Timers

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- Hold-down timers are used to prevent regular update messages from inappropriately reinstating a route that may have gone bad.
- If a route is identified as down or possibly down, any other information for that route containing the same status, or worse, is ignored for a predetermined amount of time (the hold-down period).



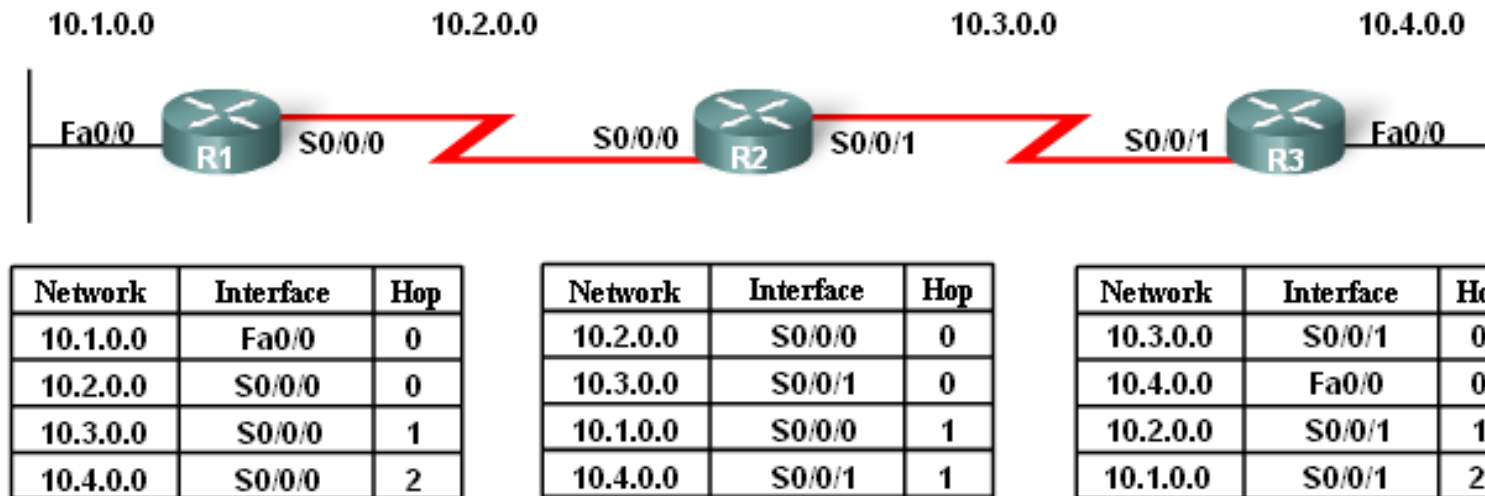
Distance Vector Routing

- Routers will leave a route marked as unreachable for a period of time that is long enough for updates to propagate the routing tables with the most current information.

Split Horizon – R1

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The rule says that a router should not advertise a network through the interface from which the update came.

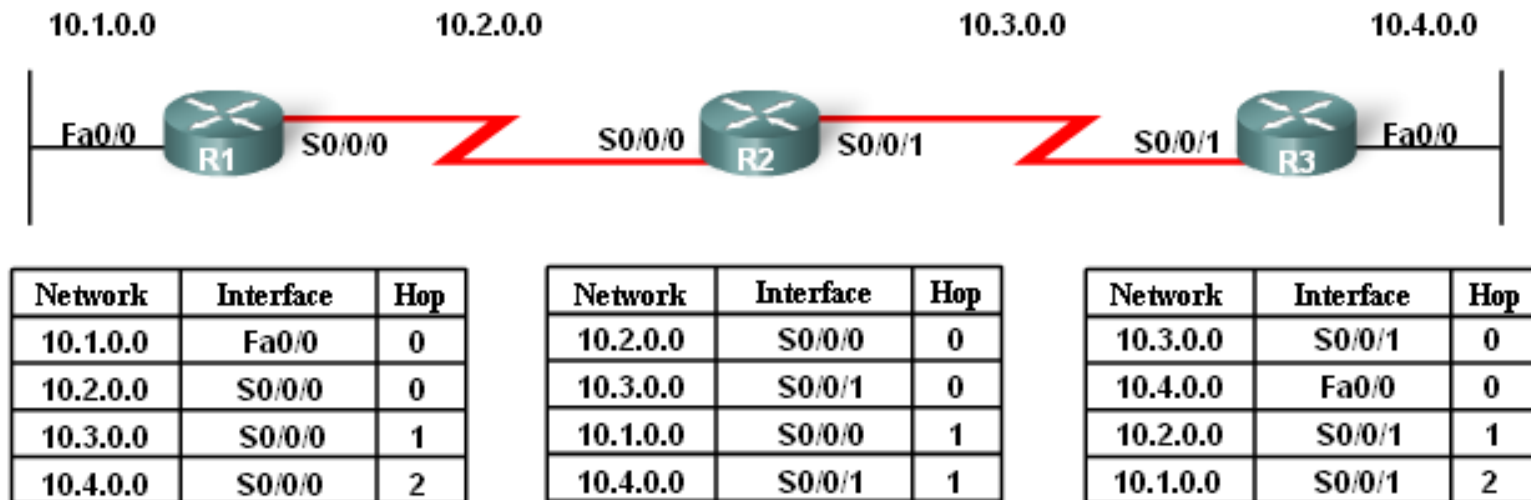


R1 sends updates from S0/0/0 about 10.1.1.1 – it has learnt all its other routes via S0/0/0, so split horizon prevents it from sending updates back to the originating networks.

Split Horizon – R3

48

The split horizon rule says that a router should not advertise a network through the interface from which the update came.

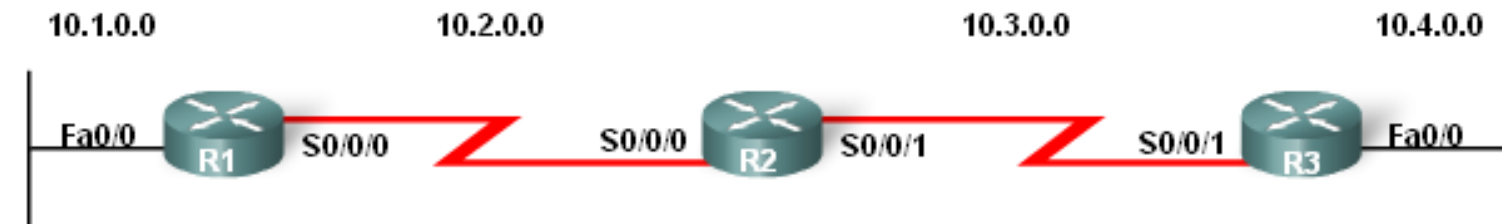


R3 sends updates from S0/0/1 about 10.1.4.0 – it has learnt all its other routes via S0/0/1, so split horizon prevents it from sending updates back to the originating networks.

Split Horizon – R2

49

The split horizon rule says that a router should not advertise a network through the interface from which the update came.



Network	Interface	Hop
10.1.0.0	Fa0/0	0
10.2.0.0	S0/0/0	0
10.3.0.0	S0/0/0	1
10.4.0.0	S0/0/0	2

Network	Interface	Hop
10.2.0.0	S0/0/0	0
10.3.0.0	S0/0/1	0
10.1.0.0	S0/0/0	1
10.4.0.0	S0/0/1	1

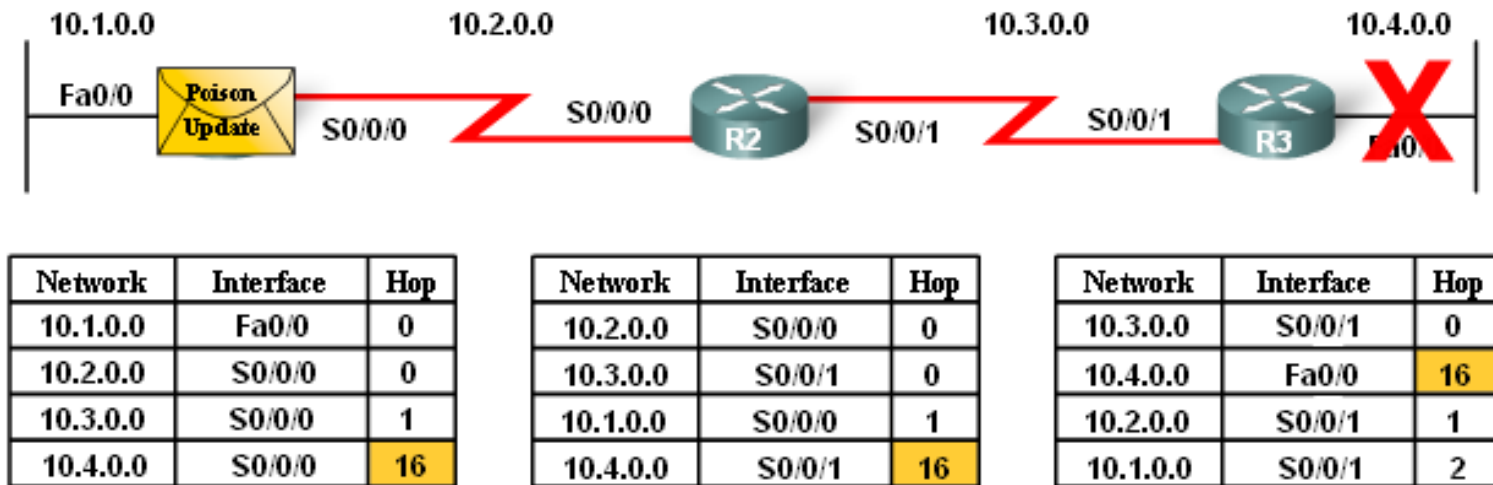
Network	Interface	Hop
10.3.0.0	S0/0/1	0
10.4.0.0	Fa0/0	0
10.2.0.0	S0/0/1	1
10.1.0.0	S0/0/1	2

- R2 sends updates from S0/0/1 about 10.1.0.0 & 10.2.0.0, which it learnt via S0/0/0.
- R2 sends updates from S0/0/0 about 10.3.0.0 & 10.4.0.0, which it learnt via S0/0/1.

Split Horizon with Poison Reverse.

50

- Route poisoning is used to mark the route as unreachable in a routing update that is sent to other routers.
- Unreachable is interpreted as a metric that is set to the maximum - for RIP, a poisoned route has a metric of 16.

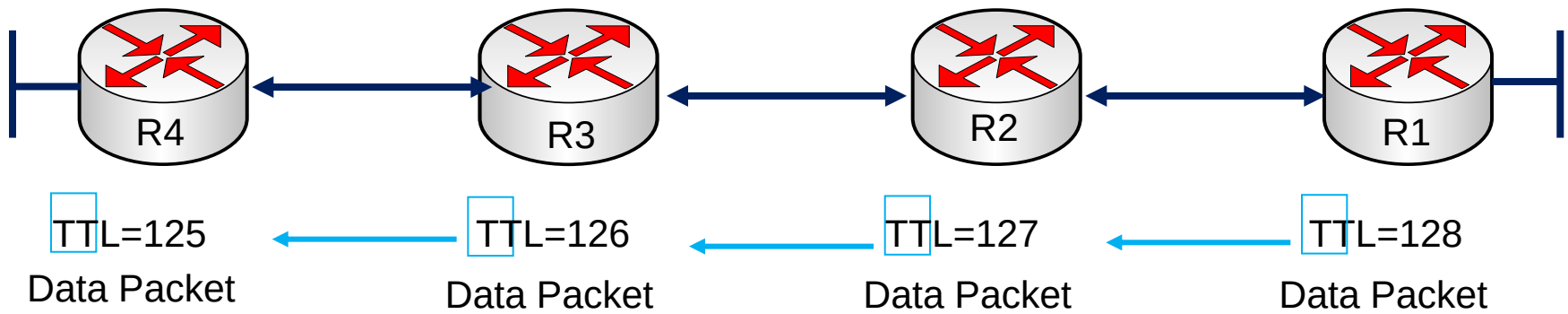


Distance Vector Routing

Time To Live (TTL)

51

- Time to Live (TTL) is an 8-bit field in the IP header that limits the number of hops a packet can traverse through the network before it is discarded.
- For looping packets, the TTL value will be decreased to 0 and the packet will be discarded by the router.



Distance Vector Routing

Features of RIP

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- RIPv1 supports the following features:
 - ▣ Supports split horizon and split horizon with poison reverse to prevent loops.
 - ▣ Is capable of load balancing up to six equal cost paths . The default is four equal cost paths.
- RIPv2 introduced the following improvements to RIPv1:
 - ▣ Includes the subnet mask in the routing updates, making it a classless routing protocol.
 - ▣ Has authentication mechanism to secure routing table updates.
 - ▣ Supports VLSM.
 - ▣ Uses multicast addresses instead of broadcast.
 - ▣ Supports manual route summarisation.