Dynamic Routing Protocols

Network Technology 1 – Routing protocol and concepts

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Chapter 3 - Introduction to Dynamic Routing Protocols

The role of dynamic routing protocols (Adaptive routing)

- Exchange routing tables between routers,
  - Sends and receives routing messages on its interfaces,
  - allows routers to learn about remote networks
  - advertises topology changes.
- Calculate paths based on routing information retrieved.
- Also known as adaptive routing protocols.

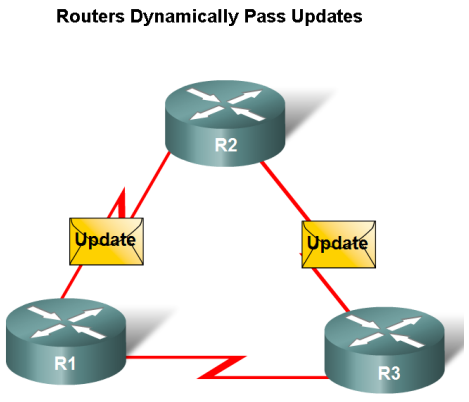


Figure : Dynamic routing updates

Pro et contra with dynamic routing protocols

- Advantages
  - Less administrative overhead,
  - automatically adapts to network changes,
  - Independent of network size,
- Disadvantage
  - High overhead (CPU, network link bandwidth),

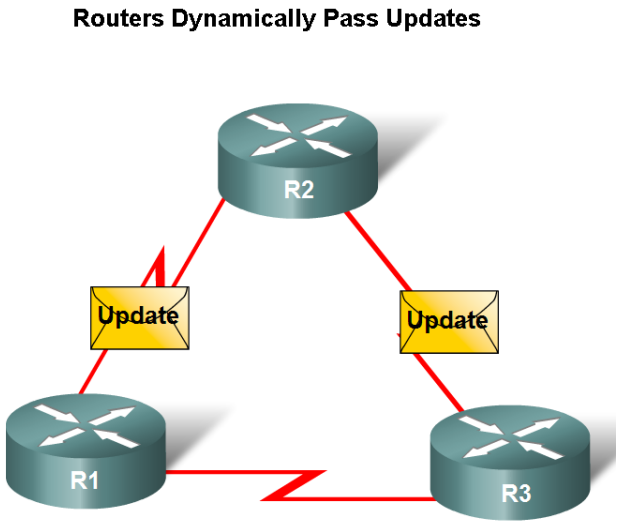


Figure : Dynamic routing updates

Pro et contra with static routing (non-adaptive routing)

- Advantages
  - Easy to configure,
  - no overhead,
  - security,
- Disadvantages
  - manually maintain network changes,
  - does not scale well in large topologies.

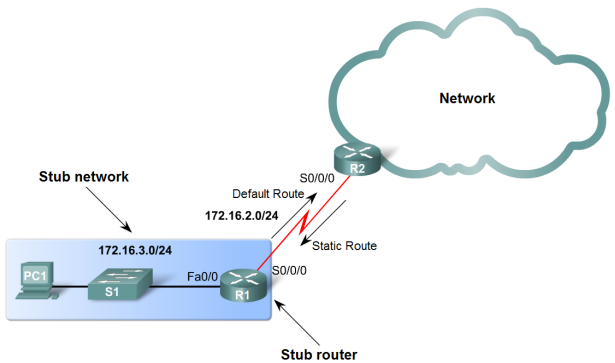


Figure : Static routing

Components of a dynamic routing protocol

- Data Structures: Store routing information
- Algorithm: Process routing information, best-path calculation
- Routing protocol messages: Exchanging routing information

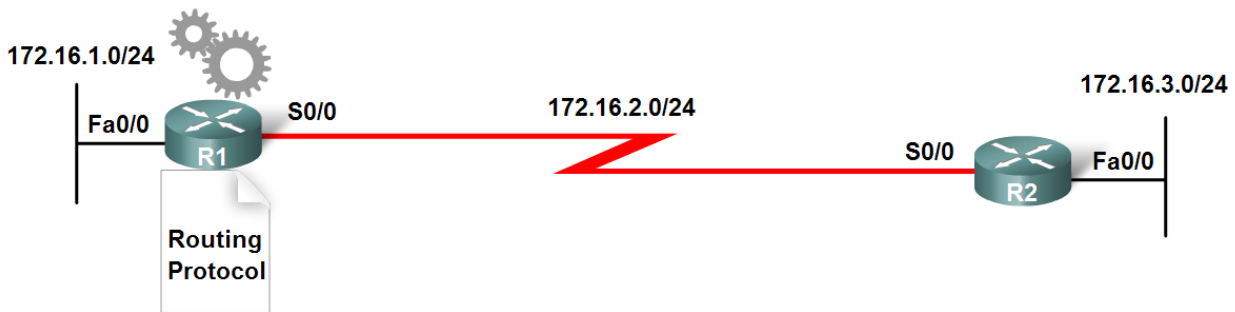


Figure : Dynamic routing updates

Desirable properties in a routing algorithm

There are some properties we would like to see in a routing algorithm

- Correctness,
  - Ensure correct result.
- Stability,
  - quickly reach *convergence*, and don't change unless needed.
- Fairness
  - distribute available bandwidth fairly (not same as equal)
- Simplicity,
  - High complexity
  - bugs, difficulty troubleshooting
- Robustness,
  - Must be able to withstand the constant changes in the network.
- Efficiency.
  - reduce number of hops,
  - send data over low latency links,
  - maximize throughput

Fairness contra Efficiency

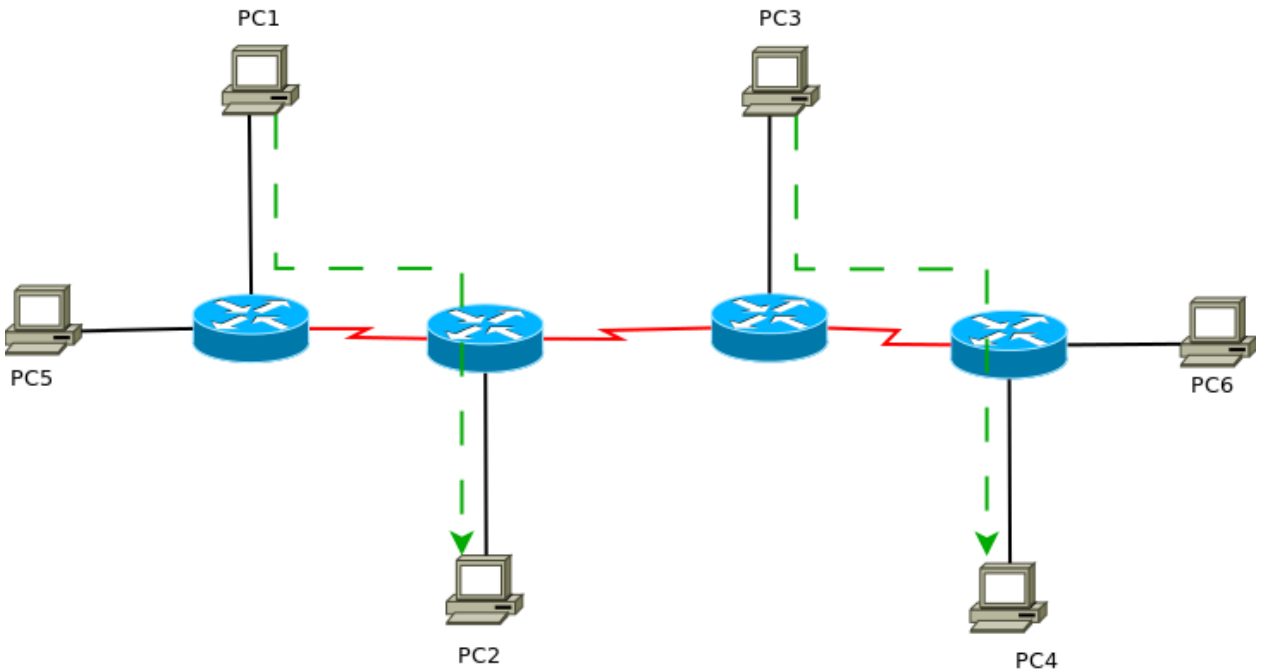


Figure : Efficiency vs fairness

Classifying dynamic routing protocols

Classifying different routing protocols depending on their characteristics:

- Interior Gateway Protocols or Exterior Gateway Protocols.
- Distance vector or Link-state.
- Classful or Classless.

IGP and EGP

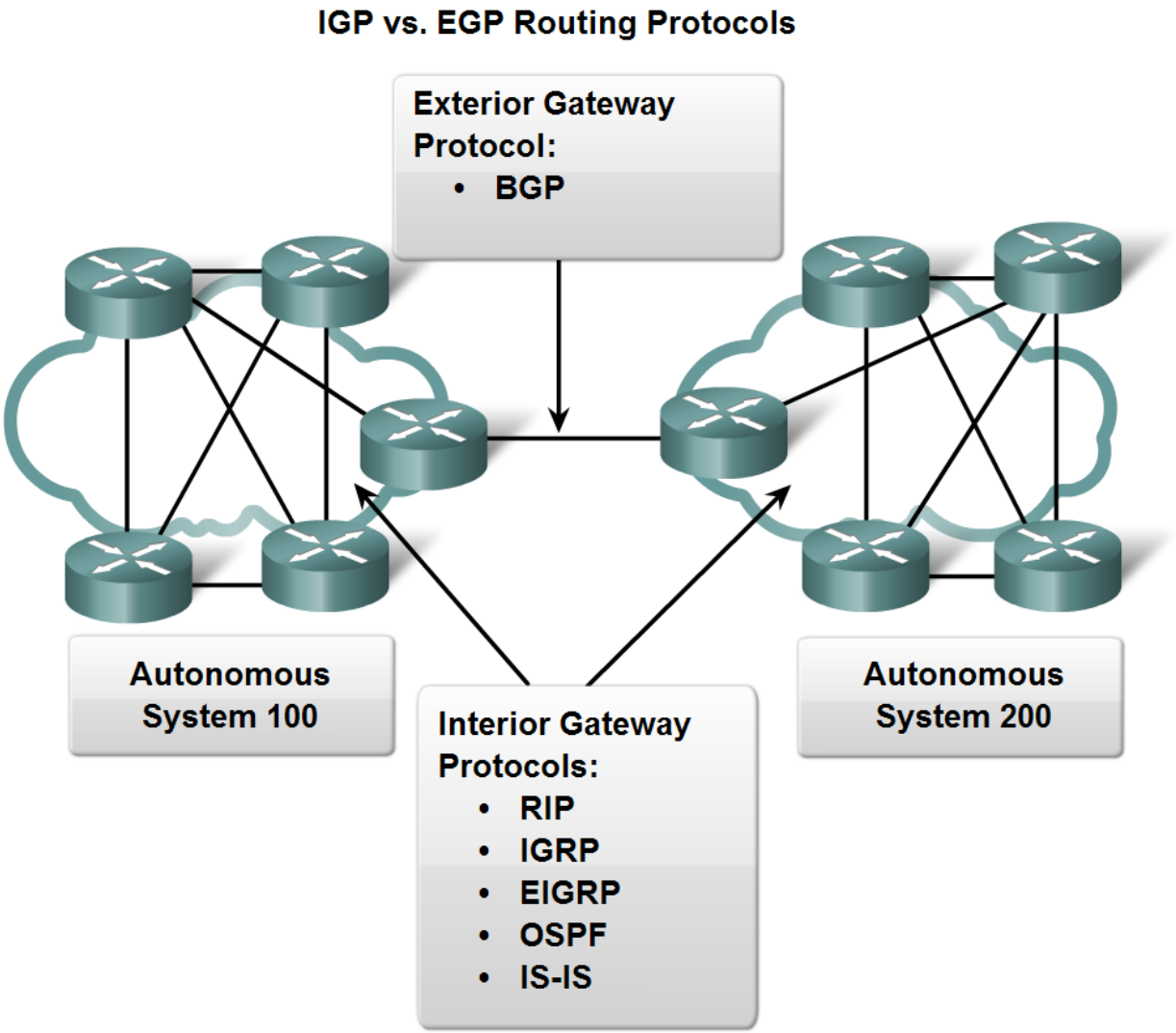


Figure : IGP and EGP

IGP and EGP

- Interior Gateway Protocols (IGP)
  - Used for routing within an autonomous system
  - Examples: RIP, OSPF and EIGRP
- Exterior Gateway Protocols (EGP)
  - Used to route between autonomous systems
  - Example: BGPv4

Link State routing protocols

- Creates a complete map of the network
- Updates are sent when needed
- Dijkstra's SPF algorithm
- Example: OSPF

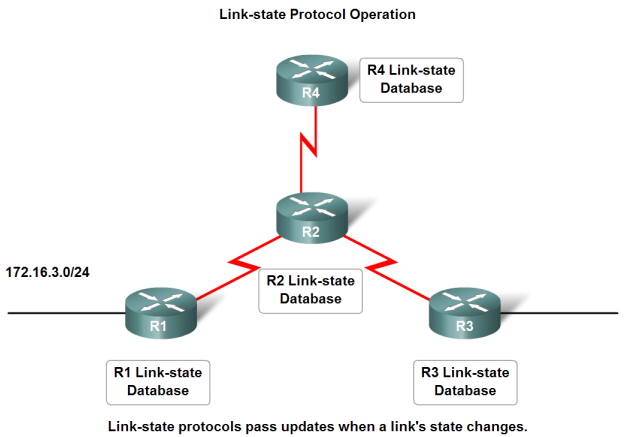


Figure : Link state routing protocol

Link State routing protocols

When is it suitable to use a link state routing protocol?

- Large complex networks
- fast convergence time is desirable.

Distance vector routing protocol

- Routes are advertised as vectors (distance and direction).
  - Distance is a metric such as hop count.
  - Direction is the next hop router or exit interface.
- Not a complete view of the network.
- Advertised generally through periodic updates.
- Bellman-Ford, DUAL.
- Example: RIP, EIGRP

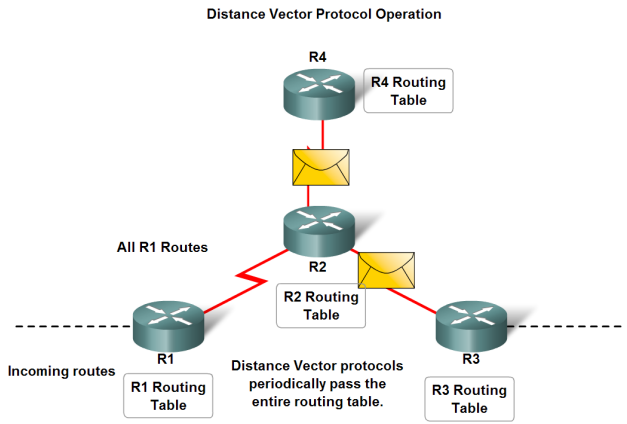


Figure : Distance vector protocol

Distance vector routing protocol

When is it suitable to use a distance vector routing protocol?

- Flat network topology.
- Hub and spoke networks.
- Convergence time is not a problem.

Classful and Classless routing

Whether or not the routing protocol includes the subnet mask in its routing updates.

- Classful routing protocols:
  - Do not include the subnet mask.
- Classless routing protocols:
  - Includes the subnet mask.

Multiple routing protocols

- Multiple routing protocols can be in place in a network.
- A router needs a way to know which advertised route it should place in the routing table.
- Administrative distance is used as a preference value (0-255).

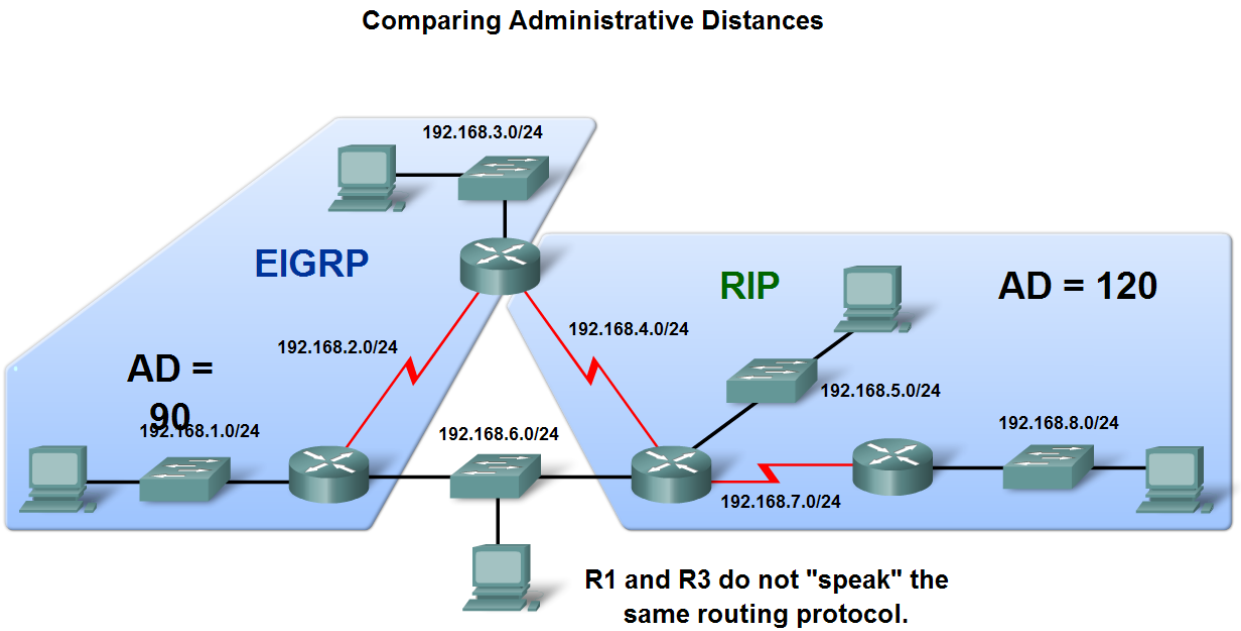


Figure : Multiple routing protocols in an autonomous system

Metric and Administrative distance

- Metric:
  - A value that symbolizes the cost of the route for a certain routing protocol.
  - Based on bandwidth, hop count, latency, reliability et cetera.
- Administrative Distance:
  - Defines the preference of a routing source.
  - The lower the value, the more preferred the route source is.

```
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
```

Figure : Metric and Administrative distance

```
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
```

Figure : RIP database

Administrative distance - Table

Route source	Default AD
Directly connected	0
Static	1
EIGRP summary route	5
eBGP	20
EIGRP (internal)	90
IGRP	100
OSPF	110
IS-IS	115
RIP	120
EIGRP (External)	170
iBGP	200
Unknown	255

Table : Default administrative distance

A routing source with an administrative distance of 255 will not be installed in the routing table.

Routing information from other routing sources are still saved on the router.

```
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
```

Figure : RIP database

Static routes and administrative distance

Default administrative distance for a static route is always 1.

- Even though we can't see this when configured with an exit interface.

```
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
```

Figure : Routing table with static routes

- `show ip route` can confirm this.

```
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
```

Figure : Output from `show ip route`

Floating static routes

- Floating static routes
  - A static route with a higher administrative distance.
  - Used as a fall back route.
  - `ip route <destination IP> <destination mask> <Next Hop | Exit interface> <distance metric>`

Chapter 4 - Distance Vector Routing

Distance Vector Routing Protocols

Recapitulate.

- Routes are advertised as vectors (distance and direction).
  - Distance is a metric such as hop count.
  - Direction is the next hop router or exit interface.
- Not a complete view of the network.
- Advertised generally through periodic updates.
- Bellman-Ford Algorithm.
- Example: RIP, EIGRP

Characteristics

- Periodic updates
- Updates are broadcast
- Entire routing table is sent.

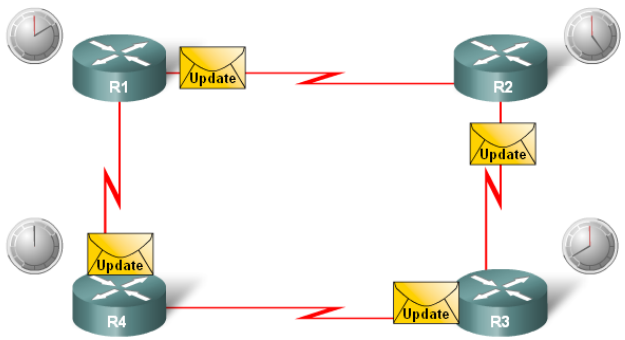


Figure : Periodic updates

Routing algorithm

"An algorithm is an ordered set of unambiguous, executable steps that defines a terminating process" –
Brookshear, *Computer Science: An overview*, 10th ed.

Purpose of a routing protocol

- An ordered set of clearly defined steps for accomplishing a certain task.
- Purpose of a routing algorithm:
  - 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.

Comparing routing protocols

- Convergence time
  - How quickly can all the involved routers get in a state of consistency.
- Scalability
  - How large of a network can the protocol support.
- Classless of Classful
- Resource usage
  - CPU utilization
  - Link bandwidth
  - Memory requirements
- Implementation and Maintenance
  - Knowledge needed to implement and maintain or troubleshoot.

Network discovery

Cold start

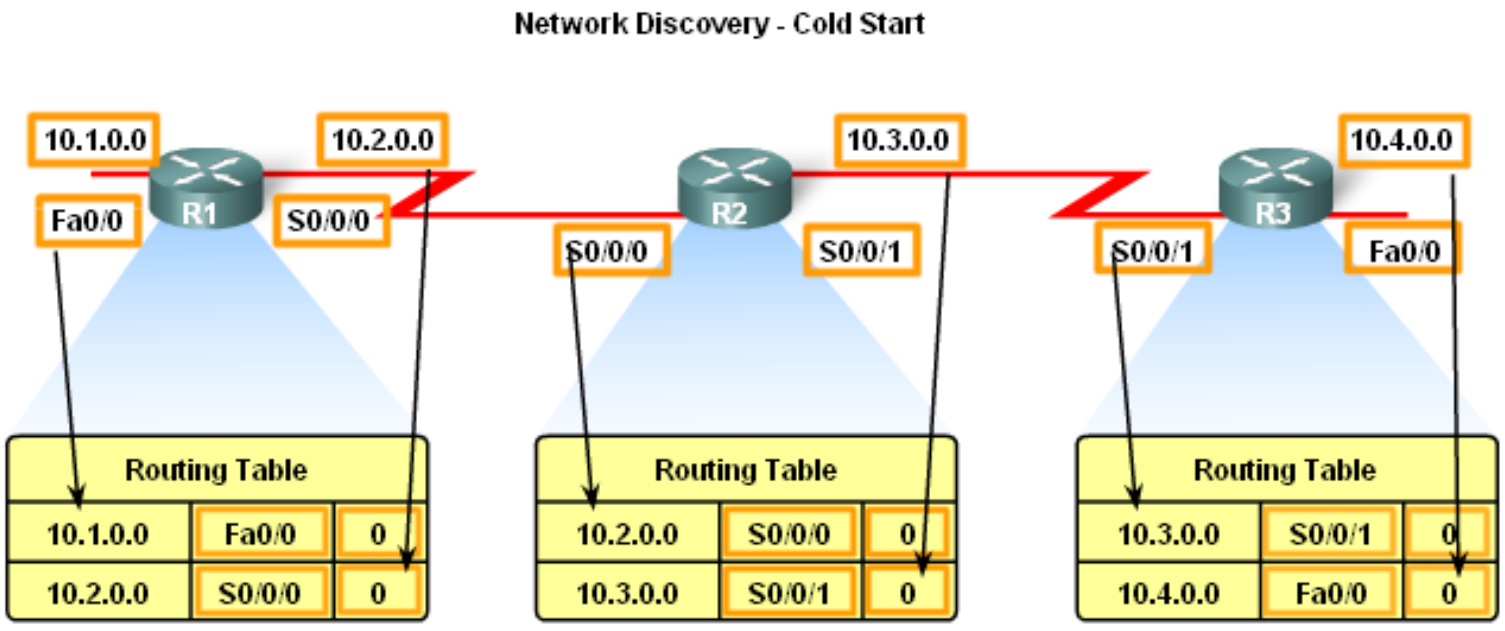


Figure : Cold Start

Network discovery

Initial exchange

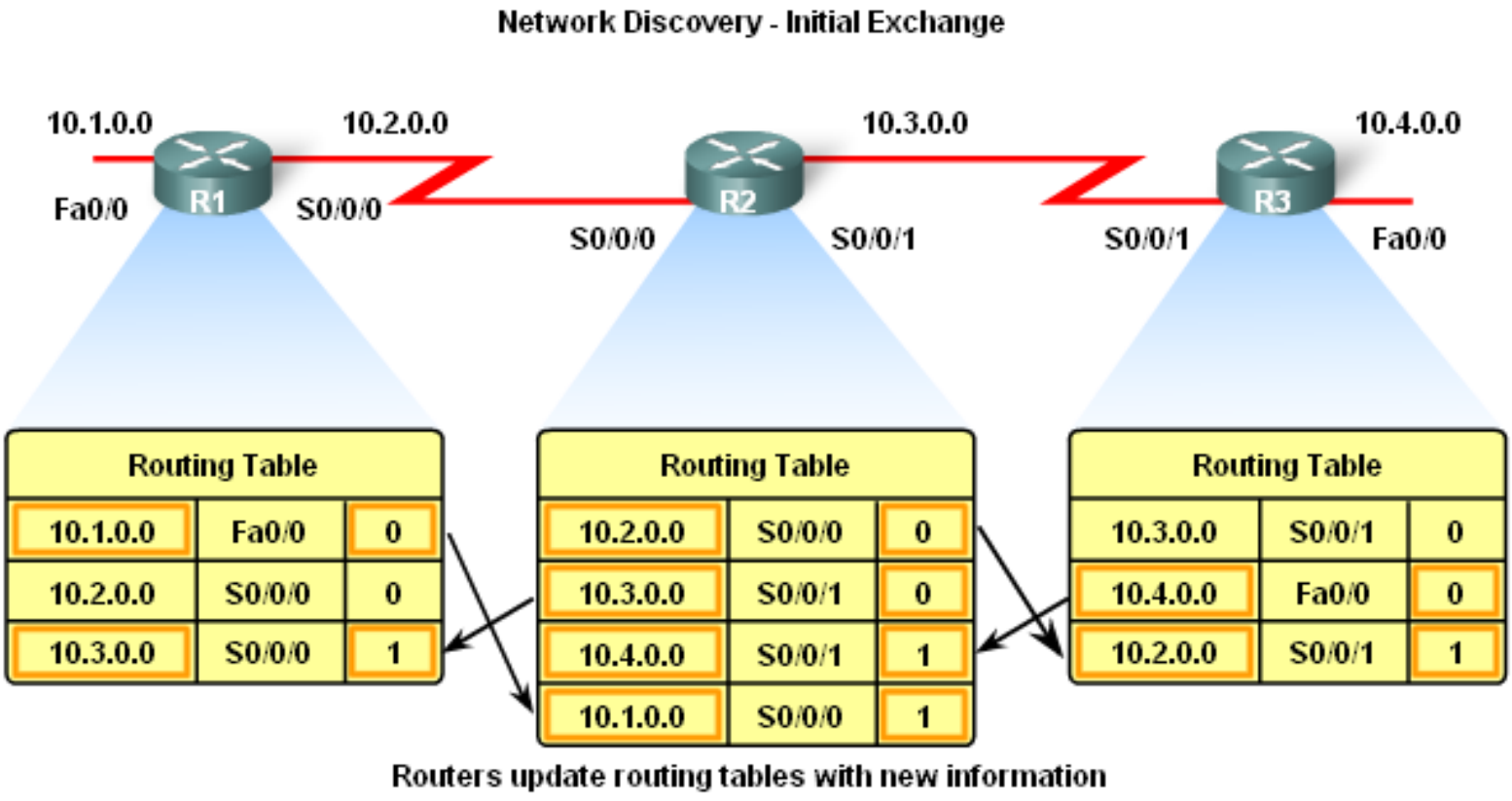


Figure : Initial Exchange

Network discovery

Exchange of routing information

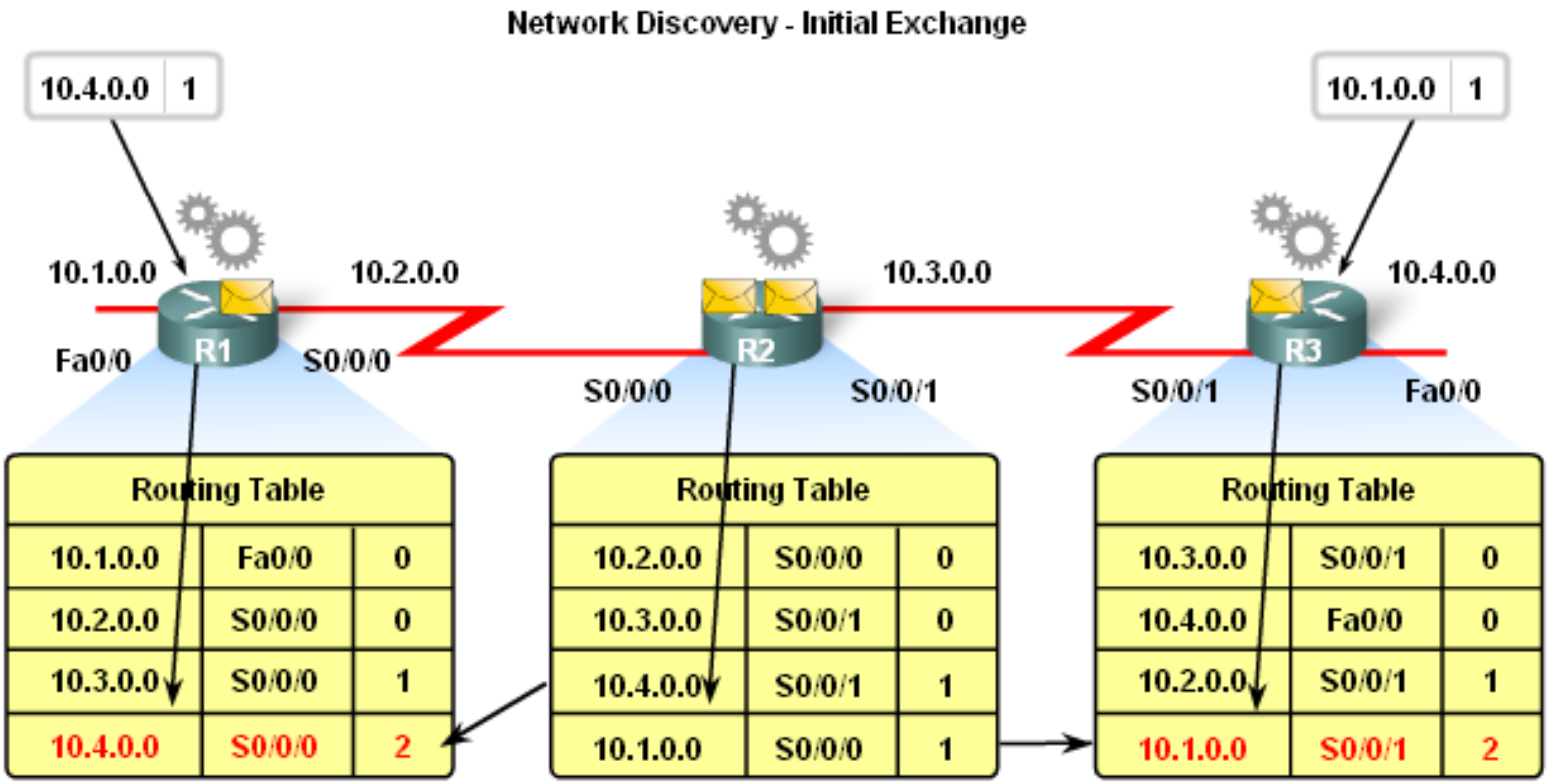


Figure : Next update

Convergence

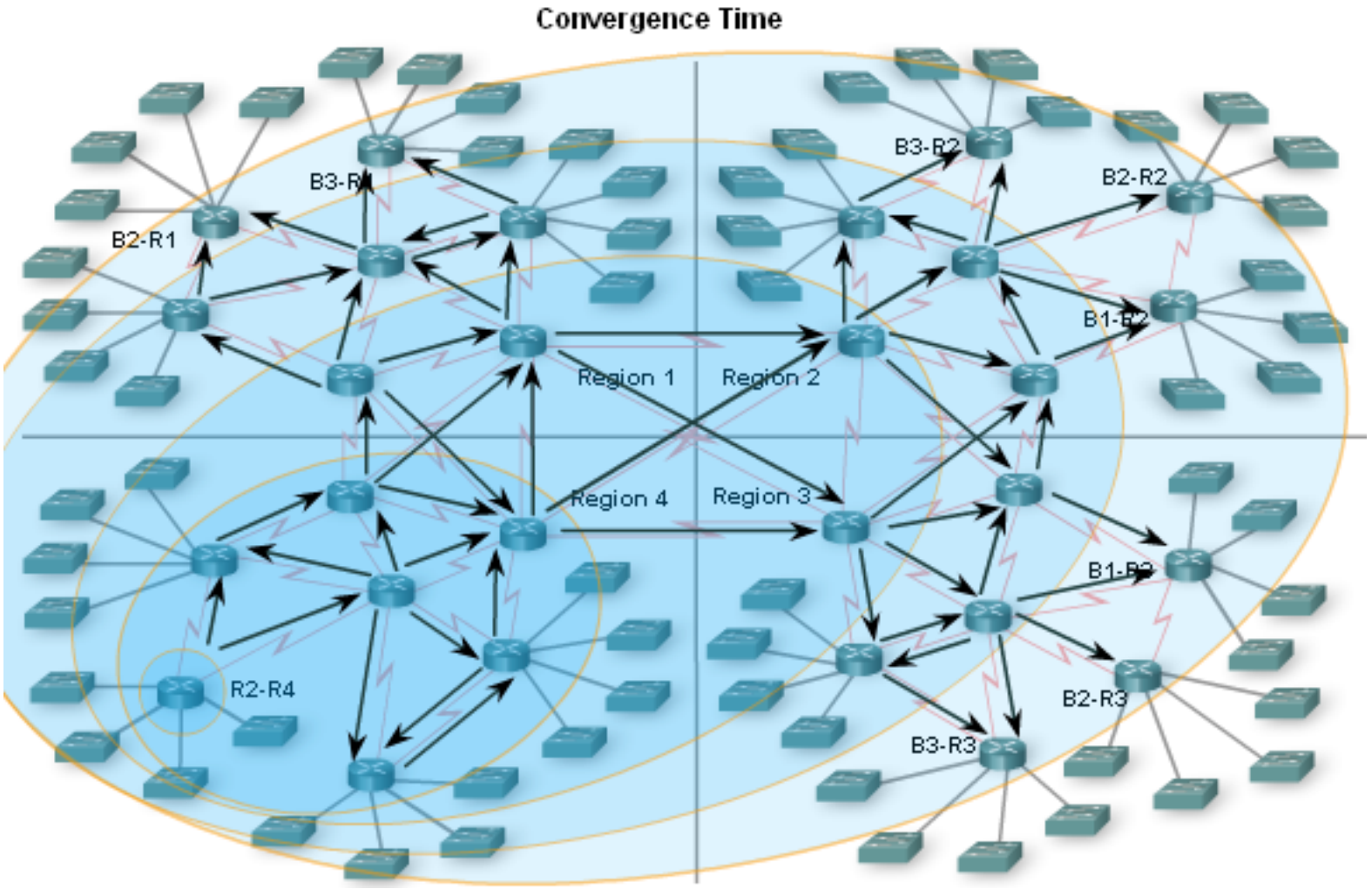


Figure : Convergence time

Routing table maintenance

Based on RIP routing protocol.

- Update timer - 30 seconds
  - Entire routing table
  - Used to inform of new networks and refresh existing ones.
- Invalid timer - 180 seconds
  - Marks route as invalid if it has not been refreshed.
  - Still kept in routing table in case the routes becomes available.
- Flush timer - 240 seconds
  - Removes the route from the routing table.
- hold-down timer - 180 seconds
  - Will not reinstate a route to this destination during this time.
  - Ensures that the network has been fully converged.

```
R1#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
R       172.16.1.0 [120/1] via 172.16.2.2, 00:00:18, Serial0/0/0
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
R    192.168.1.0/24 [120/1] via 192.168.3.1, 00:00:27, Serial0/0/1
                            [120/1] via 172.16.2.2, 00:00:18, Serial0/0/0
C    192.168.3.0/24 is directly connected, Serial0/0/1
R1#
```

Figure : Show ip route

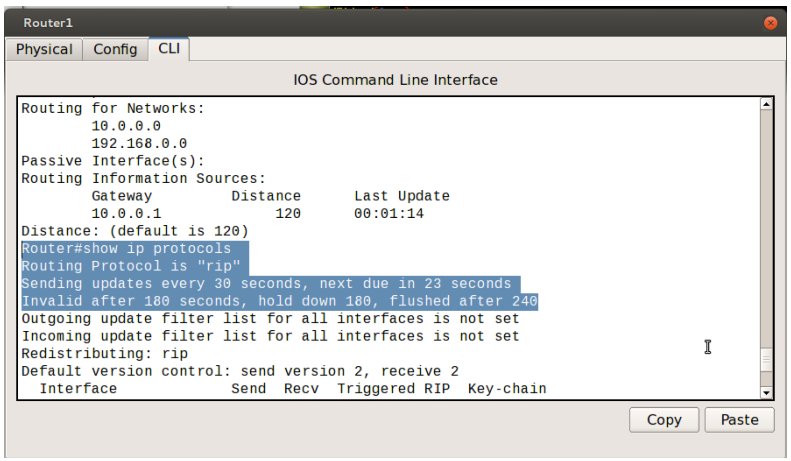


Figure : Show ip protocols

Routing Updates

- Triggered Updates
  - Sent when topology changes
    - Interface change state
    - Route becomes unreachable
    - New route
- Bounded
  - Non-periodic
  - Triggered
  - Partial
  - Bounded

Routing loops

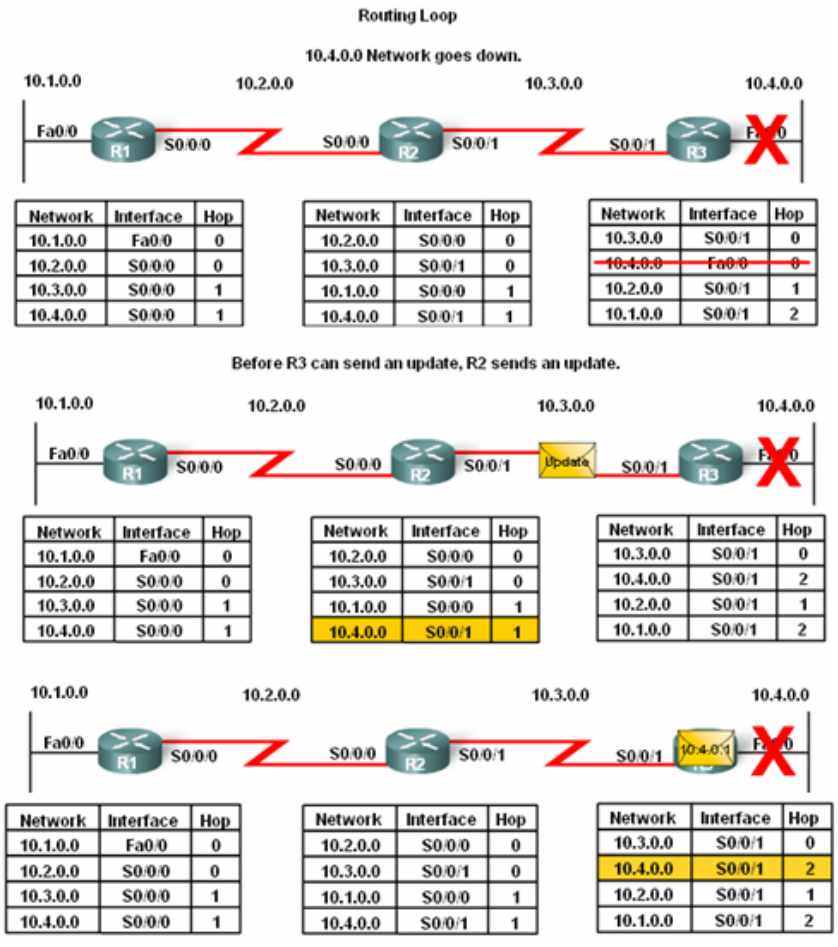
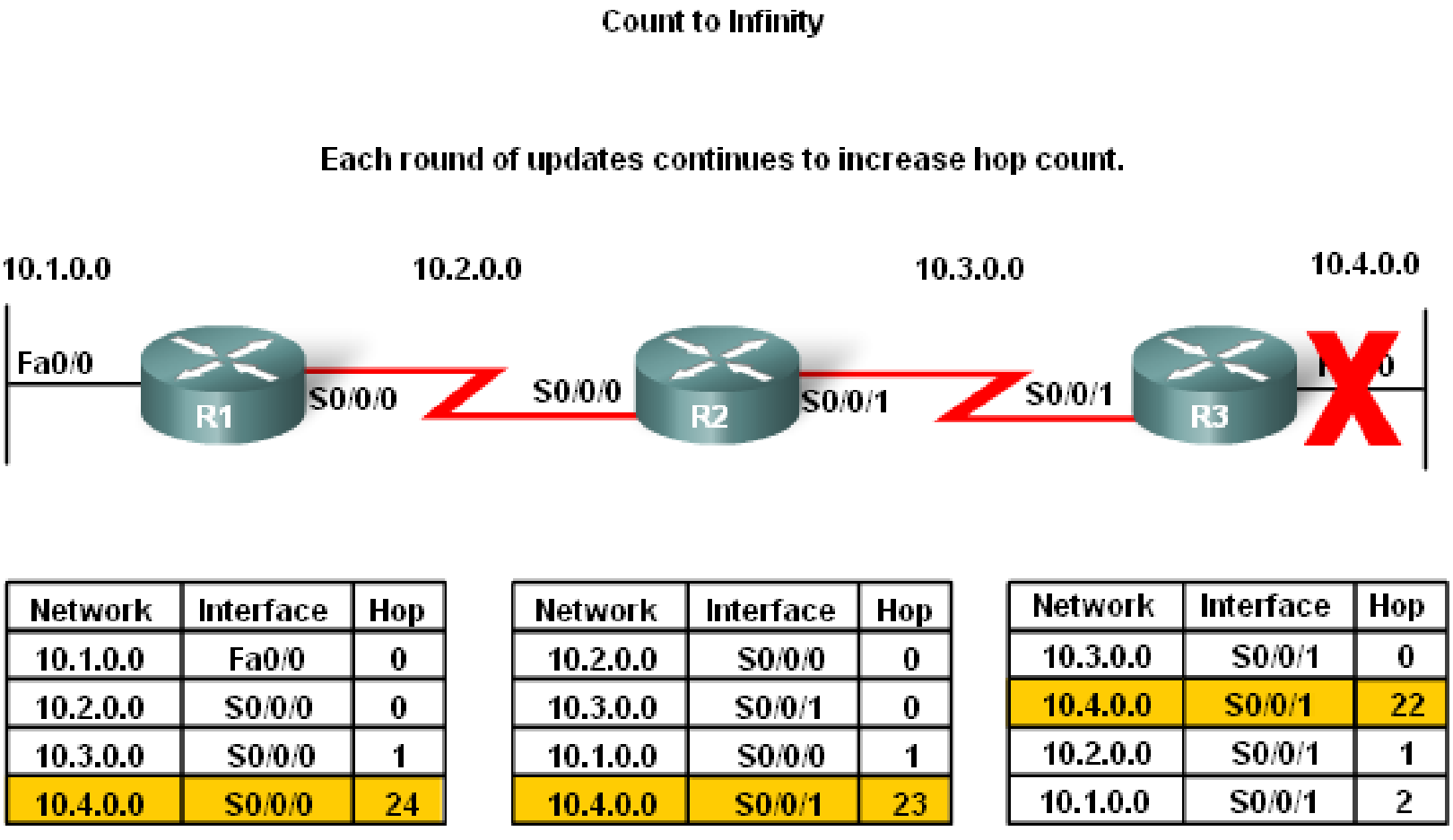


Figure : routing loops

Count to infinity problem

Routing table metric will increment to ∞



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	24

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	23

Network	Interface	Hop
10.3.0.0	S0/0/1	0
10.4.0.0	S0/0/1	22
10.2.0.0	S0/0/1	1
10.1.0.0	S0/0/1	2

Figure : Count to infinity

Implications

- Link bandwidth
- Unnecessary CPU usage
- Interfere with regular updates
- Interfere with data packets.

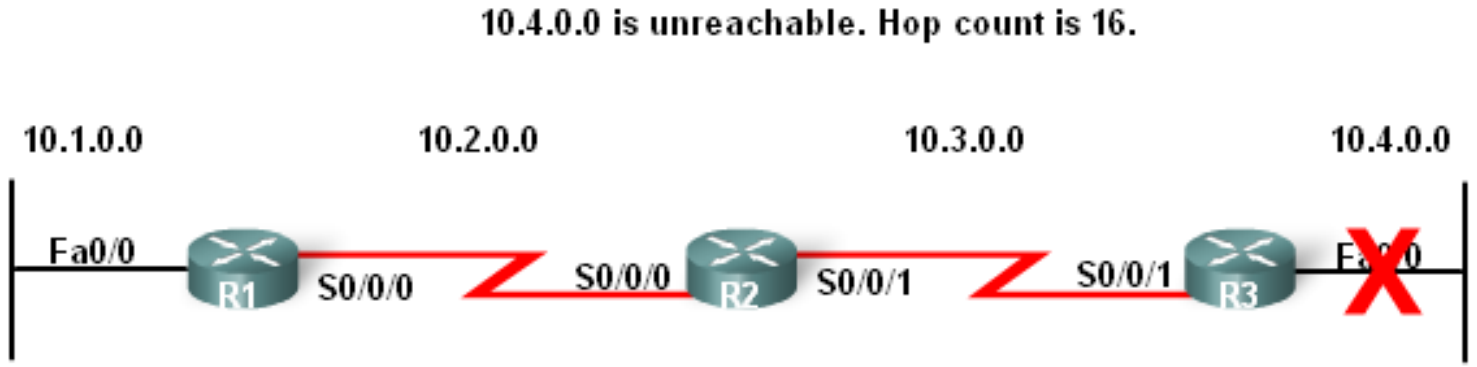
Causes for routing loops

- Incorrect static routes
- Route redistribution
- Slow Convergence

Mechanisms preventing routing loops

- Triggered Updates
- TTL
- Metric constriction
- Hold-down timers
- Split Horizon
- Route Poisoning

Metric constriction



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

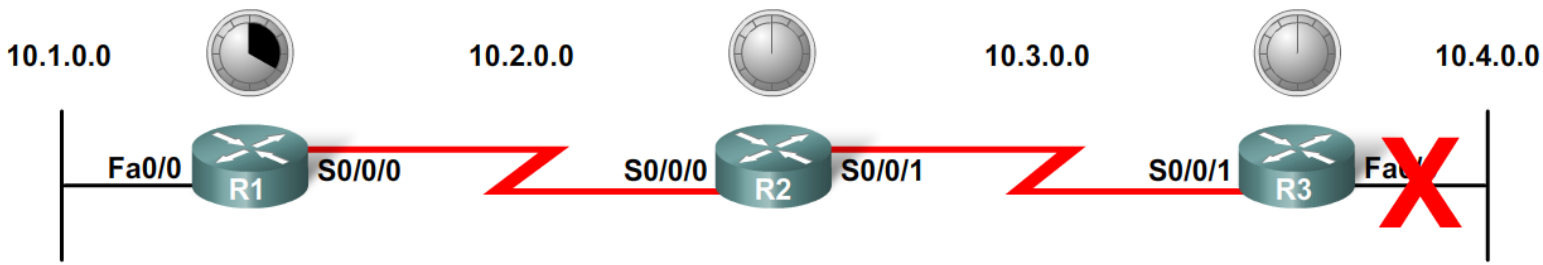
Figure : Maximum metric

Route poisoning

- Set maximum metric directly as a route becomes unreachable.
- Speeds up convergence.

Hold down timers

- During this time no route to that network will be added to the routing table if they have the same metric or worse.
- Ensures full convergence



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	S0/0/1	0
10.2.0.0	S0/0/1	1
10.1.0.0	S0/0/1	2

Figure : Hold down timers

Split Horizon

- Will not advertise a network through the interface which it received the update.

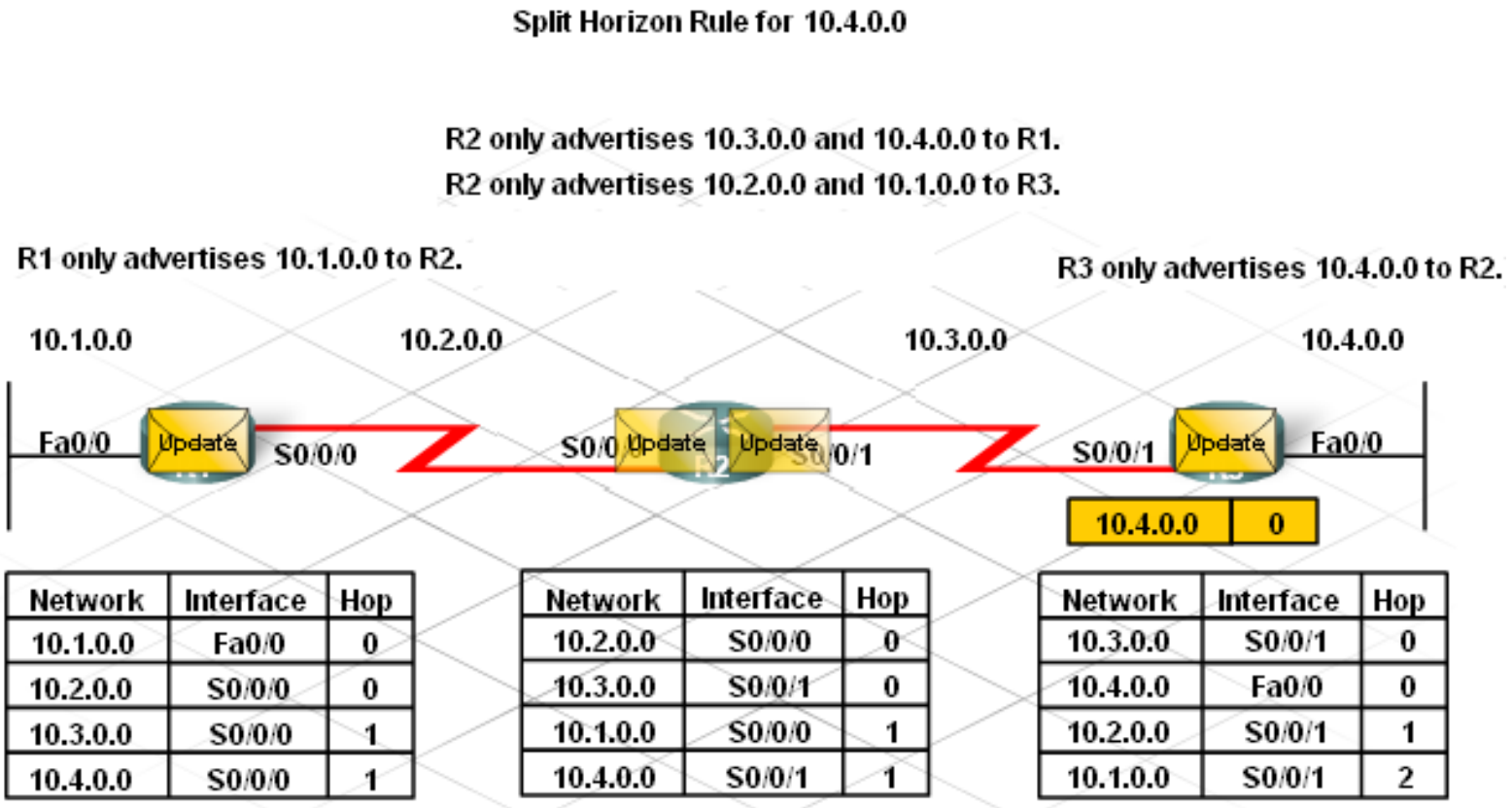


Figure : Split Horizon

Split Horizon with poison reverse

- Inform neighbours to ignore the route.
- Better than not informing of the route.

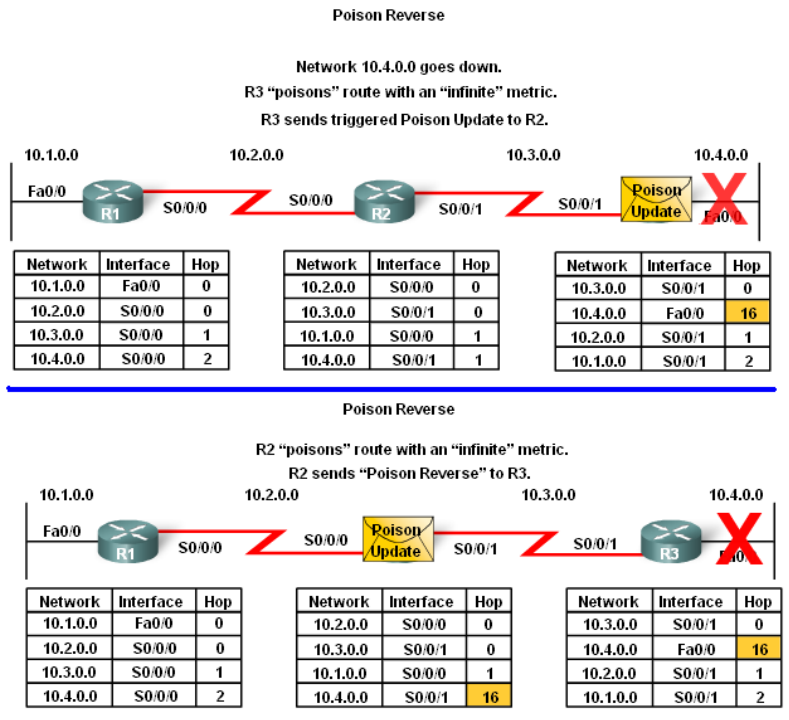


Figure : Split Horizon with poison reverse

Questions?