



Chapter 5: Dynamic Routing

CCNA Routing and Switching

Scaling Networks v6.0



Chapter 5 - Sections & Objectives

- 5.1 Dynamic Routing Protocols
 - Explain the features and characteristics of dynamic routing protocols.
 - Compare the different types of routing protocols.
- 5.2 Distance Vector Dynamic Routing
 - Explain how distance vector routing protocols operate.
 - Explain how dynamic routing protocols achieve convergence.
 - Describe the algorithm used by distance vector routing protocols to determine the best path.
 - Identify the types of distance-vector routing protocols.
- 5.3 Link-State Dynamic Routing
 - Explain how link-state protocols operate.
 - Describe the algorithm used by link-state routing protocols to determine the best path.
 - Explain how the link-state routing protocol uses information sent in a link-state update.
 - Explain the advantages and disadvantages of using link-state routing protocols.

5.1 Dynamic Routing Protocols



Types of Routing Protocols Classifying Routing Protocols

- The purpose of dynamic routing protocols 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 current path is no longer available.



Types of Routing Protocols IGP and EGP Routing Protocols

- Interior Gateway Protocols (IGP)
 - Used for routing within an Autonomous System (AS). RIP, EIGRP, OSPF, and IS-IS.
- Exterior Gateway Protocols (EGP)
 - Used for routing between Autonomous Systems. BGP



Types of Routing Protocols Distance Vector Routing Protocols

- Distance vector means that routes are advertised by providing two characteristics:
 - Distance Identifies how far it is to the destination network based on a metric such as hop count, cost, bandwidth, delay.
 - Vector Specifies the direction of the next-hop router or exit interface to reach the destination.
- RIPv1 (legacy), RIPv2, IGRP Cisco proprietary (obsolete), EIGRP.



For R1, 172.16.3.0/24 is one hop away (distance). It can be reached through R2 (vector)

Types of Routing Protocols Link-State Routing Protocols

- A link-State router uses the link-state information received from other routers:
 - to create a topology map.
 - to select the best path to all destination networks in the topology.
- Link-state protocols forward updates when the state of a link changes.
- Link-state routing protocols do not use periodic updates.
 - updates are only sent when there is a change in the topology
 - OSPF and IS-IS



Types of Routing Protocols Classful Routing Protocols

- Classful routing protocols do not send subnet mask information in routing updates.
- Classful routing protocols cannot support variable-length subnet masks (VLSMs) and classless interdomain routing (CIDR).
- Classful routing protocols also create problems in discontiguous networks.



Types of Routing Protocols Classless Routing Protocols

- Classless routing protocols include subnet mask information in the routing updates.
- Classless IPv4 routing protocols (RIPv2, EIGRP, OSPF, and IS-IS) all include the subnet mask information in routing updates.
- Classless routing protocols support VLSM and CIDR.
- IPv6 routing protocols are classless.



Types of Routing Protocols Routing Protocol Characteristics

Routing protocols can be compared based on the characteristics in the chart.

| | Distance V | /ector | Link State | | | |
|-----------------------------------|------------|--------|------------|---------|---------|---------|
| | RIPv1 | RIPv2 | IGRP | EIGRP | OSPF | IS-IS |
| Speed of Convergence | Slow | Slow | Slow | Fast | Fast | Fast |
| Scalability - Size of Network | Small | Small | Small | Large | Large | Large |
| Use of VLSM | No | Yes | No | Yes | Yes | Yes |
| Resource Usage | Low | Low | Low | Medium | High | High |
| Implementation and Maintenance | Simple | Simple | Simple | Complex | Complex | Complex |

Types of Routing Protocols Routing Protocol Metrics

- A metric is a measurable value that is assigned by the routing protocol to different routes based on the usefulness of that route.
- Routing metrics are used to determine the overall "cost" of a path from source to destination.
- Best path is route with the lowest cost.
- Metrics used by various dynamic protocols:
 - RIP Hop count
 - OSPF Cost based on cumulative bandwidth
 - EIGRP Bandwidth, delay, load, and reliability.



5.2 Distance Vector Dynamic Routing



Distance Vector Fundamentals Dynamic Routing Protocol Operation

- Operation of a dynamic routing protocol can be described as follows:
 - The router sends and receives routing messages on its interfaces.
 - The router shares routing messages and routing information with other routers using the same routing protocol.
 - Routers exchange routing information to learn about remote networks.
 - When a router detects a topology change, the routing protocol can advertise this change to other routers.



Distance Vector Fundamentals Cold Start

- After a router boots successfully it applies the saved configuration, then the router initially discovers its own directly connected networks.
 - It adds those directly connected interface IP addresses to its routing table



Distance Vector Fundamentals Network Discovery

- If a routing protocol is configured, the router exchanges routing updates to learn about any remote routes.
 - The router sends an update packet with its routing table information out all interfaces.
 - The router also receives updates from directly connected routers and adds new information to its routing table.



Distance Vector Fundamentals Exchanging the Routing Information

- Working toward convergence, the routers exchange the next round of periodic updates.
- Distance vector routing protocols use split horizon to avoid loops.
- Split horizon prevents information from being sent out the same interface from which it was received.



Distance Vector Fundamentals Achieving Convergence

- The network has converged when all routers have complete and accurate information about the entire network
- Convergence time is the time it takes routers to share information, calculate best paths, and update routing tables.
- Routing protocols can be rated based on the speed to convergence; the faster the convergence, the better the routing protocol.

| | 10.1.0.4 | 0 Fa0/0 | S0/0/0 |) | 10.2.0.0 S0/0/0 | R2 S0/0/ | 10.3.0 | .0 | 50/0/1 R3 | 10.4.0. Fa0/0 | • |
|---|----------------------|--------------------|----------|---|----------------------|---------------------|----------|----|----------------------|---------------------|----------|
| Ī | Network 10.1.0.0 | Interface Fa0/0 | Hop 0 | | Network 10.2.0.0 | Interface S0/0/0 | Hop 0 | | Network 10.3.0.0 | Interface S0/0/1 | Hop 0 |
| | 10.2.0.0 10.3.0.0 | S0/0/0 S0/0/0 | 0 1 | | 10.3.0.0 10.1.0.0 | S0/0/1 S0/0/0 | 0 1 | | 10.4.0.0 10.2.0.0 | Fa0/0 S0/0/1 | 0 1 |
| | 10.4.0.0 | S0/0/0 | 2 | | 10.4.0.0 | S0/0/1 | 1 | | 10.1.0.0 | S0/0/1 | 2 |

Distance Vector Fundamentals

Packet Tracer - Investigating Convergence



Part 1: View the Routing Table of a Converged Network

Part 2: Add a New LAN to the Topology

Part 3: Watch the Network Converge

Background

This activity will help you identify important information in routing tables and witness the process of network convergence.

Distance Vector Routing Protocol Operation Distance Vector Technologies

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- Distance vector routing protocols share updates between neighbors.
- Routers using distance vector routing are not aware of the network topology.
- Some distance vector routing protocols send periodic updates.
 - RIPv1 sends updates as broadcasts 255.255.255.255.
 - RIPv2 and EIGRP can use multicast addresses to reach only specific neighbor routers.
 - EIGRP can use a unicast message to reach a specific neighbor router.
 - EIGRP only sends updates when needed, not periodically.

Distance Vector Routing Protocol Operation Distance Vector Algorithm



- The distance vector algorithm 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
- RIP uses the Bellman-Ford algorithm as its routing algorithm.
- IGRP and EIGRP use the Diffusing Update Algorithm (DUAL) routing algorithm.

Types of Distance Vector Routing Protocols Routing Information Protocol

- The Routing Information Protocol (RIP)
- Easy to confgure
- Routing updates broadcasted (255.255.255.255) every 30 seconds
- Metric is hop count
- 15 hop limit
- RIPv2

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- Classless routing protocol supports VLSM and CIDR
- Increased efficiency sends updates to multicast address 224.0.0.9
- **Reduced routing entries** supports manual route summarization
- Secure supports authentication

| Characteristics and Features | RIPv1 | RIPv2 | | |
|------------------------------|--|--|--|--|
| Metric | Both use hop count as maximum number of h | Both use hop count as a simple metric. The maximum number of hops is 15. | | |
| Updates Forwarded to Address | 255.255.255.255 | 224.0.0.9 | | |
| Supports VLSM | X | J | | |
| Supports CIDR | Х | \checkmark | | |
| Supports Summarization | Х | \checkmark | | |
| Supports Authentication | X | \checkmark | | |

- RIPng
 - IPv6 enabled version of RIP
 - 15 hop limit and administrative distance is 120

Types of Distance Vector Routing Protocols Enhanced Interior-Gateway Routing Protocol

| Characteristics and Features | IGRP | EIGRP | |
|------------------------------|---|--------------|--|
| Metric | Both use a composite metric consisting of bandwidth and delay. Reliability and load can also be included in the metric calculation. | | |
| Updates Forwarded to Address | 255.255.255.255 | 224.0.0.10 | |
| Supports VLSM | X | \checkmark | |
| Supports CIDR | Х | \checkmark | |
| Supports Summarization | Х | \checkmark | |
| Supports Authentication | Х | ✓ | |

- EIGRP replaced IGRP in 1992. It includes the following features:
 - Bounded triggered updates sends updates only to routers that need it.
 - Hello keepalive mechanism Hello messages are periodically exchanged to maintain adjacencies.
 - Maintains a topology table maintains all the routes received from neighbors (not only the best paths) in a topology table.
 - **Rapid convergence** because it maintains alternate routes.
 - Multiple network layer protocol support uses Protocol Dependent Modules (PDM) to support layer 3 protocols.

Types of Distance Vector Routing Protocols Packet Tracer - Comparing RIP and EIGRP Path Selection



5.3 Link-State Dynamic Routing



Link-State Routing Protocol Operation Shortest Path First Protocols

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- Link-state routing protocols, also known as shortest path first protocols, are built around Edsger Dijkstra's shortest path first (SPF) algorithm.
- IPv4 Link-State routing protocols:
 - Open Shortest Path First (OSPF)
 - Intermediate System-to-Intermediate System (IS-IS)

Link-State Routing Protocol Operation Dijkstra's Algorithm

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- All link-state routing protocols apply Dijkstra's algorithm (also known as shortest path first (SPF)) to calculate the best path route:
 - Uses accumulated costs along each path, from source to destination.
 - Each router determines its own cost to each destination in the topology.

Link-State Routing Protocol Operation SPF Example

 The table displays the shortest path and the accumulated cost to reach the identified destination networks from the perspective of R4.



Link-State Updates Link-State Routing Process

- Each router learns about each of its own directly connected networks.
- Each router is responsible for "saying hello" to its neighbors on directly connected networks.
- Each router builds a Link-State Packet (LSP) containing the state of each directly connected link.
- Each router floods the LSP to all neighbors who then store all LSP's received in a database.
- Each router uses the database to construct a complete map of the topology and computes the best path to each destination network.
- Note: This process is the same for both OSPF for IPv4 and OSPF for IPv6.

Link-State Updates

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 The first step in the link-state routing process is that each router learns its own directly connected networks.



Link-State Updates Say Hello

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- The second step in the link-state routing process is that each router uses a Hello protocol to discover any neighbors on its links.
- When two link-state routers learn that they are neighbors, they form an adjacency.
- If a router stops receiving Hello packets from a neighbor, that neighbor is considered unreachable.

Link-State Updates Building the Link-State Packet

- The third step in the link-state routing process is that each router builds a linkstate packet (LSP) that contains the linkstate information about its links.
- R1 LSP (in diagram) would contain:
 - R1; Ethernet network 10.1.0.0/16; Cost 2
 - R1 -> R2; Serial point-to-point network; 10.2.0.0/16; Cost 20
 - R1 -> R3; Serial point-to-point network; 10.3.0.0/16; Cost 5
 - R1 -> R4; Serial point-to-point network; 10.4.0.0/16; Cost 20

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Link-State Updates Flooding the LSP

- The fourth step in the link-state routing process is that each router floods the LSP to all neighbors.
- An LSP only needs to be sent:
 - During initial startup of the routing protocol process on that router (e.g., router restart)
 - Whenever there is a change in the topology (e.g., a link going down)
- An LSP also includes sequence numbers and aging information:
 - used by each router to determine if it has already received the LSP.
 - used to determine if the LSP has newer information.

R1 Link State Contents

- R1; Ethernet network; 10.1.0.0/16; Cost 2
- R1 -> R2; Serial point-to-point network; 10.2.0.0/16; Cost 20
- R1 -> R3; Serial point-to-point network; 10.3.0.0/16; Cost 5
- R1 -> R4; Serial point-to-point network; 10.4.0.0/16; Cost 20



Link-State Updates Building the Link-State Database

 The final step in the link-state routing process is that each router uses the database to construct a complete map of the topology and computes the best path to each destination network.

| R1 Link-State Database | |
|---|--|
| R1 Link-states: Connected to network 10.1.0.0/16, cost = 2 Connected to R2 on network 10.2.0.0/16, cost = 20 Connected to R3 on network 10.3.0.0/16, cost = 5 Connected to R4 on network 10.4.0.0/16, cost = 20 | |
| R2 Link-states: • Connected to network 10.5.0.0/16, cost = 2 • Connected to R1 on network 10.2.0.0/16, cost = 20 • Connected to R5 on network 10.9.0.0/16, cost = 10 | |
| R3 Link-states: • Connected to network 10.6.0.0/16, cost = 2 • Connected to R1 on network 10.3.0.0/16, cost = 5 • Connected to R4 on network 10.7.0.0/16, cost = 10 | |
| R4 Link-states: • Connected to network 10.8.0.0/16, cost = 2 • Connected to R1 on network 10.4.0.0/16, cost = 20 • Connected to R3 on network 10.7.0.0/16, cost = 10 • Connected to R5 on network 10.10.0.0/16, cost = 10 | |
| R5 Link-states: • Connected to network 10.11.0.0/16, cost = 2 • Connected to R2 on network 10.9.0.0/16, cost = 10 • Connected to R4 on network 10.10.0.0/16, cost = 10 | |

Link-State Updates Building the SPF Tree

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| Destination | Shortest Path | Cost |
|--------------|-------------------|------|
| 10.5.0.0/16 | R1 → R2 | 22 |
| 10.6.0.0/16 | R1 → R3 | 7 |
| 10.7.0.0/16 | R1 → R3 | 15 |
| 10.8.0.0/16 | R1 → R3 → R4 | 17 |
| 10.9.0.0/16 | R1 → R2 | 30 |
| 10.10.0.0/16 | R1 → R3 → R4 | 25 |
| 10.11.0.0/16 | R1 → R3 → R4 → R5 | 27 |
| | | |

- Each router uses the link-state database and *shortest path first* algorithm to construct the SPF tree.
 - R1 identifies its directly connected networks and costs.
 - R1 adds any unknown networks and associated costs.
 - The SPF algorithm then calculates the shortest paths to reach each individual network resulting in the SPF tree shown in the diagram.
- Each router constructs its own SPF tree independently from all other routers.

Link-State Updates Adding OSPF Routes to the Routing Table

| Destination | Shortest Path | Cost | ^ |
|--------------|----------------|------|-----------------------|
| 10.5.0.0/16 | R1->R2 | 22 | |
| 10.6.0.0/16 | R1->R3 | 7 | |
| 10.7.0.0/16 | R1->R3 | 15 | |
| 10.8.0.0/16 | R1->R3->R4 | 17 | |
| 10.9.0.0/16 | R1->R2 | 30 | |
| 10.10.0/16 | R1->R3->R4 | 25 | |
| 10.11.0.0/16 | R1->R3->R4->R5 | 27 | $\mathbf{\mathbf{v}}$ |

R1 Routing Table

- 10.2.0.0/16 Directly Connected Network
- 10.3.0.0/16 Directly Connected Network
- 10.4.0.0/16 Directly Connected Network

Remote Networks

- 10.5.0.0/16 via R2 serial 0/0/0, cost = 22
- 10.6.0.0/16 via R3 serial 0/0/1, cost = 7
- 10.7.0.0/16 via R3 serial 0/0/1, cost = 15
- 10.8.0.0/16 via D3 corial 0/0/1 cost = 17

- Using the shortest path information determined by the SPF algorithm, these best paths are then added to the routing table.
- Directly connected routes and static routes are also included in the routing table.

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Link-State Routing Protocol Benefits Advantages of Link-State Routing Protocols

- Each router builds its own topological map of the network to determine the shortest path.
- Immediate flooding of LSPs achieves faster convergence.
- LSPs are sent only when there is a change in the topology and contain only the information regarding that change.
- Hierarchical design used when implementing multiple areas.

Link-State Routing Protocol Benefits Disadvantages of Link-State Routing Protocols

- Disadvantages of Link-State protocols:
 - Memory Requirements Link-state protocols require additional memory.
 - Processing Requirements Link-state protocols can require more CPU processing.
 - Bandwidth Requirements The flooding of link-state packets can adversely affect bandwidth.
- Using multiple areas can reduce the size of the link-state databases.
- Multiple areas can limit the amount of link-state information flooding and send LSPs only to those routers that need them.

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Link-State Routing Protocol Benefits Protocols that Use Link-State

- Two link-state routing protocols, OSPF and IS-IS.
- Open Shortest Path First (OSPF) most popular implementation with two versions in use:
- •OSPFv2- OSPF for IPv4 networks (RFC 1247 and RFC 2328)
- •OSPFv3-OSPF for IPv6 networks (RFC 2740)
- Integrated IS-IS, or Dual IS-IS, includes support for IP networks.
- used mainly by ISPs and carriers.



IS-IS

- ISO 10589
- Integrated IS-IS, Dual IS-IS supports IP networks
- Used mainly by ISPs and carriers

5.4 Chapter Summary



Conclusion

Chapter 5: Dynamic Routing

- Explain the features and characteristics of dynamic routing protocols.
- Explain how distance vector routing protocols operate.
- Explain how link-state protocols operate.

