Network Layer

Routing Algorithm

Link State Routing

Lecture 12 | CSE421 – Computer Networks

Department of Computer Science and Engineering
School of Data & Science

Chapter 4: Network Layer

- 4. 1 Introduction
- 4.2 Virtual circuit and datagram networks
- 4.3 What's inside a router
- 4.4 IP: Internet Protocol
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  - IPv4 addressing
  - ICMP
  - IPv6
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  - Distance Vector
  - Link state
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- 4.6 Routing in the Internet
  - RIP
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Link-State Routing Protocols

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- Distance Vector routing protocols are like road signs.
    - Routers must make preferred path decisions based on a distance or metric to a network.
- Link-State routing protocols are more like a road map.
    - They create a topological map of the network and each router uses this map to determine the shortest path to each network.

Link-State Routing Protocols

- Centralized Routing Algorithm
  - computes the least-cost path using complete, global knowledge about the network.
- Link-state routing protocols are also known as shortest path first protocols
  - The Link state routing protocol uses Dijkstra's algorithm which is used to find the shortest path from one node to every other node in the network.
- While they have the reputation of being much more complex than distance vector, the basic functionality and configuration of link state routing protocols are not complex.

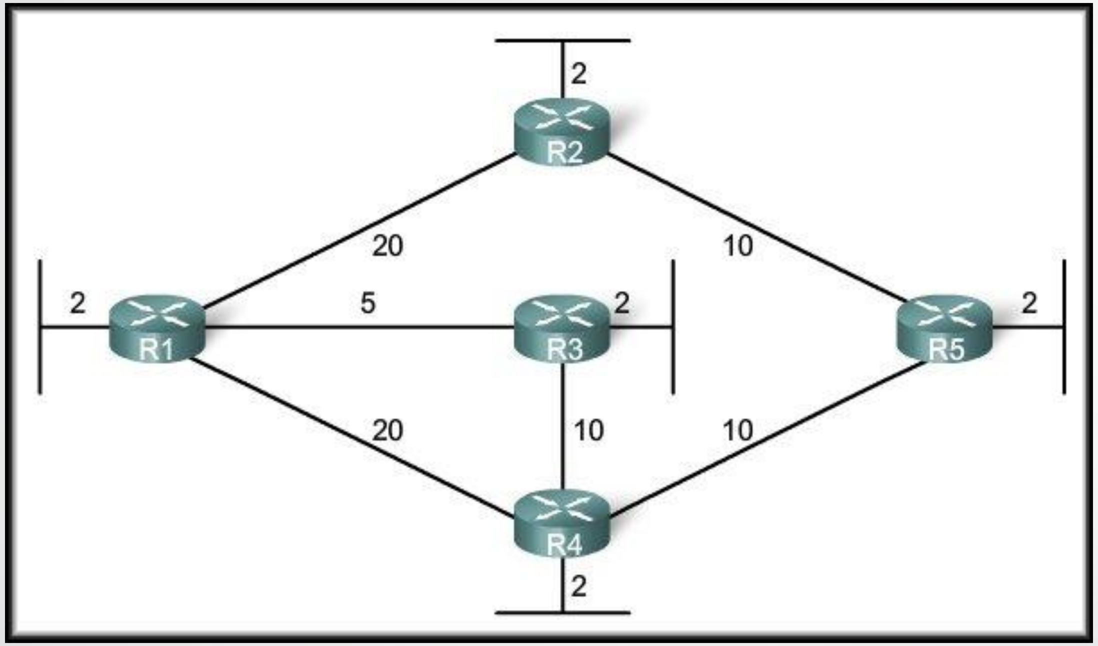
A Link-State Routing Algorithm

- **Centralized Routing Algorithm**

- **Uses Dijkstra's algorithm- Shortest Path First**

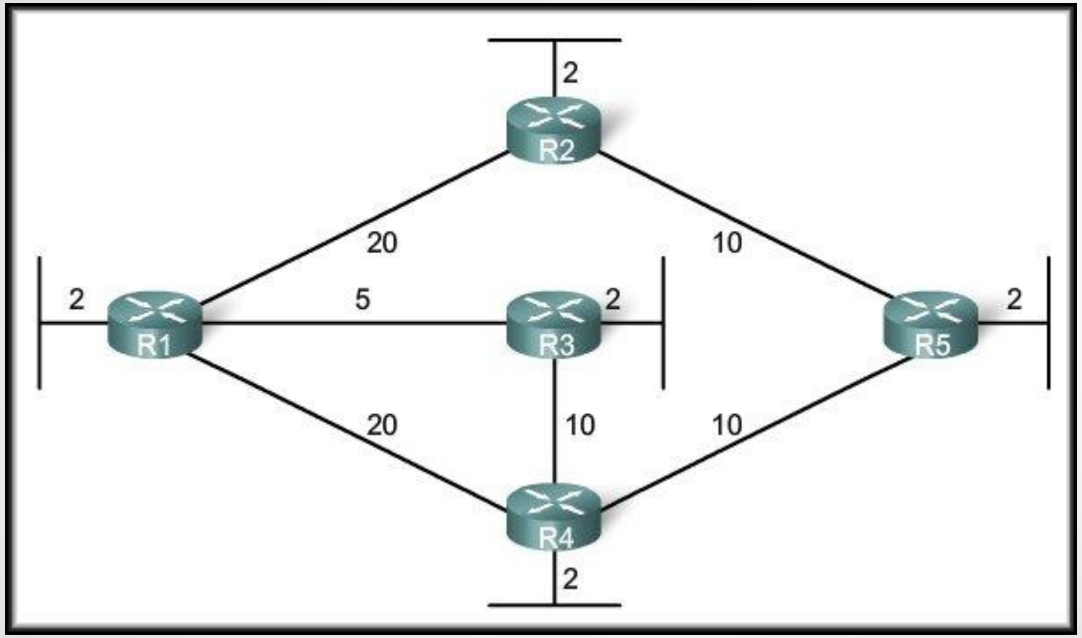
  - net topology, link costs known to all nodes
  - computes least cost paths from one node ("source") to all other nodes
    - gives **forwarding/routing table** for that node
  - iterative: after k iterations, know least cost path to k destinations

SPF Algorithm - Example



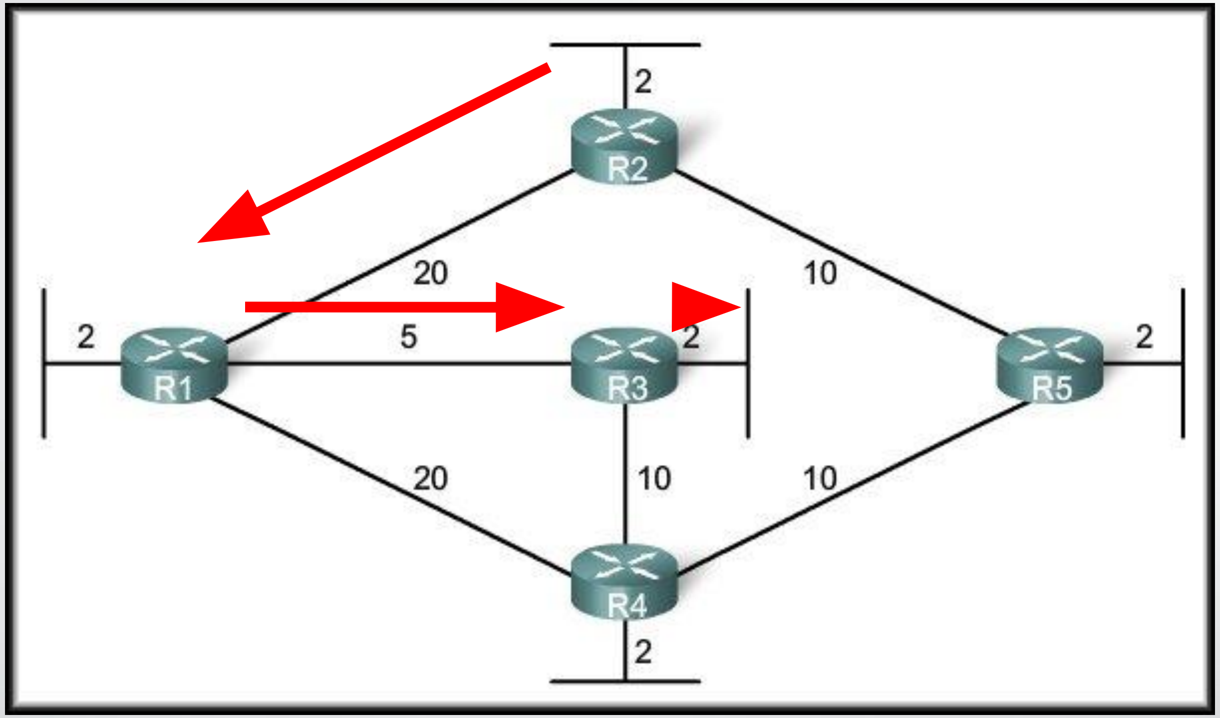
- Dijkstra's algorithm is commonly referred to as the Shortest Path First (SPF) algorithm.
- This algorithm accumulates costs along each path, from source to destination.

SPF Algorithm



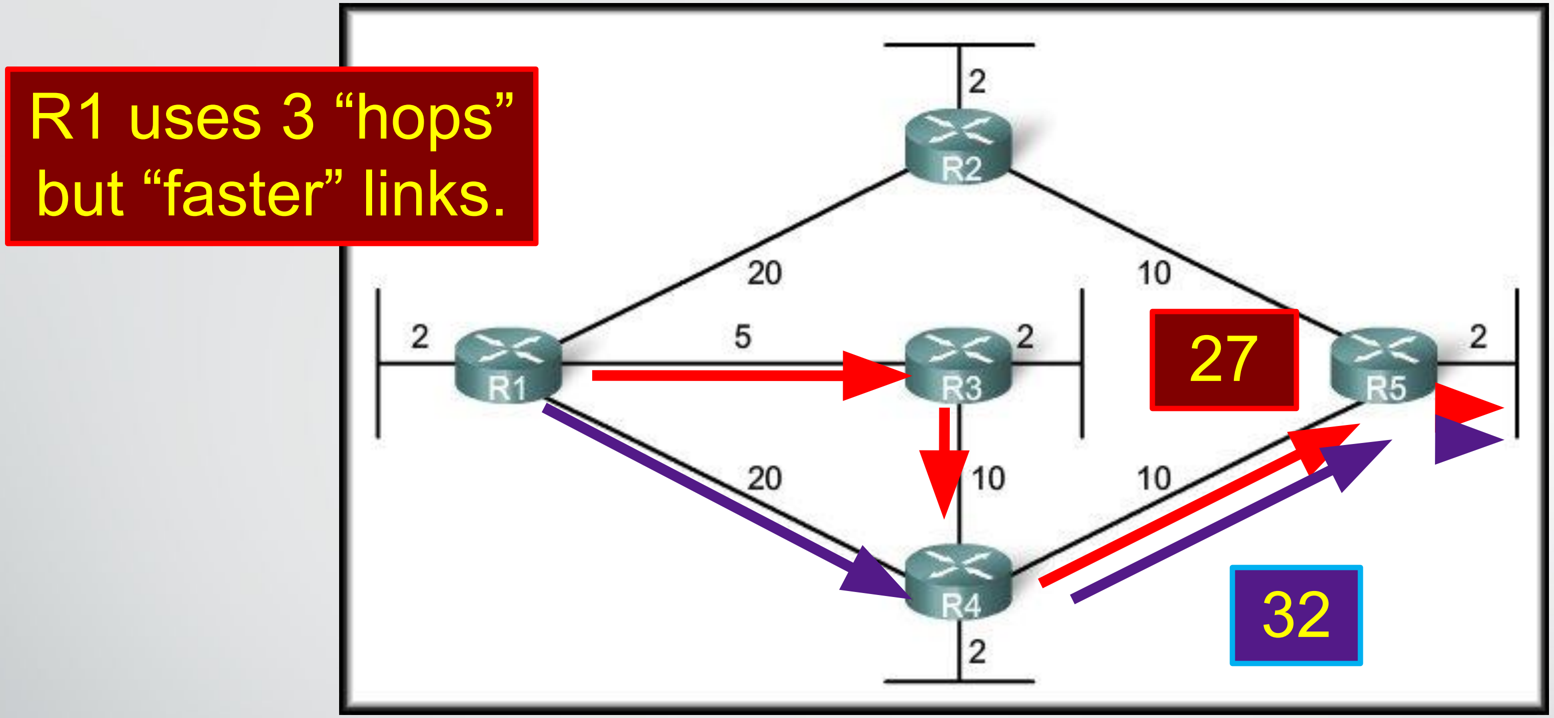
- To illustrate how SPF operates, each path in the figure is labeled with an arbitrary value for cost.
- Each router calculates the SPF algorithm and determines the cost of a link from its own perspective.

SPF Algorithm



- For example:
  - The cost of the shortest path for R2 to send packets to the LAN attached to R3 is 27 (20 + 5 + 2 = 27).

SPF Algorithm

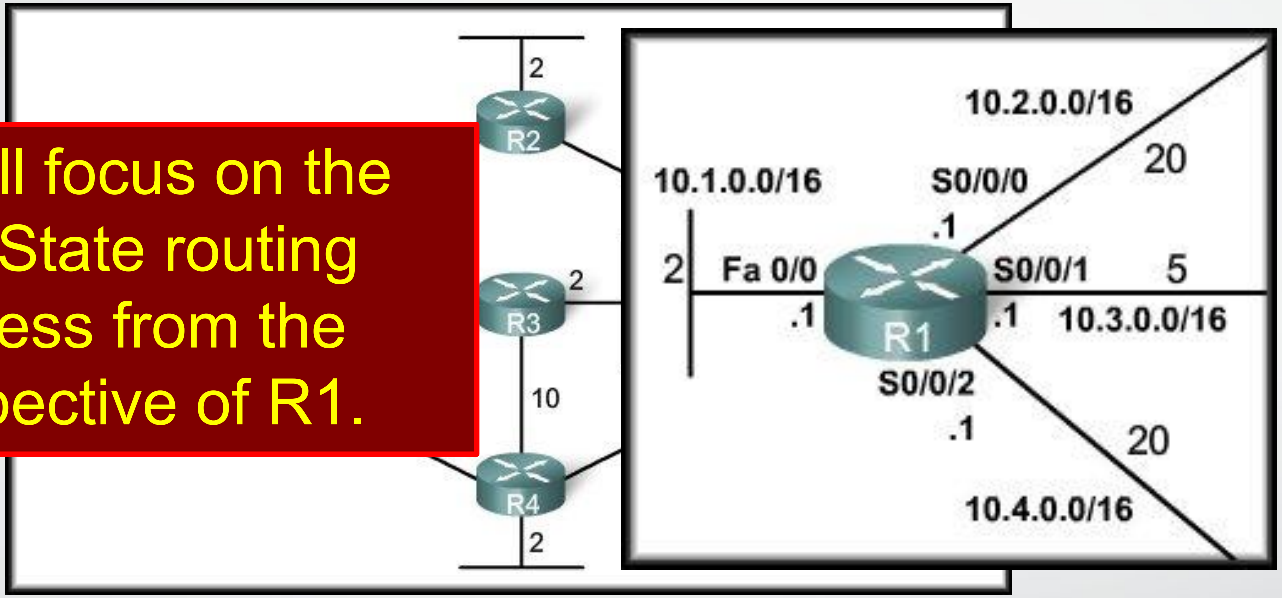


- R1 has data to send to the network on R5.
  - You might think that R1 would send directly to R4 (2 hops) instead of to R3 (3 hops).

Link-State Routing Process
5 Step Process

1. Each router learns about its own directly connected networks.
2. Each router is responsible for contacting its neighbors (exchange Hello packet) on directly connected networks.
3. Each router builds a link-state packet (LSP) containing the state of each directly connected link.
4. Each router floods the LSP to all routers, who then store all LSPs received in a database.
5. Each router uses the LSPs to construct a database that is a complete map of the topology and computes the best path to each destination network.

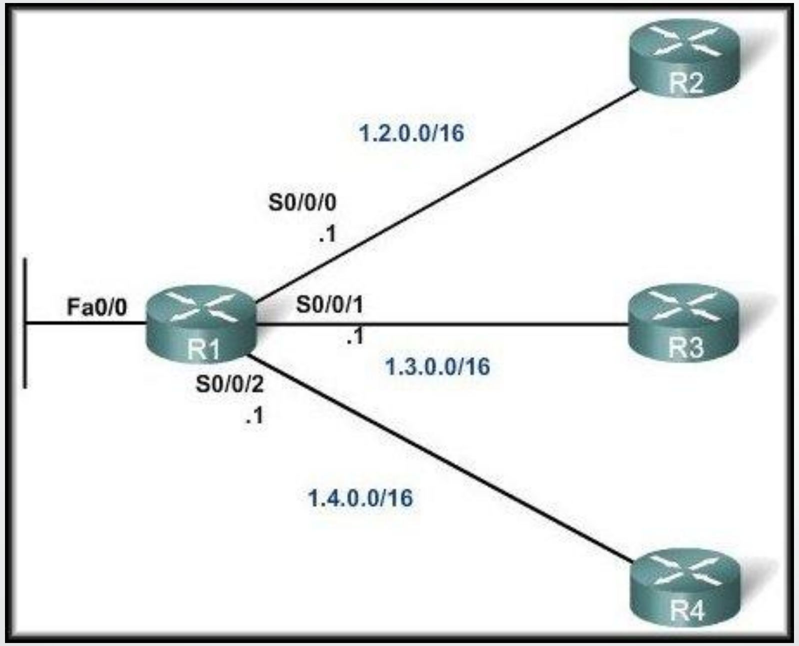
Step 1: Directly Connected Networks



We will focus on the Link-State routing process from the perspective of R1.

- Each router learns about its own directly connected networks.
- When a router interface is configured with an IP address and subnet mask and activated, the interface becomes part of that network.
- Regardless of the routing protocols used, these directly connected networks are now part of the routing table.

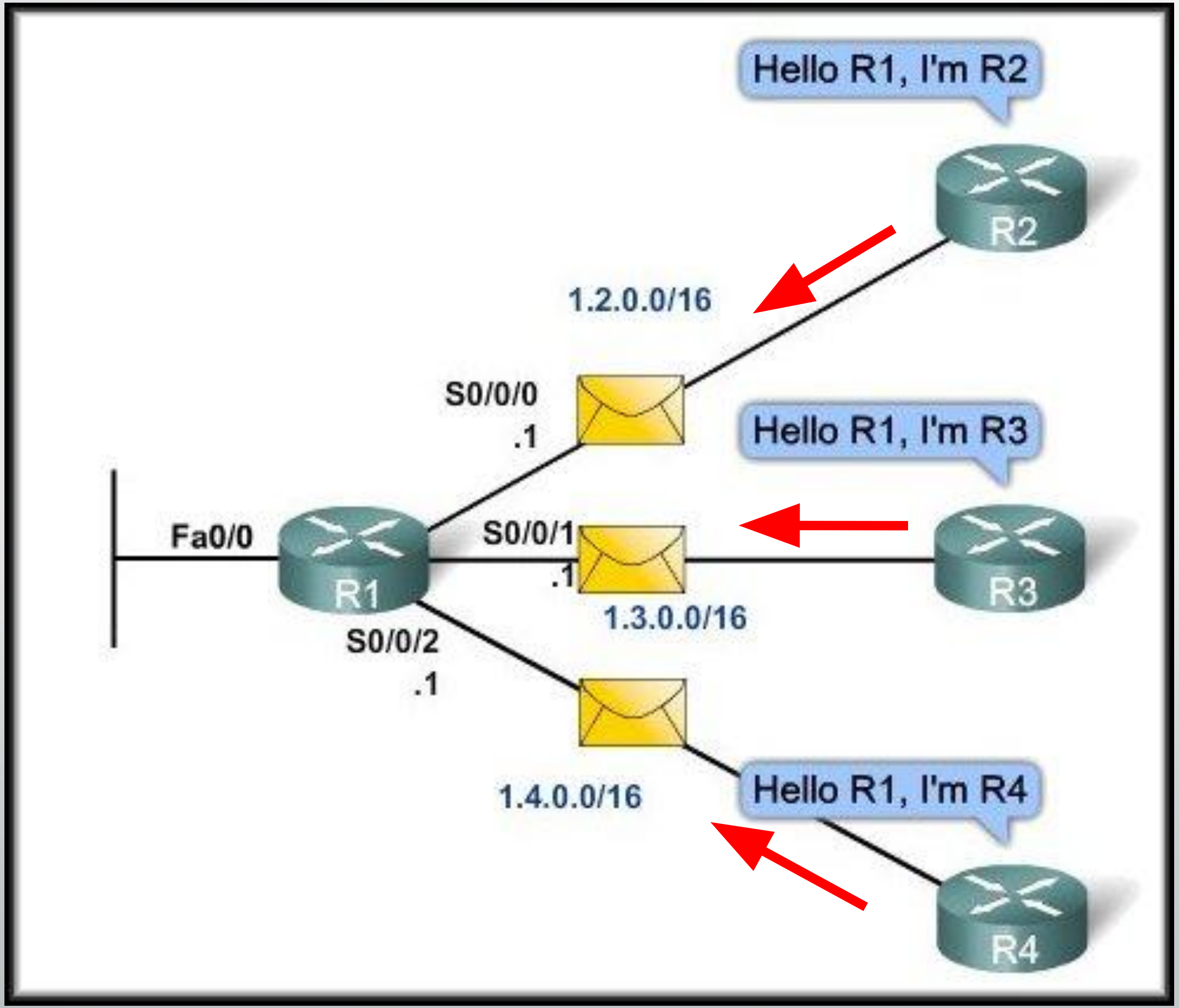
Step 2: Hello Packets



- Each router is responsible for contacting its neighbors on directly connected networks.
- The router will not be aware of any neighbor routers on the link until it receives a Hello packet from that neighbor.

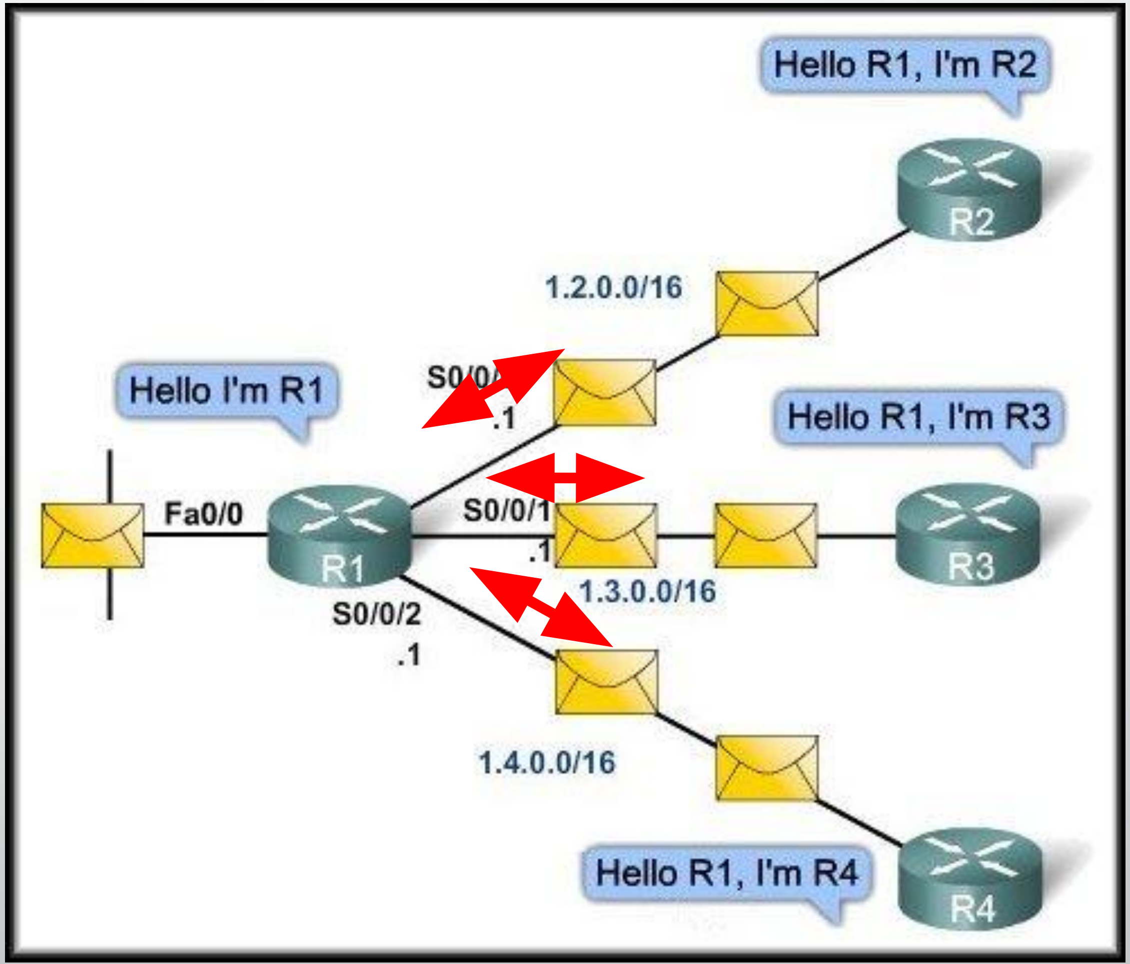
At that time, it establishes an adjacency with the neighboring router.

Step 2: Hello Packets

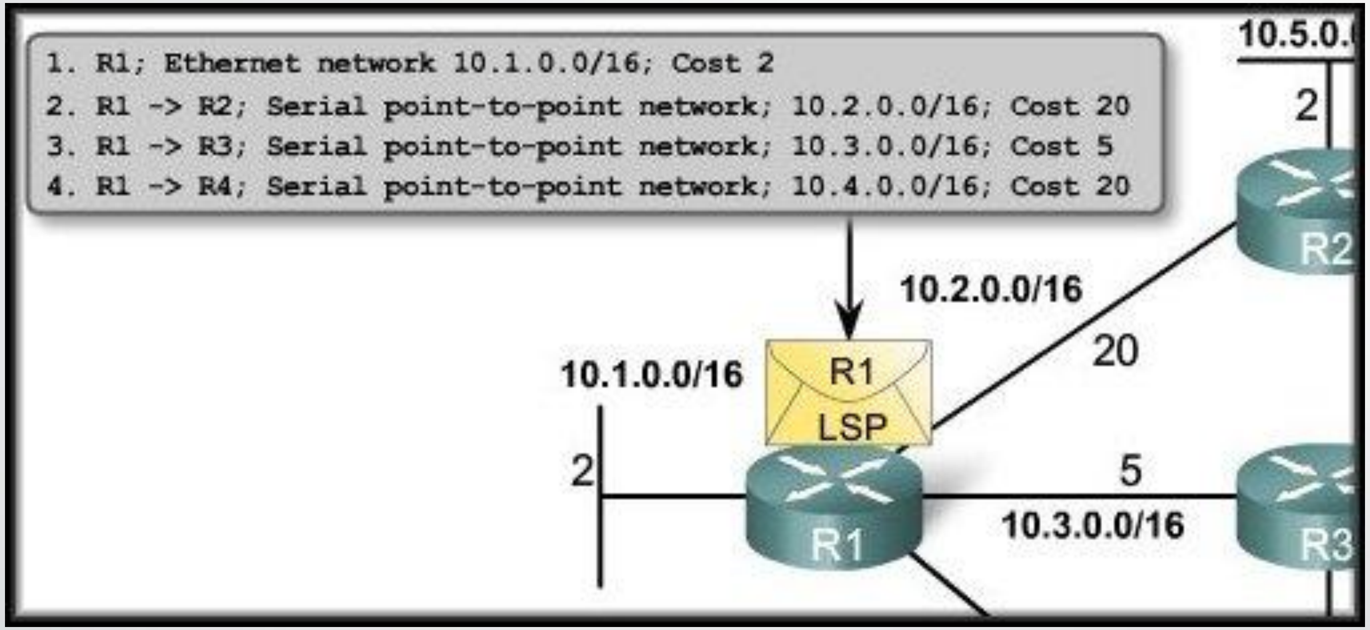


Step 2: Hello Packets

- A neighbor is any other router that is enabled with the same link-state routing protocol.
- These small Hello packets continue to be exchanged between two adjacent neighbors.
- These packets serve as a keep alive function to monitor the state of the neighbor.

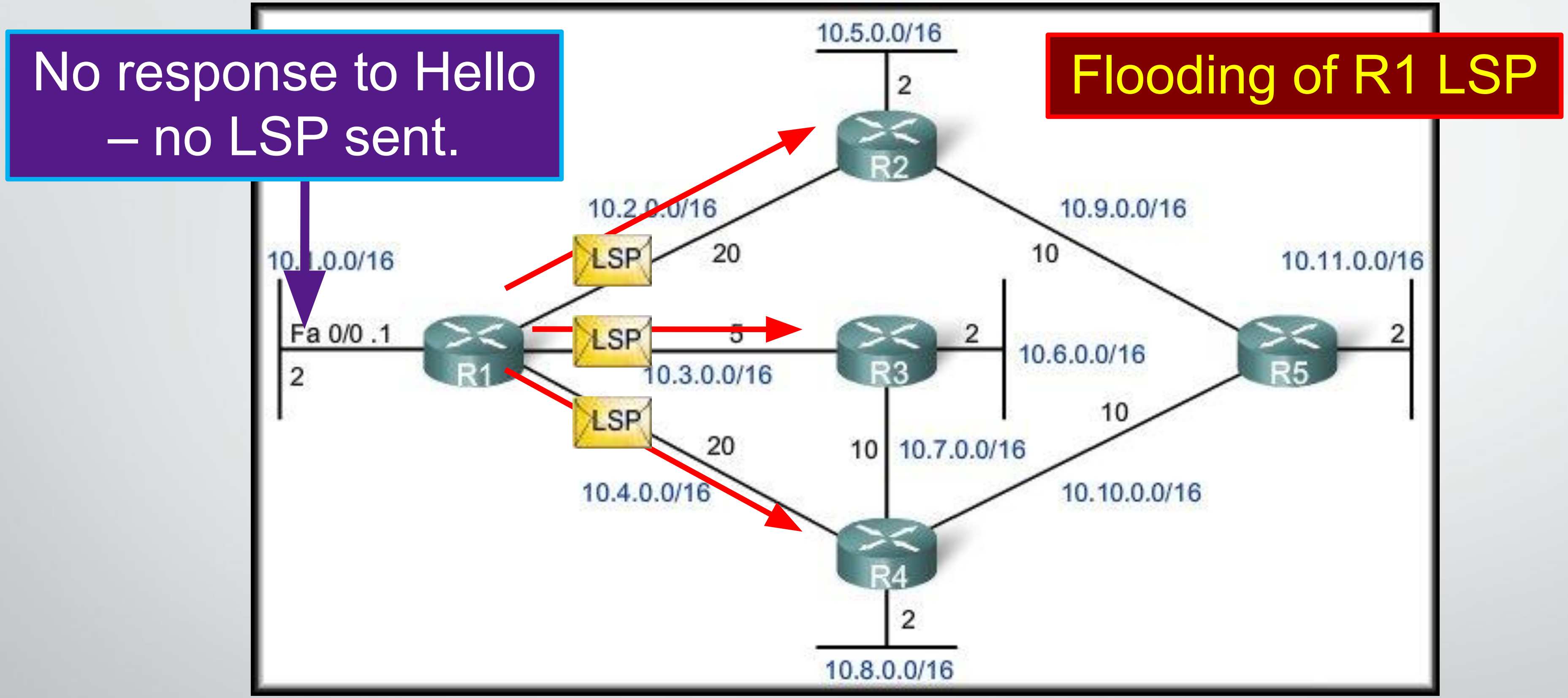


Step 3: Build the Link-State Packet



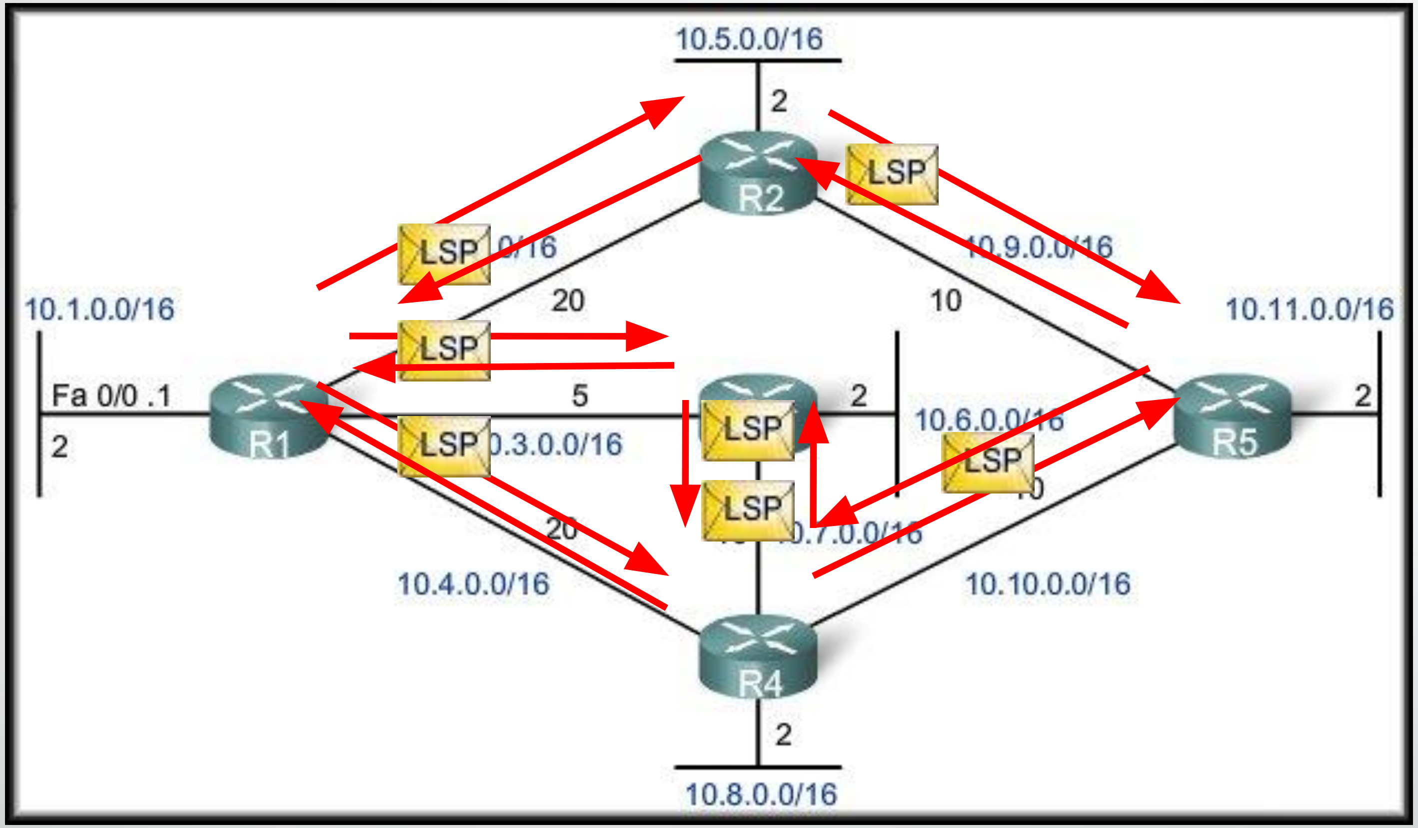
- Each router builds a link-state packet (LSP) containing the state of each directly connected link.
- The LSP contains the link-state information about the sending router's links.
- The router only sends LSPs out interfaces where it has established adjacencies with other routers.

Step 4: Flooding Link-State Packets



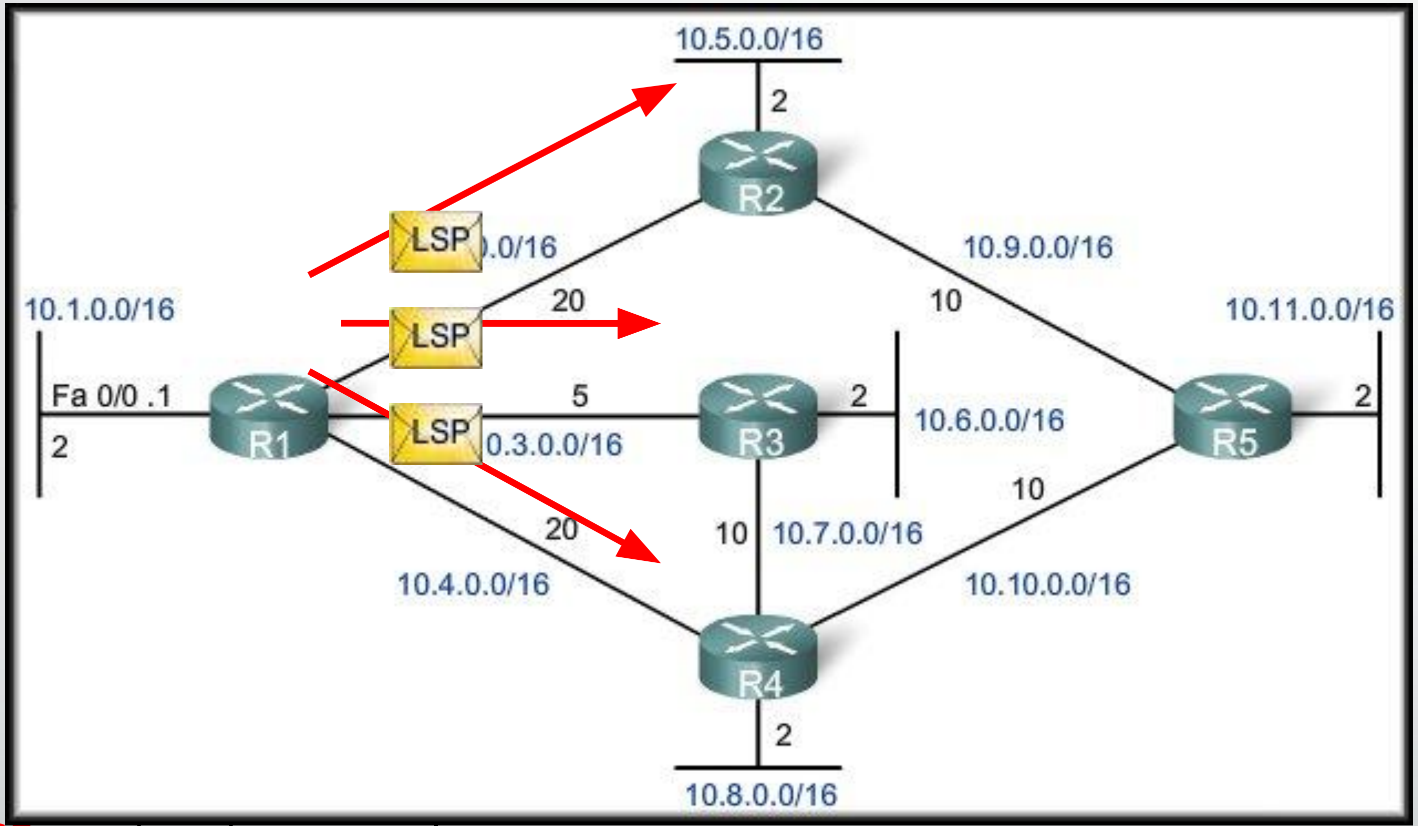
- Each router floods the LSP to all neighbors, who then store all LSPs received in a database.
  - Whenever a router receives an LSP from a neighboring router, it immediately sends that LSP out all other interfaces, except the interface that received the LSP.

Step 4: Flooding Link-State Packets



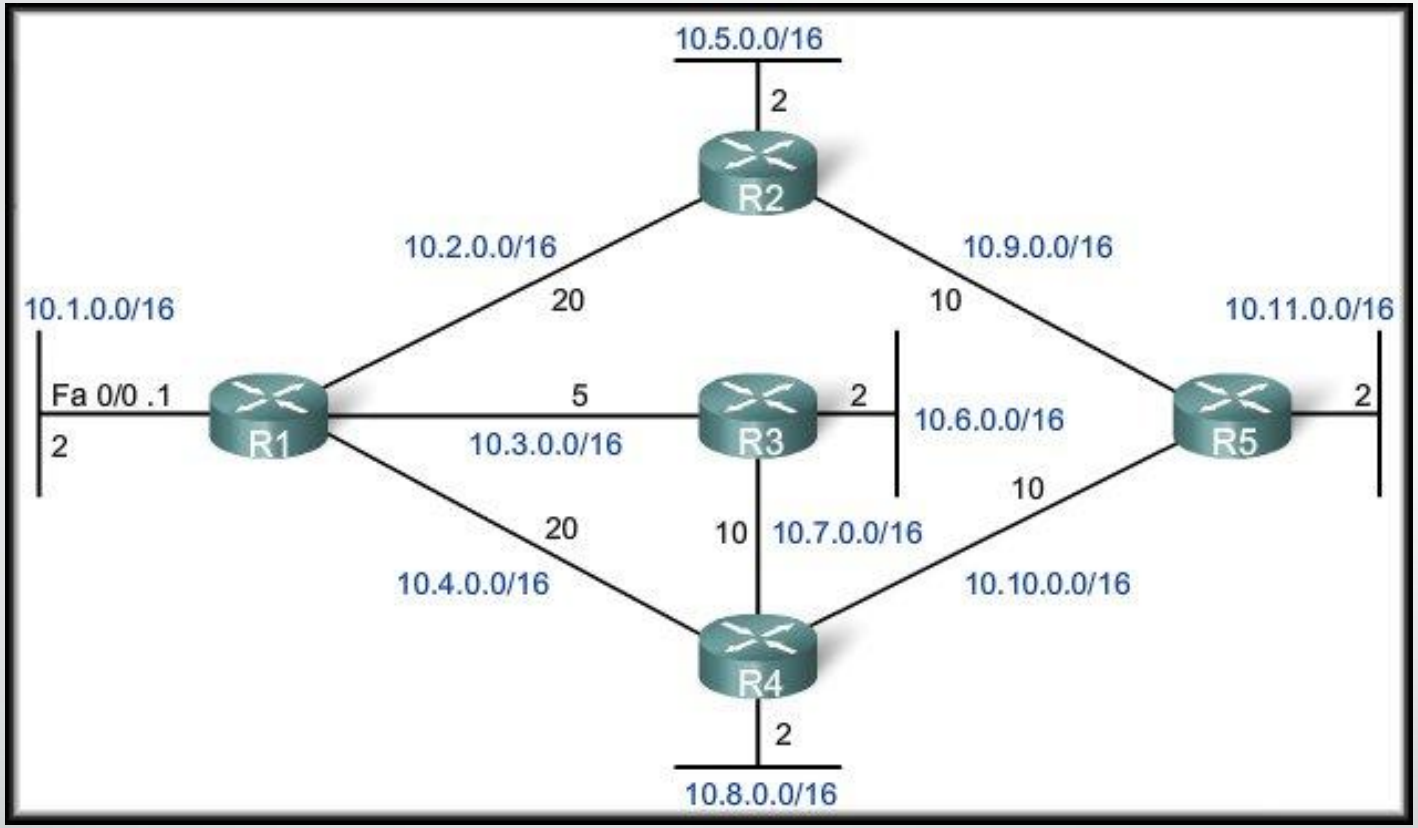
- Link-state routing protocols calculate the SPF algorithm after the flooding is complete.
- As a result, link-state routing protocols reach convergence much faster than distance vector routing protocols.

Step 4: Flooding Link-State Packets



- An LSP needs to be sent only:
  - During initial startup of the router or routing protocol.
  - Whenever there is a change in the topology (link going down or coming up) or a neighbor adjacency being established or broken.

Step 5: Constructing a Link-State Database



- Each router uses the LSPs to construct a database that is a complete map of the topology and computes the best path to each destination network.

R1: Building the SPF Tree

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R1 Link State Database

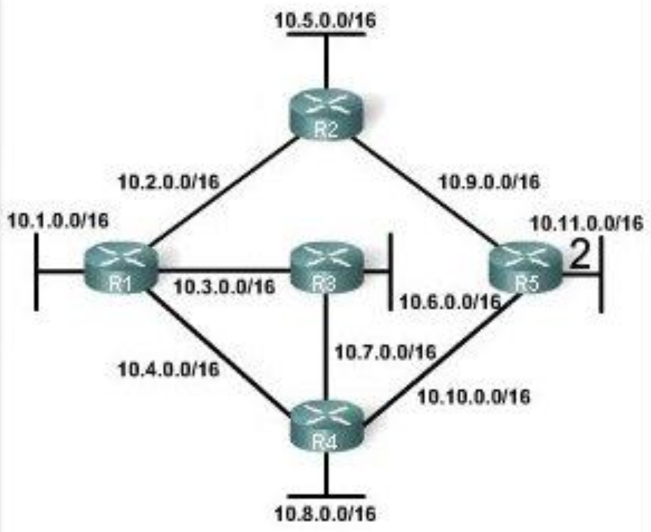
R1 Links-states:
- Connected to neighbor R2 on network 10.2.0.0/16, cost of 20
- Connected to neighbor R3 on network 10.3.0.0/16, cost of 5
- Connected to neighbor R4 on network 10.4.0.0/16, cost of 20
- Has a network 10.1.0.0/16, cost of 2

LSPs from R2:
- Connected to neighbor R1 on network 10.2.0.0/16, cost of 20
- Connected to neighbor R5 on network 10.9.0.0/16, cost of 10
- Has a network 10.5.0.0/16, cost of 2

LSPs from R3:
- Connected to neighbor R1 on network 10.3.0.0/16, cost of 5
- Connected to neighbor R4 on network 10.7.0.0/16, cost of 10
- Has a network 10.6.0.0/16, cost of 2

LSPs from R4:
- Connected to neighbor R1 on network 10.4.0.0/16, cost of 20
- Connected to neighbor R3 on network 10.7.0.0/16, cost of 10
- Connected to neighbor R5 on network 10.10.0.0/16, cost of 10
- Has a network 10.8.0.0/16, cost of 2

LSPs from R5:
- Connected to neighbor R2 on network 10.9.0.0/16, cost of 10
- Connected to neighbor R4 on network 10.10.0.0/16, cost of 10
- Has a network 10.11.0.0/16, cost of 2



Step 5: Constructing a Link-State Database

R1s Link-State Database

LSPs from R2:

- Connected to neighbor R1 on network 10.2.0.0/16, cost of 20
- Connected to neighbor R5 on network 10.9.0.0/16, cost of 10
- Has a network 10.5.0.0/16, cost of 2

LSPs from R3:

- Connected to neighbor R1 on network 10.3.0.0/16, cost of 5
- Connected to neighbor R4 on network 10.7.0.0/16, cost of 10
- Has a network 10.6.0.0/16, cost of 2

LSPs from R4:

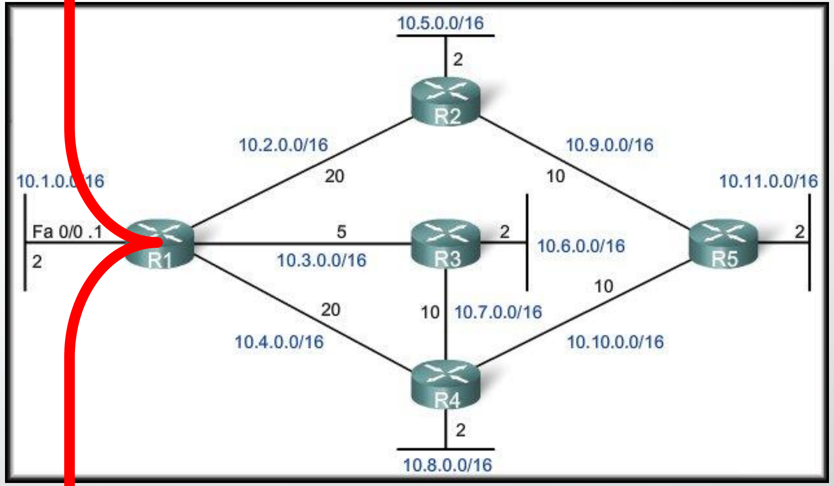
- Connected to neighbor R1 on network 10.4.0.0/16, cost of 20
- Connected to neighbor R3 on network 10.7.0.0/16, cost of 10
- Connected to neighbor R5 on network 10.10.0.0/16, cost of 10
- Has a network 10.8.0.0/16, cost of 2

LSPs from R5:

- Connected to neighbor R2 on network 10.9.0.0/16, cost of 10
- Connected to neighbor R4 on network 10.10.0.0/16, cost of 10
- Has a network 10.11.0.0/16, cost of 2

R1 Link-states:

- Connected to neighbor R2 on network 10.2.0.0/16, cost of 20
- Connected to neighbor R3 on network 10.3.0.0/16, cost of 5
- Connected to neighbor R4 on network 10.4.0.0/16, cost of 20
- Has a network 10.1.0.0/16, cost of 2

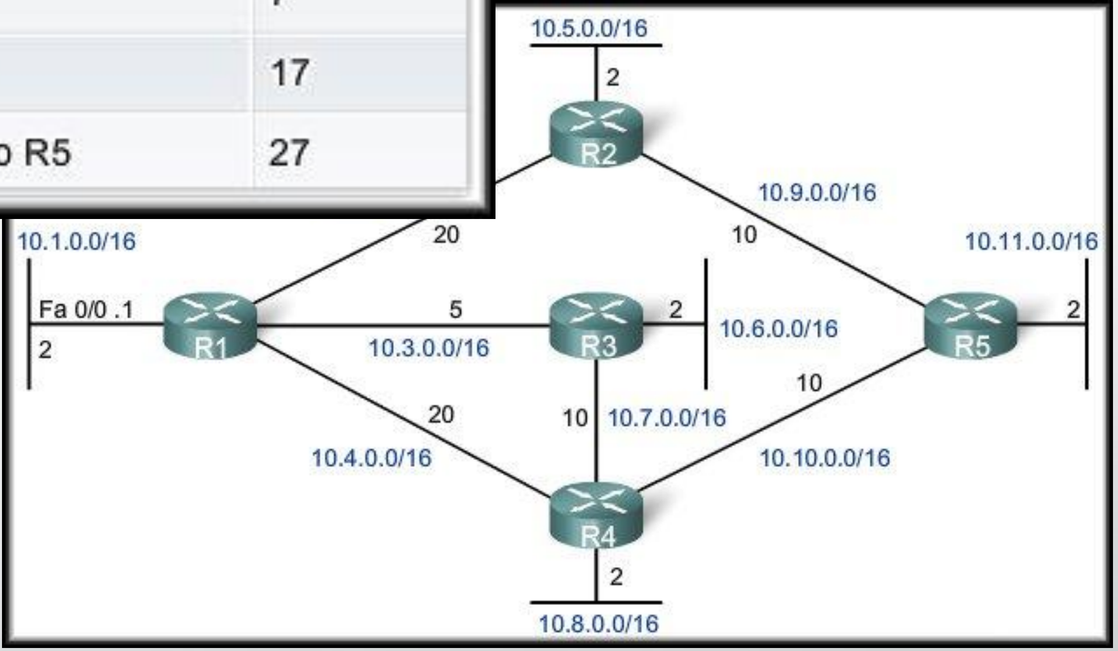


- As a result of the flooding process, router R1 has learned the link-state information for each router in its routing area.

Step 5: Constructing a Link-State Database

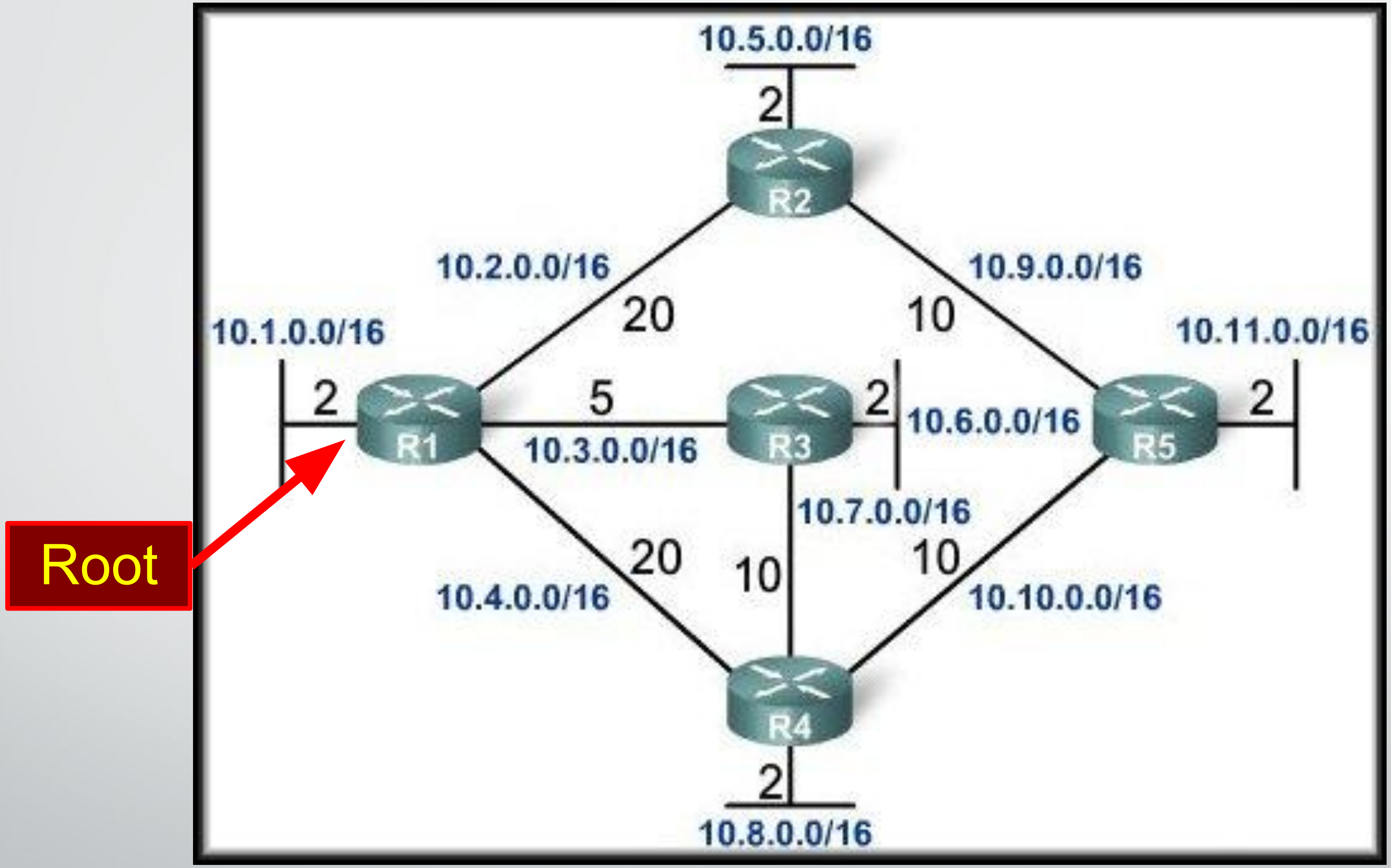
Destination	Shortest Path	Cost
R2 LAN	R1 to R2	22
R3 LAN	R1 to R3	7
R4 LAN	R1 to R3 to R4	17
R5 LAN	R1 to R3 to R4 to R5	27

Each router in the topology determines the shortest path from its own perspective.



- With a complete link-state database, R1 can now use the database and the shortest path first (SPF) algorithm to calculate the preferred path or shortest path to each network.

R1: Building the SPF Tree

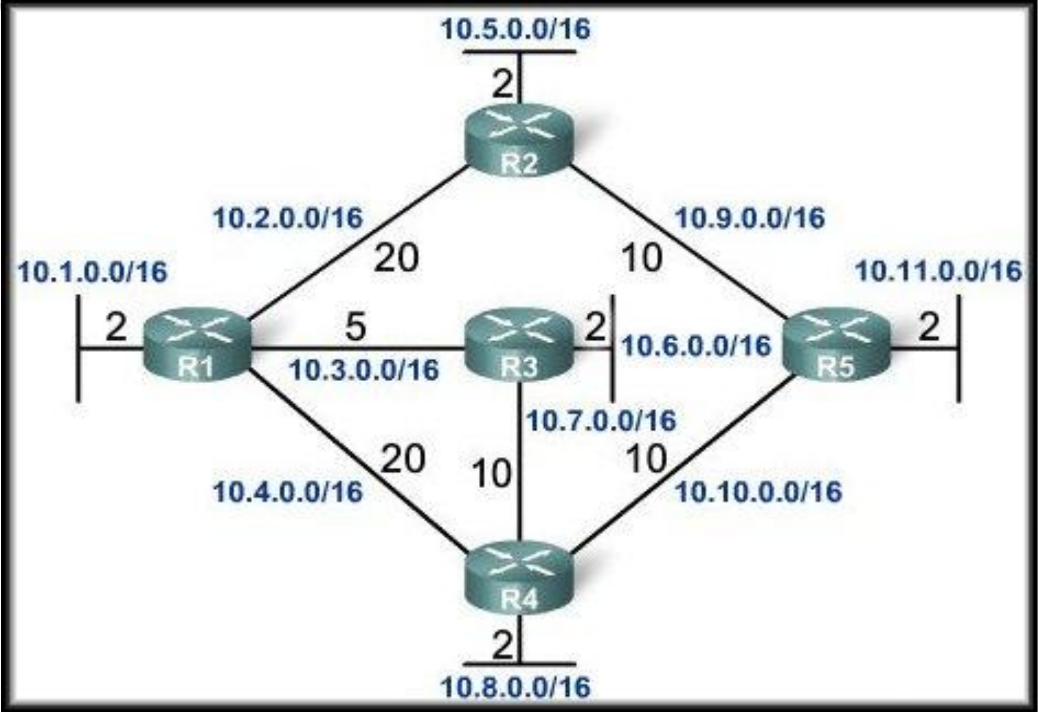


- All LSPs have been processed using the SPF algorithm and R1 has now constructed the complete SPF tree.

Generating a Routing Table

SPF Information

- Network 10.5.0.0/16 via R2 serial 0/0/0 at a cost of 22
- Network 10.6.0.0/16 via R3 serial 0/0/1 at a cost of 7
- Network 10.7.0.0/16 via R3 serial 0/0/1 at a cost of 15
- Network 10.8.0.0/16 via R3 serial 0/0/1 at a cost of 17
- Network 10.9.0.0/16 via R2 serial 0/0/0 at a cost of 30
- Network 10.10.0.0/16 via R3 serial 0/0/1 at a cost of 25
- Network 10.11.0.0/16 via R3 serial 0/0/1 at a cost of 27



Building Routing Table

- Creation of the states of the links by each node, called the link state packets (LSP)
- Dissemination of LSPs to every other routers, called flooding (efficiently)
- Constructing a Link-State Database using LSPs
- Formation of a shortest path tree for each node
- Calculation of a routing table based on the shortest path tree

Advantages: Link-State Routing

- **Fast Network Convergence**– On receiving an LSP, link-state routing protocols immediately flood the LSP out all interfaces without any changes except for the interface from which the LSP was received.
- **Topological Map**– Using the SPF tree, each router can separately determine the shortest path to every network.
- **Hierarchical Design**– Link-state routing protocols use multiple areas and create a hierarchical design to networks areas. The multiple areas allow better route summarization.
- **Event-driven Updates**– After initial flooding of LSPs, the LSPs are sent only when there is a change in the topology and contain only the information regarding that change. The LSP contains only the information about the affected link. The link-state never sends periodic updates.

Comparison

	Distance Vector	Link State
Network view	Topology knowledge from the neighbor point of view	Common and complete knowledge of the network topology
Best Path Calculation	Based on fewest number of hops	Based on the link cost
Updates	Full routing table	Link State Updates
Algorithm	Bellman-Ford	Dijsktra
CPU and Memory	Low utilization	Intensive
hierarchical Structure	No	Yes
Convergence time	Moderate	Fast

THE END