



Link-State Routing Protocols



Routing Protocols and Concepts – Chapter 10

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Objectives

- Describe the basic features & concepts of link-state routing protocols.
- List the benefits and requirements of link-state routing protocols.

Introduction

In this chapter, you will learn to:

- Describe the basic features and concepts of link-state routing protocols.
- List the benefits and requirements of link-state routing protocols.

Link-State Routing

- Link state routing protocols
 - Also known as shortest path first algorithms
 - These protocols built around Dijkstra's SPF

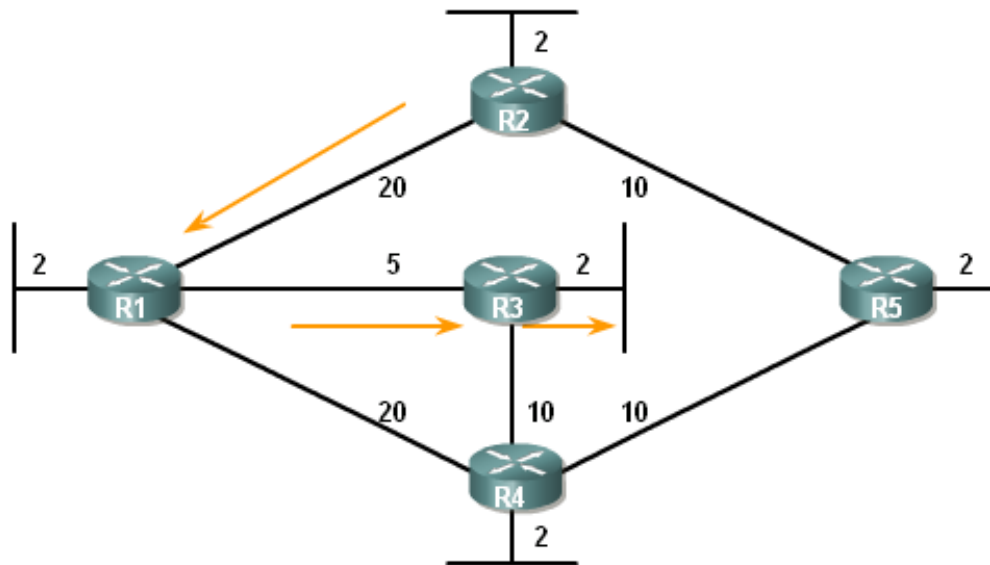
Classification of Routing Protocols

	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector Routing Protocols		Link State Routing Protocols		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

Link-State Routing

Dijkstra's algorithm also known as the shortest path first (SPF) algorithm

Dijkstra's Shortest Path First Algorithm

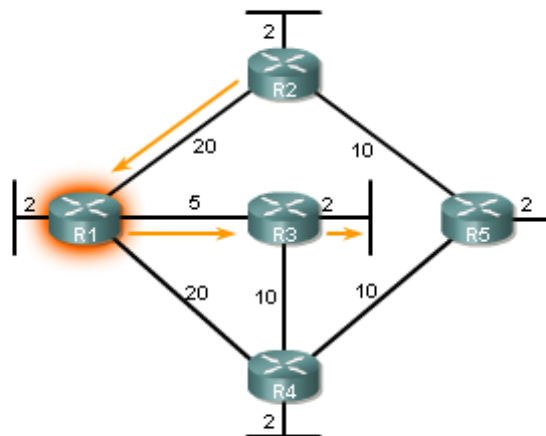


Shortest Path for host on R2 LAN to reach host on R3 LAN:
 $R2 \text{ to } R1 (20) + R1 \text{ to } R3 (5) + R3 \text{ to LAN } (2) = 27$

Link-State Routing

- The shortest path to a destination is not necessarily the path with the least number of hops

Introduction to the SPF Algorithm
SPF Tree for R1



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

Link-State Routing

Link-State Routing Process

- How routers using Link State Routing Protocols reach **convergence**
 - Each routers learns about its own directly connected networks
 - Link state routers exchange hello packet to “meet” other directly connected link state routers.
 - Each router builds its own Link State Packet (LSP) which includes information about neighbors such as neighbor ID, link type, & bandwidth.
 - After the LSP is created the router floods it to all neighbors who then store the information and then forward it until all routers have the same information.
 - Once all the routers have received all the LSPs, the routers then construct a topological map of the network which is used to determine the best routes to a destination

Link-State Routing

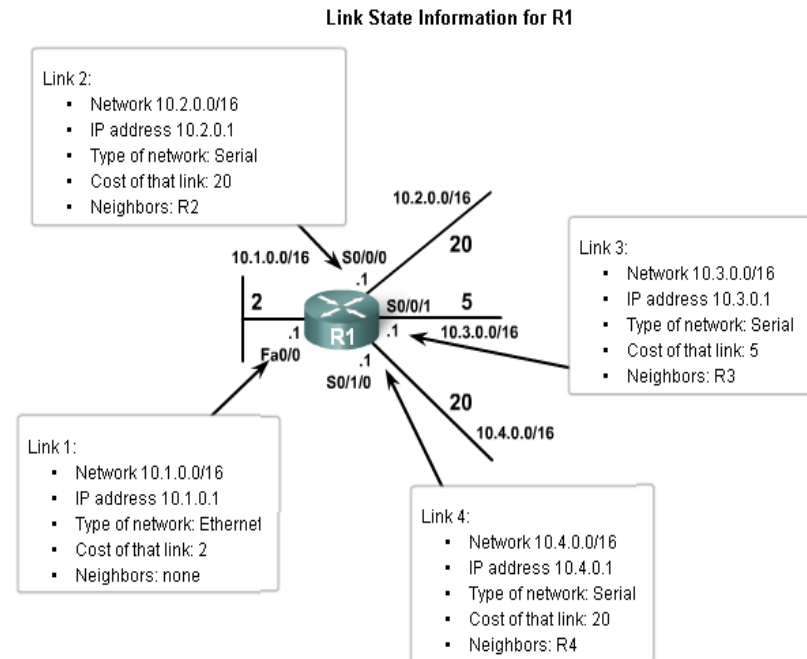
- Directly Connected Networks

- Link

This is an interface on a router

- Link state

This is the information about the state of the links



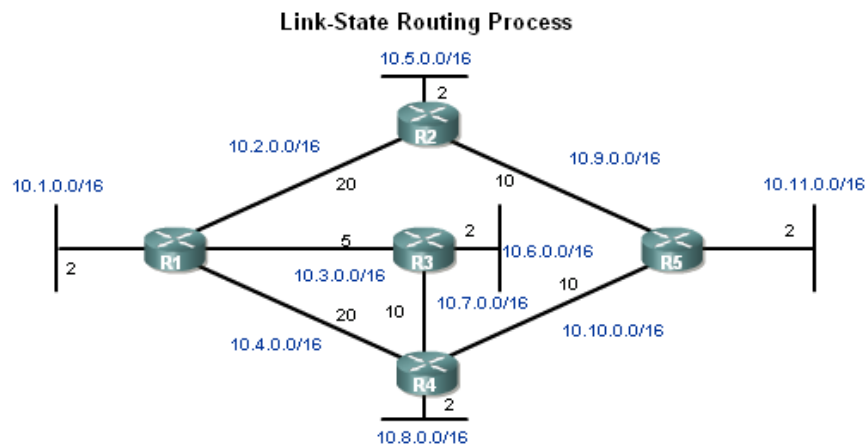
Link-State Routing

Sending Hello Packets to Neighbors

- Link state routing protocols use a hello protocol

Purpose of a hello protocol:

-To discover neighbors (that use the same link state routing protocol) on its link



- 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.

Link-State Routing

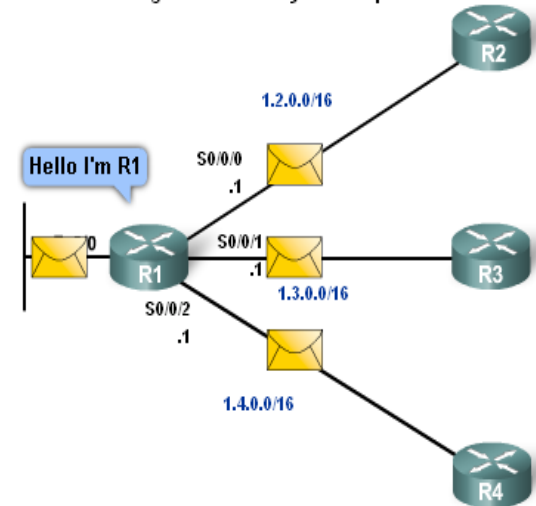
Sending Hello Packets to Neighbors

- Connected interfaces that are using the same link state routing protocols will exchange hello packets.
- Once routers learn it has neighbors they form an adjacency

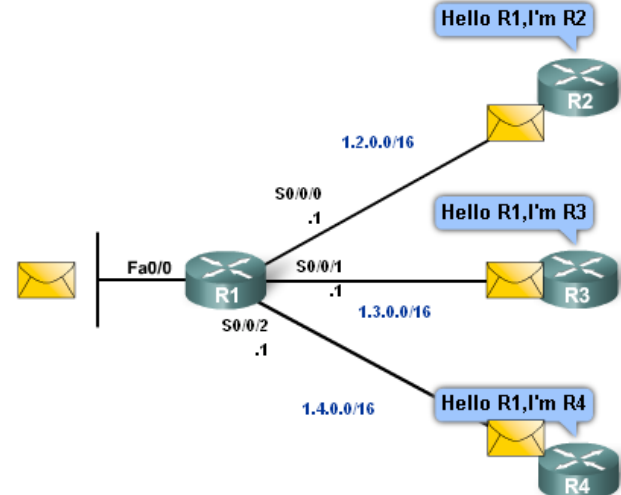
-2 adjacent neighbors will exchange hello packets

-These packets will serve as a keep alive function

Neighbor Discovery—Hello packets



Neighbor Discovery—Hello packets



Link-State Routing

Building the Link State Packet

- Each router builds its own Link State Packet (LSP)

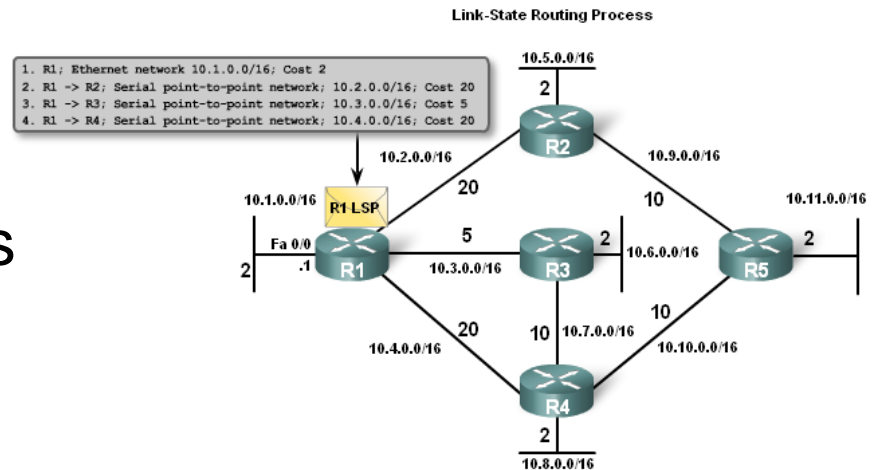
Contents of LSP:

-State of each directly connected link

-Includes information about neighbors such as neighbor ID, link type, & bandwidth.

Link-State Routing Process

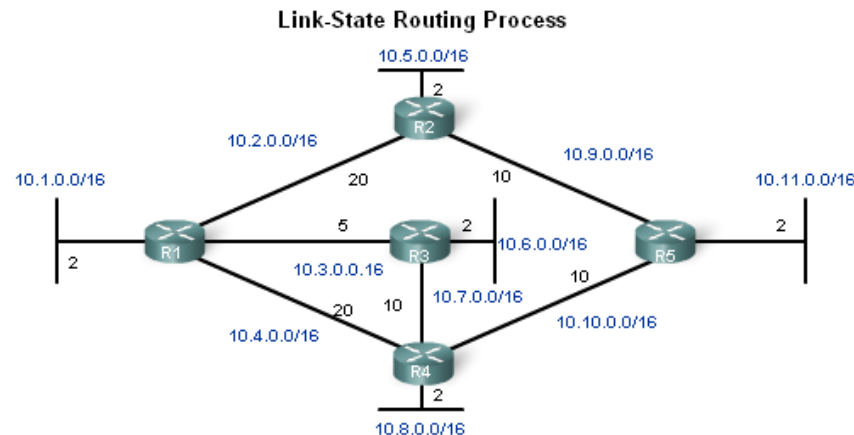
1. Each router learns about each of its own directly connected networks.
2. Each router is responsible for "saying hello" to its neighbors on directly connected networks.
3. Each router builds a Link-State Packet (LSP) containing the state of each directly connected link.



Link-State Routing

Flooding LSPs to Neighbors

- Once LSP are created they are forwarded out to neighbors.
 - After receiving the LSP the neighbor continues to forward it throughout routing area.

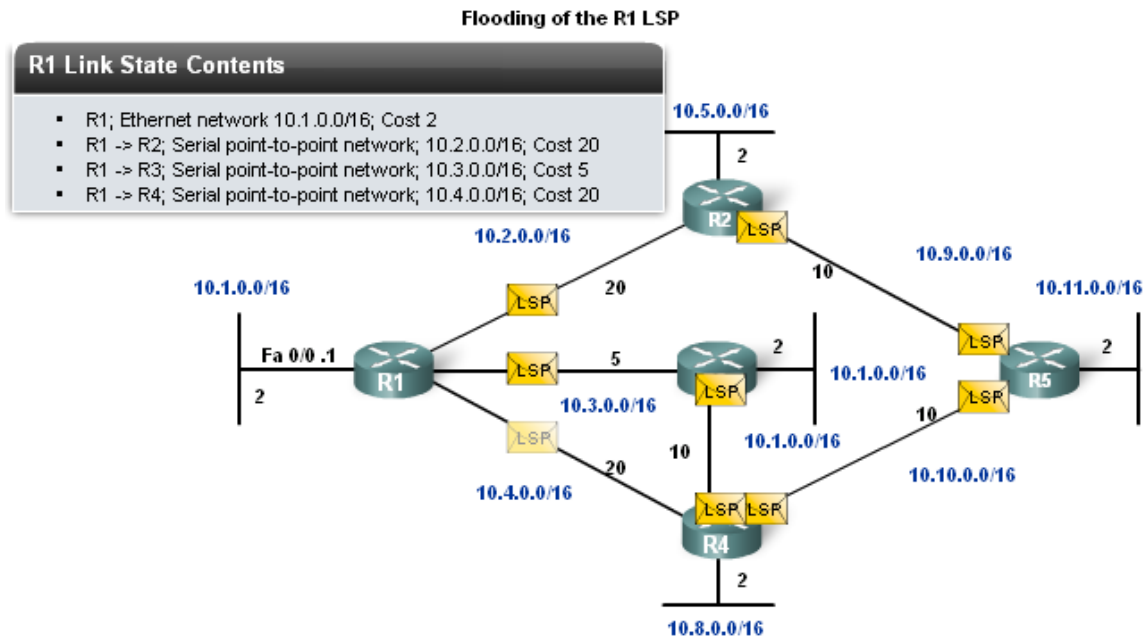


Link-State Routing Process

1. Each router learns about each of its own directly connected networks.
2. Each router is responsible for "saying hello" to its neighbors 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 neighbors, who then store all LSPs received in a database.

Link-State Routing

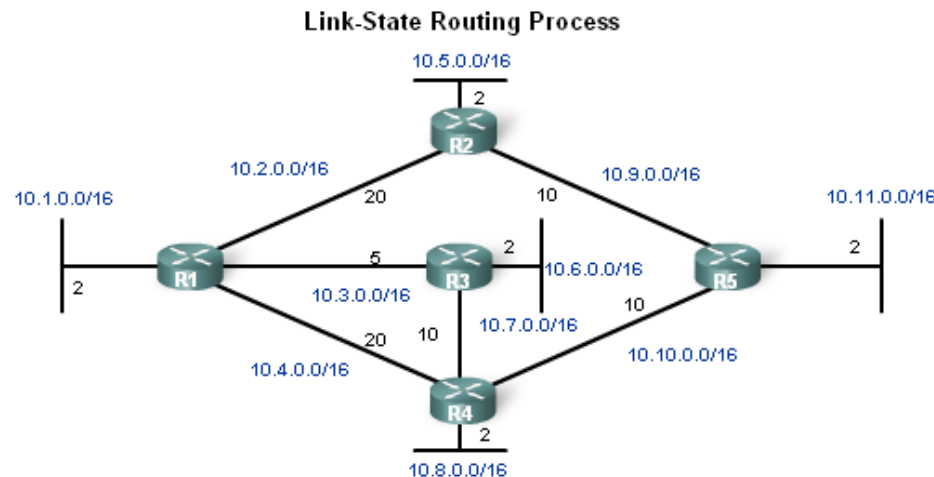
- LSPs are sent out under the following conditions
 - Initial router start up or routing process
 - When there is a change in topology



Link-State Routing

Constructing a link state data base

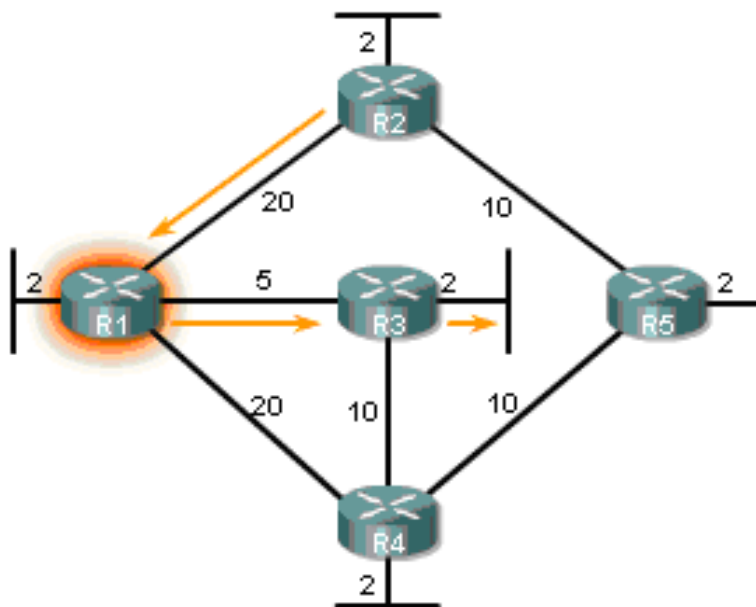
- Routers use a database to construct a topology map of the network



Link-State Routing Process

1. Each router learns about each of its own directly connected networks.
2. Each router is responsible for "saying hello" to its neighbors 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 neighbors, who then store all LSPs received in a database.
5. Each router uses the database to construct a complete map of the topology and computes the best path to each destination network.

Link-State Routing



R1 Link-State Database

R1's 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

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

Link-State Routing

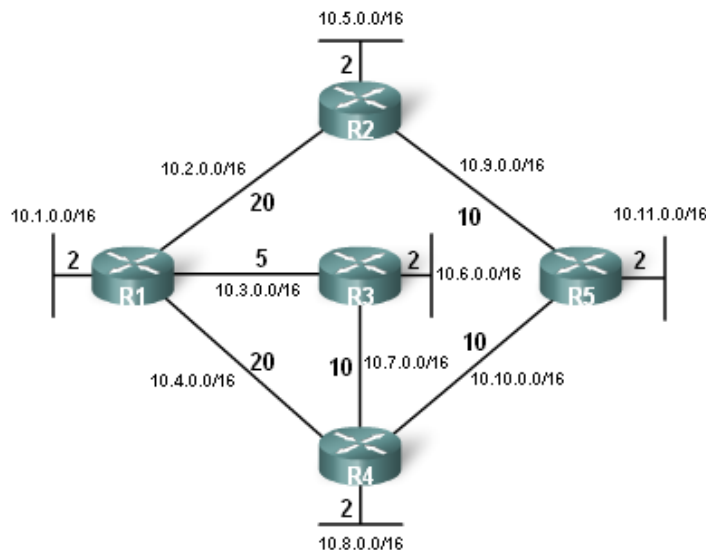
Shortest Path First (SPF) Tree

- Building a **portion** of the SPF tree

Process begins by examining R2's LSP information

-R1 *ignores* 1st LSP

Reason: R1 already knows it's connected to R2



R1's 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:

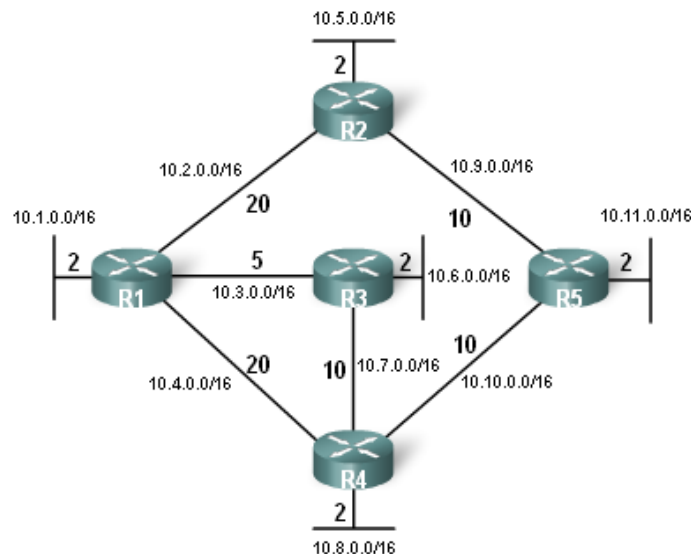
- Connected to neighbor R2 on network 10.9.0.0/16, cost of 10
- Connected to neighbor R4 on network 10.10.0.0/16, cost of 10
- Has a network 10.11.0.0/16, cost of 2

Link-State Routing

- Building a **portion** of the SPF tree

-R1 uses 2nd LSP

Reason: R1 can create a link from R2 to R5.
This information is added to R1's SPF tree



R1's 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:

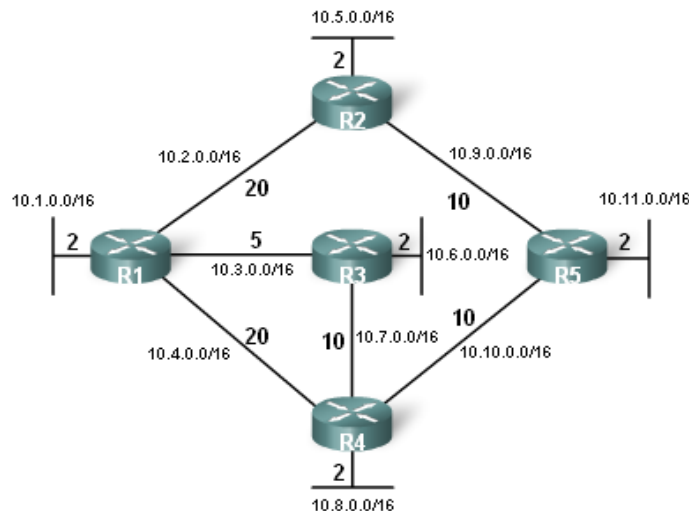
- Connected to neighbor R1 on network 10.4.0.0/16, cost of 20
- Connected to neighbor R3 on network 10.7.0.0/16, cost of 10
- Connected to neighbor R5 on network 10.10.0.0/16, cost of 10
- Has a network 10.8.0.0/16, cost of 2

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

Link-State Routing

- Building a **portion** of the SPF tree
 - R1 uses 3rd LSP
 - Reason: R1 learns that R2 is connected to 10.5.0.0/16.
 - This link is added to R1's SPF tree.



R1's 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

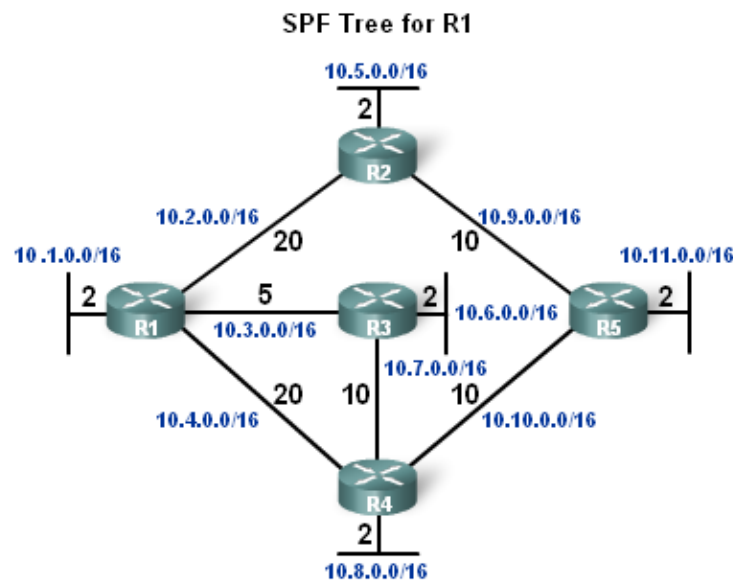
LSPs from R5:

- 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

Link-State Routing

- Determining the shortest path

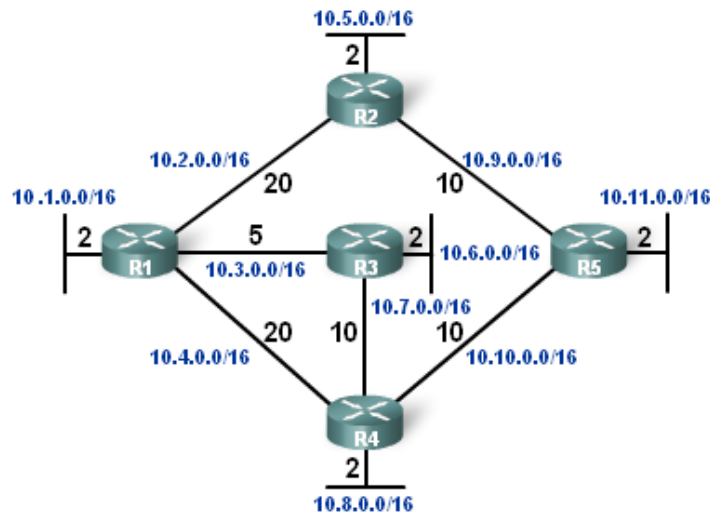
The shortest path to a destination determined by adding the costs & finding the lowest cost



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

Link-State Routing

- Once the SPF algorithm has determined the shortest path routes, these routes are placed in the routing table.



R1 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

R1 Routing Table

Directly Connected Networks

- 10.1.0.0/16 Directly Connected Network
- 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 R3 serial 0/0/1, cost = 17
- 10.9.0.0/16 via R2 serial 0/0/0, cost = 30
- 10.10.0.0/16 via R3 serial 0/0/1, cost = 25
- 10.11.0.0/16 via R3 serial 0/0/1, cost = 27

Link-State Routing Protocols

Advantages of a Link-State Routing Protocol

Routing protocol	Builds Topological map	Router can independently determine the shortest path to every network.	Convergence	A periodic/ event driven routing updates	Use of LSP
Distance vector	No	No	Slow	Generally No	No
Link State	Yes	Yes	Fast	Generally Yes	Yes

Link-State Routing Protocols

Requirements for using a link state routing protocol

- Memory requirements
 - Typically link state routing protocols use more memory
- Processing Requirements
 - More CPU processing is required of link state routing protocols
- Bandwidth Requirements
 - Initial startup of link state routing protocols can consume lots of bandwidth

Link-State Routing Protocols

- 2 link state routing protocols used for routing IP
 - Open Shortest Path First (OSPF)
 - Intermediate System-Intermediate System (IS-IS)

OSPF and IS-IS

OSPF

- OSPFv2: OSPF for IPv4 networks (RFC 1247 and RFC 2328)
- OSPFv3: OSPF for IPv6 networks (RFC 2740)
- OSPFv2 discussed in chapter 11

IS-IS

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

Summary

- Link State Routing protocols are also known as Shortest Path First protocols
- Summarizing the link state process
 - Routers 1ST learn of directly connected networks
 - Routers then say “hello” to neighbors
 - Routers then build link state packets
 - Routers then flood LSPs to all neighbors
 - Routers use LSP database to build a network topology map & calculate the best path to each destination

Summary

- Link

An interface on the router

- Link State

Information about an interface such as

- IP address
- Subnet mask
- Type of network
- Cost associated with link
- Neighboring routers on the link

Summary

- Link State Packets

After initial flooding, additional LSP are sent out when a change in topology occurs

- Examples of link state routing protocols

- Open shortest path first

- IS-IS

