

# The Network Layer

## Routing Algorithms

# Link State routing Protocols

- Routers running a link-state routing protocol send information about the state of its links to other routers in the routing domain.
- The state of those links refers to its directly connected networks and includes information about the **type of network** and any **neighboring routers** on those networks
- **Each** router participating in the protocol **builds a full topology map** of the network and uses this map to independently determine the **shortest path to each network**

# Link State Routing

1. Each router learns about its own links, its own directly connected networks.
  - This is done by detecting that an interface is in the up state.
2. Each router is responsible for meeting its neighbors on directly connected networks.
  - link state routers do this by exchanging Hello packets with other link-state routers on directly connected networks
3. Each router builds a Link-State Packet (LSP) containing the state of each directly connected link.
  - This is done by recording all the pertinent information about each neighbor, including neighbor ID, link type, and bandwidth

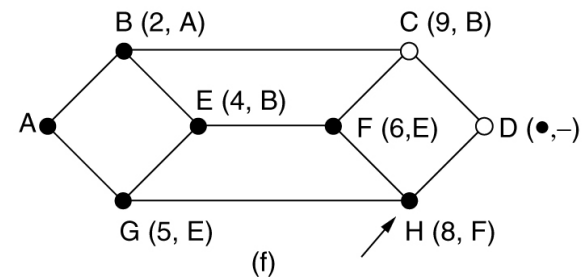
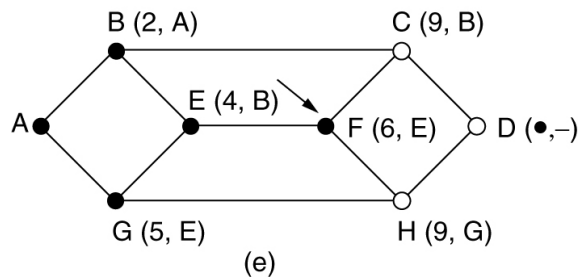
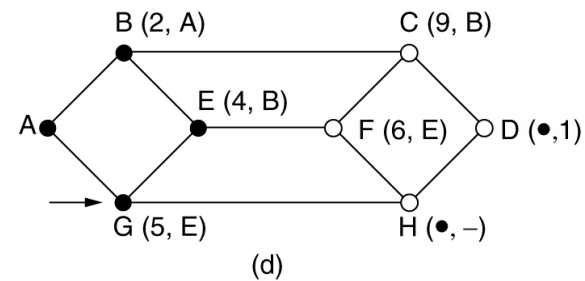
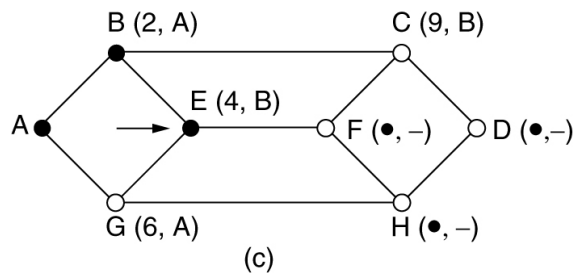
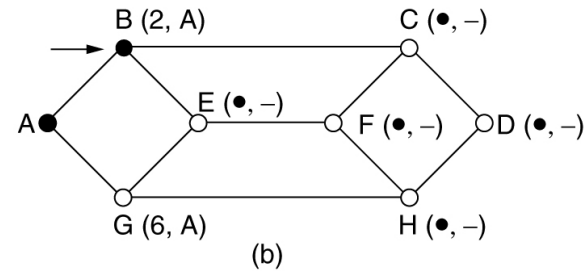
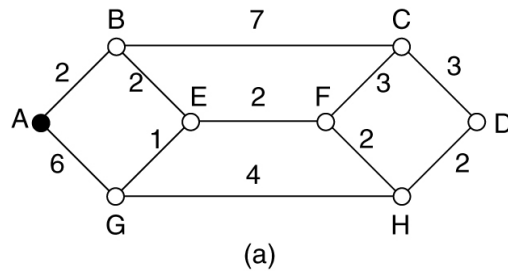
# Link State Routing

4. Each router floods the LSP to all neighbors, who then store all LSPs received in a database.
  - Each router stores a copy of each LSP received from all the routers in its area in a local database
5. Each router uses the database to construct a complete map of the topology and computes the best path to each destination network.
  - The SPF algorithm is used to construct the map of the topology and to determine the best path to each network.

# Flooding

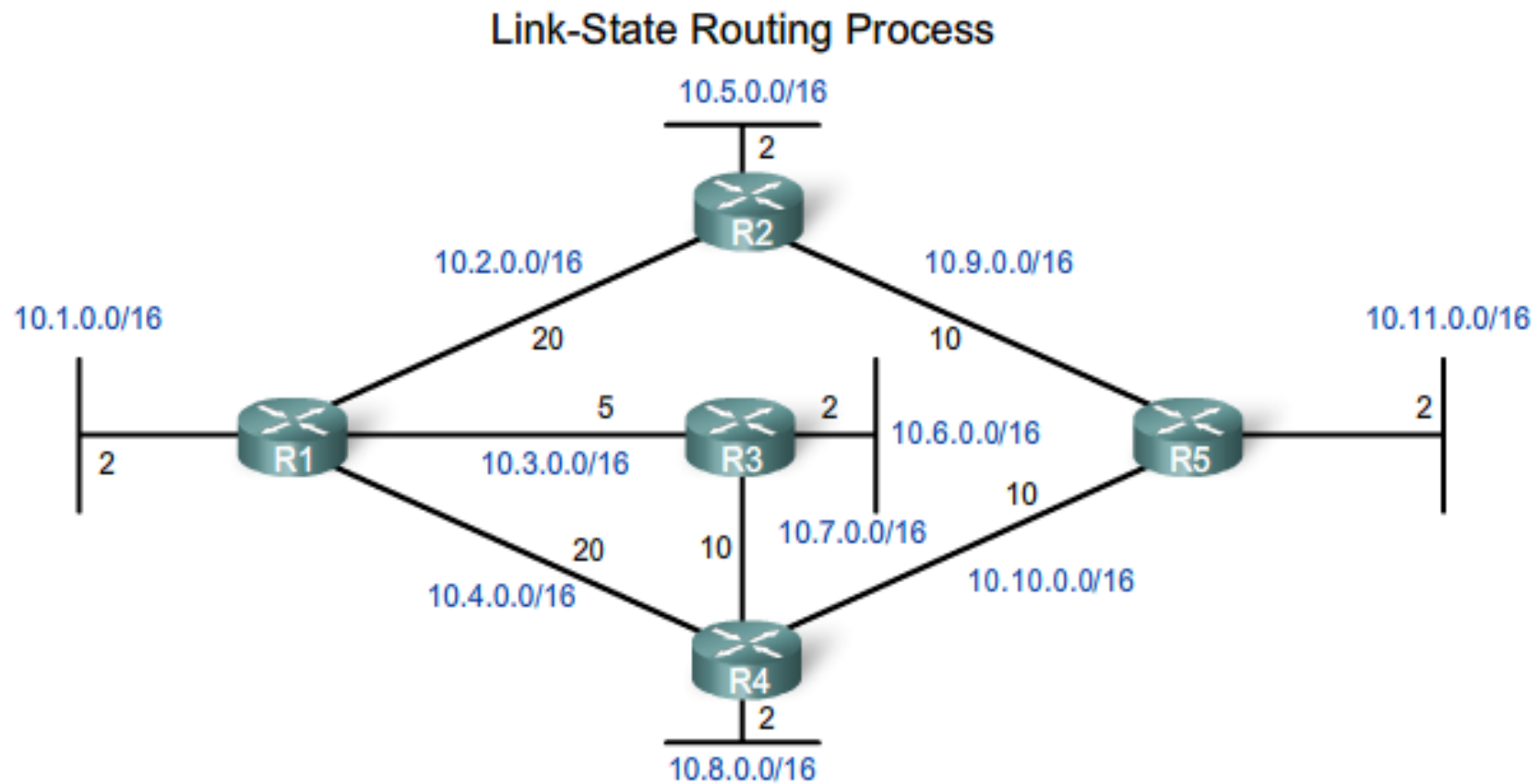
- LSPs are delivered to all routers in the area using Flooding.
- In Flooding, every incoming packet is sent on every outgoing line except the one it arrived on.
- Each router manages a list per source router telling which sequence numbers originating at that source have already been seen. If an incoming packet is on the list it is not flooded.
- To prevent the list from growing without bound, it is augmented by a counter  $k$ , meaning that all sequence numbers below  $k$  have been seen.

# Shortest Path Routing

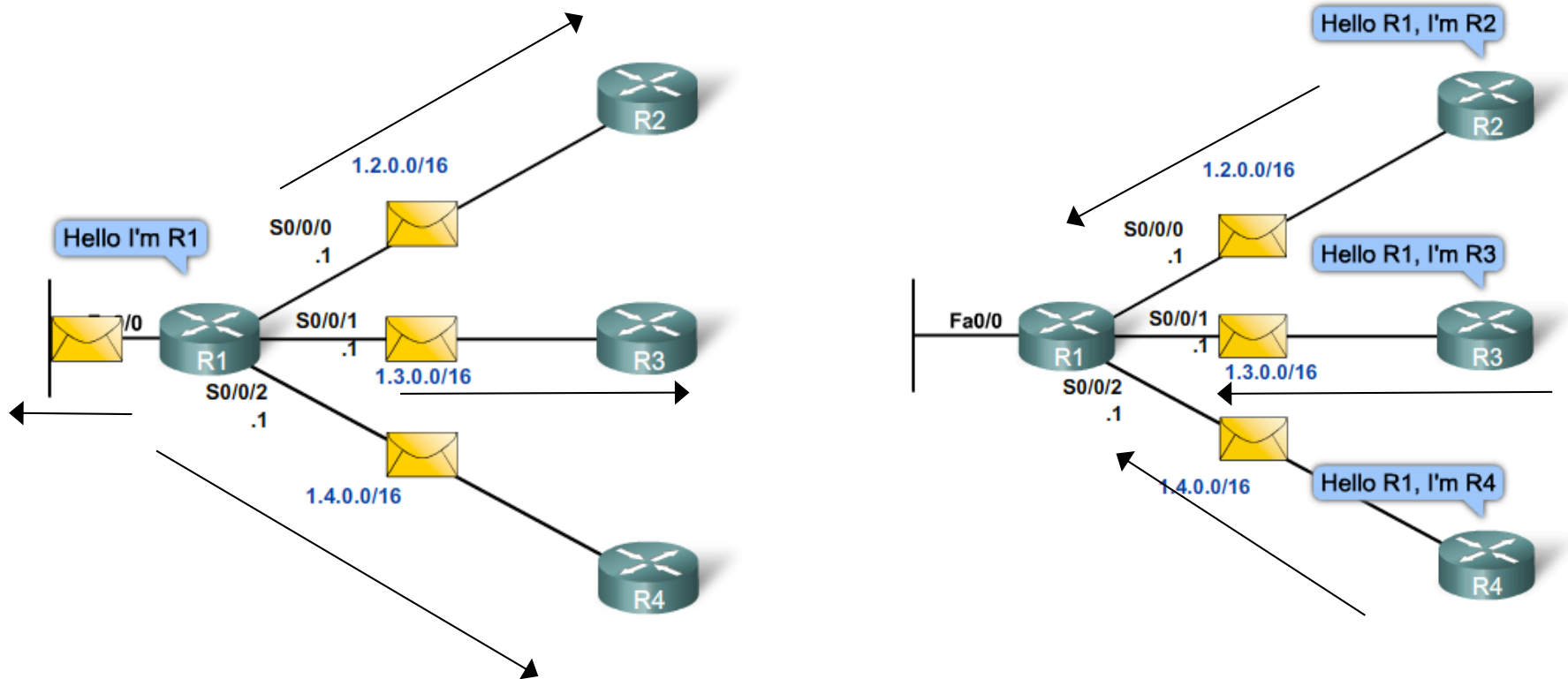


The first 5 steps used in computing the shortest path from A to D.  
The arrows indicate the working node.

# Example Topology



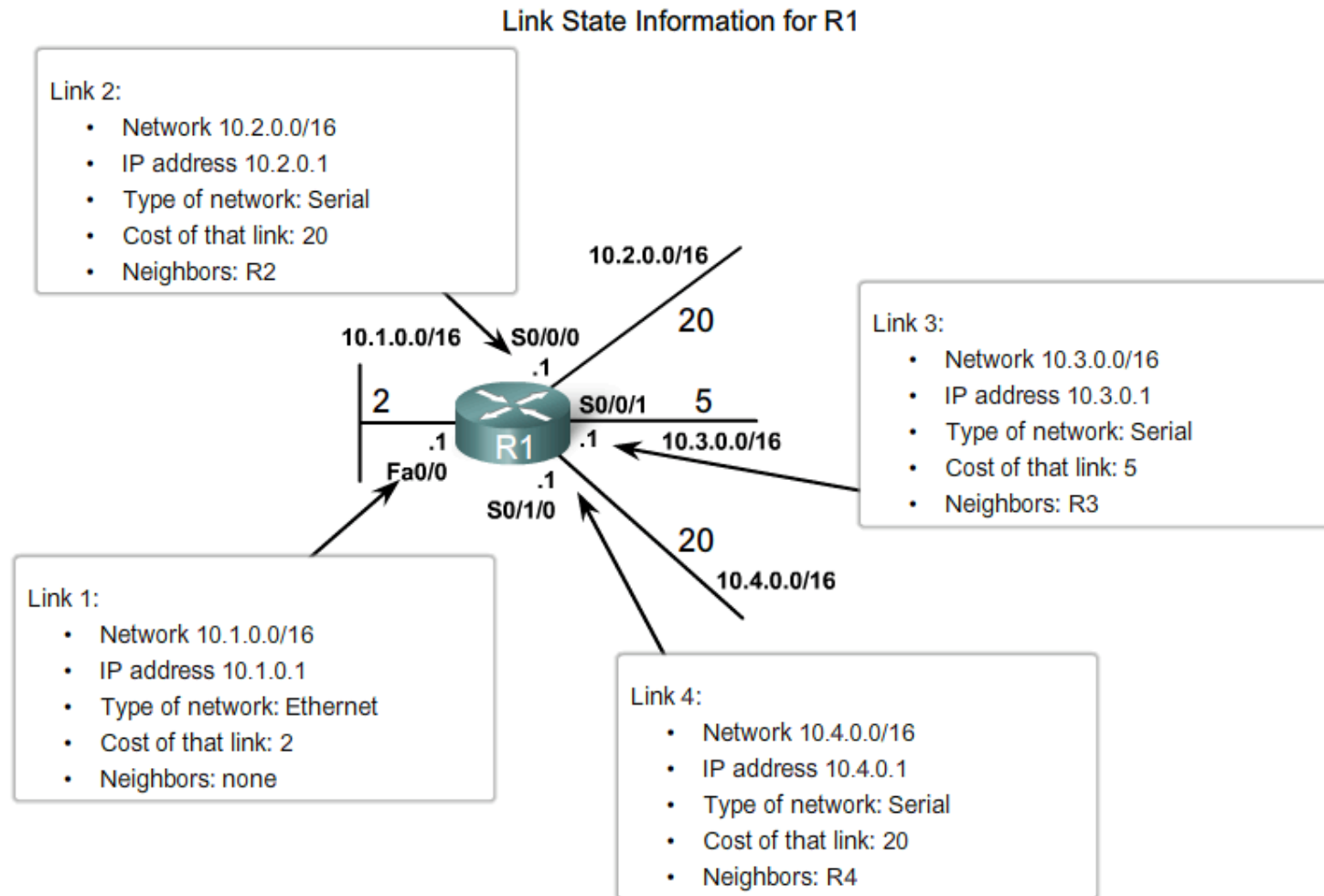
# Learning about the Neighbors



Special HELLO packets are used to discover neighbors

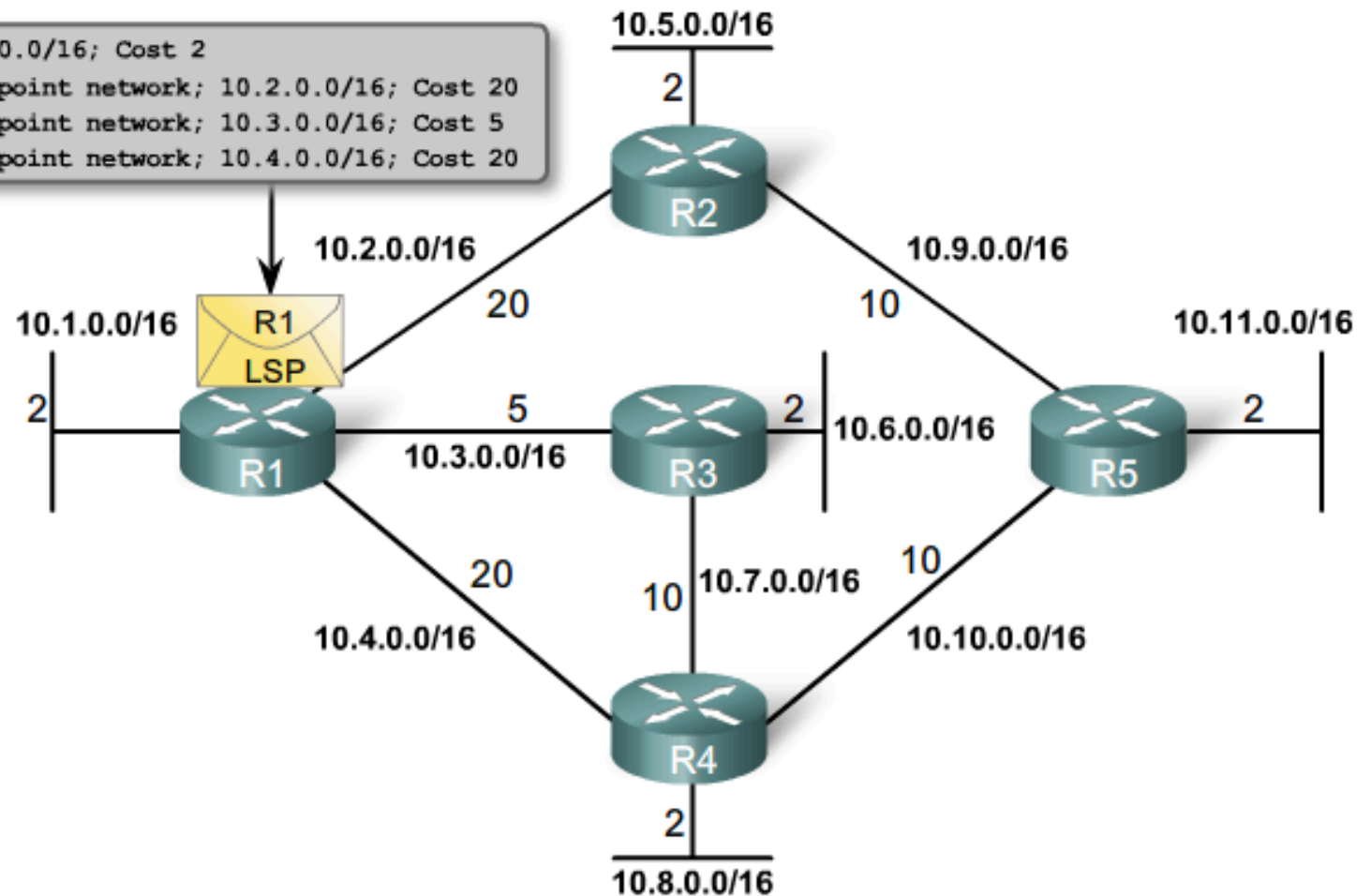


# Link State Advertisements (LSA)



# Building Link State Packets

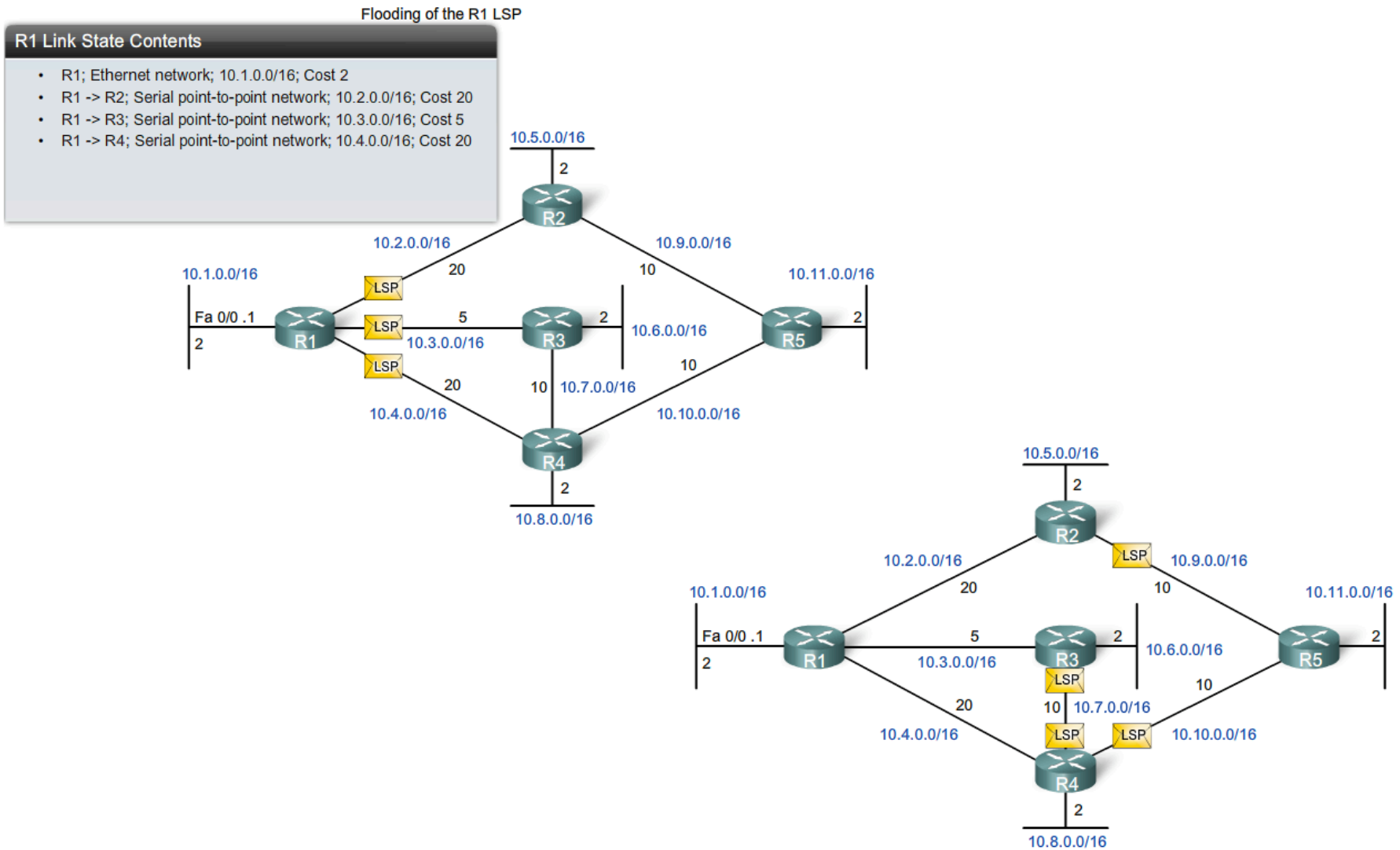
1. R1; Ethernet network 10.1.0.0/16; Cost 2
2. R1 -> R2; Serial point-to-point network; 10.2.0.0/16; Cost 20
3. R1 -> R3; Serial point-to-point network; 10.3.0.0/16; Cost 5
4. R1 -> R4; Serial point-to-point network; 10.4.0.0/16; Cost 20



# Distributing the Link State Packets

- Use flooding to distribute link state packets
- Each packet contains a sequence number and each router keep track of all the (source router, Seq.) they see:
  - If it is new it is forwarded in all lines except the one in which it was received.
  - If it is a duplicate is discarded.
  - If it has a lower Seq. number it is discarded because it's outdated.
- Sequence numbers are 32 bits to avoid them from wrapping around.

# Distributing the Link State Packets



# Building 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

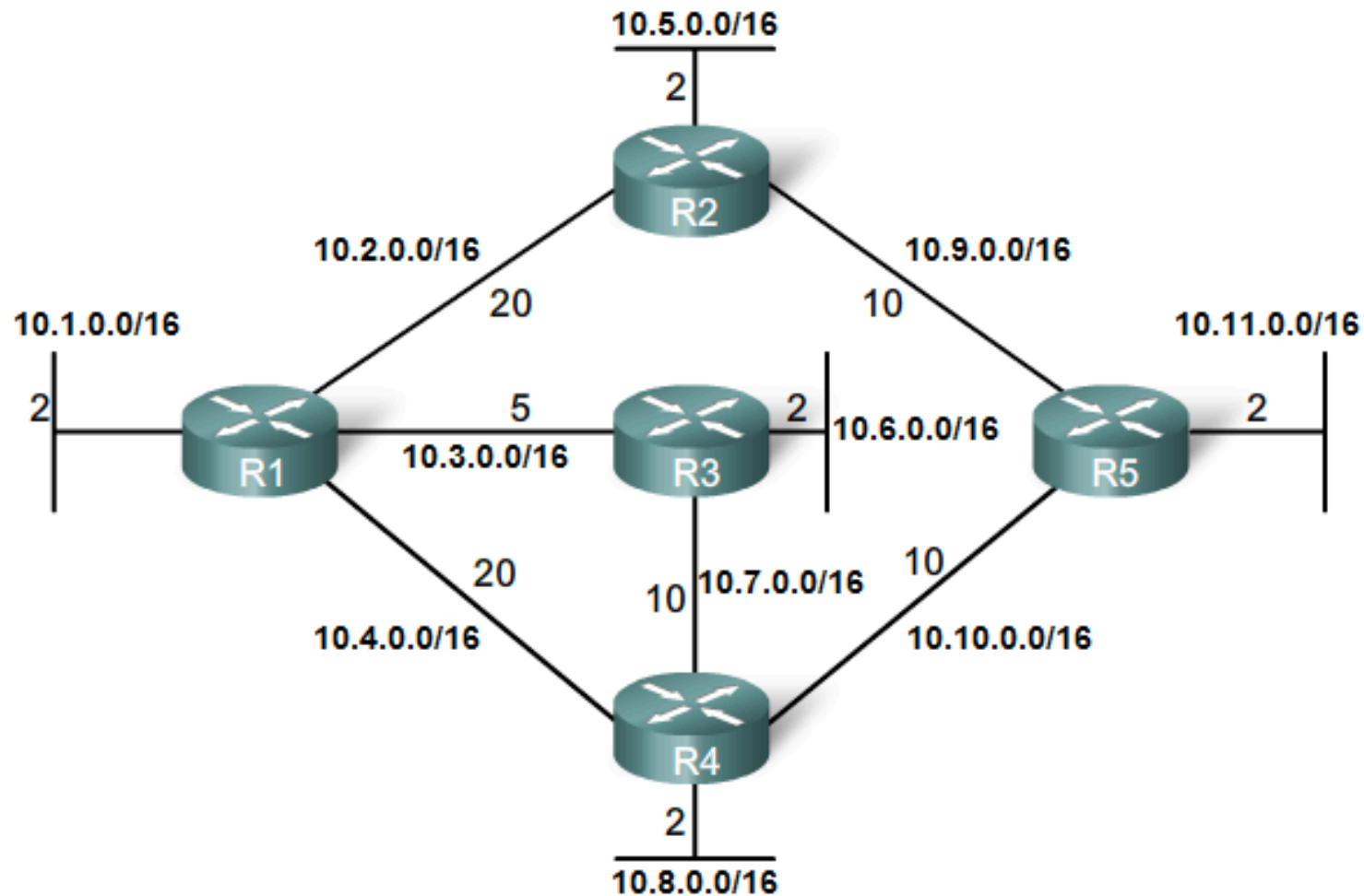
### LSPs from R5:

- 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:

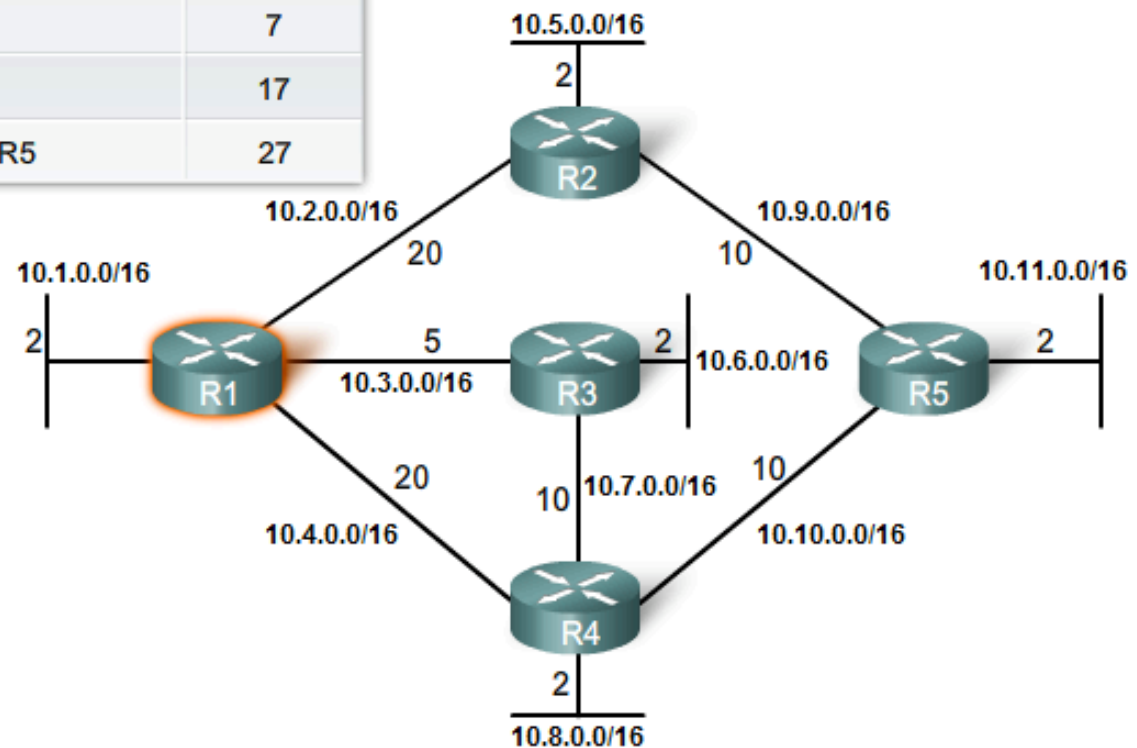
- Connected to neighbor R2 on network 10.2.0.0/16, cost of 20
- Connected to neighbor R3 on network 10.3.0.0/16, cost of 5
- Connected to neighbor R4 on network 10.4.0.0/16, cost of 20
- Has a network 10.1.0.0/16, cost of 2

# Creating the Topology Map



# Shortest Path First Tree

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



# Building 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

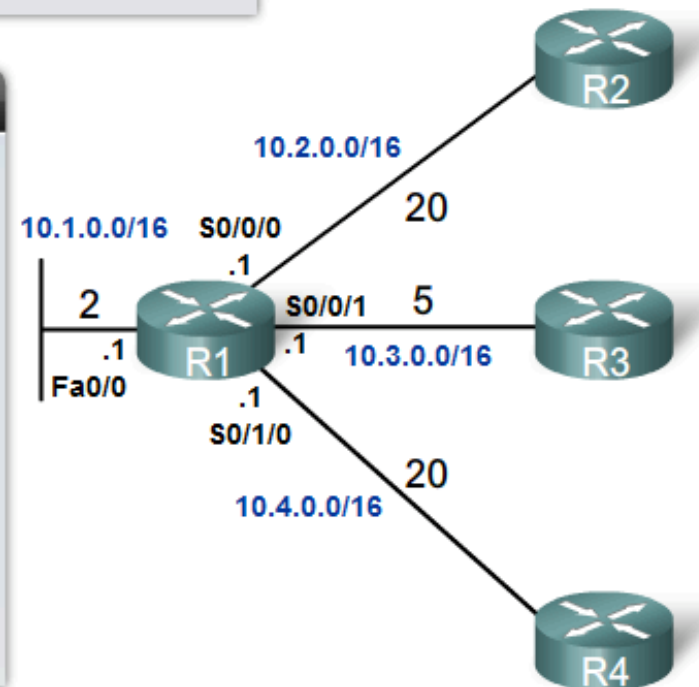
## R1 Routing Table

### 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 Protocols

- Advantages
  - Each router builds a topology map
  - The SPF algorithm can build an SPF tree of the network.
  - Using the SPF tree, each router can independently determine the shortest path to every network.
  - Fast Convergence: link-state routing protocols immediately flood the LSP out all interfaces except for the interface from which the LSP was received
  - Event-driven Updates: After the initial flooding of LSPs, link-state routing protocols only send out an LSP when there is a change in the topology. The LSP contains only the information regarding the affected link.