Internet Routing

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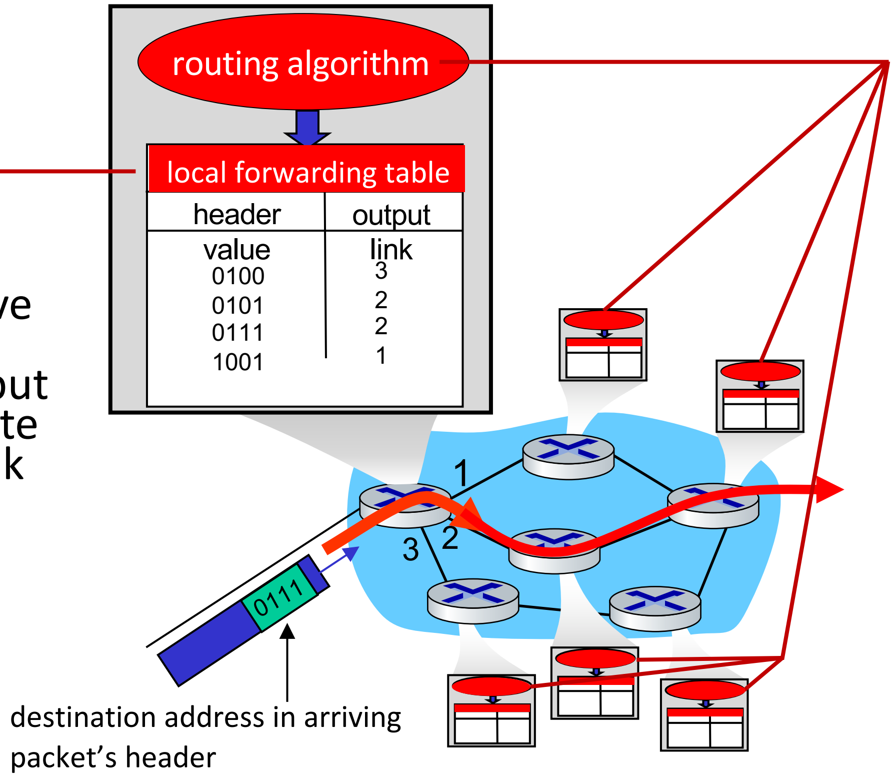
Routing Concepts

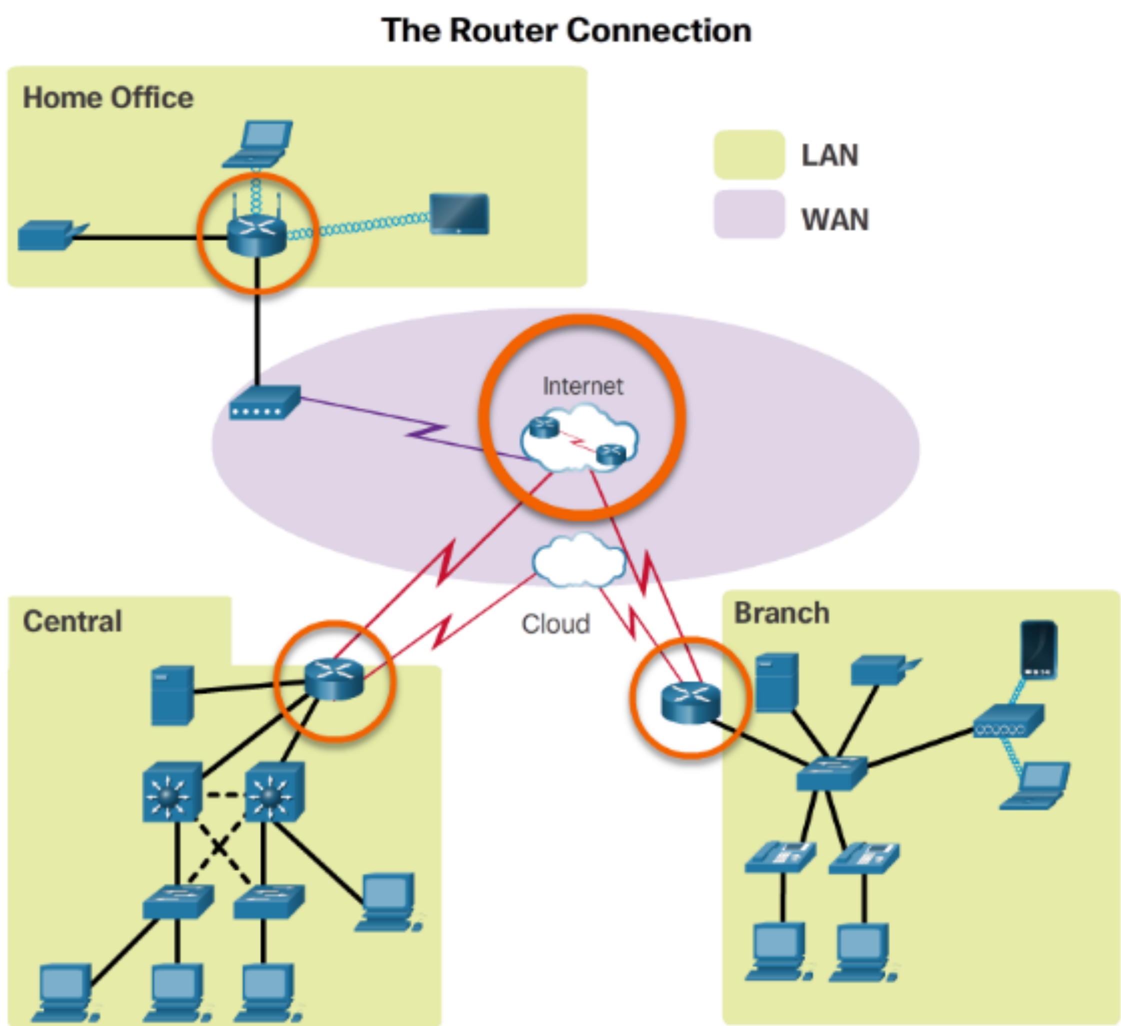
Two key network-core functions

Forwarding:
- aka “switching”
- *local* action: move arriving packets from router’s input link to appropriate router output link



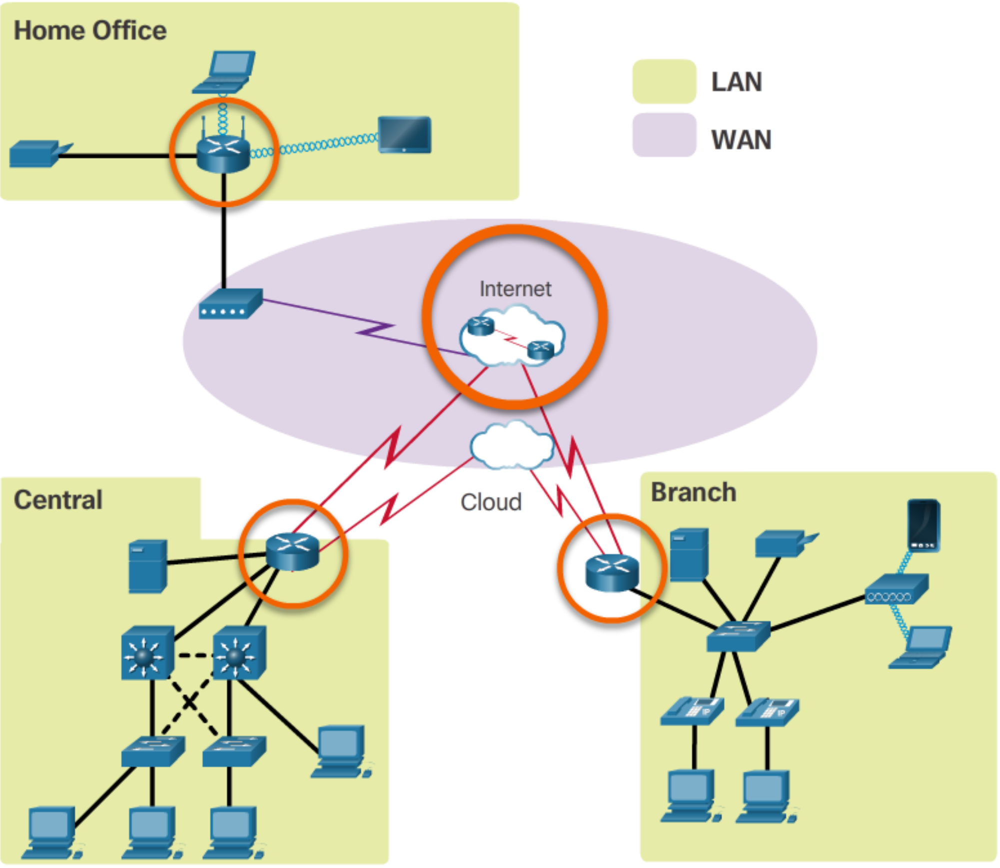
Routing:
- *global* action: determine source-destination paths taken by packets
- routing algorithms

Routers Interconnect Networks



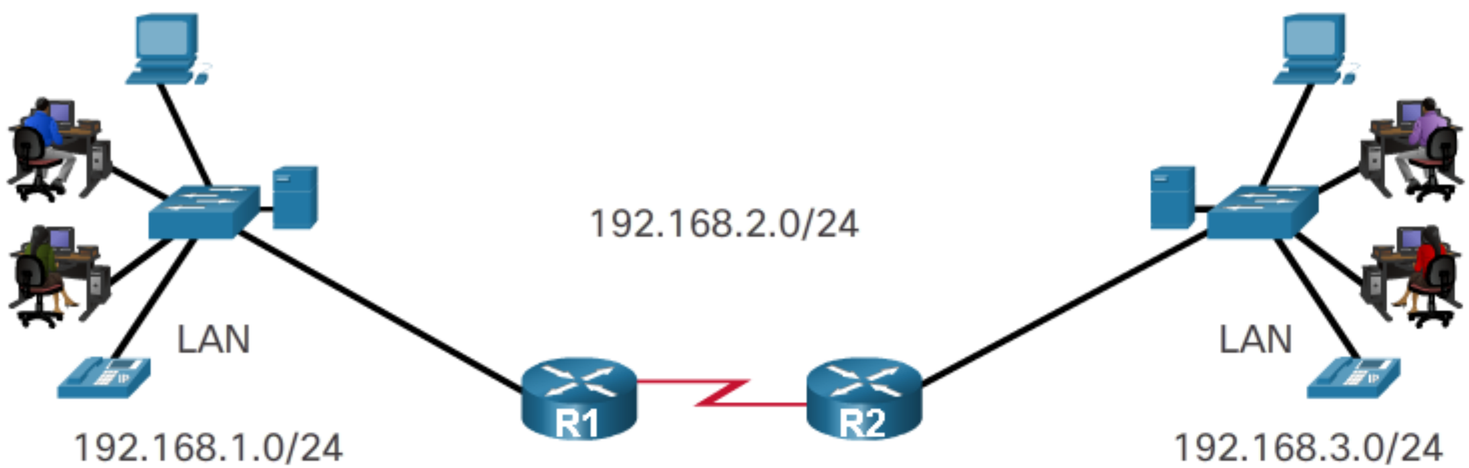
Router Functions

The router is responsible for the routing of traffic between networks.

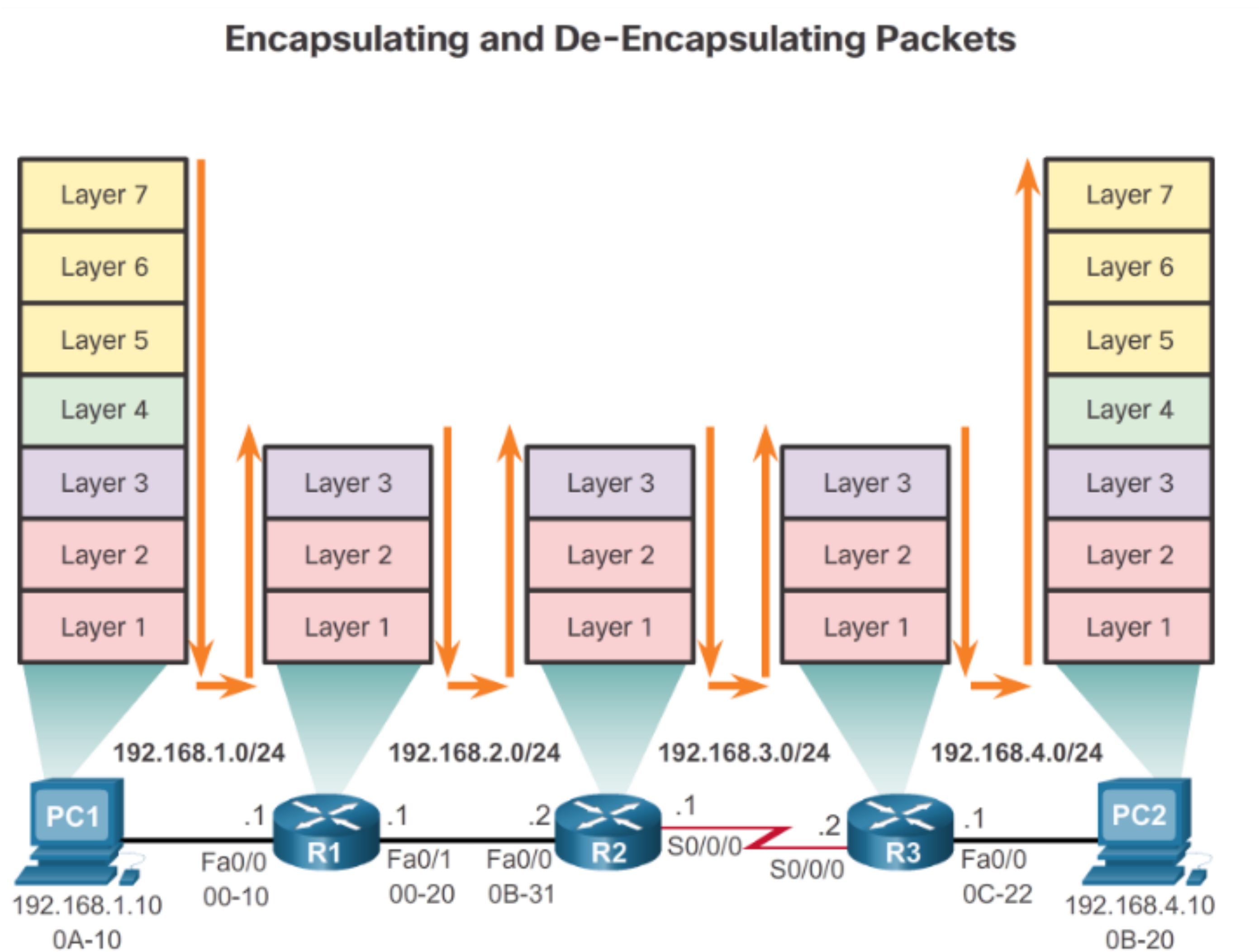


Routers Choose Best Paths

- Routers use static routes and dynamic routing protocols to learn about remote networks and build their routing tables.
- Routers use routing tables to determine the best path to send packets.
- Routers encapsulate the packet and forward it to the interface indicated in routing table.

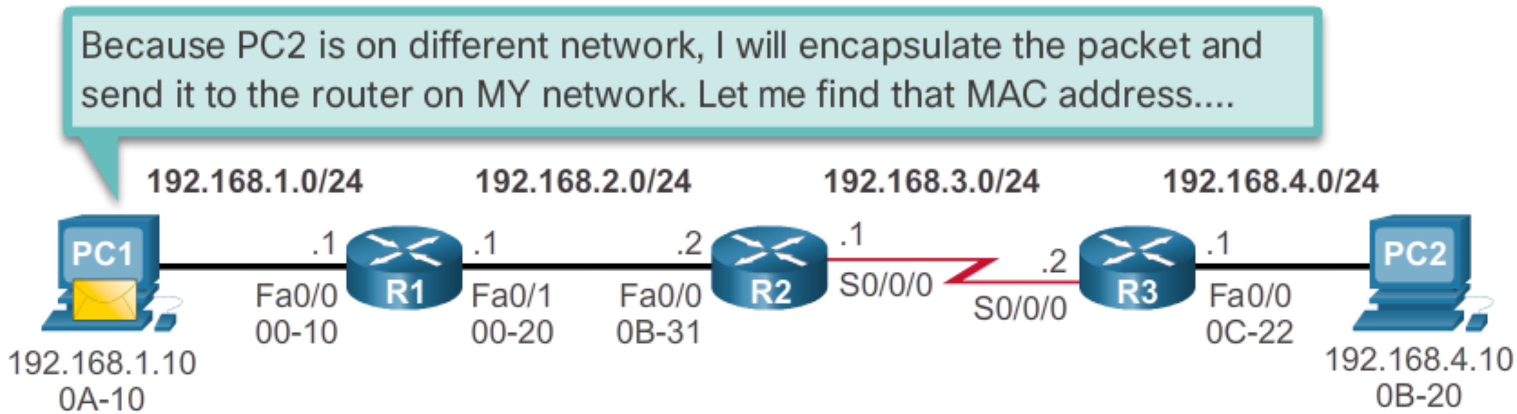


Router Switching Function



Send a Packet

PC1 Sends a Packet to PC2



Layer 2 Data Link Frame | **Packet's Layer 3 data**

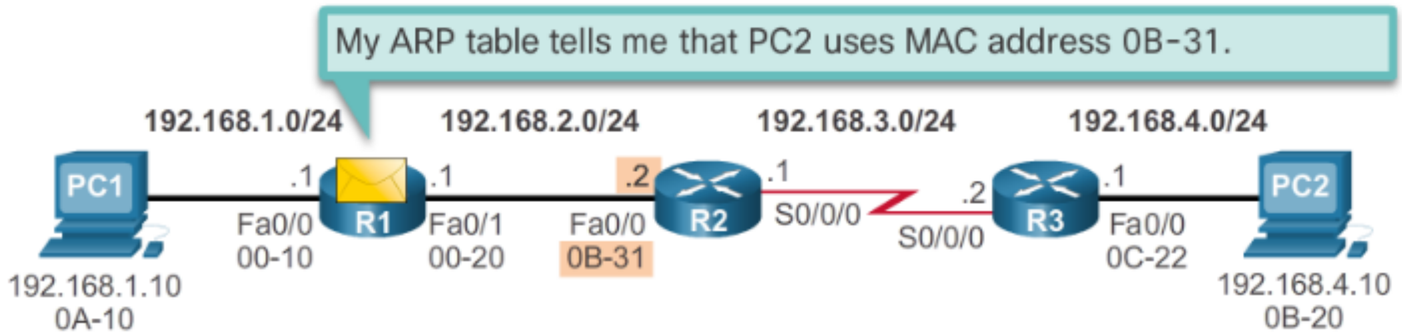
Dest. MAC 00-10	Source MAC 0A-10	Type 0x800	Source IP 192.168.1.10	Dest. IP 192.168.4.10	IP fields	Data	Trailer

PC1's ARP Cache for R1

IP Address	MAC Address
192.168.1.1	00-10

Forward to Next Hop

R1 Forwards the Packet to PC2



Layer 2 Data Link Frame **Packet's Layer 3 data**

Dest. MAC 0B-31		Type 0x800	Source IP 192.168.1.10	Dest. IP 192.168.4.10	IP fields	Data	Trailer

R1's ARP Cache

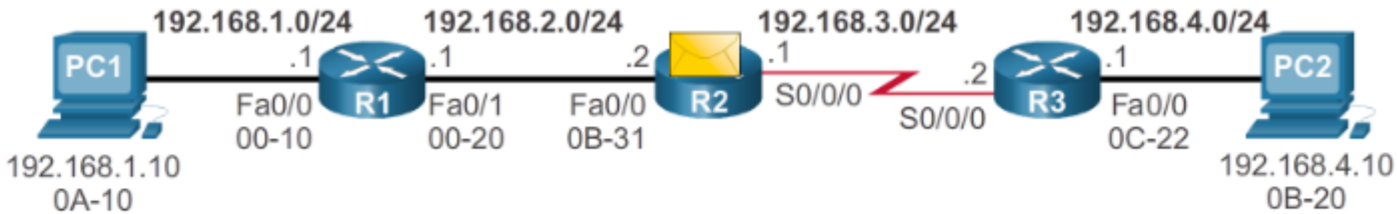
IP Address	MAC Address
192.168.2.2	0B-31

R1's Routing Table

Network	Hops	Next-hop-IP	Exit Interface
192.168.1.0/24	0	Dir. Connect.	Fa0/0
192.168.2.0/24	0	Dir. Connect.	Fa0/1
192.168.3.0/24	1	192.168.2.2	Fa0/1
192.168.4.0/24	2	192.168.2.2	Fa0/1

Packet Routing

R2 Forwards the Packet to R3



Layer 2 Data Link Frame **Packet's Layer 3 data**

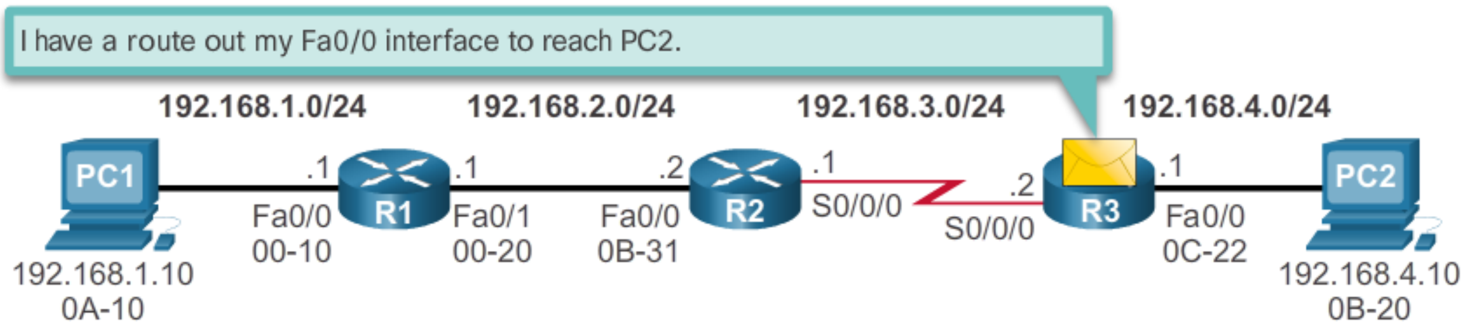
			Source IP 192.168.1.10	Dest. IP 192.168.4.10	IP fields	Data	Trailer

R2's Routing Table

Network	Hops	Next-hop-IP	Exit Interface
192.168.1.0/24	1	192.168.3.1	Fa/0/0
192.168.2.0/24	0	Dir. Connect.	Fa/0/0
192.168.3.0/24	0	Dir. Connect.	S0/0/0
192.168.4.0/24	1	192.162.3.2	S0/0/0

Reach the Destination

R3 Forwards the Packet to PC2



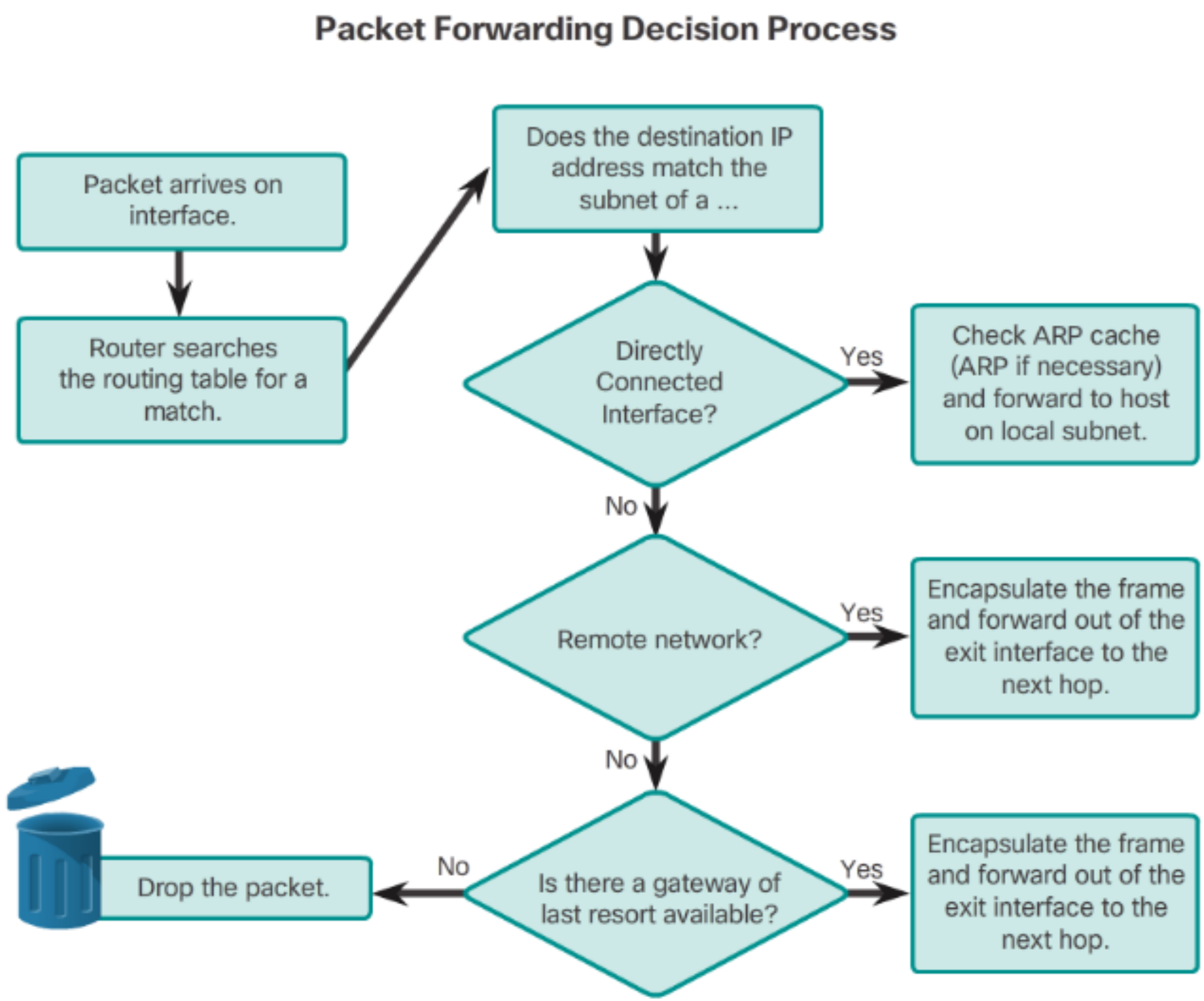
Layer 2 Data Link Frame **Packet's Layer 3 data**

		Type 0x800	**Source IP 192.168.1.10**	**Dest. IP 192.168.4.10**	**IP fields**	**Data**	Trailer

R3's Routing Table

Network	Hops	Next-hop-IP	Exit Interface
192.168.1.0/24	2	192.168.3.1	S0/0/0
192.168.2.0/24	1	192.168.3.1	S0/0/0
192.168.3.0/24	0	Dir. Connect.	S0/0/0
192.168.4.0/24	**0**	Dir. Connect.	**Fa0/0**

Routing Decisions

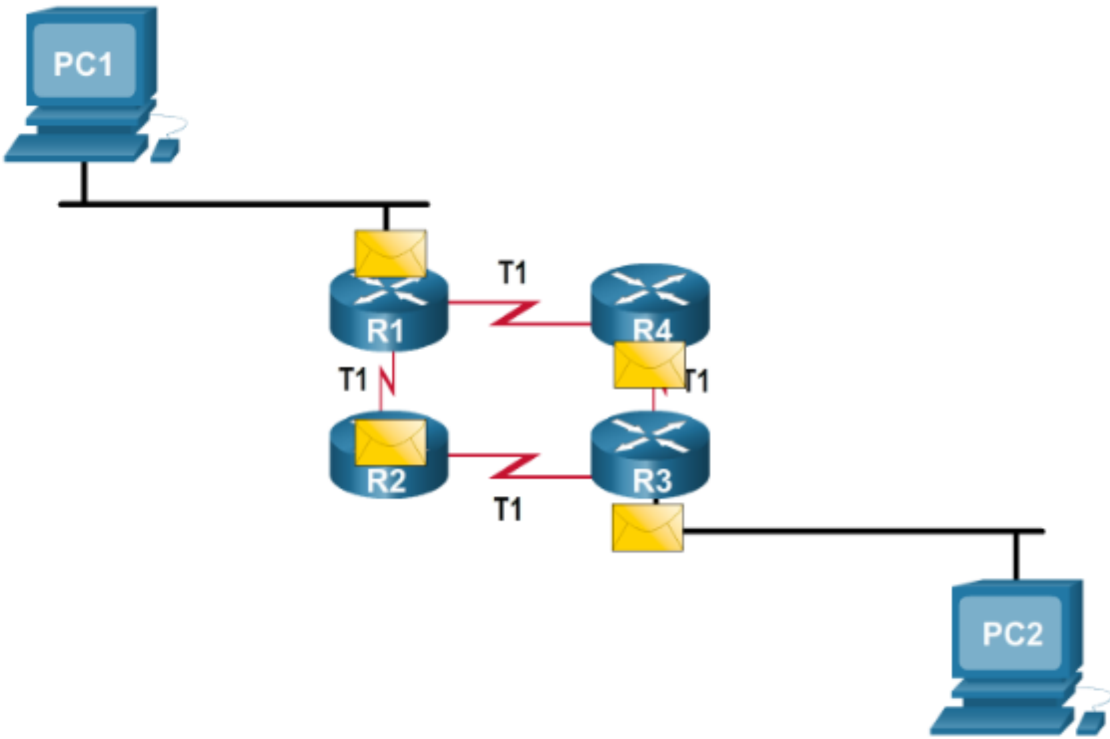


Best Path

- **Best path is selected by a routing protocol based on the value or metric it uses to determine the distance to reach a network**:
  - A metric is the value used to measure the distance to a given network.
  - Best path to a network is the path with the lowest metric.
- **Dynamic routing protocols use their own rules and metrics to build and update routing tables**:
  - Routing Information Protocol (RIP) - Hop count
  - Open Shortest Path First (OSPF) - Cost based on cumulative bandwidth from source to destination
  - Enhanced Interior Gateway Routing Protocol (EIGRP) - Bandwidth, delay, load, reliability

Load Balancing

- When a router has two or more paths to a destination with equal cost metrics, then the router forwards the packets using both paths equally:
  - Equal cost load balancing can improve network performance.
  - Equal cost load balancing can be configured to use both dynamic routing protocols and static routes.



Administrative Distance

- If multiple paths to a destination are configured on a router, the path installed in the routing table is the one with the lowest Administrative Distance (AD):
  - A static route with an AD of 1 is more reliable than an EIGRP-discovered route with an AD of 90.
  - A directly connected route with an AD of 0 is more reliable than a static route with an AD of 1.

Route Source	Administrative Distance
Connected	0
Static	1
EIGRP summary route	5
External BGP	20
Internal EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
RIP	120
External EIGRP	170
Internal BGP	200

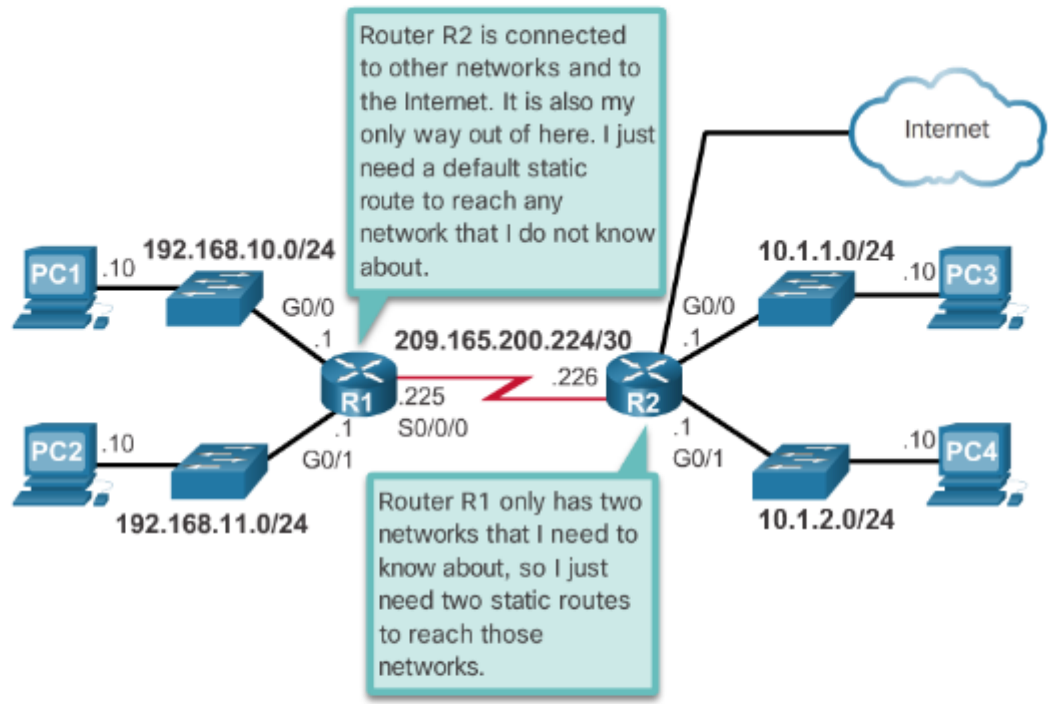
Static Routing

Reach Remote Networks

A router can learn about remote networks in one of two ways:

- **Manually** - Remote networks are manually entered into the route table using static routes.
- **Dynamically** - Remote routes are automatically learned using a dynamic routing protocol.

Static and Default Route Scenario



Why Use Static Routing?

Static routing provides some advantages over dynamic routing, including:

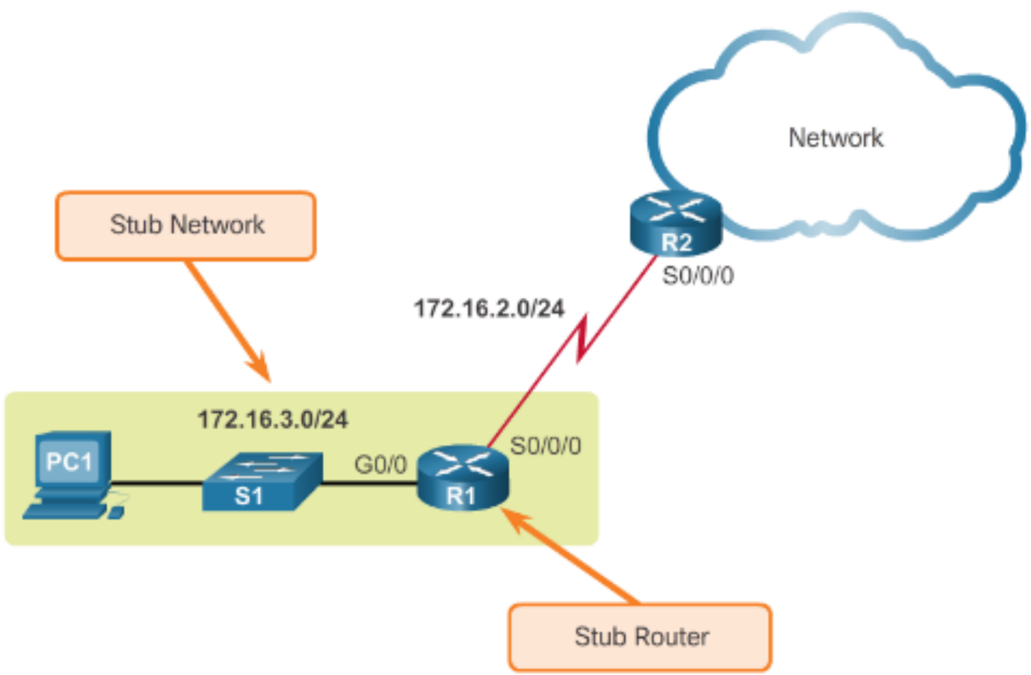
- Static routes are not advertised over the network, resulting in better security.
- Static routes use less bandwidth than dynamic routing protocols, no CPU cycles are used to calculate and communicate routes.
- The path a static route uses to send data is known.

	Dynamic Routing	Static Routing
Configuration Complexity	Generally independent of the network size	Increases with network size
Topology Changes	Automatically adapts to topology changes	Administrator intervention required
Scaling	Suitable for simple and complex topologies	Suitable for simple topologies
Security	Less secure	More secure
Resource Usage	Uses CPU, memory, link bandwith	No extra resources needed
Predictability	Route depends on the current topology	Route to destination is always the same

When to Use Static Routes

Static routing has three primary uses:

- Providing ease of routing table maintenance in smaller networks.
- Routing to and from stub networks. A stub network is a network accessed by a single route, and the router has no other neighbors.
- Using a single default route to represent a path to any network that does not have a more specific match with another route in the routing table.

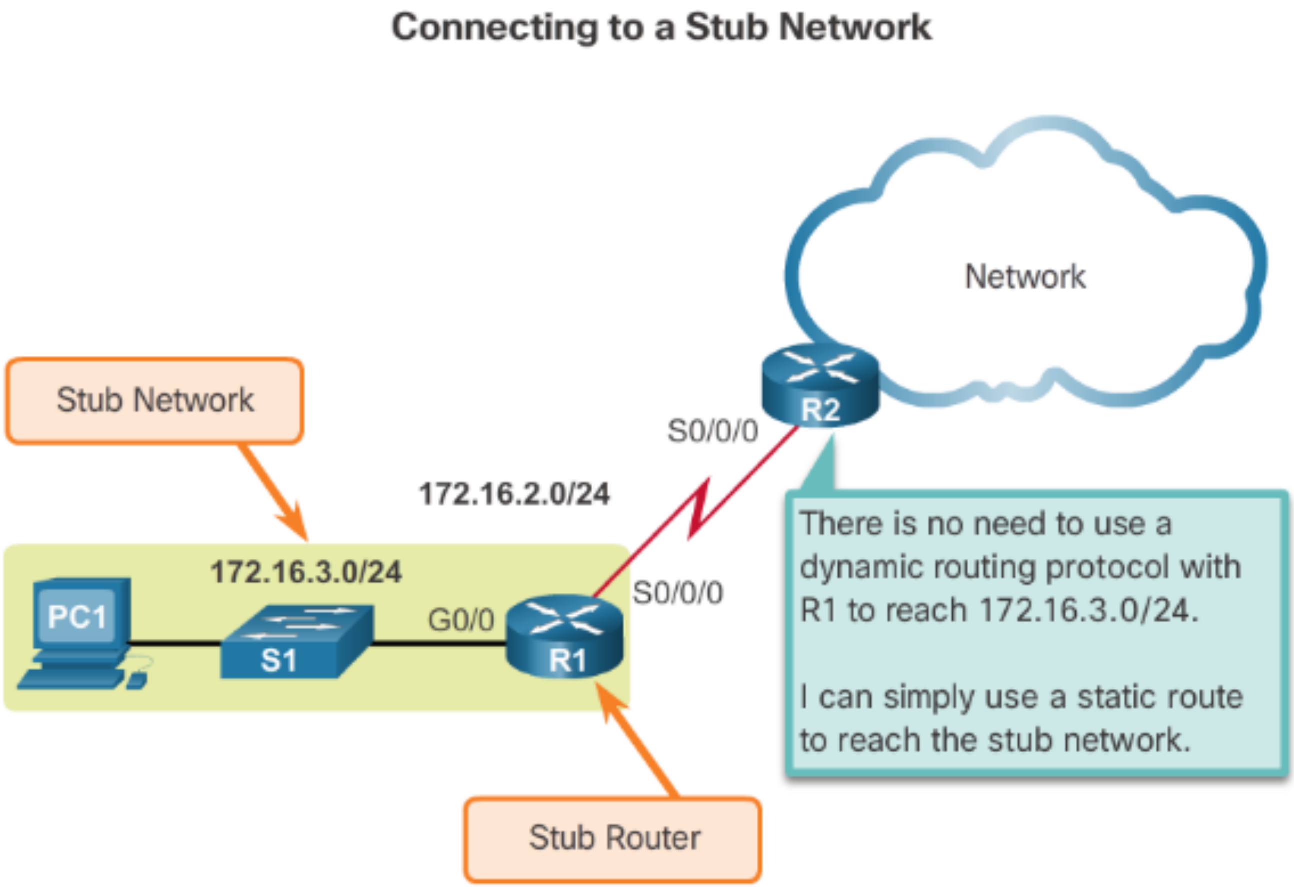


Static Route Applications

Static Routes are often used to:

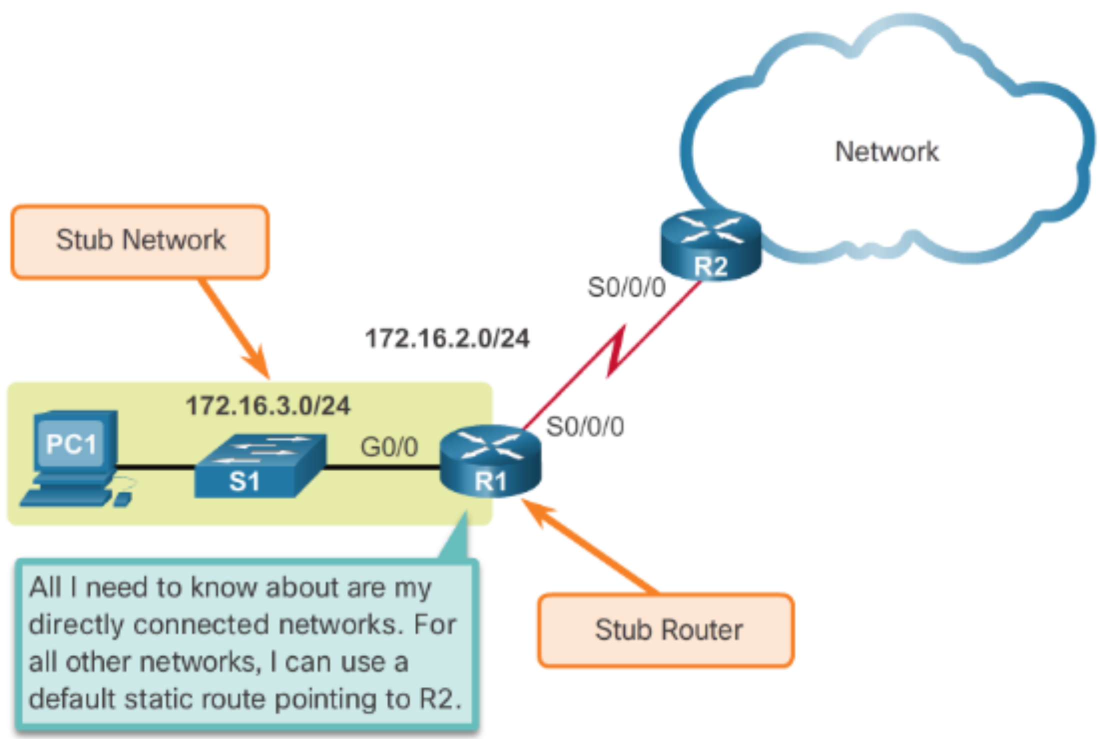
- Connect to a specific network.
- Provide a Gateway of Last Resort for a stub network.
- Reduce the number of routes advertised by summarizing several contiguous networks as one static route.
- Create a backup route in case a primary route link fails.

Standard Static Route

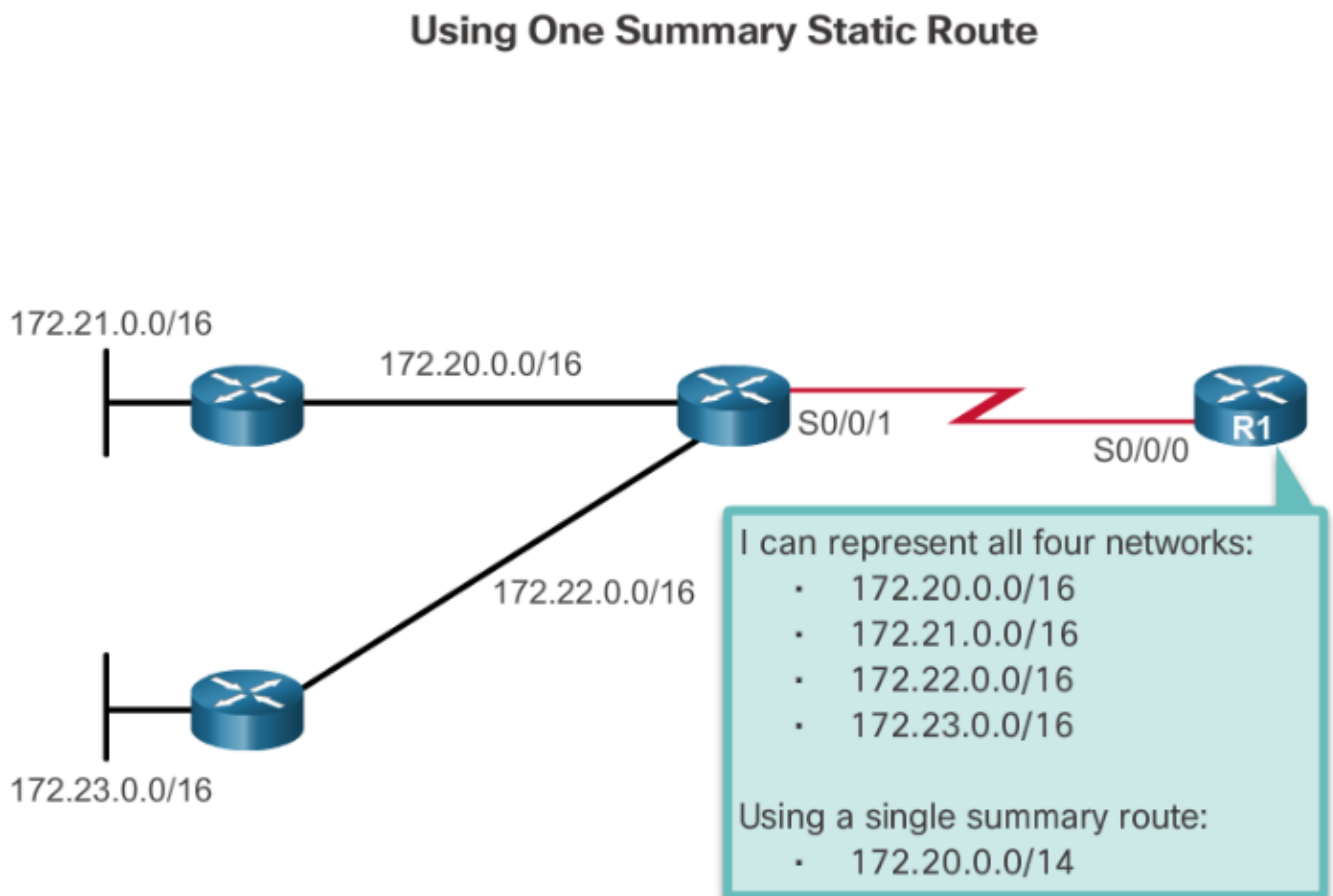


Default Static Route

- A default static route is a route that matches all packets.
- A default route identifies the gateway IP address to which the router sends all IP packets that it does not have a learned or static route.
- A default static route is simply a static route with 0.0.0.0/0 as the destination IPv4 address.



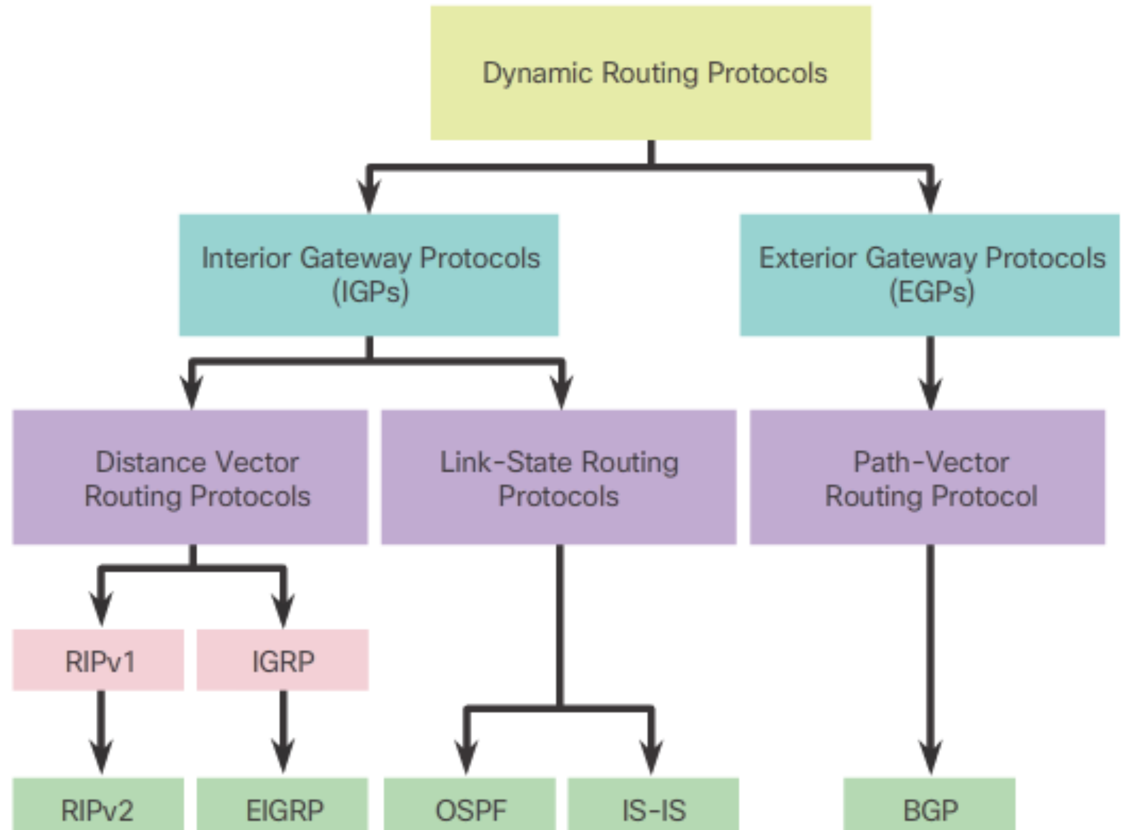
Summary Static Route



Dynamic Routing

Dynamic Routing Protocol Evolution

- Dynamic routing protocols have been used in networks since the late 1980s.
- Newer versions support the communication based on IPv6.



Dynamic Routing Protocols Components

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 the current path is no longer available

Dynamic Routing Protocols Components

Main components of dynamic routing protocols include:

- **Data structures -** Routing protocols typically use tables or databases for its operations. This information is kept in RAM.
- **Routing protocol messages -** Routing protocols use various types of messages to discover neighboring routers, exchange routing information, and other tasks to learn and maintain accurate information about the network.
- **Algorithm -** Routing protocols use algorithms for facilitating routing information for best path determination.

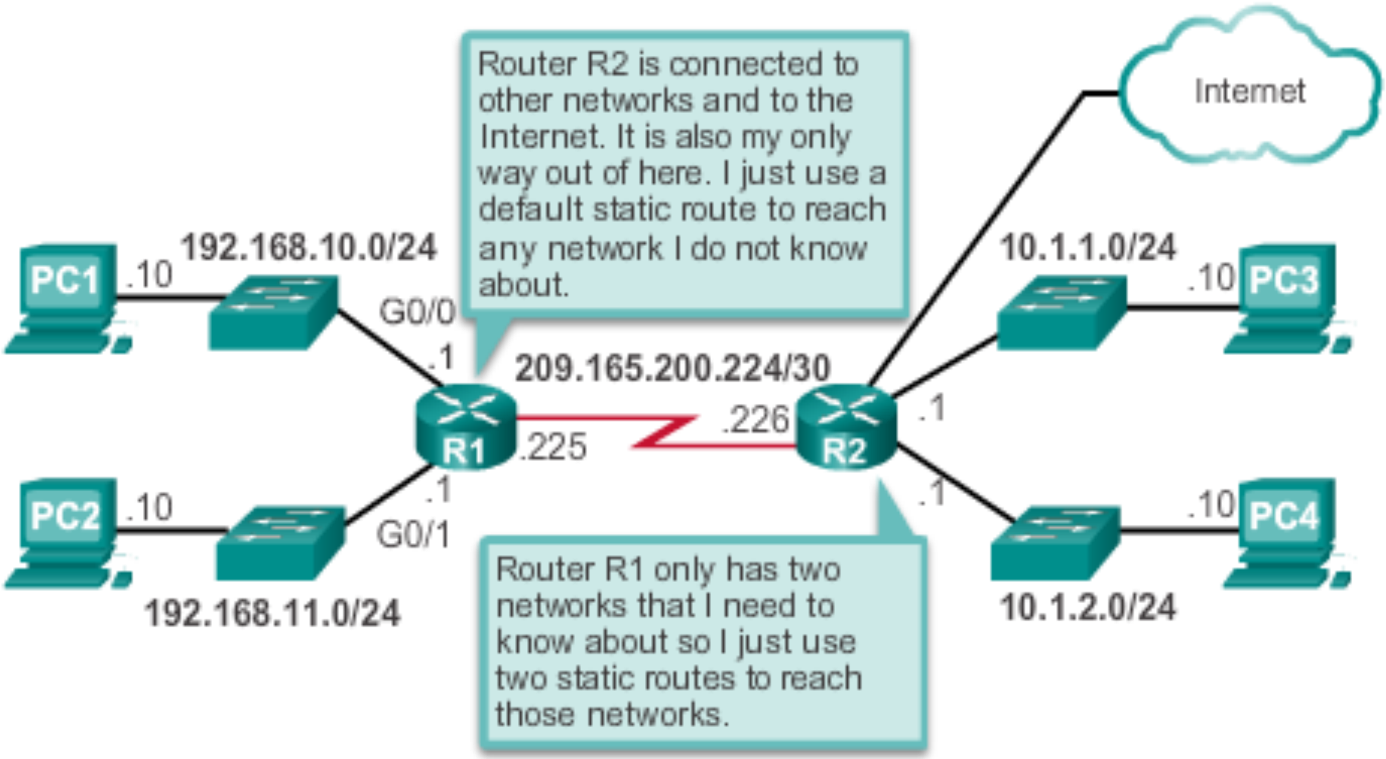
Static Routing Uses

Networks typically use a combination of both static and dynamic routing.

Static routing has several primary uses:

- Providing ease of routing table maintenance in smaller networks that are not expected to grow significantly.
- Routing to and from a stub network. A network with only one default route out and no knowledge of any remote networks.
- Accessing a single default router. This is used to represent a path to any network that does not have a match in the routing table.

Static Routing Uses (cont.)



Static Routing Advantages and Disadvantages

Advantages	Disadvantages
Easy to implement in a small network.	Suitable only for simple topologies or for special purposes such as a default static route.
Very secure. No advertisements are sent as compared to dynamic routing protocols.	Configuration complexity increases dramatically as network grows.
Route to destination is always the same.	Manual intervention required to re-route traffic.
No routing algorithm or update mechanism required; therefore, extra resources (CPU or RAM) are not required.	

Dynamic Routing Advantages & Disadvantages

Advantages	Disadvantages
Suitable in all topologies where multiple routers are required.	Can be more complex to implement.
Generally independent of the network size.	Less secure. Additional configuration settings are required to secure.
Automatically adapts topology to reroute traffic if possible.	Route depends on the current topology.
	Requires additional CPU, RAM, and link bandwidth.

Interior Gateway Protocols (IGP)

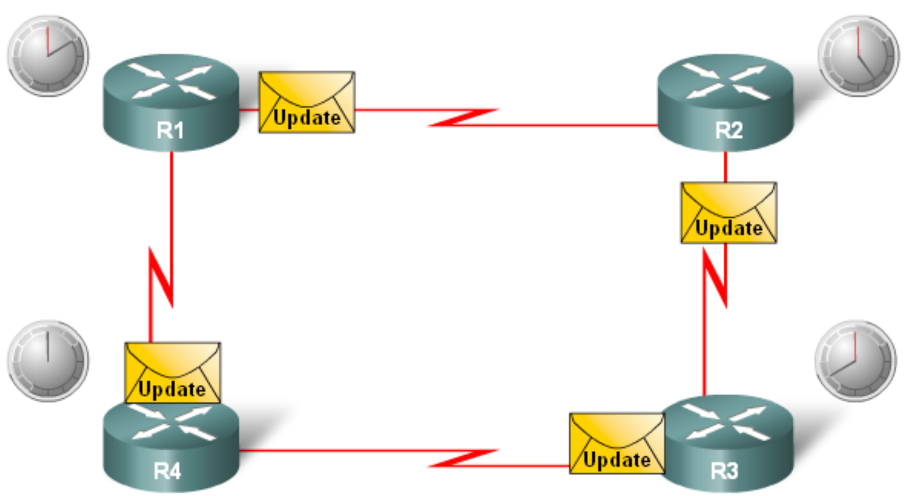
Distance Vector Routing Protocols

Distance Vector Routing Protocols

- **Distance Vector Technology** - the Meaning of Distance Vector
  - A router using distance vector routing protocols knows 2 things:
    - Distance to final destination
    - Vector, or direction, traffic should be directed

Distance Vector Routing Protocols

- **Characteristics of Distance Vector routing protocols**:
  - Periodic updates
  - Neighbors
  - Broadcast updates
  - Entire routing table is included with routing update

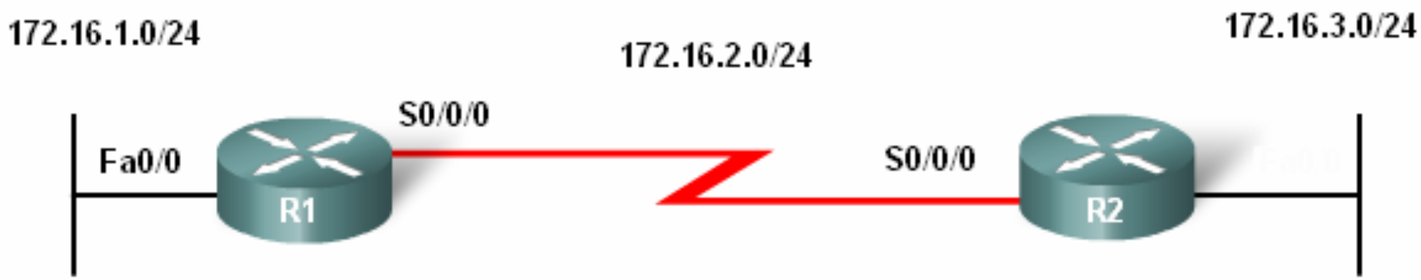


Distance Vector Routing Protocols

- **Routing Protocol Algorithm**:
  - Defined as a procedure for accomplishing a certain task

Purpose of Routing Algorithms

1. Send and Receive Updates
2. Calculate best path; install routes
3. Detect and react to topology changes



Network	Interface	Hope
172.16.1.0/24	Fa0/0	0
172.16.2.0/24	S0/0/0	0
172.16.3.0/24	S0/0/0	1

Network	Interface	Hope
172.16.3.0/24	Fa0/0	0
172.16.2.0/24	S0/0/0	0
172.16.1.0/24	S0/0/0	1

Distance Vector Routing Protocols

- Routing Protocol Characteristics
  - Criteria used to compare routing protocols includes
    - Time to convergence
    - Scalability
    - Resource usage
    - Implementation & maintenance

Distance Vector Routing Protocols

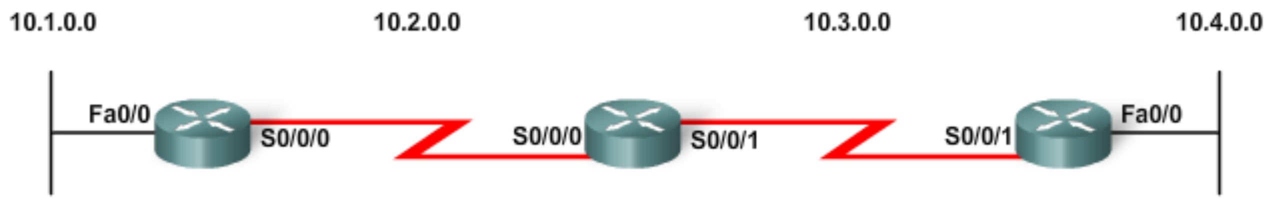
Advantages & Disadvantages of Distance Vector Routing Protocols

Advantages:	Disadvantages:
Simple implementation and maintenance. The level of knowledge required to deploy and later maintain a network with distance vector protocol is not high.	**Slow convergence.** The use of periodic updates can cause slower convergence. Even if some advanced techniques are used, like triggered updates which are discussed later, the overall convergence is still slower compared to link state routing protocols.
Low resource requirements. Distance vector protocols typically do not need large amounts of memory to store the information. Nor do they require a powerful CPU. Depending of the network size and the IP addressing implemented they also typically do not require a high level of link bandwidth to send routing updates. However, this can become an issue if you deploy a distance vector protocol in a large network.	**Limited scalability.** Slow convergence may limit the size of the network because larger networks require more time to propagate routing information.
	Routing loops. Routing loops can occur when inconsistent routing tables are not updated due to slow convergence in a changing network.

Network Discovery

- **Router initial start up** (Cold Starts)
  - **Initial network discovery**
    - Directly connected networks are initially placed in routing table

Network Discovery - Cold Start



Network	Interface	Hop
10.1.0.0	Fa0/0	0
10.2.0.0	S0/0/0	0

Network	Interface	Hop
10.2.0.0	S0/0/0	0
10.3.0.0	S0/0/1	0

Network	Interface	Hop
10.3.0.0	S0/0/1	0
10.4.0.0	Fa0/0	0

Network Discovery

- **Initial Exchange** of Routing Information
  - If a routing protocol is configured then:
    - Routers will exchange routing information
    - Routing updates received from other routers
- Router checks update for new information
  - If there is new information:
    - Metric is updated
    - New information is stored in routing table

Network Discovery - Initial Exchange

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

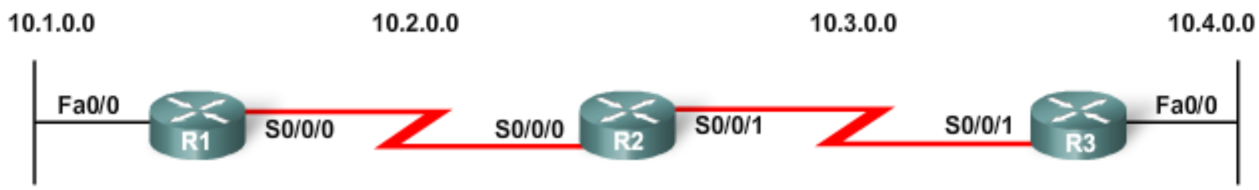
Network	Interface	Hop
10.2.0.0	S0/0/0	0
10.3.0.0	S0/0/1	0
10.1.0.0	S0/0/0	1
10.4.0.0	S0/0/1	1

Network	Interface	Hop
10.3.0.0	S0/0/1	0
10.4.0.0	Fa0/0	0
10.2.0.0	S0/0/1	1

Network Discovery

- **Exchange of Routing Information**
  - **Router convergence** is reached when
    - All routing tables in the network contain the same network information
  - Routers continue to exchange routing information
    - If no new information is found then Convergence is reached

Network Discover - Next Update



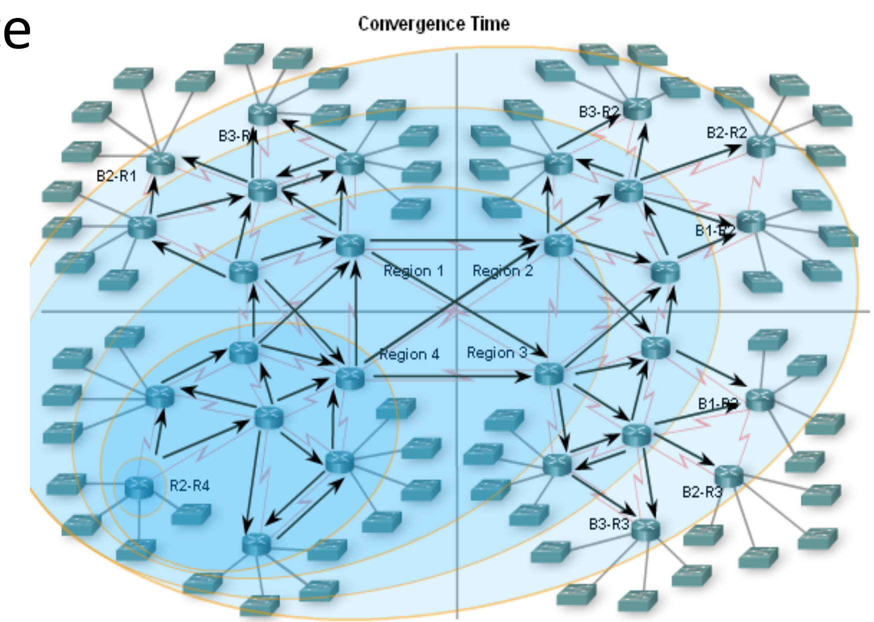
Network	Interface	Hop
10.1.0.0	Fa0/0	0
10.2.0.0	S0/0/0	0
10.3.0.0	S0/0/0	1
10.4.0.0	S0/0/0	2

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

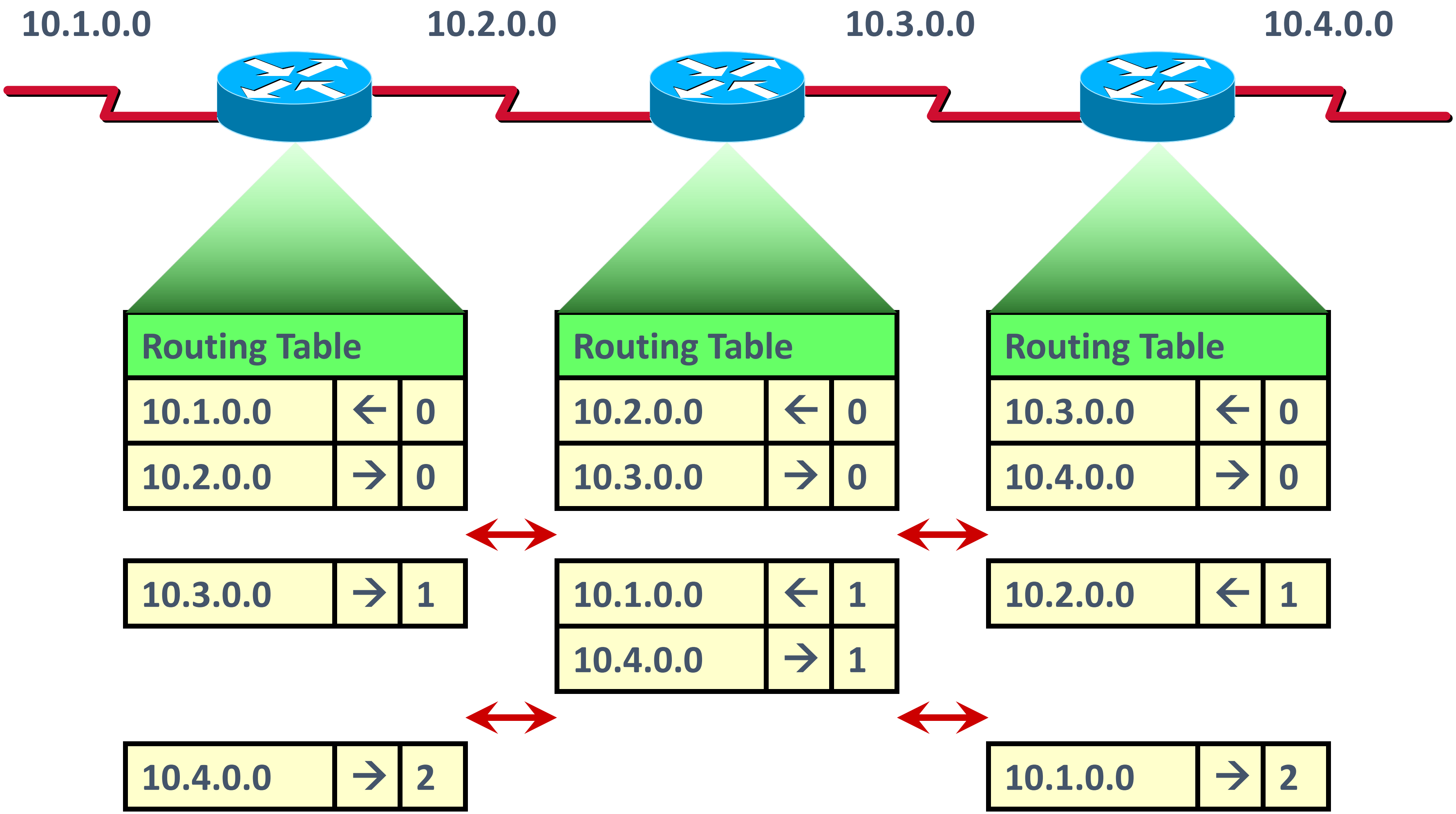
Network	Interface	Hop
10.3.0.0	S0/0/1	0
10.4.0.0	Fa0/0	0
10.2.0.0	S0/0/1	1
10.1.0.0	S0/0/1	2

Network Discovery

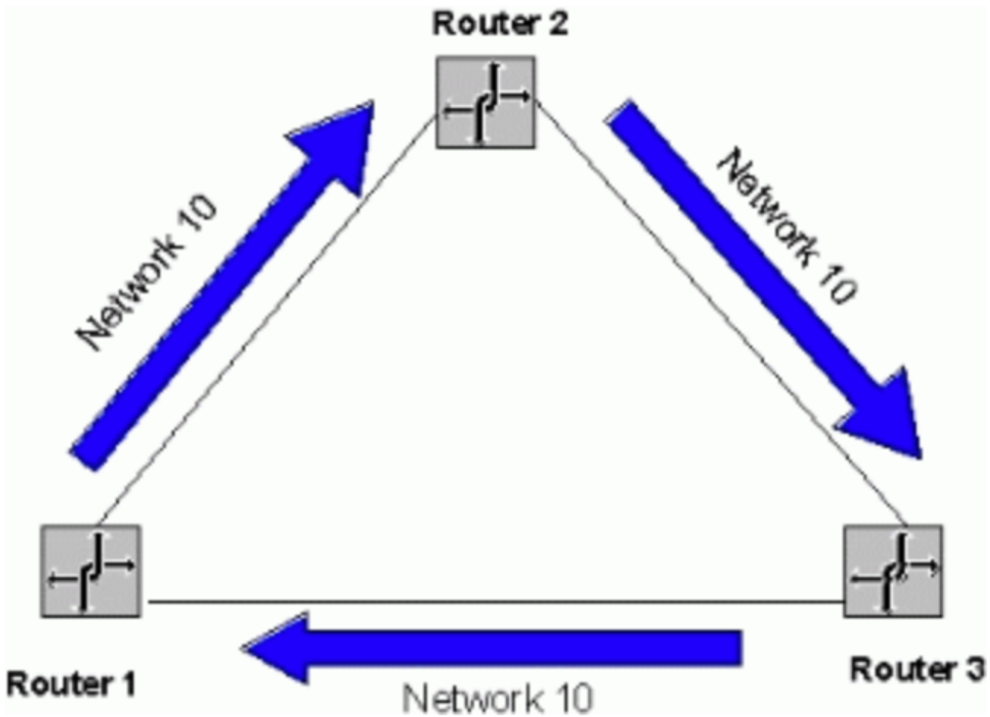
- **Convergence must be reached** before a network is considered completely operable
- Speed of achieving convergence consists of 2 interdependent categories
  - Speed of broadcasting routing information
  - Speed of calculating route



Network Discovery



Routing Loop



Link State Routing Protocols

Link-State Routing

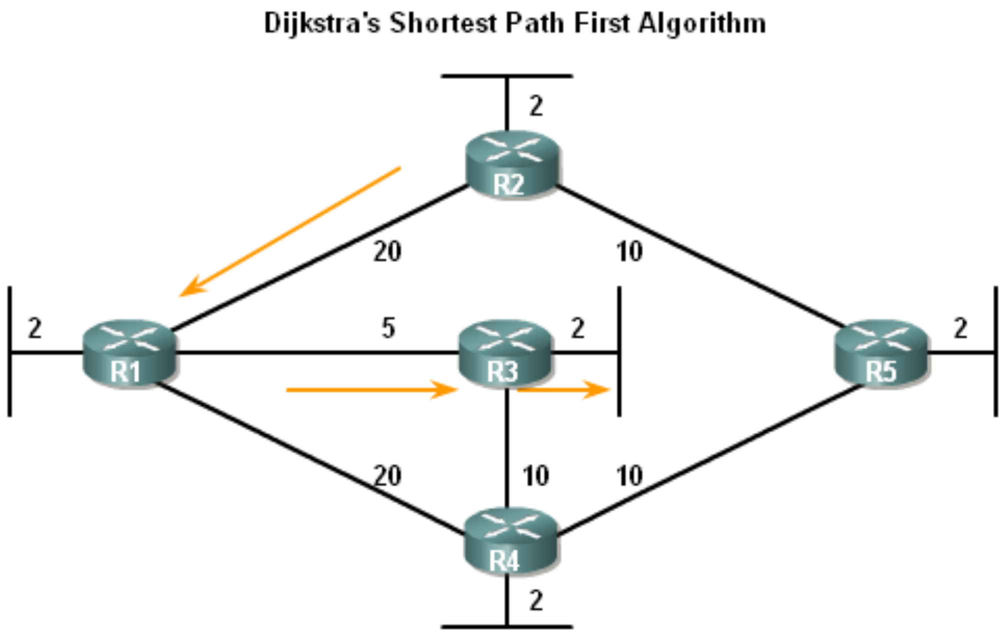
- Link state routing protocols
  - Also known as shortest path first algorithms
  - These protocols built around Dijkstra's SPF

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

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



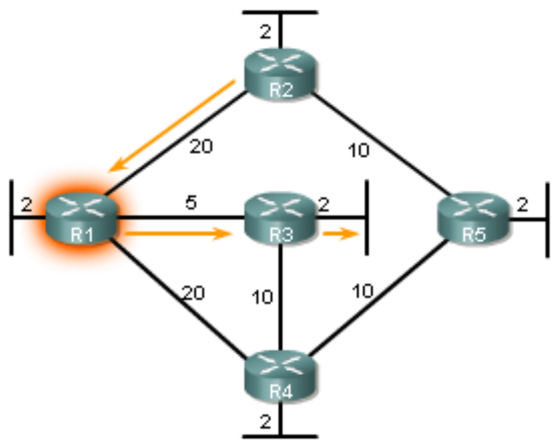
Shortest Path for host on R2 LAN to reach host on R3 LAN:
R2 to R1 (20) + R1 to R3 (5) + R3 to LAN (2) = 27

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



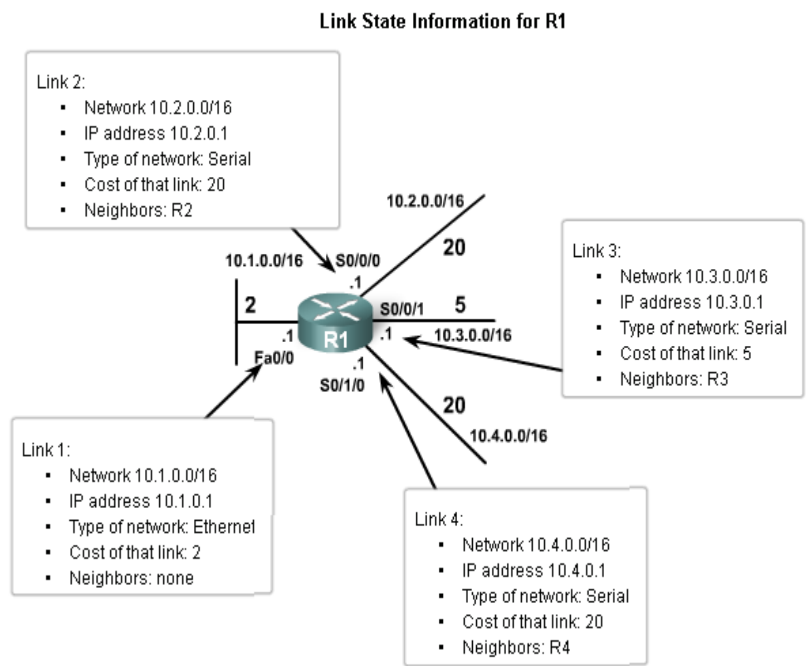
Destination	Shortest Path	Cost
R2 LAN	R1 to R2	22
R3 LAN	R1 to R3	7
R4 LAN	R1 to R3 to R4	17
R5 LAN	R1 to R3 to R4 to R5	27

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

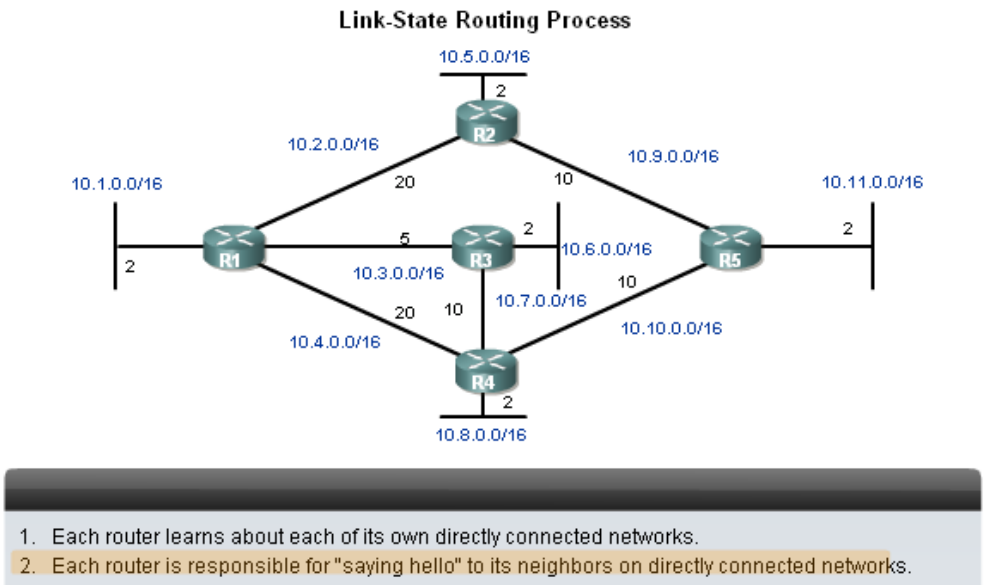
Link-State Routing

- Directly Connected Networks
- Link
  - This is an interface on a router
- Link state
  - This is the information about the state of the links



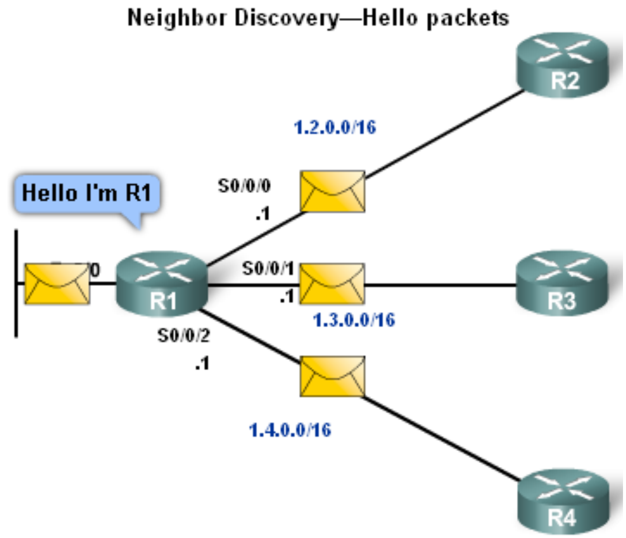
Link-State Routing

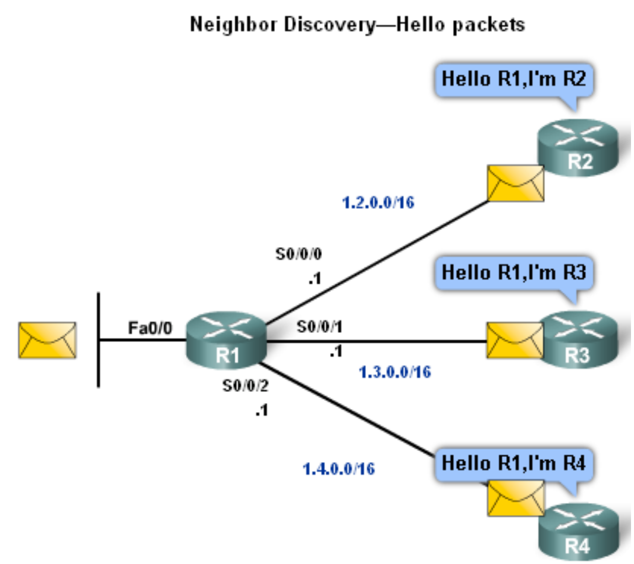
- Sending Hello Packets to Neighbors
  - Link state routing protocols use a hello protocol
  - Purpose of a hello protocol:
    - To discover neighbors (that use the same link state routing protocol) on its link



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



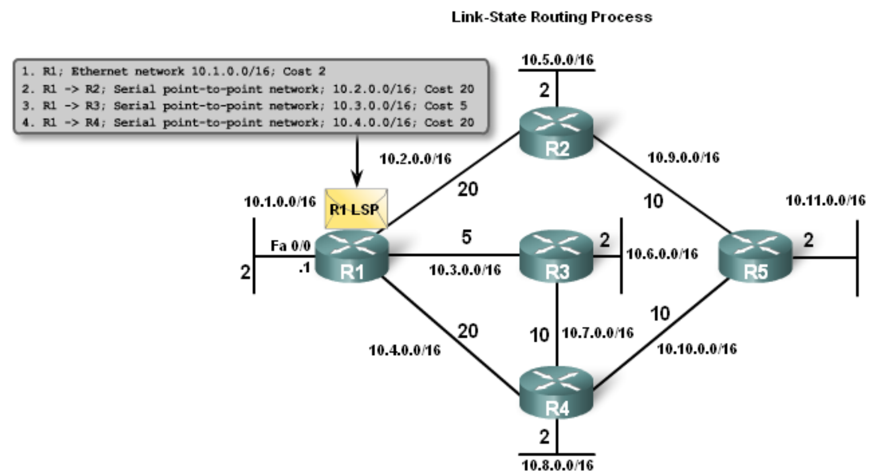


Link-State Routing

- 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

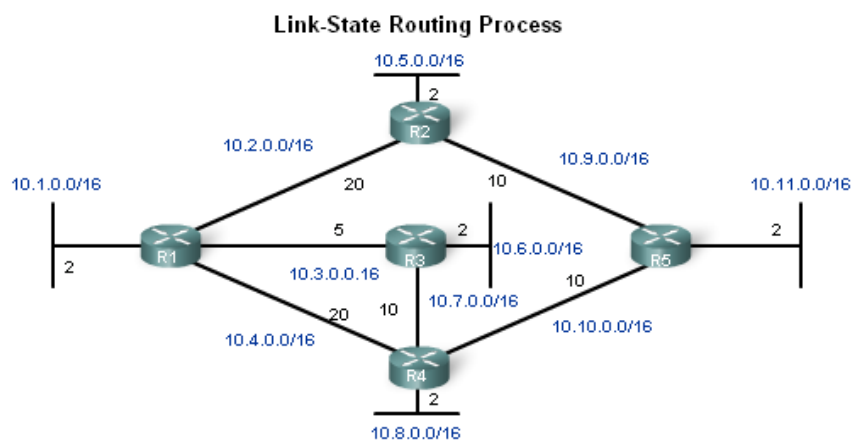
Link-State Routing Process

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

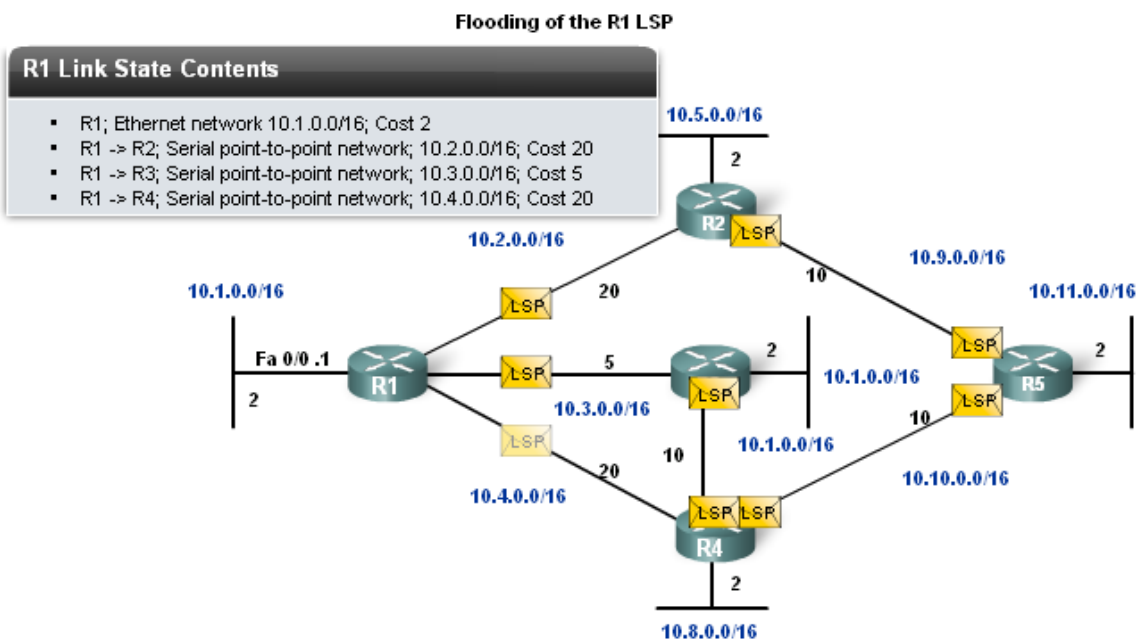


Link-State Routing Process

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

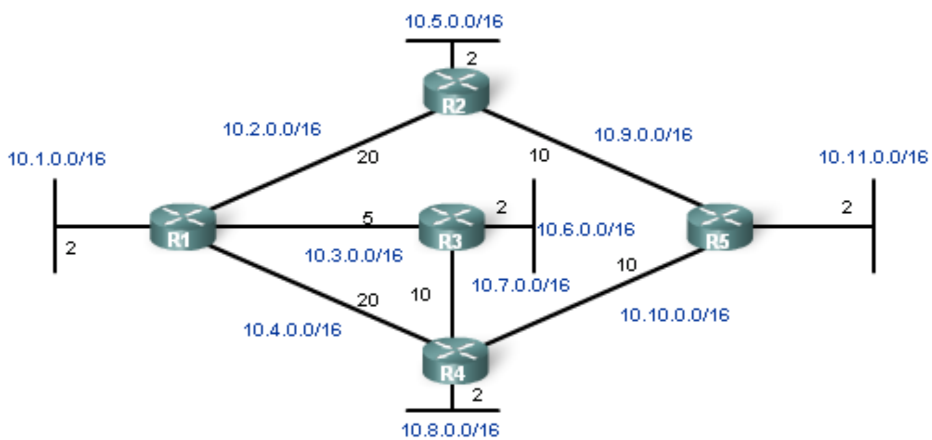
- LSPs are sent out under the following conditions:
  - Initial router start up or routing process
  - When there is a change in topology



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



Link-State Routing Process

1. Each router learns about each of its own directly connected networks.
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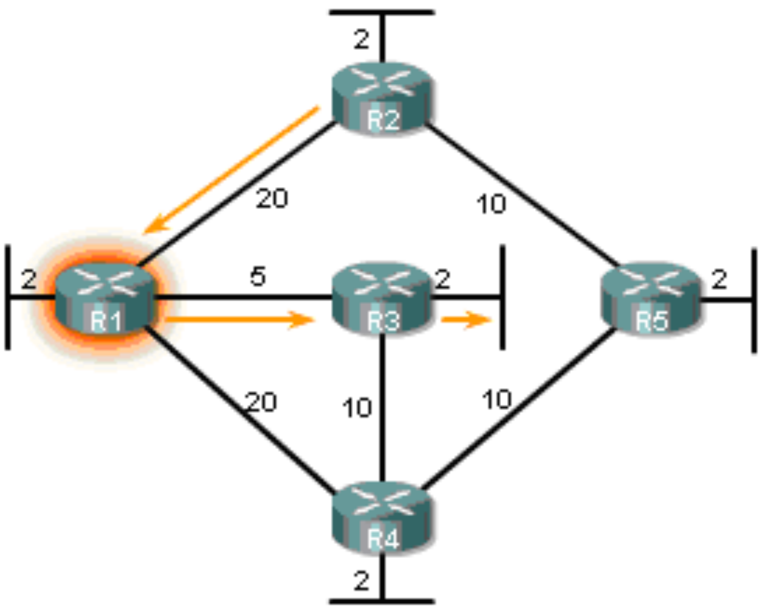
3. Each router builds a Link-State Packet (LSP) containing the state of each directly connected link.
4. Each router floods the LSP to all neighbors, who then store all LSPs received in a database.
5. Each router uses the database to construct a complete map of the topology and computes the best path to each destination network.

Link-State Routing



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

R1 Link-State Database

R1s Link-State DatabaseLSPs 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

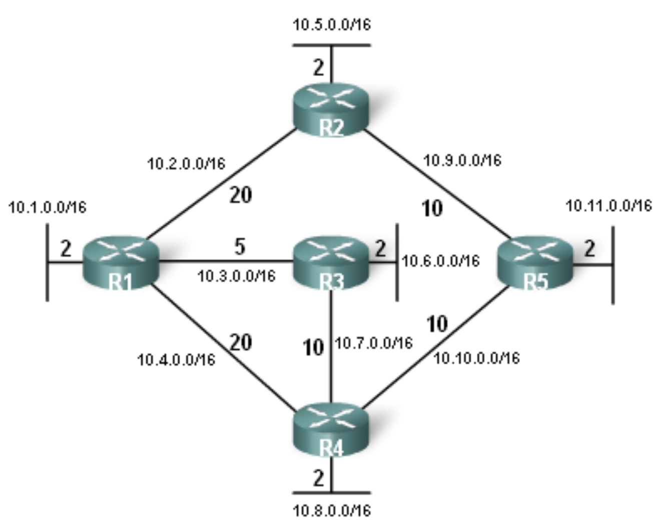
LSPs from R4:
- Connected to neighbor R1 on network 10.4.0.0/16, cost of 20
- Connected to neighbor R3 on network 10.7.0.0/16, cost of 10
- Connected to neighbor R5 on network 10.10.0.0/16, cost of 10
- Has a network 10.8.0.0/16, cost of 2

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

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



R1s 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
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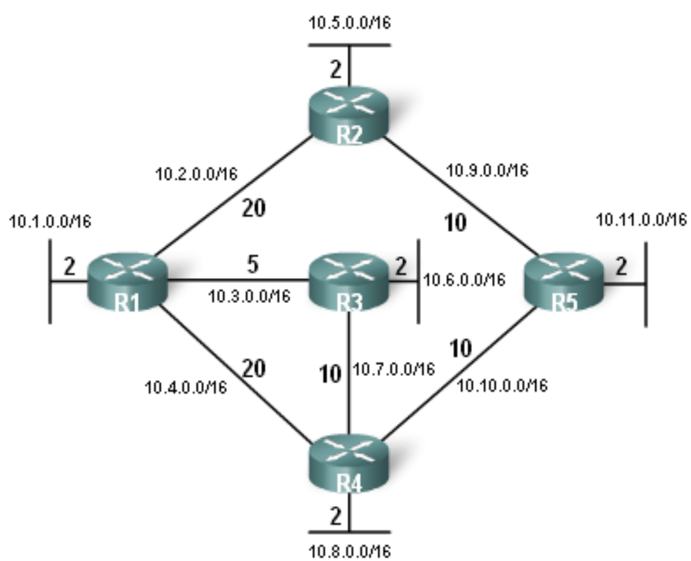
- Has a network 10.6.0.0/16, cost of 2
- LSPs from R4:
- Connected to neighbor R1 on network 10.4.0.0/16, cost of 20
- Connected to neighbor R3 on network 10.7.0.0/16, cost of 10
- Connected to neighbor R5 on network 10.10.0.0/16, cost of 10
- Has a network 10.8.0.0/16, cost of 2

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



R1s 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

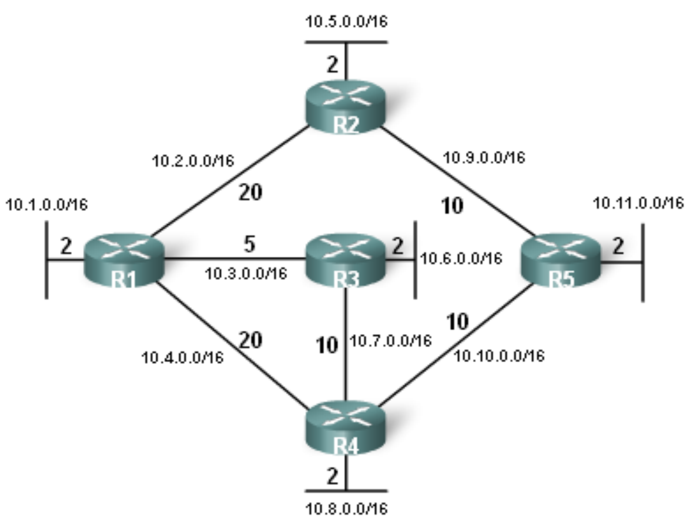
LSPs from R2:
- Connected to neighbor R1 on network 10.2.0.0/16, cost of 20
- Connected to neighbor R5 on network 10.9.0.0/16, cost of 10
- Has a network 10.5.0.0/16, cost of 2

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 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



R1s 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

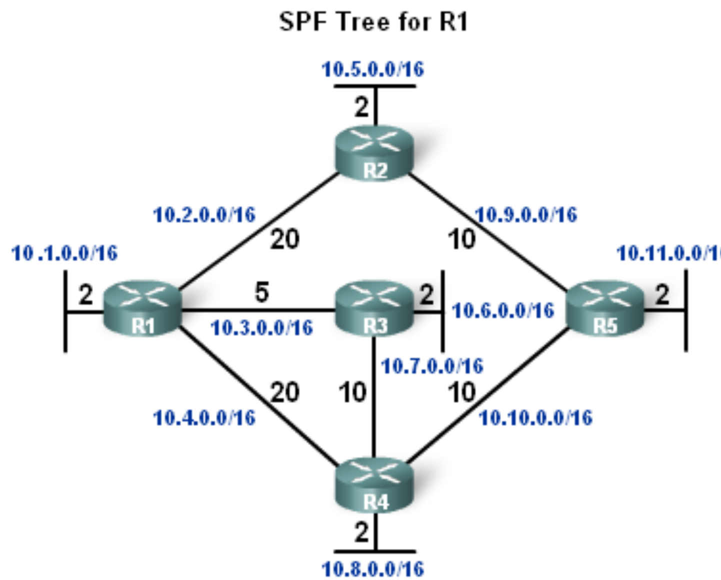
LSPs from R2:
- Connected to neighbor R1 on network 10.2.0.0/16, cost of 20
- Connected to neighbor R5 on network 10.9.0.0/16, cost of 10
- Has a network 10.5.0.0/16, cost of 2

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
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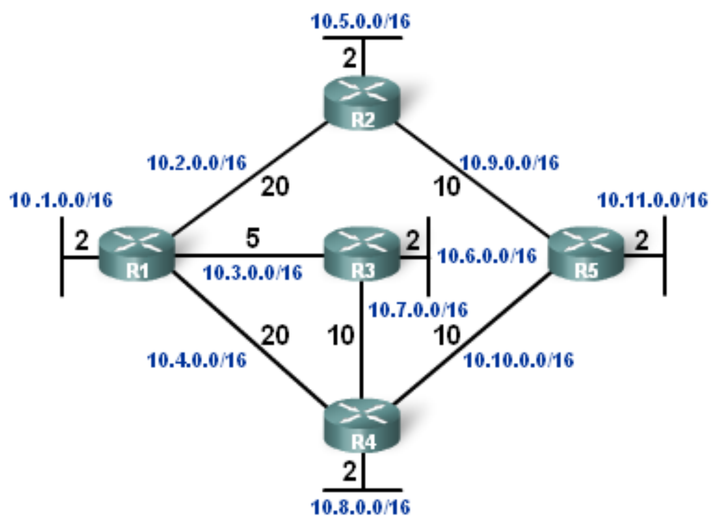
R5 LAN	R1 to R3 to R4 to R5	27

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

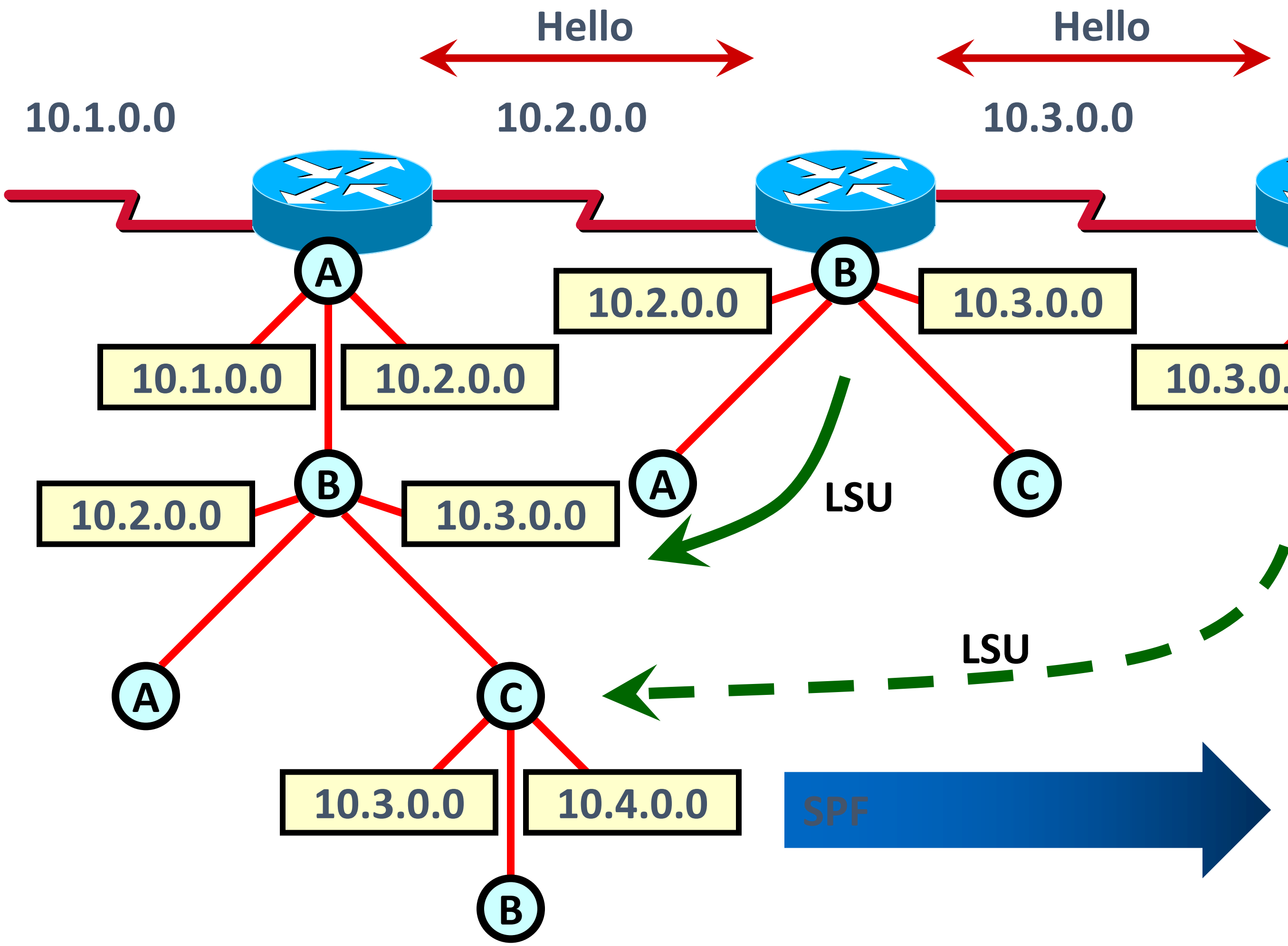
OSPF

- 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

Link state



Routing Table		
10.1.0.0	←	0
10.2.0.0	→	0
10.3.0.0	→	1
10.4.0.0	→	2

Routing Information Protocol (RIP)

Open Shortest Path First (OSPF)