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CAP256: Computer Networks

Lecture 24-28
Routing Protocols

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Objectives

- *Understand Routing*
- *Static and Dynamic Routing*
- *Routing Algorithms*
- *Distance Vector Routing.*
- *Link State Routing*
- *Dijkstra Algorithm.*

Routing

- *Routing is the act of moving information across an inter-network from a source to a destination.*

- *It's also referred to as the process of choosing a path over which to send the packets.*

- *The routing algorithm is the part of the network layer software responsible for deciding which output line an incoming packet should be transmitted on, i.e. what should be the next intermediate node for the packet.*

Routing

- ***A router is a device that determines the next network point to which a packet should be forwarded toward its destination.***

- ***Allow different networks to communicate with each other***

- ***A router creates and maintain a table of the available routes and their conditions and uses this information to determine the best route for a given packet.***

Routing

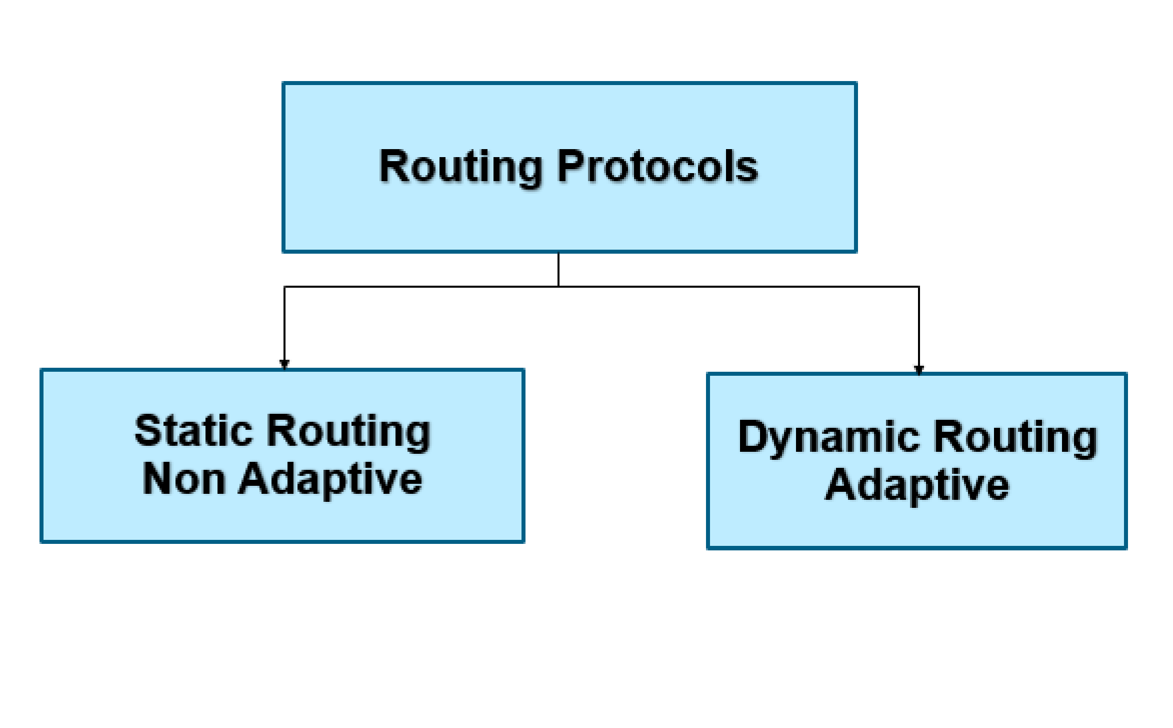
- *A packet will travel through a number of network points with routers before arriving at its destination.*

- *Allow different networks to communicate with each other*

- *There can be multiple routes defined. The route with a lower weight/metric will be tried first.*

Classification of Routing

- *Static Routing*
- *Dynamic Routing*
- *Default Routing*



Classification of Routing

- ***Static Routing***

- ***This is the method by which an administrator manually adds routes to the routing table of a router. This is a method for small networks but it is not scalable for larger networks.***

Classification of Routing

- ***Dynamic Routing***

- ***This is the method where protocols and algorithms are used to automatically propagate routing information. This is the most common method and most complex method of routing.***

Classification of routing.

- ***Default Routing***
- ***This is the method where all routers are configured to send all packets towards a single router.***
- ***This is a very useful method for small networks or for networks with a single entry and exit point.***
- ***It is usually used in addition to Static and/or Dynamic routing.***

Classification of Routing

- ***IGP (Interior Gateway Protocol): Route data within an Autonomous System***

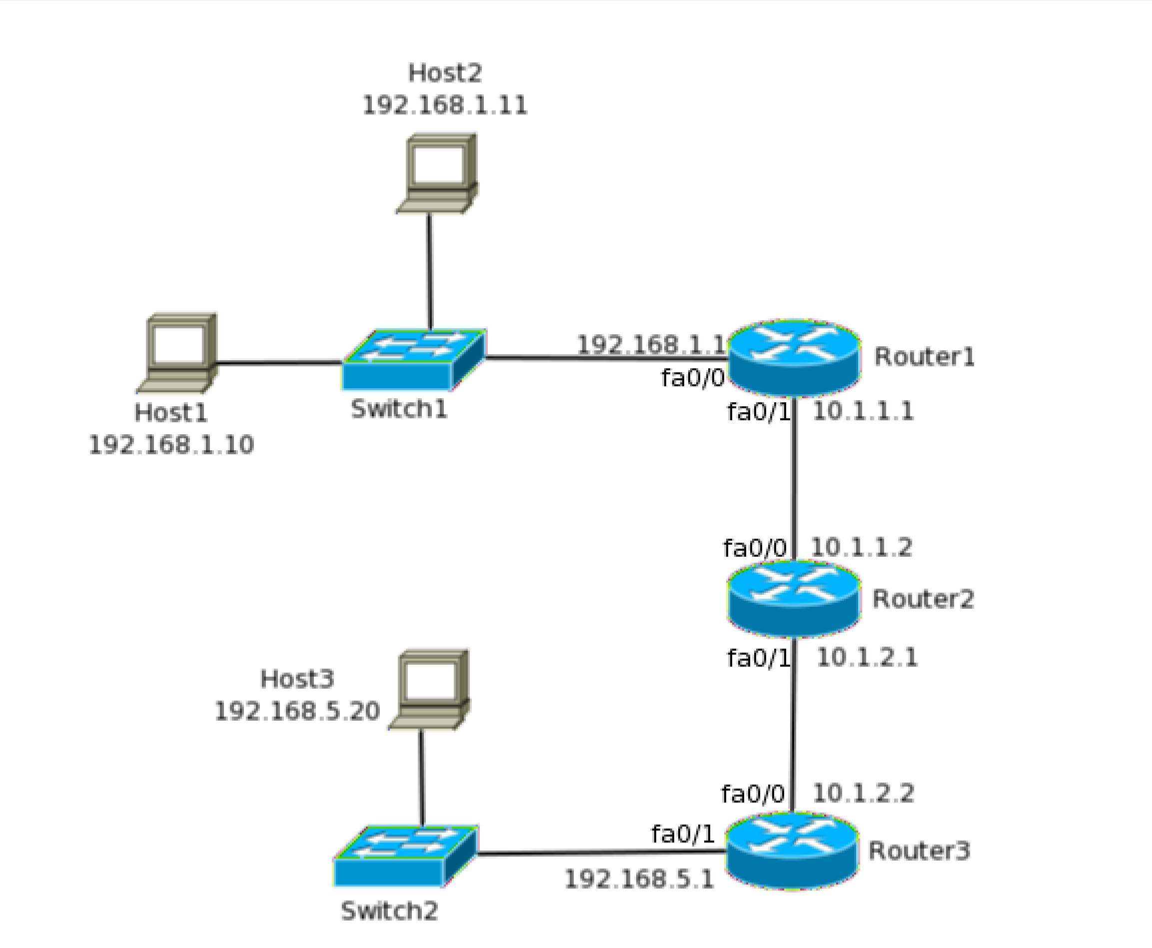
- ***EGP (Exterior Gateway Protocol): Route data between Autonomous Systems***

Static Routing

- ***A static route is created, maintained, and updated by a network administrator, manually.***

- ***A static route to every network must be configured on every router for full connectivity***

Static Routing



Static Routing

- ***Advantages are:***
  - ***There is no overhead in terms of CPU usage of the router as well as bandwidth between routers.***
  - ***When dynamic routing is used, packets are exchanged between routers and that uses bandwidth. That can be costly when they traverse across WAN links. The routers also need to process these packets and that consumes some CPU cycles as well.***
  - ***It adds a certain degree of security since the administrator controls which routes the routers can know and learn.***
  - ***Secure networks as only administrator knows the path.***

Static Routing

The disadvantages of static routing are:

- ***The administrator needs to know the internetwork so well that he/she knows where each destination network lies and which is the next hop towards it.***
- ***Every change needs to be manually done on each router in the internetwork.***
- ***In large networks this can be unmanageable.***

Default Routing

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Default routing can be considered a special type of static routing.

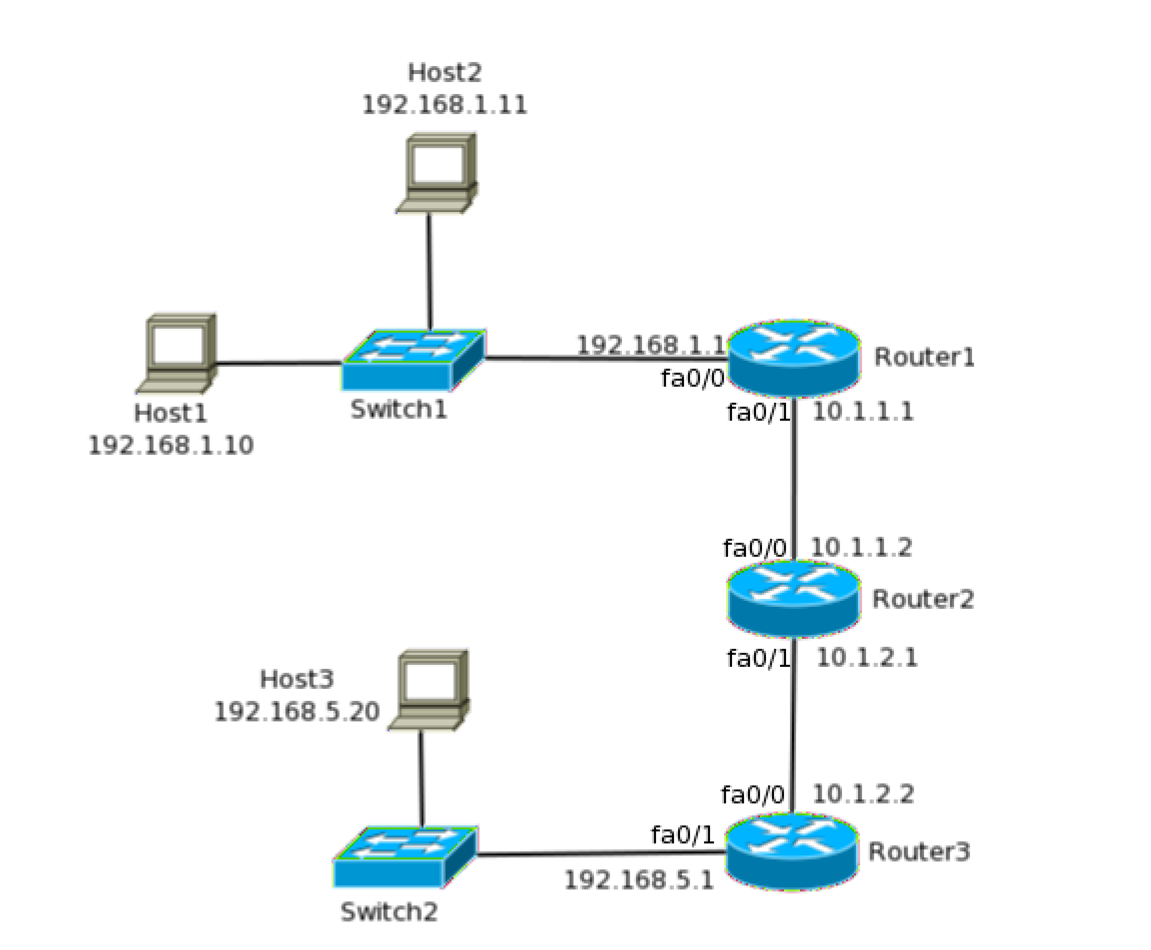
The difference between a normal static route and a default route is that a default route is used to send packets destined to any unknown destination to a single next hop address.

Default Routing

To understand how this works, consider Router1, without any static routes in it.

When it receives a packet destined to 192.168.5.0/24 it will drop it since it does not know where the destination network is.

If a default route is added in Router1 with next hop address of Router2, all packets destined to any unknown destination, such as 192.168.5.0/24 will be sent to Router2.



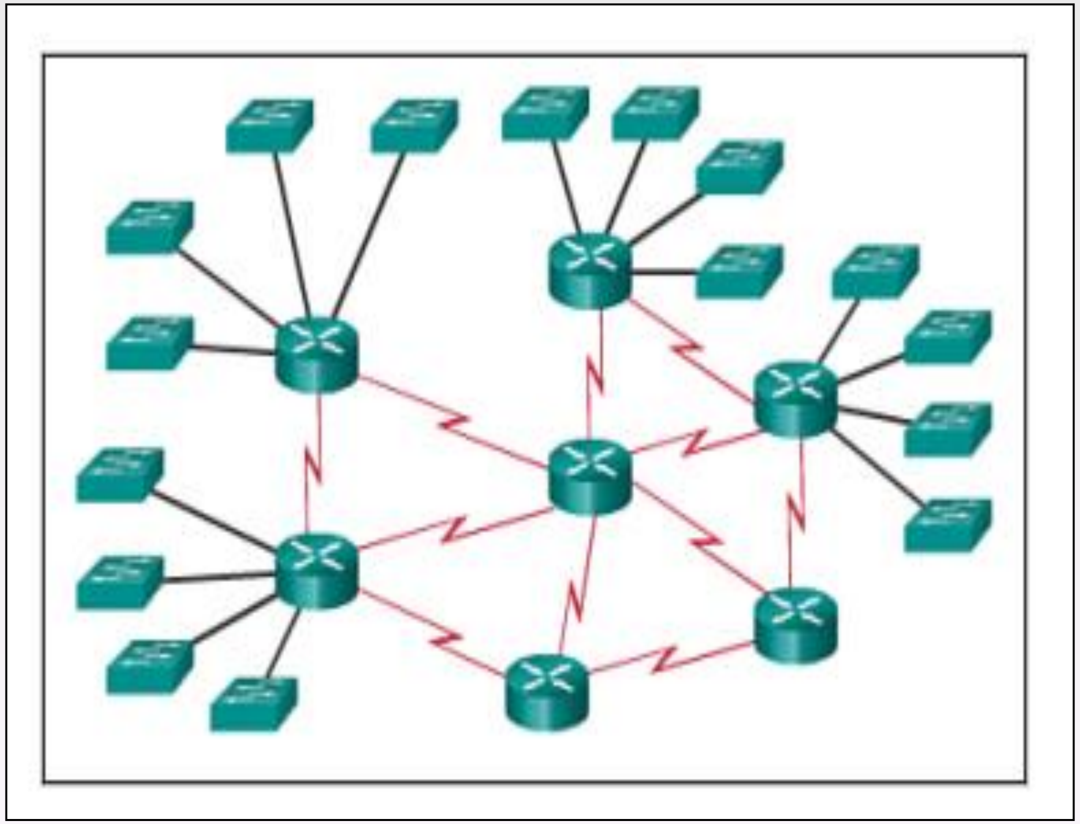
Dynamic Routing

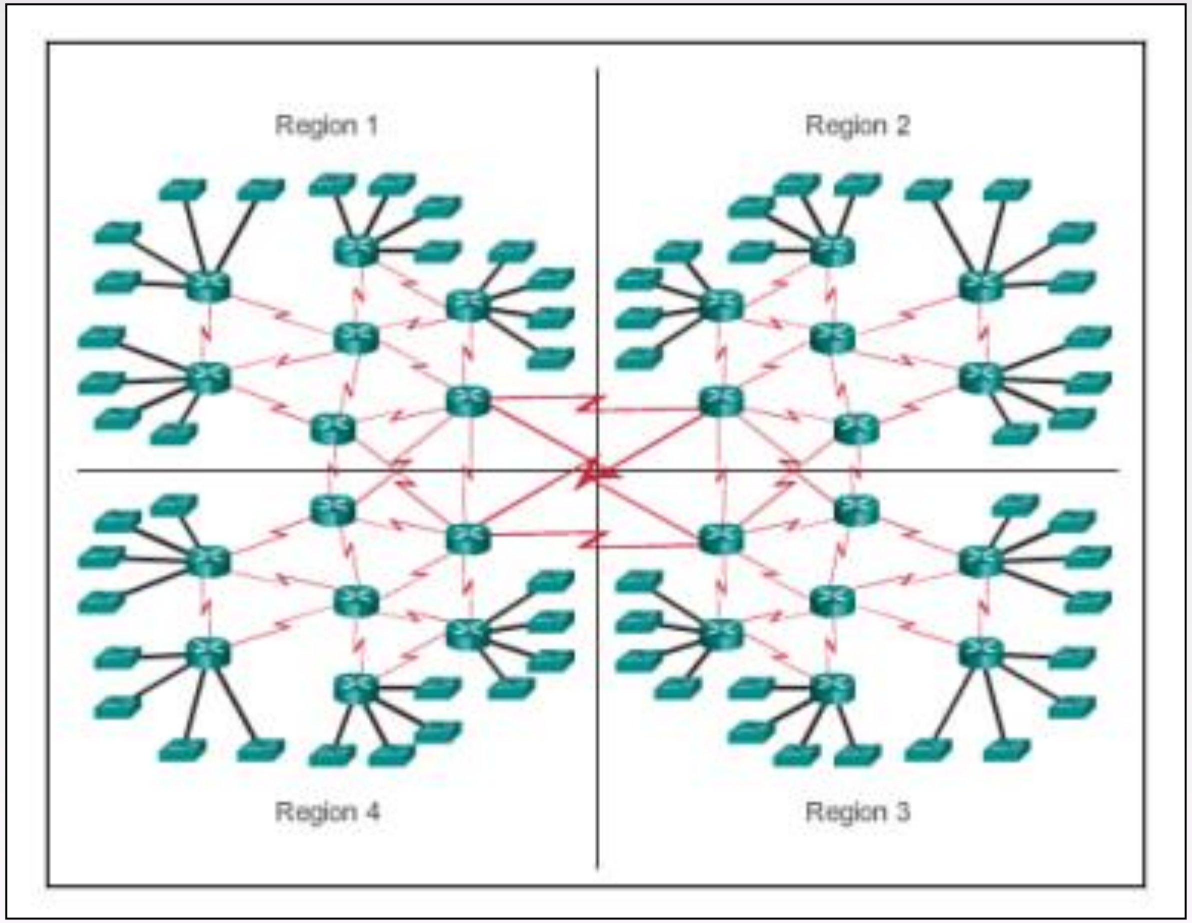
Dynamic routing is when protocols, called routing protocols, are used to build the routing tables across the network.

Using a routing protocol is easier than static routing and default routing, but it is more expensive in terms of CPU and bandwidth usage.

Every routing protocol defines its own rules for communication between routers and selecting the best route.

Dynamic Routing





Dynamic Routing

Advantages of Dynamic Routing

- ***Suitable in all topologies where multiple routers are required.***
- ***Generally independent of the network size.***
- ***Automatically adapts topology to reroute traffic if possible.***
- ***Generally independent of the network size.***

Dynamic Routing

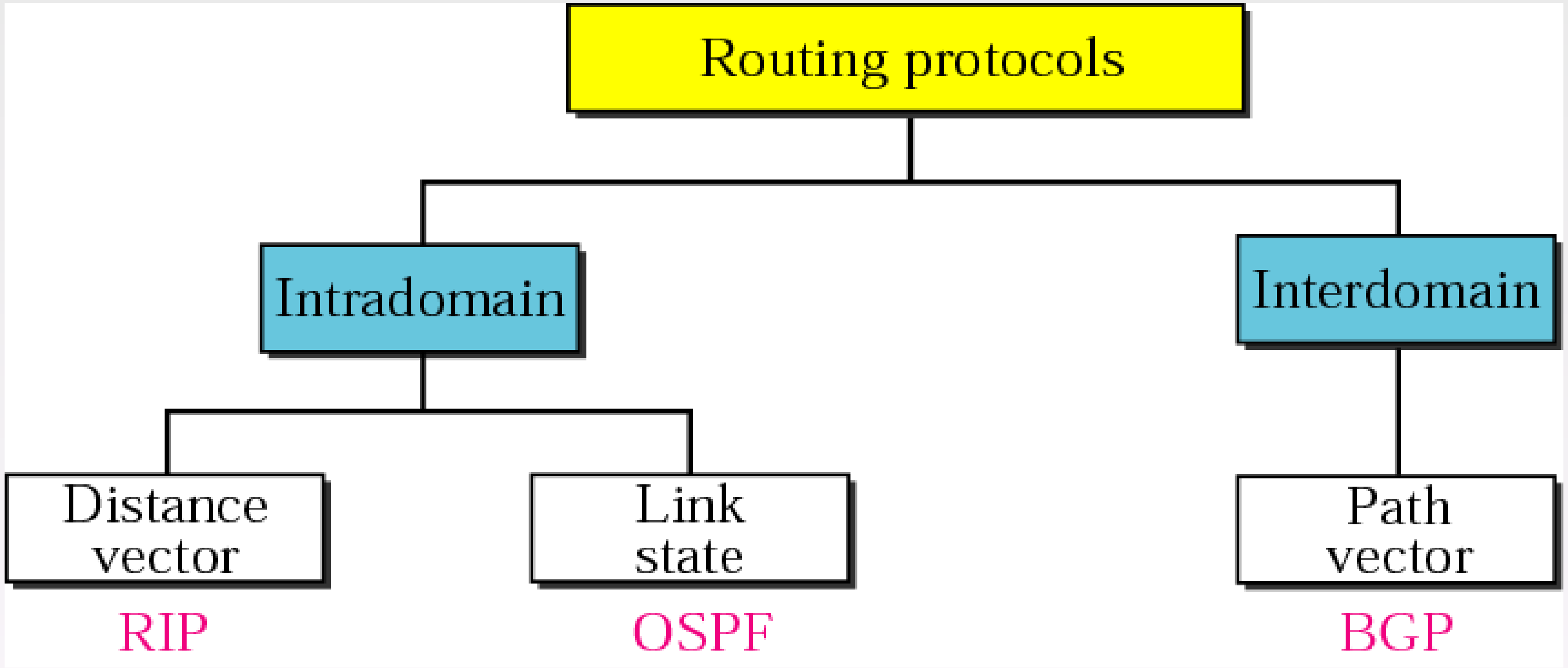
Disadvantages of Dynamic Routing

- ***Can be more complex to initially implement.***

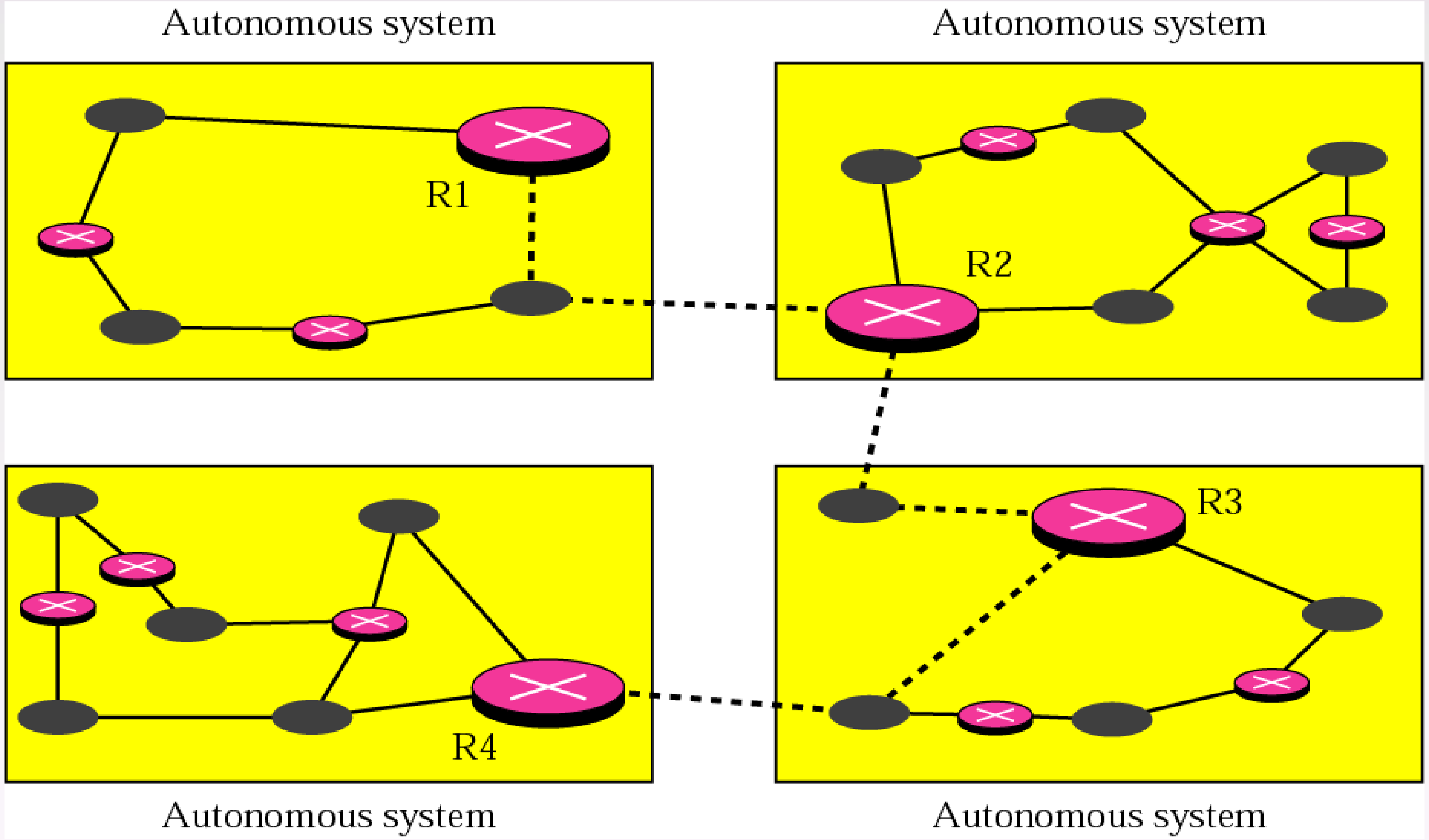
- ***Less secure due to the broadcast and multicast routing updates. Additional configuration settings such as passive interfaces and routing protocol authentication are required to increase security.***

- ***Requires additional resources such as CPU, memory, and link bandwidth***

Routing Protocols



Routing Protocols



Dynamic Routing

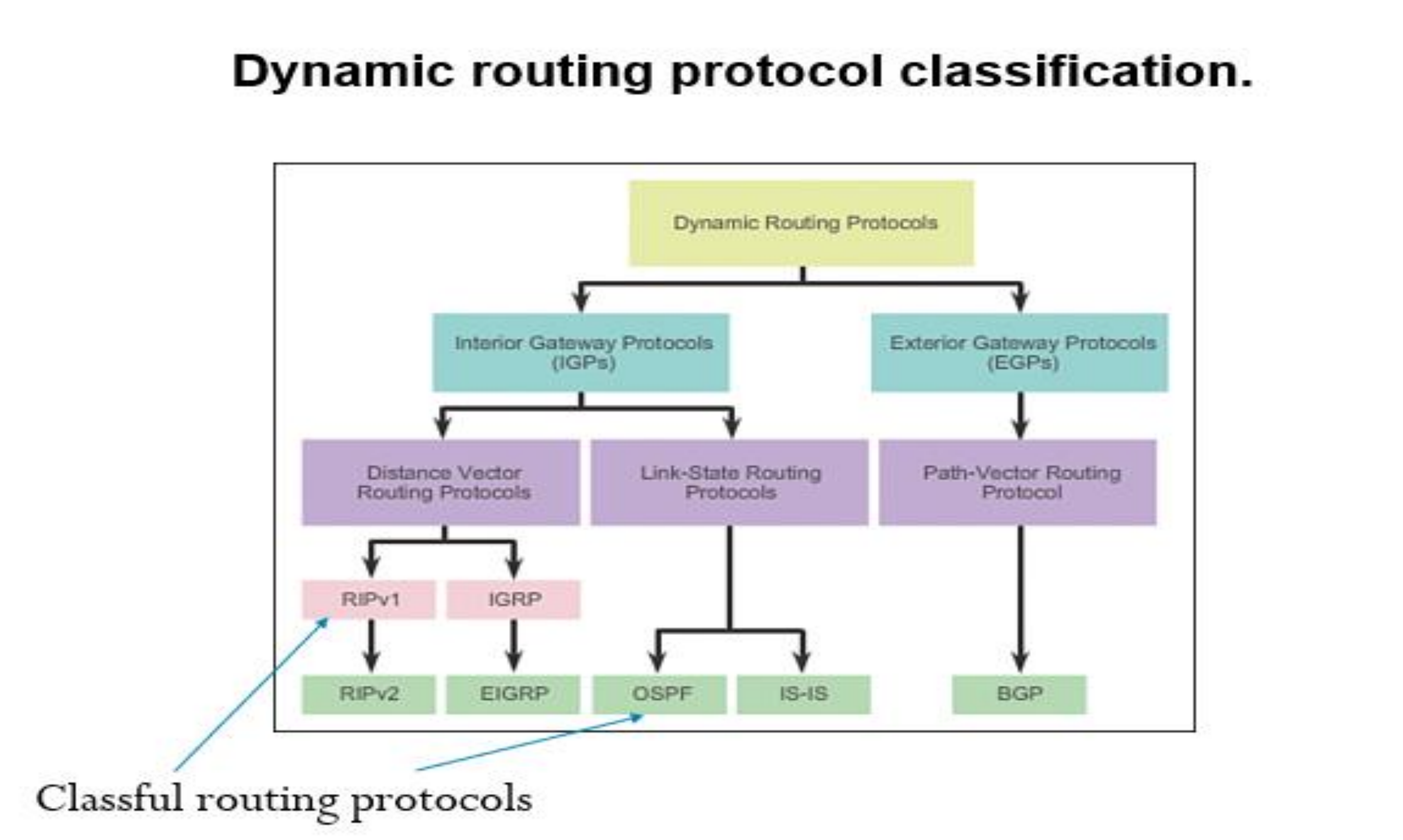
IGP (Interior Gateway Protocol): Route data within an Autonomous System

- ***RIP (Routing Information Protocol)***
- ***RIP-2 (RIP Version 2)***
- ***OSPF (Open Shortest Path First)***
- ***IGRP (Interior Gateway Routing Protocol)***
- ***EIGRP (Enhanced Interior Gateway Routing Protocol)***

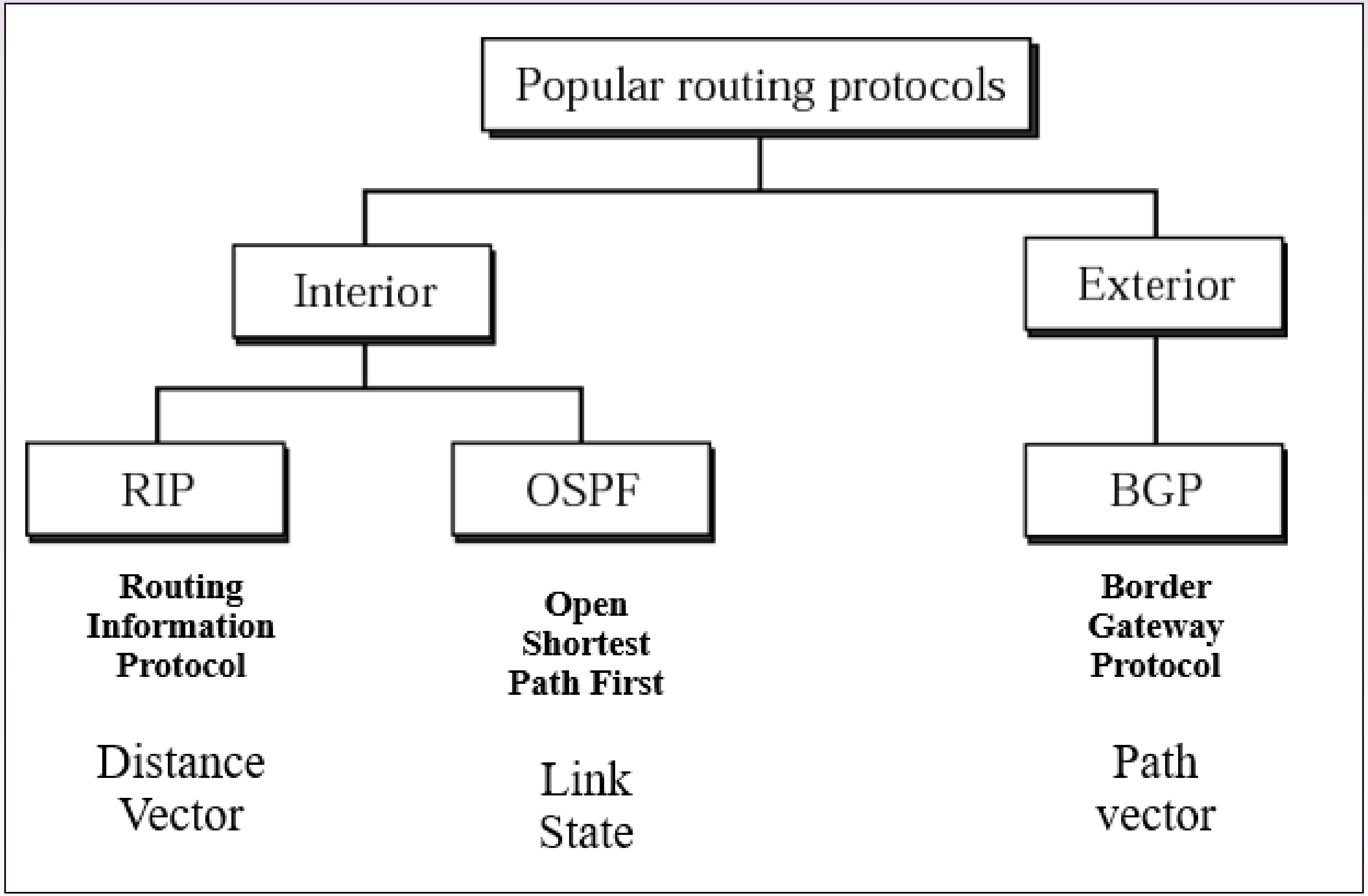
EGP (Exterior Gateway Protocol): Route data between Autonomous Systems

- ***BGP (Border Gateway Protocol)***

Dynamic Routing



Routing



Popular routing protocols
Interior
Exterior
RIP
OSPF
BGP
Routing Information Protocol
Open Shortest Path First
Border Gateway Protocol
Distance Vector
Link State
Path vector

Routing Algorithm

A routing algorithm is a procedure that lays down the route or path to transfer data packets from source to the destination.

They help in directing Internet traffic efficiently.

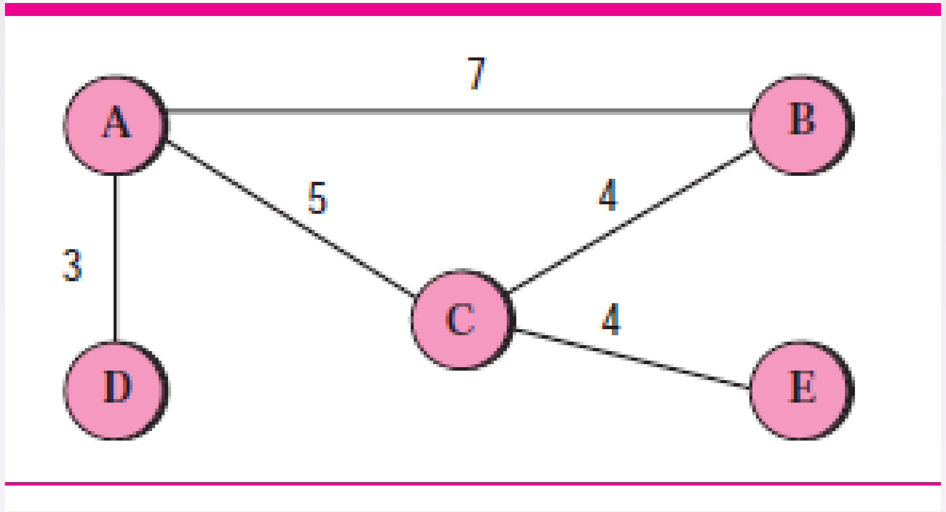
After a data packet leaves its source, it can choose among the many different paths to reach its destination.

Routing algorithm mathematically computes the best path, i.e. "least – cost path" that the packet can be routed through.

Distance Vector Routing

- We first discuss **distance vector routing.** This method sees an AS Autonomous Station, with all routers and networks, as a *graph*, a set of nodes and lines (edges) connecting the nodes.

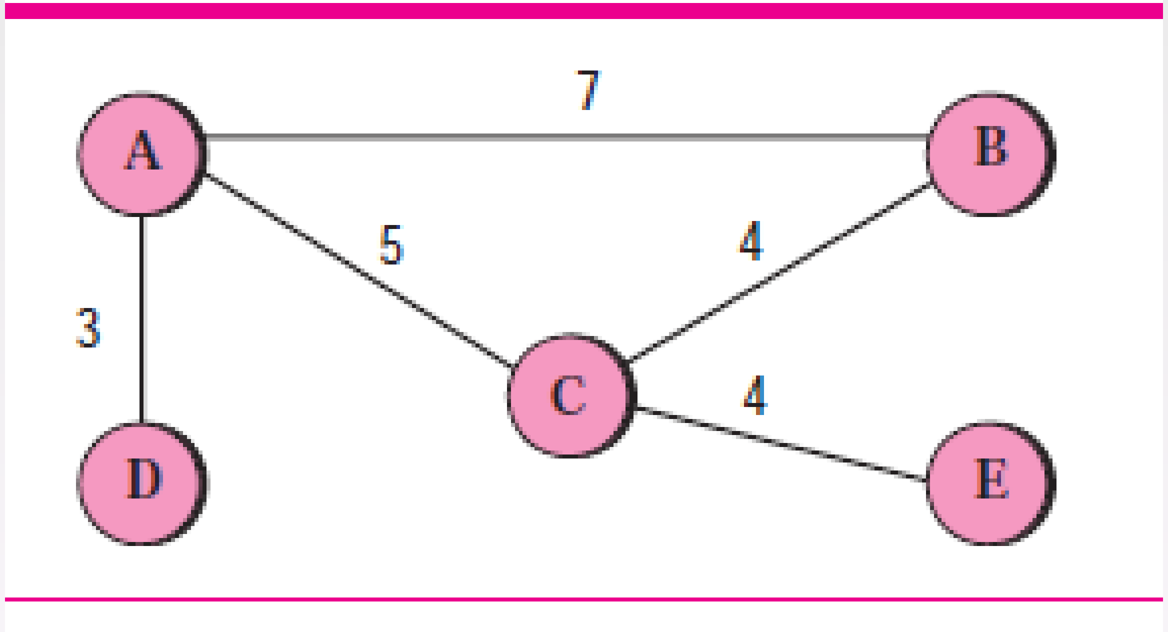
- A router can normally be represented by a node and a network by a link connecting two nodes, although other representations are also possible.



Distance Vector Routing

- The graph theory used an algorithm called Bellman-Ford to find the shortest path between nodes in a graph given the distance between nodes.

- If we know the cost between each pair of nodes, we can use the algorithm to find the least cost (shortest path) between any two nodes.



Distance Vector Routing

We can use the algorithm for creating the routing table for routers in an AS, we need to change the algorithm:

1. In distance vector routing, the cost is normally hop counts (how many networks are passed before reaching the destination). So the cost between any two neighbours is set to 1.

2. Each router needs to update its routing table *asynchronously*, whenever it has received some information from its neighbours. In other words, each router executes part of the whole algorithm in the Bellman-Ford algorithm.

Distance Vector Routing

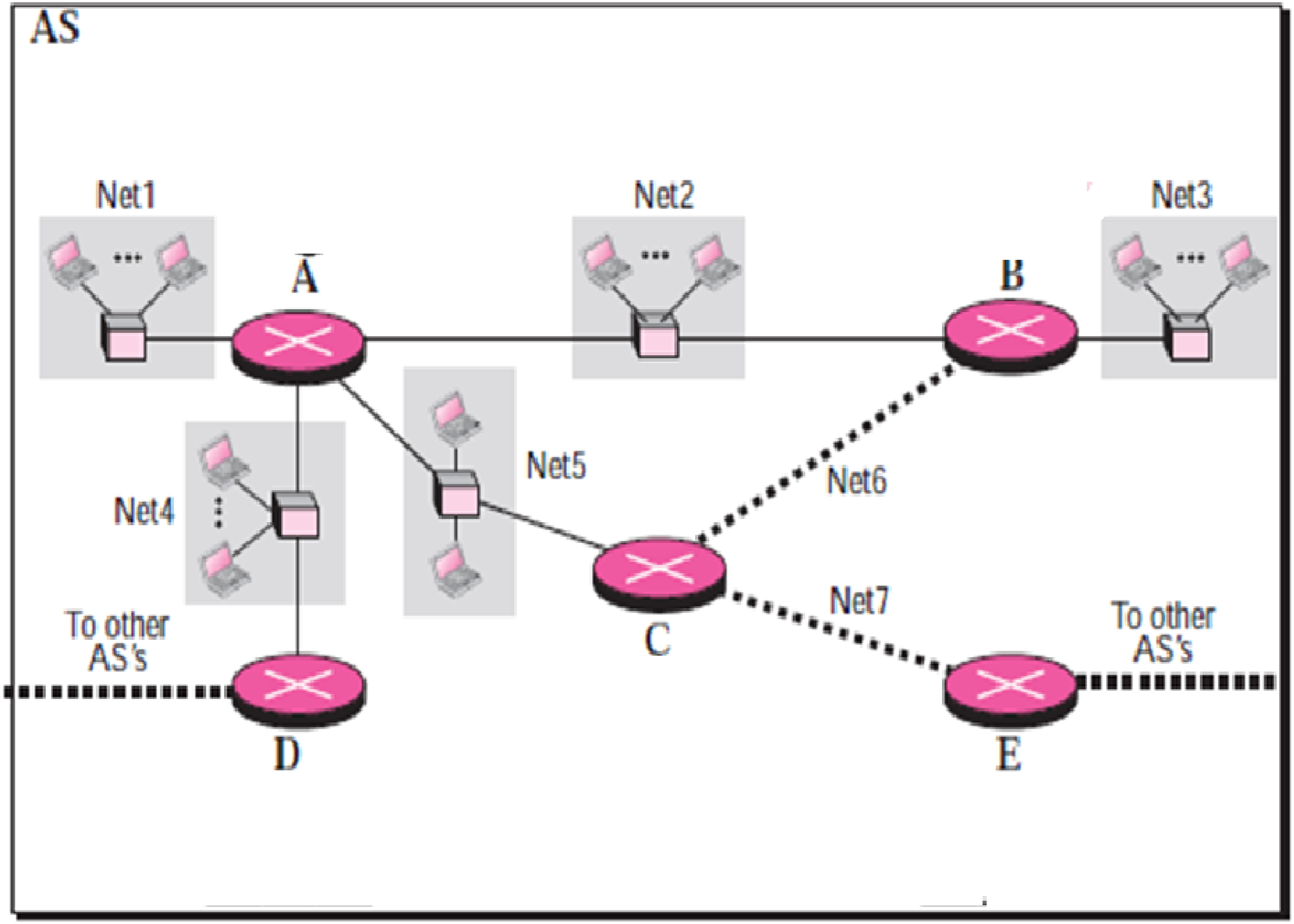
3. After a router has updated its routing table, it should send the result to its neighbours so that they can also update their routing table.

4. Each router should keep at least three pieces of information for each route:

destination network, the cost, and the next hop.

Table*i*.dest, Table*i*.cost, and Table*i*.next.

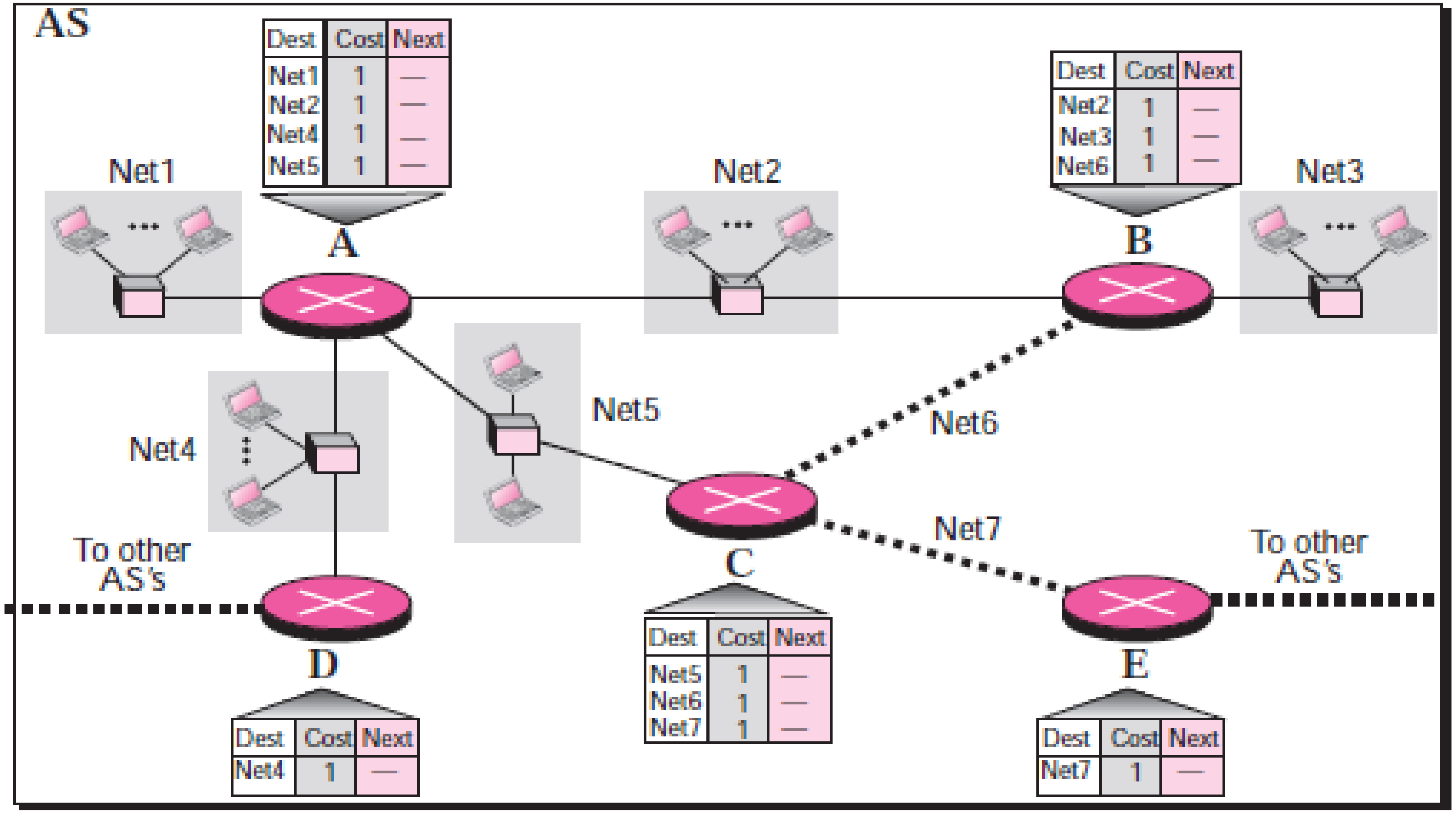
5. We refer to information about each route received from a neighbour as R (record), which has only two pieces of information: R.dest and R.cost. The next hop is not included in the received record because it is the source address of the sender.


AS
Net1
Net2
Net3
A
B
Net4
Net5
Net6
Net7
C
To other AS's
To other AS's
D
E

Example 11.1

Figure 11.5 shows the initial routing table for an AS. Note that the figure does not mean that all routing tables have been created at the same time; each router creates its own routing table when it is booted.

Figure 11.5 *Example 11.1*



Example 11.2

Now assume router A sends four records to its neighbors, routers B, D, and C. Figure 11.6 shows the changes in B's routing table when it receives these records. We leave the changes in the routing tables of other neighbors as exercise.

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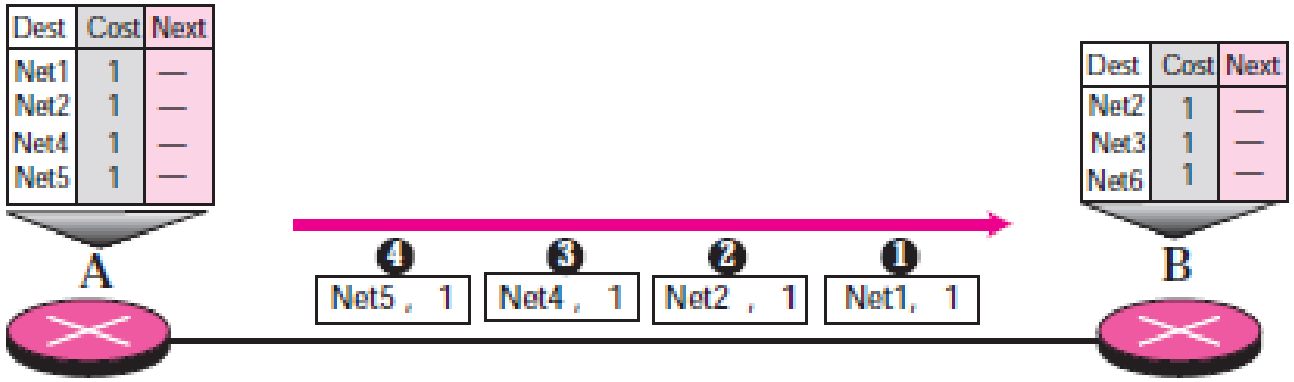
Figure 11.6 *Example 11.2*



Dest	Cost	Next
Net1	2	A
Net2	1	—
Net3	1	—
Net6	1	—

Routing Table B — After receiving record 1

Dest	Cost	Next
Net1	2	A
Net2	1	—
Net3	1	—
Net6	1	—

Routing Table B — After receiving record 2

Dest	Cost	Next
Net1	2	A
Net2	1	—
Net3	1	—
Net4	2	A
Net6	1	—

Routing Table B — After receiving record 3

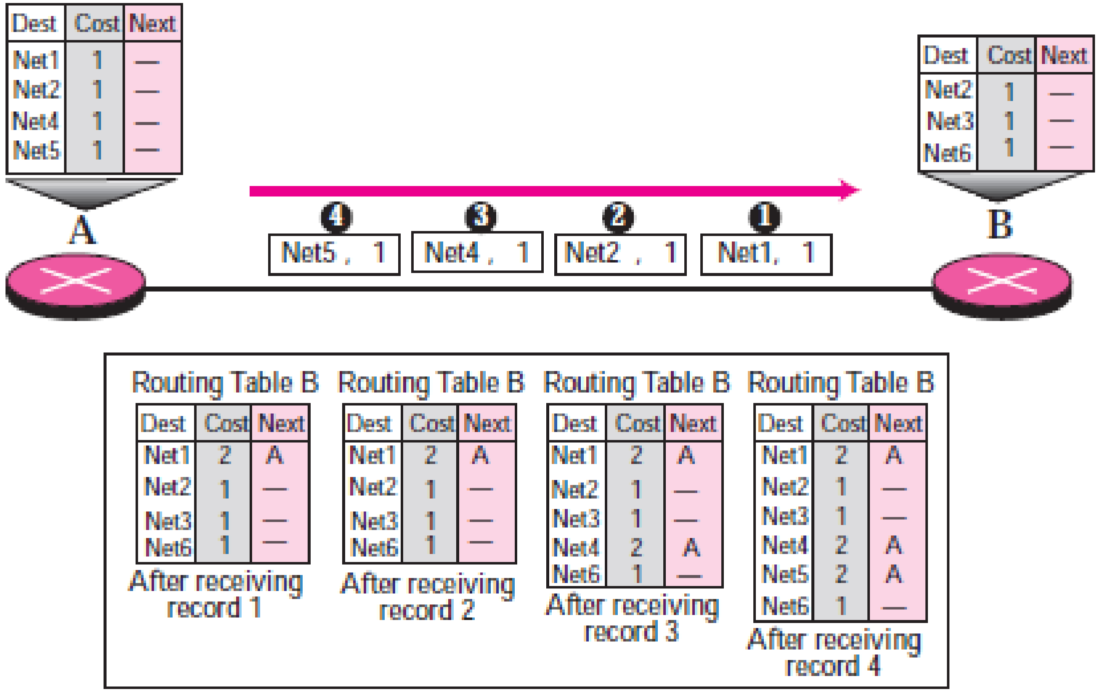
Dest	Cost	Next
Net1	2	A
Net2	1	—
Net3	1	—
Net4	2	A
Net5	2	A
Net6	1	—

Routing Table B — After receiving record 4

a. When router B receives record 1, it searches its routing table for the route to net1, and since it is not found there, it adds one hop to the cost (distance between B and A) and adds it to the table with the next hop to be A.

b. When router B receives record 2, it searches its routing table and finds the destination net2 there. However, since the announced cost plus 1 is larger than the cost in the table, the record is discarded.

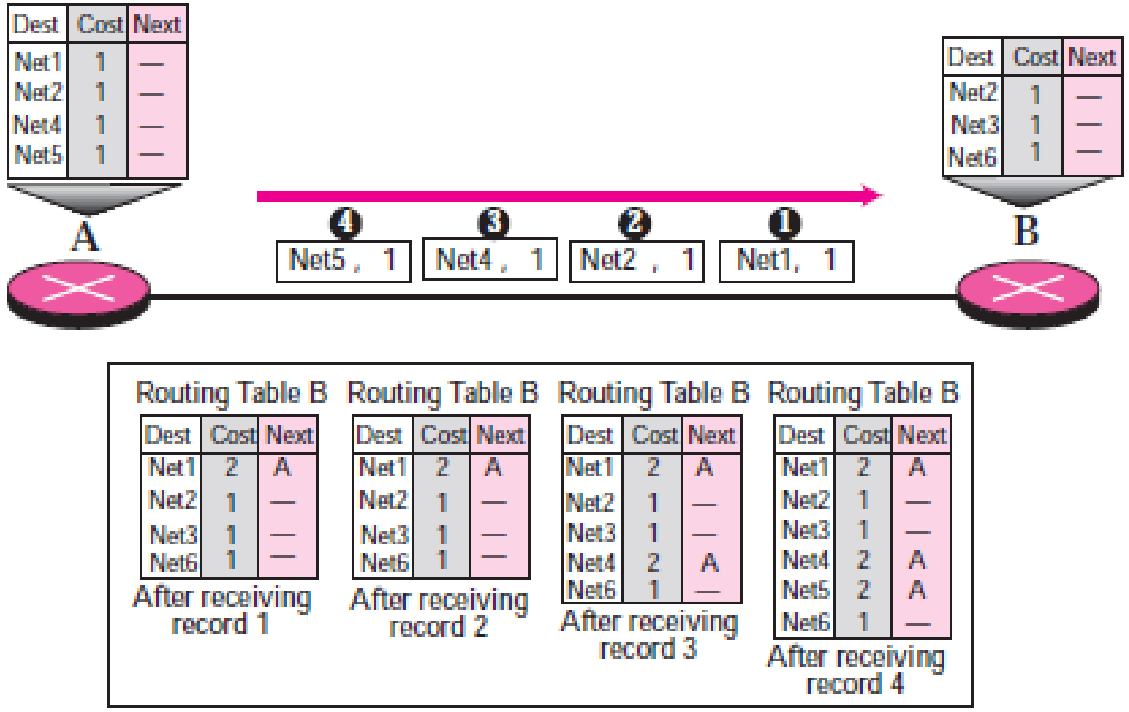
Figure 11.6 *Example 11.2*



c. When router B receives record 3, it searches its router, and since Net4 is not found, it is added to the table.

d. When router B receives record 4, it searches its router, and since Net5 is not found, it is added to the table.

Figure 11.6 *Example 11.2*



Round 1: After first sharing with nearest neighbor

i.e Router A swaps its information with Router B , Router C and Router D

Router B swaps its information with Router A and Router C

Router C swaps its information with Router A, Router B and Router E

Router D swaps its information with Router A

Router E swaps its information with Router C

Router A

Destination	Cost	Next
Network1	1	-
Network2	1	-
Network3	2	B
Network4	1	-
Network5	1	-
Network6	2	C
Network7	2	C

Router B

Destination	Cost	Next
Network1	2	A
Network2	1	-
Network3	1	-
Network4	2	A
Network5	2	C
Network6	1	-
Network7	2	C

Router C

Destination	Cost	Next
Network1	2	A
Network2	2	A
Network3	2	B
Network4	2	A
Network5	1	-
Network6	1	-
Network7	1	-

Router D

Destination	Cost	Next
Network1	2	A
Network2	2	A
Network4	1	-
Network5	2	A

Router E

Destination	Cost	Next
Network5	2	C
Network6	2	C
Network7	1	

Round2:   After second sharing with nearest neighbor

i.e   Router A swaps its information with Router B , Router C and Router D

Router B swaps its information with Router A and Router C

Router C swaps its information with Router A, Router B and Router E

Router D swaps its information with Router A

Router E swaps its information with Router C

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Router A

Destination	Cost	Next
Network1	1	-
Network2	1	-
Network3	2	B
Network4	1	-
Network5	1	-
Network6	2	C
Network7	2	C

Router B

Destination	Cost	Next
Network1	2	A
Network2	1	-
Network3	1	-
Network4	2	B
Network5	2	C
Network6	1	-
Network7	2	C

Router C

Destination	Cost	Next
Network1	2	A
Network2	2	A
Network3	2	B
Network4	2	A
Network5	1	-
Network6	1	-
Network7	1	-

Router D

Destination	Cost	Next
Network1	2	A
Network2	2	A
Network3	3	A
Network4	1	
Network5	2	A
Network6	3	A
Network7	3	A

Router E

Destination	Cost	Next
Network1	3	C
Network2	3	C
Network3	3	C
Network4	3	C
Network5	2	C
Network6	2	C
Network7	1	-

Example 11.3

Figure 11.7 shows the final routing tables for routers in Figure 11.5.

Figure 11.7 *Example 11.3*

A

Dest	Cost	Next
Net1	1	—
Net2	1	—
Net3	2	B
Net4	1	—
Net5	1	—
Net6	2	C
Net7	2	C

B

Dest	Cost	Next
Net1	2	A
Net2	1	—
Net3	1	—
Net4	2	A
Net5	2	A
Net6	1	—
Net7	2	C

C

Dest	Cost	Next
Net1	2	A
Net2	2	A
Net3	2	B
Net4	2	A
Net5	1	—
Net6	1	—
Net7	1	—

D

Dest	Cost	Next
Net1	2	A
Net2	2	A
Net3	3	A
Net4	1	—
Net5	1	A
Net6	3	A
Net7	3	A

E

Dest	Cost	Next
Net1	3	C
Net2	3	C
Net3	3	C
Net4	3	C
Net5	2	C
Net6	2	C
Net7	1	—

Round 1: After first sharing with nearest neighbor

i.e Router A swaps its information with Router B , Router C and Router D

Router B swaps its information with Router A and Router C

Router C swaps its information with Router A, Router B and Router E

Router D swaps its information with Router A

Router E swaps its information with Router C

Router A

Destination	Cost	Next
Network1	1	-
Network2	1	-
Network3	2	B
Network4	1	-
Network5	1	-
Network6	2	C
Network7	2	C

Router B

Destination	Cost	Next
Network1	2	A
Network2	1	-
Network3	1	-
Network4	2	A
Network5	2	C
Network6	1	-
Network7	2	C

Router C

Destination	Cost	Next
Network1	2	A
Network2	2	A
Network3	2	B
Network4	2	A
Network5	1	-
Network6	1	-
Network7	1	-

Router D

Destination	Cost	Next
Network1	2	A
Network2	2	A
Network4	1	-
Network5	2	A

Router E

Destination	Cost	Next
Network5	2	C
Network6	2	C
Network7	1	

Round2: After second sharing with nearest neighbor

i.e Router A swaps its information with Router B , Router C and Router D

Router B swaps its information with Router A and Router C

Router C swaps its information with Router A, Router B and Router E

Router D swaps its information with Router A

Router E swaps its information with Router C

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Router A

Destination	Cost	Next
Network1	1	-
Network2	1	-
Network3	2	B
Network4	1	-
Network5	1	-
Network6	2	C
Network7	2	C

Router B

Destination	Cost	Next
Network1	2	A
Network2	1	-
Network3	1	-
Network4	2	B
Network5	2	C
Network6	1	-
Network7	2	C

Router C

Destination	Cost	Next
Network1	2	A
Network2	2	A
Network3	2	B
Network4	2	A
Network5	1	-
Network6	1	-
Network7	1	-

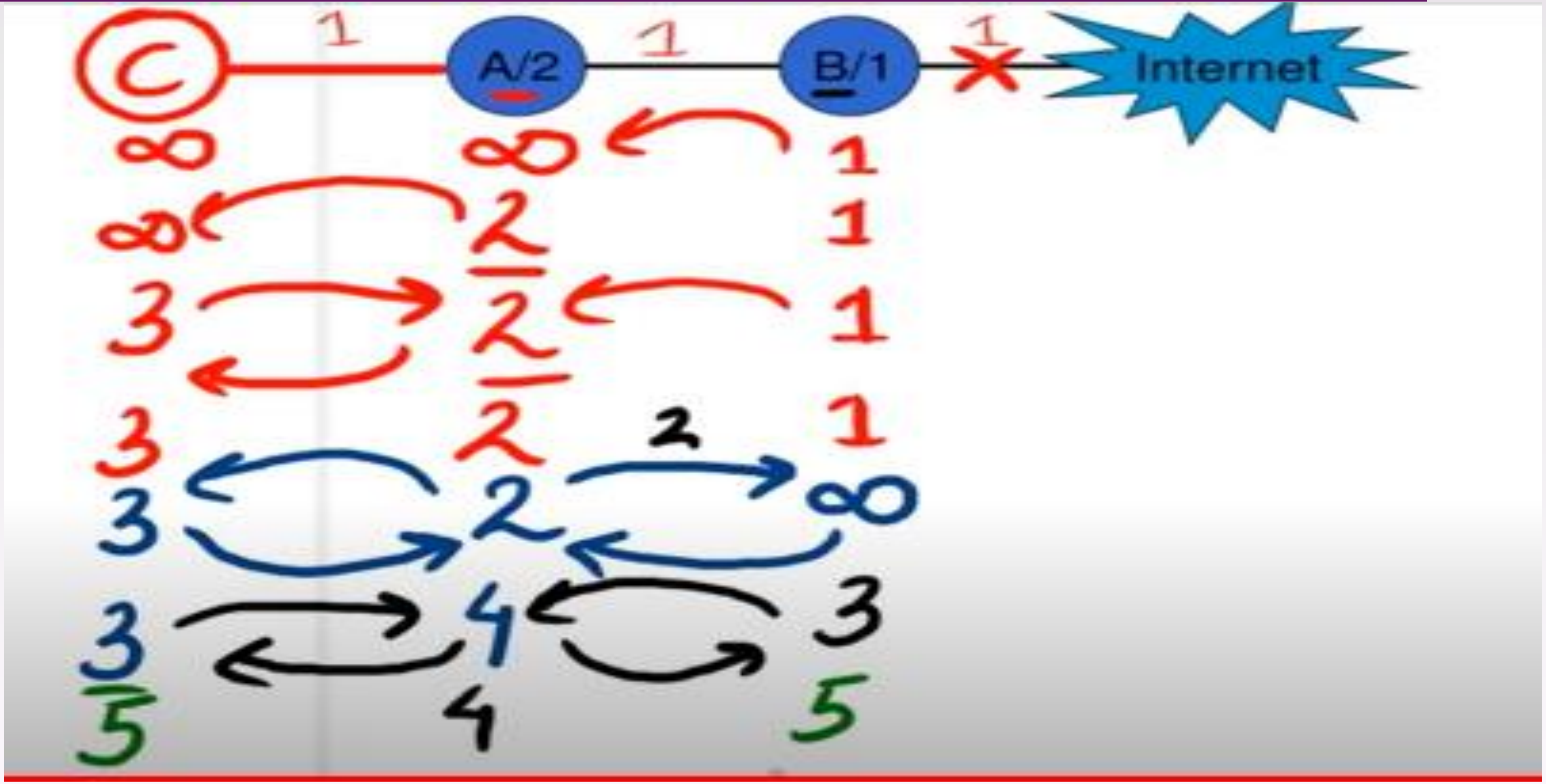
Router D

Destination	Cost	Next
Network1	2	A
Network2	2	A
Network3	3	A
Network4	1	
Network5	2	A
Network6	3	A
Network7	3	A

Router E

Destination	Cost	Next
Network1	3	C
Network2	3	C
Network3	3	C
Network4	3	C
Network5	2	C
Network6	2	C
Network7	1	-

Count to infinity problem in distance vector routing.



Link-State Routing

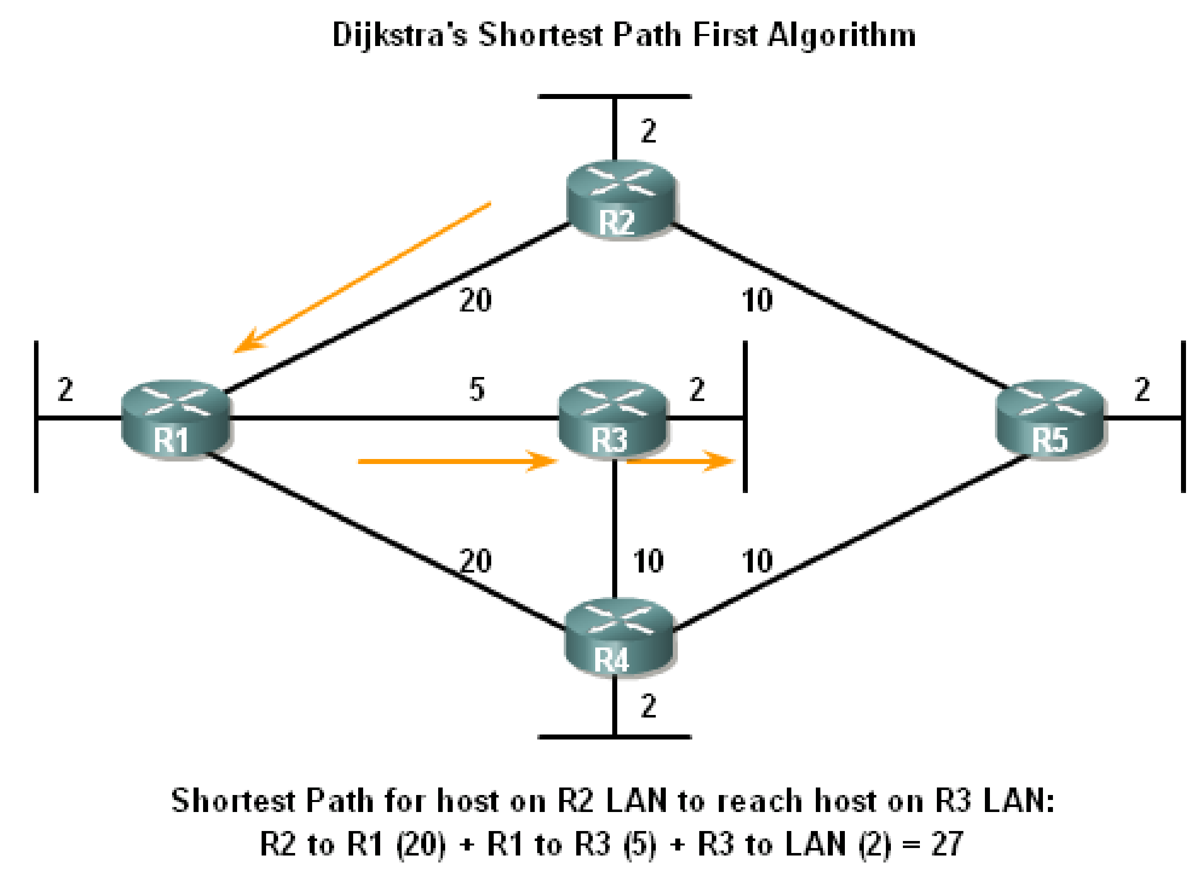
Link state routing protocols

-Also known as shortest path first algorithms

-These protocols built around Dijkstra’s algorithm

Link-State Routing

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



Link-State Routing

Question: In the given network find the shortest distance from node A to node H using Dijkstra algorithm / OSPF

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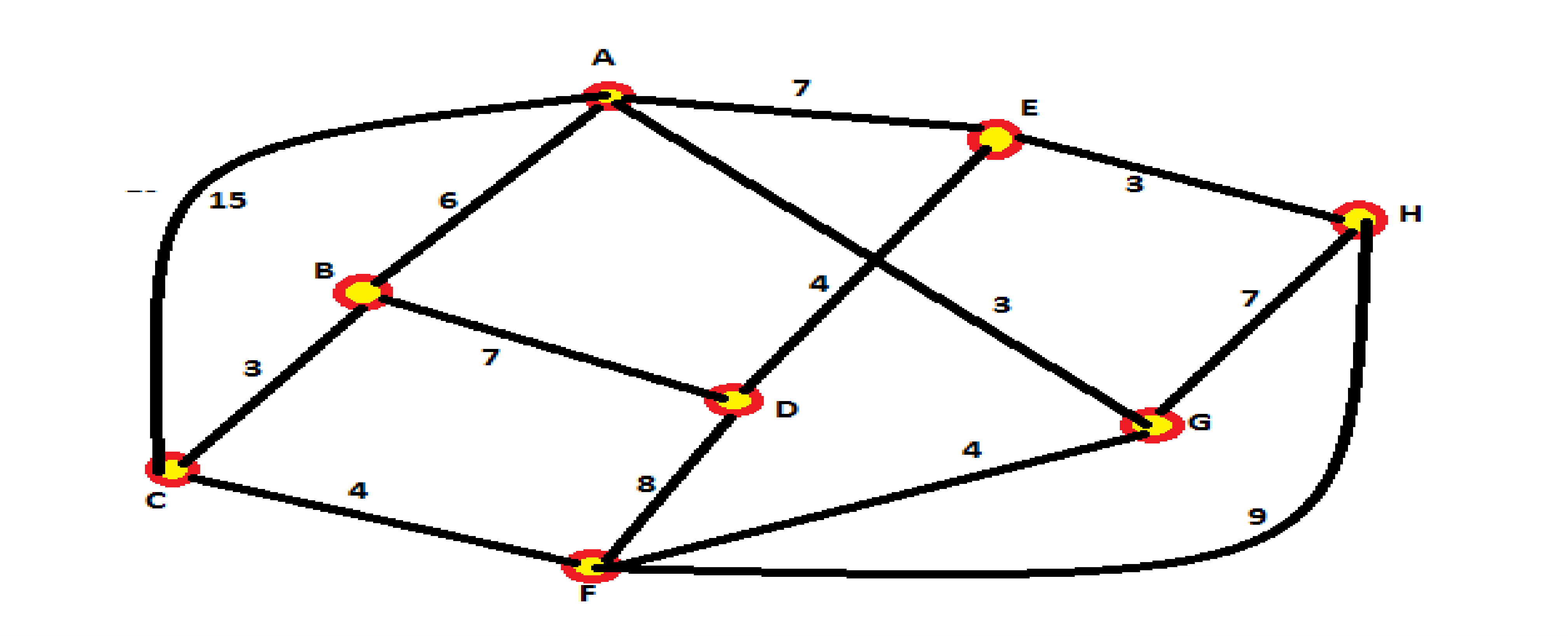
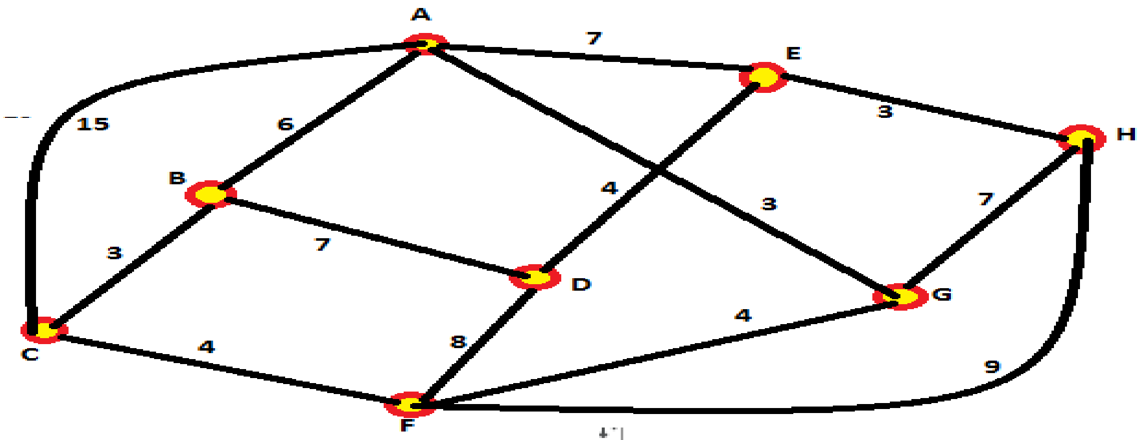
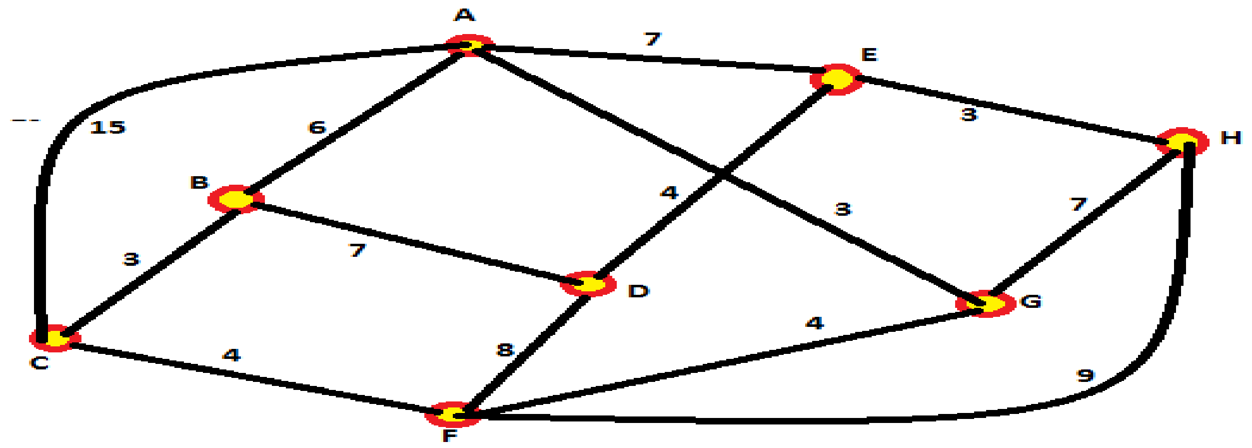




	Node A	Node B	Node C	Node D	Node E	Node F	Node G	Node H



	Node A	Node B	Node C	Node D	Node E	Node F	Node G	Node H	Remarks
A	0	6(A,B)	15(A,C)	∞	7(A,E)	∞	3(A,G)	∞	∞ means not directly connected, choose the smallest value i.e. Node G
G	-	6(A,B)	15(A,C)	∞	7(A,E)	3+4(A,G,F)	-	3+7(A,G,H)	Previous lowest value is to be added
B	-	-	6+3(A,b,C)	6+7(A.B,D)	7(A,E)	7(A,G,F)	-	10(A,G,H)	
E	-	-	9(A,B,C)	7+4(A,E,D)	-	7(A,G,F)	-	10(A,G,H)	We can change H value to 10(A,E,H)
F	-	-	9(A,B,C)	11(A,E,D)	-	-	-	10(A,G,H)	
C	-	-	-	11(A,E,D)	-	-	-	10(A,G,H)	

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.

Link-State Routing Process

-*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

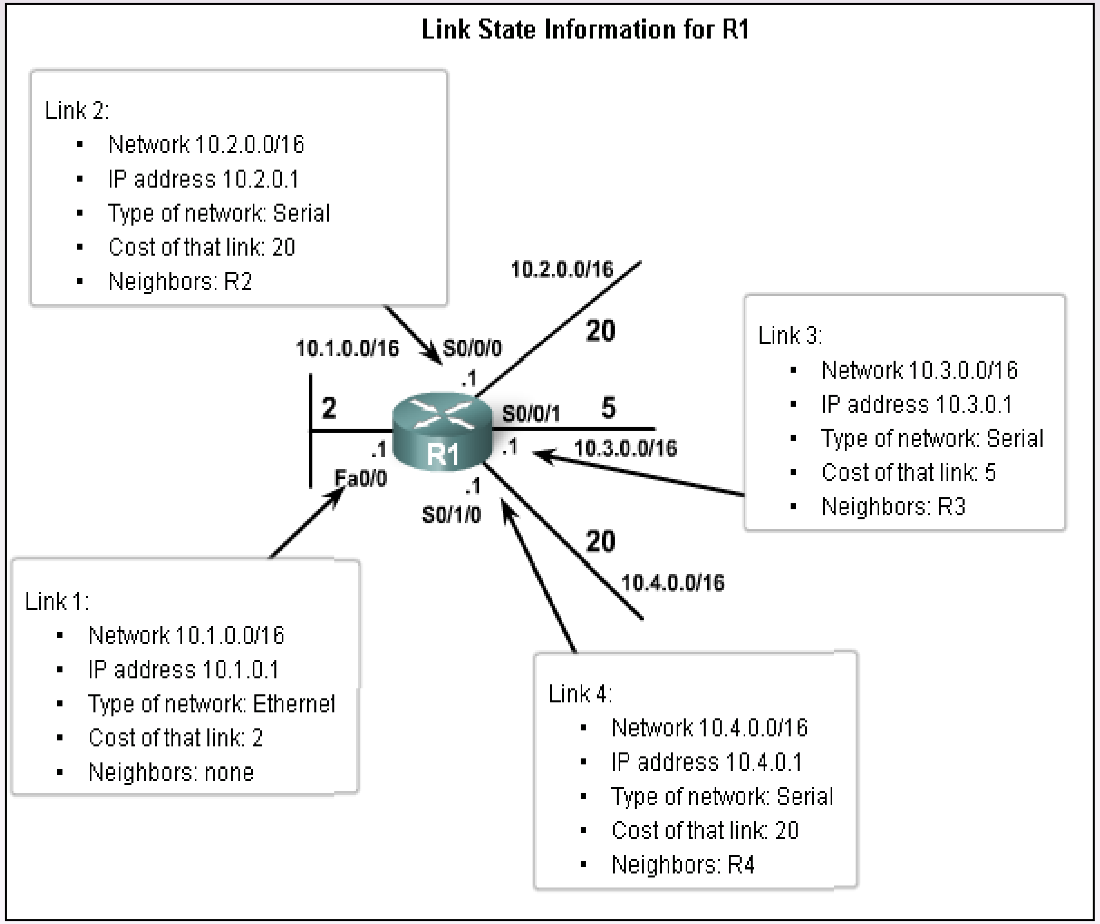
Directly Connected Networks

Link

This is an interface on a router

Link state

This is the information about the state of the links

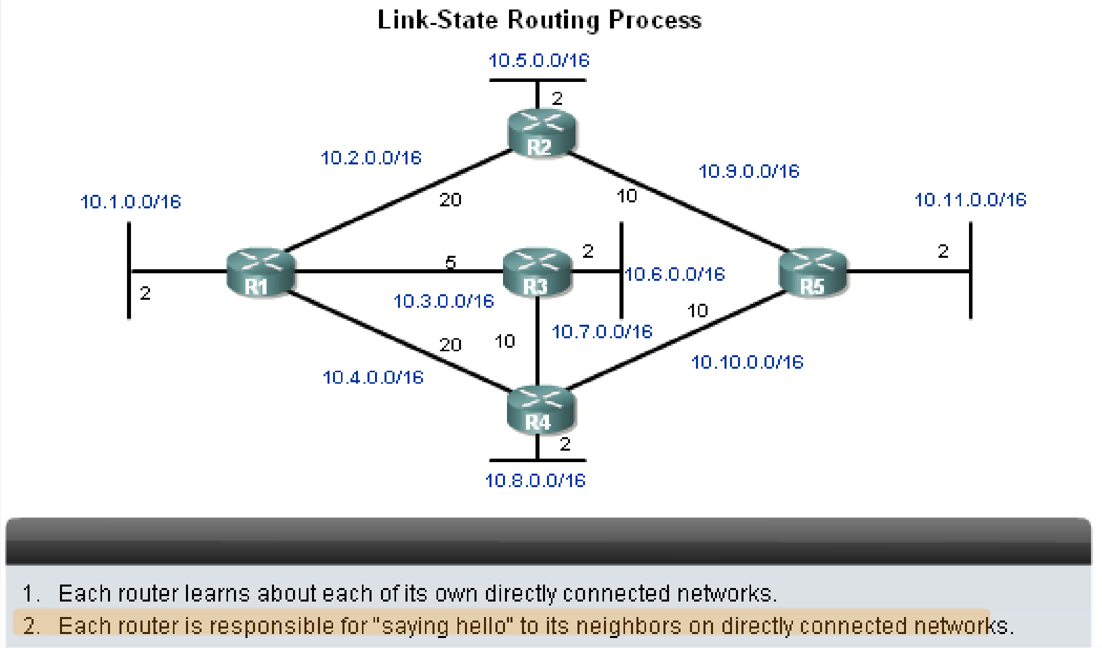


Link-State Routing

Sending Hello Packets to Neighbors

Link state routing protocols use a hello protocol

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



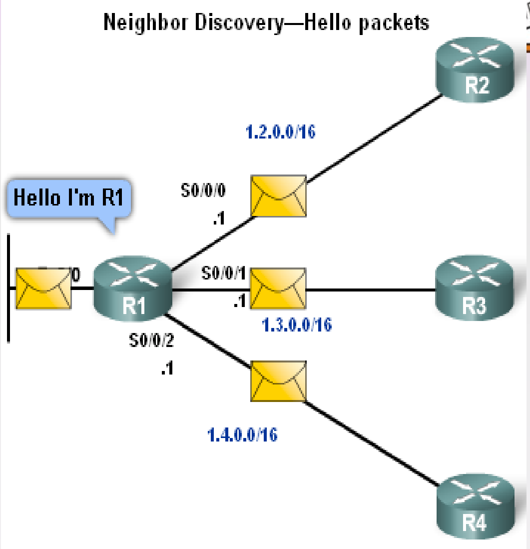
Link-State Routing

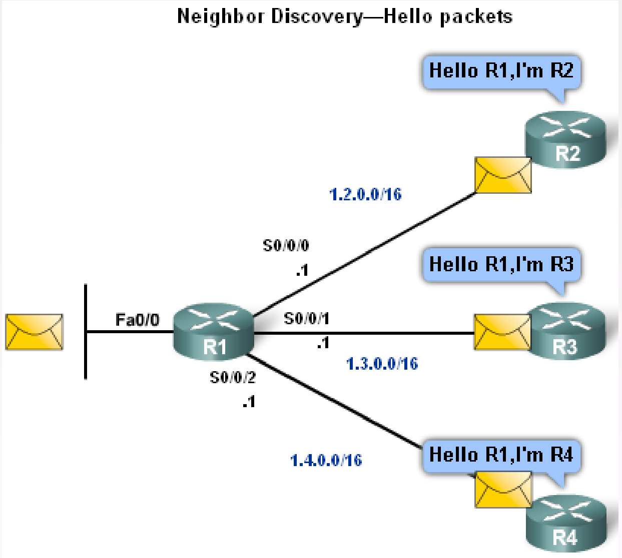
Sending Hello Packets to Neighbors

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 and 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:

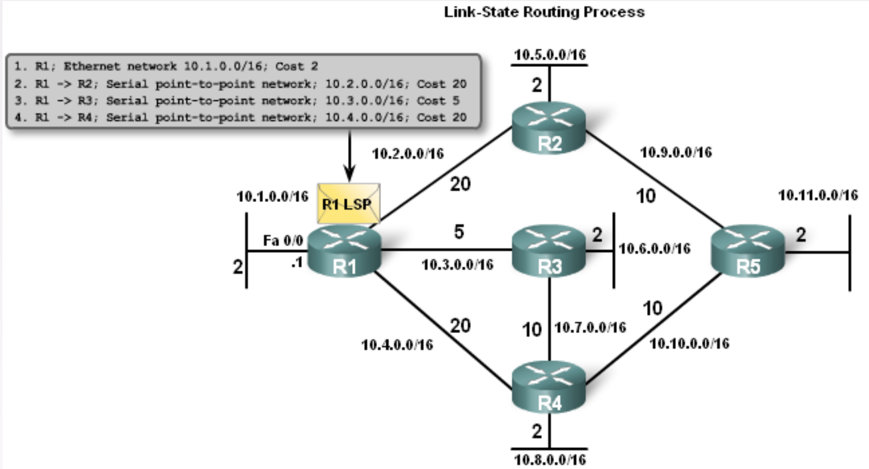
State of each directly connected link Includes

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.

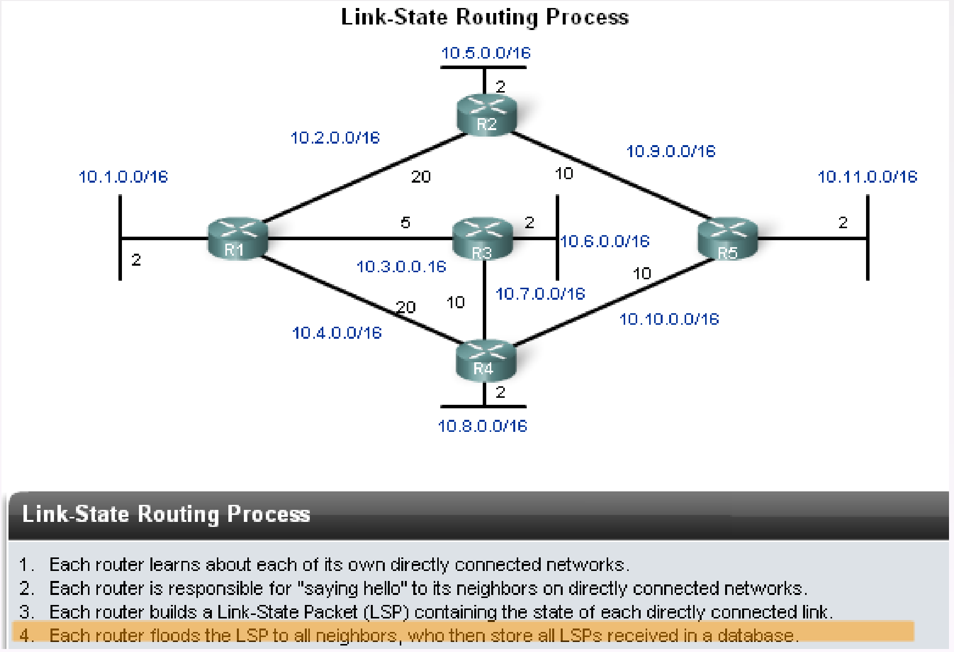


Link-State Routing

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.

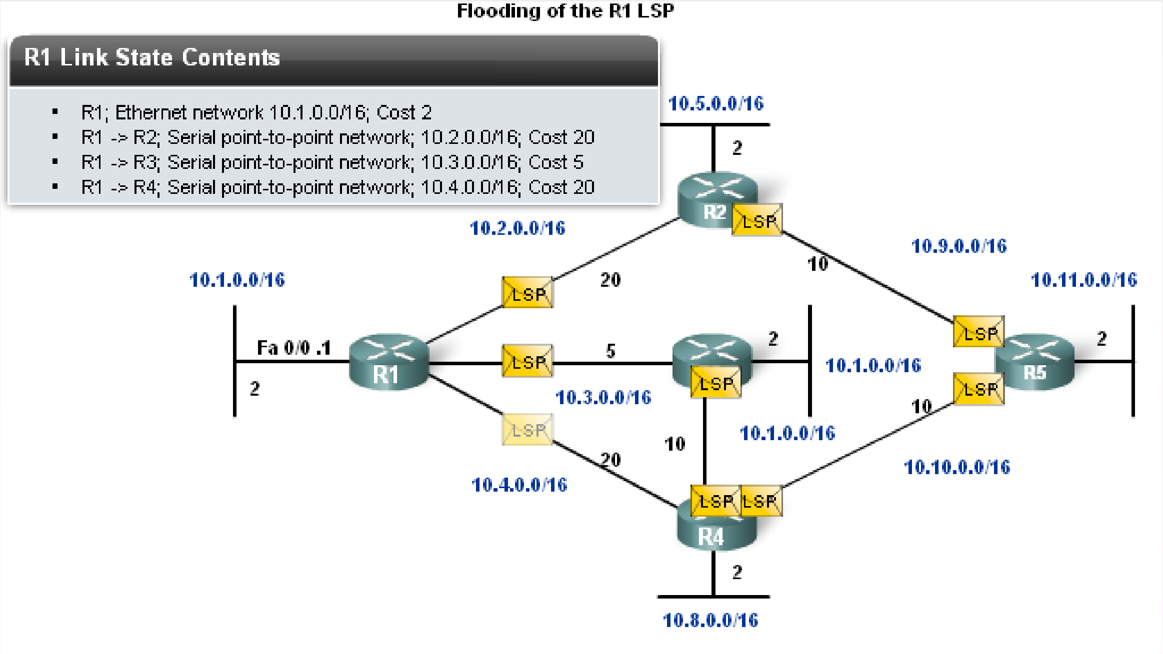


Link-State Routing

LSPs are sent out under the following conditions

-Initial router start up or routing process

-When there is a change in topology



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

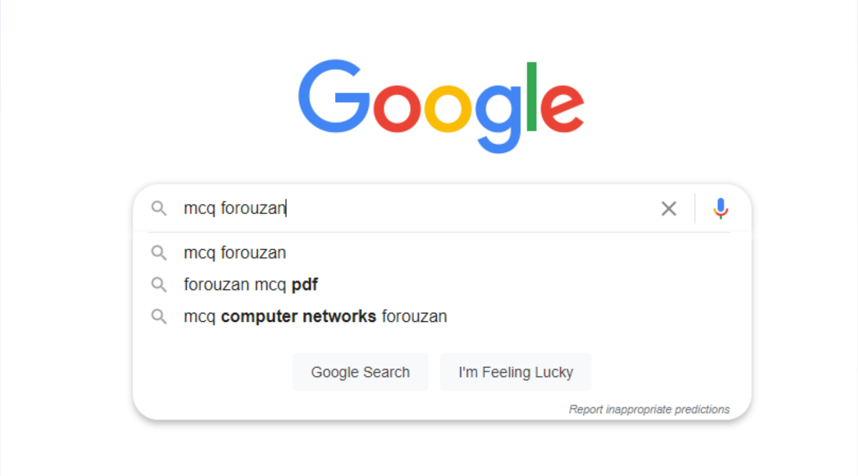
After initial flooding, additional LSP are sent out when a change in topology occurs

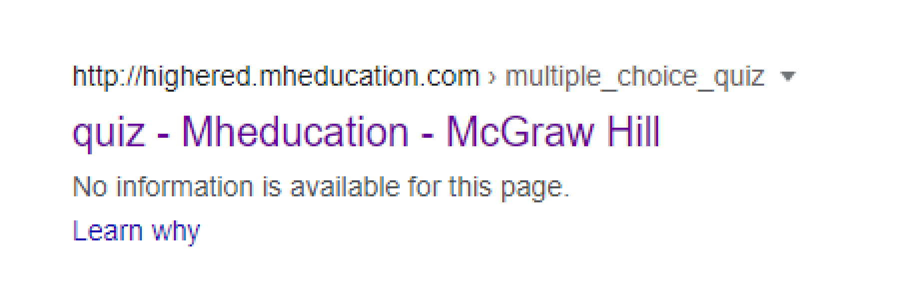
Examples of link state routing protocols

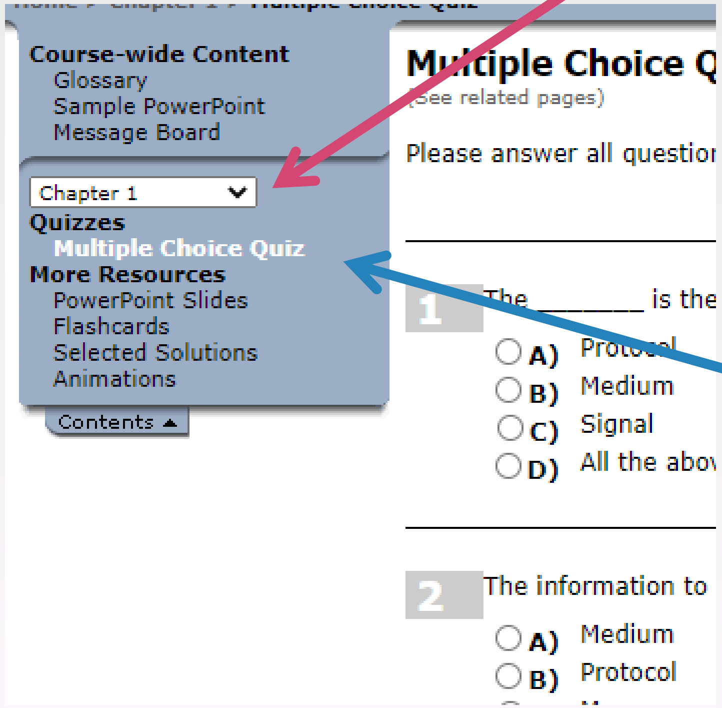
-Open shortest path first

-IS-IS

Links for mcq







Link for books mcq

http://highered.mheducation.com/sites/0072967757/student_view0/chapter1/multiple_choice_quiz.html

From the above link chose the chapter number and click on Multiple Choice Quiz.

See you in next class