Ch 20 - Summary

- In unicast routing, a packet is routed, hop by hop, from its source to its destination by the help of forwarding tables.

- Although there are several routes that a packet can travel from the source to the destination, the question is which should be the best.

- The interpretation of the term *best* depends on the cost and policy imposed on the trip.

- Several routing algorithms, and the corresponding protocols, have been devised to find the best route among them; three have survived.

- In distance-vector routing, the first thing each node creates is its own least-cost tree with the rudimentary information it has about its immediate neighbors.

- The incomplete trees are exchanged between immediate neighbors to make the trees more and more complete and to represent the whole internet.

- In other words, in distance-vector routing, a router continuously tells all of its neighbors what it knows about the whole internet.

- The protocol that implements distance-vector routing is called *Routing Information Protocol (RIP).*

- Another routing algorithm that has been used in the Internet is link-state routing.

- This method uses the term *link-state* to define the characteristic of a link (an edge) that represents a network in the internet.

- In this algorithm the cost associated with an edge defines the state of the link.

- In this algorithm, all routers flood the internet, with information related to their link states.

- When every router has the complete picture of the states, a link-state database can be created.

- The least-cost tree for each router and the corresponding forwarding table can be made from the link-state database.

- A protocol that implements link-state routing is called *Open Shortest Path First (OSPF)*.

- Both link-state and distance-vector routing are based on the least-cost goal.

- However, there are instances where this goal is not the priority.

- Path-vector routing algorithms have been designed for this purpose.

- We can always insert policies in the forwarding table by preventing a packet from visiting a specific router.

- In path-vector routing, the best route from the source is the best path, the one that complies with the policy imposed.

- The protocol that implements path-vector routing is the Border Gateway Protocol (BGP).

20.5.2 Questions

Q20-1. In a graph, if we know that the shortest path from node A to node G is (A → B → E → G), what is the shortest path from node G to node A?

Q20-1. According to the principle we mentioned in the text, the shortest path is the inverse of the original one. The shortest path is G → E → B → A.

Q20-2. Assume the shortest path in a graph from node A to node H is A → B → H. Also assume that the shortest path from node H to node N is H → G → N. What is the shortest path from node A to node N?

The solution will be : A -> B -> H -> G -> N

In case there is no other shorter path from A to G . And we can assume that there is no such case as it is not mentioned in the question :)

Q20-3. Explain why a router using link-state routing needs to receive the whole LSDB before creating and using its forwarding table. In other words, why can't the router create its forwarding table with a partially received LSDB?

Q20-3. Link-state routing uses Dijkstra's algorithm to first create the shortest-path tree before creating the forwarding table. The algorithm needs to have the complete LSDB to start.

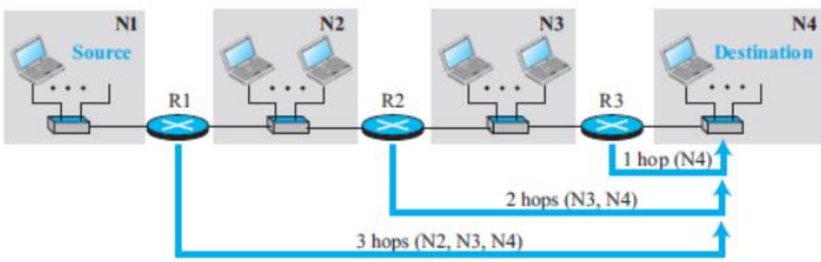
Q20-4. Is the path-vector routing algorithm closer to the distance-vector routing algorithm or to the link-state routing algorithm? Explain.

- Path vector routing is closer to distance vector routing algorithm, as in both the algorithm, the path vector that is the best path is calculated between the nodes in a network, not the shortest path is calculated.
- Both routing techniques update their routing tables periodically whenever new path from a node to its neighbor is identified. Where as in link state routing algorithm the routing table is calculated in the last after identifying all the shortest paths between different nodes in the network.

Q20-5. List three types of autonomous systems (ASs) described in the text, and make a comparison between them.

Q20-5. The three ASs described in the text are *stub*, *multihomed*, and *transient*. The first two do not allow transient traffic; the third does. The stub and multi-homed ASs are similar in that they are either the sink or source of traffic; the first is connected to only one other AS, but the second is connected to more than one ASs.

Q20-6. Explain the concept of hop count in RIP. Can you explain why no hop is counted between N1 and R1 in Figure 20.15?



• Hop count in RIP indicates, between how many routers or intermediate nodes a packet is forwarded to reach its destination network.

• Generally while calculating the hop count the source network or router is not included. This is done to reduce the traffic over the network in exchanging routing information.

• In the given network the source host is N1 and the source router is R1, therefore there is no hop count while forwarding the packet from N1.

Q20-7. Assume that we have an isolated AS running RIP. We can say that we have at least two different kinds of datagram traffic in this AS. The first kind carries the messages exchanged between hosts; the second carries messages belonging to RIP. What is the difference between the two kinds of traffic when we think about source and destination IP addresses? Does this show that routers also need IP addresses?

Q20-7. The source and destination IP addresses in datagrams carrying payloads between the hosts are the IP addresses of the hosts; the IP addresses carrying routing update packets between routers are IP addresses of the routing interfaces from which the packets are sent or received. This shows that a router needs as many IP addresses as it has interfaces.

Q20-8. Router A sends two RIP messages to two immediate neighboring routers, B and C. Do the two datagrams carrying the messages have the same source IP addresses? Do the two datagrams have the same destination IP addresses?

- Each datagram or message usually has the IP address of the interface from which the message is forwarded as the source IP address.
- Each router B and C receive messages from two different interfaces as a router can have only one neighbor on an interface.
- Therefore the two datagram's have different IP addresses as source IP addresses. As both the destination routers B and C receive messages from different interfaces.

- Each datagram or message usually has the IP address of the interface to which the message is forwarded as the destination IP address.
- Therefore the two datagram's have different IP addresses as destination IP addresses. As both the destination routers B and C have different interfaces.

Q20-9. At any moment, a RIP message may arrive at a router that runs RIP as the routing protocol. Does it mean that the RIP process should be running all the time?

Q20-9. Although RIP is running as a process using the service of the UDP, the process is called a *daemon* because it is running all the time in the background. Each router acts both as a client and a server; it acts as a client when there is a message to send; it acts as a server when a message arrives.

Q20-10. Why do you think RIP uses UDP instead of TCP?

The implementation of Routing Information Protocol (RIP) depends on the Distance-Vector routing protocol. The implementation Routing Information Protocol uses UDP applications instead of TCP for transmission of the datagrams.

Explanation:

- The UDP provides high-speed transmission of the data packets.
- To exchange a message using the UDP, the RIP need not establish a connection between the systems and need not disconnect the connection.
- To exchange messages using TCP it is required to establish a connection first and tear down the connection after message transfer.
- The RIP messages are small and simple. To transfer the data quickly, it uses the UDP.
- The UDP is a broadcast. But, the TCP is not broadcast.
- The TCP is more complex and complicated than the UDP.

Therefore, to overcome the overhead of the connection establishment and terminates the connection, RIP uses USP instead of TCP to exchange the data.

Q20-11. We say that OSPF is a hierarchical intradomain protocol, but RIP is not. What is the reason behind this statement?

Q20-11. OSPF divides an AS into areas, in which routing in each area is independent from the others; the areas only exchange a summary of routing information between them. RIP, on the other hand, considers the whole AS as one single entity.

Q20-12. In a very small AS using OSPF, is it more efficient to use only one single area (backbone) or several areas?

• OSPF open shortest path first uses link state routing and tries to identify the shortest path between two nodes.

• To improve performance, efficiency, and to overcome load over the CPU in managing multiple router information an OSPF divides entire a large AS into small areas where all the areas are connected to each other but routing in each area is independent of each the areas are linked to each other in a hierarchical fashion.

• Such a type of OSPF is called as multiarea OSPF.

• The main aim of OSPF to divide a network into smaller areas is to improve efficiency and performance of the Link state databases, smaller databases are easy to manage and exchange. This also reduces the overhead over the CPU in calculating and maintaining link state updates.

• Single area OSPF: In a single area OSPF the AS is considered as a single area and all the routers exists in the same area. This single area is called as a backbone area.

• But in a small area as the number of routers in the area is less, it is easy to manage a link state database and exchange of routing information is also easy. Therefore it is always efficient to use a Single area OSPF for small AS.

Q20-13. Why do you think we need only one RIP update message, but several OSPF update messages?

Q20-13. In RIP, each router just needs to share its distance vector with its neighbor. Since each router has one type of distance vector, we need only one update message. In OSPF, each router needs to share the state of its links with every other router. Since a router can have several types of links (a router link, a network link, …), we need several update messages.

Q20-14. OSPF messages are exchanged between routers. Does this mean that we need to have OSPF processes run all the time to be able to receive an OSPF message when it arrives?

• In OSPF routing protocol update messages are exchange only when there is a change in the routing information. Messages are not sent periodically.

• An OSPF process once started can run in the background until the process is terminated.

Q20-15. OSPF messages and ICMP messages are directly encapsulated in an IP datagram. If we intercept an IP datagram, how can we tell whether the payload belongs to OSPF or ICMP?

Q20-15. The type of payload can be determined from the value of the protocol field. The protocol field value for ICMP is 01; for OSPF, it is 89.

Q20-16. Explain what type of OSPF link state is advertised in each of the following cases:

a. A router needs to advertise the existence of another router at the end of a point-to-point link.

b. A router needs to advertise the existence of two stub networks and one transient network.

c. A designated router advertises a network as a node.

OSPF maintains a link state database, where advertisements related to different links are saved.

a) When a router needs to advertise the existence of another router at the end of a point to point link OSPF uses a Router link state advertisement.

• In a router link state advertisement it identifies the neighboring router as a node and also includes the address of the neighbor router.

b) To advertise a stub network and a transient network:

• A type of router link that is a stub link is used to advertise a stub network. In the advertisement the network address and the cost are also mentioned

• A type of router link that is a transient link is used to advertise a transient network and the address of the network and the cost to reach the network are also included in the advertisement.

c) To advertise a network as a node:

• A network link is used to advertise a network as a node.

• To advertise the network it is considered as a router and this router advertises the network as a node.

Q20-17. Can a router combine the advertisement of a link and a network in a single link-state update?

Q20-17. It cannot. A link needs to be advertised in a router link LSP; a network needs to be advertised in a network link LSP.

Q20-18. Explain why we can have different intradomain routing protocols in different ASs, but we need only one interdomain routing protocol in the whole Internet.

• Routing in a single Autonomous system is handled by Intra domain routing protocol.

• There are various Intra domain routing protocols like OSPF, RIP where the routing update information is exchanged between the routers periodically whenever there is an update.

• Routing between various Autonomous systems in an internet or networks is handled by Inter domain routing protocol. Where various organizations are involved.

• In Inter domain routing as the update information is very large and to overcome internet traffic and cost of exchanging the routing information. This update information is not exchanged periodically.

• Many intra domain protocols like OSPF, RIP exchange information periodically

• There is only one protocol that is BGP which does not exchange all the routing information periodically.

• BGP is used in creating routing policies which is required by the Internet to manage all the networks managed by different organizations.

• Therefore as only one routing protocol supports Inter domain routing, only one Inter domain routing protocol is used for the whole Internet and many routing protocols including BGP supports Intra domain routing many routing protocols can be used for Intra domain routing.

Q20-19. Can you explain why BGP uses the services of TCP instead of UDP?

Q20-19. BGP is designed to create semi-permanent communication between two BGP speakers; this requires the service of TCP. A connection is made between the two speakers and remains open, while the messages are exchanged between them. UDP cannot provide such a service.

Q20-20. Explain why policy routing can be implemented on an interdomain routing, but it cannot be implemented on a intradomain routing.

• Routing in a single Autonomous system is handled by Intra domain routing protocol.

• There are various Intra domain routing protocols like OSPF, RIP where the routing update information is exchanged between the routers periodically whenever there is an update.

• Routing between various Autonomous systems in an internet or networks is handled by Inter domain routing protocol. Where various organizations are involved.

• In Inter domain routing protocol the information is not exchanged periodically.

• Inter domain routing protocol requires routing policies as it needs to manage communication between different AS's or networks belonging to different organizations.

Therefore as Intra domain routing is handled with in a single AS or a single network and Inter domain routing has to handle networks belonging to different organizations, to enable communication between these networks a routing policy is required in Inter domain routing protocol.

Q20-21. Explain when each of the following attributes can be used in BGP:

a. LOCAL-PREF b. AS-PATH c. NEXT-HOP

Q20-21. The following shows the use of each attribute:

a. The LOCAL-PREF is used to implement the organization policy.

b. The AS-PATH defines the list of autonomous systems through which the destination can be reached.

c. The NEXT-HOP defines the next router to which the data packet should be forwarded.

20.5.3 Problems

P20-1. Assume that the shortest distance between nodes *a*, *b*, *c*, and *d* to node *y* and the costs from node *x* to nodes *a*, *b*, *c*, and *d* are given below:

$D_{ay} = 5$	$D_{by} = 6$	$D_{cy} = 4$	$D_{dy} = 3$
$c_{xa} = 2$	$c_{xb} = 1$	$c_{xc} = 3$	$c_{xd} = 1$

What is the shortest distance between node *x* and node *y*, D_{xy}, according to the Bellman-Ford equation?

P20-1. We have

$$D_{xy} = \min \{(c_{xa} + D_{ay}), (c_{xb} + D_{by}), (c_{xc} + D_{cy}), (c_{xd} + D_{dy})\}$$

$$D_{xy} = \min \{(2 + 5), (1 + 6), (3 + 4), (1 + 3)\} = \min \{7, 7, 7, 4\} = 4$$

P20-2. Assume a router using RIP has 10 entries in its forwarding table at time t_1. Six of these entries are still valid at time t_2. Four of these entries have been expired 70, 90, 110, and 210 seconds before time t_2. Find the number of periodic timers, expiration timers, and garbage collection timers running at time t_1 and time t_2.

- At time t1:
- A router generally has one periodic timer, its value is in between 25 to 35 and when the timer reaches '0', the timer is reset again.
- Therefore at time t1, for one router there is one periodic timer.
- An expiration timer indicates the validity of a route, at time t1 all the entries in the routing table are active therefore the expiration timers is 10,
- A garbage timer indicates the neighbors about invalid routes, at time t1 as all routes are valid, garbage timer value is '0'.

- At time t2:
- At time t2, for one router one periodic timer is used.
- As 4 routes are invalid the expiration timer value is 6. As only 6 entries are valid out of 10 entries in the table.
- Garbage time value is '4' as 4 routes are invalid at time t2.

P20-3. When does an OSPF router send each of the following messages?

a. hello
b. data description
c. link-state request
d. link-state update
e. link-state acknowledgment

P20-3.

a. The *hello message* (type 1) is used by a router to introduce itself to neighboring routers and to introduce already-known neighboring routers to other neighbors.

b. The *data description message* (type 2) is sent in response to a hello message. A router sends its full LSDB to the newly joined router.

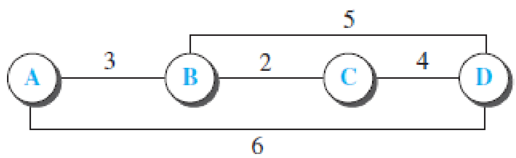
c. The *link-state request message* (type 3) is sent by a router that needs information about a specific LS.

d. The *link-state update message* (type 4) is sent by a router to other routers for building the LSDB. There are five different versions of this message to announce different link states.

e. The *link-state acknowledge message* (type 5) is sent by a router to announce the receiving of a link-state update message. This message is used to provide reliability for the main message used in OSFP.

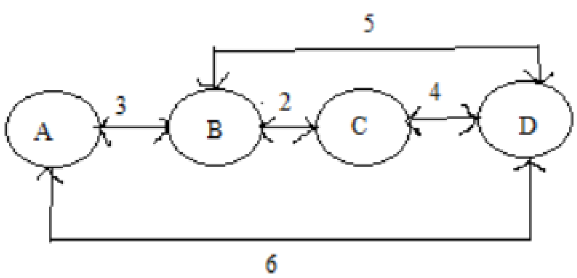
P20-4. To understand how the distance vector algorithm in Table 20.1 works, let us apply it to a four-node internet as shown in Figure 20.32.

Figure 20.32 *Problem P20-4*



Assume that all nodes are initialized first. Also assume that the algorithm is applied, one at a time, to each node respectively (A, B, C, D). Show that the process converges and all nodes will have their stable distance vectors.

- In distance vector algorithm, each node waits for a change in the link cost or distance. If there is a change it recalculates the distances and updates the same to all its neighbors.
- Initially: the nodes and their distances are



Nodes	Distance at nodes A B C D			
A	0	3	5	6
B	3	0	2	5
C	5	2	0	4
D	6	5	4	0

Suppose the algorithm starts from node A then the distance between the nodes are updated as:

Nodes	Distance at nodes A B C D			
A	0	3	5	6
B	3	0	2	5
C	5	2	0	4
D	6	5	4	0

• The least cost from A to C is calculated and is updated and sent to all other nodes.

Algorithm processes node B as there are no changes in the distance from node B to other nodes, node C is considered and the distance are updated with minimum costs.

Nodes	Distance at nodes A B C D			
A	0	3	5	6
B	3	0	2	5
C	5	2	0	4
D	6	5	4	0

• Algorithm is applied on node D and as there is no change the algorithm is applied on node A followed by B, C and D (repeat).

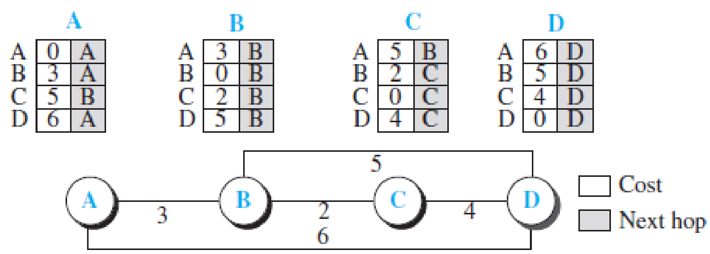
• It is observed that there is no change in the distances between the nodes after the first round of update.

• That means the resulting distance vector table does not have any changes and the process converges.

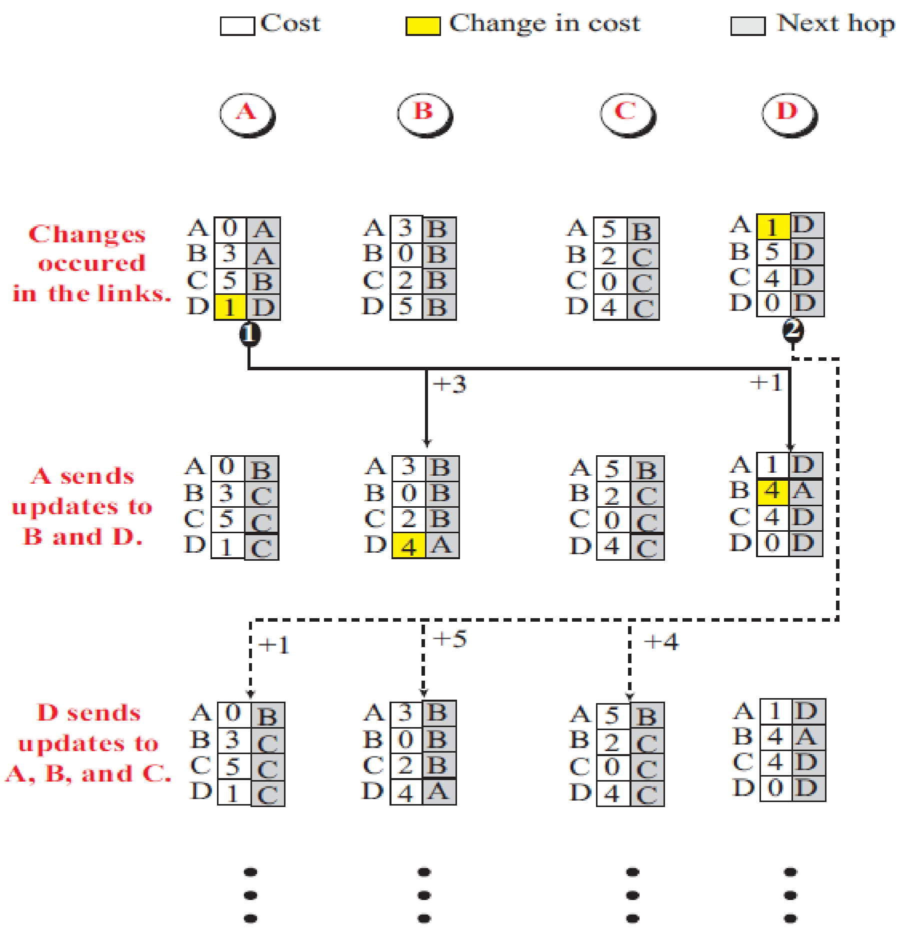
• It is also observed that the process converges irrespective of the order in which the nodes are considered and also all the nodes have stable distances between each node.

P20-5. In distance-vector routing, good news (decrease in a link metric) will propagate fast. In other words, if a link distance decreases, all nodes quickly learn about it and update their vectors. In Figure 20.33, we assume that a four-node internet is stable, but suddenly the distance between nodes A and D, which is currently 6, is decreased to 1 (probably due to some improvement in the link quality). Show how this good news is propagated, and find the new distance vector for each node after stabilization.

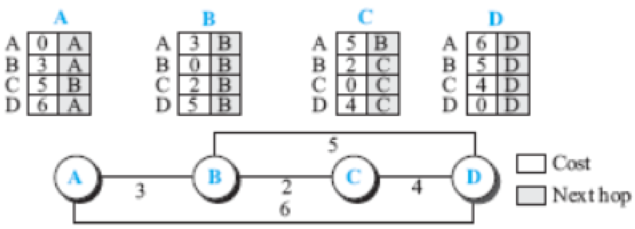
Figure 20.33 *Problem P20-6*



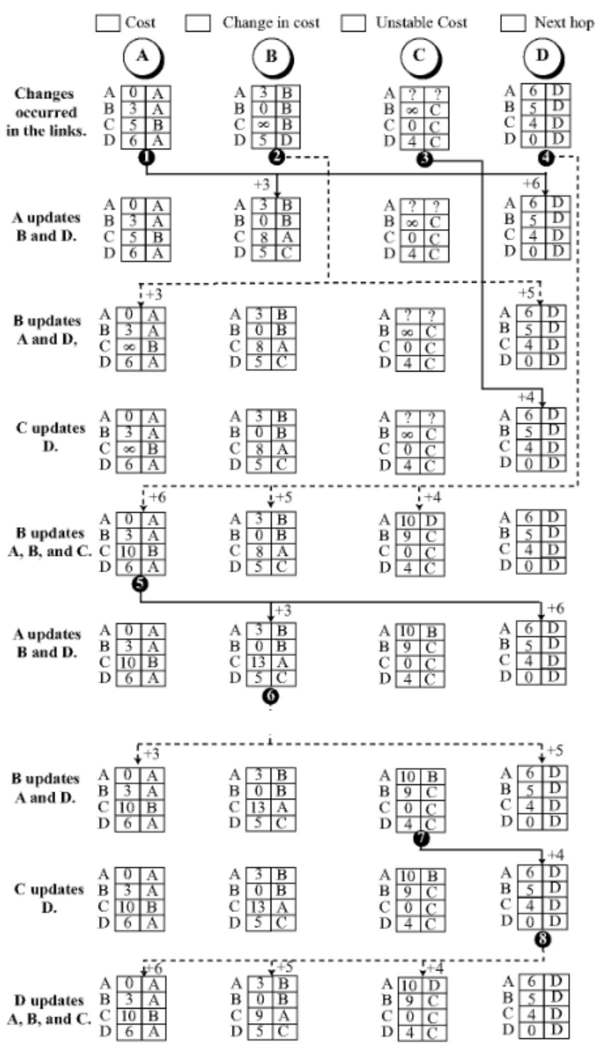
P20-5. Two nodes, A and D, see the changes. These two nodes update their vectors immediately. We assume that changes in each round are fired in the order A, B, C, D. The following shows that the internet is actually stable after two rounds of updates, but more updates are fired to assure the system is stable. We have shown only three columns for each forwarding table, but RIP usually uses more than columns. Also note that we have used the yellow color to show the changed in cost field, which triggers updates. The cost and the next hop fields participate in updating.



P20-6. In distance-vector routing, bad news (increase in a link metric) will propagate slowly. In other words, if a link distance increases, sometimes it takes a long time for all nodes to know the bad news. In Figure 20.33 (see the previous problem), we assume that a four-node internet is stable, but suddenly the distance between nodes B and C, which is currently 2, is increased to infinity (link fails). Show how this bad news is propagated, and find the new distance vector for each node after stabilization. Assume that the implementation uses a periodic timer to trigger updates to neighbors (no more updates are triggered when there is change). Also assume that if a node receives a higher cost from the same previous neighbor, it uses the new cost because this means that the old advertisement is not valid anymore. To make the stabilization faster, the implementation also suspends a route when the next hop is not accessible.



P4-36. The following shows how the forwarding tables will be changed.



No more updates need to be sent; the system is stable.

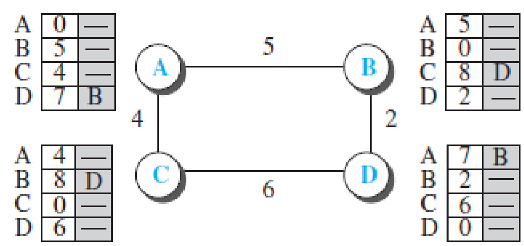
Note that there are some unstable cost values that are not finalized. These wrong pieces of information may create looping in the system; the packet may bound back and forth until the system becomes stable. Eight updates are needed to stabilize the system.

P20-7. In computer science, when we encounter an algorithm, we often need to ask about the complexity of that algorithm (how many computations we need to do). To find the complexity of the distance vector's algorithm, find the number of operations a node needs to do when it receives a vector from a neighbor.

P20-7. The number of operations in each iteration of the algorithm is n, in which n is the number of nodes in the network. In computer science, this complexity is written as $O(n)$ and is referred to as Big-O notation.

P20-8. Assume that the network in Figure 20.34 uses distance-vector routing with the forwarding table as shown for each node.

Figure 20.34 *Problem P20-8*



If each node periodically announces their vectors to the neighbor using the poison-reverse strategy, what is the distance vector advertised in the appropriate period:

a. from A to B? **b.** from C to D? **c.** from D to B? **d.** from C to A?

P4-38. The following shows the advertisement in each case (a triplet defines the destination, cost, and the next hop):

a. From A to B: (A, 0, A), (C, 4, A), (D, ∞, B).

b. From C to D: (A, 4, C), (B, ∞, D), (C, 0, C), (D, ∞, C).

c. From D to ?: (A, ∞, B), (B, ∞, D), (C, 6, D), (D, 0, D).

d. From C to A: (A, ∞, C), (B, 8, D), (C, 0, C), (D, 6, C).

P20-9. Assume that the network in Figure 20.34 (previous problem) uses distance-vector routing with the forwarding table as shown for each node. If each node periodically announces their vectors to the neighbor using the split-horizon strategy, what is the distance vector advertised in the appropriate period:

a. from A to B? **b.** from C to D? **c.** from D to B? **d.** from C to A?

P20-9. The following shows the advertisement in each case (a triplet defines the destination, cost, and the next hop):

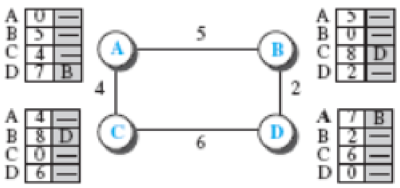
a. From A to B: (A, 0, A), (C, 4, A).

b. From C to D: (A, 4, C), (C, 0, C).

c. From D to B: (C, 6, D), (D, 0, D).

d. From C to A: (B, 8, D), (C, 0, C), (D, 6, C).

P20-10. Assume that the network in Figure 20.34 (Problem P20-8) uses distance vector routing with the forwarding table as shown for each node. If node E is added to the network with a link of cost 1 to node D, can you find the new forwarding tables for each node without using the distance-vector algorithm?



Finding the new forwarding tables:

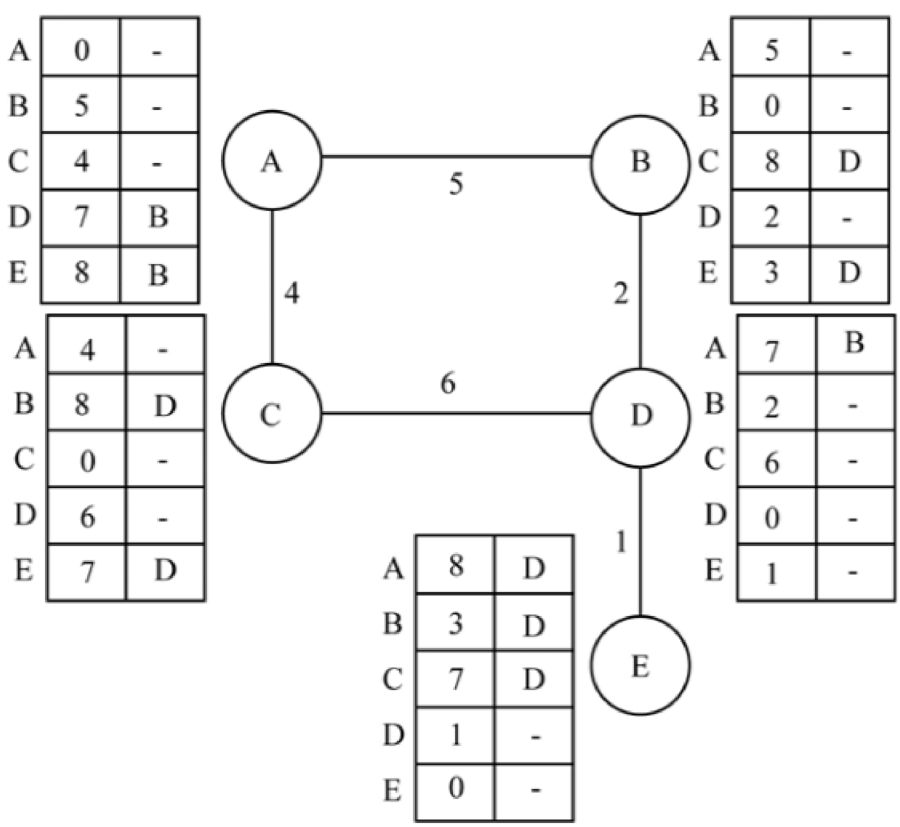
No, it is not possible to find the new forwarding tables to each node of given network without using the distance-vector algorithm.

• The new node E is added to the network with link cost 1, after adding the node E it will be available like other nodes A, B, C, D.

• The node E does not do any special activities to replace the work of distance-vector algorithm; even Node E also requires the distance-vector algorithm to find the forwarding table.

Therefore, even if a new node is added in the network then also finding the forwarding table without the distance-vector algorithm is not possible.

Network diagram after adding the node E:



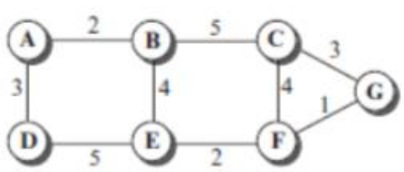
P20-11. Create the forwarding table for node A in Figure 20.10.

P20-11. The forwarding table for node A can be made using the least-cost tree, as shown below:

Forwarding table for node A

Destination	Cost	Next hop
A	0	—
B	2	—
C	7	B
D	3	—
E	6	B
F	8	B
G	9	B

P20-12. Create the shortest path tree and the forwarding table for node G in Figure 20.8.



a. The weighted graph

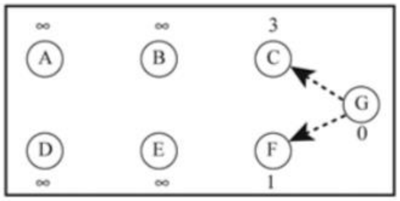
	A	B	C	D	E	F	G
A	0	2	∞	3	∞	∞	∞
B	2	0	5	∞	4	∞	∞
C	∞	5	0	∞	∞	4	3
D	3	∞	∞	0	5	∞	∞
E	∞	4	∞	5	0	2	∞
F	∞	∞	4	∞	2	0	1
G	∞	∞	3	∞	∞	1	0

b. Link state database

Shortest path:

- The minimum distance required to reach other node from a current node in a network is called as shortest path.
- Each path or a link is assigned with a weight or cost, the weight or cost is tells that how much it is required to reach other node from current node in the network.
- The weight or cost is used to calculate minimum distance.

Shortest-path tree and the forwarding table for node G:



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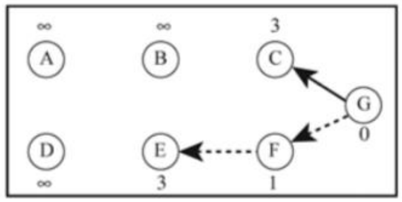
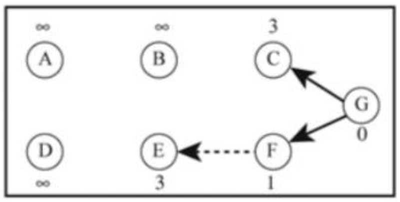
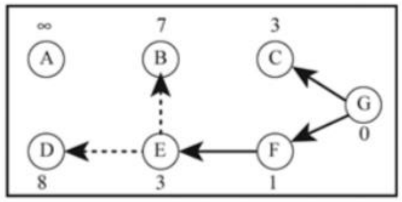


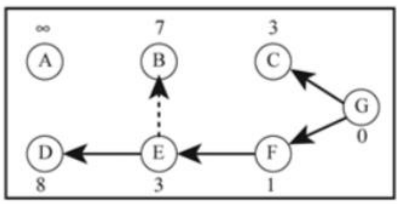
Iteration 1



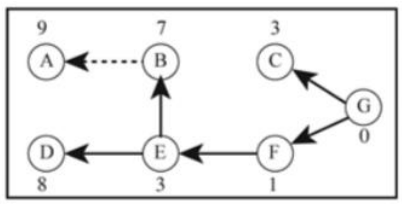
Iteration 2



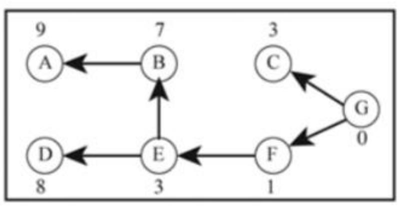
Iteration 3



Iteration 4



Iteration 5



Iteration 6

• At the initial stage node G is having two neighbour nodes F with a path cost 1 and C with a path cost 3.

• In first iteration Node G is reached to Node C.

• In second iteration Node G is reached to Node F.

• In third iteration Node G is reached to Node E with a next hop F and a cost is 3.

• In fourth iteration Node G is reached to Node D via nodes F, E and a cost is 8.

• In fifth iteration Node G is reached to Node B via nodes F, E and a cost is 7.

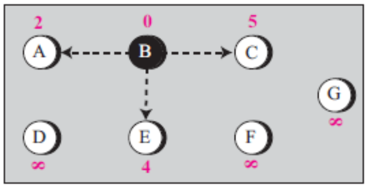
• In sixth iteration Node G is reached to Node A via nodes F, E, B and a cost is 9.

Forwarding table:

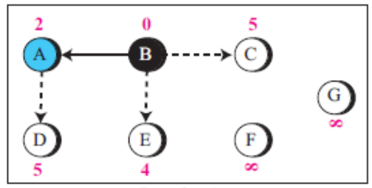
Destination	Cost	Next Hop
A	9	F
B	7	F
C	3	-
D	8	F
E	3	F
F	1	-
G	0	-

P20-13. Create the shortest path tree and the forwarding table for node B in Figure 20.8.

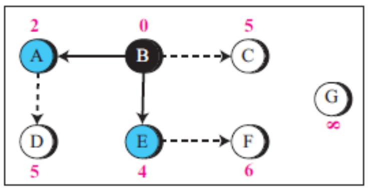
P20-13. The following shows the steps to create the shortest path tree for node B and the forwarding table for this node.



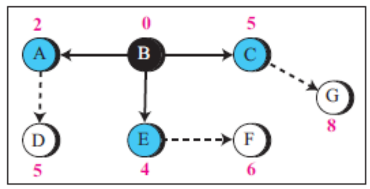
Initialization



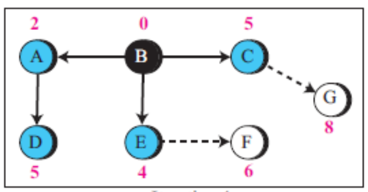
Iteration 1



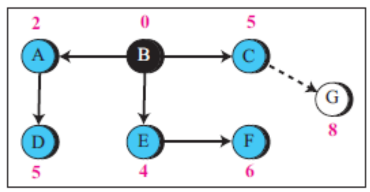
Iteration 2



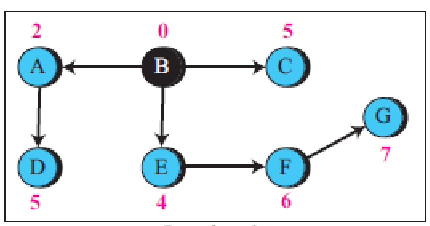
Iteration 3



Iteration 4



Iteration 5



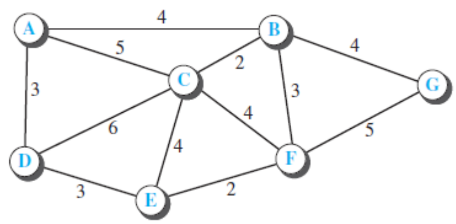
Iteration 6

Destination	Cost	Next hop
A	2	——
B	0	——
C	5	——
D	5	A
E	4	——
F	6	E
G	8	E

Forwarding table for node B

P20-14. Use Dijkstra's algorithm (Table 20.2) to find the shortest path tree and the forwarding table for node A in the Figure 20.35.

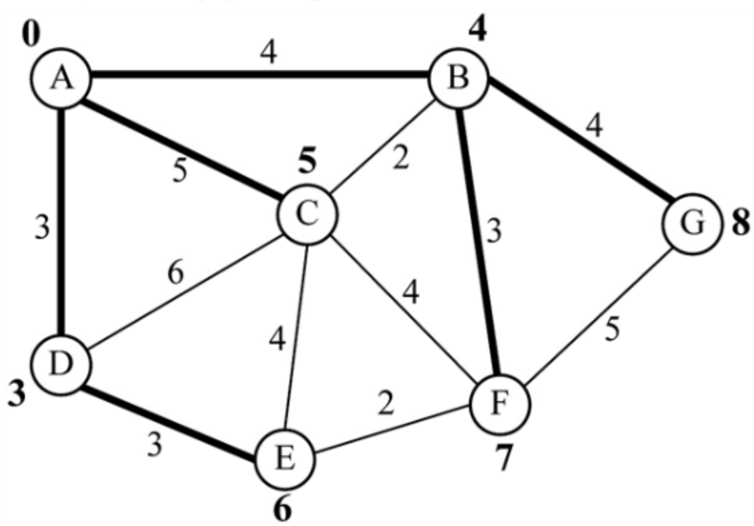
Figure 20.35 *Problem P20-14*



Dijkstra's algorithm:

- Dijkstra's algorithm is used to find the shortest path from the source node to destination node.
- Set the initial node as current node and mark all the other nodes as unvisited.
- From the current node, compute the distance of its unvisited neighbour node, compare the calculated values, and find the optimal path to the node.
- Mark the current node as visited. Select the next unvisited node and mark it as current node and continue step to find the shortest path to every node from the source node.

Shortest-path tree using Dijkstra's algorithm:



- In the given network, Node A having the neighbours B, C, D and the optimal path cost to reach the node are 4, 5, 3.
- From Node A to Node G the optimal path cost is 4+4=8, the next hop to Node A is Node B.
- From Node A to Node F the optimal path cost is 4+3=7, the next hop to Node A is Node B.
- From Node A to Node E the optimal path cost is 3+3=6, the next hop to Node A is Node D.

Forwarding table:

Destination	Cost	Next Hop
A	0	-
B	4	-
C	5	-
D	3	-
E	6	D
F	7	B
G	8	B

P20-15. In computer science, when we encounter an algorithm, we often need to ask about the complexity of that algorithm (how many computations we need to do). To find the complexity of Dijkstra's algorithm, find the number of searches we have to do to find the shortest path for a single node when the number of nodes is n.

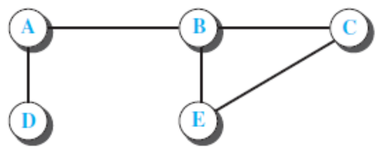
P20-15. The number of searches in each iteration of Dijkstra's algorithm is different. In the first iteration, we need n number of searches, in the second iteration, we need $(n - 1)$, and finally in the last iteration, we need only one. In other words, the total number of searches for each node to find its own shortest-path tree is

$$\text{Number of searches} = n + n - 1 + n - 2 + n - 3 + \ldots + 3 + 2 + 1 = n\,(n + 1) / 2$$

The series can be calculated if it is written twice: once in order and once in the reverse order. We then have n items, each of value $(n + 1)$, which results in $n(n + 1)$. However, we need to divide the result by 2. In computer science, this complexity is written as $O(n^2)$ and is referred to as Big-O notation.

P20-16. Assume that A, B, C, D, and E in Figure 20.36 are autonomous systems (ASs). Find the path vector for each AS using the algorithm in Table 20.3. Assume that the best path in this case is the path which passes through the shorter list of ASs. Also assume that the algorithm first initializes each AS and then is applied, one at a time, to each node respectively (A, B, C, D, E). Show that the process converges and all ASs will have their stable path vectors.

Figure 20.36 *Problem P20-16*



A path vector algorithm is used to get the best path from the source node to the destination node. It initializes each node and create path vector table for all nodes. Refer Table 4.6 of textbook for Path vector algorithm.

Suppose there are 5 autonomous systems as nodes of a graph as shown in Figure 1.

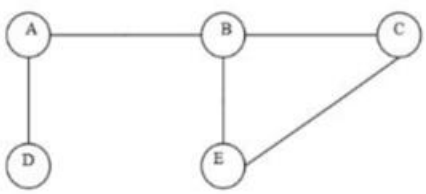


Figure 1

To find the Path vector for each autonomous system(AS), initialize each AS first, then update each path vector table to get the best path vector. Best path vector here is the path which passes through shorter number of ASs.

Initialize each AS (A,B,C,D,E) using path vector algorithm.

• Initialize A. Scan the autonomous systems which are directly connected to A.

A	A
B	A,B
C	
D	A,D
E	

• Initialize B.

A	B,A
B	B
C	B,C
D	
E	B,E

• Initialize C.

A	
B	C,B
C	C
D	
E	C,E

• Initialize D.

A	D,A
B	
C	
D	D
E	

• Initialize E.

A	
B	E,B
C	E,C
D	
E	E

P20-17. In Figure 20.24, assume that the intra-AS routing protocol used by AS1 is OSPF, but the one used by AS2 is RIP. Explain how R5 can find how to route a packet to N4.

P20-17. Router R1, using its OSPF forwarding table, knows how to forward a packet destined for N4. R1 announces this reachability to R5 using an eBGP session. R5 adds an entry to its RIP forwarding table that shows R1 as the next router for any packet destined for N4.

P20-18. In Figure 20.24, assume that the intra-AS routing protocol used by AS4 and AS3 is RIP. Explain how R8 can find how to route a packet to N13.

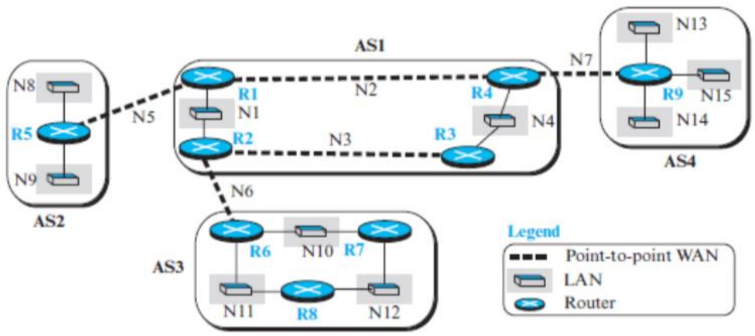


Figure 4.79 *A sample internet with four ASs*

- Using OSPF method Router R9 identifies the shortest path from R9 to network N13.
- Router R9 using eBGP session announces its reachbility to other AS's that is to AS1.
- Router R4 enters this advertisement by R9 in its forwarding table.
- A router in Autonomous system AS1 can state its reach-ability to other routers within the same autonomous system using an iBGP session, iBGP is an internal Border gateway protocol which runs between two nodes in the same AS.
- Using iBGP session R2 identifies the shortest path from R2 to R4.
- Similarly using an iBGP session Router R8 identifies the shortest path from R8 to R6 in AS3.
- Router R2 using eBGP session announces its reach ability to other AS's that is to AS3.
- Router R6 enters this in its forwarding table.
- When R8 wants to connect to N13, it uses the path from R6R2R4R9 to reach N13.