LONGEST PREFIX MATCHING

Consider a datagram network using 8-bit host addresses.
Suppose a router uses longest-prefix matching, and has the following forwarding table:

Prefix Match	Interface
10	1
01	2
100	3
010	4
110	5
otherwise	6

https://gaia.cs.umass.edu/kurose_ross/interactive/

QUESTION LIST

1. Suppose a datagram arrives at the router, with destination address 11010010. To which interface will this datagram be forwarded using longest-prefix matching?

2. Suppose a datagram arrives at the router, with destination address 01001011. To which interface will this datagram be forwarded using longest-prefix matching?

3. Suppose a datagram arrives at the router, with destination address 11110111. To which interface will this datagram be forwarded using longest-prefix matching?

SOLUTION

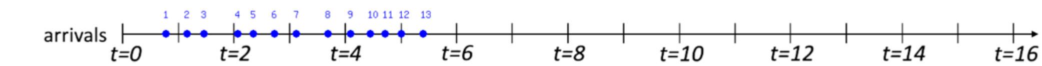
1. Since the address is 11010010, it will go to interface 5.

2. Since the address is 01001011, it will go to interface 4.

3. Since the address is 11110111, it will go to interface 6.

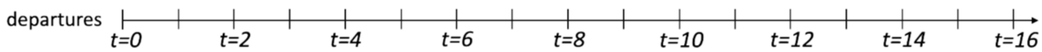
PACKET SCHEDULING

Consider the arrival of 13 packets to an output link at a router in the interval of time [0, 5], as indicated by the figure below. We'll consider time to be "slotted", with a slot beginning at t = 0, 1, 2, 3, etc. Packets can arrive at any time during a slot, and multiple packets can arrive during a slot. At the beginning of each time slot, the packet scheduler will choose one packet, among those queued (if any), for transmission according to the packet scheduling discipline (that you will select below). Each packet requires exactly one slot time to transmit, and so a packet selected for transmission at time t, will complete its transmission at t+1, at which time another packet will be selected for transmission, among those queued. You might want to review section 4.2.5 in the 8th edition of our textbook, on packet scheduling.



Packets (#: time): 1: 0.78, 2: 1.15, 3: 1.45, 4: 2.06, 5: 2.33, 6: 2.71, 7: 3.09, 8: 3.65, 9: 4.06, 10: 4.41, 11: 4.67, 12: 4.96, 13: 5.34

Packets (#: class): 1: 2 , 2: 3 , 3: 3 , 4: 2 , 5: 2 , 6: 2 , 7: 3 , 8: 3 , 9: 3 , 10: 3 , 11: 3 , 12: 3 , 13: 3

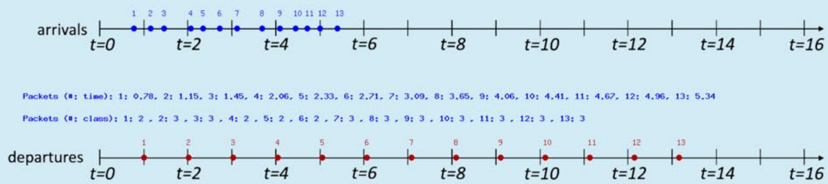


Choose a specific packet scheduling discipline (FCFS, Priority, RR, and WFQ) from the list below. In the case of Priority, RR, and WFQ there will be three classes of traffic (1, 2, 3), with lower class numbers having higher priority in the case of priority schedule, or beginning earlier in the case of RR and WFQ. In the case of WFQ, scheduling weights are 0.5, 0.3, and 0.2.

Select Scheduling Discipline

FIFO

SOLUTION



1. At time t=1, the packet sent is 1.

2. At time t=2, the packet sent is 2.

3. At time t=3, the packet sent is 3.

4. At time t=4, the packet sent is 4.

5. At time t=5, the packet sent is 5.

6. At time t=6, the packet sent is 6.

7. At time t=7, the packet sent is 7.

8. At time t=8, the packet sent is 8.

9. At time t=9, the packet sent is 9.

10. At time t=10, the packet sent is 10.

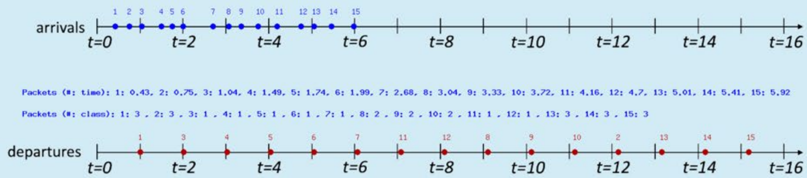
11. At time t=11, the packet sent is 11.

12. At time t=12, the packet sent is 12.

13. At time t=13, the packet sent is 13.

Priority

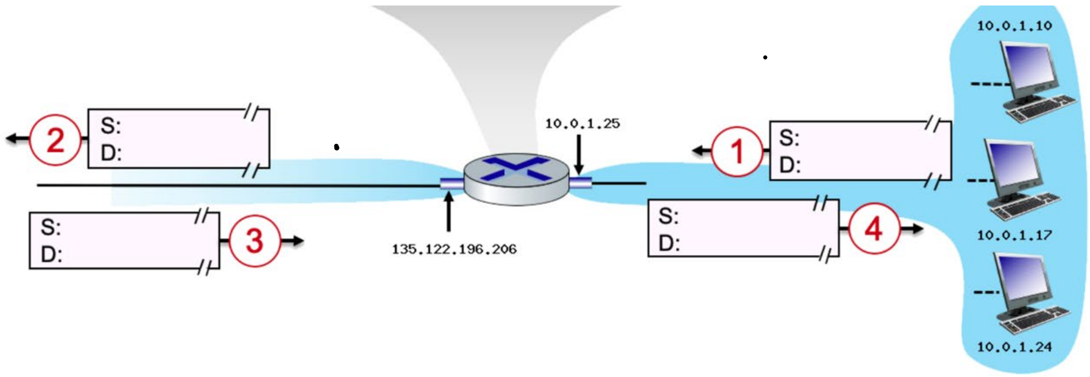
SOLUTION



1. At time t=1, the packet sent is 1.
2. At time t=2, the packet sent is 3.
3. At time t=3, the packet sent is 4.
4. At time t=4, the packet sent is 5.
5. At time t=5, the packet sent is 6.
6. At time t=6, the packet sent is 7.
7. At time t=7, the packet sent is 11.
8. At time t=8, the packet sent is 12.
9. At time t=9, the packet sent is 8.
10. At time t=10, the packet sent is 9.
11. At time t=11, the packet sent is 10.
12. At time t=12, the packet sent is 2.
13. At time t=13, the packet sent is 13.
14. At time t=14, the packet sent is 14.
15. At time t=15, the packet sent is 15.

Network Address Translation

Consider the scenario below in which three hosts, with private IP addresses 10.0.1.10, 10.0.1.17, 10.0.1.24 are in a local network behind a NAT'd router that sits between these three hosts and the larger Internet. IP datagrams being sent from, or destined to, these three hosts must pass through this NAT router. The router’s interface on the LAN side has IP address 10.0.1.25, while the router’s address on the Internet side has IP address 135.122.196.206



Suppose that the host with IP address 10.0.1.17 sends an IP datagram destined to host 128.119.179.183. The source port is 3385, and the destination port is 80.

Question List

1. Consider the datagram at step 1, after it has been sent by the host but before it has reached the router. What is the source IP address for this datagram?

2. At step 1, what is the destination IP address?

3. Now consider the datagram at step 2, after it has been transmitted by the router. What is the source IP address for this datagram?

4. At step 2, what is the destination IP address for this datagram?

5. Will the source port have changed? Yes or No.

6. Now consider the datagram at step 3, just before it is received by the router. What is the source IP address for this datagram?

7. At step 3, what is the destination IP address for this datagram?

8. Last, consider the datagram at step 4, after it has been transmitted by the router but before it has been received by the host. What is the source IP address for this datagram?

9. At step 4, what is the destination IP address for this datagram

Solution

1. The source address will be the local host's IP, which is 10.0.1.17

2. The destination address will be the remote machine's IP, which is 128.119.179.183

3. The source address will be the router's public IP, which is 135.122.196.206

4. The destination address will be the remote machine's IP, which is 128.119.179.183

5. Yes, the NAT will change the source port.

6. The source address will be the remote machine's IP, which is 128.119.179.183

7. The destination address will be the router's public IP, which is 135.122.196.206

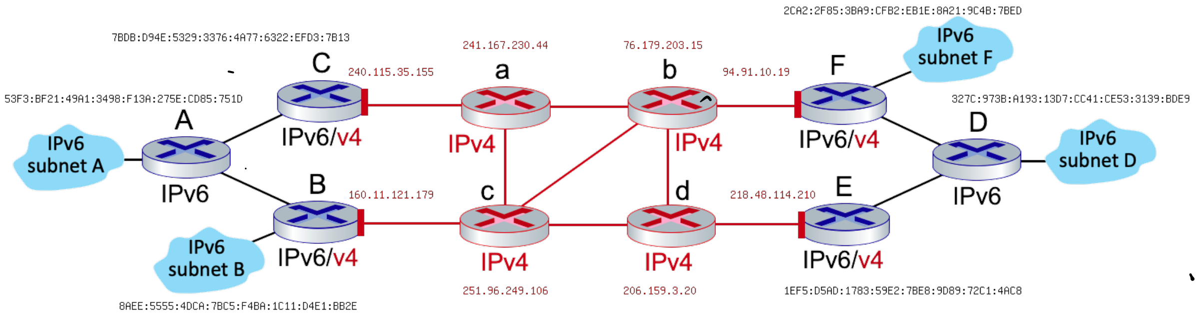
8. The source address will be the remote machine's IP, which is 128.119.179.183

9. The destination address will be the local host's IP, which is 10.0.1.17

10. No, an entry is made when there's an outbound request, which only happens between step 1 and step 2.

IPv6 Tunneling and Encapsulation

Consider the network shown below which contains four IPv6 subnets, connected by a mix of IPv6-only routers (shaded blue), IPv4-only routers (shaded red) and dual-capable IPv6/IPv4 routers (shaded blue with red interfaces to IPv4 routers). You might want to review Section 4.3.4 in the textbook before doing this problem.



Suppose that a host of subnet A wants to send an IPv6 datagram to a host on subnet D. Assume that the forwarding between these two hosts goes along the path: A --> B --> c --> d --> b --> F --> D

---

question List

1. Is the datagram being forwarded from A to B an IPv4 or IPv6 datagram?

2. What is the source address of this A to B datagram?

3. What is the destination address of this A to B datagram?

4. Is this A to B datagram encapsulating another datagram? Yes or No.

5. Is the datagram being forwarded from B to c an IPv4 or IPv6 datagram?

6. What is the source address of this B to c datagram?

7. What is the destination address of this B to c datagram?

8. Is this B to c datagram encapsulating another datagram? Yes or No.

9. What is the source address of this encapsulated datagram?

10. What is the destination address of this encapsulated datagram?

11. Is the datagram being forwarded from c to d an IPv4 or IPv6 datagram?

12. What is the source address of this c to d datagram?

13. What is the destination address of this c to d datagram?

14. Is this c to d datagram encapsulating another datagram? Yes or No.

15. What is the source address of this encapsulated datagram?

16. What is the destination address of this encapsulated datagram?

17. Is the datagram being forwarded from d to b an IPv4 or IPv6 datagram?

18. What is the source address of this d to b datagram?

19. What is the destination address of this d to b datagram?

20. Is this d to b datagram encapsulating another datagram? Yes or No.

21. What is the source address of this encapsulated datagram?

22. What is the destination address of this encapsulated datagram?

23. Is the datagram being forwarded from b to F an IPv4 or IPv6 datagram?

24. What is the source address of this b to F datagram?

25. What is the destination address of this b to F datagram?

26. Is this b to F datagram encapsulating another datagram? Yes or No.

27. What is the source address of this encapsulated datagram?

28. What is the destination address of this encapsulated datagram?

29. Is the datagram being forwarded from F to D an IPv4 or IPv6 datagram?

30. What is the source address of this F to D datagram?

31. What is the destination address of this F to D datagram?

32. Is this F to D datagram encapsulating another datagram? Yes or No.

33. What router is the 'tunnel entrance'? Give the router's letter

34. What router is the 'tunnel exit'? Give the router's letter

35. Which protocol encapsulates the other, IPv4 or IPv6?

Solution

1. The datagram is an IPv6 datagram.

2. The source IP address is 53F3:BF21:49A1:3498:F13A:275E:CD85:751D

3. The destination IP address is 327C:973B:A193:13D7:CC41:CE53:3139:BDE9

4. No, the datagram is NOT encapsulated.

5. The datagram is an IPv4 datagram.

6. The source IP address is 160.11.121.179

7. The destination IP address is 94.91.10.19

8. Yes, the datagram is encapsulated.

9. The source address of this encapsulated datagram is 53F3:BF21:49A1:3498:F13A:275E:CD85:751D

10. The destination address of this encapsulated datagram is 327C:973B:A193:13D7:CC41:CE53:3139:BDE9

11. The datagram is an IPv4 datagram.

12. The source IP address is 160.11.121.179

13. The destination IP address is 94.91.10.19

14. Yes, the datagram is encapsulated.

15. The source address of this encapsulated datagram is
53F3:BF21:49A1:3498:F13A:275E:CD85:751D

16. The destination address of this encapsulated datagram is
327C:973B:A193:13D7:CC41:CE53:3139:BDE9

17. The datagram is an IPv4 datagram.

18. The source IP address is 160.11.121.179

19. The destination IP address is 94.91.10.19

20. Yes, the datagram is encapsulated.

21. The source address of this encapsulated datagram is
53F3:BF21:49A1:3498:F13A:275E:CD85:751D

22. The destination address of this encapsulated datagram is
327C:973B:A193:13D7:CC41:CE53:3139:BDE9

23. The datagram is an IPv4 datagram.

24. The source IP address is 160.11.121.179

25. The destination IP address is 94.91.10.19

26. Yes, the datagram is encapsulated.

27. The source address of this encapsulated datagram is
53F3:BF21:49A1:3498:F13A:275E:CD85:751D

28. The destination address of this encapsulated datagram is
327C:973B:A193:13D7:CC41:CE53:3139:BDE9

29. The datagram is an IPv6 datagram.

30. The source IP address is 53F3:BF21:49A1:3498:F13A:275E:CD85:751D

31. The destination IP address is 327C:973B:A193:13D7:CC41:CE53:3139:BDE9

32. No, the datagram is NOT encapsulated.

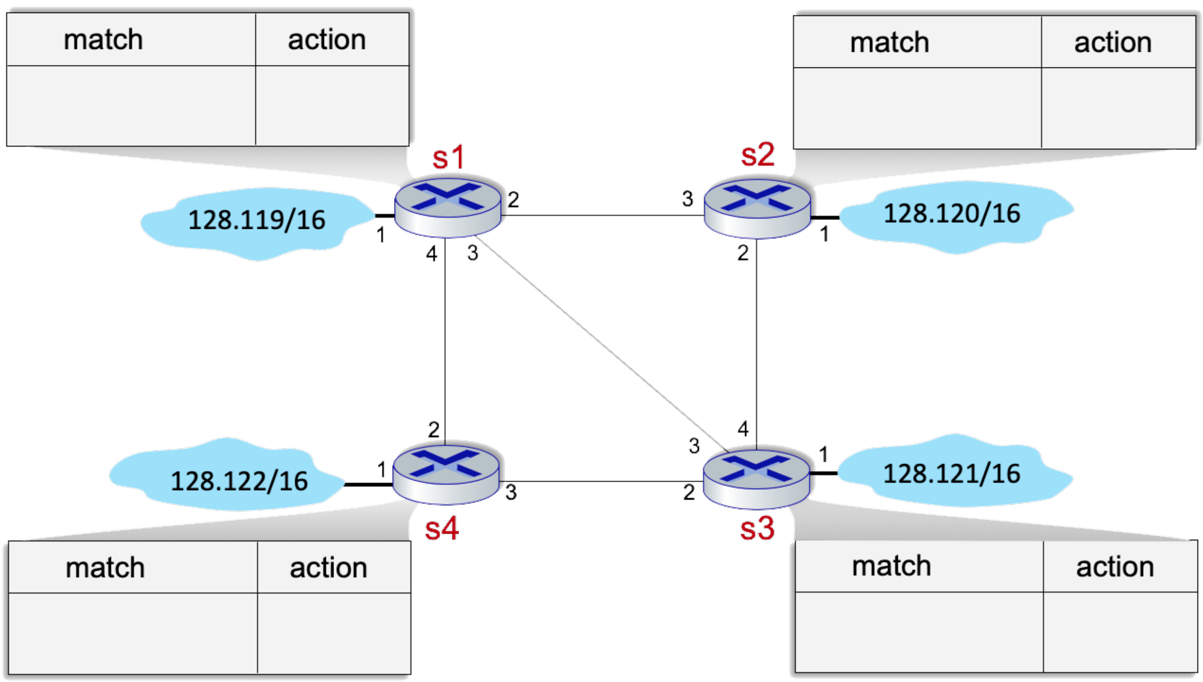
33. The tunnel entrance is router B

34. The tunnel exit is router F

35. IPv4, in order to maintain compatibility with existing IPv4 infrastructure, IPv6 datagrams are put in the payload of an IPv4 datagram. These IPv4 datagrams are passed on until it reaches a router which supports IPv6, where the IPv6 datagram is decapsulated and passed on.

Openflow Flow Tables

Consider the 4-router network shown below, where packet forwarding is controlled by flow tables (e.g., configured via OpenFlow in an SDN controller), rather than by a forwarding table computed by a routing algorithm. The addresses of networks attached to each of the router is also shown. The interfaces at each of the routers are also as indicated.



Suppose we want the following forwarding behavior of packets to be implemented:

- TCP packets coming from the source network attached to s4 and destined to the network attached to s3 should be forwarded along the path: s4 -> s3. UDP packets coming from the source network attached to s4 and destined to the network attached to s3 should be forwarded along the different path: s4 -> s1 -> s2 -> s3

Complete the match-plus-action tables in each of the routers, s1, s2, s3, and s4, that implement these forwarding behaviors. Your rules should be as strict as possible (should only allow these behaviors, and no other forwarding behaviors). You can assume that any packet arriving at a router that does not match a rule in that table will be dropped.

Question List

1. For router s1, what should the value of the 'IP Src' be? Pick either a specific address (including CIDR), any, or none

2. For router s1, what should the value of the 'IP Dst' be? Pick either a specific address (including CIDR), any, or none

3. For router s1, what should the value of the 'Src Port' be? Pick either a specific port, or any

4. For router s1, what should the value of the 'Dst Port' be? Pick either a specific port, or any

5. For router s1, what should the value of the 'IP Proto' be? Pick either TCP, UDP, or any

6. For router s1, what should the action of the rule be? Some examples include forward, allow, deny, etc

7. For router s1, what interface should the packets be forwarded to?

8. For router s2, what should the value of the 'IP Src' be? Pick either a specific address (including CIDR), any, or none

9. For router s2, what should the value of the 'IP Dst' be? Pick either a specific address (including CIDR), any, or none

10. For router s2, what should the value of the 'Src Port' be? Pick either a specific port, or any

11. For router s2, what should the value of the 'Dst Port' be? Pick either a specific port, or any

12. For router s2, what should the value of the 'IP Proto' be? Pick either TCP, UDP, or any

13. For router s2, what should the action of the rule be? Some examples include forward, allow, deny, etc

14. For router s2, what interface should the packets be forwarded to?

15. For router s3, what should the value of the 'IP Src' be? Pick either a specific address (including CIDR), any, or none

16. For router s3, what should the value of the 'IP Dst' be? Pick either a specific address (including CIDR), any, or none

17. For router s3, what should the value of the 'Src Port' be? Pick either a specific port, or any

18. For router s3, what should the value of the 'Dst Port' be? Pick either a specific port, or any

19. For router s3, what should the value of the 'IP Proto' be? Pick either TCP, UDP, or any

20. For router s3, what should the action of the rule be? Some examples include forward, allow, deny, etc

21. For router s3, what interface should the packets be forwarded to?

22. For router s3, what should the value of the 'IP Src' be? Pick either a specific address (including CIDR), any, or none

23. For router s3, what should the value of the 'IP Dst' be? Pick either a specific address (including CIDR), any, or none

24. For router s3, what should the value of the 'Src Port' be? Pick either a specific port, or any

25. For router s3, what should the value of the 'Dst Port' be? Pick either a specific port, or any

26. For router s3, what should the value of the 'IP Proto' be? Pick either TCP, UDP, or any

27. For router s3, what should the action of the rule be? Some examples include forward, allow, deny, etc

28. For router s3, what interface should the packets be forwarded to?

29. For router s4, what should the value of the 'IP Src' be? Pick either a specific address (including CIDR), any, or none

30. For router s4, what should the value of the 'IP Dst' be? Pick either a specific address (including CIDR), any, or none

31. For router s4, what should the value of the 'Src Port' be? Pick either a specific port, or any

32. For router s4, what should the value of the 'Dst Port' be? Pick either a specific port, or any

33. For router s4, what should the value of the 'IP Proto' be? Pick either TCP, UDP, or any

34. For router s4, what should the action of the rule be? Some examples include forward, allow, deny, etc

35. For router s4, what interface should the packets be forwarded to?

36. For router s4, what should the value of the 'IP Src' be? Pick either a specific address (including CIDR), any, or none

37. For router s4, what should the value of the 'IP Dst' be? Pick either a specific address (including CIDR), any, or none

38. For router s4, what should the value of the 'Src Port' be? Pick either a specific port, or any

39. For router s4, what should the value of the 'Dst Port' be? Pick either a specific port, or any

40. For router s4, what should the value of the 'IP Proto' be? Pick either TCP, UDP, or any

41. For router s4, what should the action of the rule be? Some examples include forward, allow, deny, etc

42. For router s4, what interface should the packets be forwarded to?

Solution

(Q1-Q7) Rule 1. | IP_Src=128.122/16, IP_Dst=128.121/16, Src_Port=Any, Dst_Port=Any, IP_Protocol=UDP, Action=Forward(2) |

(Q8-Q14) Rule 2. | IP_Src=128.122/16, IP_Dst=128.121/16, Src_Port=Any, Dst_Port=Any, IP_Protocol=UDP, Action=Forward(2) |

(Q15-Q21) Rule 3. | IP_Src=128.122/16, IP_Dst=128.121/16, Src_Port=Any, Dst_Port=Any, IP_Protocol=TCP, Action=Forward(1) |

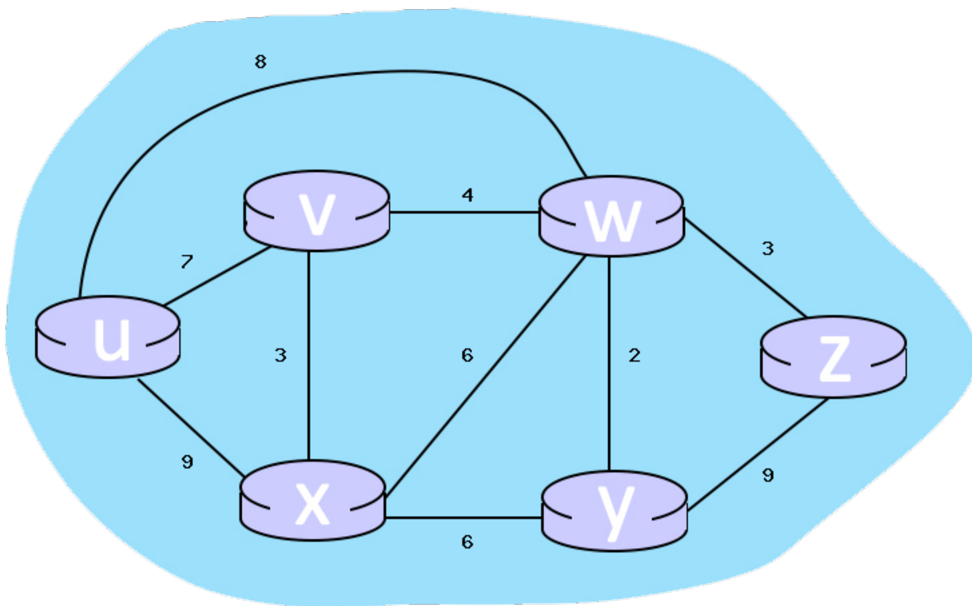
(Q22-Q28) Rule 4. | IP_Src=128.122/16, IP_Dst=128.121/16, Src_Port=Any, Dst_Port=Any, IP_Protocol=UDP, Action=Forward(1) |

(Q29-Q35) Rule 5. | IP_Src=128.122/16, IP_Dst=128.121/16, Src_Port=Any, Dst_Port=Any, IP_Protocol=TCP, Action=Forward(3) |

(Q36-Q42) Rule 6. | IP_Src=128.122/16, IP_Dst=128.121/16, Src_Port=Any, Dst_Port=Any, IP_Protocol=UDP, Action=Forward(2) |

Dijkstra's Link State Algorithm (for computing least cost paths)

Consider the 6-node network shown below, with the given link costs.



Using Dijkstra's algorithm, find the least cost path from source node U to all other destinations and answer the following questions

---

Question List

1. What is the shortest distance to node x and what node is its predecessor? Write your answer as n,p

2. What is the shortest distance to node w and what node is its predecessor? Write your answer

as n,p

3. What is the shortest distance to node v and what node is its predecessor? Write your answer as n,p

---

Solution

1. The minimum distance from node u to node x is 9, and node x's predecessor is node u. The full answer was: 9,u

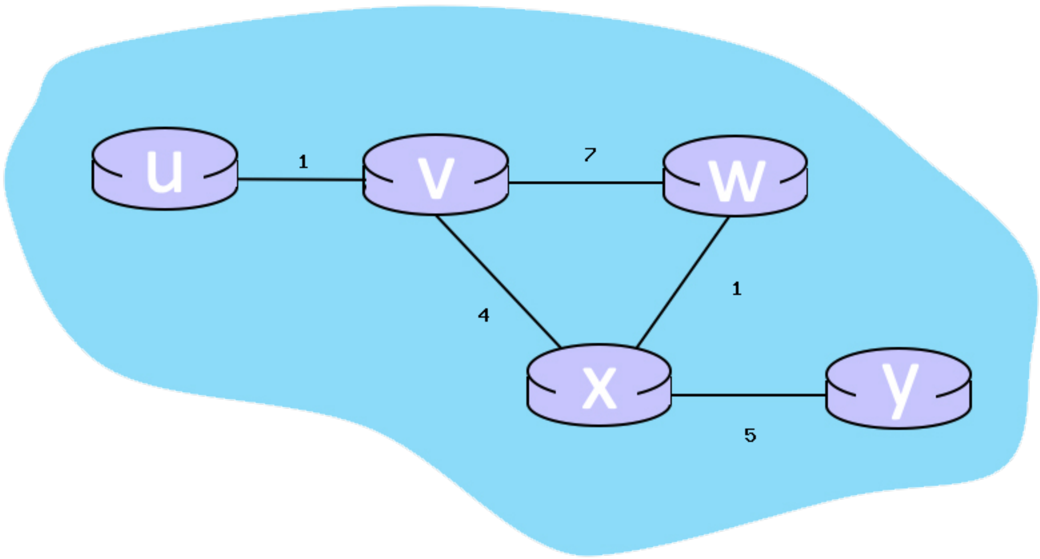
2. The minimum distance from node u to node w is 8, and node w's predecessor is node u. The full answer was: 8,u

3. The minimum distance from node u to node v is 7, and node v's predecessor is node u. The full answer was: 7,u

---

Bellman Ford Distance Vector Algorithm (for computing least cost paths)

Consider the 6-node network shown below, with the given link costs:



Question List

1. When the algorithm converges, what are the distance vectors from router 'Y' to all routers? Write your answer as u,v,w,x,y

2. What are the initial distance vectors for router 'X'? Write your answer as u,v,w,x,y and if a distance is ∞, write 'x'

3. The phrase 'Good news travels fast' is very applicable to distance vector routing when link costs decrease; what is the name of the problem that can occur when link costs increase?

Solution

1. When the algorithm converges, router Y has distance vectors (u,v,w,x,y) = (10,9,6,5,0)

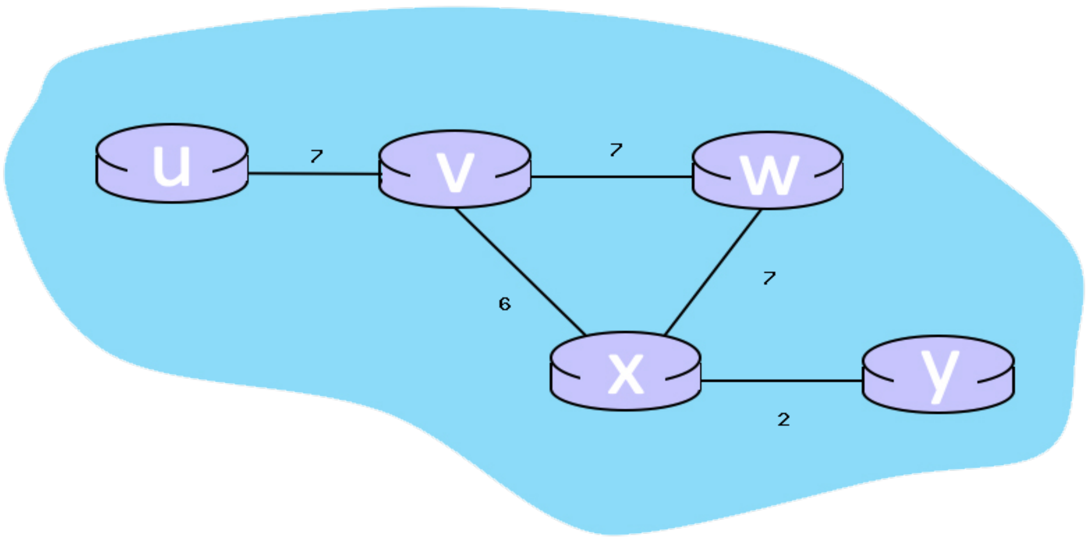
2. The initial distance vectors of router X are: (u,v,w,x,y) = (x,4,1,0,5) where x is ∞

3. It is called the 'Count to Infinity' problem.

https://gaia.cs.umass.edu/kurose_ross/interactive/

Bellman Ford Distance Vector Algorithm (for computing least cost paths)

Consider the 6-node network shown below, with the given link costs:



Question List

1. When the algorithm converges, what are the distance vectors from router 'V' to all routers? Write your answer as u,v,w,x,y

2. What are the initial distance vectors for router 'W'? Write your answer as u,v,w,x,y and if a distance is ∞, write 'x'

3. The phrase 'Good news travels fast' is very applicable to distance vector routing when link costs decrease; what is the name of the problem that can occur when link costs increase?

Solution

1. When the algorithm converges, router V has distance vectors (u,v,w,x,y) = (7,0,7,6,8)

2. The initial distance vectors of router W are: (u,v,w,x,y) = (x,7,0,7,x) where x is ∞

3. It is called the 'Count to Infinity' problem.