

Name\_\_\_\_\_ Student ID\_\_\_\_\_ Department/Year\_\_\_\_\_

### **3rd Examination**

Introduction to Computer Networks (Online)

Class#: EE 4020, Class-ID: 901E31110

Fall 2022

10:20-12:10 Thursday

December 22, 2022

### **Cautions**

1. There are in total 100 points to earn. You have 90 minutes to answer the questions. Skim through all questions and start from the questions you are more confident with.
2. Use only English to answer the questions. Misspelling and grammar errors will be tolerated, but you want to make sure with these errors your answers will still make sense.

1. (ch41, 6pt) Recall the functionalities supported by the network layer. For each of the following statements, tell whether it is true or false.
  - (1) Routing is one of the functionalities. (1pt)
  - (2) Breaking of datagrams into segments is one of the functionalities. (1pt)
  - (3) Routing is in the control plane. (1pt)
  - (4) Forwarding is in the data plane. (1pt)
  - (5) Connectionless service is the service model of the Internet network layer. (1pt)
  - (6) Connection-oriented service is the service model of the Internet network layer. (1pt)

Sample Solution:

TFTTTF

2. (ch42, 6pt) A router's major functionality is to forward a packet out on the right network interface so the packet can continue on and eventually reach its destination. Suppose the packets destined to the following address ranges should go to the corresponding network interfaces in a router.

<u>Destination Address Range</u>	<u>Network Interface</u>
11001000 00010111 01001100 00000000 through 11001000 00010111 01001111 11111111	0
11001000 00010111 00011010 00000000 through 11001000 00010111 00011011 11111111	1
11001000 00010111 00011011 00000000 through 11001000 00010111 00011011 11111111	2
otherwise	3

Based on how longest match works, fill in below the destination prefixes for network interface 0, 1, and 2.

<u>Destination Address Prefix</u>	<u>Network Interface</u>
(a)	0
(b)	1
(c)	2
default	3

- (1) What should the destination address prefix (a) be? (1pt)
- (2) What should the destination address prefix (b) be? (1pt)
- (3) What should the destination address prefix (c) be? (1pt)

Sample Solution:

<u>Destination Prefix</u>	<u>Network Interface</u>
(a) 11001000 00010111 010011	0
(b) 11001000 00010111 0001101	1
(c) 11001000 00010111 00011011	2
Default	3

3. (ch42, 4pt) Consider a traditional router containing a forwarding table as follows.

<u>Destination Prefix</u>	<u>Interface</u>
11001000 00010111 1100	1
11001000 00010111 10101	2
11001000 00010111 1010	3
11001000 00010111 101011	4
default	5

Now 4 packets come along with the following destination addresses. Based on the longest match principle, which interfaces will the 4 packets be forwarded to?

- (1) 11001000 00010111 **01000000** 10110000 (1pt)
- (2) 11001000 00010111 **10000011** 10110000 (1pt)
- (3) 11001000 00010111 **10101100** 10110000 (1pt)
- (4) 11001000 00010111 **10101000** 10110000 (1pt)

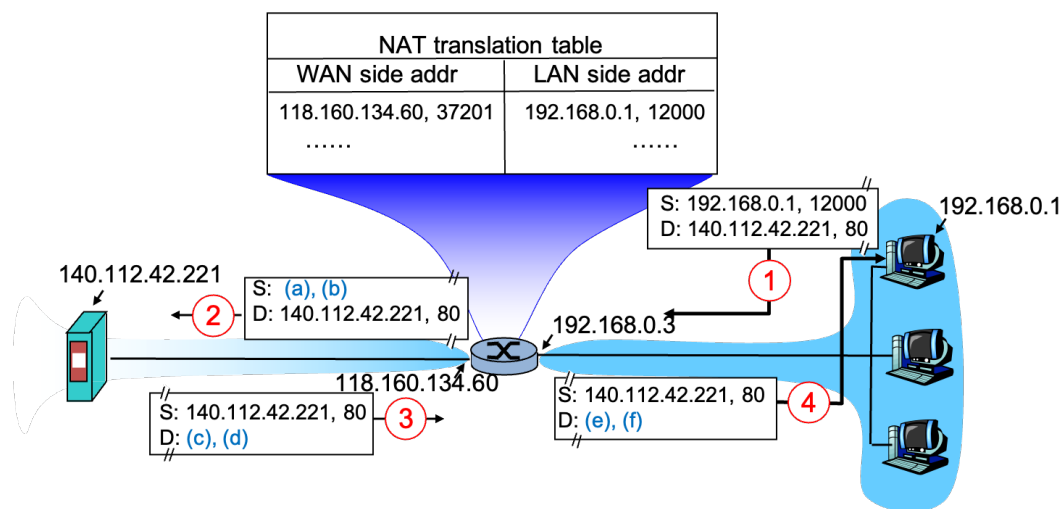
Sample Solution:

- (1) 5
- (2) 5

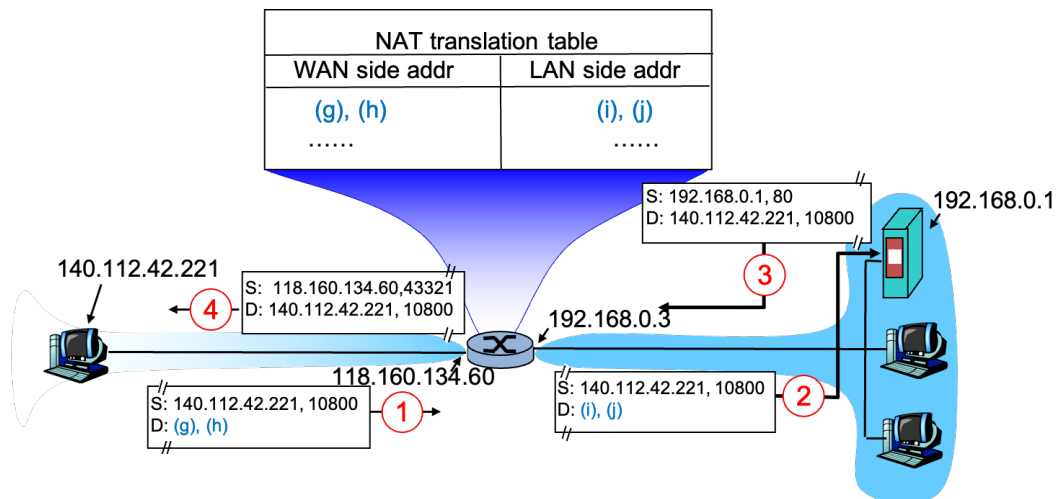
(3) 4

(4) 2

4. (ch43, 10pt) Most homes are allowed only 1 IP address for Internet access. To allow multiple smart devices accessing the Internet simultaneously at home, a common practice is to run NAT at the home gateway. Illustrated below is a home user at 192.168.0.1 port 12000 requesting a Web page from a Web server at 140.112.42.221 port 80 via the home gateway. Based on your knowledge of how NAT operates, please tell the value of (a)(b)(c)(d)(e)(f).



Illustrated below is a home user at 192.168.0.1 port 80 providing a Web service to users outside of NAT. To allow arbitrary users to access the server, the user needs to (1) set up an entry manually in the NAT translation table and to (2) inform all users the Web server's WAN side address to access the server. Based on your knowledge of how NAT operates, please tell the value of (g)(h)(i)(j).



Sample Solution:

- (a)= 118.160.134.60
- (b)= 37201
- (c)= 118.160.134.60
- (d)= 37201
- (e)= 192.168.0.1
- (f)= 12000
- (g)= 118.160.134.60
- (h)= 43321
- (i)= 192.168.0.1
- (j)= 80

5. (ch43, 10pt) We know we need to update to IPv6 to address several known issues in IPv4. However, IPv6 adoption rate remains low after decades of effort. The adoption rate varies also from region to region. We need some serious marketing effort, to motivate various organizations to move on.

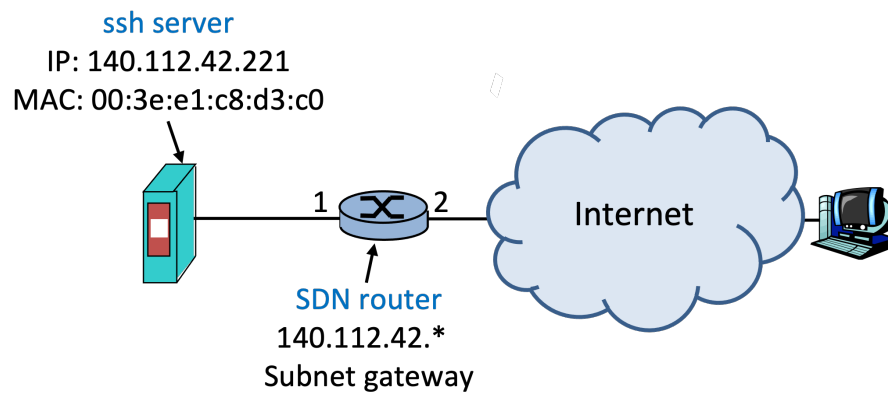
- (1) Name 2 known issues in IPv4 that are addressed in IPv6. (2pt)
- (2) Search on the Web for the world wide IPv6 adoption rate. Tell the rate and give the URL (i.e., the reference) to the article you refer to. (2pt)
- (3) Search on the Web for your home country's IPv6 adoption rate. Tell the rate and give the URL to the article you refer to. (2pt)
- (4) Are you satisfied with the IPv6 adoption rate in your home country and why (or why not)? (2pt)
- (5) Satisfied or not, can you think of a way for the authorities in your home country to encourage the subnet owners (or managers) to change? (2pt)

Sample Solution:

- (1) Address space shortage, datagram fragmentation/reassembly overhead, fixed header size etc.
- (2) Depending on what you can find.
- (3) Depending on what you can find.
- (4) Up to you and as long as the reason makes sense.
- (5) Any promotional technique that makes sense.

6. (ch44, 8pt) SDN routers are general machines capable of traffic discrimination based on Transport, Network, and Link layer packet headers. When an SDN router receives a packet, it looks up the flow table and finds all the matching entries. Among the entries, find the one with the highest priority. Then take the action indicated in the entry.

Below is a server allowing users from outside to remote login via ssh. The IP address and the MAC address are configured as shown. The server is connected to its subnet gateway, which is an SDN router. The SDN router connects to the ssh server via switch port 1 and the Internet via switch port 2.



The flow table in the SDN router consists of 2 entries:

Switch Port	MAC Src	MAC Dst	Eth Type	VLAN ID	IP Src	IP Dst	IP Proto	TCP Sport	TCP Dport	Action	Priority
*	*	*	*	*	*	*	*	*	22	allow	high
*	*	*	*	*	*	*	*	*	*	drop	low

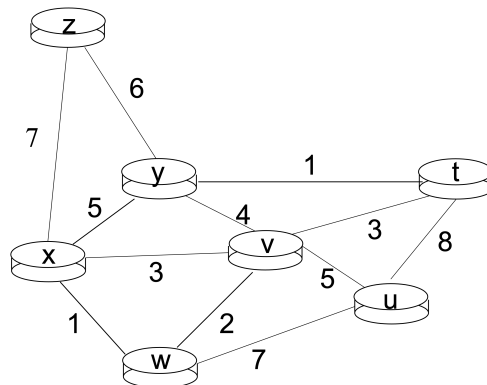
- (1) Does this SDN router allow all packets to go through? (1pt) If yes, why? If not, why not? (2pt)

- (2) Continue from (1). This SDN router does allow packets going to the ssh port to go through. It does not allow establishment of an ssh connection however. This is because the returning message from the server will be dropped at SDN as the returning message's destination port number is not going to be 22. Can you add a flow entry to the SDN router to allow the messages from the ssh server to go through? (2pt)
- (3) Continue from (2) and to see better the benefit of allowing very general matching rules in SDN. Can you add a flow entry that is different from the one you've provided in (2) but for the same goal – allowing the messages from the ssh server to go through? (3pt)

Sample Solution:

- (1) No. Only packets to destination port 22 can pass.
- (2) All fields \* except for IP src = 140.112.42.221
- (3) All fields \* except for MAC src = 00:3e:e1:c8:d3:c0  
or all fields \* except for Switch port = 1  
or all fields \* except for TCP sport = 22

7. (ch52, 10pt) Using the Dijkstra algorithm, one can compute the shortest path from a source node to all other nodes in the network. Consider the 7-node network illustrated below. Generate the table indicating the steps deriving the cost  $D(*)$  and previous hop  $p(*)$  from node x to all other nodes. Note that when the path costs are equal, add nodes to the traversed set  $N'$  in alphabetic order.



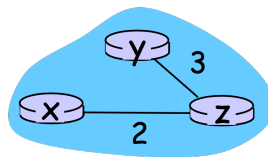
$N'$	$D(t),p(t)$	$D(u),p(u)$	$D(v),p(v)$	$D(w),p(w)$	$D(y),p(y)$	$D(z),p(z)$
x						

- (1) Tell the traversed set  $N'$  (in order) when Dijkstra algorithm terminates. (2pt)
- (2) Fill the derivation table till Dijkstra algorithm terminates. (8pt)

Sample Solution:

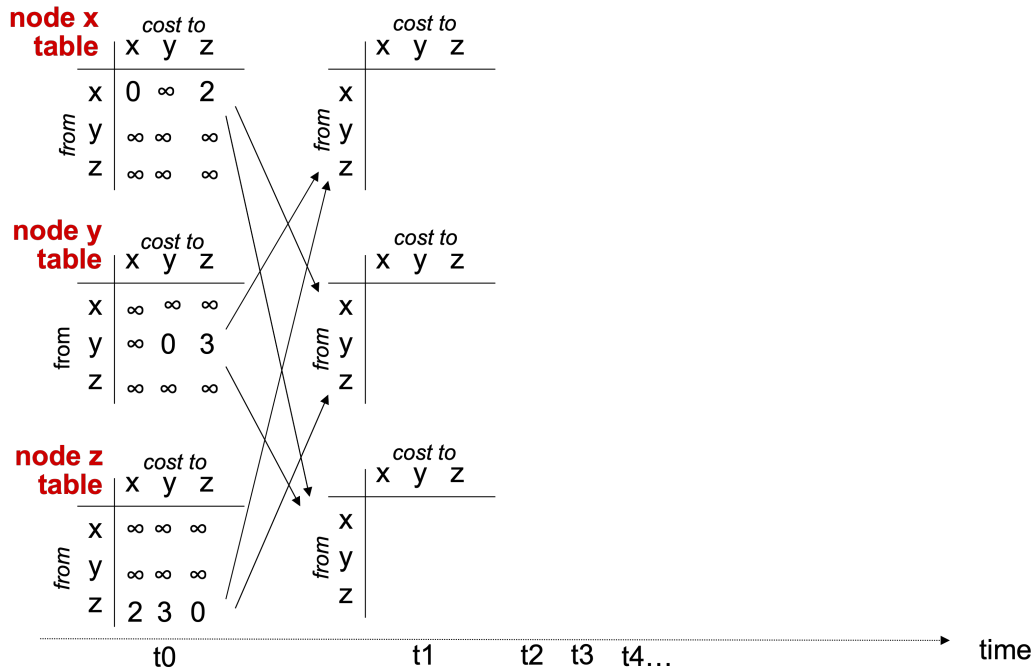
$N'$	$D(t),p(t)$	$D(u),p(u)$	$D(v),p(v)$	$D(w),p(w)$	$D(y),p(y)$	$D(z),p(z)$
x	Infinity	infinity	3,x	1,x	5,x	7,x
xw	infinity	8,w	3,x		5,x	7,x
xwv	6,v	8,w			5,x	7,x
xwvy	6,v	8,w				7,x
xwvyt		8,w				7,x
xwvytz		8,w				
xwvytzu						

8. (ch52, 22pt) Consider a simple network below. Develop the full DV tables at node x, y, and z until the DV routing algorithm converges (i.e., no more changes to propagate further).



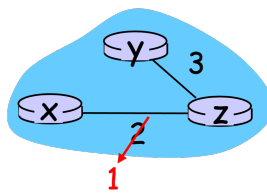
Please follow the derivation style as shown in the lecture. Assume the 3 nodes synchronously receive, compute, and send the DVs if there's any change. The initialization step at  $t_0$  is illustrated below. The first iteration happens at  $t_1$ , the 2<sup>nd</sup> iteration at  $t_2$ , and so on so forth.



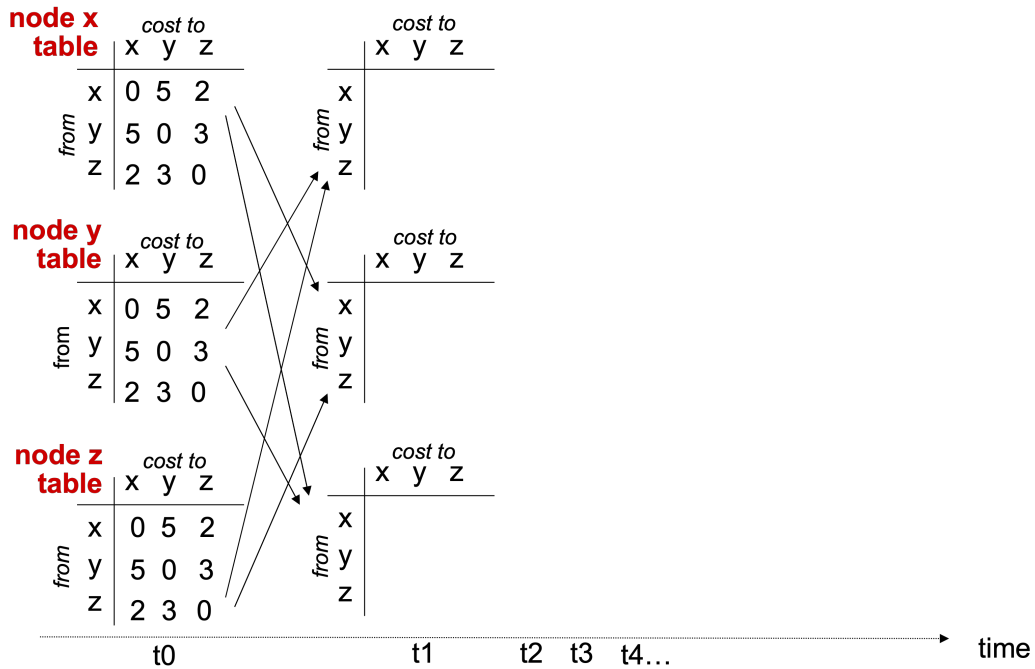


- (1) Show the Bellman-Ford computation to derive  $D_x$  at node X at  $t_1$ . Type 'inf' to represent infinity on the exam form. (3pt)
- (2) Show the Bellman-Ford computation to derive  $D_z$  at node Z at  $t_1$ . Type 'inf' to represent infinity on the exam form. (3pt)

Continue from (2). Good news travel fast. Let's consider the following change to the network. Develop the full DV tables at node x, y, and z until the DV routing algorithm converges (i.e., no more changes to propagate further).

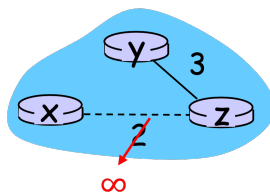


Please follow the derivation style as shown in the lecture. Assume also the 3 nodes synchronously receive, compute, and send the DVs if there's any change. The tables before the change are those shown at  $t_0$ . The first iteration at  $t_1$  is triggered by the link cost change, the 2<sup>nd</sup> iteration at  $t_2$  is triggered by receiving the subsequent DV reports, and so on so forth.

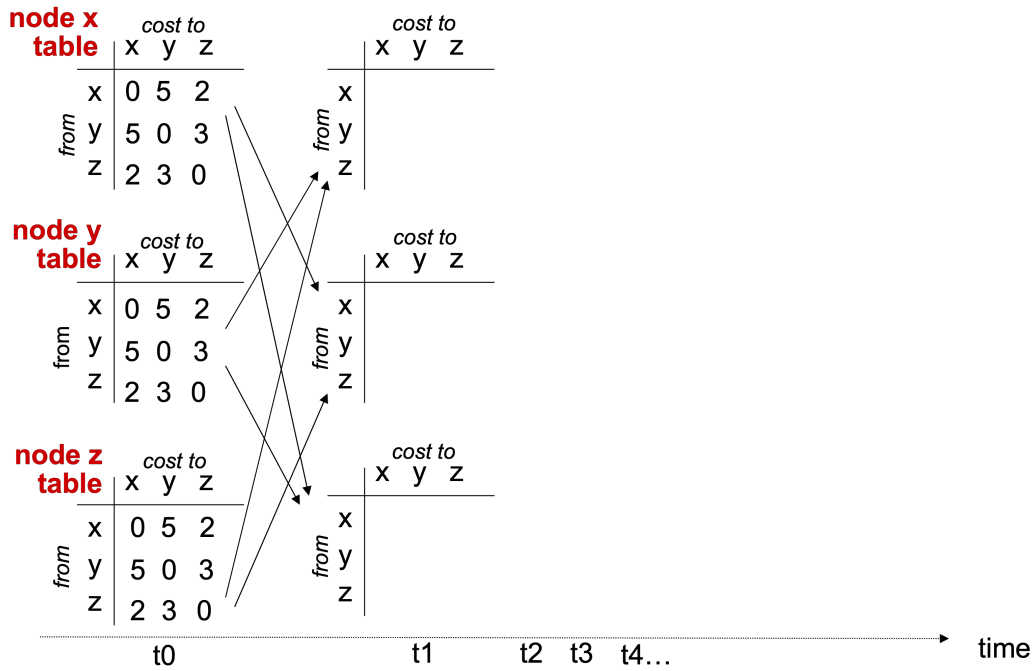


- (3) Tell Dx at node X at t1. (1pt)
- (4) Tell Dz at node Z at t1. (1pt)
- (5) Tell Dy at node Y at t2. (2pt)
- (6) Tell to which iteration (the n in the final tn) the DV tables converge. (2pt)

Continue from (2). Bad news travel slow. Let's consider the following change to the network. Develop the full DV tables at node x, y, and z until the DV routing algorithm converges (i.e., no more changes to propagate further).



Again, use the derivation style shown in the lecture. Assume the 3 nodes synchronously receive, compute, and send the DVs if there's any change. The tables before the change are those shown at t0. The first iteration at t1 is triggered by the link cost change, the 2<sup>nd</sup> iteration at t2 is triggered by the subsequent DV changes, and so on so forth. Assume also that the poisoned reverse mechanism is disabled.



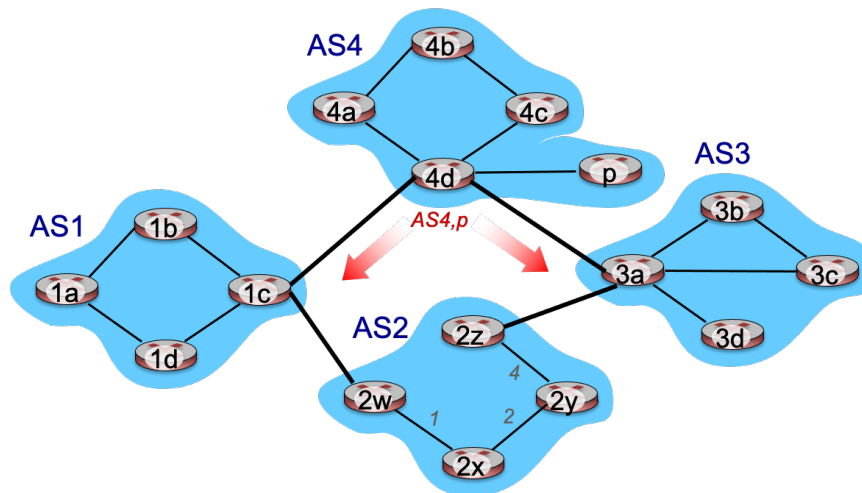
- (7) Tell Dx at node X at t1. (1pt)
- (8) Tell Dz at node Z at t1. (1pt)
- (9) Tell Dy at node Y at t2. (2pt)
- (10) Tell Dz at node Z at t3. (2pt)
- (11) Tell Dy at node Y at t4. (2pt)
- (12) Tell to which iteration (the n in the final tn) the DV tables converge. (2pt)

Sample Solution:

- (1) Dx at X at t1 = (0, 5, 2)
  - $dx(y) = \min\{c(x,z)+dz(y)\} = \min\{2+3\}=5$  (x got only 1 neighbor)
  - $dx(z) = \min\{c(x,z)+dz(z)\} = \min\{2+0\}=2$  (x got only 1 neighbor)
- (2) Dz at Z at t1 = (2, 3, 0)
  - $dz(x) = \min\{c(z,x)+dx(x), c(z,y)+dy(x)\} = \min\{2+0, 3+\infty\}=2$
  - $dz(y) = \min\{c(z,x)+dx(y), c(z,y)+dy(y)\} = \min\{2+\infty, 3+0\}=3$
- (3) Dx at X at t1 = (0, 4, 1)
- (4) Dz at Z at t1 = (1, 3, 0)
- (5) Dy at Y at t2 = (4, 0, 3)
- (6) t2
- (7) Dx at X at t1 = (0,  $\infty$ ,  $\infty$ )
- (8) Dz at Z at t1 = (8, 3, 0)
- (9) Dy at Y at t2 = (11, 0, 3)
- (10) Dz at Z at t3 = (14, 3, 0)
- (11) Dy at Y at t4 = (17, 0, 3)

(12)  $t_{\infty}$  or never converge (count to infinity problem)

9. (ch53, 6pt) Consider the network below where BGP runs inter-AS and LS runs intra-AS. Destination subnet p in AS4 starts by announcing its existence. AS4's gateway router 4d then advertises the AS path "AS4, p" to 1c and 3a, the gateway routers to neighboring ASes.



- (1) Suppose there are no import or export restrictions in AS3. What would 3a Advertise to 2z? (1pt)
- (2) Suppose there are no import or export restrictions in AS1. What would 1c Advertise to 2w? (1pt)
- (3) If there're no import restrictions in AS2 either, what would the entry be for destination p in 2y's forwarding table, and why? (2pt)
- (4) If there's an import restriction in AS2 preventing 2w from propagating the received AS path further, what would the entry be for destination p in 2x's forwarding table, and why? (2pt)

Sample Solution:

- (1) AS3, AS4, p
- (2) AS1, AS4, p
- (3) 

Destination	Output link
p	(2y->2x)

Reason – 2y receives two AS paths to p. There are no local preferences. The two paths are equal length. Therefore, 2x will hot-potato route to the gateway router that's closer.

- (4) 

Destination	Output link
p	(2x->2y)

Reason – 2x receives only 1 AS path from 2z. Therefore, the output link will be on the shortest path to 2z.

10. (PA, 18pt) Please go on the PA workstation and work under the exam3 directory for this problem set (create the exam3 subdirectory if you haven't done so). Grading policy: pts for later problems will be given only when the formers are completed.

- (1) Develop exam3-p10-1.go such that it works as a Web server – (1) accepting HTTP requests for files and (2) returning the file requested. Assume the file is always there. (4pt)
- (2) Develop exam3-p10-2.go such that it works as a Web server – (1) accepting HTTP requests for files, (2) returning the file requested if the file is found or returning "Sorry, not here." if the file is not found. (5pt)
- (3) Move the exam3.key and exam3.cer file in your home directory to exam3 directory. (1pt)
- (4) Develop exam3-p10-3.go such that it extends exam3-p10-2.go to allow HTTPS requests. Use the exam3.key and exam3.cer for the secure Web server. (8pt)

Sample Solution:

Whatever that works.