Introduction to Computer Networks **Name:** ____________

Fall 2021

Homework 2 (**Due: 12/26/2021**) **ID:** ____________

This homework contains 8 questions. The deadline is on Dec. 26 (Sun) at 23:59. Please submit your answers to new E3.

1. (10 points) **Router:**

   (a) (4 points) List the four components of a router.

   > **Solution:**
   > input port, switching fabric, output port, routing processor

   (b) (2 points) When will the input queue (or the output queue) of a router overflow, leading to packet losses?

   > **Solution:**
   > When the arrival rate is larger than the service rate

   (c) (2 points) Why we prefer *prefix matching*, instead of ID matching, during packet forwarding?

   > **Solution:**
   > save memory space

   (d) (2 points) Explain when will a flow match multiple rules in a forwarding table. Explain WHY we adopt *longest prefix matching* to resolve this issue.

   > **Solution:**
   > (a) When a prefix is a subset of another prefix, we might want to give the subset of flows a more specific forwarding rule. (b) The longer prefix defines a smaller group, which should follow a more specific rule.

2. (10 points) **Queueing.** Consider a router that help forward packets classified into two classes. Say that ten packets arrive the router with the following class and arrival time:

sequence	1	2	3	4	5	6	7	8	9	10
class	1	1	2	2	1	2	2	1	2	1
time (second)	0.5	1.0	1.2	2.5	3.0	5.0	5.5	6.3	8.2	8.6

Assume that the transmission time of each packet is *one second*.

(a) (5 points) Assume that class 1 has a high priority, while class 2 has a low priority. When will each packet be sent if the router forwards packets using priority queueing? (Note that there is no preemptive.)

Solution:
see: order: sending time

1: 1: 0.5-1.5
2: 2: 1.5-2.5
3: 3: 2.5-3.5
4: 5: 4.5-5.5
5: 4: 3.5-4.5
6: 6: 5.5-6.5
7: 8: 7.5-8.5
8: 7: 6.5-7.5
9: 9: 8.5-9.5
10: 10: 9.5-10.5

(b) (5 points) When will each packet be sent if the router forwards packets using round robin queueing?

Solution:

1: 1: 0.5-1.5
2: 3: 2.5-3.5
3: 2: 1.5-2.5
4: 4: 3.5-4.5
5: 5: 4.5-5.5
6: 6: 5.5-6.5
7: 8: 7.5-8.5
8: 7: 6.5-7.5
9: 9: 8.5-9.5
10: 10: 9.5-10.5

3. (15 points) **Subnet.**

   (a) (4 points) What is the maximum number of hosts in the subnet 140.113.10.0/22?

   Solution: $2^{10} - 2 = 1022$

   (b) (3 points) Following the above question, what is the IP address reserved for broadcasting?

   Solution: 140.113.11.255

   (c) (4 points) What is the subnet mask of subnet 140.113.10.0/22 in decimal?

   Solution: 255.255.252.0

   (d) (4 points) If this subnet only includes 2,000 host, what is a more efficient subnet mask? (hint: minimize the number of non-occupied IP addresses)

   Solution:
   $\min_x 2^x - 2 > 2000 \rightarrow x = 11$
   subnet: 255.255.248.0

4. (10 points) **DHCP.**

   (a) (3 points) Explain why DHCP uses link-layer broadcasting to send requests.

   Solution: A new joining node does not know the IP address of the DHCP server. Can only use L2 broadcasting to locate the DHCP server.

   (b) (2 points) Why does a DHCP request require two requests, instead of just one request?

   Solution: There might be multiple DHCP servers in a LAN. Should send the second one for confirmation.

   (c) (2 points) Explain what is a lease of a dynamic address allocated by DHCP?

   Solution: The DHCP can retrieve back the IP address when a node leaves.

   (d) (3 points) Explain why DHCP can address the issue of insufficient IP addresses.

   Solution: Though there are a large number of devices, the probability of having all the device online is pretty small.

5. (10 points) **SDN:**

   (a) (2 points) Explain what is the major difference between traditional routers and programmable switches.

Solution: Traditional routers cannot be modified after manufacture. Programmable switches allow developers to modify their behaviors via software (programming).

(b) (4 points) List the fields that can be matched in the OpenFlow protocol.

Solution: Switch port / VLAN ID / MAC src / MAC dst / Eth Type / IP src / IP dst / IP port / TCP src port / TCP dst port

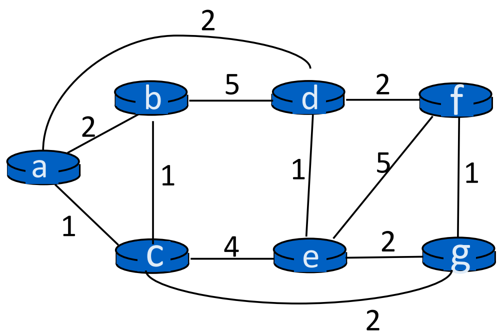
(c) (2 points) List the actions that can be performed in the OpenFlow protocol.

Solution: forwarding / load balancing / rewrite / blocking / further processing

(d) (2 points) Define what is the 5-tuple of a flow.

Solution: src IP / dst IP / src port / dst port / protocol type

6. (15 points) **Link-state routing.** Consider the following network topology with 6 nodes. Let the number associated with each link be the cost of the link. Try to find the shortest path from node a to the remaining nodes using the link-state algorithm.



(a) (8 points) Write down the step-by-step procedure of the link-state algorithm as building the distance/predecessor table from node a to all the remaining nodes.

Solution: (ignore)

(b) (3 points) What is the routing path from a to g?

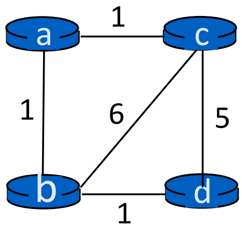
Solution: $a \to c \to g$

(c) (4 points) What is the forwarding table at node c?

Solution:

destination	next hop
g	g

7. (20 points) **Distance-vector routing.** Consider the following network topology with 4 nodes. Let the number associated with each link be the cost of the link. Try to find the shortest path from each node to the remaining nodes using the distance-vector algorithm.



(a) (4 points) What is the initial distance vector of each of the four nodes?

Solution:
$D_a = (0, 1, 1, \infty)$
$D_b = (1, 0, 6, 1)$
$D_c = (1, 6, 0, 5)$
$D_d = (\infty, 1, 5, 0)$

(b) (4 points) Assume that all the nodes broadcast their distance vectors $\mathbf{D}_i$ at the same time. What will be the distance vector of each of the four nodes after receiving the initial distance vector from the neighbors (i.e., the distance vector of all nodes after the first information exchange)?

Solution:
$D_a = (0, 1, 1, \infty), D_{a\to b} = (2, 1, 7, 2), D_{a\to c} = (2, 7, 1, 6)$
$D_a = (0, 1, 1, 2)$
$D_b = (1, 0, 6, 1), D_{b\to a} = (1, 2, 2, \infty), D_{b\to c} = (7, 12, 6, 11), D_{b\to d} = (\infty, 2, 6, 1)$
$D_b = (1, 0, 2, 1)$
$D_c = (1, 6, 0, 5), D_{c\to a} = (1, 2, 2, \infty), D_{c\to b} = (7, 6, 12, 7), D_{c\to d} = (\infty, 6, 10, 5)$
$D_c = (1, 2, 0, 5)$
$D_d = (\infty, 1, 5, 0), D_{d\to b} = (2, 1, 7, 2), D_{d\to c} = (6, 11, 5, 10)$
$D_d = (2, 1, 5, 0)$

(c) (8 points) Assume that all the nodes broadcast their updated distance vectors at the same time. Write down the detailed information exchange and distance vector update procedure until convergence.

Solution: (ignore)

(d) (2 points) How many iterations are required to achieve convergence? (Note that the last iteration, which is duplicated with the previous iteration, should also be counted.

> **Solution:**
> 4 (four vector exchanges)

(e) (2 points) What is the shortest path from node c to node d?

> **Solution:**
> $c \to a \to b \to d$

8. (10 points) **MAC.** Medium access control protocols.

(a) (2 points) Give two key shortages of channel partitioning.

> **Solution:**
> low utilization, need synchronization, centralized control

(b) (3 points) Explain what is *collision avoidance* in a random access protocol. Why could random access be better than channel partitioning?

> **Solution:**
> (1) Wait for a random time interval before transmissions. (2) only users with traffic patterns compete for transmissions. Hence, the channel utilization can be higher.

(c) (5 points) Explain the difference between *collision detection* and *collision avoidance*. Why does 802.3 exploit collision detection, but 802.11 exploit collision avoidance?

> **Solution:**
> detection: transmit and detect whether the packet is collided. Terminate immediately when a collision is detected
>
> avoidance: wait for a random interval before transmission to reduce the collision probability
>
> 802.3 is full-duplex. That is, a node can transmit and receive at the same time. 802.11 is half-duplex. That is, a node cannot overhear the medium when it is sending.