CS/ECE 438: Communication Networks **Spring 2023**

Homework 3

Handed Out: March 26^{th}, 2023 *Due: 11:59pm, April 2^{nd}, 2023*

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- Homework assignments must be submitted online through GradeScope. Hard copies are not accepted. Please submit a pdf file to GradeScope (`https://www.gradescope.com`). You can either type your solution or scan a **legible** hand-written copy. We will not correct anything we do not understand. Contact the TAs via Campuswire if you face technical difficulties in submitting the assignment. Note: Please select your page(s) for each question during submission on GradeScope; Otherwise, your submission will not be graded.
- Homework assignments can be done in groups of two, but only one person needs to submit on GradeScope. Remember to include your partners name in the solution and on GradeScope by editing "Group Members". It is your responsibility that your partner's name is included. For detailed instruction please refer to (`https://youtu.be/rue7p_kATLA`).
- You can use Campuswire to find a partner. We highly recommend working in groups. You will not get extra credit for working alone.
- Please use Campuswire and come to office hours if you have questions about the homework. Failure to understand the solutions will be the student's fault.
- While we encourage discussion within and outside of the class, cheating and copying is strictly prohibited. Copied solutions will result in the entire assignment being discarded from grading at the very least and a report filed in the FAIR system. It is also your responsibility to ensure that your partner obeys the academic integrity rules as well.

1 TCP RTT Estimation – 7 points

One difficulty with the original TCP SRTT estimator is the choice of an initial value. In the absence of any special knowledge of network conditions, the typical approach is to pick an arbitrary value, such as 3 seconds, and hope this will converge quickly to an accurate value. If this estimate is too small, TCP will perform unnecessary retransmissions. If it is too large, TCP will wait a long time before retransmitting if the first segment is lost. Also, the convergence might be slow.

1. Choose $\alpha = 0.7$ and RTT-timeout(0) $= 1$ seconds, and assume all measured RTT values $= 0.5$ second with no packet loss. What is RTT-timeout(20)? Recall,

$$\text{RTT-timeout}(k+1) = \alpha \times \text{RTT-timeout}(k) + (1-\alpha) \times \text{RTT}(k+1)$$

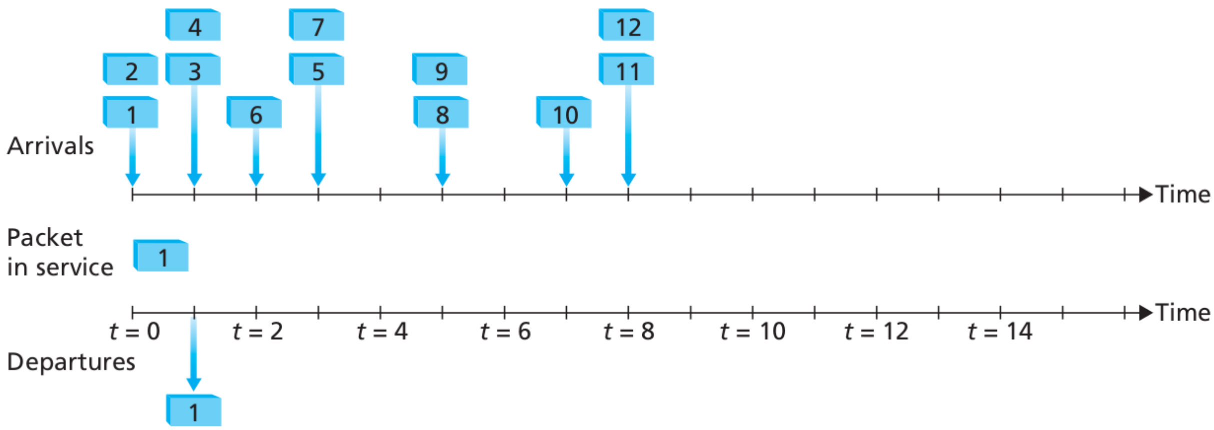
   Describe your solution approach AND provide the numerical result (approximate to 4^{th} decimal place).

2. Using the same values as in above part, what happens if we use $\alpha = 0.5$ or $\alpha = 0.95$? Provide a numerical result for RTT-timeout(20) in both cases, then describe the effect of a larger or smaller α on the RTT estimation procedure.

2 Fair Queuing – 18 points

Consider Fig. 1. Now consider the following scenarios:

Figure 1:



- Packets are scheduled using FIFO policy
- Packets are scheduled using Highest Priority First policy. Assume odd-numbered packets are high priority and even-numbered packets are low priority.
- Packets are scheduled using Round Robin policy. Assume that packets (1, 4, 6, 7, 8, 9, 10) are from class 1, and packets (2, 3, 5, 11, 12) are from class 2. Scheduling starts with class 1 at $t = 0$.
- Packets are scheduled using Weighted Fair Queuing (WFQ) policy. Assume there are three classes. Let us denote the packet ID of packet i as ID_i. Class j (where $j = 0, 1, 2$), will contain packets which satisfy $\{i | ID_i\%3 = j\}$. Let the three classes (i.e. Class 0,1 and 2) have the weights 3, 2 and 1 respectively. Scheduling starts with class 0 at $t = 0$.

Note: In case of ties under the above schemes, you must resort to FIFO scheme. In Fig. 1, you can assume that Packet 1 arrives before Packet 2 at $t = 0$, Packet 3 before Packet 4 at $t = 1$ and so on. Also assume that packets can be immediately scheduled for transmission when they arrive. For Round Robin and WFQ, you must skip a Class if packets are not available for that particular class.

1. Fill this Table. 1 for which packet departs at each time point and the delay of each packet (i.e., delay is time interval between the arrival and departure of a packet).
2. What is average delay for these 4 polices? For Highest priority, Round Robin, and WFQ, you must also list average delay for each class separately. (In WFQ, the average delay among different classes might not be perfect in this question.)
3. What observations can you draw about the average delay from the above 4 polices? Two concise observations are sufficient.

Table 1: Packet Scheduling

Time of Departure (t in sec)	FIFO		Highest Priority		Round Robin		WFQ	
	Packet	Delay	Packet	Delay	Packet	Delay	Packet	Delay
1	1	1	1	1	1	1	1	1
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

3 Forwarding and CIDR – 15 points

1. Consider a router that interconnects three subnets: Subnet A, Subnet B and Subnet C. Suppose all of the interfaces in each of these three subnets are required to have the prefix 200.20.15.0/24. Also suppose that Subnet A is required to support up to 80 interfaces, and Subnets B and C are each required to support up to 25 interfaces. Provide three network addresses (of the form a.b.c.d/x) for each of the above subnet that satisfy these constraints.

Suppose a router has built up the routing table shown below in Table. 2. CIDR addresses are used, with "/22" indicating a mask of 22 1's followed by 10 0's.

Net/Masklength	NextHop
128.174.240.0/20	Interface 1
128.174.240.128/25	R1
128.174.240.17	R2
128.174.252.0/22	Interface 3
128.174.240.16/29	R3
128.174.248.0/22	Interface 2
default	Interface 4

Table 2:

2. How many individual IP addresses match each Net/Masklength pair? (Compute this for all entries in the table except the last one, i.e. for the default Masklength entry).
3. The router can deliver packets directly over interfaces 1, 2, 3, 4, or it can forward to routers R1, R2, R3. Specify the next hop for each of the following destinations. Use the longest prefix match, i.e., if a destination matches more than one line of the table,

the longest match is used.

(a) 128.174.240.17

(b) 128.174.245.17

(c) 128.174.250.17

(d) 128.174.254.17

(e) 128.174.225.17

(f) 128.174.240.18

4 DHCP and NAT – 8 points

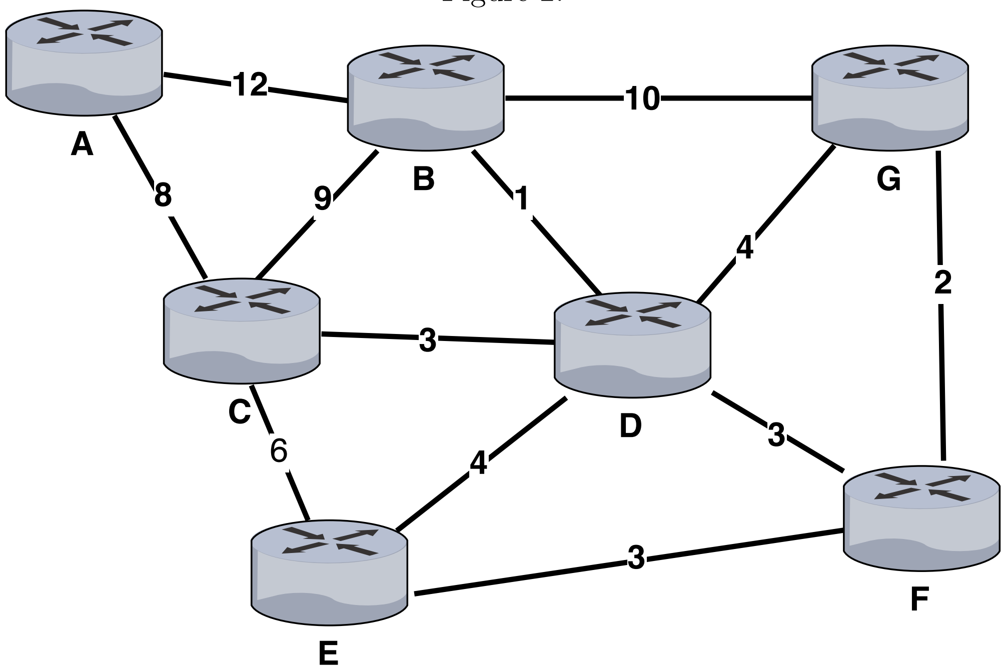
Alice and Bob are neighbors and they each buy a new home wireless router. After connecting each of their laptops to their own router they each enter the command `hostname -i`, which prints out their IP address.

1. Briefly describe the process how they get the IP address.
2. After doing this, is it possible that they get the same IP address, if the routers use private subnet addresses?
3. Give one reason that wide-spread deployment of IPv6 would let them get rid of the NAT service provided by thier routers.
4. Give one reason that they might want to continue using the router's NAT service even if they could use IPv6.

5 Distance Vector Routing – 21 points

Consider the following network topology as shown in Fig. 2.

Figure 2:



1. Derive and draw the shortest-path tree from nodes E using the Dijkstra's algorithm. Show how the cost of path and predecessor node along path converge step-by-step in a table as demonstrated in the lecture slides.
2. Compute routing tables for nodes B, D and E using the distance vector algorithm. The table rows should include a *Destination*, *Distance*, and *Next Hop*. Please show intermediate results for partial credit.
3. Now consider a situation in which link between the D-C becomes congested and its costs become 30. List a sequence of updates to routing tables at nodes B and D, in order, until the routing tables converge.

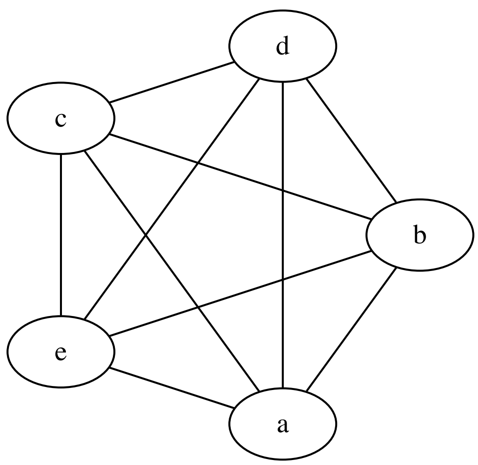
6 Routing Algorithms – 9 points

1. Consider the network of routers as shown in Fig. 3. Suppose you are told that traffic from a to b is routed by the path $a \to c \to e \to b$

   (a) List all the possible routes from d to e that could coexist with the above route from a to b on this network, if routing is performed using the link-state algorithm. Hint: Consider what the routing decision $a \to c \to e \to b$ says about the relative costs of individual edges. Can you use them to rule some items out.

   (b) List all the possible routes from d to a that could coexist with the above route from a to b on this network, if routing is performed using software- defined networking.

Figure 3:



2. Sort the following protocols by the amount of state each node maintains, and give clear explanation.

   - Link State
   - Distance Vector
   - Path Vector