CSC358H5: Principles of Computer Networking — Winter 2025

Problem Set 2

Due Date: Sunday, March 30, 11:59 PM, on Crowdmark and Quercus

Submission Instructions: You must submit your answer to Q1 and Q2 electronically via Quercus PS1-Q1 and PS1-Q2 quizzes, respectively.[1] For other questions, you must submit your assignment electronically via Crowdmark, **with each question's solution uploaded separately**. For your convenience, we have provided a template file, `ps2_sol_template.tex`, which you may use to prepare your solution. However, you are free to use any other LaTeX format or any other tool of your choice (*e.g.*, Word, scanned handwritten submission, etc.). If you choose to submit a handwritten assignment, ensure your writing is legible; otherwise, TAs may have the discretion not to grade your work.

Q1 **[16 points]** [**NOTE:** This question will be auto-graded on Quercus. We prepared the quiz **PS2-Q1** on Quercus to collect your answers. Please carefully follow the instructions for inserting your answers on Quercus.]
Consider the illustrated network topology. Assume all links are full-duplex and the routers use distance vector routing protocol. Below are the initial routing table for each router, and routers are aware of the costs for each of their neighboring links.

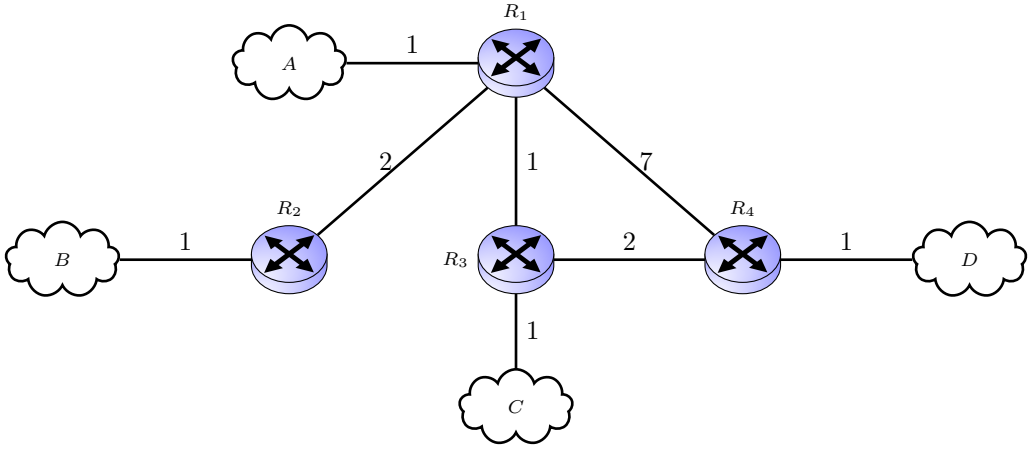

Figure 1: Network graph.

R_1		
Destination	**NextHop**	**Distance**
A	Direct	1

R_2		
Destination	**NextHop**	**Distance**
B	Direct	1

R_3		
Destination	**NextHop**	**Distance**
C	Direct	1

R_4		
Destination	**NextHop**	**Distance**
D	Direct	1

The following questions indicate events that happen consecutively. You can assume that no other events occur other than the ones specified.

1.a **EVENT 1:** R_3 advertises its routes to R_1 and R_4, and R_1 and R_4 update their routing table after receiving this advertisement.

[1] Why Quercus and not Crowdmark? Because Crowdmark auto-grader only works with multiple choice questions and does not work with fill in the blanks questions. Implementing these question as multiple choice ones would just kill the fun.

1.a.i [2 points] What does the routing table for R_1 look like? **[Instruction for Quercus:** When inserting your answer in Quercus, please follow the instructions below:

- If the NextHop of a prefix in your routing table is R_1, R_2, R_3, R_4, or Direct, enter your answer as R1, R2, R3, R4, Direct, respectively.
- Use integer numbers to insert the distance of an entry in your routing table (*e.g.*, we accept 1 but NOT 1.0).
- If your routing table does not have an entry for a prefix, you should use **N/A** when inserting your answer for the NextHop and Distance of that prefix in Quercus. For example, assume that R_1's table is the following.

R_1		
Destination	NextHop	Distance
A	Direct	10
D	R_2	2

Then, you should enter your table on Quercus as

R_1		
Destination	NextHop	Distance
A	Direct	10
B	N/A	N/A
C	N/A	N/A
D	R2	2

]

1.a.ii [2 points] What does the routing table for R_4 look like? **[Instruction for Quercus:** See the instructions in **1.a.i**.**]**

1.a.iii [1 points] Which router among R_1 and R_4 are expected to advertise their routes after receiving R_3's routes?

1.b EVENT 2: R_1 advertises its routes to R_2, R_3, and R_4, and they update their routing table after receiving this advertisement.

1.b.i [2 points] What does the routing table for R_2 look like? **[Instruction for Quercus:** See the instructions in **1.a.i**.**]**

1.b.ii [2 points] What does the routing table for R_3 look like? **[Instruction for Quercus:** See the instructions in **1.a.i**.**]**

1.b.iii [2 points] What does the routing table for R_4 look like? **[Instruction for Quercus:** See the instructions in **1.a.i**.**]**

1.c The two following events occur consecutively.
EVENT 3: R_4 advertises its routes to R_1 and R_3, and they update their routing table after receiving this advertisement.
EVENT 4: R_1 advertises its routes to R_2, R_3, and R_4, and they update their routing table after receiving this advertisement.

1.c.i [0.5 points] At this point, what NextHop does R_2 use to reach D?

1.c.ii [0.5 points] At this point, what is the of the path that R_2 uses to reach D?

1.d EVENT: R_3 advertises its routes to R_1 and R_4.

1.d.i [2 points] What does the routing table for R_1 look like now?

1.d.ii [2 points] What does the routing table for R_2 look like now? [**NOTE:** We are asking for R_2's routing table, NOT R_4's routing table.]

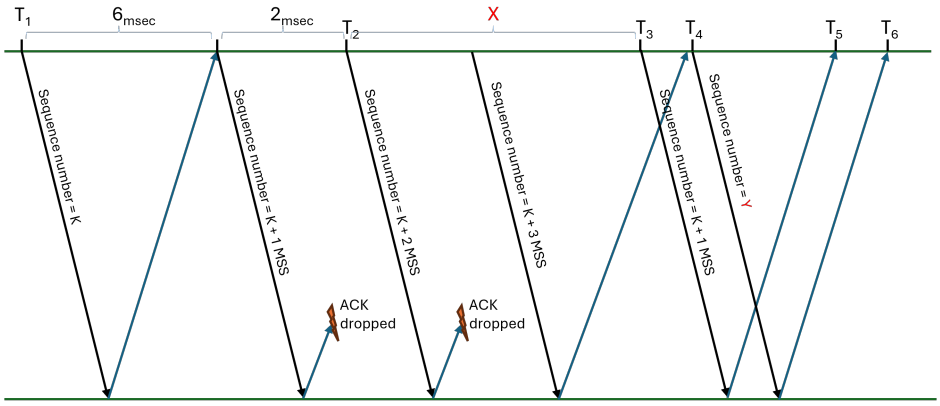

Figure 2: Illustration of the TCP transmission.

Q2 **[3 points]** [**NOTE:** This question will be auto-graded on Quercus. We prepared the quiz **PS2-Q2** on Quercus to collect your answers. Please carefully follow the instructions for inserting your answers on Quercus.] Consider the situation where a sender A and a receiver B communicate with each other using a TCP implementation that is modified to use stop-and-wait ARQ. Assume that the sequence numbers (SN) that the protocol uses refer to bytes. Suppose that A uses 200 as the initial sequence number (ISN), *i.e.*, we have that ISN=200 for the TCP SYN message. Furthermore suppose that the first data containing packet that A sends to B consists of 100 bytes.

2.a **[1 points]** What is the SN number that A puts into the packet header (such as for example a TCP packet header) **of the first data-containing packet** that it sends?
[Instruction for Quercus: Insert your answer as integer number (*e.g.*, 1234).**]**

2.b **[1 points]** If B receives the first data-containing packet from A without an error, what is the ACK number that B uses in the packet that it sends to A in response to the packet it received?
[Instruction for Quercus: See the instruction in **2.a**.**]**

2.c **[1 points]** If B detects an error in the first data-containing packet that it received from A (*i.e.*, Checksum didn't verify and the packet is detected as being corrupted), what is the ACK number that B uses in the packet that it sends to A in response to the packet it received?
[Instruction for Quercus: See the instructions in **2.a**.**]**

Q3 **[6 points]** In figure 2 below, TCP transmits packets with the given sequence numbers on a 3.75Mb/sec link. At time T_1, EstimateRTT $= 8$msec, and DevRTT $= 2.25$msec. All values on the figure are in msec. Given the following computation:

$$\text{DevRTT} \leftarrow 0.8 \times \text{DevRTT} + 0.2\times \mid \text{SampleRTT} - \text{EstimateRTT} \mid$$
$$\text{EstimateRTT} \leftarrow 0.85 \times \text{ExtimateRTT} + 0.15 \times \text{SampleRTT}$$
$$\text{RTO} \leftarrow \text{EstimateRTT} + 4.5 \times \text{DevRTT}$$

3.a **[4 points]** Find the value of X, *i.e.*, the length of the interval between T2 and T3. Show your process.

3.b **[2 points]** Find Y, the sequence number of the last segment sent by the sender. [**NOTE:** You don't need to show your process.]

Q4 **[4 points, It's research time!]** HTTP/3 was published in 2022 and is now used on almost 40% of websites and is supported by most web browsers. HTTP/3 uses QUIC instead of TCP for the underlying transport protocol. Explain what was the issues with TCP that motivated the designer of HTTP/3 to use QUIC.
[**NOTE:** This question will be graded based on the effort you put in. You are not expected to provide an extremely detailed answer. We recommend spending no more than 30 minutes conducting online research to complete your answer. Your textbook has a nice section describing QUIC.[2]]

[2] https://book.systemsapproach.org/e2e/tcp.html#quic

Q5 **[4 points, It's research time!]** IP tunneling is the key idea behind VPN (Virtual Private Network) technology. Read the "Virtual Networks and Tunnels" section from the course textbook[3] and explain how IP tunneling works and why would anyone want to use IP tunneling.
[**NOTE:** This question will be graded based on the effort you put in. You are not expected to provide an extremely detailed answer. We recommend spending no more than 30 minutes conducting online research to complete your answer.]

Q6 **[10 points]** Consider the network topology shown in figure 3. Assume that routers use distance vector routing protocol with poisoned reversed. The topology consists of multiple routers interconnected by full-duplex links. Each link has a cost of 1 unit associated with it, except for the link between R_1 and R_3, the link between R_4 and R_6, and the link between R_1 and R_9 which have cost 10 unit associated with them.

Assume that all routers' routing tables had converged (*i.e.* Bellman-Ford's distributed algorithm had converged) and then the link between R_6 and R_7 fails. Furthermore, assume that routers synchronously advertise their distance vector every t seconds, starting from the link failure incident. Calculate how long it takes for the routing tables on R_6 to become stable again. Write your answer as a multiple of t (*e.g.*, $123 \times t$). Justify your answer.

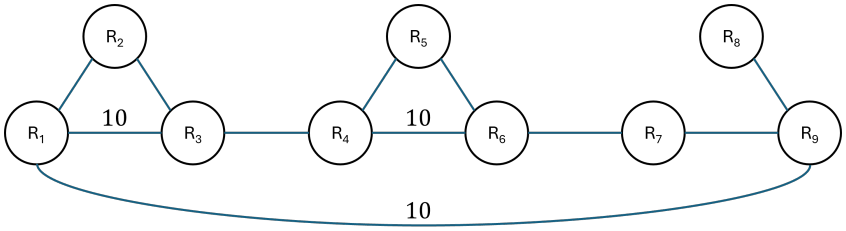

Figure 3: Network topology.

[3] https://book.systemsapproach.org/internetworking/basic-ip.html#virtual-networks-and-tunnels