ECE/CS 438: Communication Networks	**Fall 2023**
Homework 2	
Handed Out: September 18^{th}, 2023	*Due: 11:59pm, September* 27^{th}, 2023
Students Name:	

- Homework assignments must be submitted online through Gradescope. Hard copies are not accepted. Please submit a pdf file to Gradescope (`https://www.gradescope.com/courses/581425`). 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 email if you face technical difficulties in submitting the assignment.
- 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.
- This assignment has a total of 110 points. The grade will be capped at 100 points.
- **Please write your answer in the white space to the right of the corresponding problem.**

1 Web caching (1) - 5×2 points

1. We understand that web caching reduces access latency because the content a client is looking for is already in the cache (hence, the client does not need to fetch the content from the server). This suggests that the latency reduction is proportional to the cache hit rate. However, it is often observed that the actual latency reduction is more than this. Give one reason for this. Please answer this question in less than 20 words.

2. If UIUC has excellent web-caching performance, Parkland College (which is also located in Urbana Champaign area) ______(will/will not) benefit. Give one reason for this. Please answer this question in less than 30 words.

2 Web caching (2) - 7×3 points

Assume a group of students in UIUC want to access a private server A outside of UIUC. The bottleneck link from UIUC to this server supports a bitrate of 1MB/S. Assume the average request rate from UIUC is 90 times/s and each request is 0.01MB. Assuming there is no other traffic within or outside of UIUC, answer the following questions. Assume that queueing delay dominates so you can neglect the much smaller propagation delays, transmit times, and processing delays.

1. What is the average access time for a student in UIUC to access this server? Assume the queuing delay is $1/(1 - L)$ milliseconds, where L is the fraction of link usage. (Your answer should be in milliseconds)

2. To improve network performance, we now increase the bitrate of this bottleneck link to 5MB/s. Calculate the average access time again. Your unit should be milliseconds and must be computed up to 2 decimal places.

3. Another way to improve network performance is to add a cache server within UIUC without increasing the bandwidth of bottleneck link. The bitrate to the cache server is 10MB/s. Assume there is a 80% cache hit rate. The queuing delay for both cache server and server A follows the formula in Q5.1. Calculate the average access time in this case. (Assume the network knows cache server so no additional delays are needed to find that cache server; also, your unit should be milliseconds, computed to 2 decimal places).

3 Overlay Network - 5 points

True or false? Use one sentence to explain the reason. In an overlay network, A is connected to B, and B is connected to C. Then if A wants to send a packet to C, the physical route from A to C will always need to pass through B. Please justify your answer.

4 Trace route - 4×3 points

The figure below shows the result of running traceroute (with the -q 1 option to send one probe per hop) from a machine located in UIUC. Please answer the following questions.

```
traceroute to www.auckland.ac.nz (130.216.159.127), 64 hops max, 52 byte packets
 1  0148-cslgeneral-net.gw.uiuc.edu (192.17.100.1)  0.967 ms
 2  t-core1-1.gw.uiuc.edu (172.20.101.25)  0.536 ms
 3  t-exit1.gw.uiuc.edu (130.126.0.242)  0.407 ms
 4  t-fw1.gw.uiuc.edu (130.126.0.134)  0.666 ms
 5  t-exite1.gw.uiuc.edu (130.126.0.141)  0.937 ms
 6  t-dmzo.gw.uiuc.edu (130.126.0.202)  12.626 ms
 7  ur1rtr-uiuc.ex.ui-iccn.org (72.36.127.1)  1.051 ms
 8  t-ur2rtr.ix.ui-iccn.org (72.36.126.66)  1.576 ms
 9  internet2-710rtr.ex.ui-iccn.org (72.36.127.158)  4.107 ms
10  et-7-1-0.4070.rtsw.kans.net.internet2.edu (198.71.45.15)  21.305 ms
11  et-4-1-0.4070.rtsw.salt.net.internet2.edu (198.71.45.19)  41.337 ms
12  et-4-1-0.4070.rtsw.salt.net.internet2.edu (198.71.45.19)  41.280 ms
13  aarnet-1-is-jmb-776.lsanca.pacificwave.net (207.231.241.149)  81.268 ms
14  et-1-2-1.pe1.a.koa.aarnet.net.au (113.197.15.86)  205.814 ms
15  et-1-2-1.pe1.a.koa.aarnet.net.au (113.197.15.86)  205.753 ms
16  et-1-0-0-202.and12-nsh.reannz.co.nz (182.255.119.201)  205.921 ms
17  br-cpf1-north.net.auckland.ac.nz (130.216.95.106)  206.111 ms
18  cxj-alfa-430.net.auckland.ac.nz (130.216.95.122)  208.200 ms
19  cxj-alfa-430.net.auckland.ac.nz (130.216.95.122)  207.881 ms
20  *
21  www.auckland.ac.nz (130.216.159.127)  206.567 ms
```

1. Which hop(s) (if any) is transoceanic with one end in the United States?

   (a) Does not exist.

   (b) 5-6

   (c) 9-10

(d) 10-11

(e) 12-13

(f) 13-14

2. Based on the RTT to the last hop, calculate the furthest distance at which the server could possibly be located? (Note: use average speed of packet propagation: $2 \times 10^8 m/s$.) Choose the closest value from the following.

   (a) 10000km

   (b) 20000km

   (c) 40000km

3. Sometimes the RTT of a subsequent hop is lower than the RTT of a previous one. Give one reason for this.

5 HTTP - 7×3 points

Suppose a webpage has nothing but 8 large images each of size 10 MB. A client wants to access the webpage and load the images in his browser. The RTT between the client and the server is 30 ms and the transmission rate at the server is 1 GB/s. How long will it take to load the webpage in each of the following cases. (Note: the size of the object for indexing is negligible.) Assume 1GB=1000 MB. For all answers, please answer in milliseconds, and include the detail.

1. Using Non-Persistent HTTP?

2. Using Persistent HTTP?

3. Using Pipelined Persistent HTTP?

6 Assorted Questions - 3×7 points

1. Between the following two networks, which one is better on average? (1) a network that guarantees average throughput of 1000 bps, or (2) a network that guarantees average latency of 1ms.

2. True or False: At any given time, a single host can have only one active HTTP connection to a server.

3. In HTTP, a conditional GET offers benefits because (select the most appropriate answer):

   (a) it fetches the new object only if it has changed.

(b) it prevents the cache from giving stale information.

(c) most of the time the cached copy is not stale.

(d) the transmit time of the object over all the links can be substantial.

4. Which type of DNS records need to be provided to the registrar to create a new domain (select all correct answers):

   (a) A

   (b) NS

   (c) CNAME

   (d) MX

5. The following application benefits more from time division multiplexing (TDM) than frequency division multiplexing (FDM):

   (a) High speed car racing games

   (b) High volume data back (like Dropbox)

   (c) Sensors that have bursty traffic to send out, such as traffic intersection cameras counting cars.

   (d) Battery operated IoT devices that must send data periodically, such as soil moisture sensors in agricultural farms.

6. Caching is most beneficial when the traffic is distributed as follows:

   (a) Exponential

   (b) Power law

   (c) Uniform

   (d) Gaussian

7. The TLD server communicates the following resource record(RR) to the Root DNS server: RR(downtown.nunet.com, 128.34.55.12, A).

   From this, we can say that (select all correct statements):

   (a) Iterative DNS is in progress.

   (b) Recursive DNS is in progress.

   (c) downtown.nunet.com is an authoritative DNS server.

   (d) downtown.nunet.com is a mail server.

   (e) downtown.nunet.com is neither an authoritative nor a mail server.

7 Simulating Router Queues - $10 + 10$ points

This question requires you to simulate a router queue where packets are arriving at some average ARRIVING RATE (A) and the router is draining the queue at some SERVICE RATE (R). You need to plot graphs from the results of your simulation, where the Y axis is average QUEUEING DELAY (QD) and the X axis is (A/R).

Here are guidelines for the simulation:

- Any programming language is fine.
- You need to simulate a queue data structure and at every time tick (simulated as 0.1 second), add and remove packets to/from that queue.
- Note that the time tick is simulated, not real clock, which means you can treat one cycle of your for loop as a simulated 0.1 second. You can implement it in other ways too.
- You need to simulate each session for 1,000 seconds.
- At the end of a session, you get one value of average QD.
- Assume the router takes 0.1 second to service a packet, so R = 10.
- This means you will remove packets from the queue at a periodic rate.
- Now, for packet arrival, you need to simulate different values of A ... but note that this A is the average arrival rate.
- This means that when A = 10, you are not going to add packets to the queue once every 0.1s.
- Instead, you will add packets to the queue such that over 1,000 seconds, 10,000 packets arrive in total into the queue.
- This means you need to scatter the packet arrivals randomly over the 1000 seconds.
- Implement your own random scattering ... and run many sessions with many random seeds.
- Now that you have the packets arriving and exiting the queue, track the duration for which each packet stays in the queue.
- Note that this per-packet queueing delay should be in the granularity of 0.1 seconds.
- The QD is now an average over all the packets for a given A.
- Of course, since you will run your simulation for many seeds for a given A, your QD should be averaged over the seeds as well.
- Ok, now you have a QD for A=10, which means you have one data point for your plot where X axis value = 1.
- Now do the same for A = 9, 8, 7 ... 1, 0, which means X axis values are 0.9, 0.8, and so on.
- This will give you all the data points for your plot.

Submit the following:

- Plot the result as a bar graph.
  - Feel free to also plot error bars in your graph, showing the 25th and 75th percentile of QD for each A/R.
  - Note that you should get the 25th and 75th percentile from the many seeds over which you run the results.
- Plot the max queue size needed for every value of A/R (which tells us how large the queue should be if we do not want any packets to be dropped by the router).

1. Bar graph

2. Max queue size plot