COMP 5416 Assignment 1 (2021)

Due: 19 September 23:59 Sydney time

Question 1 (Delay, 18%)**.** As shown in the figure below, a file of size $F = 1000 + S$ bytes is transmitted on an end-to-end connection over four links, wh igits of your student number. For example, if your student number is 490123456, then $S = 456$ and

Each link is 100 km. The signa $\times 10^8$ m/s. Assume that a header of 40 bytes is added to each packet. The bandwidth of all links is I ning. The nodes use the store-and-forward scheme. (Ignore processing delays at each node.)

(0) What is your student numbe other student's number as S value to answer the question, the following sub-questions will not be marked and you will get 0 in Question 1.

(1) How long does it take to transmit the file if the whole file is transmitted as a single packet.

Now assume that the bandwidth of link $B - C$ and $D - E$ become 0.5 Mbps. Answer (2)–(4).

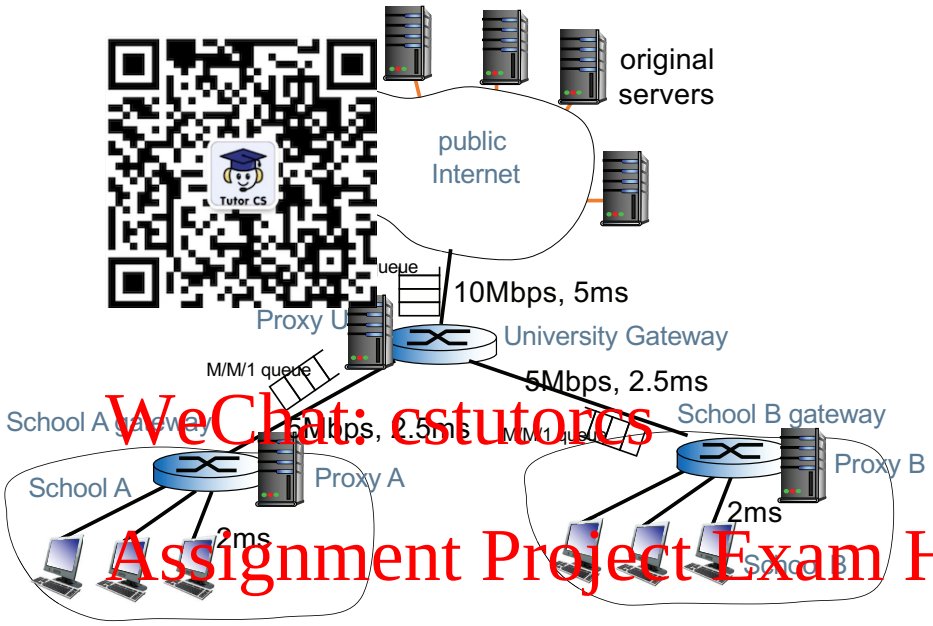
(2) Repeat (1).

(3) We would like to break the file into smaller packets to decrease the overall delay in the store-and-forward scheme. Assume that each time you break the file to make a new packet, you have to add 40 bytes as the header of the new packet. Repeat (2) when we break the file into $N = 4$ packets.

(4) What should be the optimal size of the packets to have the minimum overall delay to deliver the whole file? Find the overall delay.

Hint: Since the link $B - C$ has a smaller bandwidth compared with $A - B$, packets could be queued for some time!

Question 2 (Web Cache, 18%)**.** Consider the following scenario where two schools of one university are installing web caches for users. (You only need to review the contents discussed in lectures in weeks 1–3 to complete this question.)



Inside each school, the one-way propagation delay from each host to the school's gateway is 2ms. The link bandwidth is assumed to be infinity (sufficient large). The link bandwidth from each school's gateway to the university's gateway is 5Mbps, and one-way propagation delay is 2.5ms. The access link bandwidth from the university's gateway to the Internet is 10Mbps, and assume that the one-way propagation delay from the gateway to any server in the public Internet is 5ms.

On average, the requests from each school to view the webpage (of the public Internet) arrive at the rate of 500 requests per second and the webpage is 1000 bytes (which fits exactly one packet). Ignore the header size. The requests themselves are very small and we assume that they do not take any bandwidth.

Without cache, the link from the university's gateway to school A's gateway can be modelled as an $M/M/1$ queue, where the arrival rate is 500 packets per second, and the service rate is $\frac{5\times10^6}{8000} = 625$ packets per second. The queueing delay can be calculated as $\frac{1}{625-500} = 0.008s= 8$ms. Similarly, the link from the university's gateway to school B's gateway and the university's access link can also be modelled as $M/M/1$ queues. (You need to find out the queueing delays by using the formula introduced in week 1, i.e., $\frac{1}{\mu-\lambda}$. You do not need to know how this formula is derived at this stage).

(1) Without cache, what is the average overall delay for each user to derive its requested webpage? (Only the propagation delays and the queueing delays are considered. All other delays are ignored.)

(2) Now, caches can be installed at the school's gateway, so that 10% of the original requests can be served by the schools' proxies (proxies A and B). What is the average overall delay for each user to derive its requested webpage?

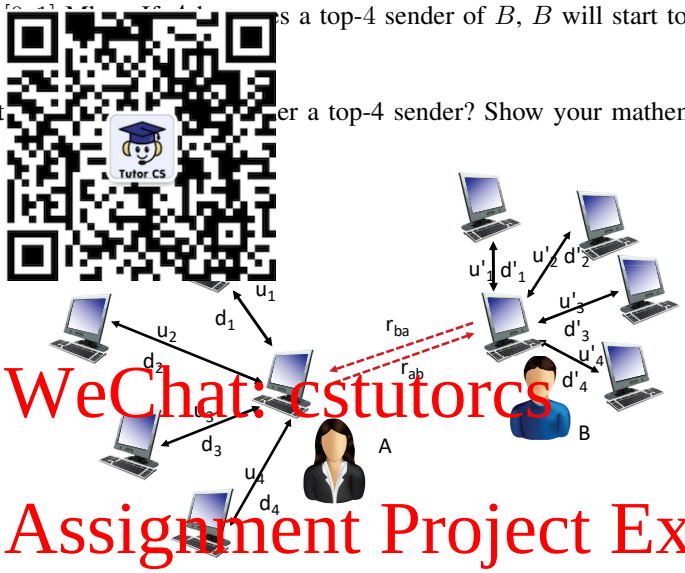
(3) Now, cache can be installed at the university's gateway, so that 20% of the original requests can be served by the university's proxy (proxy U). What is the average overall delay for each user to derive its requested webpage?

(4) Now, caches can be installed at all gateways (proxies A, B, and U). $a\%$ of the original requests can be served by the schools' proxies, and $b\%$ of the original requests can be served by the university's proxy. However, due to the limited storage owned by the university's ICT department, we have $2a\% + b\% \leq 20\%$. Calculate the average overall delay for each user to derive its requested webpage as a function of a and b and find the optimal a and b. (Note, $a\%$ and $b\%$ are defined with respect to the original requests, do not use $(1-a\%)(1-b\%)$, but to use $(1-a\%-b\%)$ to calculate the rest of the requests served by the original Internet servers).

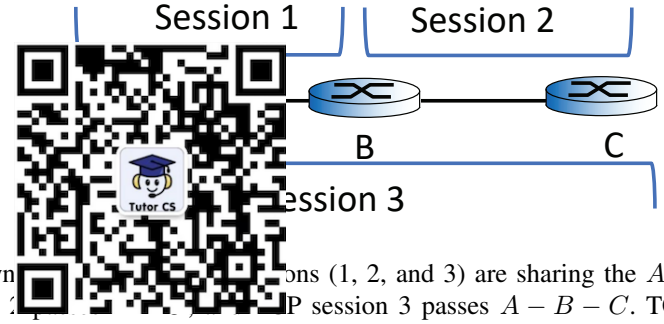
Question 3 (P2P Tit-for-Tat, 18%)**.** As shown in the figure below, A and B are communicating with their top-4 partners in a BitTorrent system. A's uploading and downloading data rates of the ith partner are u_i and d_i respectively; B's uploading and downloading data rates of the ith partner are u'_i and d'_i respectively. For $i = 1, 2, 3, 4$, u_i, d_i, u'_i, d'_i are randomly distributed. They are independent random variables, following uniform distribution in $[0, 1]$ Mbps.

Now A optimistically unchoked B, with a sending data rate of r_{ab}. r_{ab} is a random variable, independent of u_i, u'_i, d_i, d'_i. It follows uniform distribution in [illegible]. As a top-4 sender of B, B will start to serve A with a sending data rate of $r_{ba} = r_{ab}$.

What is the probability that bot[illegible]er a top-4 sender? Show your mathematical derivations.



Question 4 (TCP and max-min fairness, 16%)**.** In this task, you will investigate the performance of TCP and discuss if max-min fairness can be achieved. (In the lecture, we have already discussed the simple case where two TCP sessions are sharing one link.)



The network topology is shown [illegible] ons (1, 2, and 3) are sharing the $A-B$ and $B-C$ links. TCP session 1 passes $A-B$; TCP session [illegible] P session 3 passes $A-B-C$. TCP Reno is employed for each TCP session. The link capacity of $A-B$ and $B-C$ are 3.2 Mbps. Each TCP packet size (MSS) is 1000 bytes. We assume that the RTTs of TCP sessions 1, 2, and 3 are 100 ms, 100 ms, and 100 ms respectively. As discussed in the lecture, if the sum data rate of TCP sessions passing a link exceeds the link bandwidth, the link is congested and all TCP sessions passing the link will be "multiplicatively decreased". If a TCP session does not pass any congested link, then it will be "additively increased". Hint: you may use $\frac{\text{cwnd}}{\text{RTT}}$. cwnd may not be an integer in MSS.

(1) At the beginning, the windows sizes (cwnd) of TCP sessions 1, 2, and 3 are 10MSS, 5MSS, and 1MSS respectively. Draw a figure to show cwnd vs time of the three TCP sessions. After a sufficient amount of time, can the *average* data rates of the TCP sessions realise max-min fairness? You may use Python/excel to plot the figure. Repeat the the above steps if the initial windows sizes (cwnd) of TCP sessions 1, 2, and 3 are 1MSS, 5MSS, and 10MSS respectively.

(2) Repeat (1) if the RTTs of TCP seasons 1, 2, and 3 are 100 ms, 100 ms, and 200 ms, respectively.

Question 5 (Wireshark Experiment, 15%)**.** In this task, you will run a Wireshark experiment. Please follow the following procedure and answer questions.

Please note that you will need to connect to VPN if you are not on campus. Both FortiClient and Cisco AnyConnect are available. You need to choose the correct interface in Wireshark indicating the VPN you are using. Otherwise, you cannot see the correct packets captured.

You are only allowed to use o browsers: Google Chrome, Firefox, Safari, or Microsoft Edge. Please update it to the latest version.

1) Open a web browser. **Cle wser.**
2) Start up the capture of W
3) Enter the following URL
   http://wbserver.cs.usyd.edu
4) Your browser should disp
5) When the images are completely loaded, enter the following URL into your browser
   http://wbserver.cs.usyd.edu.au/A2.html
6) When the images are completely loaded, refresh your browser (e.g., press F5).
7) When the images are completely loaded, stop Wireshark packet capture.

Questions

(0) What is the time (date, hour, and minute) that you capture the packets? What is the web browser you use to complete this question? You will get 0 mark in Question 5 if you do not provide the time and browser.

(1) What is the IP address of the server that sends you the base web page?

(2) What is the IP address of the server that sends you the images?

(3) Is non-persistent HTTP or persistent HTTP employed? Why?

(4) What are the sizes of the images? How do you know that? You can only use the information provided by Wireshark capture.

(5) In step 3), your browser has downloaded the images for the first time. These images may or may not be re-downloaded again in the following steps. In step 5), did you browser send the request for the images? If so, did the server send back the images to your browser again? In step 6), did you browser send the request for the images? If so, did the server send back the images to your browser again? (To answer these two questions, you should give screen-shots.)

(6) Now you need to have a close investigation of the first image you have downloaded (when you download the image USYD.jpg for the first time). Locate the first four bytes of the image (.jpg file) in Wireshark. Screenshot the packet and location of the first four bytes shown by Wireshark. Locate the last four bytes of the image (.jpg file) in Wireshark. Screenshot the packet and location of the last four bytes shown in Wireshark.

To help you locate the bytes, you may consider to convert the original .jpg file into a byte-stream format. You may use the following website https://www.onlinehexeditor.com/ to do so.

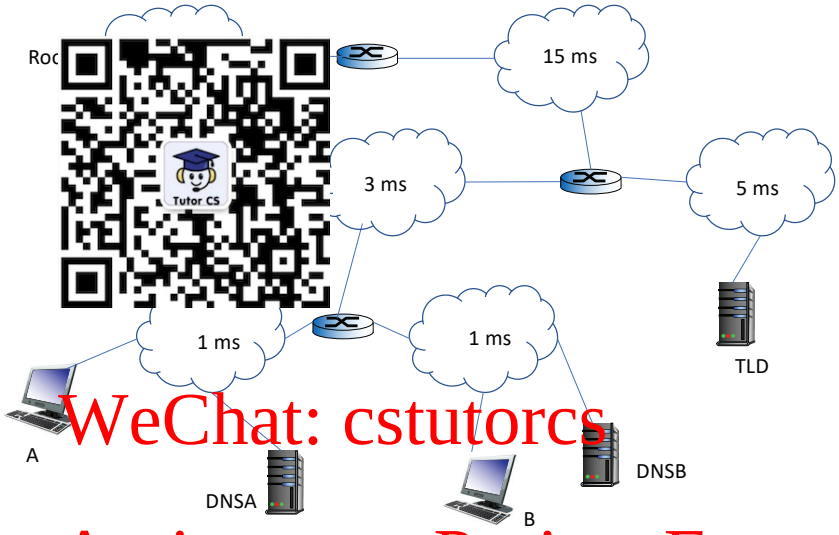
(7) Following (6), which one of the following statements is correct when you download USYD.jpg for the first time. Give your screenshots to justify your answer.

(a) The image is downloaded by a single packet.

(b) The image is downloaded by multiple packets and the last packet includes HTTP response (200 OK) and the last portion of the image.

(c) The image is downloaded by multiple packets. The last packet includes the last portion of the image. Then, an HTTP response (200 OK) is received in a separate packet.

Question 6 (DNS, 15%)**.** Consider the network shown below. In the figure, DNSA is A's local and authoritative DNS server and DNSB is B's local and authoritative DNS server. TLD is the TLD DNS server of .com. Assume that the one-way propagation delay through each network (shown as clouds in the figure) is labeled in the figure. The cached resource records at each host are listed in the table below. "." means the root DNS server.



	Host name and/or IP address	Cached records
Root	60.60.60.60	(.com, dns.com, NS) (dns.com, 121.121.121.1, A)
TLD for .com	121.121.121.1	(sydney.com, dns.sydney.com, NS) (dns.sydney.com, 220.220.220.1, A) (comp5416.com, dns.comp5416.com, NS) (dns.comp5416.com, 111.111.111.1, A)
DNSA for .sydney.com	dns.sydney.com 220.220.220.1	(., dns., NS) (dns., 60.60.60.60, A) (.com, dns.com, NS) (dns.com, 121.121.121.1, A) (student.sydney.com, 220.220.220.220, A)
DNSB for .comp5416.com	111.111.111.1 dns.comp5416.com	(sydney.com, dns.sydney.com, NS) (dns.sydney.com, 220.220.220.1, A) (.com, dns.com, NS) (dns.com, 121.121.121.1, A) (., dns., NS) (dns., 60.60.60.60, A) (semester2021.comp5416.com, 111.111.111.111, A)
A	student.sydney.com 220.220.220.220	None
B	semester2021.comp5416.com 111.111.111.111	None

(1) How long does host A take to resolve the IP address of host B when address resolution is done iteratively? Why?

(2) How long does host B take to resolve the IP address of host A when address resolution is done iteratively? Why?

Hint: You may not need to visit a DNS server as long as the requested information is already available.