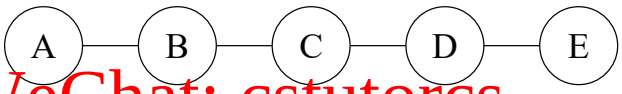
COMP 5416 Assignment 2

Due: 6/November/2021 23:59

Question 1 (TCP, 20%)**.** In the following network, node A transmits packets that pass through B, C, and D, and arrive at the destination E. The bit rate of a[illegible]ec. The maximum packet size in the network is 500 Bytes. Ignore the header size. The one-way propa[illegible]k is 4 msec.

How long does it take to transm[illegible]P Reno is used, where s is the last two digits of your student number. At the beginning, `ssthresh` i[illegible]bytes). B, C, and D use Store-and-Forward. No packet is lost. There is no bit-error in transmission. Th[illegible] negligible. The size of TCP header is negligible.



Question 2 (Token Bucket Simulation, 20%)**.** In this task, you need to simulate and analyze a token bucket. You can reuse some the codes in Week 6 Lab. You Python code must be submitted as supplementary material. Only Python 3 is allowed.

The token bucket scheduler consists of a bucket which can accommodate x tokens and a queue which can accommodate infinite packets. The arrival of packets follows an independent Poisson process with rate $\lambda > 0$ unit/second. The arrival of tokens follows a deterministic process. That it, the inter-arrival time is a constant, i.e., $\frac{1}{\mu}$ unit/second. We assume that $\lambda = 1$ unit/second, and $\mu = 1.25$ unit/second.

Let $x = 3 + floor(s/2)$, where s is the last digit of your student number. For example, if your student number is 490012345, then $s = 5$ and $x = 5$.

Let $1, 2, 3, 4, \ldots$ denote the state where there are $1, 2, 3, 4, \ldots$ packets in the buffer. Let $-1, -2, \ldots, -x$ denote the states where there are $1, 2, \ldots, x$ tokens in the bucket. Let 0 denote the state where there are 0 packet and 0 token.

(1) By simulation, find out the steady-state distribution of the system states $-x, -x+1, \ldots, 0, 1, 2, \ldots$.

(2) By simulation, find out the conditional distribution of the the system states when a packet arrives.

(3) By simulation, find out the conditional distribution of the the system states when a token arrives.

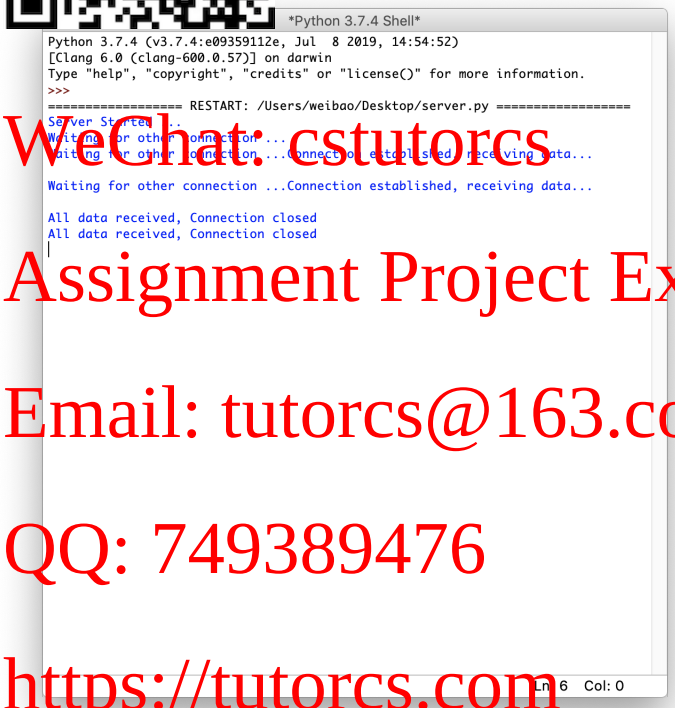
(4) By simulation, find out the mean time that a packet waits in the buffer.

(5) Find out the probability that a token is dropped.

Question 3 (Multi-thread Server: Implementation, 20%)**.** You are given the complete code for the client in Lab in Week 8. Your task is to write the TCP server. The client code is in `client.py`. You must not modify this code. (However, you are allowed to change `ServerName` and `ServerPort`). Only Python 3 is allowed.

Different from the server in the lab, the new server must be able to serve multiple clients simultaneously. Please note that the server code in Week 8 can only accept one client! In order to serve multiple clients simultaneously. The server should run multiple threads. The server will establis[illegible]t to communicate with one new client, and each new connection socket will be managed by a new thre[illegible] the following function: `_thread.start_new_thread()`.

The following figure shows an [illegible]two clients are sending images at the same time. The two connections are closed in the end, demonstr[illegible]oncurrent transmissions before the first "Connection closed".



You also need to capture the concurrent data transmission by Wireshark. In the example in the next page, we can see that the two clients are running at 192.168.0.3, with port numbers 60458 and 60462. The server is running at 192.168.0.4, with port number 12011. The throughputs of the two connections are both positive at around the 4th second.

Tasks and submissions:

(1) Build up a multi-thread server which can serve multiple clients **at the same time**. Submit your server-side Python code. Submit your server code as `Lastname_Firstname_Server.py`. We will use the client in Week 8 to test against your server.

(2) Test your server with three clients sending images at the same time. Capture the packets by Wireshark at the server side. You are allowed to run the server and clients in one computer using `localhost`. Submit your Wireshark capture. Your capture file must be smaller than 10MB. Your capture will be ignored and will not be marked if it is greater than 10MB. Submit your capture as `Lastname_Firstname_Capture.pcapng` (or `.pcap`).

(3) In the main submission file, based on your capture in (2), plot the throughput vs. time of the three connections (similar to the figures in the next page). Show that they are operated in parallel. In the main file, you also need to give the three clients' IP addresses, clients' port numbers, server's IP address, and server's port number.

You overall mark will be zero if you do not submit code in (1), no matter if you submit (2) or (3).

You submission in (2) and (3) will be ignored and will not be marked if your submission in (1) does not work.

You overall mark will be zero if your Wireshark capture in (2) does not match the throughput plots in (3).

Question 4 (BER vs SNR with different modulation schemes, 20%)**.** We aim to plot BER vs SNR curves of different modulation schemes in this question.

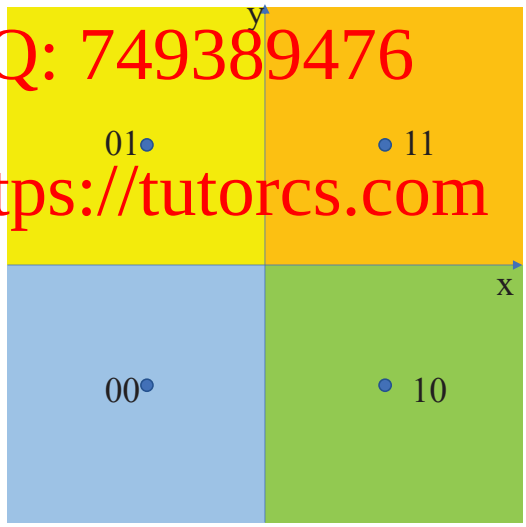
(1) BPSK. In wireless communication, we can transmit 0 and 1 through signals -1 and 1 respectively. Both -1 and 1 signals have power of 1, so that the mean signal power is 1. This is called Binary Phase Shift Keying (BPSK). Due to the existence of noise, the received signal is $-1+n$ or $1+n$ respectively, where n is the noise term. n follows normal distribution $n \sim N(0, \sigma^2)$. σ^2 is the power of the noise, and [illegible] received signal is ≥ 0, it is decoded as 1; if the received signal is < 0, it is decoded as 0. We assume [illegible]th equal probabilities. Compute average BER vs SNR of BPSK when SNR = [0,5,10,15,20,25] dB. H[illegible]

(2) 4QAM. Now we consider an[illegible], where we can use two orthogonal signals (x, y) to represent 2 bits. (x is usually carried by a cosine sig[illegible]ied by a sine signal.) We can transmit 00, 01, 11, and 10 through signals $(-1,-1)$, $(-1,1)$, $(1,1)$, and [illegible] signal power is 2. This is called 4 quadrature amplitude modulation (4QAM). Still, due to the existe[illegible] signal (r_1, r_2) is $(-1+n_1, -1+n_2)$, $(-1+n_1, 1+n_2)$, $(1+n_1, 1+n_2)$, and $(1+n_1, -1+n_2)$ respectiv[illegible]e noise term. n_1 and n_2 are independent random variables with normal distribution, with mean 0 and variance σ^2. The power of the noise calculated as $E(n_1^2+n_2^2)$. The received signal is decoded as

- 00, if $r_1 < 0$ and $r_2 < 0$;
- 01, if $r_1 < 0$ and $r_2 \geq 0$;
- 11, if $r_1 \geq 0$ and $r_2 \geq 0$;
- 10, if $r_1 \geq 0$ and $r_2 < 0$;

where the regions $r_1 < 0$ and $r_2 < 0$; $r_1 < 0$ and $r_2 \geq 0$; $r_1 \geq 0$ and $r_2 \geq 0$; and $r_1 \geq 0$ and $r_2 < 0$ are called decision regions (see the figure below).

Compute average BER vs SNR of 4QAM when SNR =[0,5,10,15,20,25] dB. Still, we assume that bits 0 and 1 are sent with equal probabilities. You can make reasonable approximations to calculate the probabilities using Q function or erfc function through computer. It is not necessary to calculate double integral.



(3) 16QAM. Now we consider an even more complicated modulation scheme. We use two orthogonal signals (x, y) to represent 4 bits. x and y can be -3, -1, 1, or 3, and the represented four bits are shown in the figure below. For example, $(-1,-1)$ represents 0101. Please note that through this arrangement, there is only one bit difference between two neighbors, which will reduce bit error rate. Still, the noise is (n_1, n_2). n_1 and n_2 are independent random variables with normal distribution, with mean 0 and variance σ^2. The power of the noise is calculated as $E(n_1^2+n_2^2)$. The decision regions are shown in the figure below. For example, for the received signal (r_1, r_2), if $-2 \leq r_1 < 0$ and $-2 \leq r_2 < 0$, it is decoded as 0101. The average signal power is $\frac{(3^2+3^2)+(3^2+1^2)+(1^2+3^2)+(1^2+1^2)}{4} = 10$.

Compute average BER vs SNR of 16QAM when SNR =[0,5,10,15,20,25] dB. Still, we assume that bits 0 and 1 are sent with equal probabilities. You can make reasonable approximations to calculate the probabilities using Q function or erfc function through computer. It is not necessary to calculate double integral.

(4) Plot the BER vs SNR curves of BPSK, 4QAM, and 16QAM. You should derive a figure like Page 53 in the slides of Week 8. Discuss why improved data rate can cause higher BER.

Question 5 (Cellular network with guard channel, 20%)**.** Consider one cell in a cellular network. There are 60 available channels and each channel can be used by exactly one user. New user arrivals follow an independent Poisson Process with arrival rate λ_n and handoff user arrivals follow an independent Poisson Process with arrival rate λ_h. Both new and handoff users stay active for a random duration, following exponential distribution with mean $\frac{1}{\mu}$. The cell reserves X channels for handoff user arrivals. As discussed in the class, new arrivals will be blocked if $60 - X$ or more channels are occupied. Handoff arrivals will be dropped if 60 channels are occupied. We assume that $\lambda_n = 2400$ units/hour, $\lambda_h = 600$ units/hour, and $\frac{1}{\mu} = 1$ minute.

(1) Let $X = 5$. Compute the pr al is blocked. Compute the probability that a handoff arrival is dropped.

(2) If a new arrival is blocked, rred; If a handoff arrival is dropped, a \$0.1 loss will be incurred. Find the optimal X so that the overa

Submission Instructions: You should submit one main file and several supplementary files. You should include your answers to Q1–Q5 and explanations of your answers in the main file. You should submit your main file at "main file submission". The main file is in the format of pdf. For Q2, you *must* submit your simulator at "Q2 code submission". For Q3, you *must* submit your Python code at "Q3 code submission" and Wireshark capture at "Q3 capture submission". Your code and capture will be examined against your answers in the main file. Penalty would be incurred if your code/capture does not match your answer in the main file. For Q4/Q5, you *may* upload Python code to calculate the result in "Q4/Q5 calculation". Please note that, files uploaded in Q4/Q5 will be [illegible] steps. Wrong answers in Q4/Q5 without file uploads will incur heavier penalties.

	File format	Must upload?
	pdf	Yes
	Python 3 code	Yes
	Python 3 code	Yes
n	Wireshark capture	Yes
	Python 3 code	No
	Python 3 code	No

TABLE I
FILE UPLOAD

All your submissions will be checked by plagiarism examination tools.

This is one assignment with multiple pieces to submit. Your submission time is equal to the submission time of the *last* piece.

Submission instruction of Q6 (bonus question) will be released when Q6 is available in Week 12.