ECE/CSE 636: Communications Networking

End Semester Exam

09/05/2024

Sanjit K. Kaul

Submit on Classroom by 12 noon, May 10, 2024. Individual interaction with respect to your submission will happen on May 10 as already discussed. You must cite any resource (book section, webpage, paper, etc.) that you may have used. You must not collaborate with any other human being. It goes without saying that you will have to defend, explain, and be able to reproduce what you have submitted, during our personal interaction. Your submission must be a single PDF and separately any code that you may have used. You should be able to execute the code during the personal interaction. Bring your device to do so.

Question 1. 25 **marks** Consider a single queue single server system with memoryless arrivals and service and an infinite buffer. Updates that complete service are received by a monitor. Assume that age $\Delta(t)$ at the monitor increases and resets as described in the paper "Real-Time Status: How Often Should One Update?", other than at instants where an arrival enters an empty system. On such an arrival, age resets to 0 at the instant of arrival, that is just when the arrival enters service. Further assume an arrival to an empty system at time $t = 0$. Answer the following questions.

(a) Illustrate a sample outcome of the modified age function capturing its key characteristics.
(b) Use the renewal-reward theorem and the strong law of large numbers to derive the time-average age.
(c) Derive the time-average CCDF of the packet service time.

Question 2. 20 **marks** A Chai-Stop outlet employs one server. The server takes time that is uniformly distributed over the interval $(5, 10)$ minutes to serve a customer. Customer service times are independent. The server can only service one customer at a time. The server can go on a break only when there is no customer waiting to be served or being actively served. A break lasts for exactly 5 minutes. If there is no customer when the server returns from a break, the server goes back on a break. If a customer arrives when the server is on a break, the customer must wait for the server to return from the break before starting service. Assume a customer arrival takes place at $t = 0$. Derive from first principles the average steady-state time a customer spends at the Chai-Stop outlet.

Question 3. 25 **marks** Assume the Bianchi model for the 802.11 DCF. Choose $W = 32$. Let $m = 5$. Assume basic access.

(a) Solve for τ and p. Show how you arrived at your solution. You may need to use graphical techniques. If so, then show your graphs.
(b) Create a figure. On the figure plot the saturation throughput for $10, 50, 100$ stations in the network. For the plot assume a data rate of 1Mbps, a packet payload of 8184 bits, and a slot time of $50\mu s$. Refer to Table II in Bianchi's paper for any other constants you may require. Explain in detail how you obtained your plot and make explicit the calculation of all the entities that are needed to calculate saturation throughput. Do this for each of the above listed numbers of stations.
(c) Pick three rates from a continuous uniform distribution over $(1, 54)$ Mbps. Assume that we can only choose the rate of transmission of the payload. All other control and header information is always transmitted at 1Mbps. Arrange the rates in ascending order. Let $R_0 = $ 1Mbps. Let us denote the other three rates you picked, in ascending order, by R_1, R_2 and R_3. For R_1, R_2, and R_3, plot the saturation throughput for $10, 50, 100$ stations.

Assume a packet payload of 8184 bits and a slot time of $50\mu s$. The plots must be on the figure you earlier created for a rate of 1Mbps. Make all necessary calculations explicit. How does the throughput change with increasing rate? Explain your observation.

(d) For rate R_3 do the above plots for slot times of $25\mu s$, $5\mu s$, and $800ns$. How does throughput change with reducing slot time? Explain what you observe.

(e) Manipulate (13) in Bianchi's paper to explicitly show the dependence of saturation throughput on the rate at which the payload is transmitted. How (and how fast) does throughput change with slot time?

Question 4. 20 **marks** We will now modify Bianchi's model. In our model a node doubles its CW size on a collision with probability $0 < a < 1$, which quantifies node aggression. In Bianchi's model, $a = 1$. Our model behaves in a manner similar to the Bianchi's model if the CW size is set to its maximum value. Draw the Markov chain for the modified DCF. Derive equations for the modified model that correspond to equations $(7) - (13)$ in Bianchi's paper.

What do your equations reduce to for $a = 0$ and $a = 1$?

Plot the saturation throughput for $10, 50, 100$ stations in the network. For the plots assume basic access, a data rate of 1Mbps, a packet payload of 8184 bits, and a slot time of $50\mu s$. Refer to Table II in Bianchi's paper for any other constants you may require. Show how you obtained the values of parameters needed to calculate the saturation throughput. Do the plots for $a = 0.1, 0.4, 0.8, 1.0$. All the four plots must be on the same figure.

How do the plots of saturation throughput compare with those obtained by Bianchi? How does saturation throughput vary with a and the number of stations? Explain your observations.

Question 5. 10 **marks** Generate the plot Figure $16(b)$ in the paper "ACP+: An Age Control Protocol for the Internet" shared on Classroom. Your generated plot should be qualitatively similar to the figure in the paper. Note that the y-axis in the paper is expected system time for our purposes. For the curve corresponding to a stochastic facility pick any queueing system with a single queue and a finite queue size. The queue must accommodate a finite number of packets in addition to the 1 packet in the server. One should be able to vary the parameters of the queueing system to generate the corresponding plot.

Explain the behavior of curves in Figure $16(a)$ in the paper. Why is Figure $16(a)$ in the paper different from Figure $16(b)$ in the paper? Note that the y-axis of Figure $16(a)$ is the instantaneous amount of time a packet spends in the system.