CS-4
August 2017 QE

1. (**25 points**) State whether the following statements are true or false. **No justification is necessary.**

   (a) (5 points) Consider an M/M/2 queueing system with arrival rate λ and service rate μ for each server. Also consider an M/M/1 queueing system with arrival rate λ and service rate 2μ.
   Statement: The expected queueing delay in the M/M/2 system is larger than that in the M/M/1 system.

   (b) Let $N(t)$ be a Poisson process with rate λ. Let $L(t)$ be another process constructed by removing every other packet from $N(t)$.

      i. (5 points) **Statement:** The inter-arrival times in $L(t)$ are exponentially distributed.

      ii. (5 points) **Statement:** The mean inter-arrival time in $L(t)$ is $2/\lambda$.

   (c) (5 points) The computational complexity of Dijkstra's algorithm to find the shortest path from one source to all destinations is $O(N^2)$, where N is the total number of nodes in the network.

   (d) (5 points) As the link speed increases, the throughput of the Go-back-N ARQ protocol will approach that of the Stop-and-Wait protocol.

2. (**40 points**) Packets arrive to a server according to a Poisson process with rate 1. The service time of each packet is *i.i.d.* exponentially distributed with mean of 1. The server has a buffer of K packets, including the packet being served. If an incoming packet sees the buffer full, it will be dropped. Packets that enter the buffer are served in a first-come-first-serve manner.

   (a) (20 points) Draw the state-transition diagram, set up the balance equations, and find the probability P_n that there are n packets in the system.

   (b) (10 points) Find the probability that an incoming packet is dropped.

   (c) (10 points) Among those packets that enter the buffer, find the average delay from the time that they enter the buffer to the time that their service complete.

3. (**35 points**) Consider a random-access system based on Aloha. However, due to the variation in the quality of the communication channel at each station, there is a

probability that a station may not be able to access the random-access channel. In this problem, you will derive the maximum capacity of such a random-access system with channel variations.

Assume that there are N stations. New packets arrive at each station according to a Poisson process with rate λ, independently of other stations. The transmission time of each packet is m. When a station has a new packet to send, it will immediately attempt transmission. However, there are two ways such a transmission attempt can fail. First, the station must check the channel. Only with probability p the channel is accessible to the station, *independently of all other transmission attempts and all other stations.* In other words, with probability $1-p$ the station must give up the transmission attempt immediately. Second, even when the station can access the channel and transmit the packet, if it encounters a collision during the transmission time m, the packet transmission will still fail. In either case, the station involved will then wait for a random time and retransmit the packet. Note that retransmission attempts may fail again due to the above two types of failures. Such a procedure continues until the packet is successfully transmitted.

Let λ' denote the aggregate rate of transmission attempts at each station (measured before the station checks the channel), including both new and retransmission attempts. **Assume that the aggregated arrivals of both new and retransmission attempts are also Poisson.**

(a) (10 points) Suppose that you already know λ'. Find the rate with which actual packet transmissions occur on the channel (i.e., after each station checks the channel and finds the channel to be accessible).

(b) (15 points) Suppose that you already know λ'. Find the probability that a typical transmission attempt will succeed. (Make sure you account for both types of failures.)

(c) (10 points) Set up an equation that relates λ and λ'. Using this equation, find the maximum value of λ that this random-access system can support.

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