CS-4
August 2010 QE

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

   (a) (5 points) Assume that $\{N(t), t \geq 0\}$ is a Poisson process with rate λ. Then $\mathbf{P}[N(1) = 1, N(2) = 2] = \mathbf{P}[N(1) = 1]\mathbf{P}[N(2) = 2]$.

   (b) (5 points) Consider the closed queueing network in Fig. 1. There are N packets circulating in the system. The service time of each packet at each queue is assumed to be *i.i.d.* and exponentially distributed with mean $1/\mu$.

   Statement: The arrival process at the bottom queue is a Poisson process.

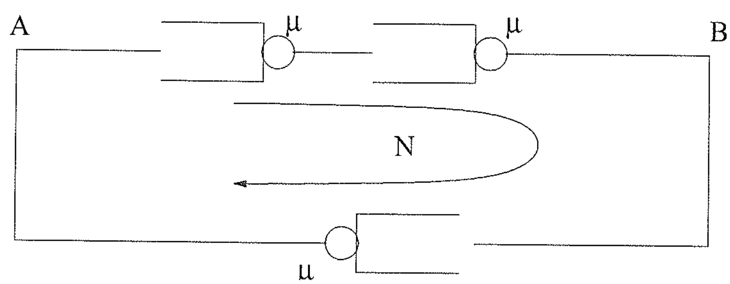

Figure 1: A closed queueing network

   (c) (5 points) As the propagation delay decreases, the throughput of Stop-and-Wait ARQ protocol approaches that of Go-Back-N.

   (d) (5 points) Suppose that the service time of a customer is exponentially distributed with mean $1/\mu$. Assume that the customer has been served for t amount of time and has not completed service yet.

   Statement: Conditioned on the above event, the conditional expectation of the customer's total service time remains to be $1/\mu$.

   (e) (5 points) The OSPF protocol is only used for intra-domain routing of small autonomous systems (AS) due to the counting-to-infinity problem.

2. **(35 points)**

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(a) (15 points) Carefully describe the Bellman-Ford algorithm for computing the shortest path in a directed network (i.e., each edge is directed, e.g., the network in Fig. 2).

(b) (20 points) Using the Bellman-Ford algorithm, find the shortest path from all other nodes to node A in the network shown below. The number next to each edge represents its cost/length. When you execute the Bellman-Ford algorithm, please update according to the following node sequence: B-C-D-E-F-G.

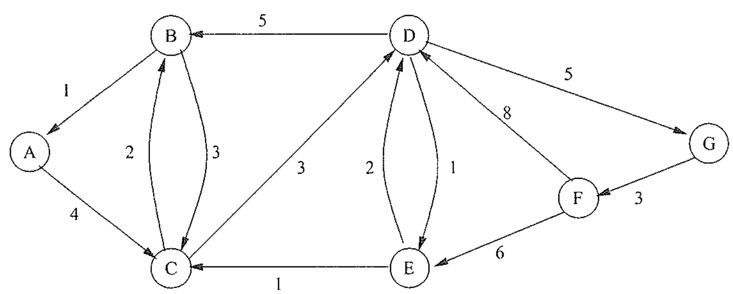

Figure 2: A directed network

3. (**40 points**) A computer virus is a piece of program that can replicate itself among computers. Typically, an "infected" computer randomly scans other computers in the Internet. If the target computer has not been infected yet, and its operating system or application software has a known vulnerability, the infected computer will then be able to replicate the virus program at the target computer. The target computer then also becomes a new "infected" computer. This process continues and each infected computer may potentially infect many other computers. An infected computer may be fixed and its virus program be removed by an administrator sometime later. In this problem, you are asked to use a simple model to analyze the spreading of this type of computer viruses.

Assume that each infected computer scans and replicates the virus program to other computers according to a Poisson process with rate λ. (In other words, it took an infected computer $1/\lambda$ time on average to infect a new computer that was not infected before.) Assume that each infected computer scans for other computers independently.

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Further, assume that the number of computers in the Internet is very large, and hence the chance that two infected computers scan for the same target computer is negligible.

Assume that after a computer is infected, the time that it takes for its administrator to get it fixed (i.e., the virus program removed) is exponentially distributed with mean $1/\mu$. Assume that the time to fix a computer is independent of that for other computers. However, we assume that there is one infected computer that is owned by the designer of the virus program and will never be fixed. (In other words, at any time when there are n infected computers in the system, only $n-1$ of them will potentially be fixed.)

(a) (20 points) Draw the state-transition diagram of the system and derive the probability that there are n infected computers in the system.

(b) (10 points) Under what condition will the number of infected computers increase to infinity? (Note that in queueing theory we typically refer to this scenario as "the system is unstable".)

(c) (10 points) Assume that the system is stable (i.e., the opposite of the condition in part (b)). Derive the average number of infected computers in the system.

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