Ollscoil na hÉireann
The National University of Ireland

Coláiste na hOllscoile, Corcaigh
University College, Cork

Final Examination 2011

CS6323 Complex Networks and Systems

M.Sc. Software and Systems for Mobile Networks
M.Sc. Computer Science

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Attempt all questions

Total marks: 80

60 minutes

Please answer all questions
Points for each question are indicated by [xx]

1. **[10]** Consider a network in Figure 1 under steady-state conditions, with input I that has a packet stream of λ_1 packets/sec. Processors X and Y have processing rates of μ_1 and μ_2 respectively. (Assume that all arrival and service rates are exponentially-distributed.) The input stream I splits evenly to provide data to X and Y. After leaving X fraction *p* of the packet stream goes to processor V, and fraction *1-p* exits from the system. The flow-rates are as described in the figure. Assume the following: p=0.5, λ_1=200, μ=200 for X, Y, V.
   a) **[5]** Compute λ_4 and λ_5.
   b) **[5]** Compute the total time spent by a packet before output from processor V.

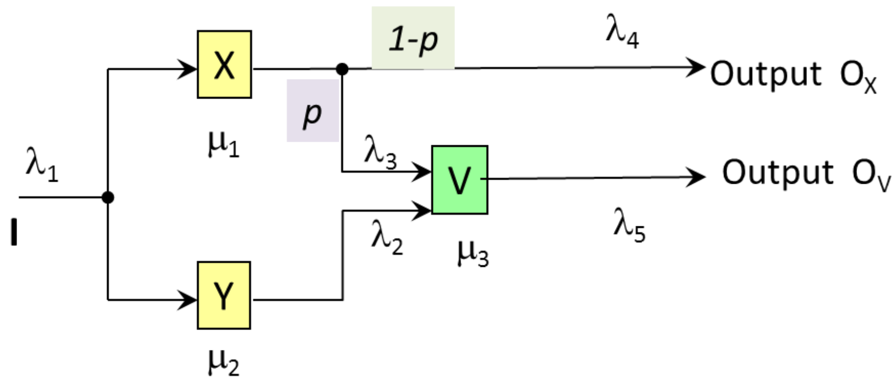

Figure 1: Steady-State Queueing Circuit

2. **[20]** Consider again the network shown in Figure 1. We assume that modules X and Y can fail, but the voter V is error-free.
   We assume that we obtain revenue of €100/job if the system functions properly (both X and Y are OK), revenue of €50/job if either X or Y are OK and the other failed, and €0 if both X and Y are failed. X and Y fail at rate 1/year, and are repaired at rate 99/year.
   (a) **[10]** Draw a Markov model for failure and repair of componentX, and derive Pr(X=fail) for such a component.
   (b) **[10]** Compute the expected revenue/year for the system.

3. **[10]** Assume that we are using a discrete-event simulator to study the performance of two queueing systems: an M/M/1/c queue with buffer size of c, and an M/M/s queue with s servers. For both systems, the (exponentially-distributed) arrival rate is λ=1/sec, and the service rate is 2/sec. The probability of having *k* packets in a queue is given by $P_k = (1-\rho)\rho^k$.
   a) **[5]** If we forgot to label the screen-shot of our simulation, for which queueing model (M/M/1/c or M/M/s) is the following snapshot (Figure 2) a valid output? State your reasons.
   b) **[5]** Compute the probability of the queue being in the state shown in the snapshot.

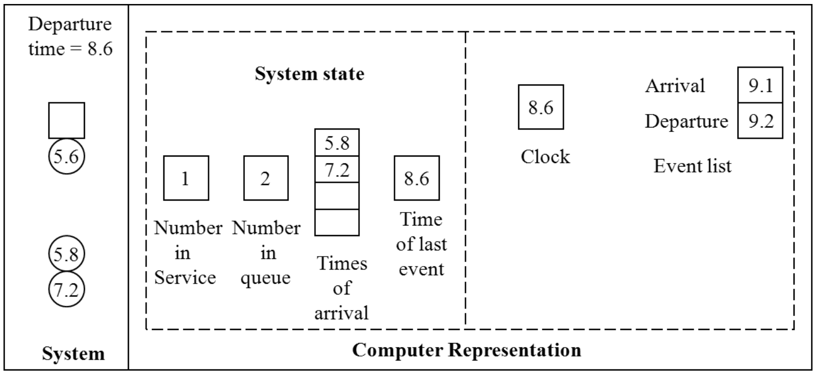

Figure 2: Snapshot of Queueing Simulator

4. **[40]** A campus Computing Centre wants to compare two computer lab designs. Design1 is a single lab with 5 terminals and a single queue, and Design2 consists of many single-terminal labs distributed across campus. Students would arrive at a computer lab at a rate λ of 10 per hour. They spend μ=20 minutes at a terminal (assume exponentially distributed times for arrival and at terminals) and then leave. The students will have a total waiting time in the lab of W, and there are *i* students in the lab with probability P_i. We assume that the students would randomly go to any of the single-terminal labs (i.e., arrivals are split evenly among all the small labs).
For a *c*-server (M/M/c) queue, we have the Erlang formula with $\rho=\lambda/(\mu c)$,

$$\sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!} + \frac{(c\rho)^c}{c!\,(1-\rho)} = 1/P_0$$

$\Pr(>c \text{ jobs}) = \kappa = P_0\,[(c\rho)^c]/[c!(1-\rho)]$
$E[W] = \kappa/[c\,\mu(1-\rho)]$.

(If needed, $P_0 = 0.0318$ and $\kappa = 0.33$ for this problem).

For a single-server (M/M/1) queue, the expected waiting time is $W = 1/(\mu - \lambda)$, and $P[X>x] = e^{-\lambda x}$ for $x > 0$.

<u>Consider Design1:</u>

a) **[10]** How many terminals can go down and the system remain stable (i.e., still be able to service the students without extremely long queues)?
b) **[5]** What is the probability that all terminals are busy?
c) **[5]** How long is the student in the lab, on average?

<u>Consider Design2:</u>

d) **[10]** What is E[W]? Will you wait longer than in Design1?
e) **[10]** How many mini-labs are needed to ensure a waiting time in the queue of no more than 10 minutes?