Ollscoil na hÉireann
The National University of Ireland

Coláiste na hOllscoile, Corcaigh
University College, Cork

Final Examination 2010

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: 65

60 minutes

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

1. **[15]** Assume that we have a communications network that can be modeled using the M/M/1 queuing network shown below in Figure 1, with queues Q_1, Q_2 and Q_3. (Assume that all arrival and service rates are exponentially-distributed.) Q_1 has incoming packet stream λ_1 of 100 packets per second (pps), and its output is split evenly to Q_2 and Q_3. The outputs for Q_2 and Q_3 are collected in a buffer B. B waits until 200 packets arrive before it bundles them together and transmits them as a large packet on a trunk. The processors Q_1, Q_2 and Q_3 have processing rates μ of 200, 60 and 60 pps, respectively. The mean waiting time for a queue with (arrival, processing) rate tuple (λ, μ) is $W = 1/(\mu - \lambda)$.

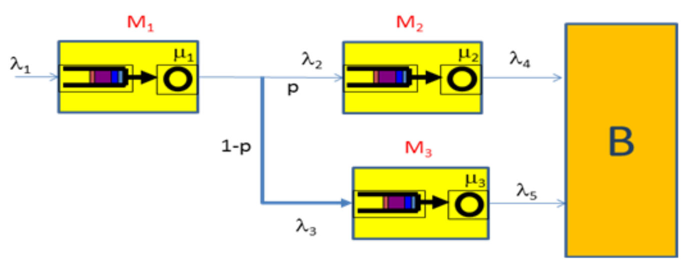

Figure 1: Queueing model for communications network

   a. [5] How long does it take for the buffer B to fill up with 200 packets?
   b. [10] What is the total system waiting time?

2. **[25]** Consider a computer network with two processing units in series, which are specified as shown in Figure 2. Unit M_1 has Poisson arrivals process with mean arrival rate $\lambda_1 = 8$ packets per millisecond and exponentially-distributed service rate $\mu_1 = 10$ packet per millisecond. Unit M_2 has Poisson arrivals process with mean arrival rate λ_2 and exponentially-distributed service rate $\mu_2 = 10$ packet per millisecond. The mean service time for a queue with input rate λ and processing rate μ is given by $W=1/(\mu - \lambda)$.

Component M_2 is failure-free, but component M_1 can operate in a degraded mode, in which case it rejects a fraction of the incoming packets such that the mean number of packets at this component (in the queue and being processed) is no more than 1, i.e., $L_1 \leq 1$. Component M_1 fails at rate α and is repaired at rate β.

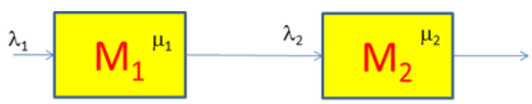

Figure 2: Computer Network

   a. [8] What is the rejection rate for degraded performance of component M_1?
   b. [8] Show how to solve a Markov failure model for component M_1.
   c. [4] If we have a failure rate α=0.1 and a repair rate β=0.5, compute the probability that M_1 is working in a degraded mode.

d. [5] If the profit of each packet delivered by the output stream from M_2 is €10, compute the expected profit rate (€/s) for the system given possible system degradation, with failure rate α=0.1 and a repair rate β=0.5.

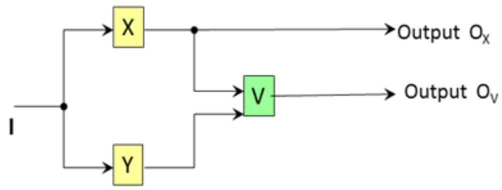

Figure 3: Error-Correction Network

3. **[10]** Consider the error-correction circuit shown in Figure 3. We assume that X and Y can fail, but V is error-free. Both X and Y will fail in inverting mode, in which case they output the inverse of the normal output. We assume that all network data is Boolean, and X and Y are buffers (i.e., their output should be the same as their input).
   a. [5] Fill out the fault-mode status of X and Y in a fault matrix as shown below.

I	O_X	O_V	X	Y
1	1	0		
1	0	0		
0	1	0		
0	0	0		
1	1	1		
1	0	1		
0	1	1		
0	0	1		

   b. [5] If the system can operate nominally if at least one buffer is working, compute Pr[system=OK].

4. **[30]** Consider the series computer system shown below. Unit M_1 has a Poisson arrivals process with mean arrival rate λ_1 packets per second and exponentially-distributed service rate μ_1. Unit M_2 has Poisson arrivals process with mean arrival rate λ_2 and exponentially-distributed service rate μ_2. Packets exit the system with probability (1-p) upon processing only by M_1, and with probability p packets must be processed by M_2 as well. We are given the information that $\rho=\lambda/\mu$, and $W=1/(\mu-\lambda)$.
The system designer wants to compare two scenarios. Under scenario 1, we allow module M_1 to fail and be repaired, at rates α and β, respectively. Module M_2 is assumed to be failure-free. Pr[M_1=OK] = $\beta/(\beta+\alpha)$. When M_1 is down, the system waiting time penalty is defined as k seconds.
Under scenario 2, we allow module M_2 to fail and be repaired, at rates α and β, respectively. Module M_1 is assumed to be failure-free. Pr[M_2=OK] = $\beta/(\beta+\alpha)$. When M_2 is down, the system waiting time penalty is defined as k seconds.

a. [5] Compute $E[L_1]$ for sub-system M_1.
b. [5] Compute E[W] for the entire system.
c. [15] Specify a Markov model for the failure states of this system, and use this model to compute the uptime probability, Pr[System=OK].
d. [5] In the case where the system performance measure is given by E[W], compare the expected system performance measure (given failure) under scenarios 1 and 2. Which measure is likely to be better?