Ollscoil na hÉireann
The National University of Ireland

Coláiste na hOllscoile, Corcaigh
University College, Cork

Examination 2013

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: 100

60 minutes

Please answer all 4 questions; Total marks: 100
Points for each question are indicated by [xx]

1. **[30]** We are designing a system consisting of an I/O device and a CPU, as shown in Figure 2. (We assume steady-state conditions for the system).

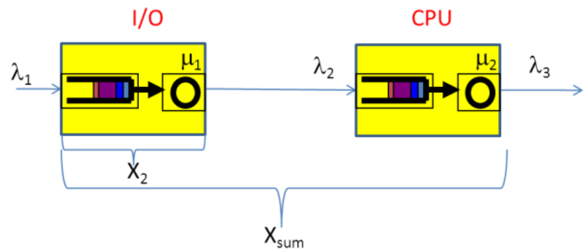

Figure 1: system consisting of I/O and CPU

We need to ensure that the longest processing time obeys certain bounds, given 2 types of incoming packet stream arrival processes:

(stream 1): a stream characterized by a 2-parameter cumulative distribution function (cdf) given by $Pr(X \le x) = F(x)$, as described below:

$$F(x) = \begin{cases} 0 & \text{for } x < a \\ \frac{x-a}{b-a} & \text{for } a \le x < b \\ 1 & \text{for } x \ge b \end{cases}$$

(stream 2): a stream characterized by a 1-parameter cumulative distribution function (cdf) given by $Pr(X \le x) = F(x) = 1 - e^{-\lambda x}$

We can define a stochastic variable denoting the total time taken using X_{sum}, the time taken by the CPU by X_1,and the time taken by the I/O by X_2. We want to compute the probability that the total processing time exceeds 25ms, given that the I/O device has exceeded a time of 15ms.

a. **[10]** For stream 1, compute $Pr(X_{sum} > 25 | X_2 > 15)$, when we have (a=15,b=30) for X_{sum} and (a=10,b=20) for X_2.
b. **[4]** Define the property for a distribution to be memoryless.
c. **[4]** Is the distribution for stream 1 memoryless? State clearly why or why not.
d. **[8]** For stream 2, compute $Pr(X_{sum} > 25 | X_2 > 15)$ when we have λ= 0.1 for X_{sum} and X_2.
e. **[4]** Is the distribution for stream 2 memoryless? State clearly why or why not.

2. **[25]** Consider a computer with 3 processors (X, Y, Z), where we model processor *i* with an M/M/1 queue with exponentially-distributed arrival rate λ_i and exponentially-distributed service rate μ_i. After exiting processor X, the output stream splits: proportion π_1 goes back to processor X, proportion π_2 goes to processor Y, and proportion π_3 goes to processor Z. Assume that processor X has rate 20 packets/second, processors Y and Z have rate 10 packets/second, and λ_X =12 packets/second. The average response time is given by $W=1/(\mu - \lambda)$, for arrival rate λ

and service rate μ. $p_k = (1-\rho)\rho^k$ is the probability of having k packets in the system for $\rho = \lambda/\mu$; we also have Pr($\geq k$ jobs in system)= ρ^k

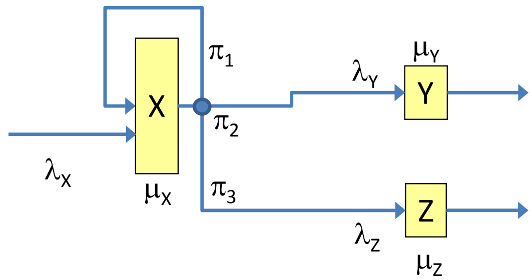

Figure 2: Computer system with processors X, Y, Z

a. [**5**] If $\pi_1=\pi_2=\pi_3$, what is the worst-case throughput time for the system?
b. **[10]** We must be the service rate of processor X to ensure that the system throughput rate is ≤ 0.5 seconds?
c. **[10]** Assume that any job arriving that exceeds the buffer size for a CPU is lost. How big a buffer is needed so only 1 in 10^5 jobs are lost at processor X?

3. **[20]** Consider a multiple-core computer that we model as an M/M/c queue: a designer wishes to build a computer with a single buffer and a number c of cores such that the mean time that a thread waits in the buffer does not exceed some specified time τ. The arrival rate λ, and service rates μ for all CPUs are exponentially-distributed. In general, we assume that all jobs that do not fit into the buffer are lost.

    a. [**10**] Draw the Markov chain (Birth/Death) model for a multi-server queue, assuming that we have c=2 CPUs to serve the threads and we have a buffer of size 0.
    b. [**10**] Write out the equations for this Markov chain and compute the distribution of number of threads in the system (in terms of λ and μ).