CompGZ02 & Comp4033: Network Performance, 2007

Answer any THREE questions

Marks for each part of each question are indicated in brackets

Calculators are permitted

1. Consider a shared access network, operating in slotted time. Suppose the length of a timeslot is Δ milliseconds, and that new packets arrive as a Poisson process of rate λ packets per millisecond. If exactly one packet arrives in a given timeslot then it is successfully transmitted; if more than one packet arrives then they all collide and no packets are successfully transmitted. Ignore retransmissions.

   (a) What is the probability that exactly one packet arrives in a given timeslot?

   {2 marks}

   (b) Suppose that at timeslot t there is a successful transmission. Let N be the number of timeslots between t and the next successful transmission. Calculate $\text{Prob}(N = r)$ for all values of r. Let n be the mean value of N; find an expression for n.

   {7 marks}

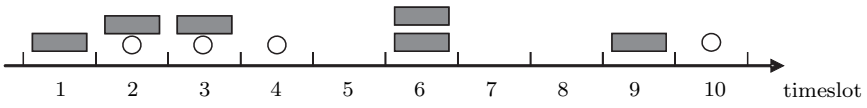
   (c) Since every successful transmission is followed on average by n timeslots with no successful transmission, the throughput θ is given by

   $$\theta = \frac{1}{\Delta(1+n)} \quad \text{packets per millisecond.}$$

   Calculate θ.

   {5 marks}

   To extend the range of my wireless network, I have bought a wireless repeater. This listens on the wireless channel, and whenever a newly arrived packet is successfully transmitted, the repeater will repeat it straight away. It keeps on repeating without pause until it has successfully sent the packet.



   In this picture, grey rectangles show newly arrived packets, and white circles show repeats. A new packet arrives in timeslot 1, and the repeater attempts retransmissions in timeslots 2–4, but is unsuccessful in timeslots 2 and 3 because other machines are attempting to transmit new packets in those timeslots.

(d) What is the probability that there are one or more new packets in a given timeslot?

{2 marks}

(e) Let m be the mean number of repeats that follow a single newly arrived packet (in the picture above, there are three repeats following the packet that arrived in timeslot 1). Find an expression for m.

{6 marks}

(f) After a successful repeat, there may be several timeslots in which no newly arrived packet is successfully transmitted (in the picture above, there are four such timeslots following the successful repeat in timeslot 4). Let n be the mean number of such timeslots. Find an expression for n.

{5 marks}

(g) After every succesful transmission of a newly arrived packet, there are on average $m+n$ timeslots with no successful transmissions of new packets, thus the throughput is

$$\theta_{\text{rep}} = \frac{1}{\Delta(1+m+n)} \quad \text{packets per millisecond.}$$

Calculate θ_{rep}, and also the relative efficiency $\theta_{\text{rep}}/\theta$.

{6 marks}

[33 marks total]

2. My brother has written a program for ripping radio programs from the BBC website. It downloads an audio file, then encodes it as an MP3, then downloads another audio file, and so on. The duration of a radio program is an exponential random variable with mean μ. Downloading happens in real-time, i.e. download time is exactly equal to the duration of the program. Encoding happens with an s-fold speedup, i.e. encoding time is an exponential random variable with mean μ/s. (Assume that downloading and encoding times times are independent.)

   This program works but is inefficient, since the CPU is underutilized during downloads. To improve efficiency, he plans to run M copies of his original program concurrently, using threads. Downloading takes the same time as before, for each thread. When there are e files being encoded, then encoding speed is e times slower for each (i.e. there is processor sharing between the threads that are encoding). He hopes that, most of the time, there will be at least one thread encoding, so that his CPU is not underutilized. He has asked me for advice on how to choose M.

(a) Let N_t be the number of threads which at time t are in the process of downloading. Draw a diagram of the state space, showing the possible values that N_t can take, and draw arrows for the possible transitions.

{3 marks}

(b) What are the transition rates in this system? Explain your answer in detail.

{18 marks}

(c) What is the equilibrium distribution of N_t? *[EITHER find the distribution OR explain the method for calculating the distribution.]*

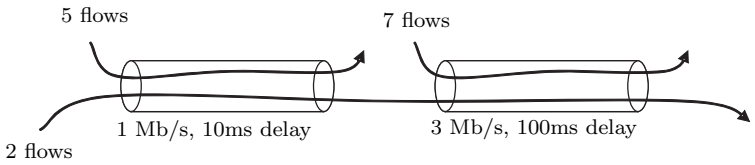
{8 marks}

(d) In which state is his CPU underutilized? For what fraction of time is his CPU underutilized?

{4 marks}

[33 marks total]

3. The diagram below shows the paths from sender to receiver for each of three sets of TCP flows, sharing two links. At a link with capacity C and incoming traffic y, the packet loss rate is $p = (y - C)/y$ if $y > C$, or $p = 0$ if $y \leq C$. The return paths have negligible delay and loss.



Describe an iterative procedure to calculate the flow rate of each of the TCP flows. Execute the first two iterations of your procedure.

[33 marks total]