Coursework 2

Simulation, Job models, Little's Law
Network Performance—DJW—2008/9

This coursework is worth 8% of your final grade. You should hand it in to Computer Science reception by the due date. For the programming tasks, you may use any computer language you wish.

An recent article reports that μTorrent will switch from TCP to UDP. The author points out that TCP has 'gentlemanly' congestion control, which saved the Internet from congestion collapse, whereas UDP does not have congestion control built in; and it suggests that that μTorrent's switch will cause severe problems for other Internet users. The author is concerned that network operators will be forced into breaking network neutrality.
`http://www.theregister.co.uk/2008/12/01/richard_bennett_utorrent_udp/`

Some commentary repeats the frequently-heard argument about network neurality: "Look, all I want is to get what I get sold. If a line is sold as a 10mbit line, I will expect it to be a 10mbit line. If I sell you a garage for 2 bucks a month, you might wonder but you will probably take the deal. Then you come around and notice that someone else is already standing in the space I sold you, and I tell you that you're allowed to use that space to park your car but only when it's free. Would you be happy? I guess not."
`http://tech.slashdot.org/article.pl?sid=08/12/01/1455245&tid=95`

This coursework proposes a model to illuminate the debate.

We will model the ISP as a single link shared by many flows. Some of these flows belong to *takers* who send at a constant rate, and some of the flows belong to *sharers* who share any capacity that is left. The link has total capacity C Mb/s, and the ISP has set a rate limit of A Mb/s for the takers. When there are N_T takers and N_S sharers, the takers each get throughput $\theta_T = \min(C/N_T, A)$ Mb/s, and the sharers each get throughput $\theta_S = (C - N_T A)^+/N_S$. Suppose that new taker flows arrive as a Poisson process of rate λ_T, new sharer flows arrive as a Poisson process of rate λ_S, mean taker flow size is f_T, and mean sharer flow size is f_S. Assume that flow sizes are exponentially distributed, and that all these random variables are independent.

Explain briefly the equations for θ_T and θ_S. Draw a state space diagram for this system, and note down all the transition rates.

We will be interested in the mean completion time for takers and for sharers. If A is very low then the sharers should see very little impact but the takers will suffer increased completion times; if A is very high then it will be the other way round. The ISP will probably want to set A small enough that the mean completion time for sharers is no worse than when everyone is a sharer.

Program an event-driven simulator of this system. Your program should be able to use any distribution for flow size, i.e. it should not be a simple Markov chain simulator. Test the correctness of your program by comparing its output to theoretical results that you have been taught. Report these tests.

Set $\lambda_T = 30$, $\lambda_S = 30$, $f_T = 1.8$, $f_s = 1$, $C = 100$, $A = 10$. Use your simulator to measure the mean completion time for the two classes of flow. Then repeat your simulations for a range of values of A, from 1 to 100. Plot your results. Remember to include error bars.

Also run a simulation in which the link runs true processor sharing, i.e. the capacity is shared equally between all active flows, with no rate caps. This represents the status quo.

We can use theory to predict the outcomes of the simulations. First, consider the status quo, in which capacity is shared equally between all active flows. The total arrival rate is then $\lambda = \lambda_T + \lambda_S$ and the mean file size is

$$f = \frac{\lambda_T}{\lambda_T + \lambda_S} f_T + \frac{\lambda_S}{\lambda_T + \lambda_S} f_S.$$

We know from Section 3.7 that the mean number of active flows is exactly what it would be if the flow sizes were exponential with mean f, and we know from Section 4.3 that the mean completion time is $f/(C - \lambda f)$. In fact, one can show that the mean completion time for the would-be takers is $f_T/(C - \lambda f)$, and the mean completion time for the would-be sharers is $f_S/(C - \lambda f)$.

Compute these quantities. How do they compare to your simulation results?

We can also use theory to approximate outcomes in the scenario where some flows are takers and others are sharers. (The method described below can be thought of as a kind of fixed-point approximation—we first write down an equation for the 'taker subsystem', which is not affected at all by the sharers; then we write down an equation for the 'sharer subsystem' which takes the answer from the former subsystem as given; then we solve the two equations.)

Draw a state space diagram for the number of active takers. Find the equilibrium distribution and the mean number of active takers $\bar{n}_T$. You may find question 4 on example sheet 4 to be helpful. Assuming that there are always exactly $\bar{n}_T$ active takers, calculate the mean number of sharers. Show your theoretical predictions on the same graph that you used to show your simulation results.

Repeat your experiment with a range of other parameter values. You should pay particular attention to parameter values where the theoretical approximation suggests the system will be unstable. Explain why you chose the parameter values you did. You should include any extra observations or mathematical analyses that shed light on your findings.

What does this model tell you about network neutrality? Is it a useful contribution to the debate about μTorrent's actions? If not, what are its major shortcomings?

Further reading: `http://www.cs.ucl.ac.uk/staff/bbriscoe/pubs.html#rateFairDis`