Network Engineering - Lab Exercises

Session 1

1 Lab Exercise 1

We are interested in studying the traffic load generated by cloud-gaming solutions. To do that, we use a sniffer to capture the incoming traffic to our computer. We obtain the following trace: $X(t)$ =[4 2 4 2 1 1 3 4 5 1 1 2 4 1 3 3 2 1 4 1 1 4 4 1 2 1 2 1 4 4 1 2 2 1 4 4 3 2 1 1 1 2 3 4 2 1 2 1 1 2 1 4 5 5 4 5 4 5 2 1 1 1 2 1 2 1 4 4 2 2 1 3 4 5 5 4] Mbps, which represents the amount of Mbps received every second.

To characterize it:

1. Find the state space of X(t). Draw the Discrete Time Markov chain representing X(t).
2. Complete the Matlab 'NE_Lab1_Exercise1_tbc.m' function able to compute the transition probability between two consecutive values of the state space, and generate the matrix **P**.
3. Obtain the stationary distribution of $X(t)$.
4. Calculate the mean and variance from the data using 'mean' and 'var' (biased estimator) functions, and do the same using the stationary distribution obtained from solving the Markov chain. Do you get the same results? Justify the differences.

Extend the function 'NE_Lab1_Exercise1_tbc.m' to generate a new stochastic process $Y(t)$ (a realization) using **P**. This is a very interesting feature as we can capture a real data flow, model it, and reproduce it in other situations. For instance, we can use our cloud-gaming traffic model to generate synthetic traffic and test the performance of a new equipment without the need to actually have anybody there playing the game.

2 Lab Exercise 2

Internet traffic (i.e., packets) usually arrive in batches. In part, this is caused by TCP, due to its congestion control mechanism. A batch is a group of packets that arrive at the same time.

In this exercise we want to study the effect of batch arrivals in the performance of a network interface. The network interface has a single transmitter and a buffer of $Q = 8$ packets, so the maximum number of packets in it is $K = 9$ packets.

Let us assume that packets are exponentially distributed and have an average packet size of $E[L] = 12000$ bits. The transmission time of a packet is $E[D_s] = 1$ ms in average, and batches of size k packets arrive at rate λ_k to the network interface following a Poisson process.

To study the effect of batch arrivals in the performance of a network interface, we aim to characterize the stochastic process $X(t)$ that represents the number of packets in the network interface. The evolution of $X(t)$ depends on the traffic load (λ_k) and the amount of time required to transmit a packet ($E[D_s]$).

Complete the function 'NE_Lab1_Exercise2_tbc.m'

Then,

1. What is the state space of X(t)?
2. Draw (in a paper) the Markov chain representing X(t) for the following three cases: a) $k = 1$ and $\lambda_1 = 900$ batches/second; b) $k = 4$ and $\lambda_4 = 225$ batches/second; and c) $k = 8$ and $\lambda_8 = 112.5$ batches/second. Note that when a batch cannot be fully accommodated inside the buffer, only the packets that do not fit in the buffer are discarded. For instance, if a batch of 4 packets arrive, but the buffer has only 3 available positions, we will fill all those 3, and discard one packet.
3. Write the **Q** matrix for each case. Encode them in Matlab. Ideally, we should write a function to generate the matrix **Q** given k, λ_k, μ and the rest of parameters. It's up to you to try.
4. Obtain the stationary probability for each case.
5. In order to compare the three cases, compute the following metrics:
   (a) Traffic load in Mbps of each case.
   (b) Probability that the network interface is not empty (i.e., prob. it contains packets).
   (c) Probability that the buffer is empty.
   (d) Probability that the network interface is full (i.e., there are K packets).
   (e) Probability to discard a packet when it arrives to the buffer. To compute this probability we will proceed as follows: we will average the fraction of packets that are lost in all system states when a new batch arrives. For instance, when $k = 1$, we only lose packets when the system in state 9. Therefore, $P_b(k = 1) = 1\pi_9$. However, when $k = 4$, we will lose a packet when we are in state 6, two packets in state 7, three packets in state 8, and all four packets in state 9. Therefore, $P_b(k = 8) = 1\pi_9 + \frac{3}{4}\pi_8 + \frac{2}{4}\pi_7 + \frac{1}{4}\pi_6$.
6. Based on the obtained results, explain what is the effect of batch arrivals in terms of packet losses, and so how the presence of batches, given the same traffic load, affects Internet performance.