Assignment 1

CSC467/CSC567 Spring 2017

Submission deadline: ***February 1, 2017***

Question 1

For QoS and traffic management first we need to understand what type of services (user- needs) are out there for data networks and what are the network needs of these applications in order to provision or design the networks efficiently. This exercise is about trying to figure out the needs (e.g., BW, delay and/or packet loss) of some of the popular applications. You can use any internet resources to get some answers:

a) Voice (compressed and un-compressed) (e.g., skype, voice-over-ip)
b) Video (real-time streaming) (e.g., webcam)
c) HD TV Channel (size and rate)
d) Netflix Service (on demand video both SD and HD quality)

Question 2

Consider the following Erlang-B equation that gives the probability of a call blocking (cannot be admitted) in a circuit switched network.

$$p_N = \frac{A^N / N!}{\sum_{n=0}^{N} A^n / n!} \qquad \text{(Equation 1)}$$

That equation is difficult to compute numerically for large *N* due to factorial function and due to *N* appearing as a power of *A*. However, this can be expressed as a recursive function that enable this evaluation very easily and is given by:

$$p_i = \frac{A.p_{i-1}}{i + A.p_{i-1}}; i = 1 \dots N; \quad p_0 = 1 \qquad \text{(Equation 2)}$$

Derive this recursive equation from Equation 1. (*Hint: Consider the ratio p_N/p_{N-1} and simplify).*

Question 3

A small local circuit switch has 5 trunks that are connected to a next switch in hierarchy. Assuming the total call arrival rate is A=5 erlangs, what is the probability of blocking at the local switch? You can use the recursive equation you derived in Question 2? What is the call arrival rate, assuming an average call holding time is 3 minutes?

Question 4

Suppose two hosts, A and B, are separated by 10,000 kilometers and are connected by a direct link of R = 1 Mbps. Suppose the propagation speed over the link is 2.0×10^8 meters/sec.

a. Calculate the bandwidth-delay product, $R.d_{prop}$

b. Consider sending a file of 400,000 bits from Host A to Host B. Suppose the file is sent continuously as one large message. What is the maximum number of bits that will be in the link at any given time?
c. Provide an interpretation of the bandwidth-delay product.

Question 5

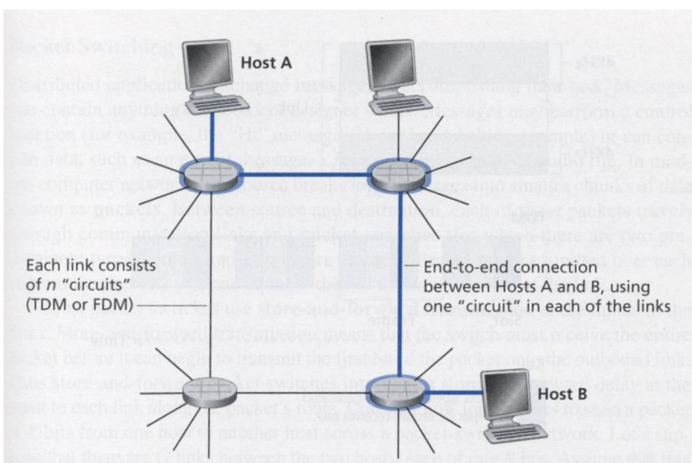
Suppose users share a 2Mbps link. Also suppose each user requires 500 Kbps when transmitting, but each user transmits only 10 percent of the time.

a. How many users can be supported when circuit switching is used?
b. For the remainder of this problem, suppose packet switching is used. Why will there be essentially no queuing delay before the link if two or fewer users transmit at the same time? Why will there be a queuing delay if five users transmit at the same time?

Question 6

Consider the circuit-switched network in the following figure. Each link can provide a maximum of *n* circuits.

a. What is the maximum number of simultaneous connections that can be in progress at any one time in this network?
b. Suppose that all connections are between the switch in the upper-left-hand corner and the switch in the lower-right-hand corner. What is the maximum number of simultaneous connections that can be in progress?



Question 7

This question is to take a look into the delays experienced at an internet router. As discussed in the class, there are four components to the delay in which the queuing delays are dominating due to packet buffering. Consider one outgoing link of a router. This link has a speed of 1Gbps. Assume that the packets (messages) have an average length of 10,000 bits. Let us also assume that there are 10 users, each sending packets at an average rate of ***r*** packets/sec.

a) What is the maximum rate (in packets/sec) that the router is able to serve? Let us call this $\boldsymbol{\mu}$.
b) What is the total packet arrival rate to the router? Let us call this $\boldsymbol{\lambda}$.

c) For the router to be stable, the total packet arrival must be less than the packet service rate. Based on this determine the maximum value for ***r.***

d) The router queuing delay can be modeled as $d_{queue} = 1/(\mu-\lambda)$. Please note that the router utilization ($\rho = \lambda/\mu$) must always be < 1 for router to be stable. Based on this determine d_{queue} for various values of ρ (=0.1, 0.2, 0.4, 0.6 and 0.8).

e) Assume a processing delay of 100 microseconds. The packets have to reach a next hop router that is 1000Km away. Using these values determine other delays experienced at the router and plot the overall nodal delay as a function of ρ.

Question 8

The average buffer occupancy of a statistical multiplexer (or data concentrator) is to be calculated for a number of cases. In such a device, the input packets from various terminals are merged in order of arrival in a buffer and are then read out on a first come first serve over an outgoing transmission link. An infinite buffer M/M/1 (see Review slides) model is used to represent the concentrator.

1. Ten terminal are connected to the statistical multiplexer. Each generates on an average, one 960-bit packet, assumed to be distributed exponentially, every 8 sec. A 2400-bit/sec outgoing line is used.
2. Repeat if each terminal now generates a packet every 5 sec on the average.
3. Repeat 1 above if 16 terminals are connected
4. Forty terminals are now connected and a 9600-bit/sec output line is used. The average packet length is also increased to 1600-bits. What is the average buffer occupancy if a packet is generated every 8 sec at each terminal.

Question 9

Suppose Host A wants to send a large file to Host B. The path from Host A to Host B has three links of rates R1=500Kb/s, R2=2Mb/s and R3=1Mb/s.

a) Assuming that there is no other traffic and hosts are not constrained in any way, what is the expected throughput for the file transfer?

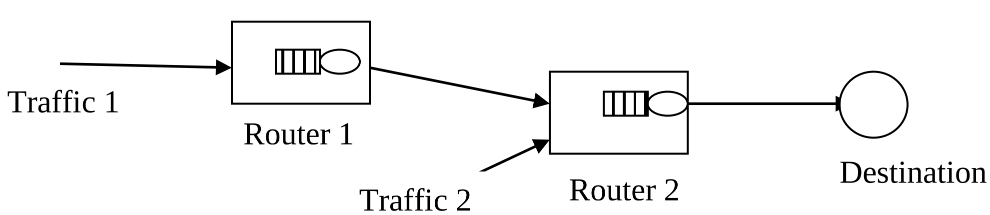
b) Suppose the file is 4 million bytes; dividing the file size by the throughput roughly how long will it take to transfer the file to Host B?

c) Assuming that there is another busy flow that travels through the same set of links (say from Host C to Host D), what will be the throughput for this file transfer?

d) Repeat (a) and (b) but now with R2 reduced to 100Kb/s.

Question 10

Suppose there are two routers in series as shown in the figure below. Assume both routers are of the same type and the links are all of the same speed.



Assume that all the traffic that goes through this network has an average packet size of 1000 bytes. Assume the link speeds are 1Mbytes/sec. Apply the M/M/1 model to both the routers. Assume Traffic 1 produces 350 packets/sec and Traffic 2 produces 450 packets/sec. Traffic 1 goes through both Router 1 and 2 while Traffic 2 only traverses through Router 2.

1. What is the utilization ($\rho 1$) of Router 1?
2. What is the utilization ($\rho 2$) of Router 2?
3. What would be delays experienced by Traffic 1 at Router 1 and Router 2? What would be the end-to-end delay?
4. What would be the delay experienced by Traffic 2?
5. On the average how many packets will be at Router 1? How many at Router 2?

Question 11 (for CSC 567 students)

Round-robin is the mechanism where a router serves packets from different customers one after another. Consider four customers (A,B,C,D) who are sending traffic to a router and the router serving them in a Round-robin fashion (A,B,C,D in that order). Assume an outgoing link rate is 1Mbps and customers always have a packet to send.

1. If all customers send traffic in 50 byte packets, what is the customer throughput?
2. If A,B,C send 50 byte packets and D sends 100 byte packet, what will be the throughput of each customer?
3. If A sends 50 byte packets, B sends 100 byte packets, C sends 150 byte packets and D sends 200 byte packets, what will be the throughput for each of these customers?

Please note that the purpose of this assignment is to understand the concepts of packet delay and throughput, bandwidth calculations and flow problems in various network and node scenarios.

Please submit the assignments only on conneX in PDF format or you can hand-in a paper copy to me before the deadline. Please do not send your solutions via e-mail.