Homework 1 – Solutions

1. (15 points) Consider a packet-switching architecture.
    a. Concisely describe the difference between transmission and propagation delay.
    Answer: Transmission delay is the time needed to put the entire packet on the link and is dependent on the length of the packet, while the propagation delay is needed time for one bit to reach to the other end of the link dependent on the length of the physical link. Essentially, transmission delay is the time it takes to push data onto the link. Once this data has been pushed onto the link, it takes some time to reach the recipient this is the propagation delay.

    b. How would the queuing delay be affected if the arrival of the packet rate increases?
    Answer: If the arrival of packet rate increases the traffic intensity will increase, hence the queuing delay will increase as well.

    c. After observing the delays of network communication, you found that the propagation delay is higher and requires immediate attention. What will you do reduce propagation delay?

    Answer: The propagation delay depends on the formula D/S or distance and speed. We can either decrease the distance or increase the speed to reduce the value of the propagation delay.

2. (10 points) Suppose we have an application that transmits data continuously at a steady rate (e.g., N-bits are sent every T time units, where T is small and fixed) for a long time.

    a. Which network type would be more appropriate for this application: circuit-switched or packet-switched? Justify your answer.

    Answer: A circuit-switched network would be well suited to the application, because the application involves long sessions with predictable smooth bandwidth requirements. Since the transmission rate is known and not bursty, bandwidth can be reserved for each application session without significant waste. In addition, the overhead costs of setting up and tearing down connections are amortized over the lengthy duration of a typical application session.

    b. Now, consider a circuit-switched network that has a 1500 Mbps link capacity where each user requires a bandwidth of 100 Mbps when transmitting, but are only active 10 percent of the time. What is the maximum number of users that can be supported? Justify your answer.

    Answer: When circuit switching is used, at most 15 circuit-switched users can be supported. This is because each circuit-switched user must be allocated its 100 Mbps bandwidth, and there is only 1500 Mbps of link capacity that can be allocated.

3. (15 points) Consider a packet-switched network that has a 1500 Mbps link capacity where each user requires a bandwidth of 100 Mbps when transmitting but are only active 1 percent of the time. Also, assume that there are 29 packet-switching users.

   a. Calculate the probability that exactly one user (i.e., any one of the 29 users) is transmitting at a given time while the remaining are not. Using binomial distribution, show the formula for the calculation and the final result to 6 decimal places. Note that it may be easier to write a program to find the final value.
   Answer :
   Binomial Probability Distribution

$$= \binom{n}{x} p^x \, (1-p)^{n-x}$$
$$= \binom{29}{1} 0.01^1 \, (1-0.01)^{29-1}$$
$$= 0.15177$$

   b. Now, calculate the summative probability that any up to 10 of the 29 users (i.e., 0, 1, 2, 3, …, 10 users) are transmitting at the same time, while the remaining users are not. Using binomial distribution, show the formula for the calculation and the final result to 6 decimal places. Note that it may be easier to write a program to find the final value.

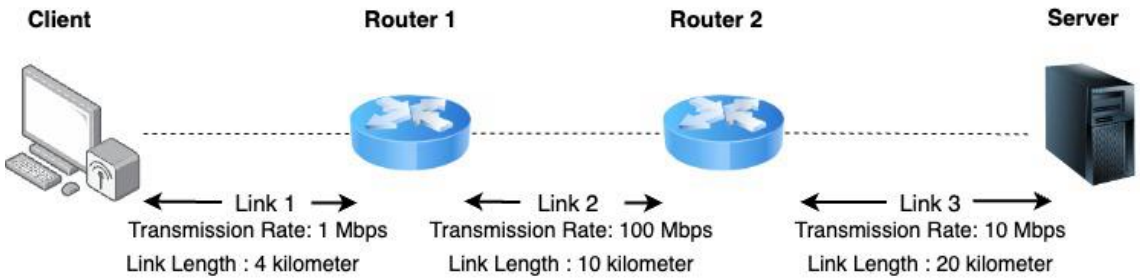
   Answer:
   Summation of 0,1,2,3 up to 10 users for PMF function in Binomial distribution is shown below.

$$= \binom{n}{x} p^x \, (1-p)^{n-x}$$
$$= \binom{29}{0} 0.01^0 \, (1-0.01)^{29-0} + \binom{29}{1} 0.01^1 \, (1-0.01)^{29-1} +$$
….
$$\ldots\ldots + \binom{29}{10} 0.01^{10} \, (1-0.1)^{29-10}$$
$$= 0.99994$$

   c. What is the probability to 6 decimal places that more than 15 of the 29 users are transmitting at the same time? What does this mean about the number of users supported under packet switching versus circuit switching for this scenario?
   Answer: Subtract the previous probability value from 1.

$$= 1 - 0.99994$$
$$= 0.00006$$

4. (24 points) Consider the following network:



You may assume a packet length of 10 Kilobyte and ignore queueing and processing delays. Use a propagation speed of 3×10^8 m/sec in the following calculations.

Answer:
Note: You can use either 1000 or 1024 to convert the 1Kbps or respective units for megabit and gigabit. If you use 1000 as your conversion rate, you should use 1000 throughout your assignment. If you use 1024, then you should use 1024 throughout your assignment. You cannot use a mix of both

a. Assuming no other traffic in the network, what is the throughput for the file transfer.
   Answer: 1 Mbps

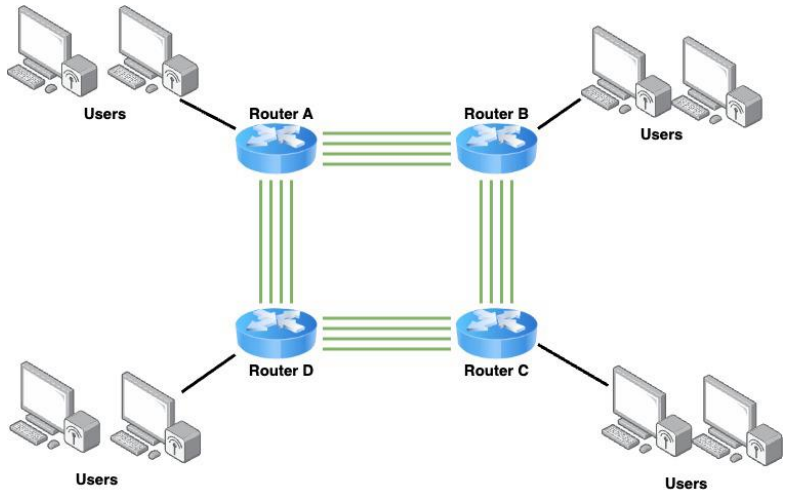
b. Calculate the transmission and propagation delays on Link 1.
   Answer:
   Transmission delay: L/R = 8*10*1024 bits / 1*1024*1024 bps = 78.125 ms.
   Alternate answer using 1000 as conversion rate is 80 ms
   Propagation delay: d/s = 4000 m / 3* 10^8m/sec = 13.33 us
c. Calculate the transmission and propagation delays on Link 2.
   Answer:
   Transmission delay: L/R = 8*10*1024 bits / 100*1024*1024 bps = 781.25 us
   Alternate answer using 1000 as conversion rate is 800 us
   Propagation delay: d/s = 10000 m / 3*10^8m/sec = 33.33 us

d. Calculate the transmission and propagation delays on Link 3.
   Answer:
   Transmission delay: L/R = 8*10*1024 bits / 10*1024*1024 bps = 7.8125 ms
   Alternate answer using 1000 as conversion rate is 8ms
   Propagation delay: d/s = 20000 m / 3*10^8 m/sec = 66.66 us

e. Assuming the processing and queueing delays are negligible (i.e., 0), calculate the end-to-end delay from the left host (when begin transmitting first bit of a packet) to the right host (when the last bit of that packet is received).
   Answer:
   The total end-to-end delay (ignoring the processing and queueing delays) is the sum of these six delays: 85.93 ms, Alternate answer: 88.008ms

f. For Link 2, determine the distance at which the transmission delay d_{trans} equals the propagation delay d_{prop}.
Answer:
d =(L/R) *s = (8*10*1024 bits / 100*1024*1024 bps) * 3 * 10^8
= 234375 meters or 234.375 kilometers

5. (15 points) Consider the following circuit-switched network where there are 4 links available between each router:



a. Determine the maximum number of simultaneous connections supported at any one time in this network.

Answer: Between routers A and B, we can have 4 connections. Similarly, between each adjacent pair of routers, we can have 4 connections. Thus, this network can support up to 16 simultaneous connections.

b. Suppose that users at the A router want to connect to end users at the C router. Determine the maximum number of simultaneous connections supported at any one time in this network for this scenario.

Answer: We can have 4 connections passing through routers A-B-C and another four connections passing through routers A-D-C, giving a total of 8 connections.

c. Now, suppose that we have 4 users at the A router wanting to connect to end users at the C router and 4 users at the B router wanting to connect to end users at the D router. Is it possible to simultaneously make these 8 connections in this network? Justify your answer.

Answer: Ideally yes, for the connections between A and C, we route 2 connections through B and 2 connections through D. For the connections between B and D, we

route 2 connections through A and 2 connections through C. In this manner, there are at most 4 connections passing through any link.

6. (5 points) Suppose that you have 20 terabytes (note that bytes, not bits, are used here) of data on a drive that you need delivered within 24 hours, but preferably faster. If your company has a dedicated 1 Gbps link available to transfer this data, would it be better to use FedEx overnight delivery (will be delivered in 24 hours, but no earlier) or transmit the data on your dedicated link if these are your only options? Show calculations to justify your answer.

   Answer: 20 $terabytes$ = $20*10^{12}$ * 8 bits. Using the dedicated link would take $20*10^{12}$ *8 bits / $1*10^{9}$ = 160000 seconds = 2666. 6 minutes = 44. 4 $hours$ = 1.85 days. So, FedEx would be a better solution since it would get there faster. (Alternatively, you can use 1024^3 for terabyte conversion)

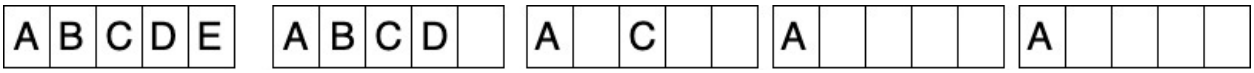
7. (6 points) Networked systems are organized into protocol layers. Briefly identify and describe four advantages of protocol layers.

   Answer: Some of the reasons for (and advantaged of) layering are :

   - It is easier to develop, maintain, and troubleshoot network systems due to modularity
   - The layers are interoperable so different systems and technologies can work together because standardized protocols at each layer ensure compatibility.
   - Multiple layer abstractions reduce the complexity of the underlying network processes.
   - Network systems can grow or adapt to new technologies more easily.

8. (5 points) Suppose that you have a multiplexer (mux) with 5 different inputs at the following bit-rates: (A) 20 Kbps, (B) 8 Kbps, (C) 12 Kbps, (D) 8 Kbps, and (E) 4 Kbps. Using a fixed slot size in the frame, how would you organize a single synchronous TDM link receiving the output of the mux? That is, how many time slots are needed? Draw a diagram of a single frame, labeling each slot appropriately.

   Answer: There are a number of possible solutions. Since we require a fixed slot size to be used, we see that they have a common divisor of 4. Using this information, we assign 5 slots for A, 2 slots for B and D, 3 slots for C, and 1 slot for E. Since it is a synchronous transmission we will use a frame of 5 slots due to 5 inputs. We propose the following frame structure with the given slot assignments:



9. (5 Points) You are a network engineer at XYZ company and monitor daily activities in look after network operations. On the weekend, you observe heavy traffic usage over the internet, and suspect unauthorized activity. What tool would you use to investigate the packets to investigate the network. What level of packet information can this tool provide?
   Answer: Wireshark or packet capture analysis tool. It provide information layer specific protocol information for application, transport, network, link and physical layer. [Any other network packet capturing tool also works]