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Due Date: 7/10/19

Assignment: Homework 1

Class: COMP-4320

1. An application transmits data at a steady rate (for example, the sender generates an L-bit unit of data every t time unit, where t is small and fixed). Also, when the application starts, it will continue running for a relatively long period of time. Answer the following questions, briefly justifying your answers:
   1. Would a packet-switched or a circuit-switched network be more appropriate for this application? Why?

**Answer:** Packet switching works better for data that is transmitted at an irregular rate, so circuit switching would be more appropriate for this application. Using this network will ensure that resources are allocated and reserved for the data, and since it comes in at a steady rate, it will always have a spot reserved. Using this network will increase the speeds at which data is transmitted, whereas using packet switching would take a longer amount of time due to store and forward (which is redundant in this situation, since we are not worried about a sudden drop/increase in traffic intensity).

* 1. Suppose that a packet-switched network is used and the only traffic in this network comes from such applications as described above. Furthermore, assume that the sum of the application data rates is less than the capacities of each and every link. Is some form of congestion control needed? Why?

**Answer:** Packet switching, in general, requires some kind of protocol for congestion control due to packet delay/loss. If the buffer in the receiving host is already filled when a packet arrives, either the arriving packet or one of the already-queued packets will be dropped. Congestion only occurs when the arrival rate exceeds the data rate for the given link for a short interval of time. If the sum of the data rates for the application is less than the capacities of every link in the network, then congestion will not be a problem, and congestion control will not be necessary. Since there is less data being produced by the application than the capacities of the links they are transmitted on can handle, the buffers will never be filled to their maximum capacities and packets will not be lost.

1. Suppose users share a 5 Mbps link. Also suppose each user requires 200 kbps when transmitting, but user transmit only 5 percent of the time.
   1. When circuit switching is used, how many users can be supported?

**Answer:** If only 5000 kbps is available with the link (since 5 mbps = 5000 kbps), and each user requires 200 kbps, the circuit-switched link can support only 25 (= 5000 kbps / 200 kbps) simultaneous users.

* 1. For the remainder of this problem, suppose packet switching is used. Find the probability that a given user is transmitting.

**Answer:** The probability that any user is transmitting is the same regardless of if packet switching or circuit switching is used. This means that the probability of a user transmitting is 5%, or 0.05.

* 1. Suppose there are 75 users. Find the probability that at any given time, exactly k users are transmitting simultaneously. (Hint: Use the binomial distribution.)

**Answer:** C(75, k) \* (0.05)k \* (0.95)75 – k

* 1. Find the probability that there are 35 or more users transmitting simultaneously.

**Answer:** A screenshot of text

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1. Consider sending real-time voice from Host X to Host Y over a packet-switched network (VoIP). Host X converts analog voice to a digital 32 kbps bit stream on the fly. Host X then groups the bits into 64-byte packets. There is one link between Host X and Y; its transmission rate is 4 Mbps and its propagation delay is 5 msec. As soon as Host X gathers a packet, it sends it to Host Y. As soon as Host Y receives an entire packet, it converts that packet’s bits to an analog signal. How much time elapses from the time a bit is created (from the original analog signal at Host X) until the bit is decoded (as part of the analog signal at Host Y)?

**Answer:** A packet consists of 512 bits (64 bytes) and the bit stream is 32000 bps (32 \* 103). The time it takes to transmit one packet between the Hosts is 0.016 seconds (= 512 / 32000). The transmission rate is 4000000 bps (4 \* 106), so the transmission delay is 0.000128 seconds (512 / 4000000). Adding the propagation delay (0.005 sec, given in the problem statement) and transmission delay to the time it takes to transmit one packet gives us 0.021128 seconds, or 21.128 msec as the final amount of time it takes to transmit each bit on this link.

1. Consider a packet of length B which begins at end system A, travels over three links to a destination end system. These three links are connected by two packet switches. Let di, si, and Ri denote the length, propagation speed and the transmission rate of link i, for i=1, 2, 3. The packet switch delays each packet by dproc. Assuming no queuing delays, in term of di, si, and Ri, (i=1, 2, 3), and B, what is the total end-to-end delay for the packet? Suppose now the packet is 2,000 bytes, the propagation speed on the three links is 2.3 x 108 m/s, the transmission rates of all three links are 4 Mbps, the packet switch processing delay is 2 msec, the length of the first link is 6,000 km, the length of the second link is 8,000 km, and the length of the third link is 3,000 km. For these values, what is the end-to-end delay?

**Answer:** For packet length B, link length d, link propagation speed s, and link transmission rate R, the total end-to-end delay for the packet would be = the sum of all propagation delays + the sum of all transmission delays + the sum of all processing delays, where the transmission delay is = to B/Ri (for i = 1, 2, 3) and the propagation delay is = to di/si (for i = 1, 2, 3). For the given values, the total end-to-end delay for a packet is = 3(0.002) + 3(16000/4000000) + (6000/2.3 x 108 + 8000/2.3 x 108 + 3000/2.3 x 108) = 0.0180739131 seconds, or 18.0739131 msec.

1. Suppose a packet switch receives a packet and determines the outbound link to which the packet should be forwarded. When a packet arrives, one other packet is one fifth done being transmitted on this outbound link and six other packets are waiting to be transmitted. Packets are transmitted in order of arrival. Suppose all packets are 4,000 bytes and the link rate is 10 Mbps. What is the queuing delay for the packet? More generally, what is the queuing delay when all packets have length L, the transmission rate is R, k bits of the currently being transmitted packet have been transmitted, and s packets are already in the queue?

**Answer:** The queuing delay for the packet is the number of bits / the link rate. Since there are 6.8 packets in the queue (6 waiting packets and four fifths of a 7th packet), and each one is 4000 bytes, we get 6.8 \* 4000 = 27200 bytes, which is equivalent to 217600 bits. This means the queuing delay is (217600 / 10000000) = 0.02176 seconds. We can derive the general formula for this as ((s + 1 – k) \* 8L) / (R \* 106), where L is the length of the packets (in bytes), R is the transmission rate (in Mbps), s is the number of packets already in the queue, and k is the fraction of bits that have already been transmitted for the first packet in the queue. Plugging our values into the general formula to check this gives us ((6 + 1 - 0.2) \* (8 \* 4000)) / (10 \* 106) = 0.02176 seconds, which is indeed the value we got earlier for the queuing delay.

1. Suppose there are M paths between the server and the client. No two paths share any link. Figure 1 shows only one of the M paths, i.e. Path i (where i = 1, …, M) which consists of N links with transmission rates Ri1, Ri2, …, RiN. If the server can only use one path to send to the client, what is the maximum throughput that the server can achieve? If the server can use all M paths to send data, what is the maximum throughput that the server can achieve?

**Answer:** A picture containing device

Description automatically generated

1. Consider the queuing delay in a router buffer. Let Q denote the traffic intensity; i.e. Q = Lλ/R, where all packets consist of L bits, λ is the average rate packets arrives at the queue in packets/sec. and R is the transmission rate in bits/sec. Suppose that the queuing delay takes the form (QL)/(R(1 – Q)) for Q < 1.
   1. Provide a formula for the total delay, i.e. the queuing delay plus the transmission delay.

**Answer:** Total Delay = L/R + (QL)/(R(1 – Q))

* 1. Plot the total delay as a function of L/R.

**Answer:** A close up of text on a whiteboard

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* 1. Suppose μ denote the link’s transmission rate in packets/sec. Derive a formula for the total delay in terms of λ and μ.

**Answer:** Included in above picture.

1. In modern packet-switched networks, the source host segments long, application-layer messages (for example an image or a music file) into smaller packets and sends the packets into the network. The receiver then resembles the packets back into the original message. We refer to this as message segmentation. Figure 2 illustrates the end-to-end transport of a message with and without message segmentation. Consider a message that is 15x106 bits long needs to be sent from source to destination in Figure 2. Suppose the transmission rate of each link is 8 Mbps. Ignore propagation, processing and queuing delay.
   1. Consider sending the message from source to destination without message segmentation. How long does it take to move the message from the source to the first packet switch? Keeping in mind that each switch uses store-and-forward packet switching, what is the total time to move the message from source host to destination host?

**Answer:** The time to move the message from the source to the first packet switch is 15x106 / 8x106 = 1.875 seconds, and the total time it takes to move the message from source host to destination host (ignoring all delays) is 1.875 \* 3 links = 5.625 seconds without segmentation.

* 1. Now suppose that the message is segmented into 10,000 packets, with each packets being 1,500 bits long. How long does it take to move the first packet from the source host to the first switch? When the first packet is being sent from the first switch to the second switch, the second packet is being sent from the source host to the first switch. At which time will the second packet be fully received at the first switch?

**Answer:** The time to move the first packet from the source host to the first switch is (1500bits / 8000000Bps) = 0.0001875 seconds, and the time it takes for the second packet to be fully received at the first switch is 2 \* 0.0001875 = 0.000375 seconds.

* 1. How long does it take to move the file from source host to destination host when message segmentation is used? Compare this result with your answer in part (a) and comment.

**Answer:** The first packet will take 0.0001875 \* 3 = 0.0005625 seconds to reach the destination, and the remaining 9999 packets will take an additional 0.0001875 seconds, giving a total of 0.0005625 + 9999(0.0001875) = 1.875375 seconds. So, message segmentation is much faster for transmitting files.

* 1. Discuss the drawbacks of message segmentation.

**Answer:** Message segmentation means that the packets will be split up into smaller groups of bytes. This brings the problem of each smaller group having a header, which would increase the amount of unnecessary data. This method also increases the overhead transmission time, since packets must be split apart and reassembled (which can take a large amount of time). Another drawback is that all packets must arrive in the same sequence that they were transmitted, which becomes a harder job to maintain with message segmentation due to there being more groups of packets.