Homework 1

Quantitative Comparison of Packet Switching and Circuit Switching

Consider the two scenarios below:

- A circuit-switching scenario in which \( N_{cs} \) users, each requiring a bandwidth of 25 Mbps, must share a link of capacity 100 Mbps.
- A packet-switching scenario with \( N_{ps} \) users sharing a 100 Mbps link, where each user again requires 25 Mbps when transmitting, but only needs to transmit 10 percent of the time.

Answer the following questions:

1. When circuit switching is used, what is the maximum number of circuit-switched users that can be supported? Explain your answer.
2. For the remainder of this problem, suppose packet switching is used. Suppose there are 7 packet-switching users (i.e., \( N_{ps} = 7 \)). Can this many users be supported under circuit-switching? Explain.
3. What is the probability that a given (specific) user is transmitting, and the remaining users are not transmitting?
4. What is the probability that one user (any one among the 7 users) is transmitting, and the remaining users are not transmitting? When one user is transmitting, what fraction of the link capacity will be used by this user?
5. What is the probability that any 4 users (of the total 7 users) are transmitting and the remaining users are not transmitting? (Hint: you will need to use the binomial distribution \([1, 2]\)).
6. What is the probability that more than 4 users are transmitting? Comment on what this implies about the number of users supportable under circuit switching and packet switching.
Computing the one-hop transmission delay

Consider the figure below, in which a single router is transmitting packets, each of length $L$ bits, over a single link with transmission rate $R$ Mbps to another router at the other end of the link.

Suppose that the packet length is $L = 4000$ bits, and that the link transmission rate along the link to router on the right is $R = 1000$ Mbps.

1. What is the transmission delay (the time needed to transmit all of a packet's bits into the link)?
2. What is the maximum number of packets per second that can be transmitted by the link?

Computing end-end delay (transmission and propagation delay)

Consider the figure below, with three links, each with the specified transmission rate and link length.

Find the end-to-end delay (including the transmission delays and propagation delays on each of the three links, but ignoring queueing delays and processing delays) from when the left host begins transmitting the first bit of a packet to the time when the last bit of that packet is received at the server at the right. The speed of light propagation delay on each link is $3 \times 10^{8}$ m/sec. Note that the transmission rates are in Mbps and the link distances are in Km. Assume a packet length of 12000 bits. Give your answer in milliseconds.
End to End Throughput and Bottleneck Links

Consider the scenario shown below, with four different servers connected to four different clients over four three-hop paths. The four pairs share a common middle hop with a transmission capacity of $R = 300$ Mbps. The four links from the servers to the shared link have a transmission capacity of $R_S = 40$ Mbps. Each of the four links from the shared middle link to a client has a transmission capacity of $R_C = 90$ Mbps per second. You might want to review Figure 1.20 in the text before answering the following questions:

1. What is the maximum achievable end-end throughput (in Mbps) for each of four client-to-server pairs, assuming that the middle link is fair-shared (i.e., divides its transmission rate equally among the four pairs)?
2. Which link is the bottleneck link for each session?
3. Assuming that the senders are sending at the maximum rate possible, what are the link utilizations for the sender links ($R_S$), client links ($R_C$), and the middle link ($R$)?