CN 2022 Homework 2

Due date: 2022/10/11 23:59

1. (30%) Consider an application that transmits data at a steady rate (for example, the sender generates an *N*-bit unit of data every *k* time units, where *k* is small and fixed). Also, when such an application starts, it will continue running for a relatively long period of time. Answer the following questions, briefly justifying your answer:
   a. (15%) Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why?
   b. (15%) 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?
2. (20%) Suppose users share a 3 Mbps link. Also suppose each user requires 150 kbps when transmitting, but each user transmits only 10 percent of the time. (See the discussion of statistical multiplexing in Section 1.3.)
   a. (5%) When circuit switching is used, how many users can be supported?
   b. (5%) For the remainder of this problem, suppose packet switching is used. Find the probability that a given user is transmitting.
   c. (5%) Suppose there are 120 users. Find the probability that at any given time, exactly n users are transmitting simultaneously. (Hint: Use the binomial distribution.)
   d. (5%) Find the probability that there are 21 or more users transmitting simultaneously.
3. (10%) Consider a router buffer preceding an outbound link. In this problem, you will use Little's formula, a famous formula from queuing theory. Let N denote the average number of packets in the buffer plus the packet being transmitted. Let a denote the rate of packets arriving at the link. Let d denote the average total delay (i.e., the queuing delay plus the transmission delay) experienced by a packet. Little's formula is $N = a \cdot d$. Suppose that on average, the buffer contains 10 packets, and the average packet queuing delay is 10 msec. The link's transmission rate is 100 packets/sec. Using Little's formula, what is the average packet arrival rate, assuming there is no packet loss?
4. (20%) This elementary problem begins to explore propagation delay and transmission delay, two central concepts in data networking. Consider two hosts, A and B, connected by a single link of rate *R* bps. Suppose that the two hosts are separated by *m* meters, and suppose the propagation speed along the link is *s* meters/sec.

Host A is to send a packet of size L bits to Host B.

a. (5%) Express the propagation delay, d_{prop}, in terms of m and s.

b. (5%) Determine the transmission time of the packet, d_{trans}, in terms of L and R.

c. (5%) Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.

d. (5%) Suppose $s = 2.5 \cdot 10^8$, $L = 120$ bits, and $R = 56$ kbps. Find the distance m so that d_{prop} equals d_{trans}.

5. (10%) In this problem, we consider sending real-time voice from Host A to Host B over a packet-switched network (VoIP). Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 56-byte packets. There is one link between Hosts A and B; its transmission rate is 2 Mbps and its propagation delay is 10 msec. As soon as Host A gathers a packet, it sends it to Host B. As soon as Host B receives an entire packet, it converts the 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 A) until the bit is decoded (as part of the analog signal at Host B)?

6. (10%) Consider the throughput example corresponding to the Figure. Now suppose that there are M client-server pairs rather than 10. Denote R_S, R_C, and R for the rates of the server links, client links, and network link. Assume all other links have abundant capacity and that there is no other traffic in the network besides the traffic generated by the M client-server pairs. Derive a general expression for throughput in terms of R_S, R_C, R, and M.