Computer Networking
Homework#1

1. Suppose Host A wants to send a large file to Host B. The path from Host A to Host B contains three hops (links), with the link rates of these hops of rates R_1 = 500 kbps, R_2 = 2Mbps, and R_3 = 1Mbps. That is, the file sent by Host A must pass through two immediate routers to reach Node B.
   (a) Assuming no other traffic in the network, what is the throughput for the file transfer.
   (b) Repeat (a), but now with R3 reduced to 200 Kbps.

2. Suppose users share a 2 Mbps link. Also suppose each user requires 100 Kbps when transmitting, but each user transmits only 20% of the time in average. (You may review the concept of statistical multiplexing for solving this problem)

   (a) When circuit switching is used, how many users can be supported?
   (b) For the remainder of this problem, suppose packet switching is used. Find the probability that a given user is transmitting.
   (c) Suppose there are 40 users. Write the formula of the following probability: P(at any given time, exactly *n* users are transmitting simultaneously). (*Hint*: Use the binomial distribution.)
   (d) Suppose there are 40 users again. Write the formula of the following probability: P(21 or more users transmitting simultaneously).

3. Consider the queuing delay in a router buffer (preceding an outbound link). Suppose all packets are *L* bits, the transmission rate is *R* bps and that *N* packets simultaneously arrive at the buffer every *LN/R* seconds. Find the average queuing delay of a packet. (*Hint*: The queuing delay for the first packet is zero; for the second packet *L/R*; for the third packet 2*L/R*. The *N*th packet has already been transmitted when the second batch of packets arrives.)

4. Consider a packet of length *L* which begins at end system A, travels over one link to a packet switch, and travels from the packet switch over a second link to a destination end system. Let d_i, s_i, and R_i denote the length, propagation speed, and the transmission rate of link *i*, for *i* = 1,2. The packet switch processes and delays each packet by d_{proc}. Assuming no queuing delays, in terms of d_i, s_i, R_i, (*i* = l,2), and *L*, what is the total end-to-end delay for the packet? Suppose now the packet length is 1,000 bytes, the propagation speed on both links is $2 \cdot 10^8$ m/s, the transmission rates of both links is 2 Mbps, the packet switch processing delay is 1

msec, the length of the first link is 4,000 km, and the length of the last link is 1,000 km. For these values, what is the end-to-end delay?

5. Suppose two hosts, Host 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 $2.5 \cdot 10^8$ meters/sec. The propagation delay of the link is d_{prop}.
   (a) Calculate the bandwidth-delay product, $R \cdot d_{\text{prop}}$.
   (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.
   (d) What is the width (in meters) of a bit in the link?
   (e) Derive a general expression for the width of a bit in terms of the propagation speed s, the transmission rate R, and the length of the link m.