CS 549: Performance Analysis of Computer Networks
Theory Assignment 2

Assigned: February 27, 2025 *Due*: March 9, 2025

Write your answers by hand on plain paper and submit. Descriptive answers must be written in your own words, copying verbatim from the textbook will not fetch you any marks.

1. 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) Express the propagation delay, d_{prop} , in terms of m and s.

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

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

   (d) Suppose Host A begins to transmit the packet at time $t = 0$. At time $t = d_{trans}$, where is the last bit of the packet?

   (e) Suppose d_{prop} is greater than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

   (f) Suppose d_{prop} is less than d_{trans}. At time $t = d_{trans}$, where is the first bit of the packet?

   (g) Suppose $s = 3 \times 10^8$, $L = 100$ bits, and $R = 56$ kbps. Find the distance m so that d_{prop} equals d_{trans}.

2. Suppose Host A wants to send a large file to Host B. The path from Host A to Host B has three links, of rates $R_1 = 300$ kbps, $R_2 = 1.2$ Mbps, and $R_3 = 1$ Mbps.

   (a) Assuming no other traffic in the network, what is the throughput for the file transfer?

   (b) Suppose the file is 4 million bytes. Dividing the file size by the throughput, approximately how long will it take to transfer the file to Host B?

   (c) Repeat (a) and (b), but now with R_2 reduced to 250 kbps.

3. Suppose four active nodes—A, B, C and D—are competing for access to a channel using Slotted ALOHA. Assume each node has an infinite number of packets to send. Each node attempts to transmit in each slot with probability p. The slots are numbered $1, 2, \cdots$.

(a) What is the probability that a give node succeeds for the first time in slot 4?

(b) What is the probability that some node (either A, B, C or D) succeeds in slot 3?

(c) What is the probability that the first success occurs in slot 6?

(d) What is the efficiency of this four-node system?

4. A system with 10 nodes uses Slotted ALOHA for channel access, with each time slot lasting 1 ms. In the entire system, packets arrive as per a Poisson process with a mean rate 512 pkts/s. Further, each backlogged node attempts a retransmission with a probability 0.15. Find the following.

   (a) Departure rate when two nodes are backlogged.

   (b) Drift when four nodes are backlogged.

   (c) Departure rate and drift when none of the nodes are backlogged.

   (d) Number of backlogged nodes that would ensure maximum departure rate.

5. Suppose that each transmitted packet in a Slotted ALOHA system is successful with some fixed probability p. New packets are assumed to arrive at the beginning of a time slot and are transmitted immediately. If a transmission is unsuccessful, the packet is retransmitted with probability q_r in each successive slot until successfully received. Find the expected delay T from the arrival of a packet until the completion of it successful transmission.

6. Let $\{X_j\}$ be a sequence of iid Bernoulli random variables, with success probability p. Let $S_N = X_1 + X_2 + \cdots + X_N$ be the sum of a random number N of the random variables X_j, where N has a Poisson distribution with mean λ. Prove that S_N has a Poisson distribution with mean λp. [Note: The distribution of the sum of a random number of independent random variables is called a compound distribution.]