Reading

Peterson and Davie, Chapter 3, the “Notes on ARQ Protocols”, and the “Notes on MAC Protocols”, available on the web.

Objectives

The purpose of this assignment is to reinforce your understanding of ARQ and MAC protocols, including what system parameters determine performance and how they affect it.

Problem 0. Does the IEEE 802 standards committee define the standards for Gigabit Ethernet? If so, what is the “official” name of the standard? If not, who specifies it?

Problem 1. Do exercises 23, 24, 33, and 35 at the end of Chapter 2.

Problem 2. In this problem you will calculate the normalized throughput for three protocols: stop-and-wait, go-back-N ARQ, and selective repeat ARQ. For this problem, the relevant parameters are as follows:

- $c$: channel transmission rate, 100 Mbps ($10^8$ bits/sec)
- $\tau$: one-way propagation delay, 0.4 ms ($400 \mu$sec)
- $l$: frame size, 8000 bits
- $Q$: probability a frame or its ack is lost, $10^{-4}$

You may assume that acknowledgement frames take zero time to transmit, and are transmitted immediately upon receipt of a correct frame (no processing time). You may also assume that all frames are the same size, and that a timeout occurs exactly when an expected acknowledgment fails to arrive. Finally, you may neglect the overhead of frame headers (i.e. assume header size is 0).

a. Assuming no errors occur, what absolute throughput is achieved by the stop-and-wait protocol on this channel?

b. Suppose the probability of either a frame or its acknowledgement being lost is $Q$. In other words, the probability that a frame is successfully transmitted and acknowledged is $(1 - Q)$. What normalized throughput is achievable using Stop-and-wait? (Hint: Recall that normalized throughput is simply the absolute throughput divided by the channel capacity. Also, the average number of frames successfully transferred per frame transmission is $(1 - Q)$.)

c. Now suppose continuous ARQ is in use with Go-Back-N, i.e. the Receive Window Size is 1, and the Sender must retransmit all outstanding frames whenever an error occurs. Compute the absolute throughput achieved with the same parameters, assuming sequence numbers are infinite. (Note: see the “Notes on ARQ Protocols” for an example of how to do this. Derive the formula first, then plug in the actual parameter values.)

d. How many bits are required for the sequence number in the protocol header in order to maximize throughput?
Problem 3. [Extra Credit.] Traditionally, timeouts are used to detect losses when transmitting data and reliability is required. But are timeouts the only way to do it? Either prove that timeouts are required, or design a protocol that achieves reliable transmission and does not use timeouts in any way. You may assume the sender has an infinite sequence of frames to transmit, and the channel is full-duplex. If you design a protocol, it must be at least as efficient as stop-and-wait. If you prove it is impossible, you must be explicit about what assumptions you make.

Problem 4. Do exercises 39, 42, 46, 47, 50 (you may use the random number generator of a calculator or other mechanical source), and 56 in Chapter 2 of Peterson and Davie.

Problem 5. In this problem we will derive the throughput curve for a variation of the ALOHA protocol. (You will want to refer to the section on ALOHA throughput in the “Notes on MAC protocols” before doing this problem.) In this protocol, the “slot” time, $\tau$, is one-third the frame duration. That is, stations can begin transmitting on slot boundaries, which come every $\tau$ seconds, and every frame takes $3\tau$ seconds to transmit. Assume an infinite number of stations, with new frames arriving (to the whole system) according to a Poisson process at the rate of $\lambda$ frames per second, and new and retransmitted arrivals also Poisson at $\lambda'$ frames/sec.

a. Suppose a frame arrives at time $t_0$, as shown on the time line below. Indicate the transmission of the frame on the time line, along with the “vulnerable period” for the frame.

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\begin{tikzpicture}
  \draw[->] (0,0) -- (6,0);
  \draw[dashed] (0,0) -- (0,-1);
  \draw[dashed] (6,0) -- (6,-1);
  \draw (0,0) -- (0.5,0);
  \draw (1,0) -- (1.5,0);
  \draw (2,0) -- (2.5,0);
  \draw (3,0) -- (3.5,0);
  \draw (4,0) -- (4.5,0);
  \draw (5,0) -- (5.5,0);
  \draw[dashed] (0.5,0) -- (0.5,-1);
  \draw[dashed] (1.5,0) -- (1.5,-1);
  \draw[dashed] (2.5,0) -- (2.5,-1);
  \draw[dashed] (3.5,0) -- (3.5,-1);
  \draw[dashed] (4.5,0) -- (4.5,-1);
  \draw[dashed] (5.5,0) -- (5.5,-1);
  \draw[->] (0,0) -- (6,0);
  \draw (3,0) -- (3,-1);
  \node at (3,-0.5) {$t_0$};
\end{tikzpicture}
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b. Write down the steady-state equation expressing $S$ (normalized throughput) in terms of $\lambda$ and $\tau$, and $G$ (normalized offered load) in terms of $\lambda'$ and $\tau$.

c. Derive the equation expressing $S$ as a function of $G$ for this system. Note: the probability of $k$ arrivals in time $t$ for a Poisson process with rate $r$ is equal to $(rt)^k e^{-rt}/k!$.

d. When the system is operating in steady state at its maximum rate of throughput, what is the expected number of retransmissions per packet?