CSE/EE 461
Assignment 2
Due Friday, October 17, 1997

Your solutions must contain the derivation of your answers.

1. This problem explores analytically why relatively short packets are used for voice transmission.

   Assume that we can transmit a voice call at b bits per second and that voice packets have a fixed h bit header. Let t_{prop} be the fixed bit propagation delay from sender to receiver. Let x be a variable representing the number of bits in a packet, so that the total number of data bits in a packet is $x - h$. Let the time to create a packet with x bits from an analog voice signal be $\alpha x + \beta$ seconds and let the time to create a voice signal from a packet with x bits also be $\alpha x + \beta$.

   (a) Give an expression for the total delay of sending a packet from sender to receiver in terms of the parameters given above.

   (b) In order to make a reasonable voice call the total delay from sender to receiver must be relatively short, say bounded by t_{max}. Give an expression for the x_{max}, which is maximum length of the data portion of a packet which allow receipt of a packet within t_{max} seconds.

   (c) For a realistic example, let b be 10^5 bps, h be 100 bits, t_{prop} be 10 μs, $\alpha = 10^{-6}$ second per bit, and $\beta = 10^{-4}$ seconds. What is the total delay as a function of x? If the total delay is to be less than 1/100 of a second then what should be the value of x_{max}?

2. This problem uses some elementary probability and calculus. The goal of the problem is analyze and understand the cost of collisions in accessing a simple broadcast channel.

   Suppose we have a broadcast channel with n stations. The channel is divided into time slots and all stations can listen to the channel to hear what is going on. When a station attempts to transmit there are two possibilities: (i) a collision, in which case the transmitter immediately halts it transmission or (ii) a successful transmission, in which case the transmitter transmits in that time slot. In each time slot each station attempts to transmit with probability p.

(a) For a given time slot, what is the probability (i) that no stations transmit, q_0, (ii) exactly one station transmits, q_1, and (iii) more than one station transmits and a collision occurs, q_*?

(b) What is the expected utilization of the broadcast channel as a function of n and p?

(c) What value of p (as a function of n) maximizes the utilization? As n grows large what number does the utilization approach? In the case of n large, what percentage of the lost utilization is due to empty slots and what percentage is due to collisions?

3. This problem analyzes the need for repeaters in a fiber optic network.

   Assume that fiber optic transmission can be achieved with frequencies up to 10^{15} Hz and is nearly noise free, with SNR at 50 dB. However, as the signal is transmitted over the fiber optic cable the signal is degraded at a rate of about .5 dB per kilometer.

   (a) What is the maximum data rate that can be achieved on a fiber optic cable of length of 50 km?

   (b) Assume each repeater imposes a one bit delay in order to regenerate the signal. Suppose we have want to achieve transmission at 5×10^{15} bps from Seattle to Hawaii (7000 km). How far apart should we place our repeaters? What is the bit delay from Seattle to Hawaii assuming that light waves can travel in a fiber optic cable at a speed of 2×10^{8} meters per second.