Fall'06
Computer Networks
TelCom 2310
http://www.cs.pitt.edu/~znati/tel2310.html

Homework 2 Solution

Problem 1

Assume that packets arrive at a node to be transmitted. The packets arrive at random times T_1, T_2, $\cdots$, T_n, $\cdots$, and are transmitted in the order of their arrivals (FIFO).

1. The diagram showing how many bits are stored in the node buffer as a function of time is depicted in Figure **??**.

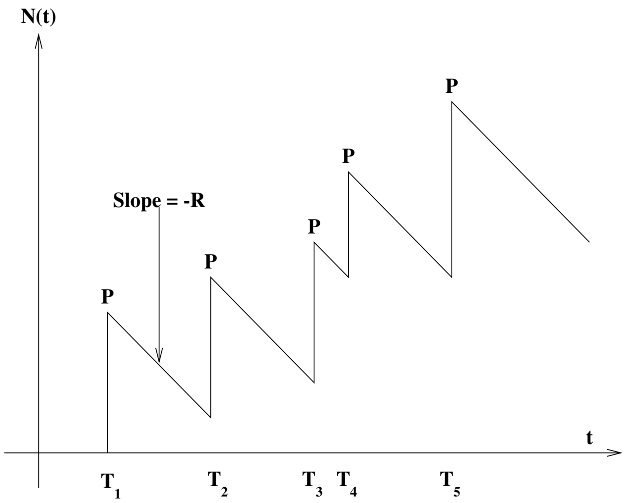

Figure 1: Number of bits, N(t), in the buffer at time t

2. Let D_n denote the delay faced by the n-th packet. We have $D_n = \frac{N(T_n)}{R}$. For packet 1, $D_1 = \frac{P}{R}$, since $N(T_1) = P$. To identify D_2, we observe that the queing time of the second packet is equal to the residual transmission time of the first packet, i.e., $\max(D_1 - (T_2 - T_1), 0)$. Consequently, we have:

$$D_2 = \max(D_1 - (T_2 - T_1), 0) + \frac{P}{R}. \tag{1}$$

In general, we find that:

$$D_{n+1} = \max(D_n - (T_{n+1} - T_n), 0) + \frac{P}{R}. \tag{2}$$

3. To show that large average queueing delays can oocur, even with low average arrival rate, consider batches of k packets that arrive every T seconds. We choose T larger than $\frac{kP}{R}$ so

that the successive batches find the buffer empty. The first packet of a batch has a delay $D_1 = \frac{P}{R}$, the second packet has a delay $D_2 = \frac{2P}{R}$, and so on. The k-th packet in a batch has a delay $D_k = \frac{kP}{R}$. Thus the average delay per packet is $\frac{(D_1+D_2+\cdots+D_k)}{k} = \frac{(k+1)P}{2R}$. By choosing k large, we can make the average delay large, even when T is so large that the average packet arrival rate $\frac{k}{T}$ is very small.