MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science
Department of Aeronautics and Astronautics

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Problem Set No.2 Due: Sep 23, 2008

Problem 1: text problem 2.18

Problem 2: text problem 2.20

Problem 3: text problem 2.22

Problem 4: text problem 2.23* **(Bonus Problem)**

Problem 5: text problem 2.26

Problem 6: text problem 3.1

Problem 7: text problem 3.7

Problem 8: TCP Window Evolution: Additive Increase and Multiplicative Decrease (AIMD)

Consider the following variation of Go-Back-N where the sender adjusts its window size dynamically as follows:

Sender (for current window size N)

- Upon receipt of an ACK, $N = N + 1/N$.
- Upon receipt of a NACK, $N = N/2$

Receiver

- Upon detection of a packet loss, send a NACK
- Upon successful reception of a packet, send an ACK

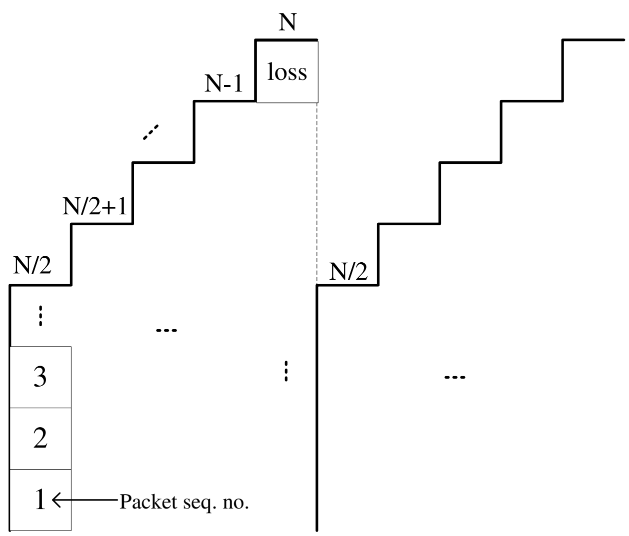
The following is assumed:

- Sender adjusts its window immediately when it receives an ACK/NACK.
- For given window size M, define a *successful round* as a period during which M packets are successfully transmitted and all their ACKs are received. Assume for simplicity that the window size increases by 1 after each successful round.

– Packets losses are independent and occur with probability $p(\ll 1)$.

Under these assumptions, we are interested in finding an average equilibrium window size in terms of p.

For simplicity, consider the following steady state. The packet loss occurs when the window size is N and the lost packet is the last packet sent (in the current window of N). Assume that the sender receives a NACK immediately (without delay). In this case, it will decrease its window size to $N/2$. Again, the window size increases up to N and decreases by half. This AIMD behavior continues to happen. A *cycle* is defined as the period from the time when the transmission with window size of $N/2$ is started to the time when a NACK is received (i.e., the period of time during which the window size increased from $N/2$ to N). The following figure depicts the evolution of the window size:



a) Show that the number of packets transmitted in a single cycle is $\frac{3}{8}N^2 + \frac{3}{4}N$.

b) Let α be the sequence number of the first lost packet. This is obviously a random variable as the packet loss occurs randomly. Show $E[\alpha] = \frac{1}{p}$ where $E[X]$ is the expectation on a random variable X.

c) Show that the *average* window size in the steady state can be approximated by $\sqrt{\frac{3}{2p}}$.