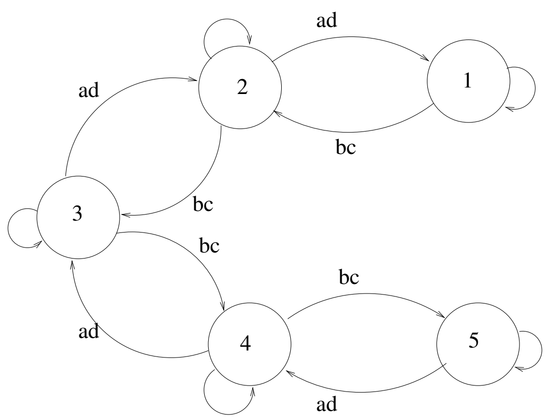
CENG461/ELEC514 Assignment 3

1. In an access network, the token bucket algorithm is used for access control. In every time step, the probability of one packet arrival is 0.5, the probability of one token arrival is also 0.5. The token buffer size $B_t = 2$, and the packet buffer size is $B_p = 2$. (a) Find the packet loss rate $N_a(lost)$.



s_1	token buffer = 2,	packet buffer = 0
s_2	1,	0
s_3	0,	0
s_4	0,	1
s_5	0,	2

Sol: Token arrival probability $a = 0.5$, packet arrival probability $c = 0.5$.

$b = 1 - a = 0.5$, $d = 1 - 0.5 = 0.5$, $\rho = ad/bc = 1$

$s_2 = \rho s_1$, $s_3 = \rho s_2 = \rho^2 s_1$, ..., $s_5 = \rho^4 s_1$.

Since $\sum_{i=1}^{5} s_i = 1$, $s_1 = s_2 = ... = s_5 = 0.2$.

$N_a(lost) = s_5 bc = 0.2 \times 0.5 \times 0.5 = 0.05$.

(b) Find the token throughput (average number of tokens leave the system per time step).

Packet throughput $Th = N_a(in) - N_a(lost) = 0.5 - 0.05 = 0.45$ packet/step. Token throughput equals packet throughput. Thus, token throughput is 0.45 token/step.

2. Consider the SW-ARQ protocol in which the packet size is n bits. Forward Error Correction (FEC) is used to improve the performance. The FEC code employed can correct up to 2 bits in error per packet.

(a) If the bit error rate is 0.001, and packet size $n = 125$ bytes, what is the packet error rate?

Given BER $\epsilon = 0.001$, and packet size 1000 bits, packet error rate e is given by

$e = 1 - (1-\epsilon)^{1000} - \binom{1000}{1}\epsilon(1-\epsilon)^{999} - \binom{1000}{2}\epsilon^2(1-\epsilon)^{998} = 0.0802$.

(b) Assume that there is no errors in the acknowledgments, what is the average number of retransmissions for a packet?

$N_t = \frac{e}{1-e} = 0.087$.

(c) If the feedback channel also has a bit error rate of 0.001, and the acknowledgment packet size is 25 bytes, no FEC code employed for the acknowledgements, what is the average number of retransmissions for a packet?

For acknowledgment packets with 200 bits, $e_a = 1-(1-0.001)^{200} = 0.181$

The probability of either the packet or the acknowledgment packet has errors equals $e' = 1-(1-e)(1-e_a) = 1 - 0.9198 \times 0.819 = 0.247$.

The average retransmissions equal to $N_t' = \frac{e'}{1-e'} = 0.327$.

3. N earth stations use the pure Aloha protocol to communicate with each other over a 100Kbps satellite channel. Each earth station generates 1000-bit packets.

   When two or more packet transmissions overlap in time, the first packet is successful (perfect capture) while others are unsuccessful and should be retransmitted later. A time slot is a packet transmission time. Assume that each earth station may transmit a new packet or retransmit a corrupt packet per time slot with probability a, and the channel traffic (sum of newly arrived packets and retransmitted packets) forms a Binomial process with the rate $N \cdot a$ packets per slot.

   (a) Determine the probability that a packet transmission is successful in terms of N and a.

   A packet transmission at time t_0 is successful if nobody else transmits during $t_0 - T$ to t_0, where T is the duration of a slot. This probability p_s equals $(1-a)^{N-1}$.

   (b) Given N = 20, a = 0.01, determine the mean packet delay.

   For each slot, the probability of the tagged packet is transmitted and the transmission is successful is $p = ap_s = a(1-a)^{N-1} = 0.00826$.

The average number of slots before the packet is transmitted successfully is $N_t = \frac{1-p}{p} = 120.06$ slots.

Considering the transmission time for the successful transmission, the total average delay equal to 121.06 slots ($= 1.2106$ sec).

(c) Now suppose that we use slotted Aloha and that when more than one packets are transmitted in a slot, one packet is successful while others are unsuccessful, repeat (a).

Method 1: When there are k other users competing with the tagged transmission, the probability of success for the tagged transmission is $1/(k+1)$. In addition, the probability of there are k other users transmit in the same time slot as the tagged one is $\binom{N-1}{k} a^k (1-a)^{N-1-k}$. Thus, the probability of success is: $p_s = \sum_{k=0}^{N-1} \frac{\binom{N-1}{k} a^k (1-a)^{N-1-k}}{k+1}$.

Method 2: We can use the Markov model for the communication channel. When there are equal to or more than one transmissions in a slot, one packet is successfully transmitted during that slot. Thus, the network throughput equals $Th = N_a(out) = s_2 + s_3 = 1 - u_0 = 1 - (1-a)^N$. Since $N_a(in) = Na$, the probability of succese is

$p_s = \frac{N_a(out)}{N_a(in)} = \frac{1-(1-a)^N}{Na}$

You can compare the results of the two methods, which are equivalent.