Departamento de Eletrónica, Telecomunicações e Informática

Mestrado Integrado em Eng. de Computadores e Telemática

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Desempenho e Dimensionamento de Redes

Assignment Guide No. 2

Impact of Transmission Errors in Network Performance

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1. Assignment Description

Implement the following 3 tasks using MATLAB to obtain the requested numerical solutions. At the end, submit a report with the answers to all questions and including not only the numerical solution values but also the MATLAB codes used to obtain them.

Task 1

RECALL FROM THEORETICAL CLASSES:

The probability function of a binomial random variable with parameters n and q is:

$$f(i) = \binom{n}{i} q^i (1-q)^{n-i} \quad , i = 0,1,\dots n$$

where $\binom{n}{i} = \frac{n!}{i!(n-i)!}$.

The probability function of a geometric random variable with parameter p is:

$$f(i) = p(1-p)^i \quad , i = 0,1,2,\dots$$

On a given network link supporting the exchange of data packets, the average bit error rate (i.e., the probability of each bit being received with error due to propagation or interference factors) is q, with $0 < q \ll 1$. Assume that errors in different bits are statistically independent (in this case, the number of errors in a data packet is a binomial random variable). Consider the following bit error rate values q=10^{-7}, q=10^{-6} and q=10^{-5}.

In this link, data packets are sent with a 32 bytes field with appropriate information for the receiver to be able to correct 1 error and to detect 2 or more errors. So, each data packet is accepted if it has 0 or 1 error and is discarded if it has 2 or more errors.

1.a. Determine the probability of a data packet of total size B = 100 bytes being received without errors, with exactly 1 error and with 2 or more errors. Fulfil the following table:

	q=10^{-7}	q=10^{-6}	q=10^{-5}
p(no errors) =			
p(1 error) =			
p(2 or more errors) =			

1.b. Consider that 10% of data packets has a total size B=64 bytes and 90% of data packets has a total size B=1500 bytes. Determine the packet discard rate (i.e., the percentage of packets that are discarded) and fulfil the following table:

	q=10^{-7}	q=10^{-6}	q=10^{-5}
Packet discard rate =			

1.c. Consider now that the total size, in number of Bytes, of the data packets is a constant value (64 Bytes) plus a geometric random value with parameter p=0.02. Determine the packet discard rate on this case and fulfil the following table:

	q=10^{-7}	q=10^{-6}	q=10^{-5}
Packet discard rate =			

1.d. Consider now that the 32 bytes field for error correction are replaced by a 4 bytes field on each data packet which only enables the receiver to detect if the data packet has been received with errors. Repeat 1.b. and 1.c. for this case and fulfill the following tables:

1.b	q=10^{-7}	q=10^{-6}	q=10^{-5}
Packet discard rate =			

1.c	q=10^{-7}	q=10^{-6}	q=10^{-5}
Packet discard rate =			

1.e. Analyzing the results of 1.b, 1.c and 1.d, take conclusions about the usefulness of single error correction in the packet discard rate performance of the link.

Task 2

RECALL FROM THEORETICAL CLASSES:

Bayes' law: consider a set of mutually exclusive events F_1, F_2, …, F_n such that its union is the set of all possible outcomes of a random experiment. Knowing that event E has occurred, the probability of event F_j is given by:

$$P(F_j|E) = \frac{P(EF_j)}{P(E)} = \frac{P(E|F_j)P(F_j)}{\sum_{i=1}^{n} P(E|F_i)P(F_i)}$$

Consider a wireless link used by two stations for data communications. The link can be either in a normal state with a probability of p or in an interference state with a probability of $1 - p$. Consider the following probability values: p = 99%, p = 99.9%, p = 99.99% and p = 99.999%.

The two stations exchange from time to time a set of n consecutive control frames to decide if the link is in interference state. The probability of a control frame being received with one or more errors is at most 0.01% in normal state and is at least 50% in interference state.

Both stations determine with a 100% probability if the control frames have been received with errors. The stations decide that the link is in interference state when the n consecutive control frames are received with errors.

A false positive is when a station decides wrongly that the link is in interference state and a false negative is when a station decides wrongly that the link is in normal state.

2.a. For each value of p, determine the probability of the link being in the interference state and in the normal state when one control frame is received with errors (fulfil the following table). What do you conclude?

	p(normal)	p(interference)
p = 99%		
p = 99.9%		
p = 99.99%		
p = 99.999%		

2.b. For each value of p and for n = 2, 3, 4 and 5, determine the probability of false positives and fulfil the follow table:

	Probability of false positives			
	$n = 2$	$n = 3$	$n = 4$	$n = 5$
$p = 99\%$				
$p = 99.9\%$				
$p = 99.99\%$				
$p = 99.999\%$				

2.c. For each value of p and for n = 2, 3, 4 and 5, determine the probability of false negatives and fulfil the follow table:

	Probability of false negatives			
	$n = 2$	$n = 3$	$n = 4$	$n = 5$
$p = 99\%$				
$p = 99.9\%$				
$p = 99.99\%$				
$p = 99.999\%$				

2.d. Describe and justify the influence of the values of p and n observed in the results obtained in 2.b and 2.c.

2.e. Assume that we aim a system where both false positive and false negative probabilities are not higher than 0.1%. From the results obtained in 2.b and 2.c, what is the best value of n to be used if the highest value of p is 99.99%.

2.f. Repeat the previous exercise 2.e but now considering that the highest value of p is 99.999%.

Task 3

RECALL FROM THEORETICAL CLASSES:

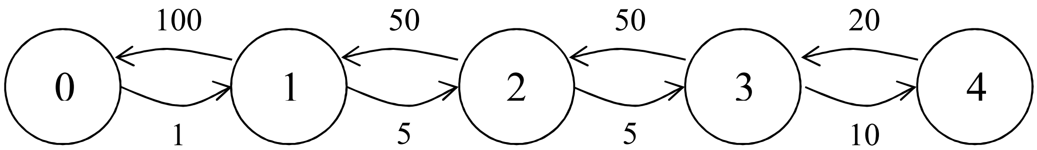
Birth-dead Markov chain: if λ_i is the birth rate of state i and μ_i is the dead rate of state i, than, the steady-state probability of state 0 is:

$$\pi_0 = \frac{1}{1 + \sum_{i=1}^{\infty} \frac{\lambda_0 \lambda_1 \cdots \lambda_{i-1}}{\mu_1 \mu_2 \cdots \mu_i}}$$

and the steady-state probability of state $n > 0$ is:

$$\pi_n = \frac{\lambda_0 \lambda_1 \cdots \lambda_{n-1}}{\mu_1 \mu_2 \cdots \mu_n} \cdot \pi_0$$

Consider a wireless link between multiple stations for data communications. The bit error rate (ber) introduced by the wireless link due to the variation along with time of the propagation and interference factors is approximately given by the following Markov chain:



The correspondence between state numbers and link bit error rate values is:

state 0 $\rightarrow$ ber = 10^{-5}
state 1 $\rightarrow$ ber = 10^{-4}
state 2 $\rightarrow$ ber = 10^{-3}
state 3 $\rightarrow$ ber = 10^{-2}
state 4 $\rightarrow$ ber = 10^{-1}.

The state transition rates are in number of transitions per hour.

3.a. What is the average percentage of time the link is on each of the five possible states?

3.b. What is the average bit error rate of the link?

3.c. What is the average time duration (in minutes) that the link is on each of the five possible states?

3.d. If the link is considered in interference state when its bit error rate is 10^{-2} or higher, what is the probability of the link being in interference state?