ELEC3500 TELECOMMUNICATIONS NETWORKS

Simulation Experiment IV

Experiment: Performance Analysis of ALOHA and S-ALOHA Medium Access Control (MAC) Protocols.

Required Reading Materials:

1. Text book, pages 483-487. Topics: Random access, S- ALOHA and ALOHA protocols.
2. Lecture slides: Lecture_20.pdf.
3. (MUST) Note on ALOHA/S-ALOHA Protocol in pages 4 and 5.

Objectives:

- Understand basic concepts of the random access techniques used in communication networks.
- Understand principles of ALOHA and S-ALOHA protocols.
- Analyse performance of ALOHA and S-ALOHA protocols for different traffic load conditions.

Procedure:

This laboratory has been developed based on the ALOHA model in the OMNET++ package. Use the ALOHA model in the ELEC3500 folder of the OMNET++ directory. This model has been prebuilt, so you don't need to develop or change any code in the model. You need to modify the simulation parameters in the omnetpp.ini file to obtain necessary simulation results. Use the simulation parameters listed in Table 1 to obtain the necessary simulation results.

Table 1: Simulation parameters

Simulation Parameter	Value(s)
Simulation length (sim-time-limit)	900 seconds
No. of hosts	12
Aloha.host[*].radioDelay	0 ms
Packet length	1728 bits
Packet size distribution	Constant, exponential (only for second ALOHA simulation)
Transmission rate	19200 bits/sec
S-ALOHA slot time	100 ms
Total offered load (normalised)	For both ALOHA and S-ALOHA: 0.1, 0.25, 0.4, 0.55, 0.7. 0.85, 1, 1.25, 1.5, 1.75, 2

Random number seed values	Use the default value and a second value only for the second ALOHA simulation.

You need to run three set of simulations to obtain necessary results for the simulation experiment.

Simulation 1

In this simulation, you will use the ALOHA simulation model to obtain the S-G graph (normalised load vs throughput). You will use a fixed packet size. Calculate the packet arrival rate per hosts using the normalised load values. Normalised load value is obtained by dividing the total arrival rate by the capacity of the system.

Example: Assume an ALOHA system uses transmission rate of 100 kbits/sec and 2000 bits packet size. Calculate the arrival rate in packets/sec at a normalised load of 0.2. Also, calculate the corresponding packet interarrival time of each host, assuming the network has 5 hosts.

System capacity $C = \frac{R}{L} = \frac{100 \times 10^3}{2000} = 50$ packets/sec

Total arrival rate at 0.2 normalised load $\lambda = 50 \times 0.2 = 10$ packets/sec

Number of packets/ host $\lambda_H = {}^{10}/_{5} = 2$ packets/sec

Packet interarrival time $T_{int} = \frac{1}{\lambda_H} = 0.5\ sec$

Scalar values to collect: Channel utilisation, number of received frames and number of collided frames. These three scalar data values will be used to generate performance plots/table. Note that channel utilisation statistics of the simulation model represents the normalised throughput. Normalised load vs the channel utilisation represents the S-G graph of a MAC protocol. Collect these values for all normalised loads from 0.1 to 2.

Simulation 2

In this simulation, you will still use the ALOHA simulation model to obtain the same statistics as in simulation 1. In this model, change the packet size distribution to the ***exponential distribution***. Use the same packet size value as the mean value of the exponential distribution function. You need to obtain two sets of results using two different ***random number seed values***. Use the default random number seed value as used in simulation 1 and a different random number seed value of your choice.

Simulation 3

In this simulation, you will use the ***S-ALOHA*** simulation model to obtain the same statistics as in simulation 1. Run this simulation using the same parameters as in simulation 1 (use the same fixed packet size). Note that you will change the inter-arrival time value under the S-ALOHA code section in the ini file.

Report Submission Instruction:

You need to submit a report with a simulation section and a knowledge section.

Simulation Section: This section is marked out of 40 and should be structured as follows.

- ***Introduction:*** Explain in a single paragraph (200 words maximum) the objectives of the laboratory simulation.

- ***Simulation model:*** Briefly describe the simulation model used in the experiment (300 words and 2 figures maximum).
- ***Results****:* It is suggested that you use four figures and one table in the following format:
    1. Figure 1: Normalised traffic load vs the channel utilisation value in simulation 1.
    2. Figure 2: Normalised traffic load vs the average channel utilisation value in simulation 2. Note that the average channel utilisation value is obtained by taking the average value of two channel utilisation values obtained using the two different seeds.
    3. Figure 3: Normalised traffic load vs channel utilisation value (not the average) in simulation 2. You will generate two separate plots in the same figure. Each plot represents the channel utilisation value obtained from each of the two different seeds.
    4. Table 1: Use four columns for the table. The first column presents the normalised traffic load; the second column presents the number of received frames in simulation 1; the third column presents the number of received frames in simulation 2; whereas the fourth column presents the number of received frames in simulation 3.
    5. Figure 4: Normalised traffic load vs channel utilisation value in simulation 3.
- ***Analysis:*** Compare the S-G/Utilisation graphs between the three simulations. Also, compare the collision patterns between these scenarios.

Knowledge Section: This section is marked out of 60. Answer the following questions.

1. Calculate the theoretical value of normalised throughput, S, when normalised arrival rate, G = ***0.25, 0.55, 0.85, 1*** and ***1.25*** for ALOHA and S-ALOHA protocols. Use the fixed packet size value and service rate used in the simulation model.

[15]

2. Compare the theoretical and simulation normalised throughput values for the fixed packet size. Explain why the simulation and theoretical values differ.

[15]

3. Explain why the S-ALOHA protocol offers higher throughput than the ALOHA protocol?

[15]

4. Aside from the higher throughput, what is the other advantage of the S-ALOHA protocol that can be observed from the load vs channel utilisation plots?

[15]

Report Submission Date:

The lab report is due on Friday at 11.59 pm of the following week after the lab is performed. Submit your report via the Assessment tab of the blackboard. Please include the university assessment cover sheet with your submission.

Note on ALOHA/S-ALOHA Protocol

Medium access control (MAC) protocols are used in communication networks to allow multiple network users to share the transmission resources of a network. ALOHA is one of the oldest random access protocol which was developed by a research group in the University of Hawaii in 1970s, allowing data terminals to share the capacity of a communication network. The protocol is still widely used. Many other modern protocols have been derived using the ALOHA concept. In the ALOHA network, data terminals can transmit their packets as soon as a terminal generates a packet. Data terminals don't need to check the transmission channel to see if the channel is currently being used or not. This simple process may cause packet collisions on the channel when multiple terminals want to transmit their packets at the same time. However, if a terminal is lucky, i.e., if there are no other terminal or terminals attempting to transmit at the same time, then the lucky terminal will be able to transmit their packets immediately. So, the packet operates in a *hit and miss* scenario. When network is lightly loaded, then most terminals' attempts to transmit will likely be successful. On the other hand, at a higher network load, many of the transmitted packets will collide and they will be unsuccessful. Collided terminals will backoff for a certain duration and will attempt to retransmit their packets. After a number of attempts, packets will likely be transmitted. Otherwise, these packets can be dropped by their respective terminals. Efficiency of a MAC protocol determines what proportion of the offered load will be successfully transmitted. Offered load is also referred as input load arriving at the input of the network.

Performance of the ALOHA protocol can be measured by using the S-G equation as shown below. Where the G represents the normalised total network input traffic and the parameter S represents the normalised throughput. Both the S and G values are normalised by the network capacity.

$$S = Ge^{-2G} \qquad (1)$$

Example: Assume that the capacity of a network, C, is 100 packets/sec. The average input arrival rate, λ, is 44 packets/sec. Calculate the normalised input/offered load and normalised throughput. Also, calculate the throughput in packets/sec.

Normalised offered load, $G = \frac{\lambda}{C} = \frac{44\ packets/sec}{100\ packets/sec} = 0.44$

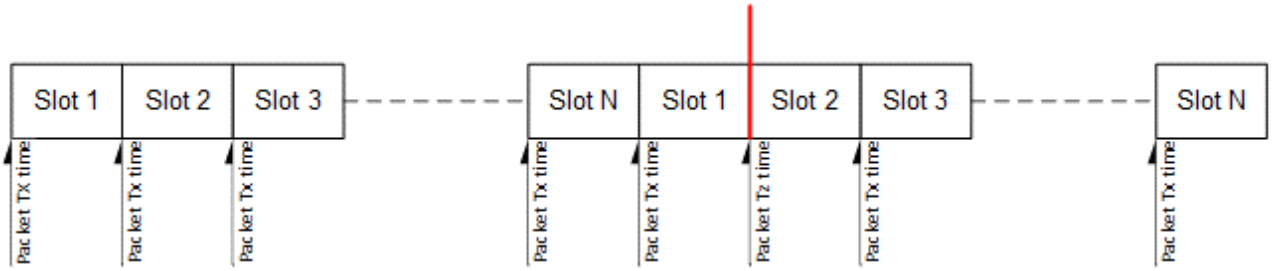
Normalised throughput, $S = Ge^{-2G} = 0.44e^{-2\times0.44} = 0.44 \times 0.414 = 0.182$

Throughput in packets/sec, $Th = S \times C = 0.182 \times 100 = 18.2\ packets$

The above calculation shows the efficiency of the ALOHA protocol and determines the throughput of an ALOHA network. According to the theory, the peak normalised throughput of the ALOHA network is 0.184 at G=0.5. The above network is operating nearly at its peak capacity.

In order to improve the throughput of the ALOHA network, the MAC protocol is enhanced as the S-ALOHA (Slotted-ALOHA) protocol where some restrictions are introduced in terms of transmission

opportunity of packets. In case of the S-ALOHA protocol, terminals are not allowed to transmit their packets except at a specific time. The transmission time is divided in time slots and terminals are only allowed to transmit their packets at the beginning of a time slot as shown in the following figure.



The figure shows that terminals are only allowed to start their packet transmission at the beginning of a time slot which appears at a discrete time. Hence, the network access time becomes discrete. Due to the change of the transmission policy, the performance of the S-ALOHA protocol is represented by the following modified S-G equation:

$$S = Ge^{-G} \qquad (2)$$

Let's calculate the S-ALOHA network throughput for same network capacity and the arrival rate as we have used in the previous example.

Using equation (2) and the example parameters, we find that the normalised throughput G = 0.2833 and the throughput in packets/sec is 28.33 packets/sec. We observe significant improvements by changing the access policy!