ELEC3500 TELECOMMUNICATIONS NETWORKS
2020
Simulation Experiment IV

Experiment: Performance analysis of ALOHA and S-ALOHA medium access control protocols

Required Reading Materials:

1. Text book pages 483-487: topics: Random access, S- ALOHA and ALOHA protocols.
2. Slide set Lecture Slide 20.
3. MUST read the attached note on ALOHA and S-ALOHA on pages 4 & 5 of this document before proceeding any further.

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 loads

Procedure:

This laboratory has been developed based on the ALOHA model of the OMNET++ package. Find the model under the ELEC3500 folder of the OMNET++ directory. The model has been prebuilt so you don't need to develop or change any code in the model. Make sure that you use the ALOHA project in the ELEC3500 folder. You need to modify simulation parameters in the **omnetpp.ini** file to obtain necessary simulation results. Use simulation parameters listed in table-1 to obtain necessary simulation results. Check the .ini file and change parameters appropriately.

Table: 1- Simulation parameters

Simulation Parameter	**Value(s)**
Simulation length (sime-time-limit)	900s
No. of hosts	12
Aloha.host[*].radioDelay	0ms
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 sets of simulations to obtain necessary results for the simulation experiment.

Simulation 1:

In this experiment you will use the ALOHA simulation model to obtain the S-G graph (normalised load vs throughput). In the first simulation you will use a fixed packet size. Calculate the packet arrival rate per hosts using the normalised load values. The 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 $C = \frac{R}{L} = \frac{100\times10^3}{2000} = 50$ 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 $T_{int} = \frac{1}{\lambda_H} = 0.5\ sec$

In this simulation obtain three scalar data values which will be used to generate performance plots/table.

Scalar values to collect: Channel utilisation, number of received frames and number of collided frames. 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 simulation normalised loads from 0.1 to 2.

Simulation 2:

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

Simulation 3:

In this experiment you will use the S-ALOHA simulation model. For this simulation, use the same parameters as simulation 1 (i.e. use the same fixed size packet). Obtain the same simulation results as simulation 1. Note that you will change the inter-arrival time value under the S-ALOHA code section in the ini file.

Report Submission Instructions:

Common section:

- **Introduction** to the experiment, a single paragraph (200 words maximum) explaining the objectives of the simulation laboratory.

- **Basic description** of the simulation model used in the experiment (250 words maximum, 2 figures).

- **Results**: Provide following plots using collected simulation results:
  - Figure 1: For ALOHA simulation-1: Normalised traffic load vs the channel utilisation value.
  - Figure 2: For ALOHA simulation -2: Normalised traffic load vs the average channel utilisation value. Average channel utilisation will be generated by taking the average value of two values obtained by using two seeds.
  - Figure 3: For ALOHA simulation -2: Normalised traffic load vs channel utilisation value for two channel utilisation values (not the average value). You will generate two separate plots on the same graph each representing channel utilisation values for two different seeds.
  - Table 1: Use four columns in the table. First column present the normalised traffic load, second column present the number of received frames for the ALOHA simulation-1, the third column present the number of received frames for the ALOHA simulation-2, and the fourth column present the number of received frames for the S-ALOHA value.
  - Figure 4: For S-ALOHA simulation: Normalised traffic load vs channel utilisation value
- **Analysis:** Compare the S-G/Utilisation graphs of three simulation scenarios. Also, compare the collision patterns for these three scenarios.

Individual section:

1. Calculate theoretical value of normalised throughput (S) for G (normalised arrival rate) = 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.

[10]

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

[10]

3. Using the simulation results of ALOHA 1 and ALOHA 2, compare the channel utilisation and number of received packet values. Briefly explain why results from two simulations differ. For ALOHA 2 simulation use the average value.

[10]

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

[10]

5. Beside higher throughput what is the other advantage of the S-ALOHA protocol comparing load vs channel utilisation plots.

[10]

6. Using simulation results, calculate the peak throughput of the S-ALOHA network in bits/sec.

[10]

Report submission date:

For all groups, the report submission date is 23.59pm Friday 6 November 2020 (Week 12)

Notes for the 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 protocols which was developed by a research group in the University of Hawaii in the 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, the transmission channel is not checked to see whether 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 the network is lightly loaded then most attempts to transmit will likely be successful. On the other hand, at a higher network load many of the transmitted packets will collide and 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 to transmitted, otherwise these packets can be dropped by the respective terminals. The efficiency of a MAC protocol determines what proportion of the offered load will be successfully transmitted. Offered load (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 G represents the normalised total network input traffic, and S represents the normalised throughput. Both the S and G values are normalised by the network capacity.

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

Example: Assume 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.

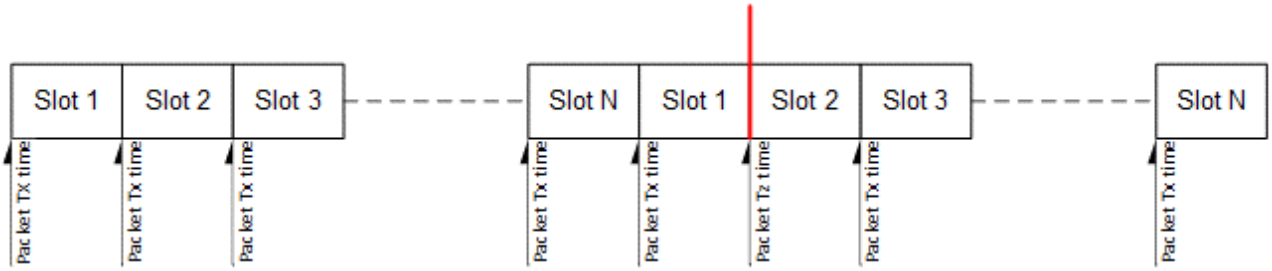
$$Normalised\ offered\ load\ G = \frac{\lambda}{C} = \frac{44\ packets/sec}{100\ packets/sec} = 0.44$$

$$Normalised\ Throughput\ S = Ge^{-2G} = 0.44e^{-2\times 0.44} = 0.44 \times 0.414 = 0.182$$

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

Above calculation shows the efficiency of the ALOHA protocol 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 its peak capacity.

To improve the throughput of the ALOHA network, the MAC protocol can be enhanced by changing it into the S-ALOHA (Slotted-ALOHA) protocol, where some restrictions to the transmission opportunity of packets are introduced. In the S-ALOHA protocol, terminals are not allowed to transmit their packets at any time: they are only allowed to transmit 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 above figure shows that terminals are only allowed to start their packet transmission at the beginning of a time slot which are segmented into discrete time intervals. 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 example parameters, we find the normalised throughput G = 0.2833 and the throughput in packets/sec is 28.33 packets/sec. There are significant improvements obtained by changing the access policy!

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