

CZ3006 Net Centric Computing

Assignment 1 Report:

Throughput Analyses for ALOHA and CSMA

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In this report, I will be analysing the throughput for the various random access protocols such as Pure ALOHA, Slotted ALOHA, Non-Persistent CSMA, 1-Persistent CSMA and 0.05-Persistent CSMA.

Figure 1 below illustrates the throughput analyses for ALOHA and CSMA with selected values of a=0.02 and p=0.05. The selected domain of G=[0,20] with step interval of 0.1. The graph is visualized using Scilab, a free and open-source alternative to Matlab that is used for numerical computation.

A close up of a map

Description automatically generated

Figure 1: Graph of Throughput Analyses for ALOHA and CSMA

**Comparison between Pure ALOHA and Slotted ALOHA**

The equation given for Pure ALOHA is . The equation given for Slotted ALOHA is .

From the graph, I have observed that the maximum throughput of Slotted ALOHA (orange) is two times higher compared to Pure ALOHA (red). Pure ALOHA achieves maximum throughput S= 0.1839397 at G=0.5, whereas Slotted ALOHA achieves maximum throughput S= 0.3678794 at G=1.

The ALOHA protocols do not sense the carrier and transmits whenever a frame is ready to transmit.

For Pure ALOHA, the implementation is simple and does not require synchronization when transmitting its packet over the data channel. There is a risk of partial transmission collision occurring, where the first packet transmitted is overlapped by the transmission of another packet, which results in both frames being corrupted.

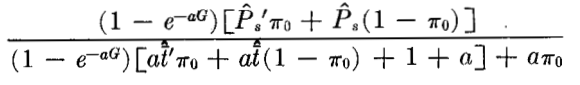
For Slotted ALOHA, it requires the use of synchronization when transmitting its packet over the data channel. When two packets conflict, they overlap entirely instead of partially and as such, its throughput is twice higher than Pure ALOHA. Therefore, when comparing which protocol to use between Pure and Slotted ALOHA, if the cost for synchronization is not important, then Slotted Aloha is the better solution as it allows better utilisation of the channel.

**Comparison between Non-Persistent CSMA, 1-Persistent CSMA and P-Persistent CSMA**

In order to improve performance, we can use Carrier-Sense Multiple-Access (CSMA) protocols over ALOHA protocols. This allows us to avoid transmissions that are known to cause collisions. The stations sense the medium for the presence of a transmission before beginning transmission of its packets. In CSMA, the vulnerable time refers to the maximum propagation time. The longer the propagation delay, the worse the performance.

The equation given for Non-Persistent CSMA is where a is the ratio of propagation delay to packet over transmission time.

The equation given for 1-Persistent ALOHA is .

The equation for P-Persistent CSMA is using the small p approximation formula given in Appendix A of the Kleinrock-Tobagi report, where is .

For Non-Persistent CSMA, the stations are deferential. When a station senses the medium is busy, it will back off by waiting a random amount of time before it senses the medium is idle for transmission. The random delays reduce the probability of collisions greatly. However, if the waiting time is long, it will remain idle for a long time and as such, bandwidth is wasted.

On the other hand, 1-Persistent CSMA is selfish. When a station senses the medium is busy, it will listen continuously until when the medium becomes idle and transmits immediately with a probability of 1. The disadvantage of 1-Persistent CSMA is that collision will occur when more than two stations becomes ready at the same time.

This is supported by the findings in the graph, where the throughput of Non-Persistent CSMA (yellow) S= 0.7472570 at G=6.5, is much higher than the throughput of 1-Persistent CSMA (green) S= 0.5195356 at G=1.

For P-Persistent CSMA, it is able to reduce the probability of collisions much like Non-Persistent CSMA and reduce the channel idle time like 1-Persistent CSMA. When the station senses the medium is busy, it listens continuously until it becomes idle. Then, it transmits the frame with a probability of P, or wait one time unit with probability of 1-P.

Since we are using the small p approximation formula, the value of p selected must be small enough and within the range of . I have selected p=0.05.

We can observe from the graph that the throughput of 0.05-Persistent CSMA (blue) is the highest with S= 0.7631677 at G=3.2, compared to Non-Persistent CSMA and 1-Persistent CSMA.

In conclusion, P-Persistent CSMA is the best solution as it achieves the highest maximum throughput although this comes at the expense of the cost. If cost is a important factor to consider, then the Pure ALOHA protocol is a more suitable solution.

# Appendix A – Scilab Code

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| /\* define values of g from 0 to 50, step interval 0.1 \*/  g\_val=[0:0.1:20]';  /\* define values of a & p  - Do not set a=0.01  - Do not set p=0.01 or 0.03  \*/  a\_val=0.02;  p\_val=0.05;  q\_val=1-p\_val;  /\* define function for pure aloha from eqn 1 \*/  function pure\_aloha\_val=pure\_aloha(G)      pure\_aloha\_val=G.\*exp(-2.\*G);  endfunction  /\* define function for slotted aloha from eqn 2 \*/  function slotted\_aloha\_val=slotted\_aloha(G)      slotted\_aloha\_val=G.\*exp(-G);  endfunction  /\* define function for non-persistent CSMA from eqn 3 \*/  function non\_persistent\_csma\_val=non\_persistent\_csma(A,G)      numerator\_np=(G.\*exp(-A.\*G));      denominator\_np=(G.\*(1+2.\*A)+exp(-A.\*G));      non\_persistent\_csma\_val=numerator\_np./denominator\_np;  endfunction  /\* define function for 1-persistent CSMA from eqn 10 \*/  function one\_persistent\_csma\_val=one\_persistent\_csma(A,G)      numerator\_op=(G).\*(1+G+(A.\*G).\*(1+G+(A.\*G)./2)).\*(exp(-G.\*(1+2.\*A)));      denominator\_op=G.\*(1+2.\*A)-(1-exp(-A.\*G))+(1+A.\*G).\*(exp(-G.\*(1+A))) ;      one\_persistent\_csma\_val=numerator\_op./denominator\_op;  endfunction  /\* define function for p-persistent CSMA from A1 aka S' \*/  function p\_persistent\_val=p\_persistent\_csma(A,G,P,Q)      numerator\_pp=(1-exp(-A.\*G)).\*((Ps\_prime\_hat(A,G,P,Q).\*pi\_0(A,G))+(Ps\_hat(A,G,P,Q).\*(1-pi\_0(A,G))));      denominator\_pp=(1-exp(-A.\*G)).\*((A.\*t\_bar\_prime\_hat(A,G).\*pi\_0(A,G))+(A.\*t\_bar\_hat(A,G)).\*(1-pi\_0(A,G))+1+A)+(A.\*pi\_0(A,G));      p\_persistent\_val=numerator\_pp./denominator\_pp;  endfunction  /\* define function for pi\_0 from eqn 25\*/  function pi\_0\_val=pi\_0(A,G)      pi\_0\_val=exp(-G.\*(1+A));  endfunction  /\* define function for Ps\_hat from eqn A20 using pi\_0(A,G) \*/  function Ps\_hat\_val=Ps\_hat(A,G,P,Q)      g=G\*A;      eqn\_a=(((pi\_0(A,G)).^P)-(pi\_0(A,G)))./(Q.\*(1-pi\_0(A,G)));      eqn\_b=((1-exp(-g.\*P)).\*(((pi\_0(A,G)).^(1-Q.^2))-pi\_0(A,G)))./((Q.\*(1-pi\_0(A,G)))-(Q.\*exp(-2.\*g.\*P)).\*(((pi\_0(A,G)).^P)-pi\_0(A,G)));      Ps\_hat\_val=eqn\_a-eqn\_b;  endfunction  /\* define function for Ps\_prime\_hat from eqn A20 replacing pi\_0(A,G) with exp(-g) where g=aG \*/  function Ps\_prime\_hat\_val=Ps\_prime\_hat(A,G,P,Q)      g=G\*A;      eqn\_a=(((exp(-(A.\*G))).^P)-(exp(-(A.\*G))))./(Q.\*(1-exp(-(A.\*G))));      eqn\_b=((1-exp(-g.\*P)).\*(((exp(-(A.\*G))).^(1-Q.^2))-exp(-(A.\*G))))./((Q.\*(1-exp(-(A.\*G))))-(Q.\*exp(-2.\*g.\*P)).\*(((exp(-(A.\*G))).^P)-exp(-(A.\*G))));      Ps\_prime\_hat\_val=eqn\_a-eqn\_b;  endfunction  /\* define function for t-bar-hat from eqn A12 \*/  function t\_bar\_hat\_val=t\_bar\_hat(A,G,P)      g=G\*A;      t\_bar\_hat\_val=((pi\_0(A,G).^P)-pi\_0(A,G))./(1-pi\_0(A,G)-((pi\_0(A,G).^P)-pi\_0(A,G)).\*exp(-P.\*g));  endfunction  /\* define function for t-bar-prime-hat from eqn A12 replacing pi-naught with exp(-g) where g=aG \*/  function t\_bar\_prime\_hat\_val=t\_bar\_prime\_hat(A,G,P)      g=G\*A;      t\_bar\_prime\_hat\_val=((exp(-(A.\*G)).^P)-exp(-(A.\*G)))./(1-exp(-(A.\*G))-((exp(-(A.\*G)).^P)-exp(-(A.\*G))).\*exp(-(P.\*g)));  endfunction  /\* --- plot2d customization options --- \*/  colors=[color("red") color("orange") color("yellow") color("green") color("blue")];  xtitle("Throughput Analyses for ALOHA and CSMA (a=0.02,p=0.05)");  xlabel("G (Offered Channel Traffic)","fontsize", 3,"fontname",8);  ylabel("S (Throughput)","fontsize", 3,"fontname",8);  option\_a=gca();  option\_a.tight\_limits=["on","on"];  option\_a.data\_bounds=[0 0;20 1];  // change font properties  option\_a.font\_foreground=1;  option\_a.font\_size=3;  option\_a.font\_style=8;  // change thickness of polyline  p=get("hdl");  p.thickness=2;  /\* plot the curves on a graph \*/  plot2d(g\_val,[pure\_aloha(g\_val) slotted\_aloha(g\_val) non\_persistent\_csma(a\_val,g\_val) one\_persistent\_csma(a\_val,g\_val) p\_persistent\_csma(a\_val,g\_val,p\_val,q\_val)],colors,leg="Pure ALOHA@Slotted ALOHA@Non-Persistent CSMA@1-Persistent CSMA@0.05-Persistent CSMA");  /\* calculate max throughput for Pure ALOHA & Slotted ALOHA \*/  disp("Max. Throughput of Pure ALOHA at G=0.5 is: ", pure\_aloha(0.5));  disp("Max. Throughput of Slotted ALOHA at G=1 is: ", slotted\_aloha(1));  /\* calculate max throughput for Non-P, 1-P, 0.05-P CSMA \*/  disp("Max. Throughput of Non-Persistent CSMA at G=6.5 is: ", non\_persistent\_csma(a\_val,6.5));  disp("Max. Throughput of 1-Persistent CSMA at G=1 is: ", one\_persistent\_csma(a\_val,1));  disp("Max. Throughput of 0.05-Persistent CSMA at G=3.2 is: ", p\_persistent\_csma(a\_val,3.2,p\_val,q\_val)); |

# Appendix B – Scilab output

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| Startup execution:  loading initial environment  --> exec('C:\Users\sherna\OneDrive - Nanyang Technological University\AY1920-S2\CZ3006 - Net Centric Computing\Assignment\Ass1-LiewZhiLi-U1821610C.sce', -1)  "Max. Throughput of Pure ALOHA at G=0.5 is: "  0.1839397  "Max. Throughput of Slotted ALOHA at G=1 is: "  0.3678794  "Max. Throughput of Non-Persistent CSMA at G=6.5 is: "  0.7472570  "Max. Throughput of 1-Persistent CSMA at G=1 is: "  0.5195356  "Max. Throughput of 0.05-Persistent CSMA at G=3.2 is: "  0.7631677 |

# References

[1] L. Kleinrock and F. Tobagi, "Packet Switching in Radio Channels: Part I--Carrier Sense Multiple-Access Modes and Their Throughput-Delay Characteristics", *IEEE Transactions on Communications*, vol. 23, no. 12, pp. 1400-1416, 1975. Available: https://ieeexplore.ieee.org/document/1092768. [Accessed 27 March 2020].