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ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA DE
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Laboratory Session 5

SIMULATION AND PERFORMANCE
EVALUATION OF SEMIMARKOVIAN AND
PRIORITY SYSTEMS

Anàlisi i Avaluació de Xarxes

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1 Objectives

The objectives of this session can be summarized as follows:

- Consolidate the previous knowledge about M/G/1 and priority systems.
- Introduction of new possibilities of the simulation tool.
 - Multiple traffic sources assigned to different categories, allowing service differentiation.
 - Different schedulers.

2 Previous work

For the M/G/1 system and for the M/G/1 system with non-preemptive priority, obtain:

- Waiting, service and transfer times.
- Number of packets in queue, server and system.

2. Previous Work

• M/G/1

$$T_{W0} = \frac{\lambda E(t_s^2)}{2} \quad T_W = T_{W0} + N_W T_s \Rightarrow T_W(1-p) = T_{W0} \Rightarrow T_W = \frac{T_{W0}}{(1-p)}$$

little $N = \lambda \cdot T_W = \rho$

$$T = T_W + T_s \Rightarrow T = \frac{\lambda E(t_s^2)}{2(1-p)} + T_s$$

• M/G/1 non-preemptive priority (prioridad sin explotación)

$$T_{Wk} = T_{W0} + T_{Wk-1} + T_{Wsk} = T_{W0} + \sum_{i=1}^k N_{Wi} T_{Si} + \sum_{i=1}^{k-1} M_{Wi} T_{Si} = T_{W0} + \sum_{i=1}^k p_i T_{Wi} + \sum_{i=1}^{k-1} p_i T_{Wk}$$

↳ break (more priority) $N_{Wi} = \lambda_i \cdot T_{Wi}$
 ↳ already waiting (more priority or less) $M_{Wi} = \lambda_i \cdot T_{Wk}$

$$T_{Wk} (1 - \sum_{i=1}^k p_i T_{Wi}) = T_{W0} + \sum_{i=1}^k p_i T_{Wi} \Rightarrow T_{Wk} = \frac{T_{W0} + \sum_{i=1}^k p_i T_{Wi}}{(1 - \sum_{i=1}^k p_i T_{Wi})}$$

↳ $T_{W0} = \sum_{i=1}^k \frac{\lambda_i E(t_{Si}^2)}{2}$

$$T_k = T_{Wk} + T_s$$

$$T_k = \frac{T_{W0} + \sum_{i=1}^k p_i T_{Wi}}{(1 - \sum_{i=1}^k p_i T_{Wi})} + T_{Sk}$$

↳ $T_{Wk-1} (1 - \sum_{i=1}^{k-1} p_i) = T_{W0} + \sum_{i=1}^{k-1} p_i T_{Wi}$

$$T_{k-1} (1 - \sum_{i=1}^{k-1} p_i) - T_{Wk} (1 - \sum_{i=1}^k p_i) = (T_{W0} + \sum_{i=1}^{k-1} p_i T_{Wi}) - (T_{W0} + \sum_{i=1}^k p_i T_{Wi})$$

$$T_{k-1} (1 - \sum_{i=1}^{k-1} p_i) - T_{Wk} (1 - \sum_{i=1}^k p_i) = -p_k T_{Wk-1}$$

$$T_{Wk-1} (1 - \sum_{i=1}^{k-1} p_i) = T_{Wk} (1 - \sum_{i=1}^k p_i) \Rightarrow T_{Wk} = \frac{T_{Wk-1} (1 - \sum_{i=1}^{k-1} p_i)}{(1 - \sum_{i=1}^k p_i)}$$

$$T_{Wk} = \frac{T_{W0}}{(1 - \sum_{i=1}^k p_i)} \quad T_{W0} = \sum_{i=1}^k \frac{\lambda_i E(t_{Si}^2)}{2}$$

$$T_k = T_{Wk} + T_{Sk}$$

↳ $N = N_W + N_S$
 $N_W = \sum_{i=1}^p N_{Wi} = \sum_{i=1}^p \lambda_i \cdot T_{Wi}$
 $N_S = \sum_{i=1}^p N_{Si} = \sum_{i=1}^p \lambda_i \cdot T_{Si}$

Figure 1: Previous Work.

3 M/G/1 System simulationn

Run the following simulation:

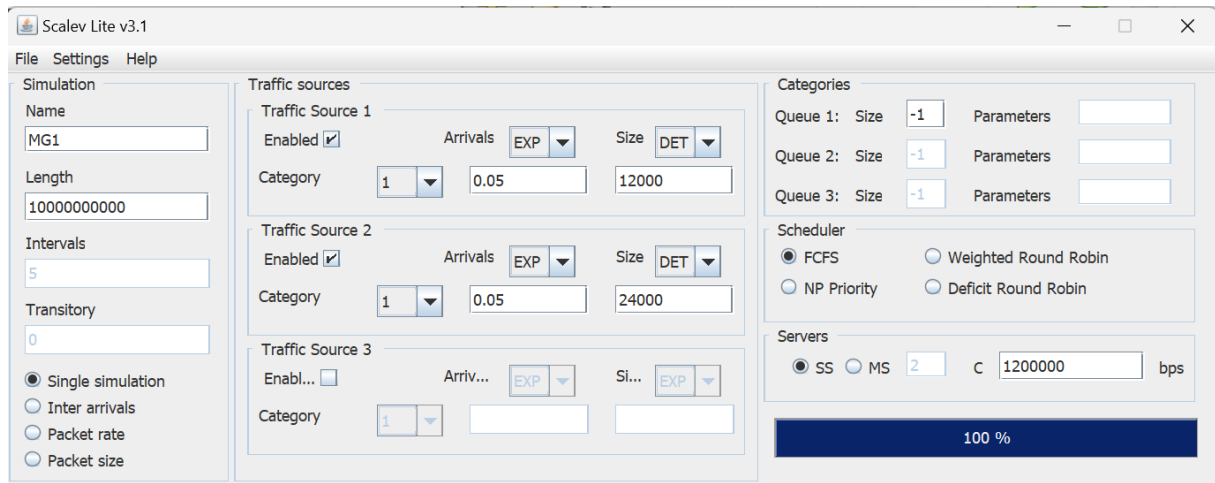


Figure 2: MG1 Scalev Simulation.

3.1 Average values analysis

Study the script MG1.m. Run it and compare the theoretical and the simulated values.

<p>SIMULATION RESULTS</p> <p>TRAFFIC SOURCES</p> <p>Traffic source number: 1 Simulated utilization (carried): 0.1999738693970659 Transmission time: 0.01 Transference time: 0.022454126231410083 Wait time: 0.012454126231410083 Total number of served packets: 166645 Total number of lost packets: 0 Loss probability: 0.0</p> <p>Traffic source number: 2 Simulated utilization (carried): 0.3997317389352013 Transmission time: 0.02 Transference time: 0.032382534042808685 Wait time: 0.012382534042808684 Total number of served packets: 166555 Total number of lost packets: 0 Loss probability: 0.0</p> <p>CATEGORIES</p> <p>Category number: 1 Simulated utilization (carried): 0.5997056083322672 Transmission time: 0.014998649459783913 Transference time: 0.027416999265706283 Wait time: 0.01241833980592237 Packet number in queue: 0.49653457451325916 Packet number in server: 0.5997056083322729 Packet number in system: 1.0962401828455322 Served packets: 333200 Lost packets: 0 Loss probability: 0.0</p>	<p>RESULTS</p> <p>TRAFFIC SOURCE NUMBER: 1 Waiting time: 0.0125 Service time: 0.01 Transfer time: 0.0225 Number of packets in queue: 0.25 Number of packets in server: 0.2 Number of packets in system: 0.45</p> <p>TRAFFIC SOURCE NUMBER: 2 Waiting time: 0.0125 Service time: 0.02 Transfer time: 0.0325 Number of packets in queue: 0.25 Number of packets in server: 0.4 Number of packets in system: 0.65</p> <p>OVERALL: Waiting time: 0.0125 Service time: 0.015 Transfer time: 0.0275 Number of packets in queue: 0.5 Number of packets in server: 0.6 Number of packets in system: 1.1</p>
---	---

Figure 3: MG1 Average values.

3.2 Transfer time analysis

- a) Obtain the transfer time distribution separately for the traffic source 1 and the traffic source 2 and plot them in the same graph. Give your conclusions.

```
%%3.2 transfer time analysis
load output_MG1_source_1.txt
ts1= output_MG1_source_1(:,4);
load output_MG1_source_2.txt
ts2= output_MG1_source_2(:,4);
[ht1,x1]=hist(ts1,20);
area=(x1(2)-x1(1))*sum(ht1);
pdf_ts1=ht1./area;
figure
bar(x1,pdf_ts1);
title('Ts pdf Source 1');
[ht2,x2]=hist(ts2,20);
area=(x2(2)-x2(1))*sum(ht2);
pdf_ts2=ht2./area;
figure
bar(x2,pdf_ts2);
title('Ts pdf Source 2');
load output_MG1_category_1.txt
ts1_cat1=output_MG1_category_1(:,4);
[ht3,x3]=hist(ts1_cat1,20);
area=(x3(2)-x3(1))*sum(ht3);
pdf_ts1_cat1=ht3./area;
figure
bar(x3,pdf_ts1_cat1);
title('Category 1 Ts pdf Source 1');
```

- b) Graph in a new plot the transfer time distribution for the category 1. Give your conclusions.

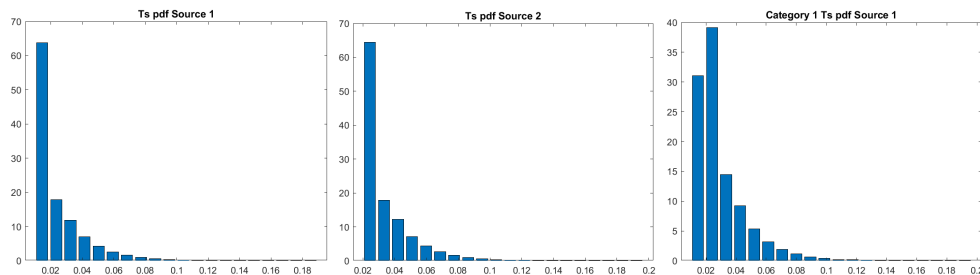


Figure 4: MG1 Transfer time analysis.

3.3 System occupation

Obtain and plot the state probabilities.

```
%%3.3 system occupation

load occupancy_MG1_1.txt;
t_n=[occupancy_MG1_1(:,1),occupancy_MG1_1(:,2),occupancy_MG1_1(:,3)];
state_prob_sim = state_prob_function(t_n);
figure(1)
bar(state_prob_sim)
title('Simulation state probabilities')
%%funcion de la practica anterior
function [output] = state_prob_function(tmp)
%UNTITLED3 Summary of this function goes here
% Detailed explanation goes here
time=tmp(:,1);
n=tmp(:,2);
prob=zeros(1,max(n)+1);
Max_time=max(time);
for i=1:length(time)-1
    prob(n(i)+1)=prob(n(i)+1)+(time(i+1)-time(i));
end
prob=prob./Max_time;
output=prob;
end

%%funcion de la practica anterior
function [output] = state_prob_function(tmp)
%UNTITLED3 Summary of this function goes here
% Detailed explanation goes here
time=tmp(:,1);
n=tmp(:,2);
prob=zeros(1,max(n)+1);
Max_time=max(time);
for i=1:length(time)-1
    prob(n(i)+1)=prob(n(i)+1)+(time(i+1)-time(i));
end
prob=prob./Max_time;
output=prob;
end
```

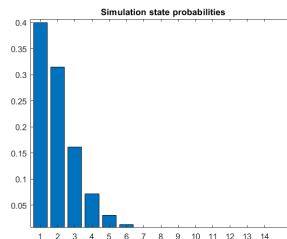


Figure 5: MG1 system occupation.

3.4 Traffic separation in different categories

In this section the same scenario will be simulated, but assigning the two traffic sources to different categories. This way we will be able to study the system occupation by each traffic.

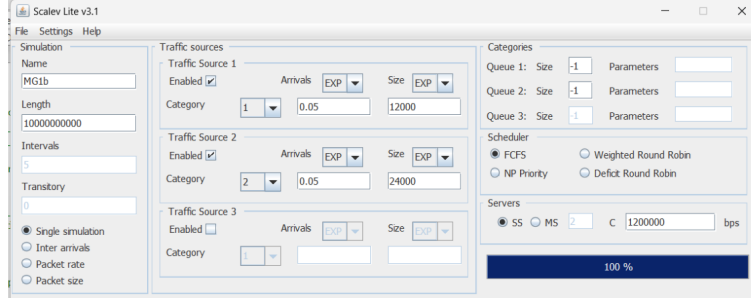


Figure 6: MG1 2 traffic sources Scalev simulation.

```
%%3.4 Traffic separation in different categories
load occupancy_MG1b_1.txt;
t_n1b=[occupancy_MG1b_1(:,1),occupancy_MG1b_1(:,2)+
occupancy_MG1b_1(:,3)];
state_prob_sim1b = state_prob_function(t_n1b);
%col1= interarrival time, col2 = paquetes cola+ servidor
figure(2)
bar(0:length(state_prob_sim1b)-1, state_prob_sim1b)
title('Simulation state probabilities cat1')
load occupancy_MG1b_2.txt
t_n1b_2=[occupancy_MG1b_2(:,1),occupancy_MG1b_2(:,2)+
occupancy_MG1b_2(:,3)];
state_prob_sim1b_2 = state_prob_function(t_n1b_2);
%col1= interarrival time, col2 = paquetes cola+ servidor
figure(3)
bar(0:length(state_prob_sim1b_2)-1, state_prob_sim1b_2)
title('Simulation state probabilities cat2')
```

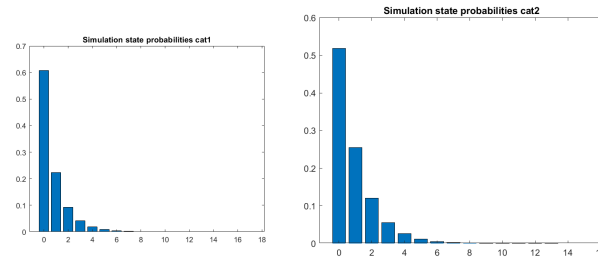


Figure 7: MG1 2 traffic sources state probabilities.

3.5 Comparison of systems with different distribution of the service time

In this section, the wait time of M/M/1 and M/D/1 systems will be compared.

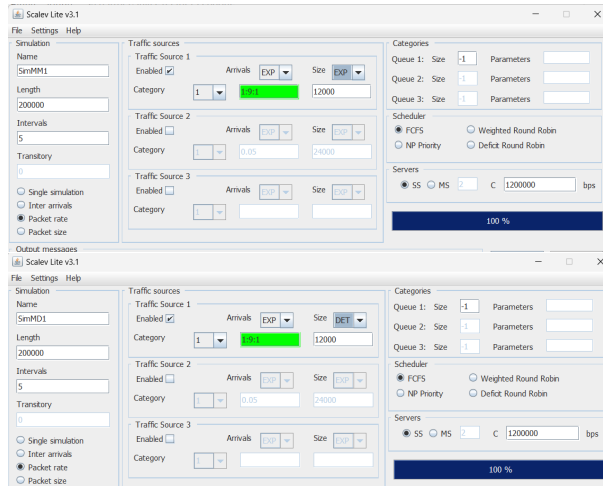


Figure 8: MM1 & MD1 Scalev simulation.

```
%%3.6 Comparison of system with different distribution
load report_SimMM1.txt;
load report_SimMD1.txt;
the_rho=[0.1:0.1:0.9];
tw1=report_SimMM1(:,7);
tw2=report_SimMD1(:,7);
figure
plot(the_rho, [tw1,tw2]);
legend('MM1', 'MD1');
title('Wait Time')
```

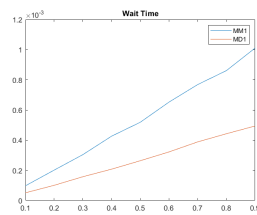


Figure 9: MM1 & MD1 wait time.

Com podem veure, el temps d'espera augmenta més en el cas del M/M/1 ja que el temps de servei no és determinista, com més paquets arribin més en trobaran a la cua.

4 Non-preemptive Priority

4.1 Average values analysis

In this section the packets will receive a different service depending on the category they belong. Compare the following system with FCFS and NPP schedulers.

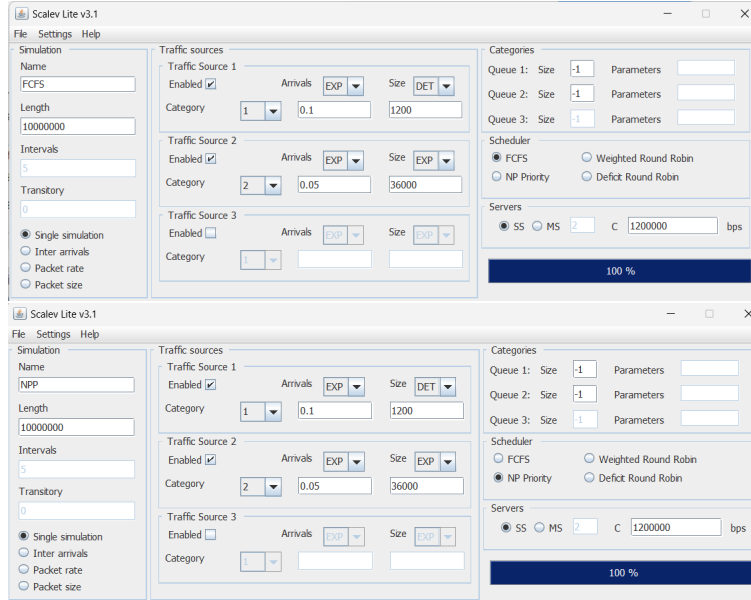


Figure 10: FCFS & NPP Scalev simulation.

- Fcfs

```

SIMULATION RESULTS

TRAFFIC SOURCES

Traffic source number: 1
Simulated utilization (carried): 0.009350854863943063
Transmission time: 0.001
Transference time: 0.04523448717948718
Wait time: 0.04423448717948718
Total number of served packets: 39
Total number of lost packets: 0
Loss probability: 0.0

Traffic source number: 2
Simulated utilization (carried): 0.6342279250892627
Transmission time: 0.0307581492248062
Transference time: 0.08133781007751938
Wait time: 0.050579660852713176
Total number of served packets: 86
Total number of lost packets: 0
Loss probability: 0.0

CATEGORIES

Category number: 1
Simulated utilization (carried): 0.009350854863943063
Transmission time: 0.001
Transference time: 0.04523448717948718
Wait time: 0.04423448717948718
Packet number in queue: 0.4136302695963347
Packet number in server: 0.009350854863943206
Packet number in system: 0.4229811244602779
Served packets: 39
Lost packets: 0
Loss probability: 0.0

Category number: 2
Simulated utilization (carried): 0.6342279250892627
Transmission time: 0.0307581492248062
Transference time: 0.08133781007751938
Wait time: 0.050579660852713176
Packet number in queue: 1.0429442005718408
Packet number in server: 0.6342279250892626
Packet number in system: 1.6771721256611034
Served packets: 86
Lost packets: 0
Loss probability: 0.0

```

Figure 11: Fcfs Scalev simulation results.

- Npp

<pre> SIMULATION RESULTS TRAFFIC SOURCES Traffic source number: 1 Simulated utilization (carried): 0.010554762726734994 Transmission time: 0.001 Transference time: 0.01645876893939394 Wait time: 0.015458768939393939 Total number of served packets: 44 Total number of lost packets: 0 Loss probability: 0.0 Traffic source number: 2 Simulated utilization (carried): 0.6417761506740356 Transmission time: 0.028162043859649124 Transference time: 0.06197227192982456 Wait time: 0.03381022807017543 Total number of served packets: 95 Total number of lost packets: 0 Loss probability: 0.0 </pre>	<pre> CATEGORIES Category number: 1 Simulated utilization (carried): 0.010554762726734994 Transmission time: 0.001 Transference time: 0.01645876893939394 Wait time: 0.015458768939393939 Packet number in queue: 0.16316363820272373 Packet number in server: 0.010554762726735183 Packet number in system: 0.17371840092945892 Served packets: 44 Lost packets: 0 Loss probability: 0.0 Category number: 2 Simulated utilization (carried): 0.6417761506740356 Transmission time: 0.028162043859649124 Transference time: 0.06197227192982456 Wait time: 0.03381022807017543 Packet number in queue: 0.7704908824241414 Packet number in server: 0.6417761506740352 Packet number in system: 1.4122670330981766 Served packets: 95 Lost packets: 0 Loss probability: 0.0 </pre>
--	---

Figure 12: Npp Scalev simulation results.

- Theoretical

```

RESULTS

TRAFFIC SOURCE NUMBER: 1
Waiting time: 0.018187
Service time: 0.001
Transfer time: 0.019187
Number of packets in queue: 0.18187
Number of packets in server: 0.01
Number of packets in system: 0.19187
TRAFFIC SOURCE NUMBER: 2
Waiting time: 0.046633
Service time: 0.03
Transfer time: 0.076633
Number of packets in queue: 0.93266
Number of packets in server: 0.6
Number of packets in system: 1.5327
OVERALL:
Waiting time: 0.037151
Service time: 0.020333
Transfer time: 0.057484
Number of packets in queue: 1.1145
Number of packets in server: 0.61
Number of packets in system: 1.7245

```

Figure 13: Theoretical Matlab results.

Veiem que els resultats són molt similars. Si comparem les dues simulacions (FCFS i NPP), veiem que les diferències només apareixen a la categoria 1 de cada simulació, on els paquets del cas NPP tenen un temps d'espera molt menor a tots els altres casos, és a dir la categoria 2 de NPP i les dues categories de FCFS, que tenen un temps d'espera molt semblant. Això es deu evidentment a que aquests paquets de categoria 1 de NPP són prioritaris.

4.2 Loss probability

Next, the loss probability with finite queues will be analyzed. To do this, compare the following system with FCFS and NPP schedulers:

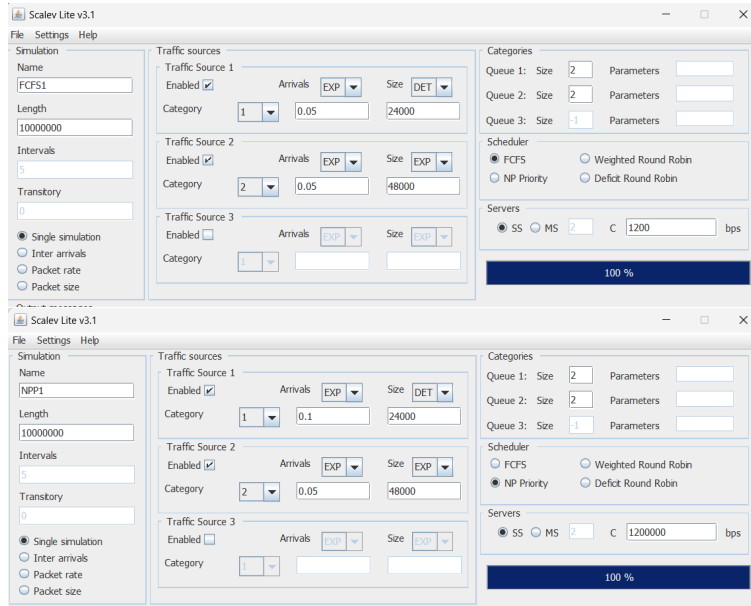


Figure 14: FCFS & NPP Scalev simulation with finite queue.

- Fcfs

```

SIMULATION RESULTS

TRAFFIC SOURCES

Traffic source number: 1
Simulated utilization (carried): 0.14380281757653904
Transmission time: 0.02
Transference time: 0.03415133333333333
Wait time: 0.014151333333333332
Total number of served packets: 30
Total number of lost packets: 0
Loss probability: 0.0

Traffic source number: 2
Simulated utilization (carried): 0.49454707704795187
Transmission time: 0.02715050438596491
Transference time: 0.048526260964912284
Wait time: 0.021375756578947372
Total number of served packets: 76
Total number of lost packets: 7
Loss probability: 0.08433734939759036

CATEGORIES

Category number: 1
Simulated utilization (carried): 0.14380281757653904
Transmission time: 0.02
Transference time: 0.03415133333333333
Wait time: 0.014151333333333332
Packet number in queue: 0.10175008028990674
Packet number in server: 0.143802817576539
Packet number in system: 0.24555289786644574
Served packets: 30
Lost packets: 0
Loss probability: 0.0

Category number: 2
Simulated utilization (carried): 0.49454707704795187
Transmission time: 0.02715050438596491
Transference time: 0.048526260964912284
Wait time: 0.021375756578947372
Packet number in queue: 0.38935990969183015
Packet number in server: 0.4945470770479519
Packet number in system: 0.8839069867397821
Served packets: 76
Lost packets: 7
Loss probability: 0.08433734939759036

```

Figure 15: Fcfs Scalev simulation results.

- Npp

```

SIMULATION RESULTS

TRAFFIC SOURCES

Traffic source number: 1
Simulated utilization (carried): 0.20136315665514223
Transmission time: 0.02
Transference time: 0.055535515873015875
Wait time: 0.03553551587301587
Total number of served packets: 42
Total number of lost packets: 2
Loss probability: 0.045454545454545456

Traffic source number: 2
Simulated utilization (carried): 0.5205699056769428
Transmission time: 0.03193518382352941
Transference time: 0.06887838235294118
Wait time: 0.03694319852941177
Total number of served packets: 68
Total number of lost packets: 20
Loss probability: 0.22727272727272727

CATEGORIES

Category number: 1
Simulated utilization (carried): 0.20136315665514223
Transmission time: 0.02
Transference time: 0.055535515873015875
Wait time: 0.03553551587301587
Packet number in queue: 0.35777718247796947
Packet number in server: 0.20136315665514212
Packet number in system: 0.5591403391331116
Served packets: 42
Lost packets: 2
Loss probability: 0.045454545454545456

Category number: 2
Simulated utilization (carried): 0.5205699056769428
Transmission time: 0.03193518382352941
Transference time: 0.06887838235294118
Wait time: 0.03694319852941177
Packet number in queue: 0.6022046868473295
Packet number in server: 0.5233576267594058
Packet number in system: 1.1255623136067352
Served packets: 68
Lost packets: 20
Loss probability: 0.22727272727272727

```

Figure 16: Npp Scalev simulation results.

Com podem veure, cap probabilitat de pèrdua coincideix si comparem la categoria 1 de les dues simulacions i el mateix per la 2. Podem observar que pel cas de NPP la probabilitat de pèrdua augmenta molt en els paquets de tipus 2, ja que són menys prioritaris i s'han d'esperar, en canvi en el cas de FCFS la probabilitat de pèrdua es manté constant independentment de la categoria del paquet.

5 Comparison between FCFS and NPP

a) Do the following simulation and use the script MG1.b.m to analyze the results.

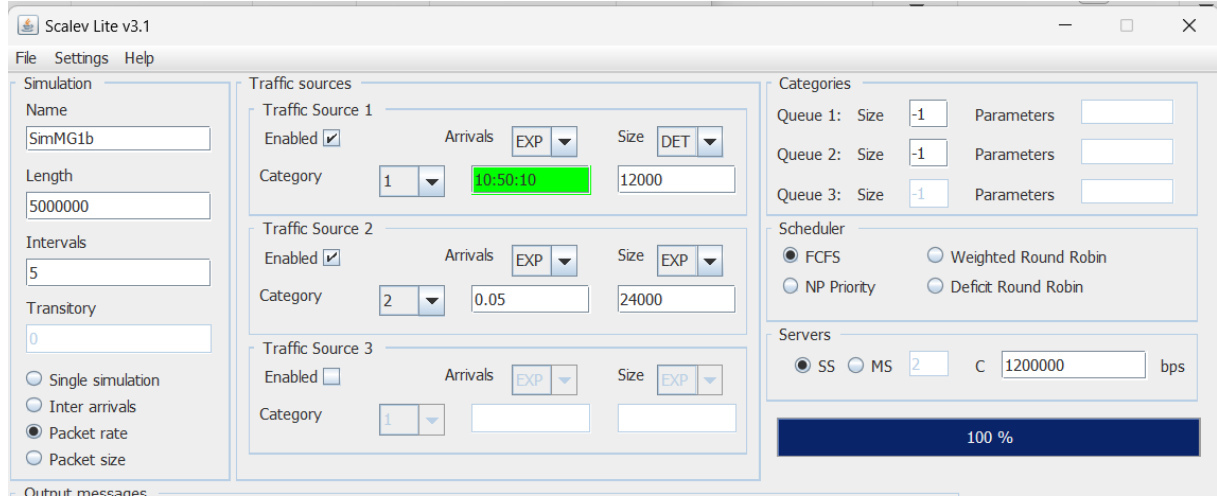


Figure 17: MG1 Scalev simulation.

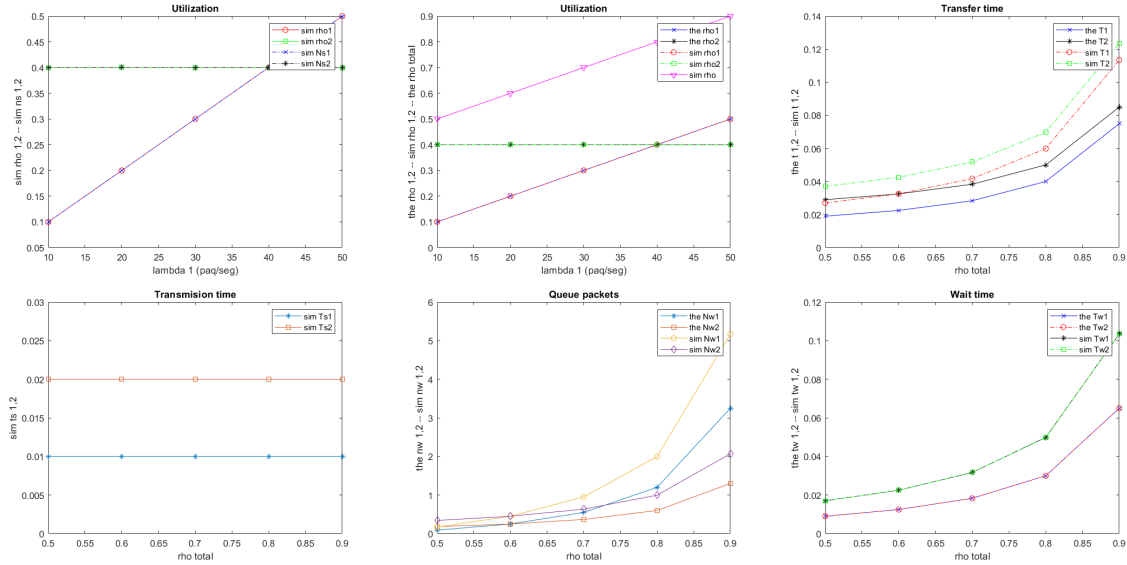


Figure 18: MG1 loss probabilities analysis.

- b) Repeat the simulation changing the scheduler to NPP. Use the script MG1_NPP.b.m to analyze the results.

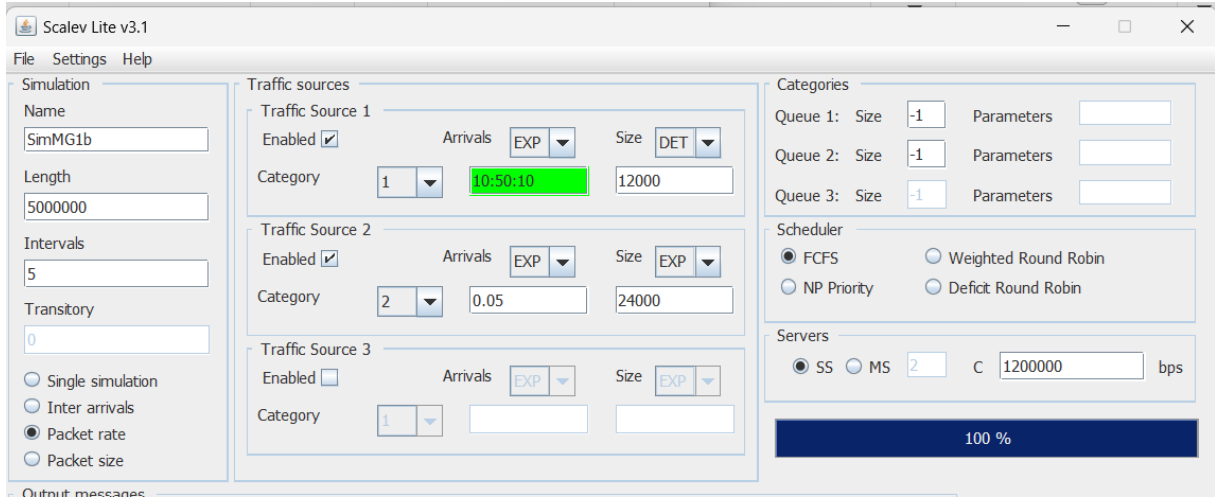


Figure 19: MG1 Scalev simulation.

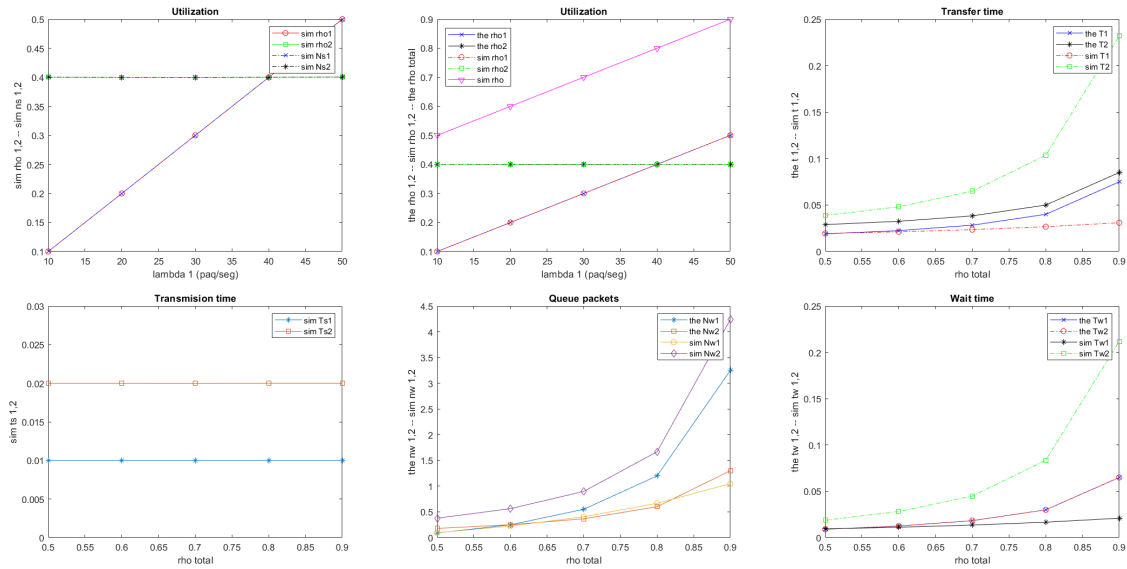


Figure 20: MG1 loss probabilities analysis.

c) Finally, use the script FCFS_NPP.m to compare the results. Give your conclusions.

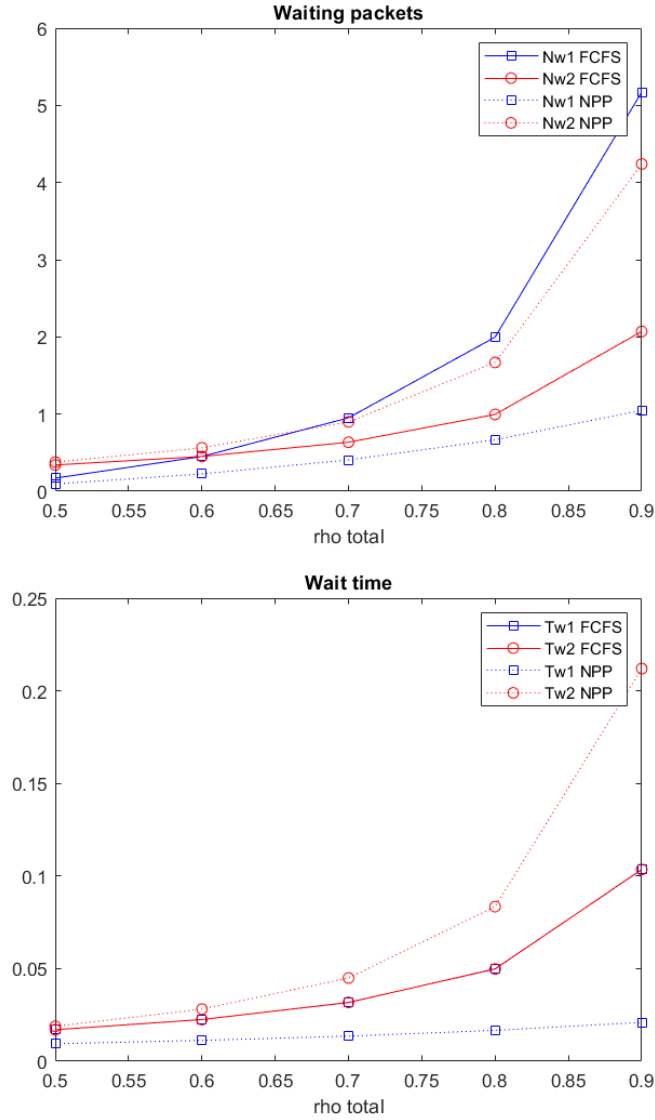


Figure 21: Comparison FCFS and NPP.

El temps d'espera és igual per les dues fonts en el cas de FCFS però en el cas de NPP és diferent. En el tipus 1 és menor que en el tipus 2. Això es deu a que els paquets que tenen prioritat a NPP tindran menys temps d'espera que els de FCFS, però els que tenen menys prioritat tenen major temps d'espera a NPP que a FCFS. Si ens fixem en el nombre mig de paquets, veiem que en el cas de NPP el tipus 1 té menys paquets en cua que el mateix tipus de FCFS, però passa a l'inversa amb els paquets de tipus 2.