Desempenho e Dimensionamento de Redes

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Performance de uma ligação de comutação de pacotes

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universidade de aveiro

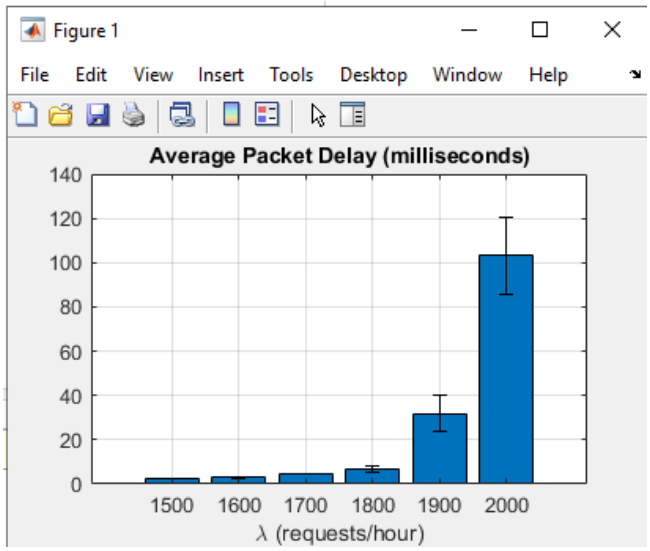
Exercício 3

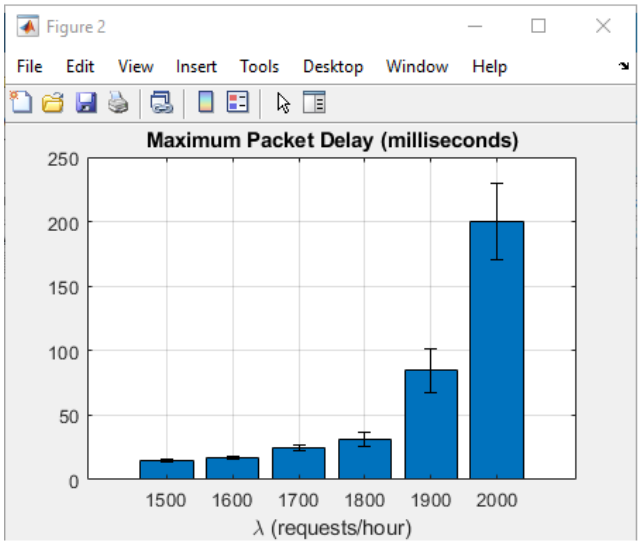
3a.

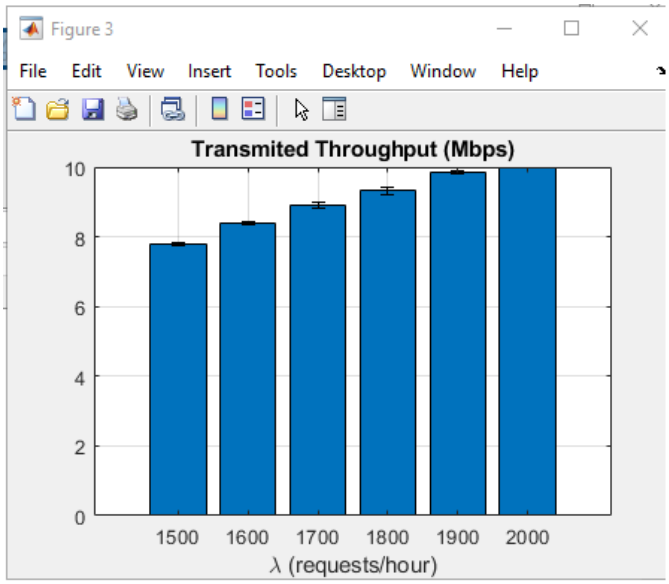
```
N = 10; % numero de simulacoes
lambdas = [1500,1600,1700,1800,1900,2000];
alfa= 0.1; %90% confidence interval%

C = 10;
f = 10000000;
P = 10000;
b = 0;

valuePL = zeros(1,length(lambdas));
valueAPD = zeros(1,length(lambdas));
valueMPD = zeros(1,length(lambdas));
valueTT = zeros(1,length(lambdas));

termPL = zeros(1,length(lambdas));
termAPD = zeros(1,length(lambdas));
termMPD = zeros(1,length(lambdas));
termTT = zeros(1,length(lambdas));

PL=zeros(1,N);
APD=zeros(1,N);
MPD=zeros(1,N);
TT=zeros(1,N);

for i=1:length(lambdas)
    for it= 1:N
        [PL(it),APD(it),MPD(it),TT(it)]= simulator2(lambdas(i),C,f,P,b);
    end
    valuePL(i) = mean(PL);
```

```
    termPL(i) = norminv(1-alfa/2) * sqrt(var(PL)/N);
    valueAPD(i) = mean(APD);
    termAPD(i) = norminv(1-alfa/2) * sqrt(var(APD)/N);
    valueMPD(i) = mean(MPD);
    termMPD(i) = norminv(1-alfa/2) * sqrt(var(MPD)/N);
    valueTT(i) = mean(TT);
    termTT(i) = norminv(1-alfa/2) * sqrt(var(TT)/N);
end


figure(1)
bar(lambdas,valueAPD)
hold on
erro=errorbar(lambdas,valueAPD,termAPD,termAPD);
erro.Color=[0 0 0];
erro.LineStyle = 'none';
hold off
grid on
xlabel('\lambda (requests/hour)')
title('Average Packet Delay (milliseconds)')

figure(2)
bar(lambdas,valueMPD)
hold on
errb=errorbar(lambdas,valueMPD,termMPD,termMPD);
errb.Color=[0 0 0];
errb.LineStyle = 'none';
hold off
grid on
xlabel('\lambda (requests/hour)')
title('Maximum Packet Delay (milliseconds)')

figure(3)
bar(lambdas,valueTT)
hold on
erro=errorbar(lambdas,valueTT,termTT,termTT);
erro.Color=[0 0 0];
erro.LineStyle = 'none';
hold off
grid on
xlabel('\lambda (requests/hour)')
title('Transmited Throughput (Mbps)')
```

Resultados:







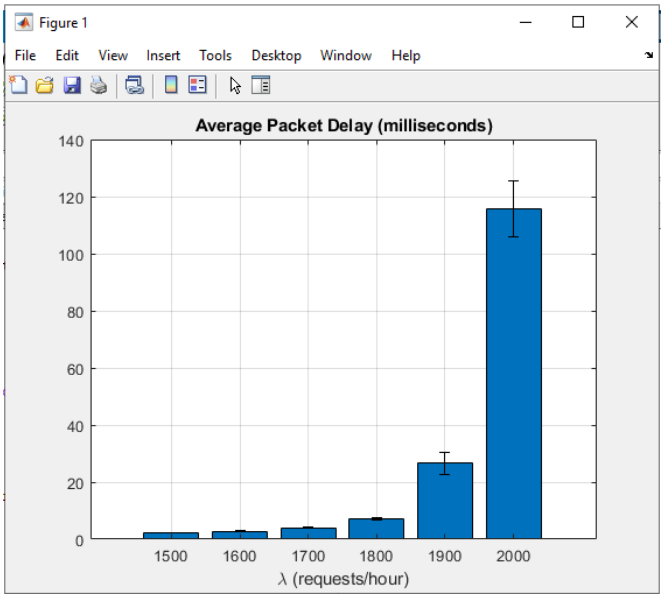
Podemos observar que os valores de average packet delay aumentam consoante o aumento da transmissão de pacotes. Algo se assemelha com os valores de maximum packet delay que aumentam também consoante o aumento da transmissão de pacotes por segundo. Estes valores de aumento devem-se ao facto de que à medida que existe uma maior transferência de pacotes, esses pacotes ficam à espera na fila. No último gráfico, relativo à taxa de transferência, os valores vão chegando ao seu limite máximo à medida que a taxa de transferência dos pacotes aumenta.

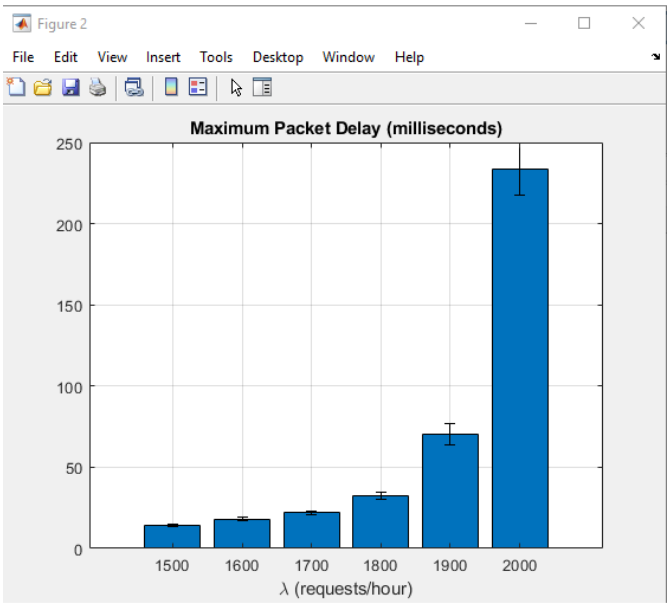
3b.

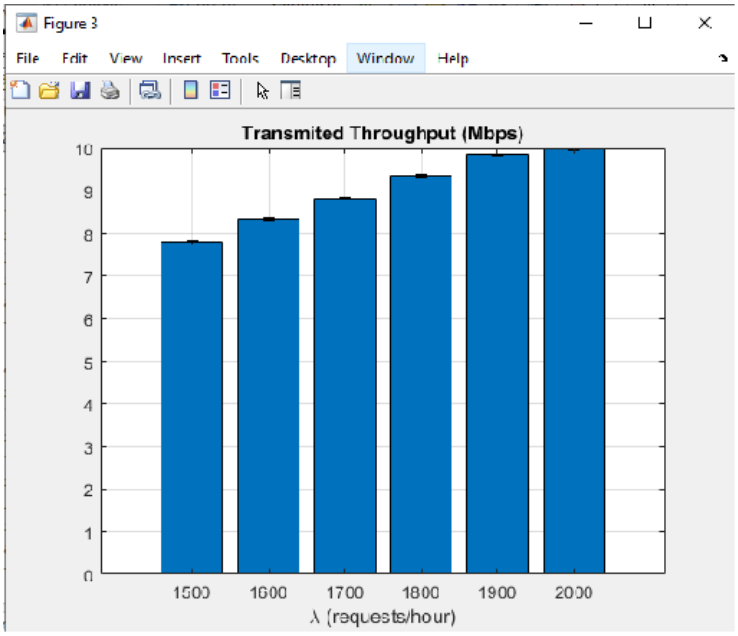
```
N = 40; % numero de simulacoes
lambdas = [1500,1600,1700,1800,1900,2000];
alfa= 0.1; %90% confidence interval%

C = 10;
f = 10000000;
P = 10000;
b = 0;

valuePL = zeros(1,length(lambdas));
valueAPD = zeros(1,length(lambdas));
valueMPD = zeros(1,length(lambdas));
valueTT = zeros(1,length(lambdas));

termPL = zeros(1,length(lambdas));
termAPD = zeros(1,length(lambdas));
termMPD = zeros(1,length(lambdas));
termTT = zeros(1,length(lambdas));

PL=zeros(1,N);
APD=zeros(1,N);
MPD=zeros(1,N);
TT=zeros(1,N);

for i=1:length(lambdas)
    for it= 1:N
        [PL(it),APD(it),MPD(it),TT(it)]= simulator2(lambdas(i),C,f,P,b);
    end
    valuePL(i) = mean(PL);
    termPL(i) = norminv(1-alfa/2) * sqrt(var(PL)/N);
    valueAPD(i) = mean(APD);
    termAPD(i) = norminv(1-alfa/2) * sqrt(var(APD)/N);
    valueMPD(i) = mean(MPD);
    termMPD(i) = norminv(1-alfa/2) * sqrt(var(MPD)/N);
    valueTT(i) = mean(TT);
    termTT(i) = norminv(1-alfa/2) * sqrt(var(TT)/N);
end


figure(1)
bar(lambdas,valueAPD)
hold on
erro=errorbar(lambdas,valueAPD,termAPD,termAPD);
erro.Color=[0 0 0];
erro.LineStyle = 'none';
hold off
```

```
grid on
xlabel('\lambda (requests/hour)')
title('Average Packet Delay (milliseconds)')

figure(2)
bar(lambdas,valueMPD)
hold on
errb=errorbar(lambdas,valueMPD,termMPD,termMPD);
errb.Color=[0 0 0];
errb.LineStyle = 'none';
hold off
grid on
xlabel('\lambda (requests/hour)')
title('Maximum Packet Delay (milliseconds)')

figure(3)
bar(lambdas,valueTT)
hold on
erro=errorbar(lambdas,valueTT,termTT,termTT);
erro.Color=[0 0 0];
erro.LineStyle = 'none';
hold off
grid on
xlabel('\lambda (requests/hour)')
title('Transmited Throughput (Mbps)')
```

Resultados:







Agora, para um número de simulações superior (40 vezes), os valores não vão ser muito diferentes, porém para um número de simulações mais elevado, torna-se mais elevada também a eficácia e a precisão dos resultados esperados. É possível observar, comparando os gráficos da alínea a) com a alínea b), que os valores mantêm-se parecidos, porém vê-se uma diminuição na barra de erro de cada gráfico, o que indica uma maior precisão dos resultados.

3c.

```
C=10;
f=10e7;
b=0;
P=10000;
N = 10; %number of simulations
lambda=[1500,1600,1700,1800,1900,2000];
valuePL = zeros(1,length(lambdas));
valueAPD = zeros(1,length(lambdas));
valueMPD = zeros(1,length(lambdas));
valueTT = zeros(1,length(lambdas));

termPL = zeros(1,length(lambdas));
termAPD = zeros(1,length(lambdas));
termMPD = zeros(1,length(lambdas));
termTT = zeros(1,length(lambdas));

PL=zeros(1,N);
APD=zeros(1,N);
MPD=zeros(1,N);
TT=zeros(1,N);

for i=1:length(lambdas)
    for it= 1:N
        [PL(it),APD(it),MPD(it),TT(it)]= simulator2(lambdas(i),C,f,P,b);
    end
    valuePL(i) = mean(PL);
    termPL(i) = norminv(1-alfa/2) * sqrt(var(PL)/N);
    valueAPD(i) = mean(APD);
    termAPD(i) = norminv(1-alfa/2) * sqrt(var(APD)/N);
    valueMPD(i) = mean(MPD);
    termMPD(i) = norminv(1-alfa/2) * sqrt(var(MPD)/N);
    valueTT(i) = mean(TT);
    termTT(i) = norminv(1-alfa/2) * sqrt(var(TT)/N);
end

B=(0.16*64+0.25*110+0.2*1518+ ((1-(0.16+0.25+0.2))/ length([65:109
111:1517]) )  * sum([65:109 111:1517]))*8;
miu=C*1000000/B;
for j=1:length(lambda)
    packet_delay(j) = 1/(miu-lambda(j))*1000;
    throughput(j) = (lambda(j)*B)/1000000;
```

```
end

figure(24)
bar(lambda,[valueAPD;packet_delay])
title('Average Packet Delay (milliseconds)')

figure(25)
bar(lambda,[valueTT;throughput])
title('Transmited Throughput (Mbps)')
```

Neste exercício somente conseguimos calcular os valores para o sistema M/M/1, porém vimos os gráficos resultantes a partir de um colega e conseguimos chegar a uma interpretação dos resultados. Os valores de average packet delay e os valores de total throughput, tanto por simulação e por valores teóricos, são bastante parecidos para os dois sistemas, M/M/1 e M/G/1 respetivamente. A partir de um certo valor de lambda, no average packet delay, no valor 2000, esse valores estão perante uma fila infinita de pacotes de chegada, daí esses valores não serem válidos.

3d.

```
N = 40; %number of simulations
alfa= 0.1; %90% confidence interval%
fd = [2500,5000,7500,10000,12500,15000,17500,20000];

lambda = 1800;
C=10;
f=10e7;
b=0;
P=10000;

valuePL = zeros(1,length(fd));
valueAPD = zeros(1,length(fd));
valueMPD = zeros(1,length(fd));
valueTT = zeros(1,length(fd));

termPL = zeros(1,N);
termAPD = zeros(1,N);
termMPD = zeros(1,N);
termTT = zeros(1,N);

PL = zeros(1,length(fd));
APD = zeros(1,length(fd));
MPD = zeros(1,length(fd));
TT = zeros(1,length(fd));

for i=1:length(fd)
    for it= 1:N
        [termPL(it), termAPD(it), termMPD(it), termTT(it)] =
simulator2(lambda,C,fd(i),P,b);
    end
    PL(i) = mean(termPL);
    valuePL(i) = norminv(1-alfa/2)*sqrt(var(termPL)/N);
    APD(i) = mean(termAPD);
    valueAPD(i) = norminv(1-alfa/2)*sqrt(var(termAPD)/N);
    MPD(i) = mean(termMPD);
    valueMPD(i) = norminv(1-alfa/2)*sqrt(var(termMPD)/N);
    TT(i) = mean(termTT);
    valueTT(i) = norminv(1-alfa/2)*sqrt(var(termTT)/N);
end

figure(1)
```

```
bar(fd, PL)
hold on
er = errorbar(fd,PL,-valuePL,valuePL);
er.Color = [0 0 0];
er.LineStyle = 'none';
hold off
title('Packet Loss (%)')
grid on

figure(2)
bar(fd, APD(:))
hold on
er = errorbar(fd,APD,-valueAPD,valueAPD);
er.Color = [0 0 0];
er.LineStyle = 'none';
hold off
title('Average Packet Delay (milliseconds)')
grid on

figure(3)
bar(fd, MPD(:))
hold on
er = errorbar(fd,MPD,-valueMPD,valueMPD);
er.Color = [0 0 0];
er.LineStyle = 'none';
hold off
title('Maximum Packet Delay (milliseconds)')
grid on

figure(4)
bar(fd, TT)
hold on
er = errorbar(fd,TT,-valueTT,valueTT);
er.Color = [0 0 0];
er.LineStyle = 'none';
hold off
title('Transmited Throughput (Mbps)')
grid on
```

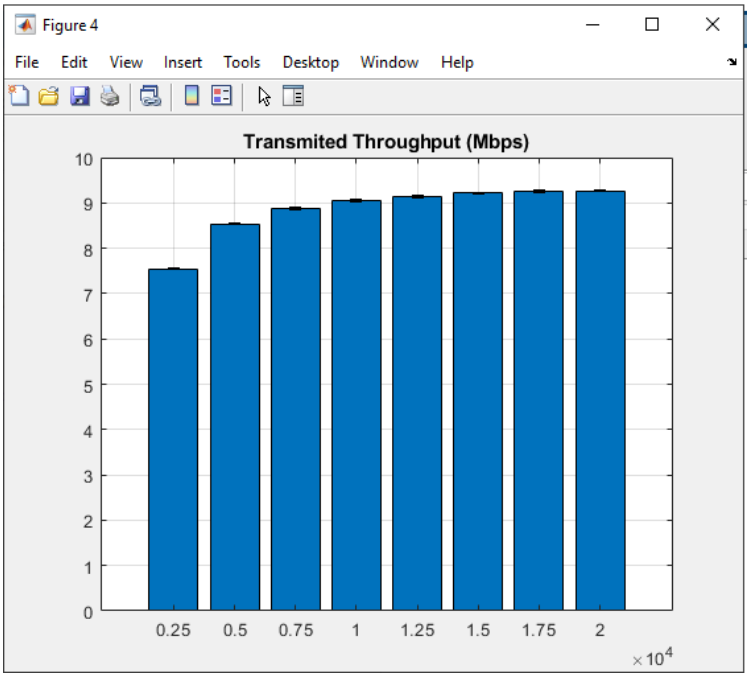


Figure 4
File Edit View Insert Tools Desktop Window Help
Transmited Throughput (Mbps)
0 1 2 3 4 5 6 7 8 9 10
0.25 0.5 0.75 1 1.25 1.5 1.75 2
×10^4

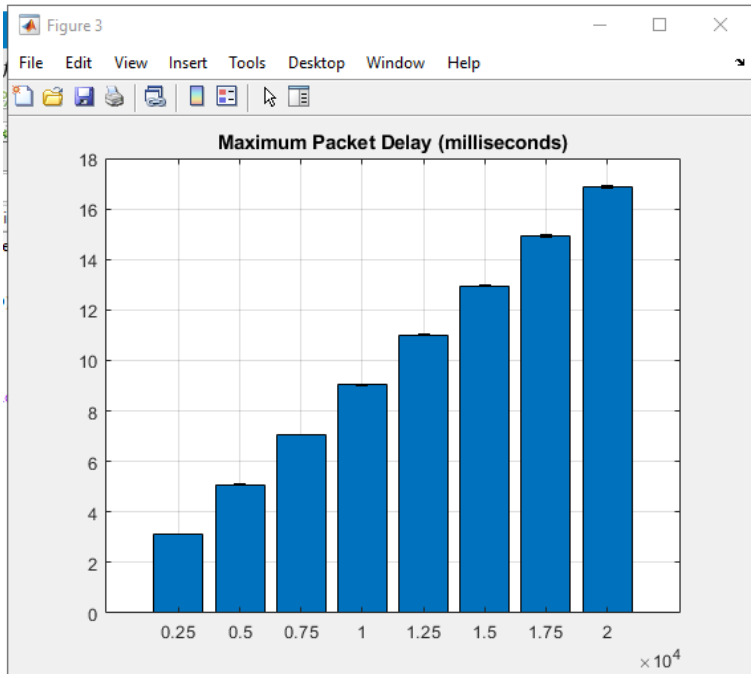


Figure 3
File Edit View Insert Tools Desktop Window Help
Maximum Packet Delay (milliseconds)
0 2 4 6 8 10 12 14 16 18
0.25 0.5 0.75 1 1.25 1.5 1.75 2
×10^4


Figure 2
File Edit View Insert Tools Desktop Window Help
Average Packet Delay (milliseconds)
0 1 2 3 4 5 6
0.25 0.5 0.75 1 1.25 1.5 1.75 2
×10^4

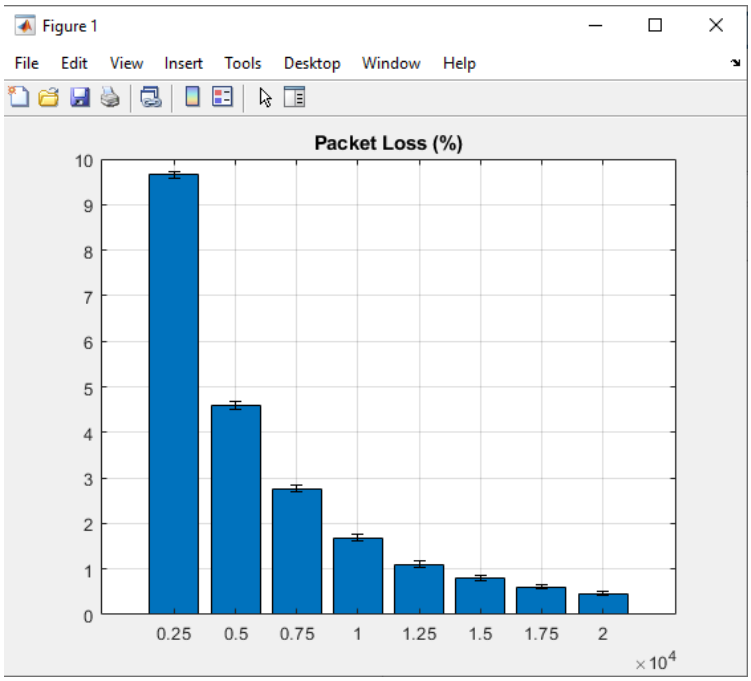


Figure 1
File Edit View Insert Tools Desktop Window Help
Packet Loss (%)
0 1 2 3 4 5 6 7 8 9 10
0.25 0.5 0.75 1 1.25 1.5 1.75 2
×10^4

Alterando agora o tamanho da fila e também o lambda, os valores vão variar um pouco. Os valores da taxa de transferência, não se alteram muito, aumentando ligeiramente com o aumento da fila de espera, chegando quase ao limite de capacidade máximo que é 10 Mbps.

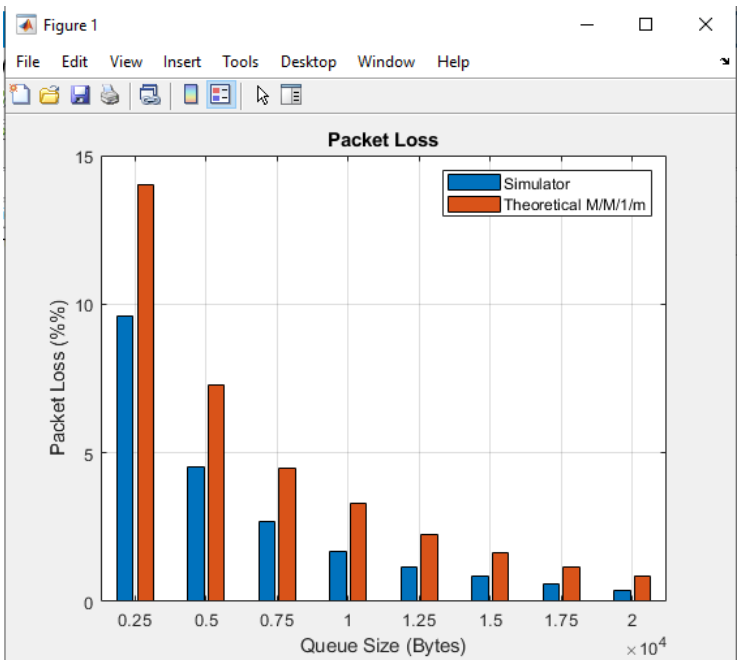
É de esperar agora, que quando a fila de espera aumenta, os valores de average e maximum packet delay vão aumentar, e os valores de packet loss diminuam, pois existem menos pacotes a serem transmitidos.

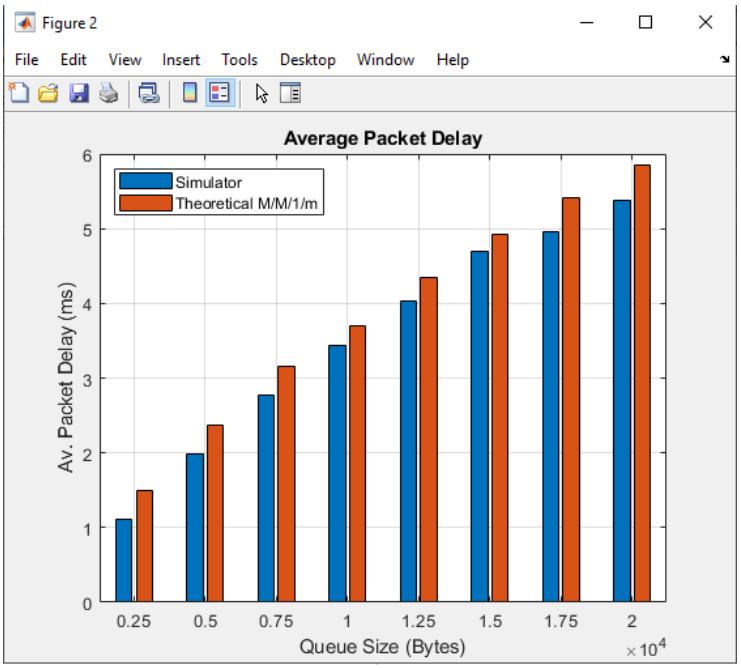
3e.

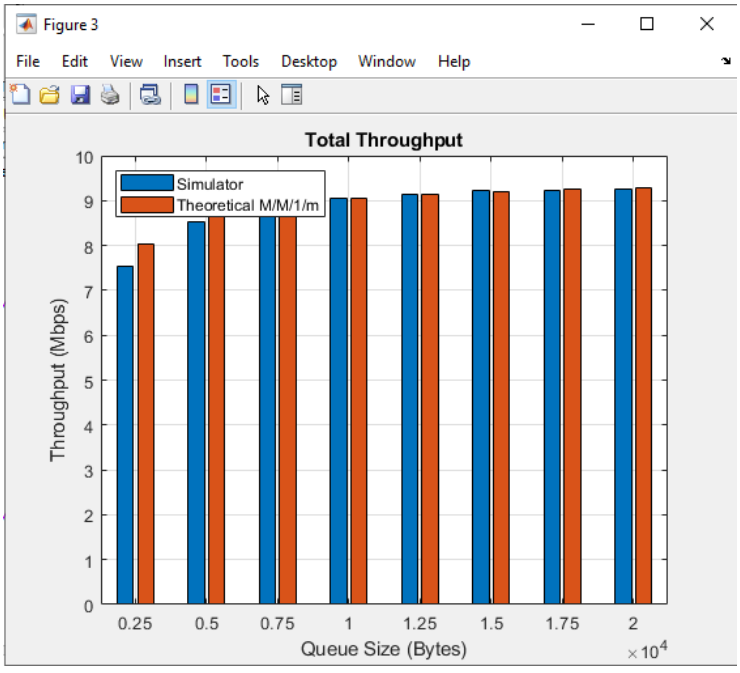
```
N = 40; %number of simulations
alfa= 0.1; %90% confidence interval%
fd = [2500,5000,7500,10000,12500,15000,17500,20000];

lambda = 1800;
C=10;
f=10e7;
b=0;
P=10000;

valuePL = zeros(1,length(fd));
valueAPD = zeros(1,length(fd));
valueMPD = zeros(1,length(fd));
valueTT = zeros(1,length(fd));

termPL = zeros(1,N);
termAPD = zeros(1,N);
termMPD = zeros(1,N);
termTT = zeros(1,N);

PL = zeros(1,length(fd));
APD = zeros(1,length(fd));
MPD = zeros(1,length(fd));
TT = zeros(1,length(fd));

m = zeros(1,length(fd));
MM1_Num = zeros(1,length(fd));
MM1_Den = zeros(1,length(fd));
MM1_PL = zeros(1,length(fd));

L = zeros(1,length(fd));
MM1_PD = zeros(1,length(fd));
th = zeros(1,length(fd));

B=(0.16*64+0.25*110+0.2*1518+ ((1-(0.16+0.25+0.2))/ length([65:109
111:1517]) )  * sum([65:109 111:1517]))*8;
u=C*1000000/B;

for i=1:length(fd)
    for it= 1:N
        [termPL(it), termAPD(it), termMPD(it), termTT(it)] =
```

```
simulator2(lambda,C,fd(i),P,b);
    end
    PL(i) = mean(termPL);
    valuePL(i) = norminv(1-alfa/2)*sqrt(var(termPL)/N);
    APD(i) = mean(termAPD);
    valueAPD(i) = norminv(1-alfa/2)*sqrt(var(termAPD)/N);
    MPD(i) = mean(termMPD);
    valueMPD(i) = norminv(1-alfa/2)*sqrt(var(termMPD)/N);
    TT(i) = mean(termTT);
    valueTT(i) = norminv(1-alfa/2)*sqrt(var(termTT)/N);

    m(i)=round(fd(i) * 8/B)+1;
    MM1_Num(i)=0;
    MM1_Den(i)=0;
    for j=0:m(i)
        MM1_Num(i)=MM1_Num(i)+(j*(lambda/u)^j);
        MM1_Den(i)=MM1_Den(i)+(lambda/u)^j;
    end
    MM1_PL(i)=((lambda/u)^m(i))/MM1_Den(i);
    L(i)=MM1_Num(i)/MM1_Den(i);
    MM1_PD(i)=L(i)/(lambda*(1-MM1_PL(i)));
    th(i) = ((lambda*B)/1000000)*(1-MM1_PL(i));
end

figure(1)
bar(fd, [PL;MM1_PL*100])
xlabel('Queue Size (Bytes)')
ylabel('Packet Loss (%%)')
title('Packet Loss')
legend('Simulator','Theoretical M/M/1/m', 'Location', 'northeast')
grid on


figure(2)
bar(fd,[APD;MM1_PD*1000])
xlabel('Queue Size (Bytes)')
ylabel('Av. Packet Delay (ms)')
title('Average Packet Delay')
legend('Simulator','Theoretical M/M/1/m', 'Location', 'northwest')
grid on

figure(3)
bar(fd,[TT;th])
xlabel('Queue Size (Bytes)')
```

```
ylabel('Throughput (Mbps)')
title('Total Throughput')
legend('Simulator','Theoretical M/M/1/m', 'Location', 'northwest')
grid on
```







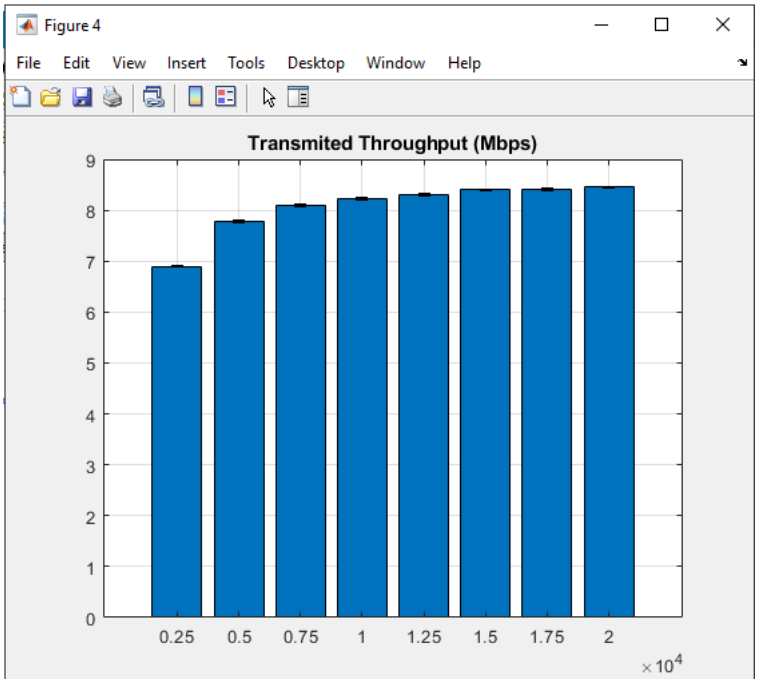
Conseguindo analisar todos os gráficos, observamos que quanto ao total throughput, os valores são bastante parecidos, quase a chegar ao valor máximo de capacidade, que é 10. Nos restantes gráficos, como o sistema M/M/1/M dispõe de um número finito de clientes, os valores do packet loss e do average packet delay vão ser maiores, o que vai levar a alguma diferença entre os valores teóricos e os de simulação.

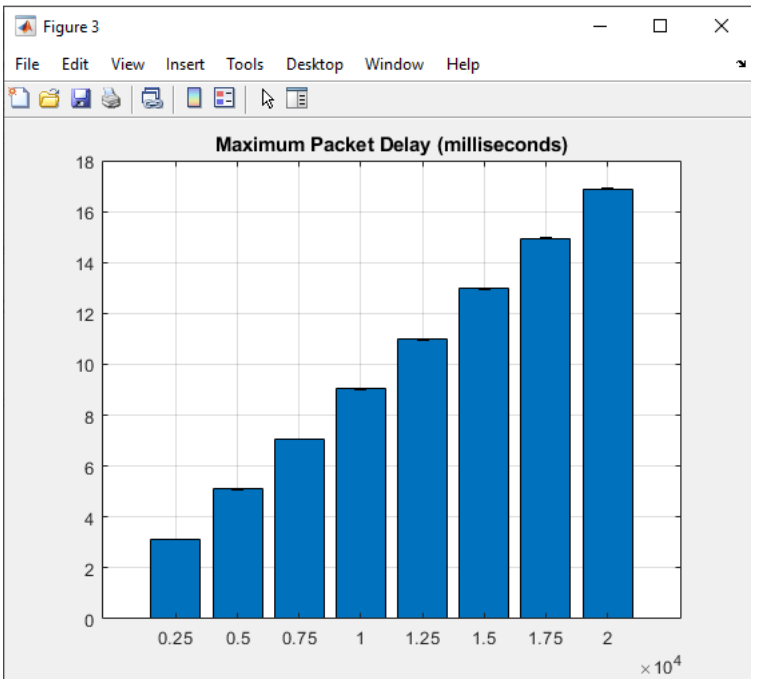
3f.

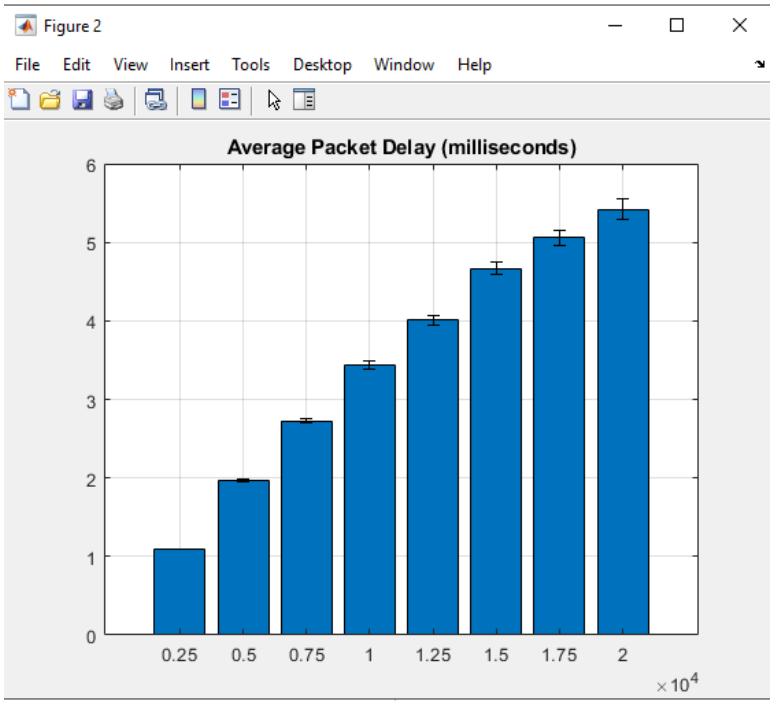
```
N = 40; %number of simulations
alfa= 0.1; %90% confidence interval%
fd = [2500,5000,7500,10000,12500,15000,17500,20000];

lambda = 1800;
C=10;
f=10e7;
b=10^(-5);
P=10000;

valuePL = zeros(1,length(fd));
valueAPD = zeros(1,length(fd));
valueMPD = zeros(1,length(fd));
valueTT = zeros(1,length(fd));

termPL = zeros(1,N);
termAPD = zeros(1,N);
termMPD = zeros(1,N);
termTT = zeros(1,N);

PL = zeros(1,length(fd));
APD = zeros(1,length(fd));
MPD = zeros(1,length(fd));
TT = zeros(1,length(fd));

for i=1:length(fd)
    for it= 1:N
        [termPL(it), termAPD(it), termMPD(it), termTT(it)] =
simulator2(lambda,C,fd(i),P,b);
    end
```

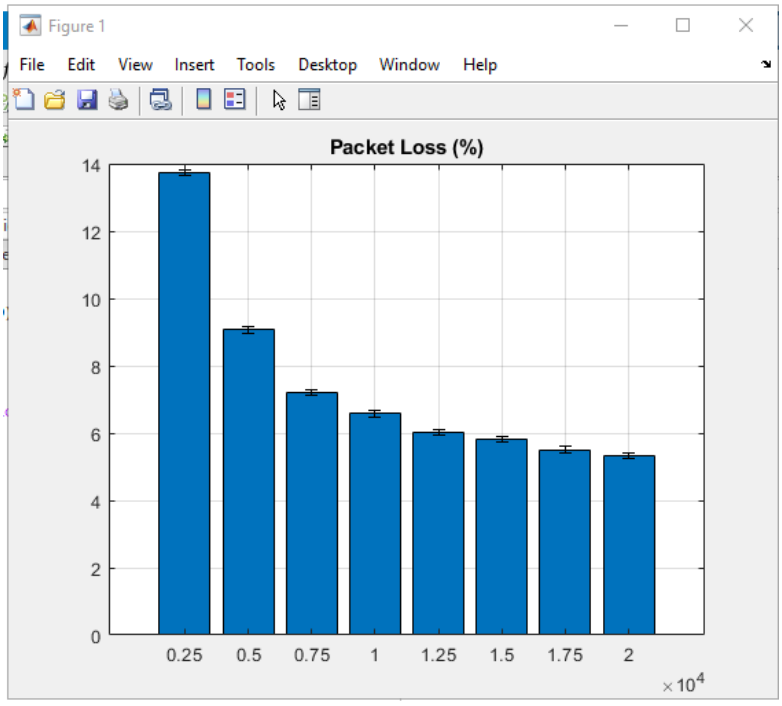
```
    PL(i) = mean(termPL);
    valuePL(i) = norminv(1-alfa/2)*sqrt(var(termPL)/N);
    APD(i) = mean(termAPD);
    valueAPD(i) = norminv(1-alfa/2)*sqrt(var(termAPD)/N);
    MPD(i) = mean(termMPD);
    valueMPD(i) = norminv(1-alfa/2)*sqrt(var(termMPD)/N);
    TT(i) = mean(termTT);
    valueTT(i) = norminv(1-alfa/2)*sqrt(var(termTT)/N);
end

figure(1)
bar(fd, PL)
hold on
er = errorbar(fd,PL,-valuePL,valuePL);
er.Color = [0 0 0];
er.LineStyle = 'none';
hold off
title('Packet Loss (%)')
grid on

figure(2)
bar(fd, APD(:))
hold on
er = errorbar(fd,APD,-valueAPD,valueAPD);
er.Color = [0 0 0];
er.LineStyle = 'none';
hold off
title('Average Packet Delay (milliseconds)')
grid on

figure(3)
bar(fd, MPD(:))
hold on
er = errorbar(fd,MPD,-valueMPD,valueMPD);
er.Color = [0 0 0];
er.LineStyle = 'none';
hold off
title('Maximum Packet Delay (milliseconds)')
grid on

figure(4)
bar(fd, TT)
hold on
er = errorbar(fd,TT,-valueTT,valueTT);
```

```
er.Color = [0 0 0];
er.LineStyle = 'none';
hold off
title('Transmited Throughput (Mbps)')
grid on
```









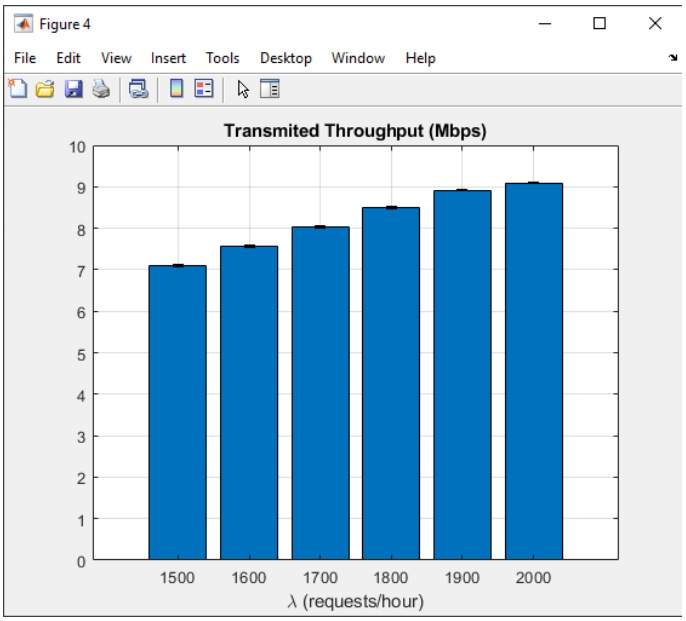
Nesta alínea alterou-se o valor do BER para b = 10^(-5), comparativamente à alínea 3.d. Comparando os gráficos com alínea 3.d, e observando que o valor do bit error rate é maior, é de esperar que o packet loss vá aumentar, já que o número de bit error rate é maior. Se existe um ber maior, o número de pacotes a serem transmitidos vai ser menor, pois vão ser transmitidos menos pacotes, daí haver uma ligeira diferença entre os gráficos da taxa de transferência de pacotes, com um ber maior que outro. Quanto ao gráfico de average packet delay, vê-se um pequeno aumento.

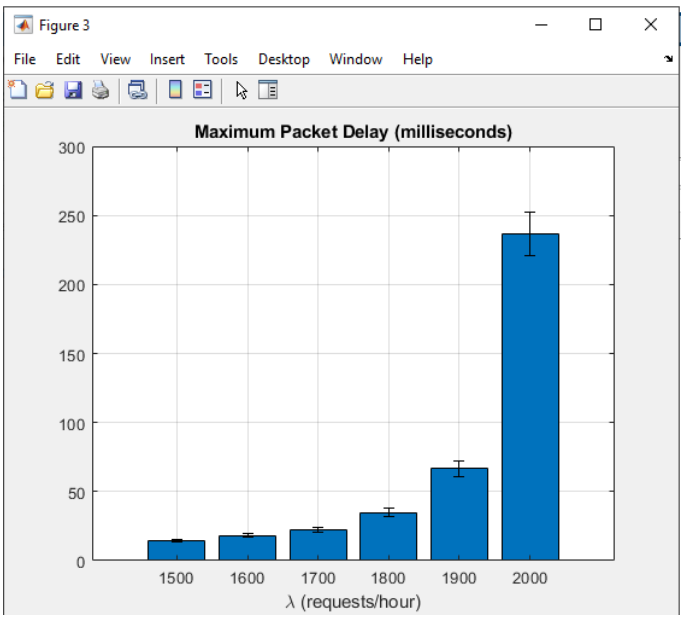
3g.

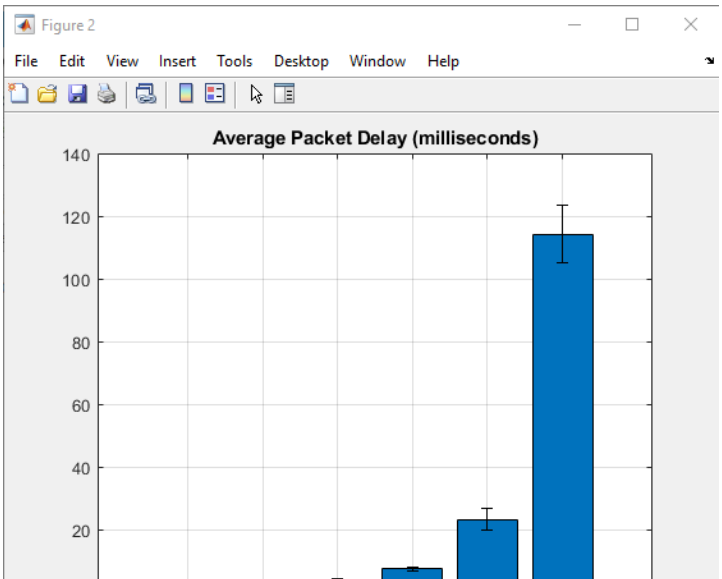
```
N = 40; % numero de simulacoes
lambdas = [1500,1600,1700,1800,1900,2000];
alfa= 0.1; %90% confidence interval%

C = 10;
f = 10000000;
P = 10000;
b = 10^(-5);

valuePL = zeros(1,length(lambdas));
valueAPD = zeros(1,length(lambdas));
valueMPD = zeros(1,length(lambdas));
valueTT = zeros(1,length(lambdas));

termPL = zeros(1,length(lambdas));
termAPD = zeros(1,length(lambdas));
termMPD = zeros(1,length(lambdas));
termTT = zeros(1,length(lambdas));

PL=zeros(1,N);
APD=zeros(1,N);
MPD=zeros(1,N);
TT=zeros(1,N);
```

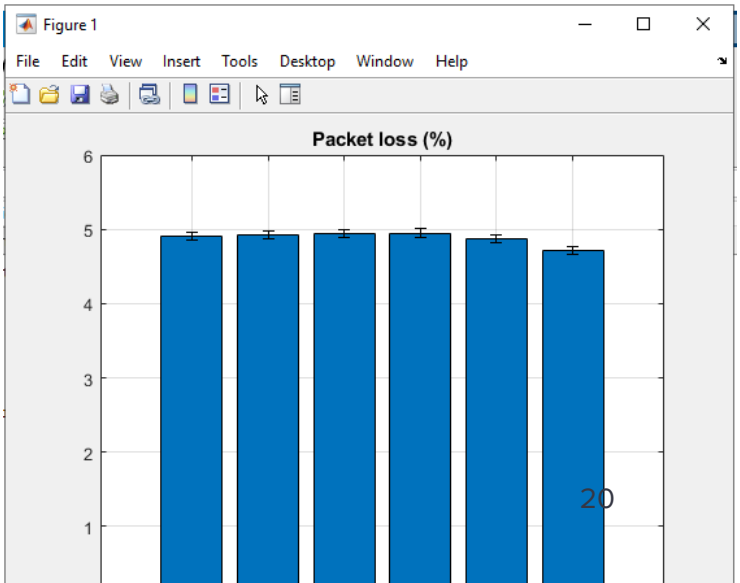
```
for i=1:length(lambdas)
    for it= 1:N
        [PL(it),APD(it),MPD(it),TT(it)]= simulator2(lambdas(i),C,f,P,b);
    end
    valuePL(i) = mean(PL);
    termPL(i) = norminv(1-alfa/2) * sqrt(var(PL)/N);
    valueAPD(i) = mean(APD);
    termAPD(i) = norminv(1-alfa/2) * sqrt(var(APD)/N);
    valueMPD(i) = mean(MPD);
    termMPD(i) = norminv(1-alfa/2) * sqrt(var(MPD)/N);
    valueTT(i) = mean(TT);
    termTT(i) = norminv(1-alfa/2) * sqrt(var(TT)/N);
end

figure(1)
bar(lambdas,valuePL)
hold on
erro=errorbar(lambdas,valuePL,termPL,termPL);
erro.Color=[0 0 0];
erro.LineStyle = 'none';
hold off
grid on
xlabel('\lambda (requests/hour)')
title('Packet loss (%)')

figure(2)
bar(lambdas,valueAPD)
hold on
erro=errorbar(lambdas,valueAPD,termAPD,termAPD);
erro.Color=[0 0 0];
erro.LineStyle = 'none';
hold off
grid on
xlabel('\lambda (requests/hour)')
title('Average Packet Delay (milliseconds)')

figure(3)
bar(lambdas,valueMPD)
hold on
errb=errorbar(lambdas,valueMPD,termMPD,termMPD);
errb.Color=[0 0 0];
errb.LineStyle = 'none';
hold off
grid on
```

```
xlabel('\lambda (requests/hour)')
title('Maximum Packet Delay (milliseconds)')

figure(4)
bar(lambdas,valueTT)
hold on
erro=errorbar(lambdas,valueTT,termTT,termTT);
erro.Color=[0 0 0];
erro.LineStyle = 'none';
hold off
grid on
xlabel('\lambda (requests/hour)')
title('Transmited Throughput (Mbps)')
```









Nesta alínea alterou-se o valor do BER para b = 10^(-5), comparativamente à alínea 3.b. Comparando os gráficos com alínea 3.b, e observando que o valor do bit error rate é maior, é de esperar que o packet loss vá aumentar, já que o número de bit error rate é maior. Se existe um ber maior, o número de pacotes a serem transmitidos vai ser menor, pois vão ser transmitidos menos pacotes, daí haver uma ligeira diferença entre os gráficos da taxa de transferência de pacotes, com um ber maior que outro. Quanto ao gráfico de average packet delay, vê-se um pequeno aumento.

4a.

Código:

```
%% 4a.
N = 10;
PL = zeros(1,N);
APD = zeros(1,N);
MPD = zeros(1,N);
TT = zeros(1,N);
for j = 1:N
   [PL(j),APD(j),MPD(j),TT(j)] = simulator3(1800,10,10^6,100000,0);
end
alfa = 0.1;
mediapl = mean(PL(:));
termpl = norminv(1-alfa/2)*sqrt(var(PL(:))/N);
mediaapd = mean(APD(:));
termapd = norminv(1-alfa/2)*sqrt(var(APD(:))/N);
mediampd = mean(MPD(:));
termmpd = norminv(1-alfa/2)*sqrt(var(MPD(:))/N);
mediatt = mean(TT(:));
termtt = norminv(1-alfa/2)*sqrt(var(TT(:))/N);
fprintf('Packet Loss (%%) = %.2e +- %.2e\n', mediapl, termpl)
fprintf('Av. Packet delay (ms) = %.2e +- %.2e\n', mediaapd, termapd)
fprintf('Max. Packet Delay (ms) = %.2e +- %.2e\n', mediampd, termmpd)
fprintf('Throughput (Mbps) = %.2e +- %.2e\n', mediatt, termtt)
```

Resultados:

```
%%4a.
Packet Loss (%) = 4.35e+00 +- 3.65e+00
Av. Packet delay (ms) = 2.37e+02 +- 1.94e+02
Max. Packet Delay (ms) = 2.67e+02 +- 1.92e+02
Throughput (Mbps) = 8.61e+00 +- 1.09e+00
```

4b.

Código:

```
%% 4b
N = 10;
PL = zeros(1,N);
APD = zeros(1,N);
MPD = zeros(1,N);
TT = zeros(1,N);
for j = 1:N
   [PL(j),APD(j),MPD(j),TT(j)] = simulator3(1800,10,10^4,100000,10^(-5));
end
alfa = 0.1;
mediapl = mean(PL(:));
termpl = norminv(1-alfa/2)*sqrt(var(PL(:))/N);
mediaapd = mean(APD(:));
termapd = norminv(1-alfa/2)*sqrt(var(APD(:))/N);
mediampd = mean(MPD(:));
termmpd = norminv(1-alfa/2)*sqrt(var(MPD(:))/N);
mediatt = mean(TT(:));
termtt = norminv(1-alfa/2)*sqrt(var(TT(:))/N);
fprintf('Packet Loss (%%) = %.2e +- %.2e\n', mediaplb, termplb)
fprintf('Av. Packet delay (ms) = %.2e +- %.2e\n', mediaapdb, termapdb)
fprintf('Max. Packet Delay (ms) = %.2e +- %.2e\n', mediampdb, termmpdb)
fprintf('Throughput (Mbps) = %.2e +- %.2e\n', mediattb, termttb)
```

Resultados:

```
%%4b.
Packet Loss (%) = 1.06e+01 +- 1.67e-01
Av. Packet delay (ms) = 4.22e+00 +- 5.57e-02
Max. Packet Delay (ms) = 9.17e+00 +- 7.61e-03
Throughput (Mbps) = 7.53e+00 +- 5.97e-02
```

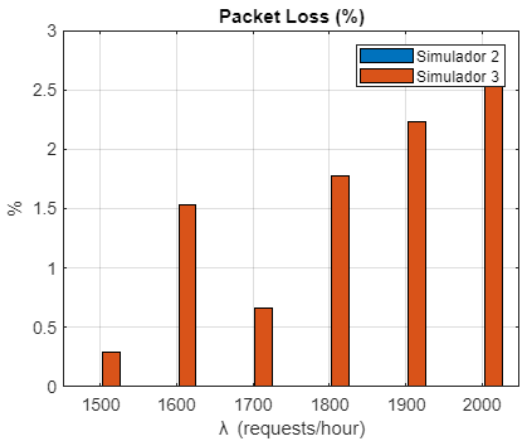
4c.

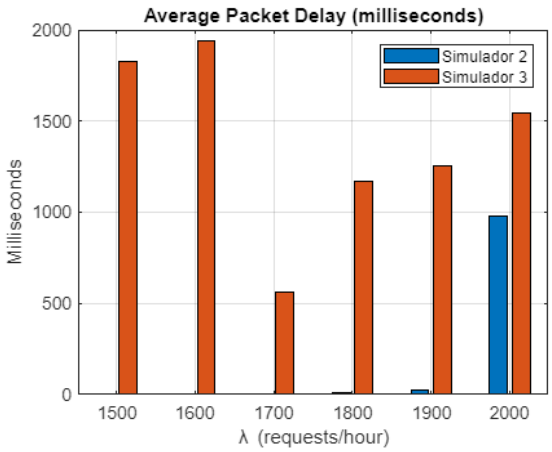
Código:

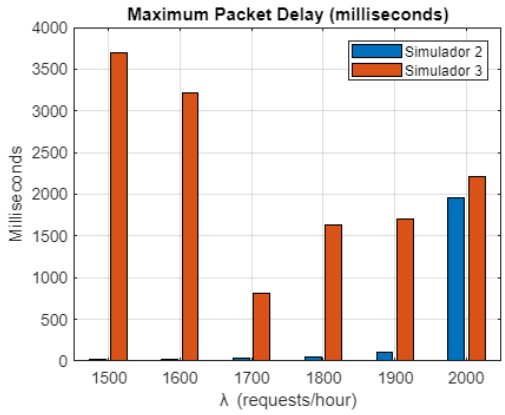
```
%% 4c
N = 10;
lambdac = [1500,1600,1700,1800,1900,2000];
PL2 = zeros(1,N);
APD2 = zeros(1,N);
MPD2 = zeros(1,N);
TT2 = zeros(1,N);
PL3 = zeros(1,N);
APD3 = zeros(1,N);
MPD3 = zeros(1,N);
TT3 = zeros(1,N);
for i=1:length(lambdac)
   for j= 1:N
       [PL2(j),APD2(j),MPD2(j),TT2(j)] =
simulator2(lambdac(i),10,10^7,100000,0);
       [PL3(j),APD3(j),MPD3(j),TT3(j)] =
simulator3(lambdac(i),10,10^7,100000,0);
   end

   alfa= 0.1;
   mediapl2(i) = mean(PL2);
   termpl2(i) = norminv(1-alfa/2)*sqrt(var(PL2)/N);
   mediaapd2(i) = mean(APD2);
   termapd2(i) = norminv(1-alfa/2)*sqrt(var(APD2)/N);
   mediampd2(i) = mean(MPD2);
   termmpd2(i) = norminv(1-alfa/2)*sqrt(var(MPD2)/N);
   mediatt2(i) = mean(TT2);
   termtt2(i) = norminv(1-alfa/2)*sqrt(var(TT2)/N);

   mediapl3(i) = mean(PL3);
   termpl3(i) = norminv(1-alfa/2)*sqrt(var(PL3)/N);
   mediaapd3(i) = mean(APD3);
   termapd3(i) = norminv(1-alfa/2)*sqrt(var(APD3)/N);
   mediampd3(i) = mean(MPD3);
   termmpd3(i) = norminv(1-alfa/2)*sqrt(var(MPD3)/N);
   mediatt3(i) = mean(TT3);
   termtt3(i) = norminv(1-alfa/2)*sqrt(var(TT3)/N);
end
figure(1)
```

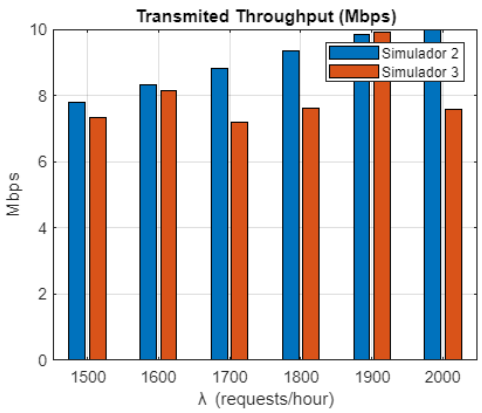
```
bar(lambdac,[mediapl2;mediapl3])
grid on
legend('Simulador 2','Simulador 3')
xlabel('\lambda (requests/hour)')
ylabel('%')
title('Packet Loss (%)')
figure(2)
bar(lambdac,[mediaapd2;mediaapd3])
grid on
legend('Simulador 2','Simulador 3')
xlabel('\lambda (requests/hour)')
ylabel('Milliseconds')
title('Average Packet Delay (milliseconds)')
figure(3)
bar(lambdac,[mediampd2;mediampd3])
grid on
legend('Simulador 2','Simulador 3')
xlabel('\lambda (requests/hour)')
ylabel('Milliseconds')
title('Maximum Packet Delay (milliseconds)')
figure(4)
bar(lambdac,[mediatt2;mediatt3])
grid on
legend('Simulador 2','Simulador 3')
xlabel('\lambda (requests/hour)')
ylabel('Mbps')
title('Transmited Throughput (Mbps)')
```

Resultados:






Maximum Packet Delay (milliseconds)
Simulador 2
Simulador 3
Milliseconds
4000
3500
3000
2500
2000
1500
1000
500
0
1500
1600
1700
1800
1900
2000
λ (requests/hour)


Transmited Throughput (Mbps)
Simulador 2
Simulador 3
Mbps
10
8
6
4
2
0
1500
1600
1700
1800
1900
2000
λ (requests/hour)

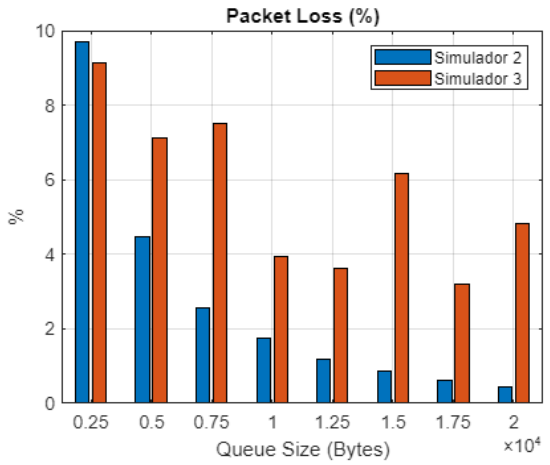
4d.

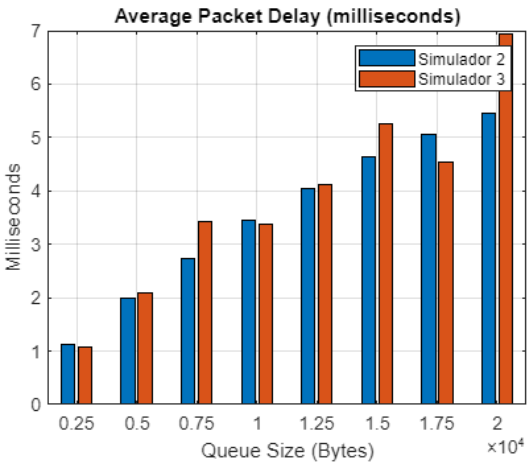
Código:

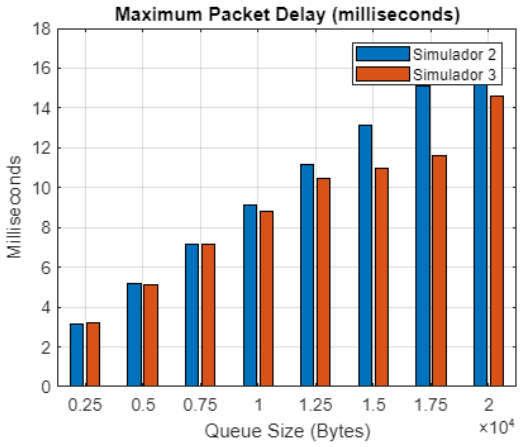
```
%% 4d
N = 10;
fd=[2500,5000,7500,10000,12500,15000,17500,20000];
PL3=zeros(1,N);
APD3=zeros(1,N);
MPD3=zeros(1,N);
TT3=zeros(1,N);
PL2=zeros(1,N);
APD2=zeros(1,N);
MPD2=zeros(1,N);
TT2=zeros(1,N);
for i=1:length(fd)
   for j= 1:N
       [PL2(j),APD2(j),MPD2(j),TT2(j)]= simulator2(1800,10,fd(i),100000,0);
       [PL3(j),APD3(j),MPD3(j),TT3(j)]= simulator3(1800,10,fd(i),100000,0);
   end

   alfa = 0.1;
   mediapl2(i) = mean(PL2);
   termpl2(i) = norminv(1-alfa/2)*sqrt(var(PL2)/N);
   mediaapd2(i) = mean(APD2);
   termapd2(i) = norminv(1-alfa/2)*sqrt(var(APD2)/N);
   mediampd2(i) = mean(MPD2);
   termmpd2(i) = norminv(1-alfa/2)*sqrt(var(MPD2)/N);
   mediatt2(i) = mean(TT2);
   termtt2(i) = norminv(1-alfa/2)*sqrt(var(TT2)/N);

   mediapl3(i) = mean(PL3);
   termpl3(i) = norminv(1-alfa/2)*sqrt(var(PL3)/N);
   mediaapd3(i) = mean(APD3);
   termapd3(i) = norminv(1-alfa/2)*sqrt(var(APD3)/N);
   mediampd3(i) = mean(MPD3);
   termmpd3(i) = norminv(1-alfa/2)*sqrt(var(MPD3)/N);
   mediatt3(i) = mean(TT3);
   termtt3(i) = norminv(1-alfa/2)*sqrt(var(TT3)/N);
end
figure(5)
bar(fd,[mediapl2;mediapl3])
grid on
```

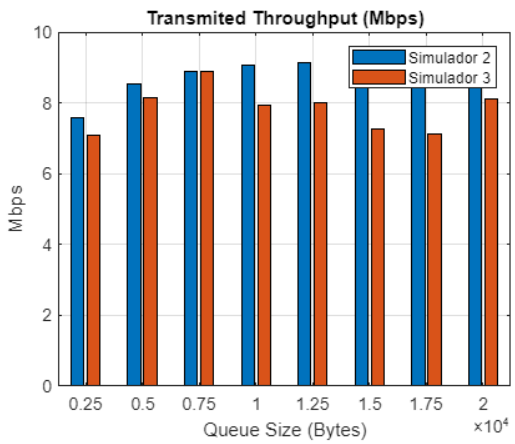
```
legend('Simulador 2','Simulador 3')
xlabel('Queue Size (Bytes)')
ylabel('%')
title('Packet Loss (%)')
figure(6)
bar(fd,[mediaapd2;mediaapd3])
grid on
legend('Simulador 2','Simulador 3')
xlabel('Queue Size (Bytes)')
ylabel('Milliseconds')
title('Average Packet Delay (milliseconds)')
figure(7)
bar(fd,[mediampd2;mediampd3])
grid on
legend('Simulador 2','Simulador 3')
xlabel('Queue Size (Bytes)')
ylabel('Milliseconds')
title('Maximum Packet Delay (milliseconds)')
figure(8)
bar(fd,[mediatt2;mediatt3])
grid on
legend('Simulador 2','Simulador 3')
xlabel('Queue Size (Bytes)')
ylabel('Mbps')
title('Transmited Throughput (Mbps)')
```

Resultados:






Maximum Packet Delay (milliseconds)
Simulador 2
Simulador 3
Milliseconds
Queue Size (Bytes)
×10^4


Transmited Throughput (Mbps)
Simulador 2
Simulador 3
Mbps
Queue Size (Bytes)
×10^4

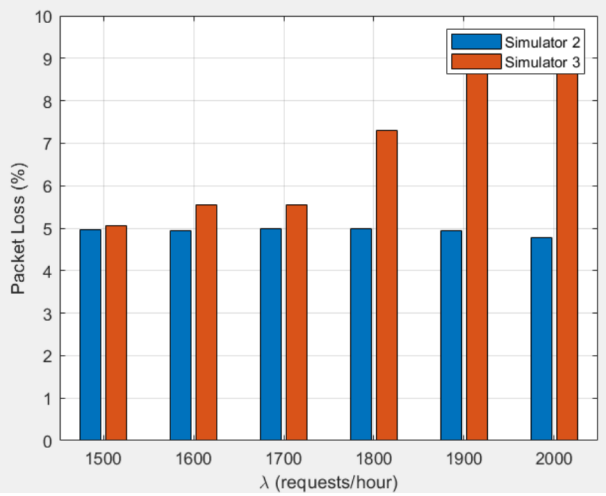
4e.

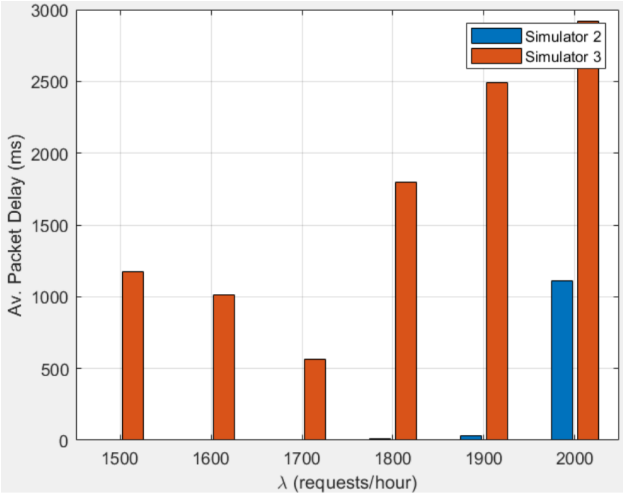
Código:

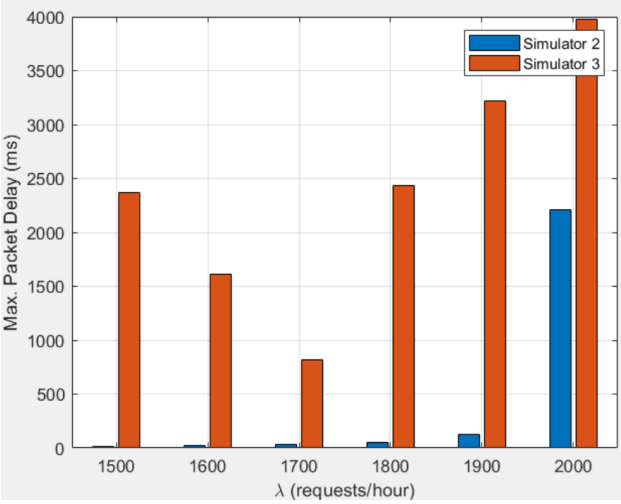
```
%% 4e
N = 10;
elambda = [1500 1600 1700 1800 1900 2000];
ePL3=zeros(1,N);
eAPD3=zeros(1,N);
eMPD3=zeros(1,N);
eTT3=zeros(1,N);
ePL2=zeros(1,N);
eAPD2=zeros(1,N);
eMPD2=zeros(1,N);
eTT2=zeros(1,N);
for i = 1:6
   for j = 1:N
       [ePL2(j),eAPD2(j),eMPD2(j),eTT2(j)] =
simulator2(elambda(i),10,10^7,100000,10^(-5));
       [ePL3(j),eAPD3(j),eMPD3(j),eTT3(j)] =
simulator3(elambda(i),10,10^7,100000,10^(-5));
   end

   alfa= 0.1;
   emediapl2(i) = mean(ePL2);
   etermpl2(i) = norminv(1-alfa/2)*sqrt(var(ePL2)/N);
   emediaapd2(i) = mean(eAPD2);
   etermapd2(i) = norminv(1-alfa/2)*sqrt(var(eAPD2)/N);
   emediampd2(i) = mean(eMPD2);
   etermmpd2(i) = norminv(1-alfa/2)*sqrt(var(eMPD2)/N);
   emediatt2(i) = mean(eTT2);
   etermtt2(i) = norminv(1-alfa/2)*sqrt(var(eTT2)/N);

   emediapl3(i) = mean(ePL3);
   etermpl3(i) = norminv(1-alfa/2)*sqrt(var(ePL3)/N);
   emediaapd3(i) = mean(eAPD3);
   etermapd3(i) = norminv(1-alfa/2)*sqrt(var(eAPD3)/N);
   emediampd3(i) = mean(eMPD3);
   etermmpd3(i) = norminv(1-alfa/2)*sqrt(var(eMPD3)/N);
   emediatt3(i) = mean(eTT3);
   etermtt3(i) = norminv(1-alfa/2)*sqrt(var(eTT3)/N);
end
```

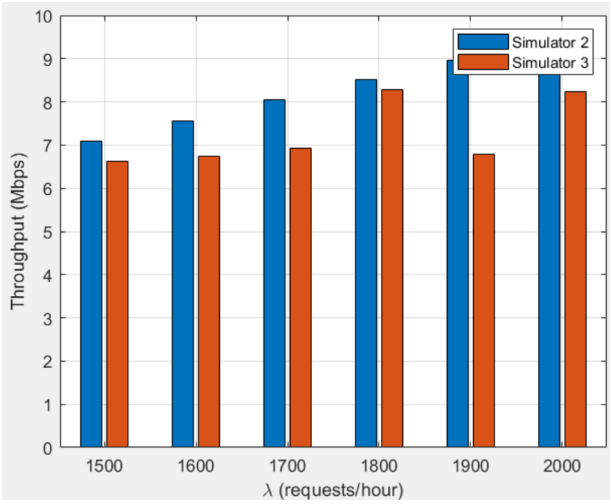
```
figure(9)
bar(lambda,[emediapl2;emediapl3])
xlabel('\lambda (requests/hour)')
ylabel('Packet Loss (%)')
grid on
legend('Simulator 2','Simulator 3')

figure(10)
bar(lambda,[emediaapd2;emediaapd3])
xlabel('\lambda (requests/hour)')
ylabel('Av. Packet Delay (ms)')
grid on
legend('Simulator 2','Simulator 3')

figure(11)
bar(lambda,[emediampd2;emediampd3])
xlabel('\lambda (requests/hour)')
ylabel('Max. Packet Delay (ms)')
grid on
legend('Simulator 2','Simulator 3')

figure(12)
bar(lambda,[emediatt2;emediatt3])
xlabel('\lambda (requests/hour)')
ylabel('Throughput (Mbps)')
grid on
legend('Simulator 2','Simulator 3')
```

Resultados:


Simulator 2
Simulator 3
Packet Loss (%)
λ (requests/hour)
0
1
2
3
4
5
6
7
8
9
10
1500
1600
1700
1800
1900
2000


Simulator 2
Simulator 3
Av. Packet Delay (ms)
λ (requests/hour)
0
500
1000
1500
2000
2500
3000
1500
1600
1700
1800
1900
2000


Simulator 2
Simulator 3
Max. Packet Delay (ms)
λ (requests/hour)
0
500
1000
1500
2000
2500
3000
3500
4000
1500
1600
1700
1800
1900
2000


Simulator 2
Simulator 3
Throughput (Mbps)
λ (requests/hour)
0
1
2
3
4
5
6
7
8
9
10
1500
1600
1700
1800
1900
2000

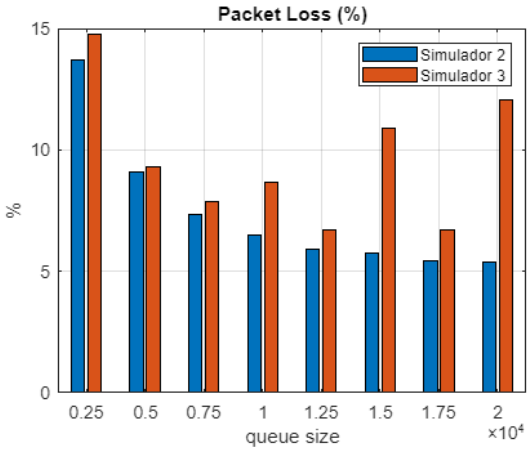
4f.

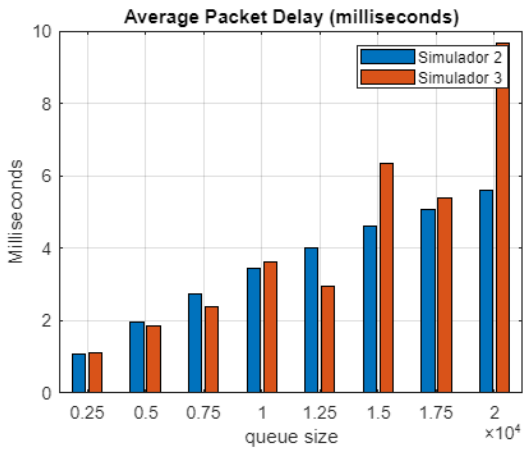
Código:

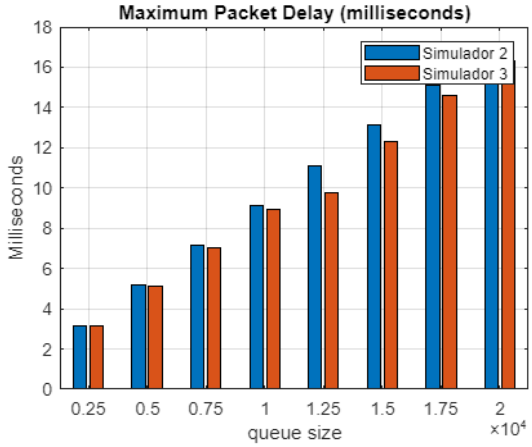
```
%% 4f
N = 10;
fd=[2500,5000,7500,10000,12500,15000,17500,20000];

PL3=zeros(1,N);
APD3=zeros(1,N);
MPD3=zeros(1,N);
TT3=zeros(1,N);
PL2=zeros(1,N);
APD2=zeros(1,N);
MPD2=zeros(1,N);
TT2=zeros(1,N);
for i=1:length(fd)
   for j= 1:N
       [PL2(j),APD2(j),MPD2(j),TT2(j)]=
simulator2(1800,10,fd(i),100000,10^(-5));
       [PL3(j),APD3(j),MPD3(j),TT3(j)]=
simulator3(1800,10,fd(i),100000,10^(-5));
   end

   alfa= 0.1;
   mediaplf2(i) = mean(PL2);
   termplf2(i) = norminv(1-alfa/2)*sqrt(var(PL2)/N);
   mediaapdf2(i) = mean(APD2);
   termapdf2(i) = norminv(1-alfa/2)*sqrt(var(APD2)/N);
   mediampdf2(i) = mean(MPD2);
   termmpdf2(i) = norminv(1-alfa/2)*sqrt(var(MPD2)/N);
   mediattf2(i) = mean(TT2);
   termttf2(i) = norminv(1-alfa/2)*sqrt(var(TT2)/N);

   mediaplf3(i) = mean(PL3);
   termplf3(i) = norminv(1-alfa/2)*sqrt(var(PL3)/N);
   mediaapdf3(i) = mean(APD3);
   termapdf3(i) = norminv(1-alfa/2)*sqrt(var(APD3)/N);
   mediampdf3(i) = mean(MPD3);
   termmpdf3(i) = norminv(1-alfa/2)*sqrt(var(MPD3)/N);
   mediattf3(i) = mean(TT3);
   termttf3(i) = norminv(1-alfa/2)*sqrt(var(TT3)/N);
End
```

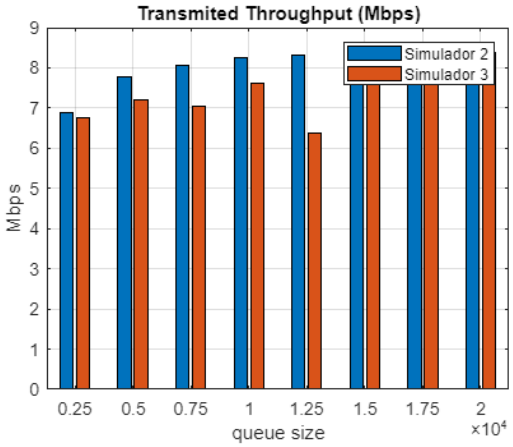
```
figure(13)
bar(fd,[mediaplf2;mediaplf3])
grid on
legend('Simulador 2','Simulador 3')
xlabel('queue size')
ylabel('%')
title('Packet Loss (%)')

figure(14)
bar(fd,[mediaapdf2;mediaapdf3])
grid on
legend('Simulador 2','Simulador 3')
xlabel('queue size')
ylabel('Milliseconds')
title('Average Packet Delay (milliseconds)')

figure(15)
bar(fd,[mediampdf2;mediampdf3])
grid on
legend('Simulador 2','Simulador 3')
xlabel('queue size')
ylabel('Milliseconds')
title('Maximum Packet Delay (milliseconds)')

figure(16)
bar(fd,[mediattf2;mediattf3])
grid on
legend('Simulador 2','Simulador 3')
xlabel('queue size')
ylabel('Mbps')
title('Transmited Throughput (Mbps)')
```

Resultados:


Packet Loss (%)
Simulador 2
Simulador 3
%
queue size
×10^4


Average Packet Delay (milliseconds)
Simulador 2
Simulador 3
Milliseconds
queue size
×10^4


Maximum Packet Delay (milliseconds)
Simulador 2
Simulador 3
Milliseconds
queue size
×10^4


Transmited Throughput (Mbps)
Simulador 2
Simulador 3
Mbps
queue size
×10^4