PERFORMANCE ESTIMATION OF PACKET SWITCHED NETWORKS

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Desempenho e Dimensionamento de Redes
4º MIECT

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a)

Table I					
Case	r (Mbps)	f (Bytes)	Average Packet Loss (%+-conf)	Avg. Packet Delay (%+-conf)	Transmitted Throughput (Mbps)
A	6	150000	00+-00	1.62 +- 2.36e-03	6.00 +- 2.83e-03
B	8	150000	00+-000	3.00 +- 8.79e-03	8.00 +- 4.85e-03
C	9	150000	00+-000	5.71e+00 +- 5.50e-02	9.00e+00 +- 8.02e-03
D	9.5	150000	00+-000	1.11e+01 +- 1.36e-01	9.50e+00 +- 5.09e-03
E	9.75	150000	7.94e-03 +- 2.47e-03	2.17e+01 +- 5.79e-01	9.75e+00 +- 4.29e-03
F	10	150000	3.14e-01 +- 2.97e-02	5.91e+01 +- 2.06e+00	9.95e+00 +- 4.40e-03
G	6	15000	1.06e-03 +- 2.85e-04	1.62e+00 +- 2.37e-03	6.00e+00 +- 5.27e-03
H	8	15000	1.46e-01 +- 3.79e-03	2.87e+00 +- 4.97e-03	7.98e+00 +- 5.06e-03
I	9	15000	8.66e-01 +- 1.47e-02	4.31e+00 +- 1.34e-02	8.88e+00 +- 4.81e-03
J	9.5	15000	1.79e+00 +- 1.64e-02	5.31e+00 +- 1.23e-02	9.27e+00 +- 2.52e-03
k	9.75	15000	2.43e+00 +- 1.38e-02	5.82e+00 +- 9.80e-03	9.42e+00 +- 3.27e-03
L	10	15000	3.20e+00 +- 1.74e-02	6.36e+00 +- 1.18e-02	9.56e+00 +- 2.98e-03

b) ***With the previous results, draw some conclusions concerning the performance of the link for the different input values of packet throughput (r) and queue size (f).***

As we can see in the table, for 1000 seconds, the only way we have an ideal performance(no package lost) is if we have a data throughput between 6 and 9.5 Mbps and a queue size of 150000 Bytes. When we start to increase the values of the data throughput, we see that there is package lost, although it's minimal.
If we change the queue size to 15000 Bytes, with the given data throughput, we are always getting package lost, even though for 6 and 8Mbps is almost despicable.

c) ***For the cases in Table I with null average packet loss, determine the theoretical values of the average packet delay assuming first the M/M/1 queuing model and, then, the M/G/1 queuing model (determine the appropriate values from the packet size statistics used in the simulator). Compare the theoretical values with the simulation results. Justify the observed differences and determine which model better approximates the system performance.***

M/M/1:

The average packet delay is: $$W = \frac{1}{\mu - \lambda} = \frac{1}{C/B - (\lambda_1 + \lambda_2)}$$

B:Average Packets Size. In order to get the average packets Size, an array has being created in the simulator, this array is used to store the size of each packet. at the end of the simulation, the elements of the array are added and divided by the length of the array.

C: b/s in the link. Using the previous array, we can obtain the b/s, dividing the sum of all elements by the time 1000s.

B=1.0020e+03
C=6000000 W=1.9084e-04s
λ=748,629

B1=1.0023e+03
C1=8000000 W=1.4317e-04s
λ=997,616

B2=1.0017e+03
C2=9000000 W=1.2718e-04s
λ=1122,587

B3=1.0014e+03
C3=9500000 W=1.2050e-04s
λ=1187,775

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M/G/1:

$$W = \frac{\lambda * E(S^2)}{2 * (1 - \lambda * E(S))} + E(S)$$

To get the value of E(S) we use the μ calculated in the previous part. E(s)=1/μ

B=1.0020e+03
C=6000000 W= 1.7892e-04s
λ=748,629

B1=1.0023e+03
C1=8000000 W=1.4317e-04s
λ=997,616

B2=1.0017e+03
C2=9000000 W=1.2718e-04s
λ=1122,587

B3=1.0014e+03
C3=9500000 W=1.2050e-04s
λ=1187,775

Case	M/M/1 (ms)	M/G/1 (ms)	Simulation (ms)
A	1.90	1.79	1.62
B	1.43	1.34	3.00
C	1.27	1.19	5.71
D	1.21	1.13	1.11

The results of the simulation are somewhat different from the calculated ones so there must be an error on the calculations or on the code.

d) ***For the cases in Table I such that the packet loss is not null, determine the theoretical values of average packet delay and average packet loss assuming the M/M/1/X model (on each case, choose the most appropriate value of X). Compare the theoretical values with the simulation results. Justify the observed differences and determine the cases for which this model is still adequate.***

Packet Loss Rate:

$$\mu_m = \frac{(\lambda/\mu)^m}{\sum_{i=0}^{m}(\lambda/\mu)^m}$$

Average number of packages in the system:

$$L = \sum_{i=0}^{m} i \times \pi_i = \frac{\sum_{i=0}^{m} i \times (\lambda/\mu)^i}{\sum_{i=0}^{m}(\lambda/\mu)^i}$$

Average Packet delay

$$W = \frac{L}{\lambda(1-\mu_m)}$$

e) Consider the following network composed by 3 routers connecting 3 networks: A, B and C. Connection 1 has a capacity of 10 Mbps and connection 2 has a capacity of 5 Mbps. Both queues are of size f = 150000 bytes. B 1 2 C A Using Simulator 2, estimate the performance parameters when the network supports a single packet flow, from A to C, with r = 4 Mbps. Run the simulator 10 times with a stopping criteria of S = 1000 seconds and present the obtained confidence intervals.

With <u>f = 150000 bytes</u> and <u>r = 4 Mbps</u>
Average Delays per Flow = 7.213772ms
Confidence of Delays per Flow = 2.363e-02
Average Packets Loss per Flow = 0%
Confidence of Packets Loss per Flow = 0

f) Using Simulator 2, estimate the performance parameters when the network supports 3 packet flows: (i) flow 1, from A to B, with r1 = 7.4 Mbps, (ii) flow 2, from A to C, with r2 = 2.3 Mbps and (iii) flow 3, from B to C, with r3 = 2.5 Mbps. Run the simulator 10 times with a stopping criteria of S = 1000 seconds and present the obtained confidence intervals.

Table III				
Case	r (Mbps)	f (Bytes)	Average Packet Loss (%+-conf)	Avg. Packet Delay (%+-conf)
Flow 1	7.4	150000/150000	3.01e-03+-1.301251e-03	1.85e+01+-4.48e-01
Flow 2	2.3	150000/150000	2.96e-03+-8.60e-04	4.5e+01+-7.07e-01
Flow 3	2.5	150000/150000	6.08e-04+-7.54e-04	2.65e+01+-5.37e-01

g) Using the Kleinrock approximation, estimate theoretically the performance of the cases simulated in e) and f). Compare the theoretical values with the results of the simulation and justify the differences.

Using the Kleinrock approximation formula:

$$W_S = \sum_{(i,j)\in R_S} \frac{1}{\mu_{ij} - \lambda_{ij}} + d_{ij}$$

with:

$$\lambda = \frac{ThroughputOfTheLink}{AverageSizeOfPacket * 8}$$

and:

$$\mu = \frac{CapacityOfLink}{AverageSizeOfPacket * 8}$$

W = 0.0093 s
W = 0.0265 s
W = 0.0662 s
W = 0.0397 s

Table IV				
Case	e)	f) Flow 1(ms)	f) Flow 2 (ms)	f) Flow 3 (ms)
W calculated	9.3	26.5	66.2	39.7
W Simulated	7.2	18.5	45	26.5

The theoretical values are always higher than the simulated ones probably due to efficiency on the running system and code. In spite of this, we can see that the values are not so different and are not so far away from the simulated ones.

h) Using simulator 2, repeat f) but now considering that the queue size of link 1 is 7500 Bytes (the queue size of link 2 remains 150000 Bytes). Compare these results with the ones obtained in f) and justify the observed differences.

Table V				
Case	r (Mbps)	f (Bytes)	Average Packet Loss (%+-conf)	Avg. Packet Delay (%+-conf)
Flow 1	7.4	7500/150000	5.32e+00+-2.328320e-02	3.19e+00+-4.360075e-03
Flow 2	2.3	7500/150000	5.33e+00+-2.902096e-02	1.75e+01+-1.769145e-01
Flow 3	2.5	7500/150000	0+-0	1.41e+01+-1.668913e-01

The results are as expected, with a queue size of link 1 much smaller, the average packet loss is much higher. This is because the queue gets full a lot sooner than the previous simulation and packets get lost when the queue if full. In this simulation, an average of more than 5 packets get lost.
The average packet delay, on the contrary, is much lower. This happens because the queue size is smaller, that is, the packets don’t have to wait so much time for their turn since there are less packets in the queue.

i)

Table VI - ISP Gateway of capacity 10 Mbps				
Case	r (Mbps)	f (Bytes)	Average Packet Loss +- conf	Avg. Packet Delay (ms) +- conf
Flow 1	2.0	every with 150000	3.26e+01+-1.020276e-01	1.19e+02+-6.401239e-03
Flow 2	6.0	every with 150000	3.26e+01+-5.018786e-02	1.51e+02+-1.211849e-01
Flow 3	10.0	every with 150000	3.25e+01+-5.088239e-02	1.91e+02+-8.427301e-02
Flow 4	16.0	every with 150000	3.68e+01+-3.812942e-02	1.20e+02+-4.993537e-03
Flow 5	50.0	every with 150000	0+-0	2.27e-01+-4.279435e-04
Flow 6	10.0	every with 150000	0+-0	1.07e-01+-6.970557e-05
Flow 7	2.0	every with 150000	3.68e+01+-1.278576e-01	1.20e+02+-5.734284e-03
Flow 8	50.0	every with 150000	0+-0	2.20e-01+-3.138204e-04
Flow 9	20.0	every with 150000	0+-0	4.63e-01+-5.162405e-04
Flow 10	2.0	every with 150000	3.68e+01+-1.180600e-01	1.20e+02+-6.665292e-03
Flow 11	10.0	every with 150000	0+-0	1.06e-01+-1.120557e-04
Flow 12	20.0	every with 150000	0+-0	3.60e-01+-4.985425e-04

Table VII. - ISP Gateway of capacity 20 Mbps				
Case	r (Mbps)	f (Bytes)	Average Packet Loss +- conf	Avg. Packet Delay (ms) +- conf
Flow 1	2.0	every with 150000	0+-0	2.85e+00+-2.763849e-02
Flow 2	6.0	every with 150000	0+-0	3.79e+00+-3.151682e-02
Flow 3	10.0	every with 150000	0+-0	4.71e+00+-4.135707e-02
Flow 4	16.0	every with 150000	3.05e-01+-3.944575e-02	2.87e+01+-7.645134e-01
Flow 5	50.0	every with 150000	0+-0	2.48e-01+-4.856031e-04
Flow 6	10.0	every with 150000	0+-0	1.12e-01+-8.718868e-05
Flow 7	2.0	every with 150000	3.12e-01+-4.324624e-02	2.90e+01+-7.711753e-01
Flow 8	50.0	every with 150000	0+-0	2.20e-01+-5.369295e-04
Flow 9	20.0	every with 150000	0+-0	4.59e-01+-8.767980e-04
Flow 10	2.0	every with 150000	3.08e-01+-4.512707e-02	2.88e+01+-7.718621e-01
Flow 11	10.0	every with 150000	0+-0	1.05e-01+-6.650233e-05
Flow 12	20.0	every with 150000	0+-0	3.79e-01+-5.202892e-04

Table VIII - ISP Gateway of capacity 30 Mbps				
Case	r (Mbps)	f (Bytes)	Average Packet Loss +- conf	Avg. Packet Delay (ms) +- conf
Flow 1	2.0	every with 150000	0+-0	5.43e-01+-1.832451e-03
Flow 2	6.0	every with 150000	0+-0	9.20e-01+-1.448120e-03
Flow 3	10.0	every with 150000	0+-0	9.85e-01+-1.678201e-03
Flow 4	16.0	every with 150000	0+-0	6.32e-01+-1.354802e-03
Flow 5	50.0	every with 150000	0+-0	2.49e-01+-6.169297e-04
Flow 6	10.0	every with 150000	0+-0	1.13e-01+-9.090123e-05
Flow 7	2.0	every with 150000	0+-0	9.26e-01+-1.303507e-03
Flow 8	50.0	every with 150000	0+-0	2.21e-01+-2.344370e-04
Flow 9	20.0	every with 150000	0+-0	4.60e-01+-6.329380e-04
Flow 10	2.0	every with 150000	0+-0	7.74e-01+-1.811715e-03
Flow 11	10.0	every with 150000	0+-0	1.03e-01+-1.293295e-04
Flow 12	20.0	every with 150000	0+-0	3.83e-01+-6.064316e-04

With the increase value of the capacity of the connection to the ISP Gateway, we see that all values (average packet loss and average packet delay) diminishes. With the ISP Gateway of capacity 30 Mbps there’s no package loss and the average packet delay is less than 1 millisecond in all 12 flows.
With a higher capacity of ISP Gateway we have an overall better simulation with less latency on the network and with no package loss.