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EVALUATION OF PACKET LOSS EFFECT ON NETWORK PERFORMANCE

Abdulaziz Alraddadi
College of Computer Science and Engenerring, Taibah University, Yanbu, Kingdom of Saudi Arabia
Corresponding Author Email: alraddadi1@yahoo.com

***Abstract**: Any advancement in new technologies requires a reliable and affordable networking infrastructure. The network performance can be expressed by several metrics such as throughput, delay and packet loss. Many networking protocols, standards and technologies were developed without full and thorough examination of the underlying performance metrics. One major metrics is the packet loss as it affects the overall performance of the network. Increased packet lost can lead to increased packets retransmissions and may worsen the network performance. In this paper, we examine the effect of packets loss in different networking scenarios. Results obtained from both simulation and analytical models are reported.*

Keywords: Network, Performance, Packet Loss, Simulation, Analytical Models.

I. INTRODUCTION

The recent and rapid advances in the networking domain require a careful examination and evaluations for the underlying assumptions used to engineer and design the flourishing new networking technologies. Many technologies and applications were developed to utilize the opportunities offered by the new networking infrastructure (wired and wireless ones). Network will play an essential role in the successful deployment of any new technological paradigm (such as cloud and ubiquitous computing).

Any advancement in new technologies requires a reliable and affordable networking infrastructure. The network performance can be expressed by several metrics such as throughput, delay and packet loss. The throughput metric represent the overall work accomplished by the network. Delay metric represent how fast this work is accomplished. And, the packet loss metric represent how faulty is the network and it is strongly associates with both throughput and delay. Higher throughput usual, but not necessarily, indicates a low packet loss. Higher delay is a strong indicator of the level of congestion in the network. If it exceeds a certain limit, a high packet loss will occur. Therefore, this paper examines the effect of packet loss on the network.

When it comes to multiplexing bursty traffic, it is wasteful to allocate to each traffic source, capacity equal to the highest rate this source can achieve (simply because the source does not send at this "peak" rate all of the time). Instead, a lesser capacity is allocated and the temporary overloads induced by an instantaneously higher arrival rate are accommodated in a buffer. Nevertheless, the introduction of a buffer brings about the possibility of losses when the buffer overflows (we assume finite buffers throughout this discussion). For example, assume that we have a single source, approximating the ON/OFF voice traffic we have seen in the past. That is, 2/3 of the time it is in OFF state (no transmission of packets) and 1/3 is in the ON state. Let us, for the sake of simplicity, assume that while in the ON state, the source emits one packet per unit of time. The ON and OFF periods are described in terms of their means. They are random periods of time, exponentially distributed, each with the corresponding mean.

It should be understood, that the moment we introduce buffers to accommodate fluctuations of the bursty input because the service rate is less than the "peak" rate, we start running the risk that the buffer cannot accommodate the bursts, or cannot accommodate several successive such bursts. Because the length of the ON and OFF periods is random, it is always possible that by the time a new burst arrives, the contents of the previous bursts have not been completely removed from the queue, hence the queue contents may increase and becomes more likely that a loss will occur. Therefore the extent to which a packet loss is observed has to do with all four factors: (1) service rate, (2) buffer size, (3) average ON period, (4) average OFF period. Take now the above example and consider what happens when we have N such sources sending their traffic to the same queue. The mixing together of several sources into one service queue is called "statistical multiplexing", equivalently, the queue can be called a "statistical multiplexer".

The rest of the paper is organized as follows. Section 2 presents some of the related work. Section 3 describes the used model and the simulation environment. Section 4 presents the obtained results and the analysis. Finally, Section 5 concludes the paper and suggests some future work.

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II. LITERATURE REVIEW

The effect of packet loss on the network performance was studied in many cases. For example, the works in [5, 6, 7, 9, 10] investigated the effect of packet loss on multimedia networks. The work in [11] studied its effect on MPLS networks. While [8] investigated the relationship between packet loss and the performance of Unmanned Aerial Vehicles.

Since the interarrival time in M/M/1 model occur based on exponential distribution, which is not the case in our system where the interarrival happen based on hyper-exponential distribution, it is not sufficient to match our results to the results generated from this analytical model. In case of CoV is equal to 1 the hyper-exponential distribution acts like exponential distribution, it is the only case where we can hold a fair comparison between our model and the M/M/1 model. In M/M/1 model, the way they compute the service time is by dividing 1 over Mu (which in this case is equal to 1) which means that M/M/1 analytical model used constant time (1) to represent the service time in their calculations. On the other hand our simulator generates service time from an exponential distribution with mean equal to 1. The same thing applies to the interarrival time distribution. A survey was done to find an existing model that can describe H/M/1 and H/M/1/K models. The only model found in the web was Thompson model [3]. This model allows you to set the value of Lambda, Mu, CoV to satisfy the requirements to your experiments. This program reports on waiting time in the queue, waiting time in the system and many other metrics.

III. SYSTEM MODEL AND SIMULATION

Two set of experiments are considered in this paper:

1- No packet loss case (unlimited buffer size)
2- Packet loss (limited buffer size)

Let us summarize the parameters introduced in the model.

- N, the number of sources.
- B, the buffer size of the statistical multiplexer.
- C, the service rate of the statistical multiplexer server (Deterministic).
- E[ON], the average ON period of single source (Exponentially distributed).
- E[OFF], the average OFF period of a single source (Exponentially distributed).
- A, the arrival rate during the ON period of a (single) source (Deterministic).

From the above, for each configuration of values, we can derive P, the packet loss probability. The simulation runs are to determine the relation of P with the rest of the parameters. However, because of the enormous set of possible settings, the simulations will be using the following additional relations between parameters: E[ON] = 20 time units. E[OFF] = 2 * E[ON]. And A = 1 packet per unit of time. Furthermore, we will normalize the service rate, C, relative to the arrival rate of packets during the ON period of a (single) source, A. That is C, is described in multiples of A. In addition, the buffer size, B, is to be normalized with respect to the average (single) source number of packets per burst, which is (E[ON]*A) = E[ON] packets. That is C, is described in multiples of E[ON]*A. Simulation time was used as a termination condition, we have to run the time long enough to reach stability state. In order to choose an appropriate simulation time several tests were done with different times. The program reports on both average unfinished work and average delay. Results indicate that the best simulation time is 1000000 time units.

IV. RESULTS AND ANALYSIS

No Packet Loss Results

This section contains the results reported by the program for both average delay and average work for H/M/1 system. Figure 1 presents the results for average unfinished work as reported by the program for H/M/1 system. Figure 2 presents the results for average delay as reported by the program for H/M/1 system.

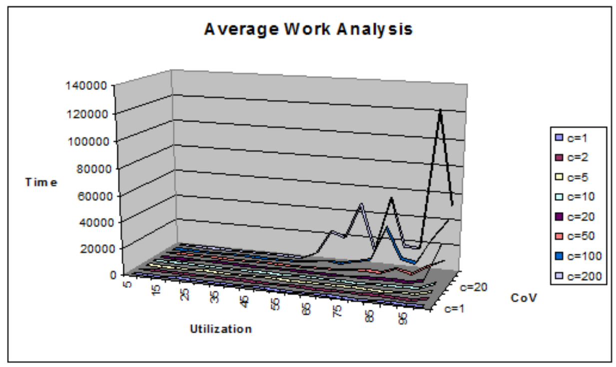

Figure 1. Average work analysis for M/M/1

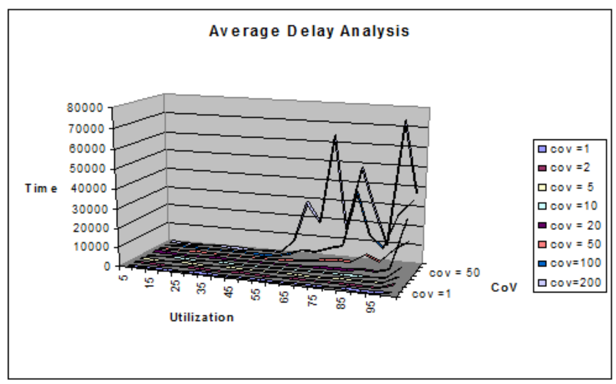

Figure 2. Average Delay analysis for M/M/1

Note: In all Figures CoV refers to Coefficient of variation. Utilization (lambda/mu) ranges from 5% to 100%.

Packet Loss Results

This section contains the results reported by the program for average delay, average work and packet loss ratio for H/M/1/B system. The experiments done for B=1, B=5 and B=10.

Figures 3, 4 and 5 present the results for H/M/1/2 system. Figure 3 presents the average work. Figure 4 presents average delay and Figure 5 presents packet loss ratio.

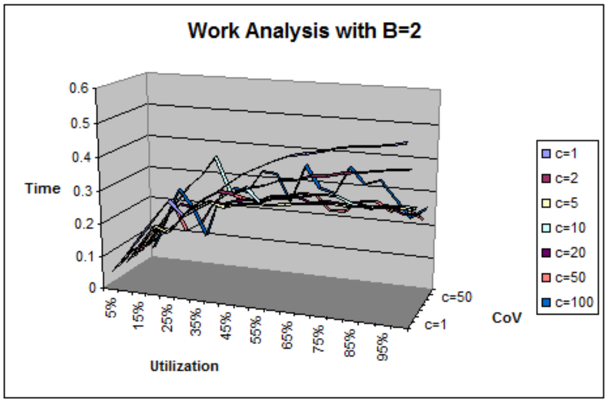

Figure 3. Work Analysis for H/M/1/2

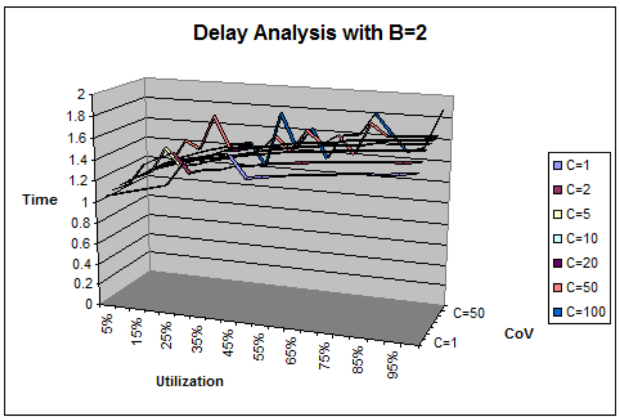

Figure 4. Work Analysis for H/M/1/2

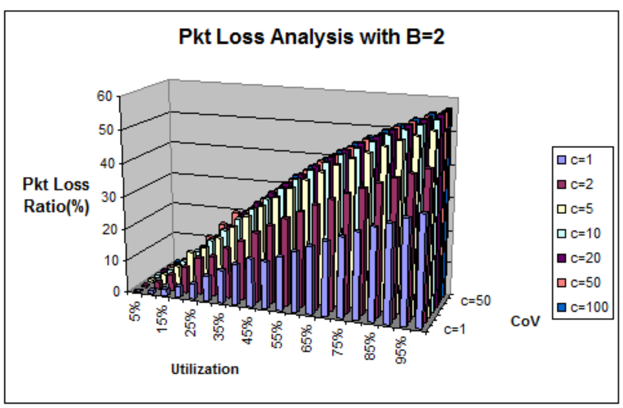

Figure 5. Work Analysis for H/M/1/2

Figure 6 presents the average work for H/M/1/5 system. Figure 4 presents average delay and Figure 5 presents packet loss ratio for the same system.

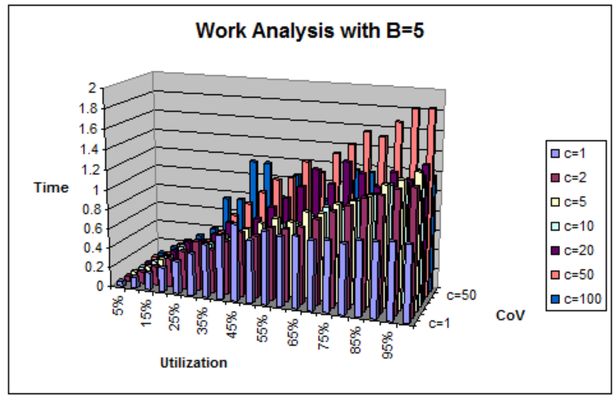

Figure 6. Work Analysis for H/M/1/5

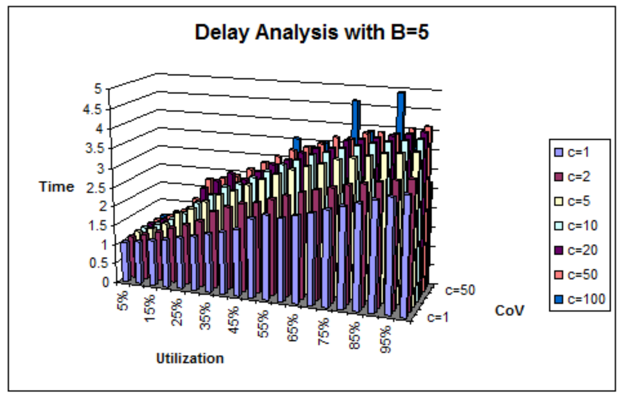

Figure 7. Delay Analysis for H/M/1/5

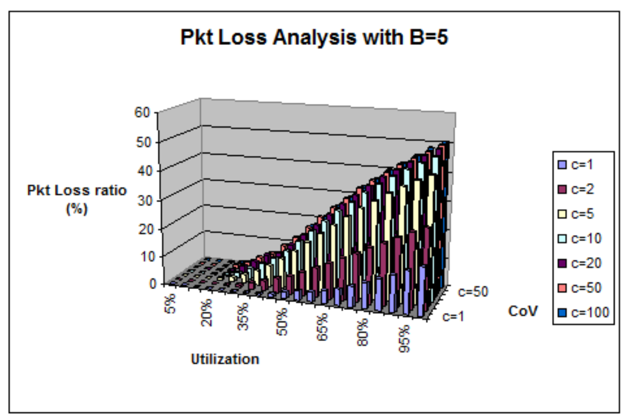

Figure 8. Packet Loss Ratio Analysis for H/M/1/5

Analysis

Figures 1 and 2 shows that while the utilization value increases the average delay and the average work values are also increasing. When the utilization value goes to 1 the values of average work and average delay are became very large. Figure 9 and Figure 10 shows the relation between average work and average delay. Figure 9 depict both average work and average delay for CoV = 2 and utilization range between 5% to 100%.

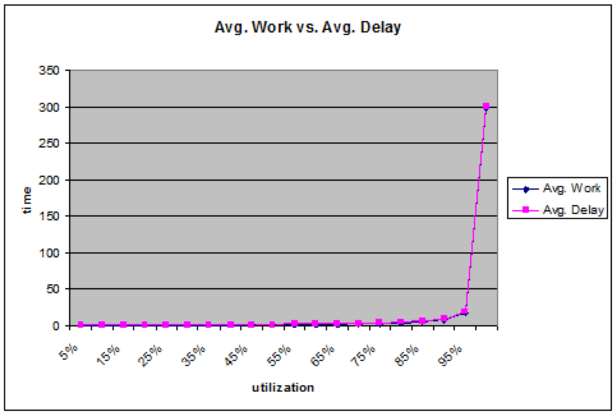

Figure 9. Relationship between avg. work and avg. delay

Figure 9 shows that the values of average work and average delay are converge while the value of utilization increases. In most cases the value of average delay is almost the same of the value of average work when the utilization is 1. Figure 10 depict both average work and average delay for CoV equal to 2 and utilization ranges between 5% to 90%. Figure 10 shows how is average work value converges to average delay value. This conclusions applies with other values of CoV.

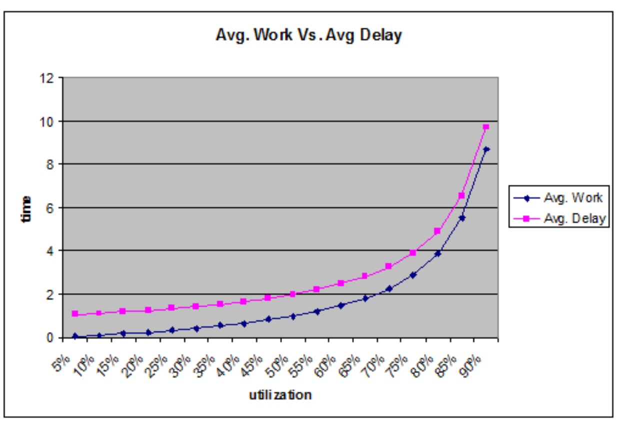

Figure 10. Relationship between avg. work and avg. delay

The results from the system with limited buffer size shows that in most cases the average work and average delay values are still increasing while the value of utilization increases. But these increases are not very large as it is in the unlimited buffer cases, the values are stay in reasonable range. In some cases, the value of average delay and average work goes up and then goes down.

The packet loss ratio is increases with the increase of the utilization value, but it is decreases with the increase of the buffer size.

A reasonable explanation for all above conclusion that with small value of utilization the arrival e rate to the system is very slow, on the other hand, the service rate is very fast. This explains the small values of average work and average delay and zero packet loss with very small utilization. On the other hand, with very high utilization the arrival rate is almost the same as or faster than the service rate. In this case the system queue will start build up, which means more waiting time in the system and more packets will be drooped in case of finite buffer size.

ANALYTICAL MODEL RESULTS

M/M/1 model with hyper-exponential distributed interarrival time and exponentially distributed service time is presented in Figure 11.

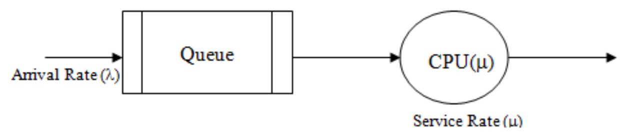

Figure 11. Simple M/M/1 System

The following formulas used to calculate average delay and average workload for M/M/1 system [2]:
Mean waiting time = $\rho\ ((1/\mu) / (1-\rho))$.

Table 2 presents the results of average work and average delay for M/M/1 system as reported by the program from [3].

Figure 12 depicts the values for both average work and average delay for analytical M/M/1 system as reported in Table 1. The analytical model was unable to predict the results for 100% utilization.

Table 1. M/M/1 model analytical results

Utilization	**Average Delay time**	**Average virtual waiting time**
5 %	1.053	0.053
10 %	1.111	0.111
15 %	1.176	0.176
20 %	1.250	0.250
25 %	0.333	1.333
30 %	1.428	0.428
35 %	1.538	0.538
40 %	1.666	0.666
45 %	1.818	0.818
50 %	2.00	1.00
55 %	2.22	1.22
60 %	2.5	1.5
65 %	2.857	1.857
70 %	3.333	2.333
75 %	4.00	3.00
80 %	5.00	4.00
85 %	6.66	5.66
90 %	10	9
95 %	20	19

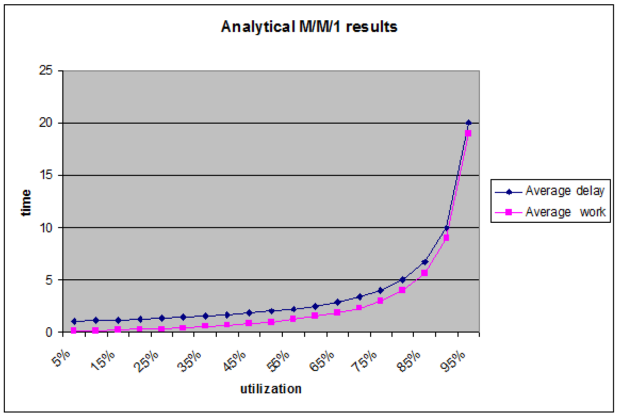

Figure 12. M/M/1 model analytical results

Table 2 compares the results obtained by our program (simulated model) with CoV equal to two against the results obtained from the analytical M/M/1 model. With CoV equal to two the simulation model became M/M/1 model instead of H/M/1 model.

Table. 2 Results of Analytical model vs. results of simulation model

Utilization	Analytical Avg. Delay	Analytical Avg. Work	Simulation Avg. Work	Simulation Avg. Delay
5 %	1.053	0.053	0.0527	1.05
10 %	1.111	0.111	0.111	1.112144
15 %	1.176	0.176	0.175	1.17617
20 %	1.250	0.250	0.2489	1.249664
25 %	0.333	1.333	0.33	1.328
30 %	1.428	0.428	0.423	1.42
35 %	1.538	0.538	0.532	1.529
40 %	1.666	0.666	0.658	1.655
45 %	1.818	0.818	0.807	1.805
50 %	2.00	1.00	0.988	1.987
55 %	2.22	1.22	1.202	2.199
60 %	2.5	1.5	1.47	2.47
65 %	2.857	1.857	1.816	2.81
70 %	3.333	2.333	2.27	3.27
75 %	4.00	3.00	2.9	3.9
80 %	5.00	4.00	3.88	4.875
85 %	6.66	5.66	5.52	6.51
90 %	10	9	8.69	9.69
95 %	20	19	17.53	18.52

The results obtained from the analytical model are compatible with the results obtained from the simulation model.

Tables 3, 4 and 5 show the comparison between the results obtained from the simulation model against the results obtained from analytical M/M/1/K model. Table 3 presents the results obtained from both analytical M/M/1/2 model and simulated model. It presents average work, average delay and packet loss ratio.

Table 3. Results comparison between analytical M/M/1/2 model vs. simulated model

Utilization	Analytical Avg. Delay	Analytical Avg. Work	Analytical Pkt loss ratio	Simulation Avg. Work	Simulation Avg. Delay	Simulated Pkt loss ratio
5 %	0.0522	1.047	0.23	0.05238	1.046916	0.22
10 %	.108	1.09	0.901	0.10767	1.089322	0.93
15 %	0.166	1.13	1.9	0.165953	1.12639	2.00
20 %	0.226	1.166	3.2	0.226082	1.168748	3.306 %
25 %	0.285	1.2	4.7	0.284821	1.199677	4.826638
30 %	0.345	1.23	6.4	0.243372	1.406509	7.750943
35 %	0.404	1.259	8.3	0.282961	1.466359	10.09193
40 %	0.46	1.285	10.25	0.315508	1.490311	12.33196
45 %	0.517	1.31	12.25	0.348649	1.522223	14.59686
50 %	0.57	1.333	14.3	0.384521	1.332308	14.32971
55 %	0.62	1.35	16.3	0.406861	1.356291	16.35768
60 %	0.67	1.375	18.3	0.427154	1.377485	18.36118
65 %	0.72	1.39	20.38	0.447667	1.400599	20.49271
70 %	0.767	1.41	22.3	0.455926	1.413787	22.44673
75 %	0.81	1.428	24.3	0.46635	1.429719	24.33714
80 %	0.852	1.444	26.2	0.478398	1.447978	26.17813
85 %	0.89	1.459	28.08	0.487075	1.463336	28.10967
90 %	0.929	1.47	29.88	0.488678	1.462243	29.61935
95 %	0.965	1.487	31.6	0.496287	1.483814	31.56953

Table 4 presents the results obtained from both analytical M/M/1/5 model and simulated model. It presents average work, average delay and packet loss ratio (percentage %).

Table 4. Results comparison between analytical M/M/1/5 model vs. simulated model

Utilization	Analytical Avg. Delay	Analytical Avg. Work	Analytical Pkt loss ratio	Simulation Avg. Work	Simulation Avg. Delay	Simulated Pkt loss ratio
5 %	.052	1.052	0	0.052818	1.053107	0
10 %	0.111	1.111	9E-6	0.111273	1.111126	0.000997
15 %	0.176	1.176	6.5E-5	0.177684	1.180221	0.005995
20 %	0.249	1.248	0.025	0.247235	1.245116	0.032636
25 %	0.33	1.328	0.073	0.332989	1.331288	0.071666
30 %	0.424	1.416	0.17	0.424421	1.418032	0.185868
35 %	0.527	1.51	0.34	0.532573	1.522725	0.35591
40 %	0.64	1.615	0.61	0.644427	1.617102	0.634043
45 %	0.768	1.724	1.02	0.768039	1.724967	1.05202
50 %	0.904	1.838	1.58	0.629859	2.040882	2.297521
55 %	1.05	1.95	2.3	0.732277	2.164818	3.272156
60 %	1.206	2.07	3.26	0.698102	2.123706	3.539956
65 %	1.367	2.2	4.39	0.720177	2.226665	4.502794
70 %	1.53	2.3	5.7	0.698271	2.330058	5.722472
75 %	1.7	2.44	7.2	0.713534	2.451431	7.256517
80 %	1.86	2.56	8.88	0.696271	2.575018	8.960027
85 %	2.03	2.678	10.68	0.746961	2.690528	10.81181
90 %	2.19	2.79	12.6	0.748724	2.796731	12.66122
95 %	2.35	2.89	14.6	0.766542	2.906241	14.70578

Analytical model always reports a non-zero value for packet loss, in the cases where you find a zero analytical packet loss ratio in tables 5, 6 and 7 this means that the value is very small. Table 5 presents the results obtained from both analytical M/M/1/10 model and simulated model. It presents average work, average delay and packet loss ratio (percentage %).

Table 5. Results comparison between analytical M/M/1/10 model vs. simulated model

Utilization	Analytical Avg. Delay	Analytical Avg. Work	Analytical Pkt loss ratio	Simulation Avg. Work	Simulation Avg. Delay	Simulated Pkt loss ratio
5 %	0.052	1.052	0	0.052818	1.053107	0
10 %	0.11	1.11	0	0.111162	1.112144	0
15 %	0.176	1.176	0	0.176809	1.17617	0
20 %	0.249	1.249	0	0.248465	1.249664	0
25 %	0.333	1.333	0	0.248488	1.414291	0
30 %	0.428	1.428	4.1E-6	0.305063	1.488601	0.002335
35 %	0.538	1.538	1.79E-5	0.370516	1.625818	0.006027
40 %	0.66	1.66	6.3E-5	0.453321	1.790352	0.01421
45 %	0.816	1.816	0.018	0.540539	1.957655	0.037346
50 %	0.994	1.99	0.0488	0.670573	2.180773	0.093829
55 %	1.2	2.19	0.11	0.81179	2.400361	0.202707
60 %	1.459	2.439	0.24	0.788845	2.513159	0.321271
65 %	1.76	2.72	0.45	0.969065	2.804439	0.600332
70 %	2.11	3.04	0.864	0.979032	3.069497	0.908895
75 %	2.5	3.4	1.46	1.09393	3.429478	1.512354
80 %	2.96	3.79	2.3	1.290715	3.811887	2.406601
85 %	3.45	4.2	3.5	1.566952	4.264267	3.693392
90 %	3.97	4.64	5.08	1.883545	4.684878	5.24951
95 %	4.489	5.07	6.9	1.949581	5.091342	6.974656

In general, tables 4, 5 and 6 show that the results obtained by our program most likely match the results obtained from the typical M/M/1/K model.

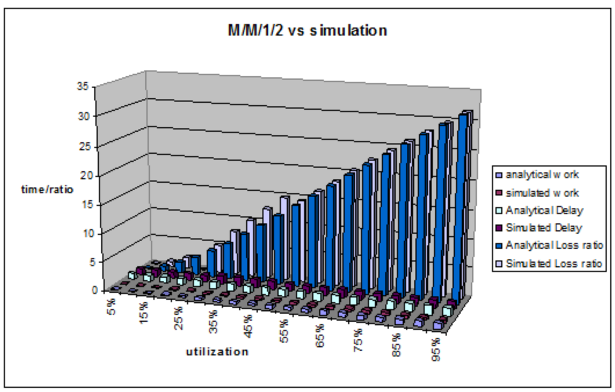

Figure 13. M/M/1/K vs. Simulated model

Figure 13 presents the results from M/M/1/2 model against the results from our program (simulated model). It depicts the average work, average delay and packet loss ratio for the both models. Figure 13 shows that there are no big differences between the values obtained by the two models. For both models, packet loss ratio increases while the utilization increases. On the other hand, packet loss ratio decreases while the buffer size increases.

V. CONCLUSION AND FUTURE WORK

In this paper we examined the behavior for both average delay and average work. It has been shown that the value of average work converges to the value of average delay while the utilization increases. In most cases, with 100% utilization the two values are equal or very close to each other. In analytical M/M/1 model with unlimited buffer size the average delay is always equal to the average work plus service time (1/Mu). Service time in this case was always equal to one.

We present the results from M/M/1 and M/M/1/k models and compare their results to the results obtained from the simulation model. It has been shown that the analytical models results are most likely match our results.

For future work, we propose to investigate the relationship between packet loss and other parameters such as link capacity. Based on the results obtained, we recommend

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