Result & Analysis:

To test the correctness of our program, we followed the instruction and test the program with following data sets:

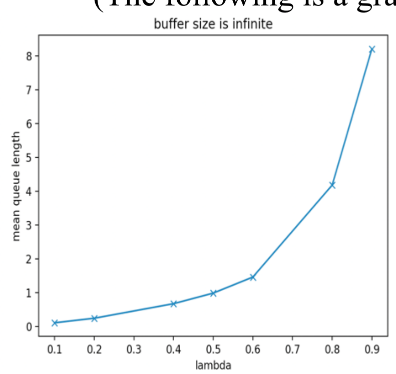
1)
Assume that $\mu = 1$ packet/second. Plot the queue-length and the server utilization as a function of λ for $\lambda = 0.1, 0.2, 0.4, 0.5, 0.6, 0.80, 0.90$ packets/second when the buffer size is infinite.

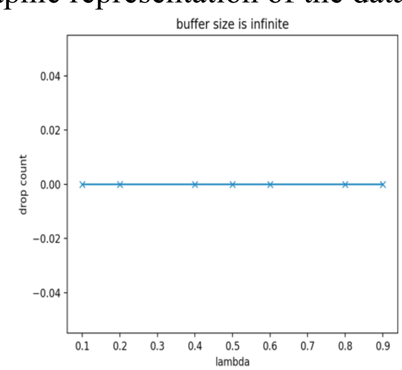
After inputting data into our program, we received the following results:

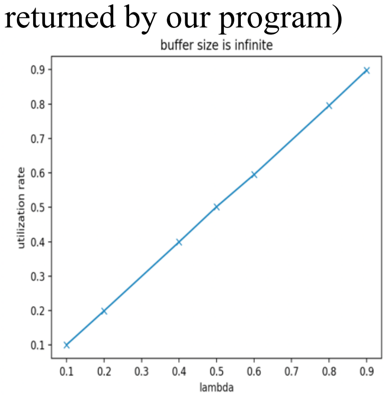
lambda	u	maxbuffer		dropcount	mean queue	utilization rate
0.1	1	-1		0	0.11142	0.100774
0.2	1	-1		0	0.245315	0.199309
0.4	1	-1		0	0.67566	0.399479
0.5	1	-1		0	0.98804	0.501785
0.6	1	-1		0	1.463251	0.5952
0.8	1	-1		0	4.18326	0.795634
0.9	1	-1		0	8.207232	0.898451

As you can see, with the buffer size set to infinite (we represent infinity with -1 in our program) and a fixed $\mu = 1$ packet/second, the number of packets dropped is constantly zero as expected, and both mean queue length and utilization rate increases as λ increases.

(The following is a graphic representation of the data returned by our program)

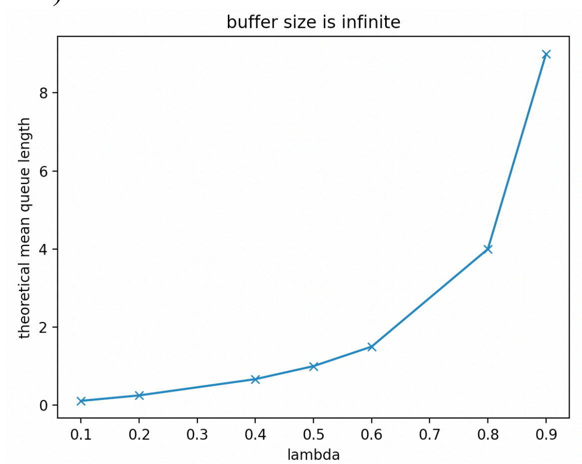


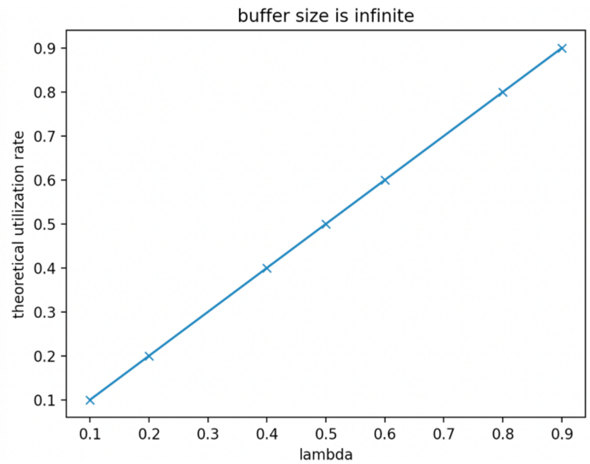




In order to further test the correctness of the results return by our program, we also compare it with the theoretical value:
We first compute the Utilization factor $p = \frac{\lambda}{\mu}$ and gets values with is essentially identical to the values of λ, and we also get the average utilization with the formula $p = \frac{\lambda}{\mu}$

(The follow is the graphic result for theoretical values of mean queue length and utilization rate.)





As the above pictures show, our results are the same as the theoretical values, which proven the correctness of our program.

2)

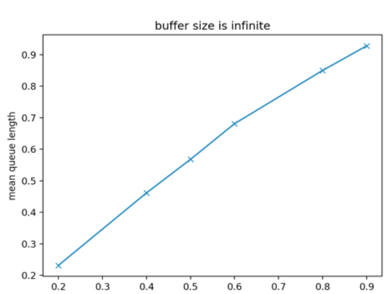
Assume that μ = 1 packet/second. Plot the total number of dropped packets as a function of λ for λ = 0.2, 0.4, 0.5, 0.6, 0.8, 0.9 packets/second for MAXBUFFER = 1.

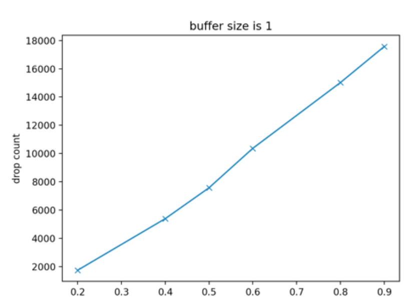
After inputting data into our program, we received the following results:

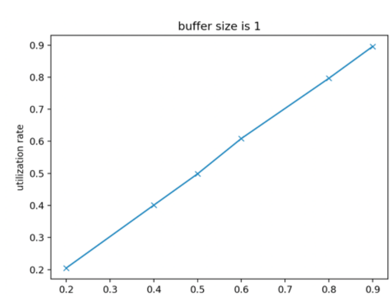
lambda	u	maxbuffer		dropcount	mean queue	utilization rate
0.2	1	1		1737	0.231674	0.204953
0.4	1	1		5387	0.461571	0.400925
0.5	1	1		7575	0.567896	0.49853
0.6	1	1		10369	0.681055	0.608637
0.8	1	1		15024	0.84986	0.796405
0.9	1	1		17575	0.927791	0.895581

As you can see, with the buffer size set to 1 and a fixed μ = 1 packet/second, the number of packets dropped, mean queue length and utilization rate increases as λ increases.

(The following is a graphic representation of the data returned by our program)



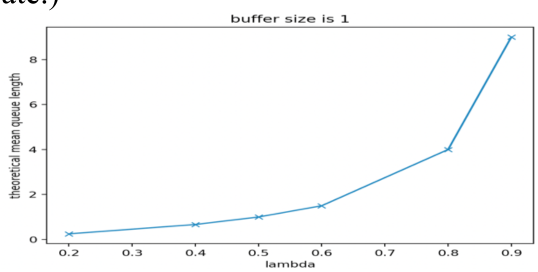


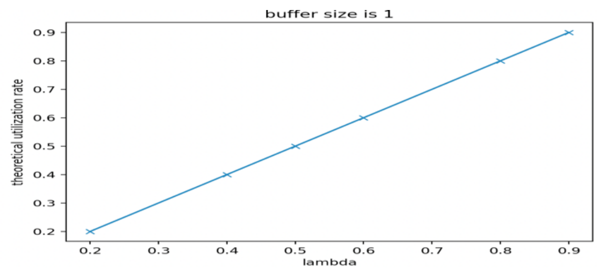


In order to further test the correctness of the results return by our program, we also compare it with the theoretical value:

We first compute the Utilization factor $p = \frac{\lambda}{\mu}$ and gets values with is essentially identical to the values of λ, and we also get the average utilization with the formula $p = \frac{\lambda}{\mu}$

(The follow is the graphic result for theoretical values of mean queue length and utilization rate.)





As the above pictures show, our result of utilization is the same as the theoretical value. However, also as above pictures show, the theoretical mean queue length is different from our result. This is because the theoretical value for mean queue length does not take the maximum buffer size into consideration, so the theoretical mean queue length is not realistic and is only for reference.

3)

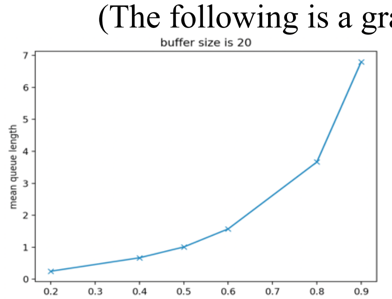
Assume that μ = 1 packet/second. Plot the total number of dropped packets as a function of λ for λ = 0.2, 0.4, 0.5, 0.6, 0.8, 0.9 packets/second for MAXBUFFER = 20.

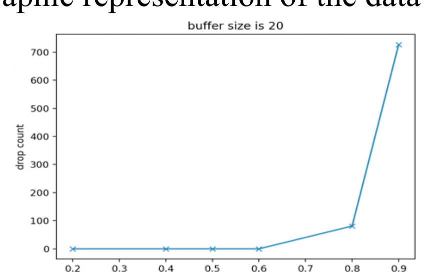
After inputting data into our program, we received the following results:

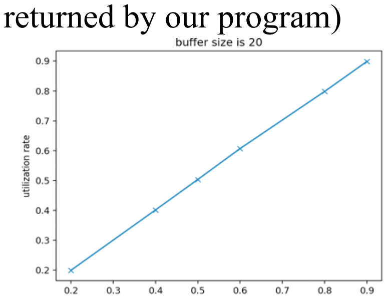
lambda	u	maxbuffer		dropcount	mean queue	utilization rate
0.2	1	20		0	0.24822	0.199073
0.4	1	20		0	0.668407	0.40126
0.5	1	20		0	1.00688	0.503206
0.6	1	20		0	1.57174	0.606748
0.8	1	20		81	3.663989	0.798178
0.9	1	20		727	6.800433	0.898606

As you can see, with the buffer size set to 1 and a fixed μ = 1 packet/second, the number of packets dropped, mean queue length and utilization rate increases as λ increases as always.

(The following is a graphic representation of the data returned by our program)



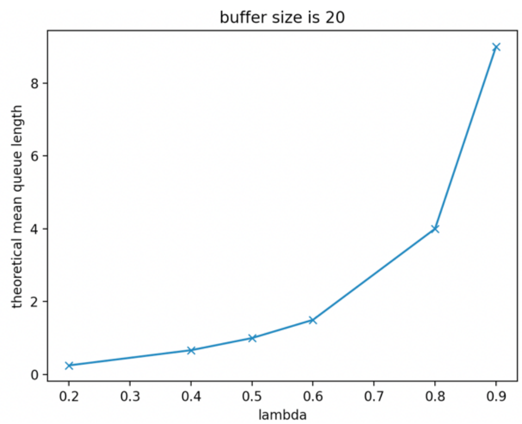


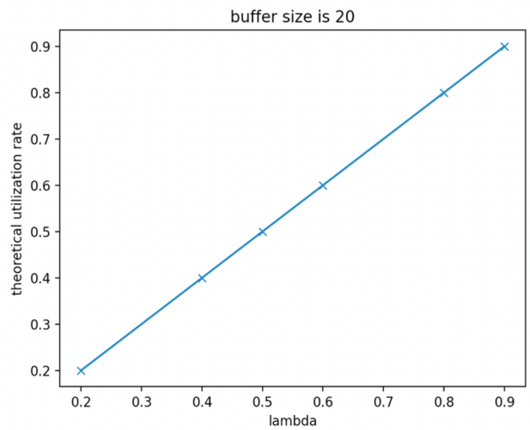


In order to further test the correctness of the results return by our program, we also compare it with the theoretical value:

We first compute the Utilization factor $p = \frac{\lambda}{\mu}$ and gets values with is essentially identical to the values of λ, and we also get the average utilization with the formula $p = \frac{\lambda}{\mu}$

(The follow is the graphic result for theoretical values of mean queue length and utilization rate.)





As the above pictures show, our results are the same as the theoretical values, which proven the correctness of our program.

4)

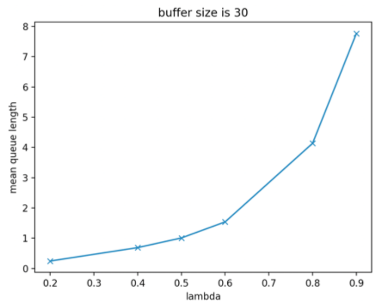
Assume that μ = 1 packet/second. Plot the total number of dropped packets as a function of λ for λ = 0.2, 0.4, 0.5, 0.6, 0.8, 0.9 packets/second for MAXBUFFER = 30.

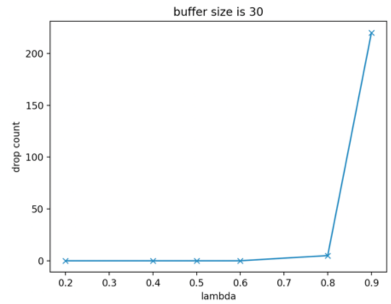
After inputting data into our program, we received the following results:

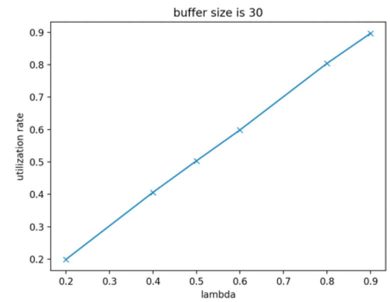
lambda	u	maxbuffer		dropcount	mean queue	utilization rate
0.2	1	30		0	0.24536	0.199022
0.4	1	30		0	0.68784	0.406016
0.5	1	30		0	1.00826	0.503396
0.6	1	30		0	1.538089	0.598665
0.8	1	30		5	4.137769	0.804323
0.9	1	30		220	7.768577	0.896989

As you can see, with the buffer size set to 1 and a fixed μ = 1 packet/second, the number of packets dropped, mean queue length and utilization rate increases as λ increases as always.

(The following is a graphic representation of the data returned by our program)

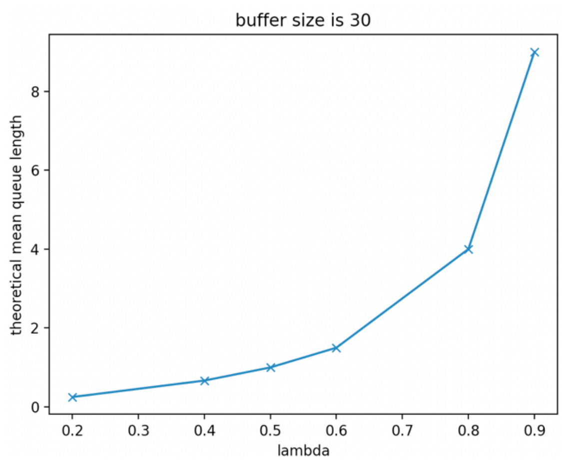


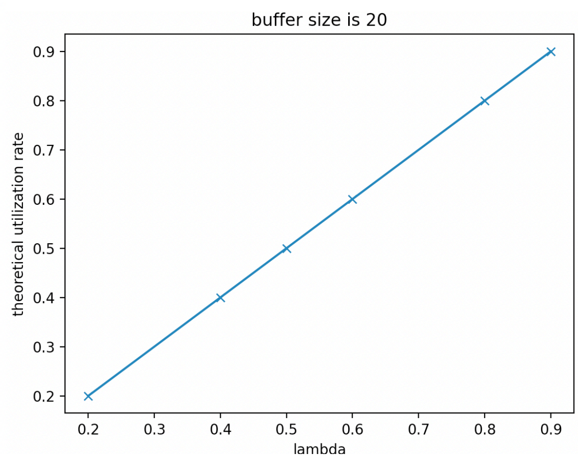




In order to further test the correctness of the results return by our program, we also compare it with the theoretical value:

We first compute the Utilization factor $p = \frac{\lambda}{\mu}$ and gets values with is essentially identical to the values of λ, and we also get the average utilization with the formula $p = \frac{\lambda}{\mu}$





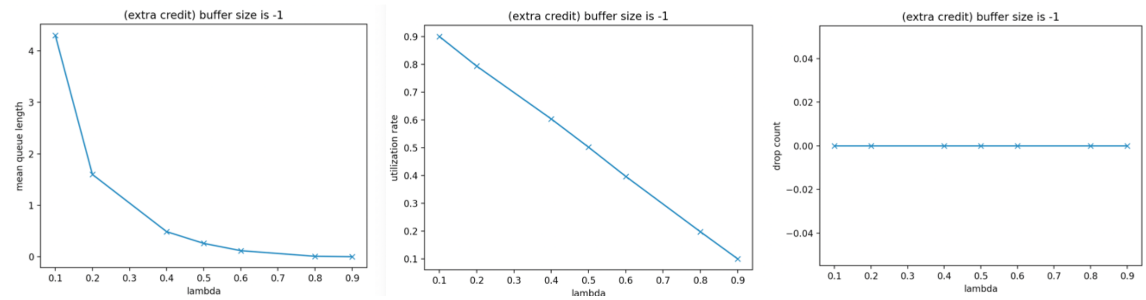
As the above pictures show, our results are the same as the theoretical values, which proven the correctness of our program.

Conclusion:

By comparing the data returned by our program and the theoretical results, our program shows a satisfying result. The only inconsistency which happens when max buffer size is 1 can also be explain with the fact that the formula does not take buffer size limitation into consideration. Therefore, our program shows a promising result overall.

Extra credit:
We let arrival rate follows the Pareto distribution and let service rate still follows negative exponential distribution as before. More specifically, we set both “scale” and “shape” parameters of Pareto distribution to 1 and get the following results.

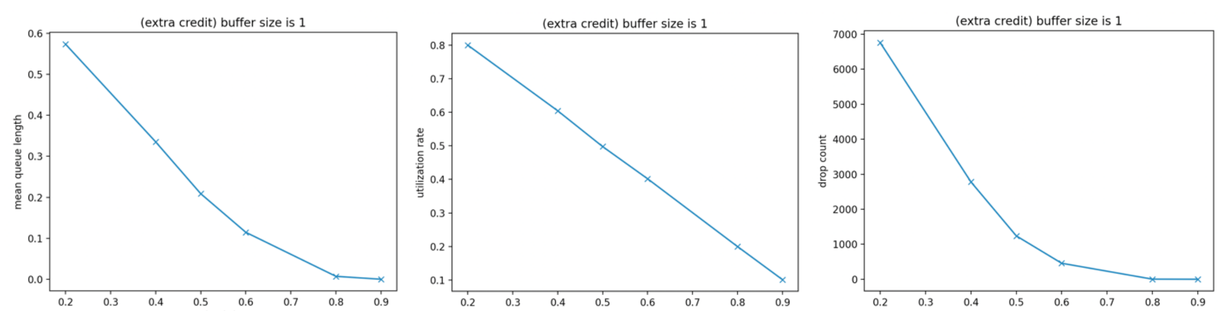
1)
Assume that $\mu = 1$ packet/second. Plot the queue-length and the server utilization as a function of λ for $\lambda = 0.1, 0.2, 0.4, 0.5, 0.6, 0.80, 0.90$ packets/second when the buffer size is infinite.



(The left most chart is the chart for mean queue length using the above setup, the middle chart is the chart for utilization rate using above setup, and the right most chart is the chart for drop count using above setup.)

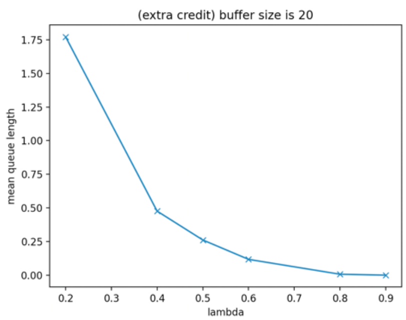
As the chart shows, the drop count is always zero as expected because we have infinite buffer so no packets should be dropped, and both mean queue length and utilization rate has a negative gradient, which are opposite to the trench when using negative exponential distribution for arrival rate.

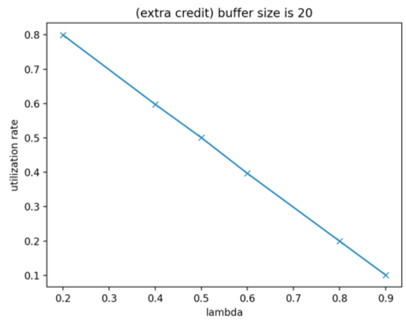
2)
Assume that $\mu = 1$ packet/second. Plot the total number of dropped packets as a function of λ for $\lambda = 0.2, 0.4, 0.5, 0.6, 0.8, 0.9$ packets/second for MAXBUFFER = 1.

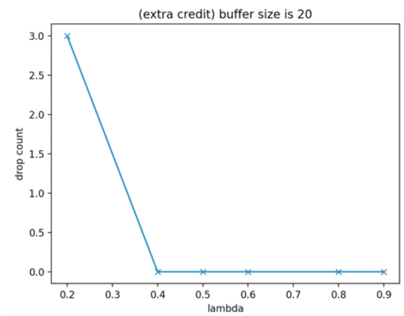


Since the maximum buffer size is now set to 1, there are now packets being dropped. As the charts shows, the gradient for mean queue length, utilization and drop count are not all negative and are still opposite to the trend when using negative exponential distribution for arrival rate.

3)
Assume that μ = 1 packet/second. Plot the total number of dropped packets as a function of λ for λ = 0.2, 0.4, 0.5, 0.6, 0.8, 0.9 packets/second for MAXBUFFER = 20.

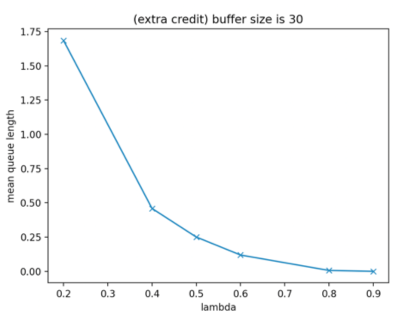


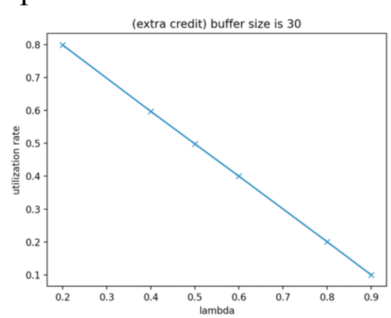


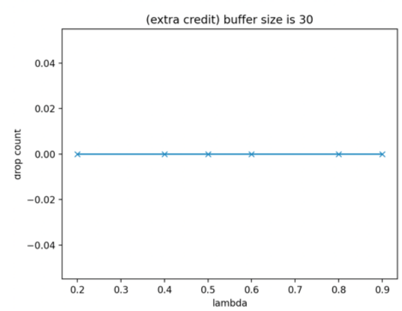


The overall trend of mean queue length and utilization rate did not change much. However, the drop count reaches and stays at 0, probably because of the pareto distribution has reached the flat area.

4)
Assume that μ = 1 packet/second. Plot the total number of dropped packets as a function of λ for λ = 0.2, 0.4, 0.5, 0.6, 0.8, 0.9 packets/second for MAXBUFFER = 30.







The overall trend of mean queue length and utilization rate did not change much. However, the drop stays at 0, probably because that the processing speed is much faster than arrival speed and the buffer never reaches its maximum size.

Conclusion:
Overall, using Pareto distribution for arrival rate and negative exponential distribution for service rate shows an opposite trending for mean queue length and utilization rate. As for drop count, it also shows the opposite trending when we set max buffer size to 1 and 10, and probably because of Pareto distribution's property, the drop count is constantly zero when we set max buffer to 30.