Name: Xingrong Zong

A) Service times

Name of service center	Service Time (S_k)
WebServer	**0.06**
ApplicationServer	**0.25**
VoucherPaymentServer	**0.075**

B) Simulation results

Name of service center	Utilization	Throughput
WebServer	**0.1898**	**3.1533**
ApplicationServer	**0.7814**	**3.1449**
Database	**0.1107**	**3.1449**
CardPaymentServer	**0.3510**	**1.7599**
VoucherPaymentServer	**0.0565**	**0.7521**

Average System Response Time: 3.8914

Average time that a user is waiting for a reply from the system 0.5499

C) System upgrade

Name of service center	Minimum number of resources	Utilization	Throughput
WebServer	**2**	**0.8599**	**14.2869**
ApplicationServer	**7**	**1**	**3.9453**
Database	**1**	**0.1393**	**4.0053**
CardPaymentServer	**3**	**0.4508**	**2.2368**
VoucherPaymentServer	**1**	**0.0725**	**0.9605**

Average System Response Time: 3.96E5

Average time that a user is waiting for a reply from the system 0.547

1 a)

1.1 Web Server

$$T = 3\ days = 3 \times 24 \times 60 \times 60 = 259200\ s$$
$$C_1 = 466560$$
$$D_1 = 104.16\ ms = 0.10416\ s$$
$$V_1 = 1.7361\ visites$$
$$S_1 = \frac{D_1}{V_1} = 0.059996544\ s\ \approx 0.06\ s$$

1.2 Application Server

$$U_2 = 0.7812$$
$$N_2 = 3.565\ jobs$$
$$R_2 = 1.1408\ s$$
$$X_2 = \frac{N_2}{R_2} = \frac{3.565}{1.1408} = 3.125$$
$$S_2 = \frac{B_2}{C_2} = \frac{U_2\ \times\ T}{C_2} = \frac{U_2}{X_2} = \frac{0.7812}{3.125} = 0.249984\ s\ \approx 0.25\ s$$
$$C_2\ =\ X_2 \times T = 3.125 \times 259200\ = 810000$$

1.3 Database

$$C_3\ =\ C_2\ \times 4 = 810000 \times 4 = 3240000$$
$$S_3 = 0.035\ s$$

1.4 User Thinking

$$C_4\ =\ C_3\ \times 0.8 = 3240000 \times 0.8 = 2592000$$
$$Z_4 = 20\ s$$

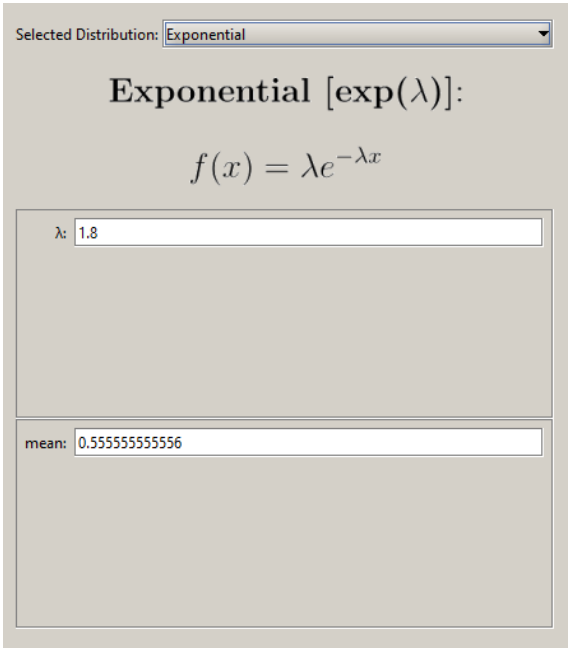
1.5 Voucher Payment Server

$$C_6\ =\ C_4\ \times 0.3 = 2592000 \times 0.3 = 777600$$
$$U_6 = 0.225$$
$$X_6 = \frac{C_6}{T} = \frac{777600}{259200} = 3$$
$$S_6 = \frac{B_6}{C_6} = \frac{U_6\ \times\ T}{C_6} = \frac{U_6}{X_6} = \frac{0.225}{3} = 0.075$$

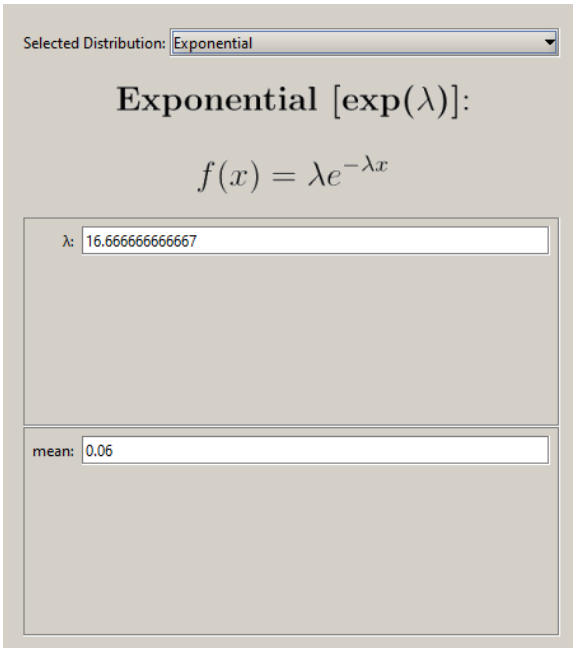
2 b)

2.1 Model

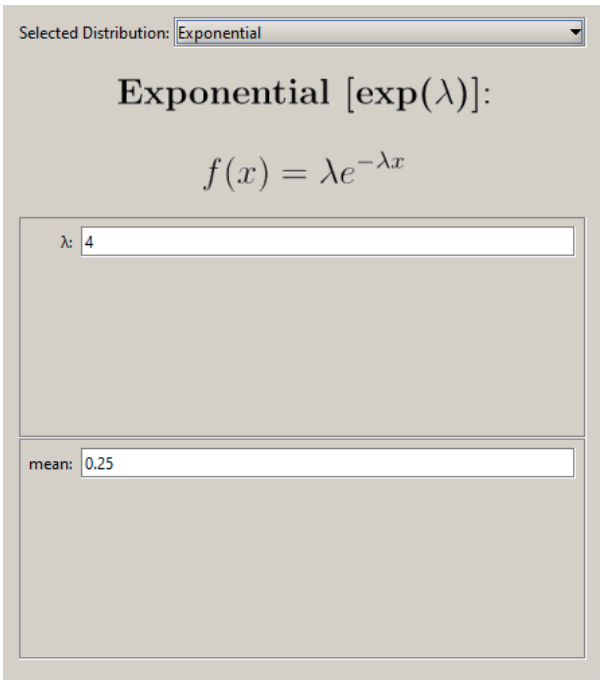
2.1.1 Source 1



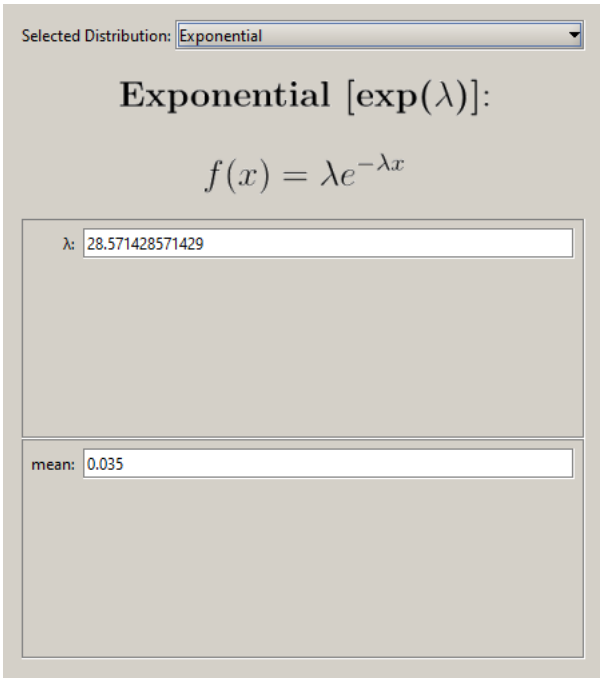
2.1.2 Web Server



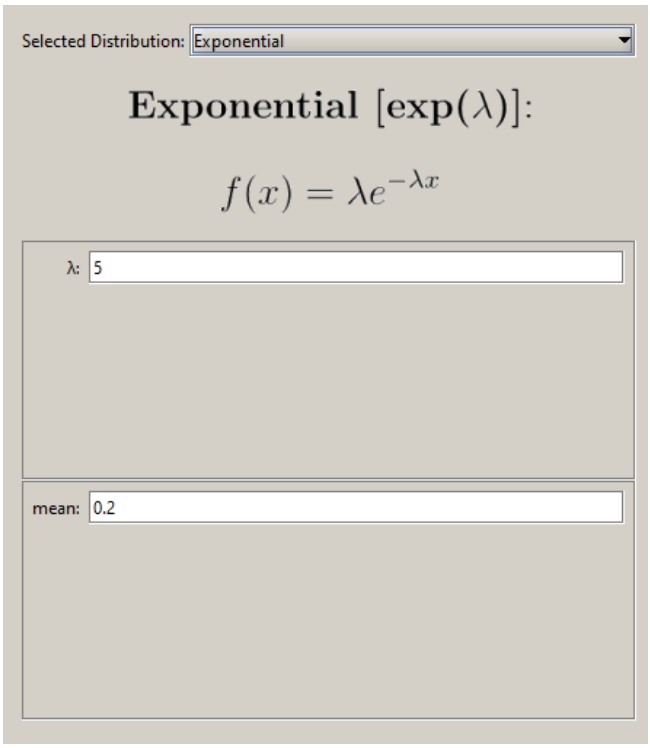
2.1.3 Application Server



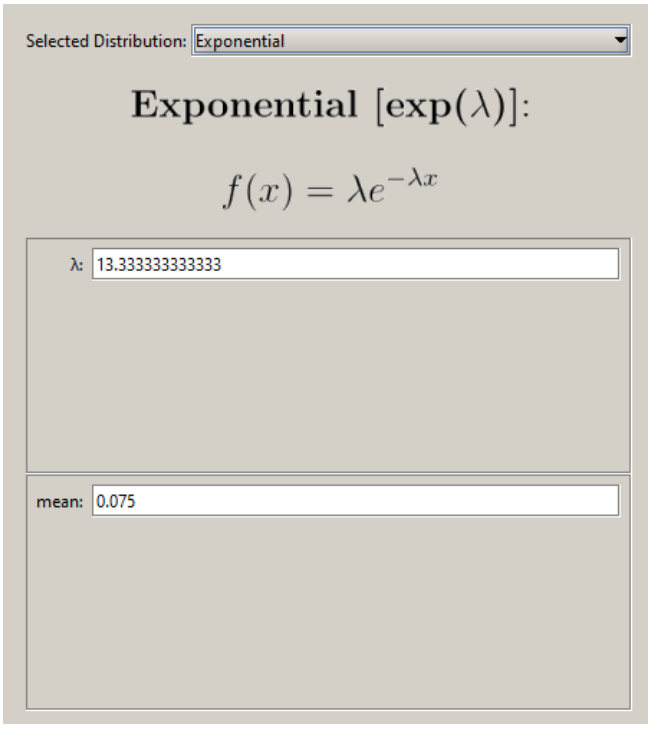
2.1.4 Database



2.1.5 CardPayment Server

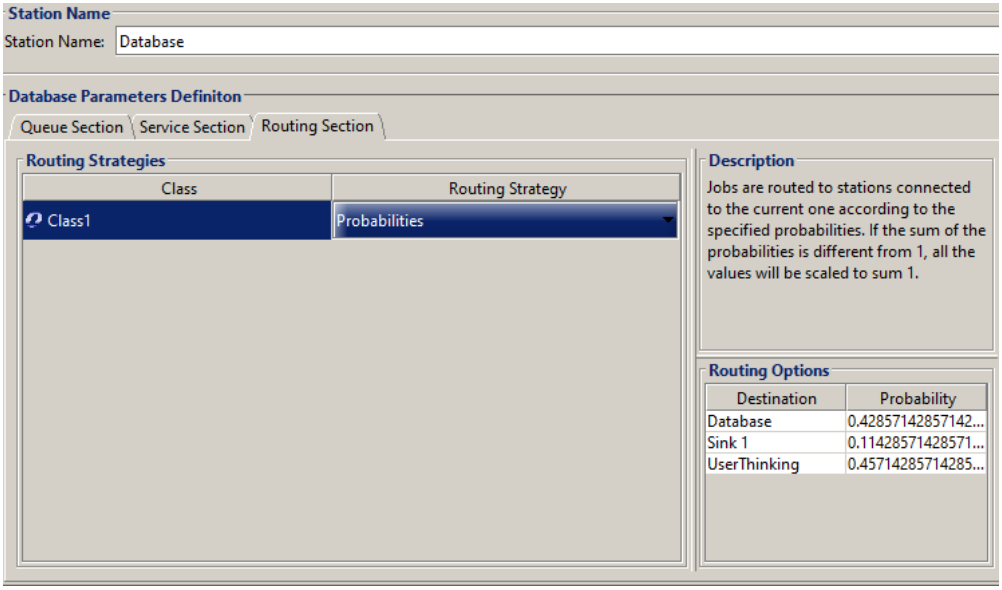


2.1.6 VoucherPayment Server

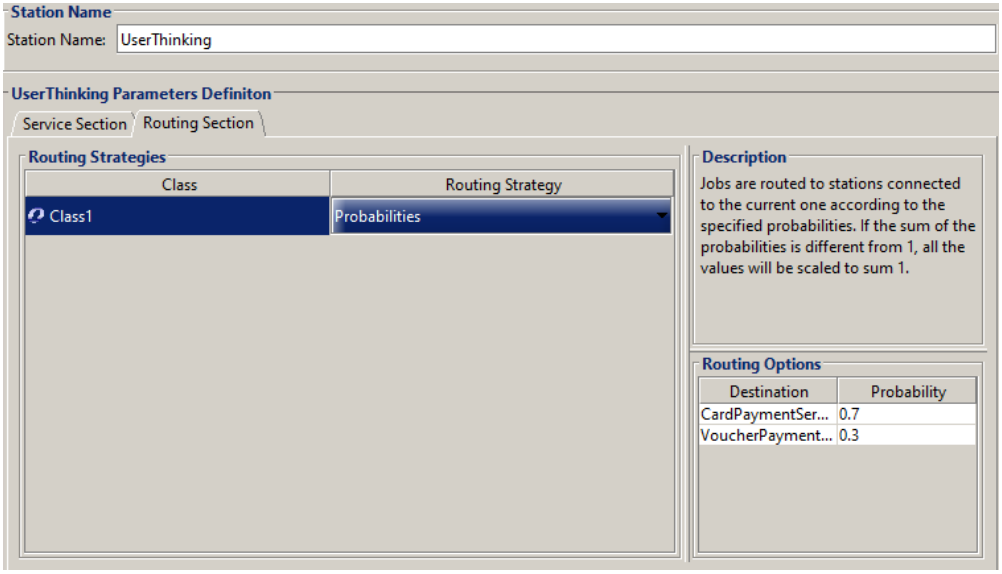


2.2 Routing Probabilities

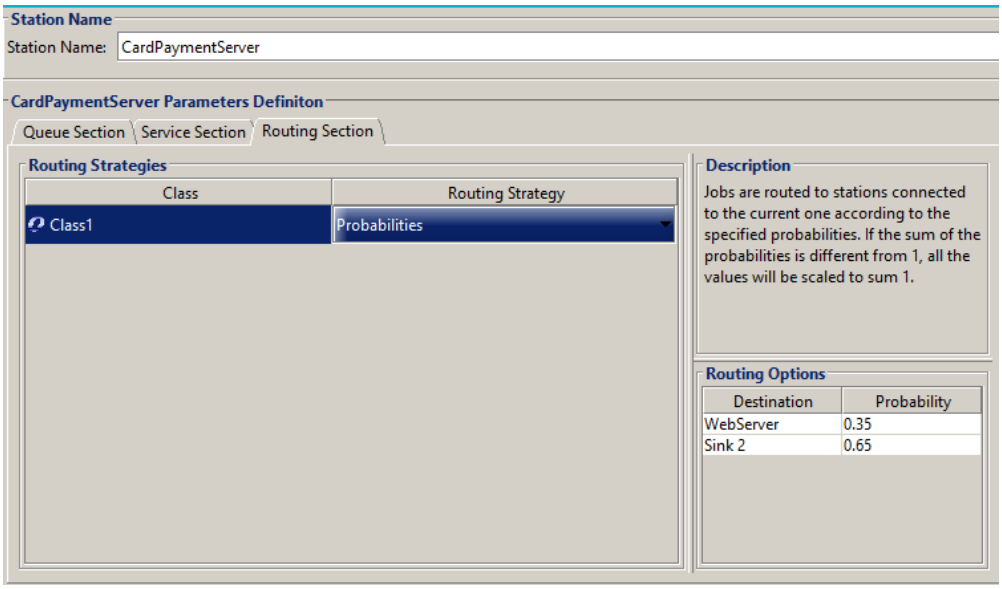
2.2.1 Database



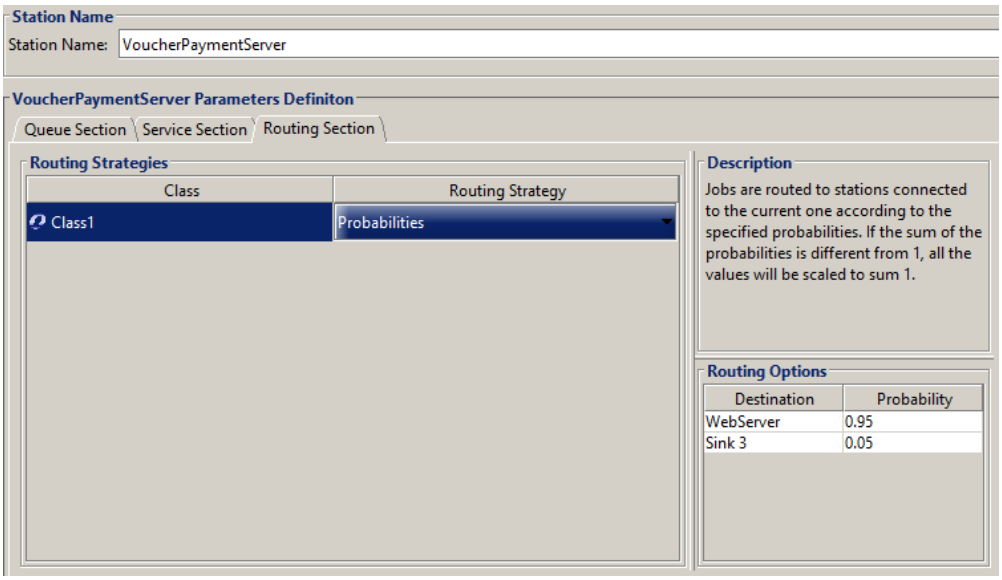
2.2.2 User Thinking



2.2.3 CardPayment Server

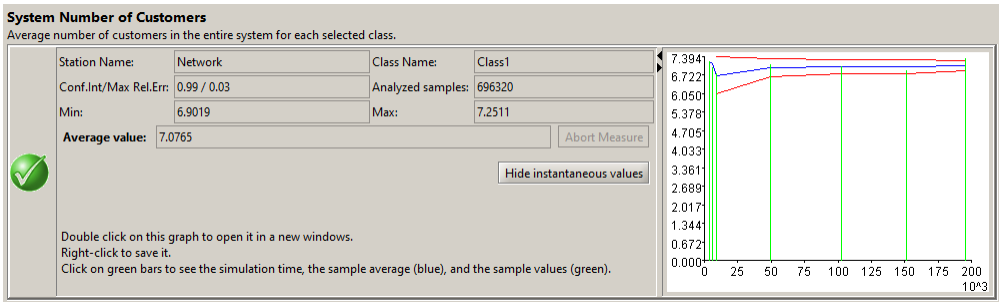


2.2.4 VoucherPayment Server

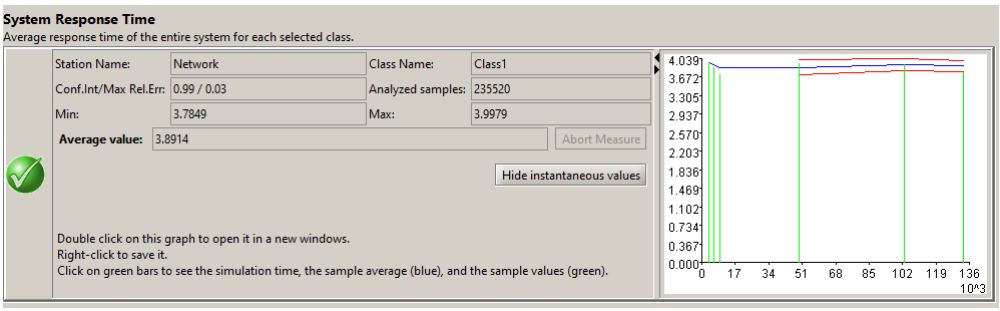


2.3 Simulations

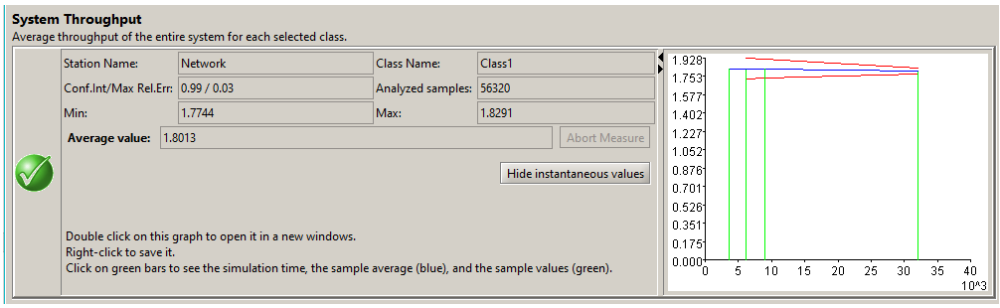
2.3.1 System Number of Customers



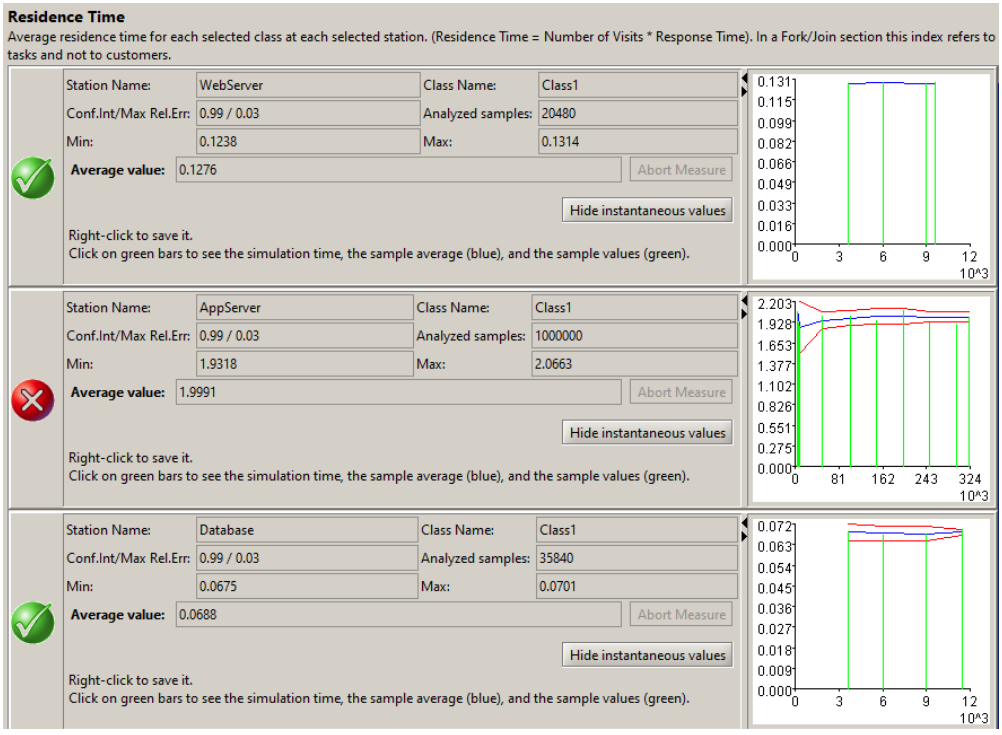
2.3.2 System Response Time

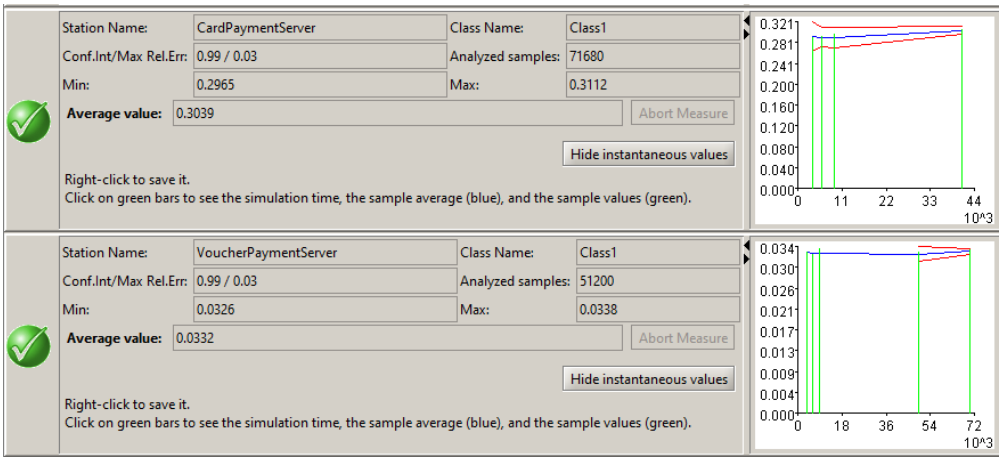


2.3.3 System Throughput

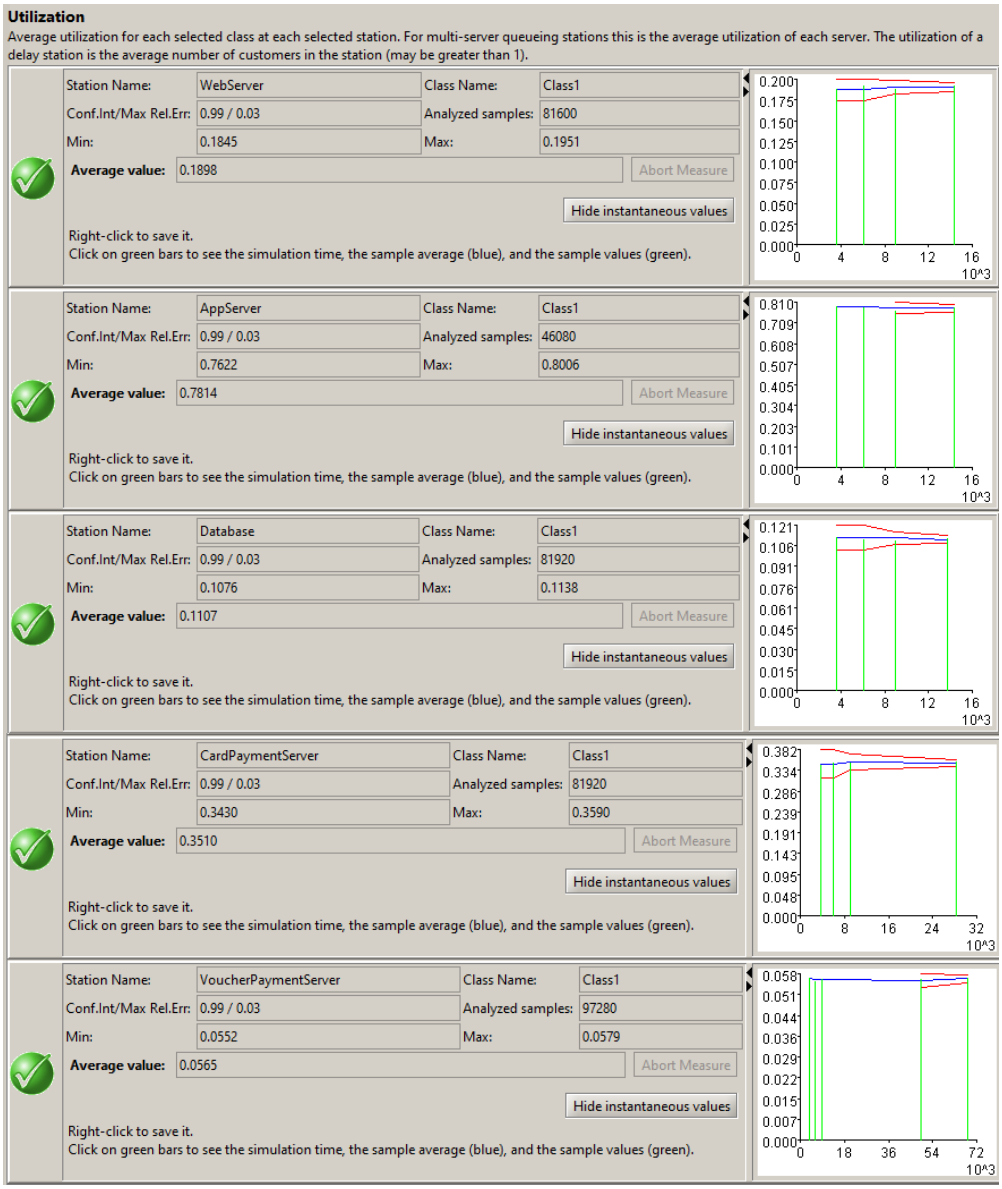


2.3.4 Residence Time

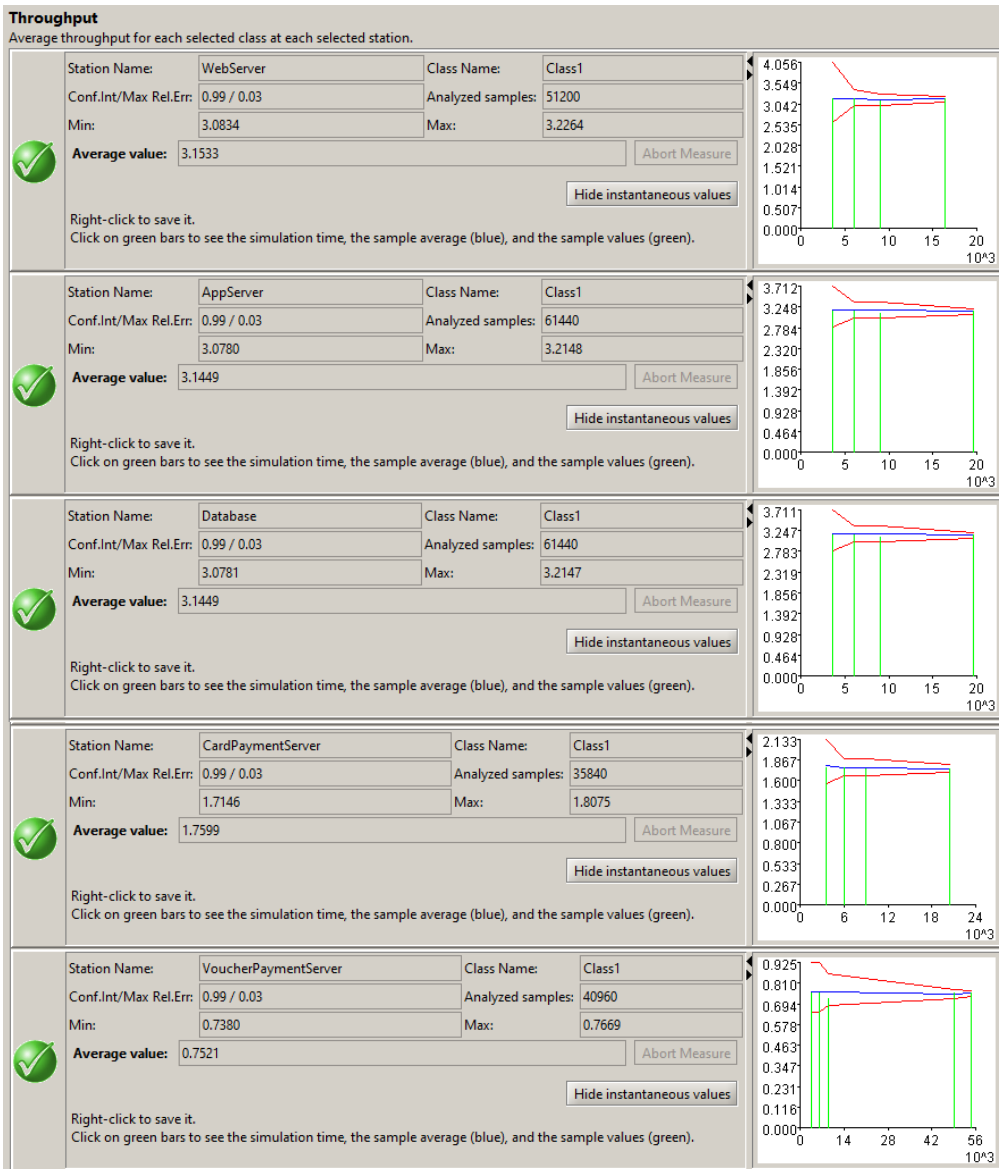




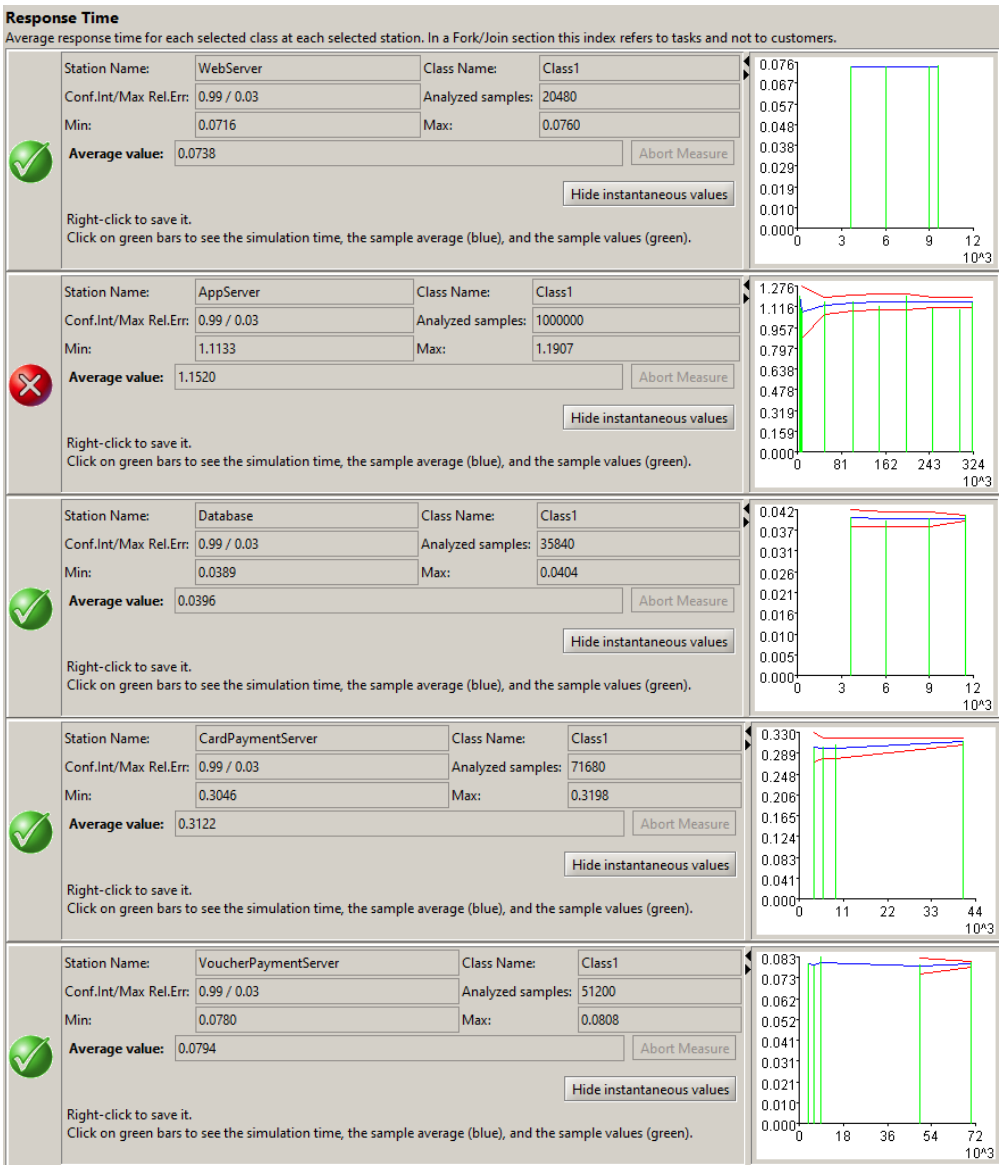
2.3.5 Utilization



2.3.6 Throughput



2.3.7 Response Time

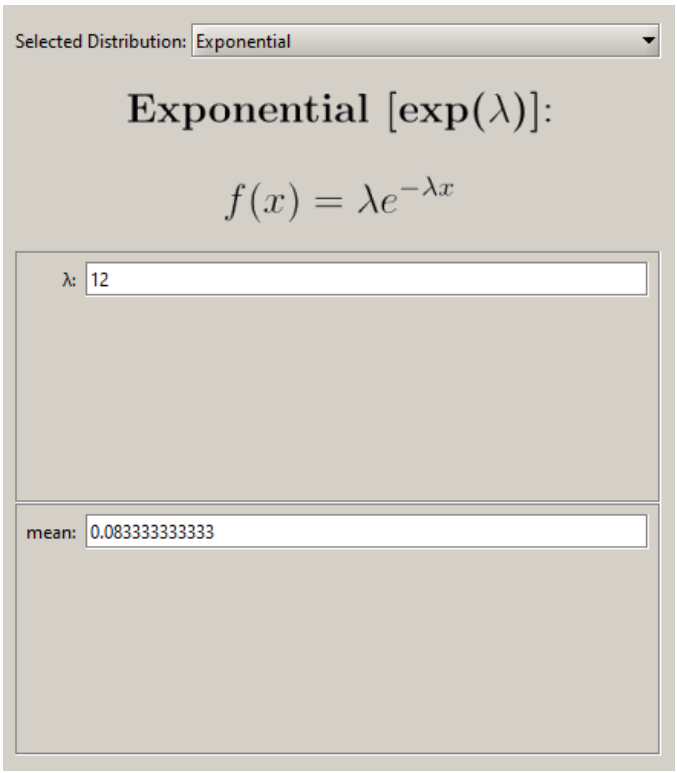


3 C)

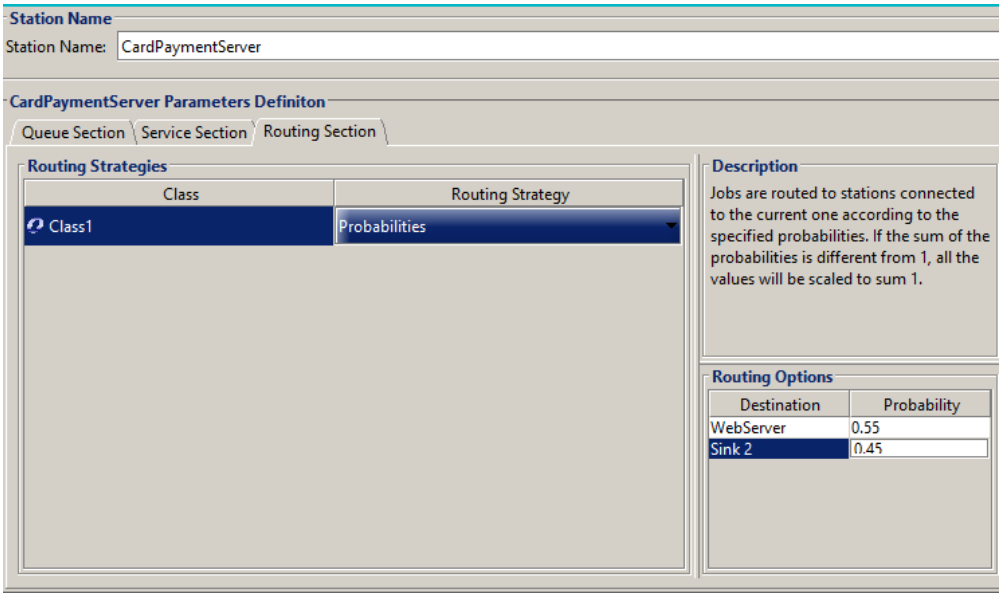
The following only shows the ones that are adjusted based on part b).

3.1 Model

3.1.1 Source 1

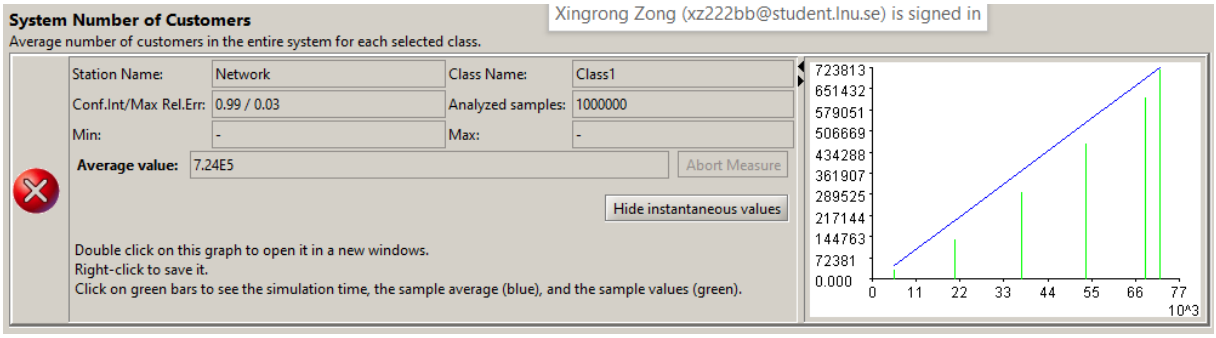


3.2 Routing Probabilities

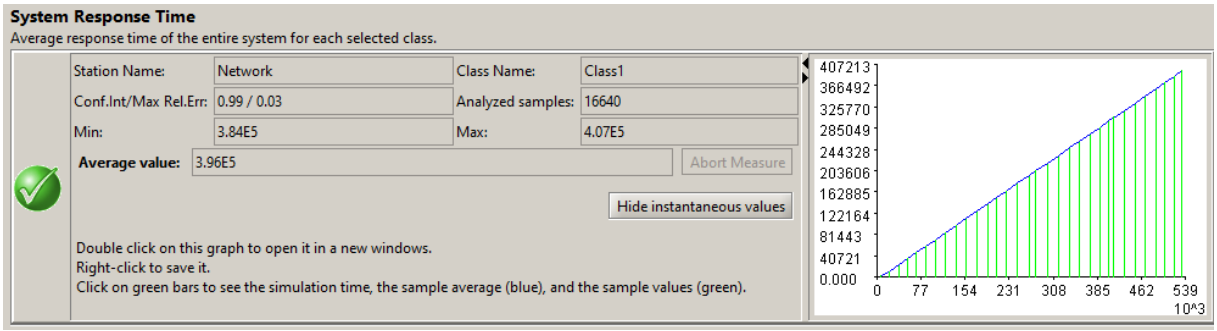


3.3 Simulations

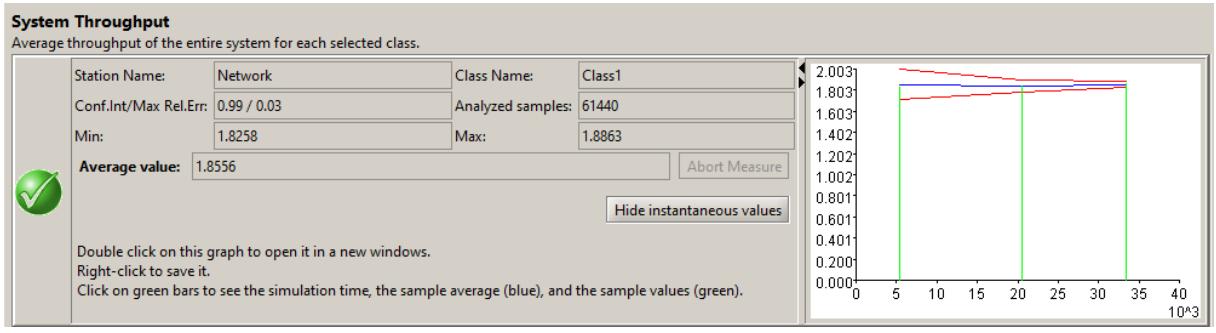
3.3.1 System Number of Customers



3.3.2 System Response Time



3.3.3 System Throughput



3.3.4 Residence Time

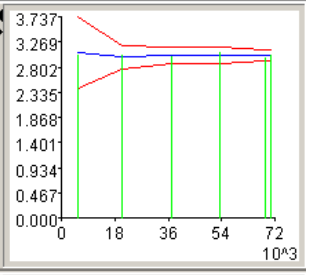
Residence Time

Average residence time for each selected class at each selected station. (Residence Time = Number of Visits * Response Time). In a Fork/Join section this index refers to tasks and not to customers.

Station Name:	WebServer	Class Name:	Class1	
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	1000000	
Min:	2.9155	Max:	3.1251	
Average value:	3.0203			Abort Measure

Hide instantaneous values

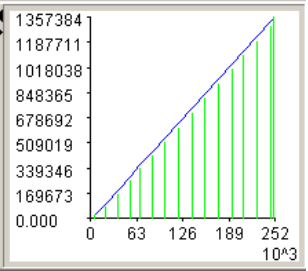
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	AppServer	Class Name:	Class1	
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	1000000	
Min:	-	Max:	-	
Average value:	1.35E6			Abort Measure

Hide instantaneous values

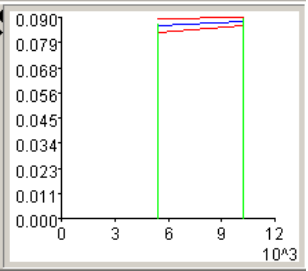
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	Database	Class Name:	Class1	
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	40960	
Min:	0.0864	Max:	0.0901	
Average value:	0.0883			Abort Measure

Hide instantaneous values

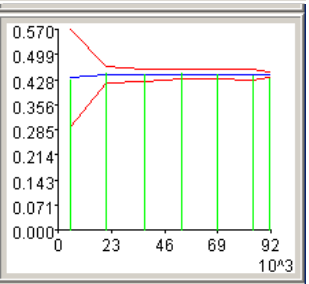
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	CardPaymentServer	Class Name:	Class1	
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	204800	
Min:	0.4321	Max:	0.4488	
Average value:	0.4405			Abort Measure

Hide instantaneous values

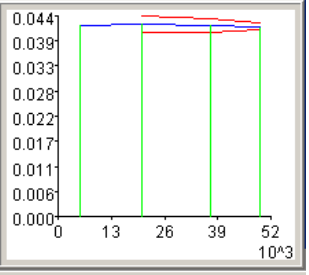
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	VoucherPaymentServer	Class Name:	Class1	
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	46080	
Min:	0.0413	Max:	0.0428	
Average value:	0.0421			Abort Measure

Hide instantaneous values

Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



3.3.5 Utilization

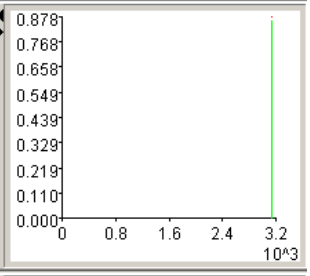
Utilization

Average utilization for each selected class at each selected station. For multi-server queueing stations this is the average utilization of each server. The utilization of a delay station is the average number of customers in the station (may be greater than 1).

Station Name:	WebServer	Class Name:	Class1
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	51200
Min:	0.8420	Max:	0.8779
Average value:	0.8599		Abort Measure

Hide instantaneous values

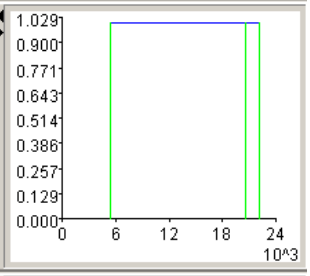
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	AppServer	Class Name:	Class1
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	12800
Min:	0.9714	Max:	1.0286
Average value:	1.0000		Abort Measure

Hide instantaneous values

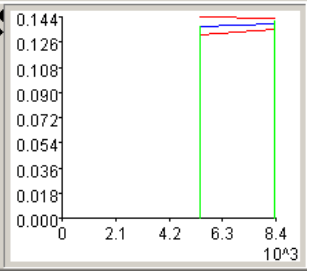
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	Database	Class Name:	Class1
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	61440
Min:	0.1355	Max:	0.1431
Average value:	0.1393		Abort Measure

Hide instantaneous values

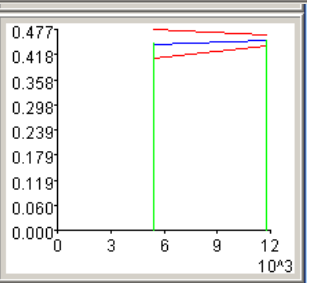
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	CardPaymentServer	Class Name:	Class1
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	40960
Min:	0.4375	Max:	0.4641
Average value:	0.4508		Abort Measure

Hide instantaneous values

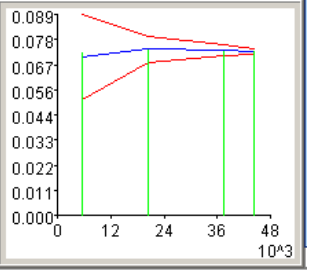
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	VoucherPaymentServer	Class Name:	Class1
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	81920
Min:	0.0712	Max:	0.0738
Average value:	0.0725		Abort Measure

Hide instantaneous values

Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



3.3.6 Throughput

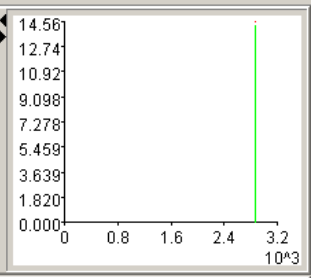
Throughput

Average throughput for each selected class at each selected station.

Station Name:	WebServer	Class Name:	Class1
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	40960
Min:	14.0268	Max:	14.5568
Average value:	14.2869		Abort Measure

Hide instantaneous values

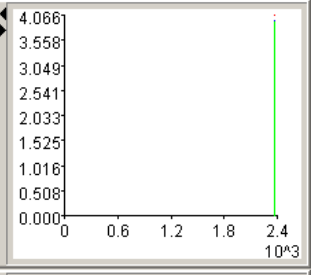
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	AppServer	Class Name:	Class1
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	8320
Min:	3.8317	Max:	4.0659
Average value:	3.9453		Abort Measure

Hide instantaneous values

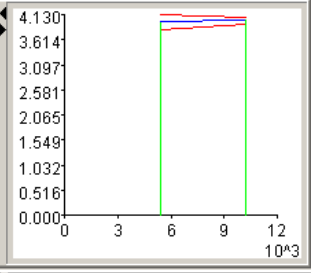
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	Database	Class Name:	Class1
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	40960
Min:	3.9322	Max:	4.0812
Average value:	4.0053		Abort Measure

Hide instantaneous values

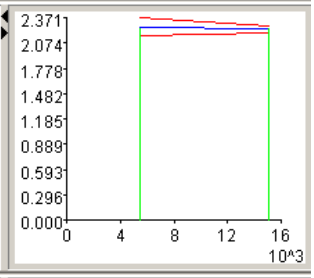
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	CardPaymentServer	Class Name:	Class1
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	33280
Min:	2.1944	Max:	2.2810
Average value:	2.2368		Abort Measure

Hide instantaneous values

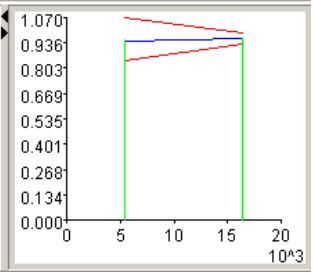
Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



Station Name:	VoucherPaymentServer	Class Name:	Class1
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	15360
Min:	0.9340	Max:	0.9884
Average value:	0.9605		Abort Measure

Hide instantaneous values

Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).



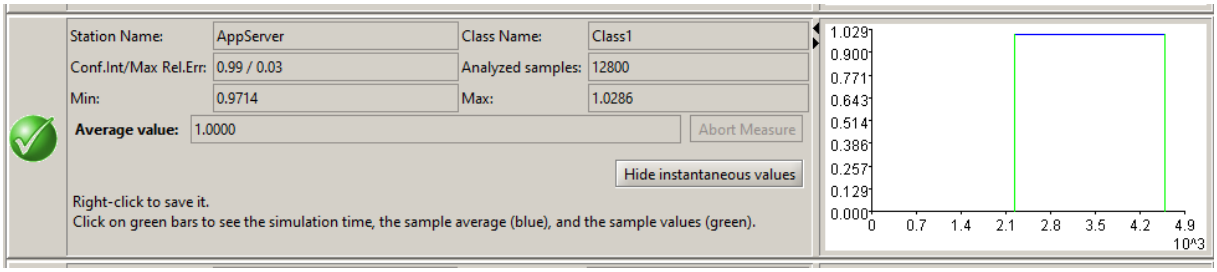
3.4 Minimum Number of Resources

When Number of Resources of AppServer is 7, Number of Resources of Web Server is 2, Number of Resources of CardPayment Server is 3, Number of Resources of the rest servers is 1:

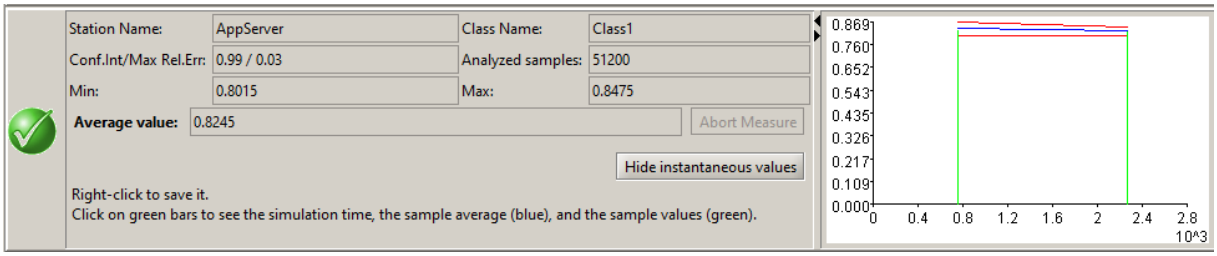
The following are the steps:

3.4.1 Application Server

Number of Resources = 4:

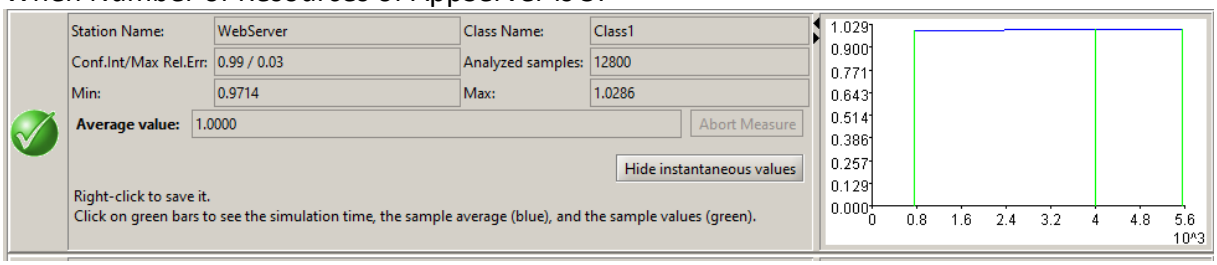


Number of Resources = 5:

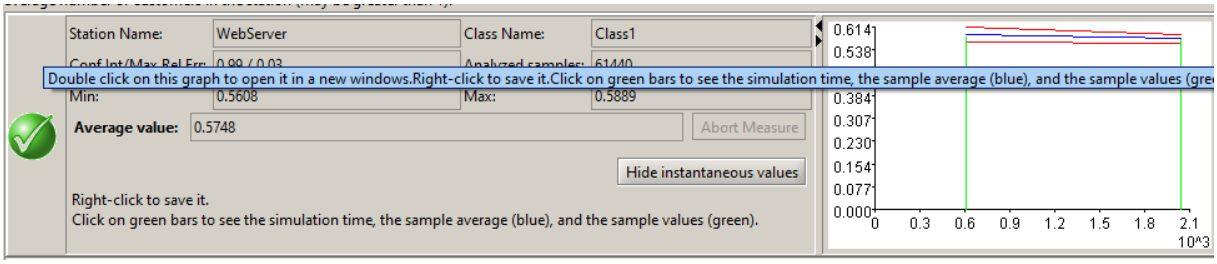


3.4.2 Web Server

When Number of Resources of AppServer is 5:

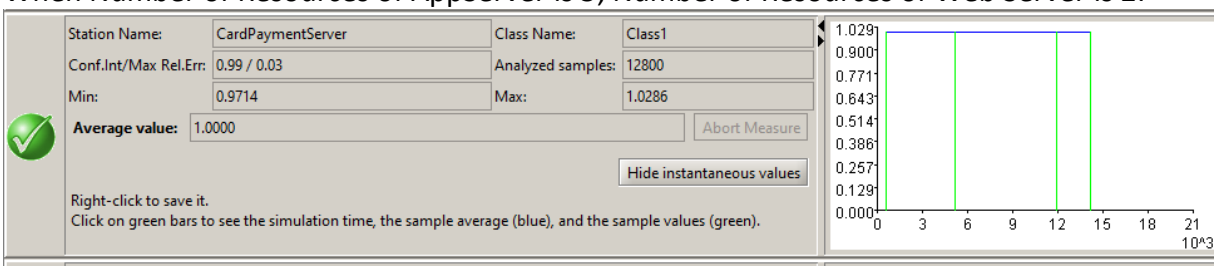


Therefore increases Number of Resources to 2:

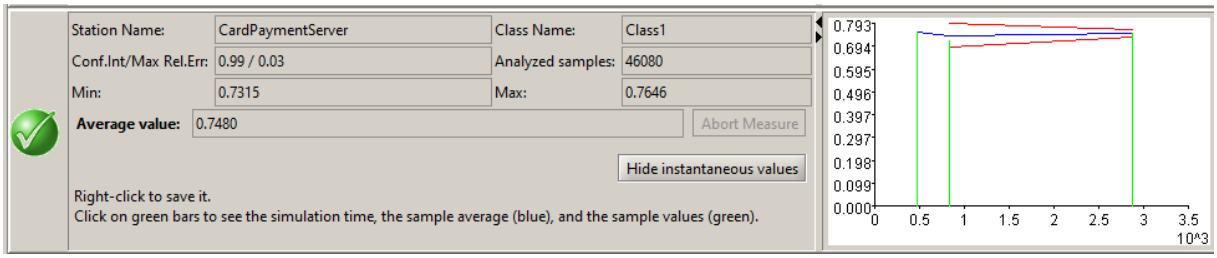


3.4.3 CardPayment Server

When Number of Resources of AppServer is 5, Number of Resources of Web Server is 2:

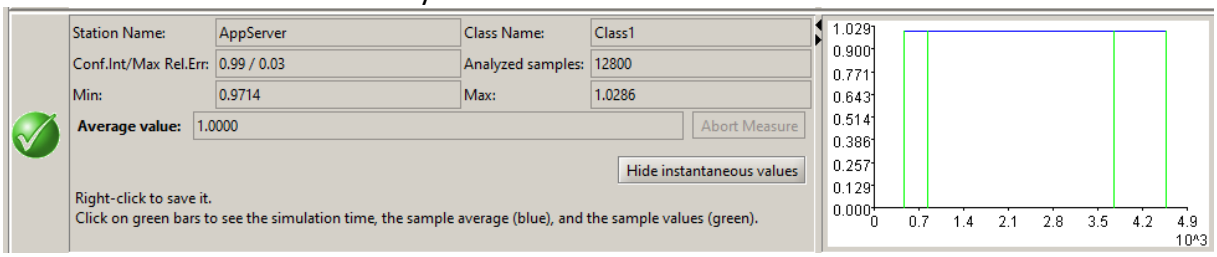
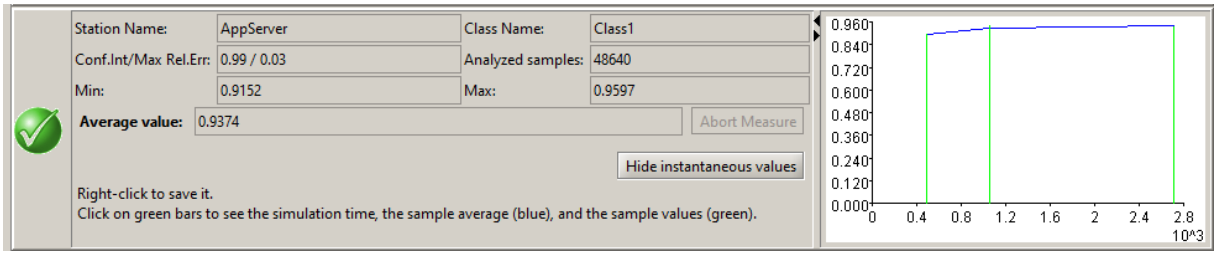


Therefore increases Number of Resources to 3:



3.4.4 Application Server

When Number of Resources of AppServer is 5, Number of Resources of Web Server is 2, Number of Resources of CardPayment Server is 3:



Therefore increases Number of Resources to 7: