High Performance Routers and Switches

Switch
Simulation

By

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Contents

Objective

To simulate switch behavior and do performance analysis using an open source cell-based switch simulator, named SIM. Generate simulation scripts for SIM to perform simulation across combinations of various switch architectures and scheduling algorithms, under different switch sizes and traffic patterns.
SIM is a slotted-time, cell-based simulator for ATM switches, written in ANSI C (normal C language). It was designed to simulate an ATM switch, as configured by the simulation scripts.

Test Scenario: Test multiple combinations of switch architectures, scheduling algorithms, switch sizes and traffic patterns.

To Analyze

Load – Latency Curves, Standard Deviation of cell Latency and Packet Drop Rate for Test multiple combinations of switch architectures, scheduling algorithms, switch sizes and traffic patterns.

Test Scenario

We have performed an analysis on **Load – Latency, Standard Deviation of cell Latency and Packet Drop Rate** for the following combinations:

A. Switch size: 8
Switch Architecture: Input Queued with VOQ
Scheduling Algorithm: ISLIP, PIM, Maxsize and LQF (Longest Queue First).
Traffic Pattern: Bernoulli iid uniform
Iteration: 1,2,4,8 for PIM and ISLIP
Utilization: 0.1 to 1.0

B. Switch size: 8
Switch Architecture: CIOQ with Speedup 2
Scheduling Algorithm: ISLIP, PIM, Maxsize and LQF (Longest Queue First).
Traffic Pattern: Bernoulli iid uniform
Iteration: 1,2,4,8 for PIM and ISLIP
Utilization: 0.1 to 1.0

C. Switch size: 32
Switch Architecture: Input Queued with VOQ
Scheduling Algorithm: ISLIP, PIM, Maxsize and LQF (Longest Queue First).
Traffic Pattern: Bernoulli iid uniform
Iteration: 1,2,4,8 for PIM and ISLIP
Utilization: 0.1 to 1.0

D. Switch size: 4
Switch Architecture: Input Queued with VOQ
Scheduling Algorithm: ISLIP, PIM, Maxsize and LQF (Longest Queue First).
Traffic Pattern: Bernoulli iid non-uniform
Iteration: 1,2,4,8 for PIM and ISLIP
Utilization: 0.1 to 1.0

E. Switch size: 8
Switch Architecture: Input Queued with VOQ
Scheduling Algorithm: ISLIP, PIM, Maxsize and LQF (Longest Queue First).
Traffic Pattern: Bursty uniform
Iteration: 1,2,4,8 for PIM and ISLIP
Utilization: 0.1 to 1.0

Test procedure:

Switch size: 8, 16, and 32.
This parameter can be set by setting the values of parameters Numinputs and Numoutputs to desired value.

Switch Architecture: Input Queued with VOQ and CIOQ
For input queued we use InputAction as **defaultInputAction** , OutputAction as **defaultOutputAction** and Fabric as **crossbar**
For CIOQ we use InputAction as defaultInputAction -n 100, OutputAction as defaultOutputAction and Fabric as outputQueued.
Note that here –n is used to set the parameter max cells per fifo to a desired value, for input action. For this analysis we use value 100.

Scheduling Algorithm: ISLIP, PIM, Maxsize and LQF (Longest Queue First).
This parameter can be changed by changing value of Algorithm to either islip, pim, maxsize or lqf.
-n parameter can be used to set the number of iterations in case of islip and pim.

Traffic Pattern: Bernoulli iid uniform, Bernoulli iid non-uniform and Bursty uniform
Set the traffic pattern for all the input ports to desired traffic pattern-“bernoulli_iid_uniform”, “bernoulli_iid_nonuniform” or “bursty”
Also –u can be used to set the utilization ranging from 0.1 to 1

You also need to take care of certain other parameters while generating configuration files.

Note 1: while working with non-uniform traffic pattern:
The traffic will be in ratio for different ports for instance the traffic pattern will be 4:3:2:1 for port 0, 1, 2, 3 respectively in our combination D. That is, if your total input load on an input port is 1.0, you will put bernoulli_iid_nonuniform -u 0.4:0.3:0.2:0.1 in each input port's configuration, which add up to 1.0.Similarly, if your load is 0.5, you will put bernoulli_iid_nonuniform -u 0.2:0.15:0.1:0.05 in each input port's configuration, which add up to 0.5.
We however have a python script that generates the configuration files easily.

Note 2: while working with the Packet Drop rate:
Please set the input buffer size to a smaller number (default is infinite), and run the simulation time for long enough period (if simulation is too short, buffer won't be overflowed).
This way you should be able to see the "overflow at each input buffer" in the simulation output, which indicate packet loss.
In our test scenario we have set input buffer to 7. Just set the parameter InputAction as defaultInputAction –m 7 in your configuration file. This will set maxCells per input buffer to 7.
7 is a very low value and if you run simulation for larger time say 50000 you will observe overflow at each input ports.
To run the simulation time for long enough period set parameter –l 50000 during executing the file in terminal.
Example: **“./sim -f /home/jay/final/inputs/islip_itr_1_0.1 -l 500000”**

Note 3: setting speed up for CIOQ
To have speed up of X use the command –tX –s1 –eX
Example: **“./sim -f /home/jay/final/inputs/ islip_itr_1_0.1 -l 500000 -t2 -s1 -e2”**
Here islip_itr_1_0.1 is just the name of the configuration file so not to get confused.

Setting the above parameters correctly you can generate your configuration file. The parameters can be varied and multiple configuration files can be generated.
Iteration can take values 1, 2, 4 and 8 in our analysis for ISLIP and PIM.
Utilization can take value from 0.1 to 1.0
Scheduling Algorithms can be SLIP, PIM, Max size, LQF
Switch Architecture can be Input Queued with VOQ and CIOQ
Traffic Pattern can be Bernoulli iid uniform, Bernoulli iid non-uniform and Bursty uniform

In general 500 configuration files can be generated for the above analysis. We have however written various Python Scripts to automate our process. Our Python Scripts generate Text files at the end of simulation that contains data like Latencies, Standard Deviation and overflows at each input buffer for different combinations.

Sample Configuration Files and Python Scripts can be found at the end of the report.

The Analysis Plots have been generated for Utilization (X-axis) VS Latency/standard deviation/ packet loss (Y-axis) for different number of iterations and Scheduling Algorithms.

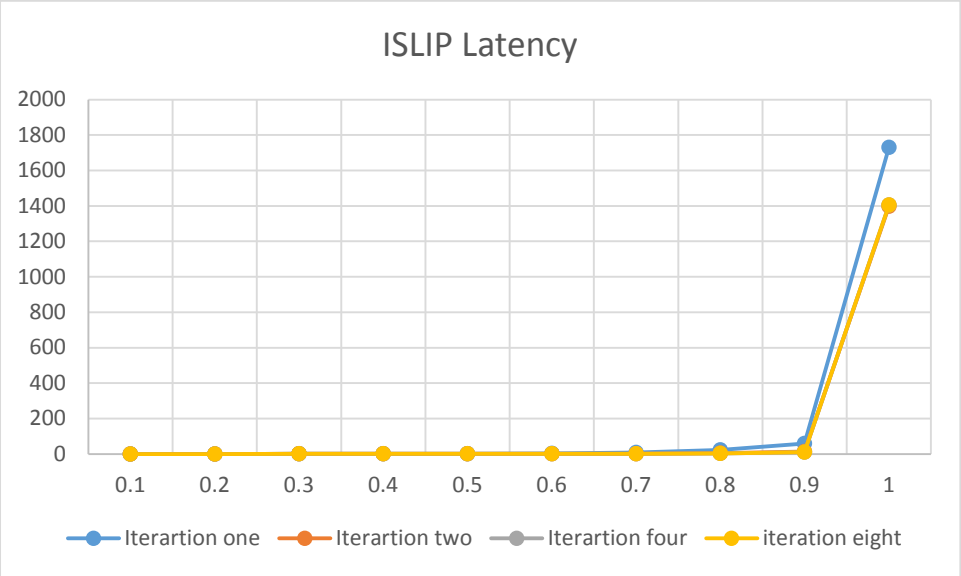
Performance:

Combination A output:

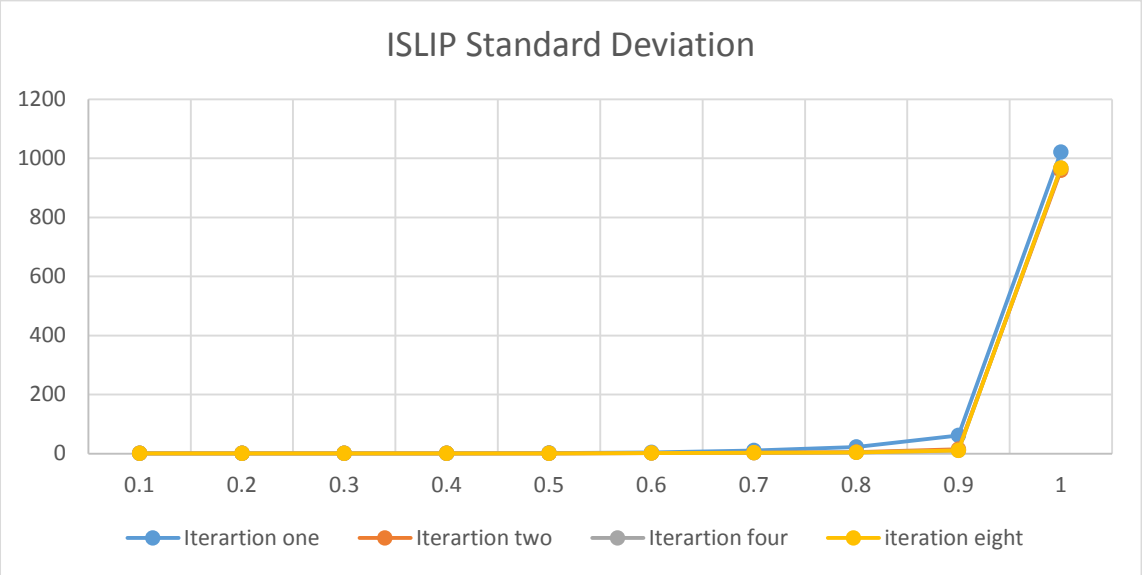
Switch size : 8
Switch Architecture: Input Queued with VOQ
Scheduling Algorithm: ISLIP, PIM, Maxsize and LQF (Longest Queue First).
Traffic Pattern: Bernoulli iid uniform
Iteration: 1,2,4,8 for PIM and ISLIP
Utilization: 0.1 to 1.0

ISLIP

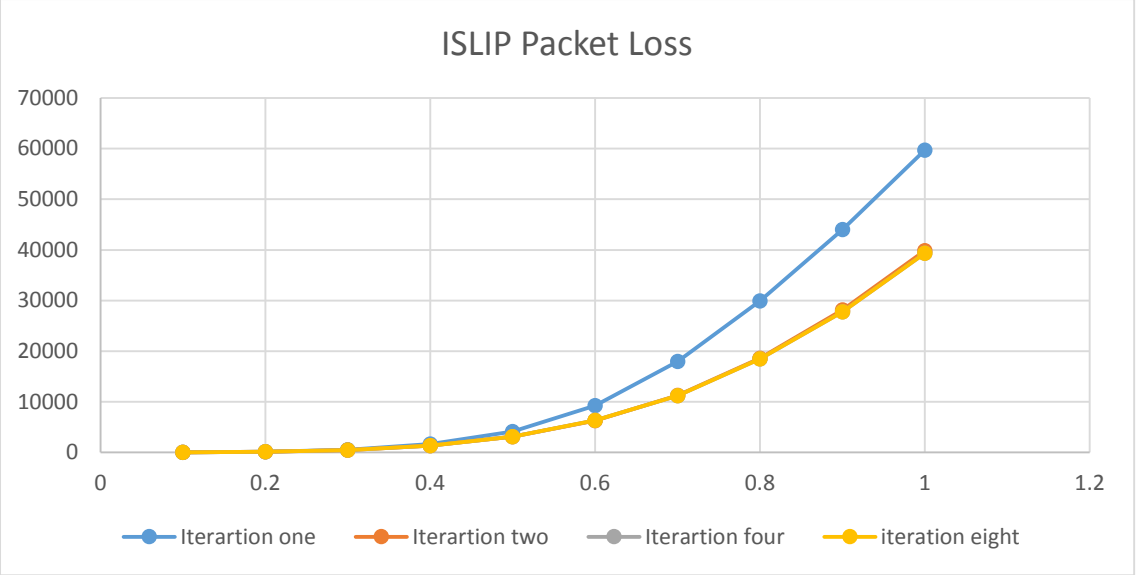
		ISLIP		
		Latency		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.052497968	0.051951114	0.051951114	0.051951114
0.2	0.13671591	0.12995343	0.12995343	0.12995343
0.3	0.27396138	0.24155303	0.24154302	0.24154302
0.4	0.52455691	0.4059128	0.40591155	0.40591155
0.5	1.0689213	0.66156785	0.66119758	0.66119758
0.6	2.7072562	1.0883489	1.0835851	1.0835851
0.7	9.202002	1.882984	1.8475155	1.8475155
0.8	22.103936	3.8828344	3.5490737	3.5490737
0.9	59.583224	13.032079	9.6725247	9.6437635
1	1729.8681	1397.8436	1404.8376	1404.8376



		standard deviation		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.24779317	0.24498713	0.24498713	0.24498713
0.2	0.43347468	0.4109316	0.4109316	0.4109316
0.3	0.67605652	0.59659559	0.59654931	0.59654931
0.4	1.0566513	0.82508126	0.82508111	0.82508111
0.5	1.7837558	1.1398334	1.1389838	1.1389838
0.6	3.8221122	1.6328595	1.6249905	1.6249905
0.7	10.290428	2.5077457	2.451992	2.451992
0.8	22.191806	4.70646	4.2644691	4.2644691
0.9	61.789002	14.212843	10.566324	10.513181
1	1021.2266	958.99175	966.73714	966.73714

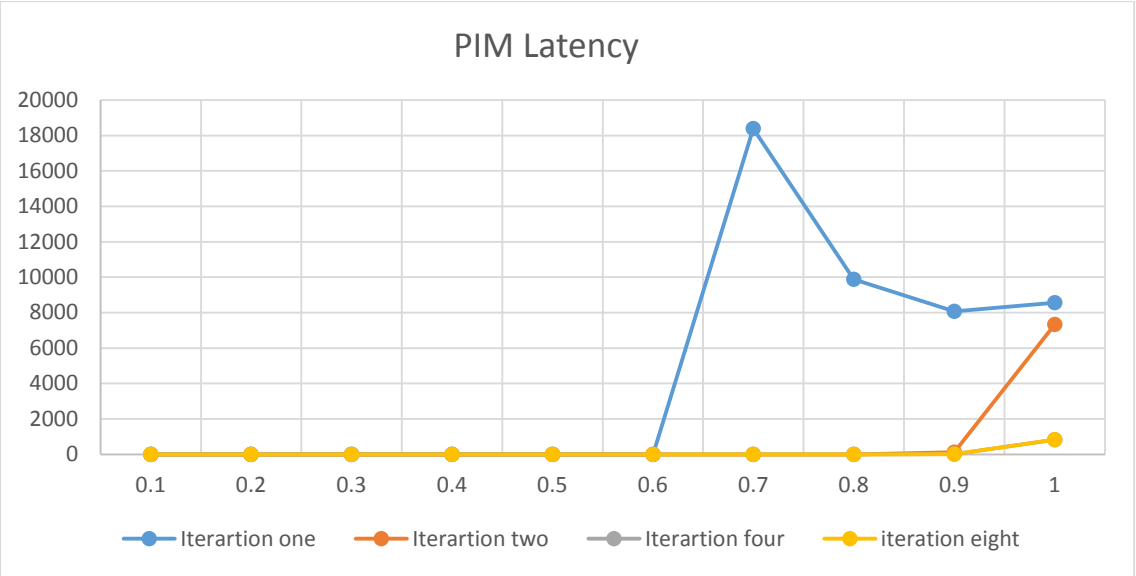


		Packet Loss		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	12	12	12	12
0.2	138	134	134	134
0.3	521	454	454	454
0.4	1625	1350	1350	1350
0.5	4124	3098	3097	3097
0.6	9217	6233	6321	6321
0.7	17985	11261	11217	11217
0.8	29922	18579	18490	18490
0.9	44009	28143	27779	27779
1	59707	39833	39340	39340

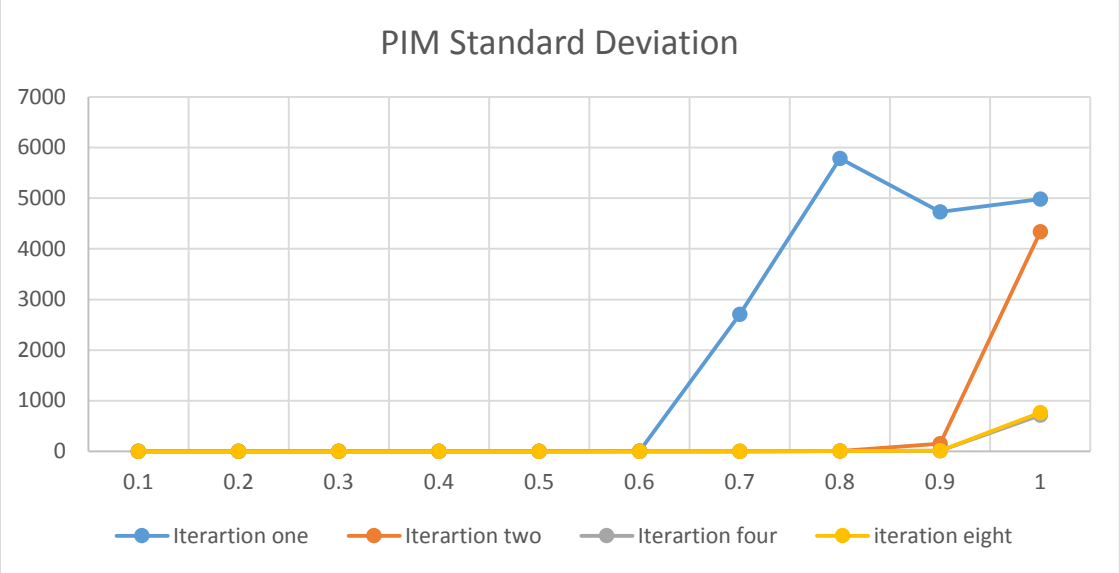


PIM

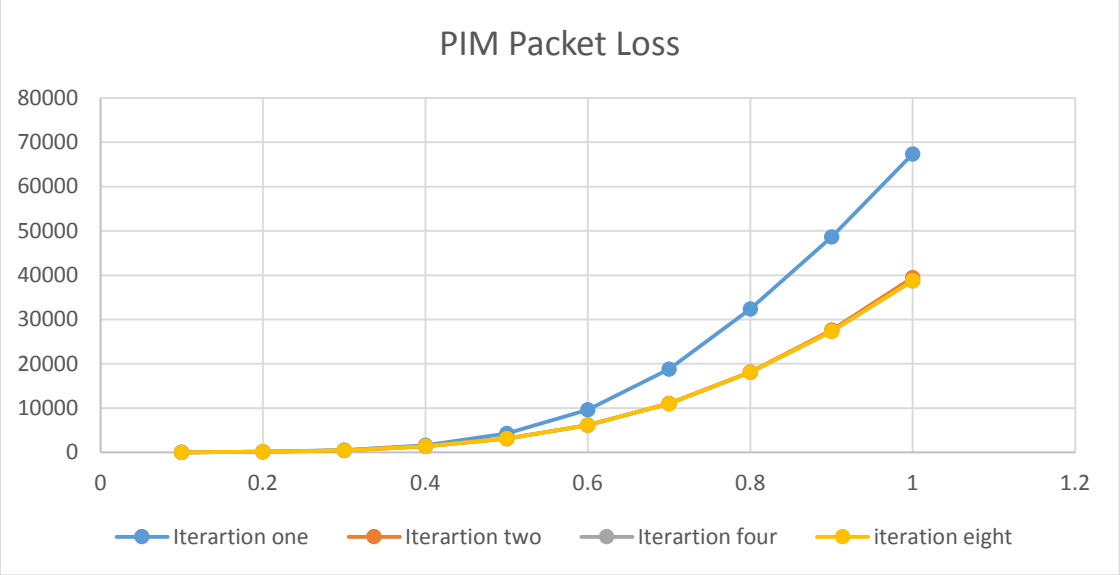
	PIM			
		Latency		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.052643461	0.051961148	0.051961148	0.051961148
0.2	0.13651539	0.12979803	0.12979803	0.12979803
0.3	0.27345882	0.24063222	0.24039535	0.24039535
0.4	0.52901702	0.40154763	0.40218808	0.40218808
0.5	1.1606723	0.65360089	0.65306519	0.65306519
0.6	4.2823282	1.0790506	1.0725327	1.0725327
0.7	18384.774	1.8786511	1.8290844	1.8290844
0.8	9882.6844	4.0463356	3.5361502	3.5361502
0.9	8072.2755	123.9733	9.3124113	9.2632477
1	8569.4083	7331.6267	837.43024	836.16772



		standard deviation		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.25474114	0.25009243	0.25009243	0.2500924
0.2	0.44740548	0.42514793	0.42514793	0.42514793
0.3	0.71771311	0.6247159	0.62453203	0.62453203
0.4	1.1695008	0.87824881	0.88043856	0.8804385
0.5	2.2082473	1.2341826	1.2350036	1.2350036
0.6	7.2926073	1.8067083	1.7868249	1.7868249
0.7	2706.8952	2.8059649	2.7135672	2.7135672
0.8	5783.3808	5.4549213	4.7159585	4.7159585
0.9	4728.8225	153.35643	11.112765	10.995716
1	4986.0386	4336.6502	712.14708	763.56482



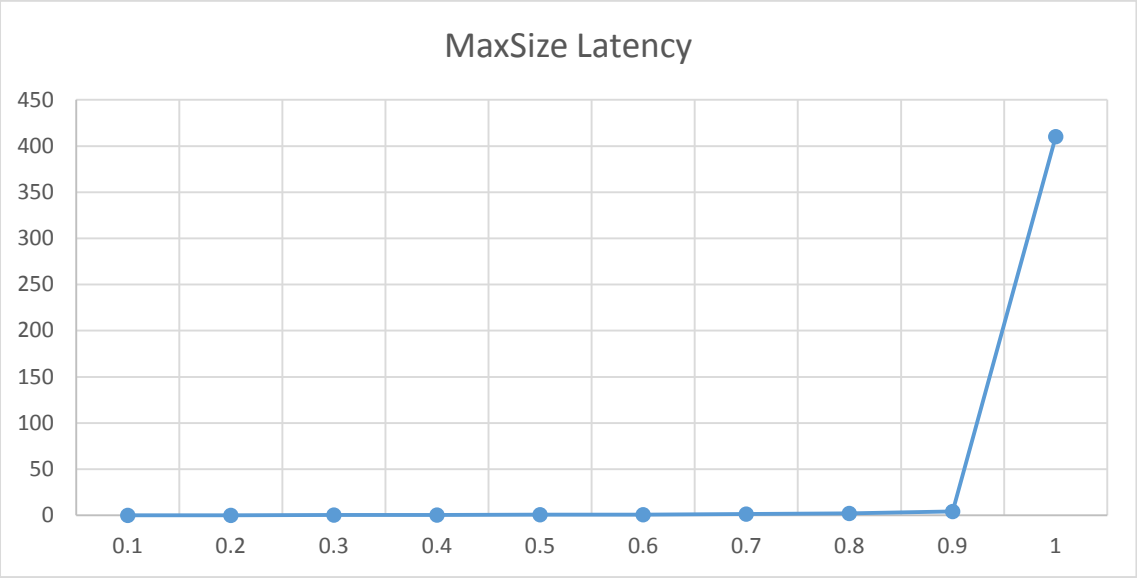
		Packet Loss		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	20	21	21	21
0.2	144	141	141	141
0.3	536	464	464	464
0.4	1619	1369	1369	1369
0.5	4266	3107	3096	3096
0.6	9600	6165	6174	6174
0.7	18828	11028	10956	10956
0.8	32411	18141	18092	18092
0.9	48669	27592	27322	27322
1	67355	39432	38728	38728

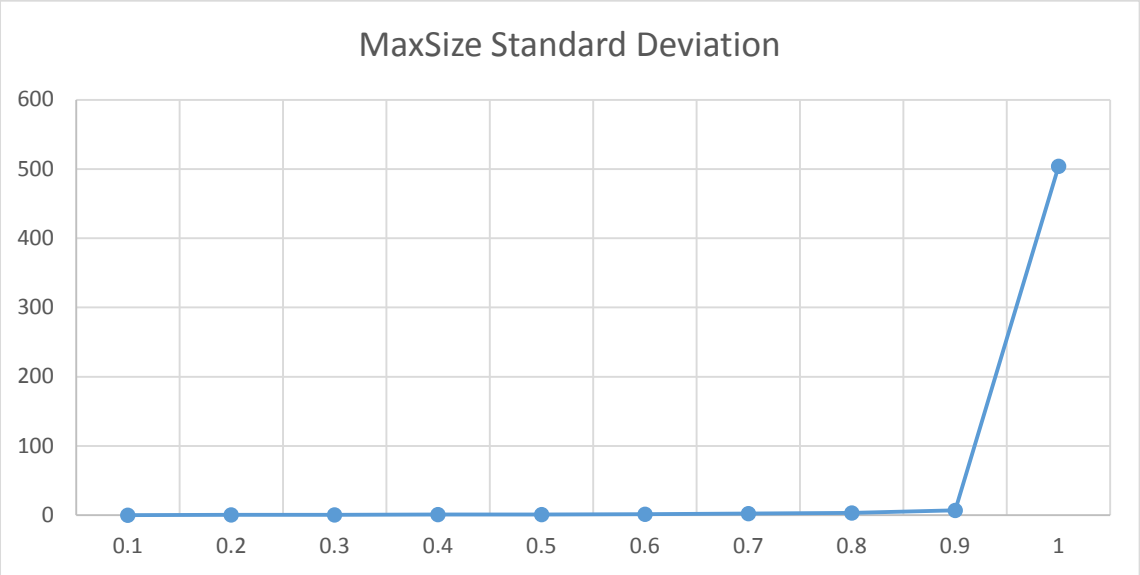


Maxsize

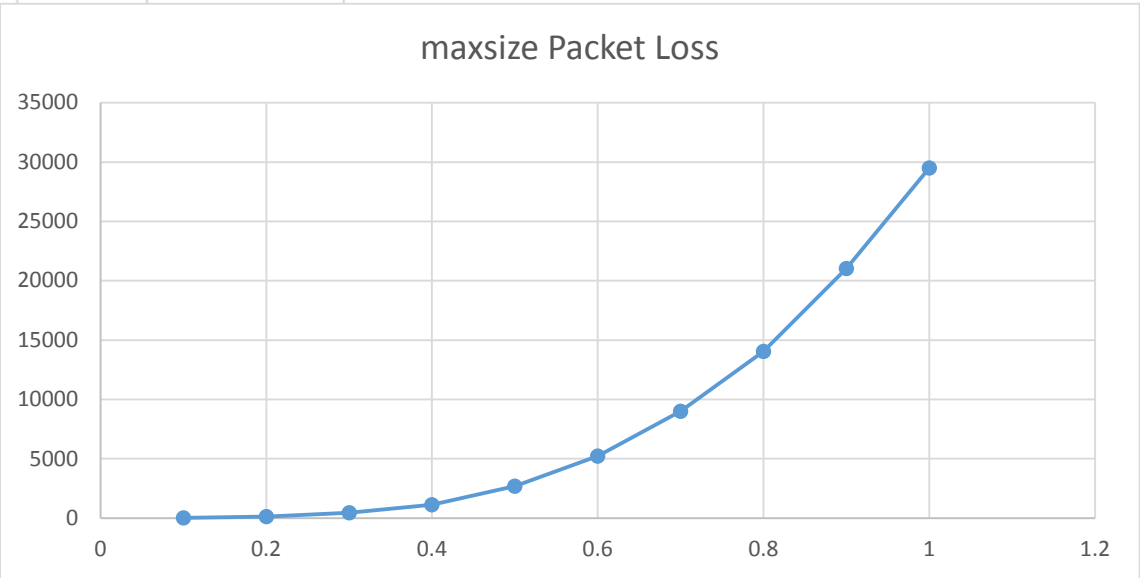
	maxsize
Load	Latency
0.1	0.051850774
0.2	0.1271963
0.3	0.22867342
0.4	0.36625037
0.5	0.55856669
0.6	0.84033672
0.7	1.2641842
0.8	2.0413226
0.9	4.1600078
1	410.21725

Load	Standard Deviation
0.1	0.24983436
0.2	0.41901585
0.3	0.6096716
0.4	0.84002937
0.5	1.1454907
0.6	1.5805674
0.7	2.2290368
0.8	3.4530148
0.9	6.8142286
1	504.2715



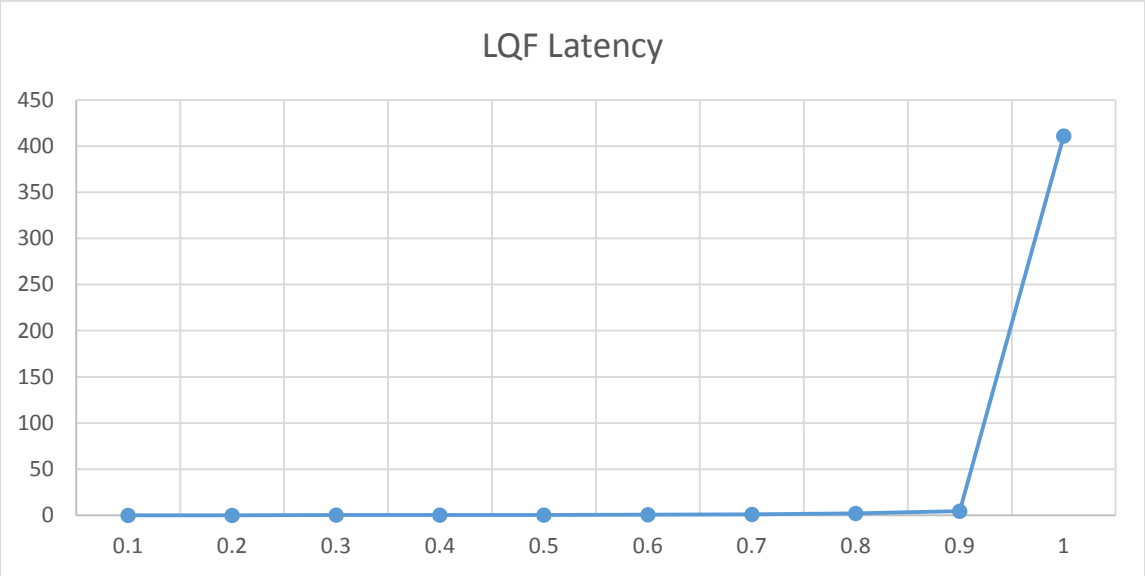


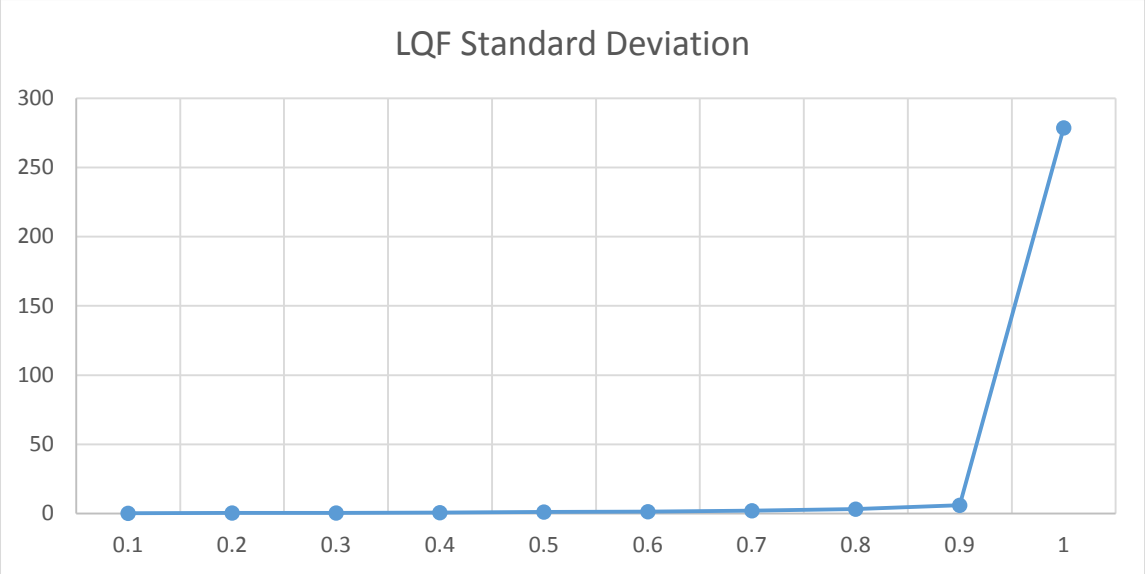
Load	Packet Loss
0.1	19
0.2	128
0.3	458
0.4	1127
0.5	2698
0.6	5225
0.7	8993
0.8	14059
0.9	21031
1	29503



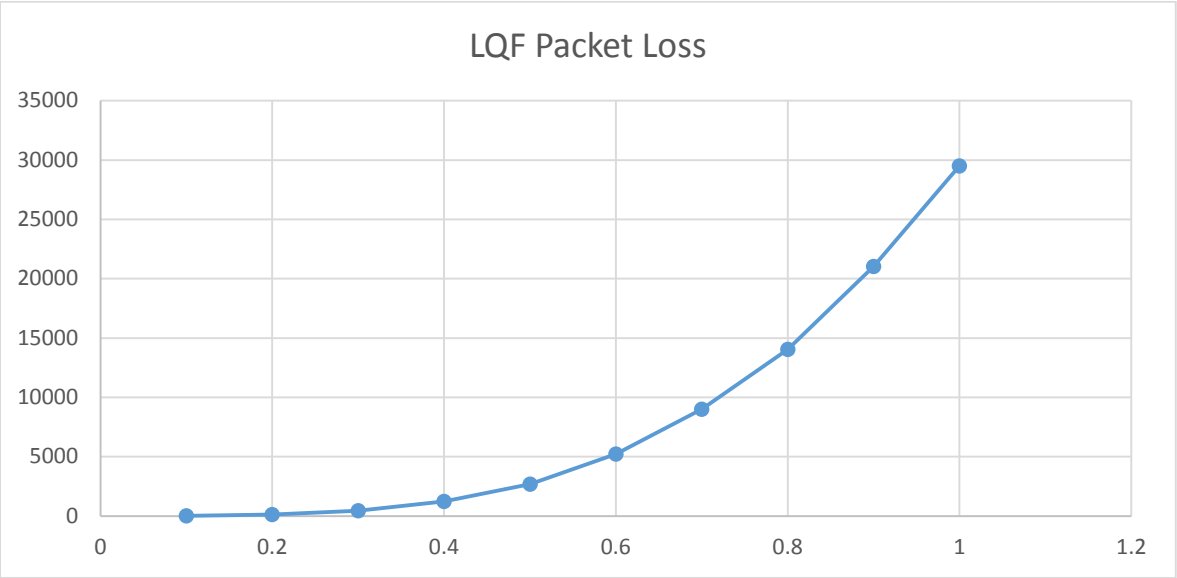
LQF

		LQF		
Load	Latency		Load	Standard Deviation
0.1	0.051815655		0.1	0.24918816
0.2	0.1270409		0.2	0.41755302
0.3	0.22787773		0.3	0.60365086
0.4	0.36430052		0.4	0.82881564
0.5	0.5541524		0.5	1.1159329
0.6	0.83237613		0.6	1.5199194
0.7	1.26008		0.7	2.1139312
0.8	2.0784733		0.8	3.2065529
0.9	4.4353183		0.9	5.9922976
1	410.95149		1	278.51356





Load	Packet Loss
0.1	19
0.2	128
0.3	458
0.4	1227
0.5	2698
0.6	5225
0.7	8993
0.8	14059
0.9	21031
1	29503



Performance Analysis:

Using ISLIP with Input Queued (with VOQ) and Bernoulli iid uniform traffic the Latency performance remains almost the same for all iterations when the load is less. However performance improves a bit for large value of load when more iterations are employed.

Using PIM the performance improves for large value of load when more iterations are employed. Iteration one however shows unusual behavior where latency increases for load value 0.7 and then gradually decreases for higher utilizations

For Maxsize and LQF as the utilization increases the latency also increases.High Latency values are seen for PIM and ISLIP. Maxsize and LQF however show low Latencies.

As far as Packet Loss Rate is concerned. Loss increases for low value of input buffer and large simulation times causes the buffer overflow. We have used a buffer of 7 and simulation length 50000.

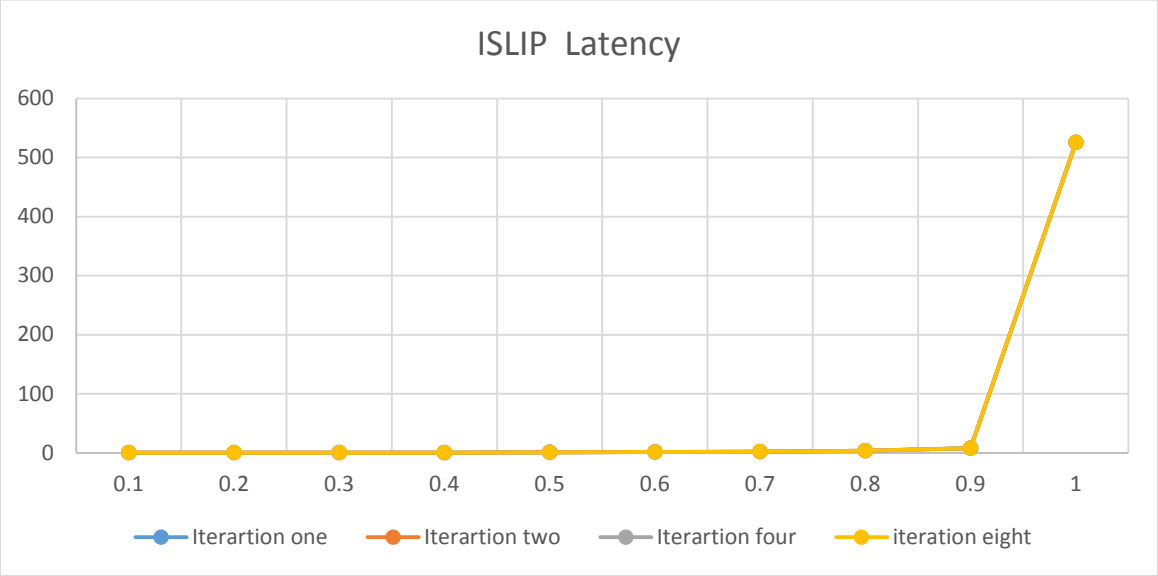
For ISLIP Loss rate is high under one iteration it however decreases for higher value of iterations. Similar performance is observed for PIM, LQF and Max size. However Maxsize and LQF demonstrate lower Packet Losses. Also as the load increases the packet loss increases.

Combination B output:

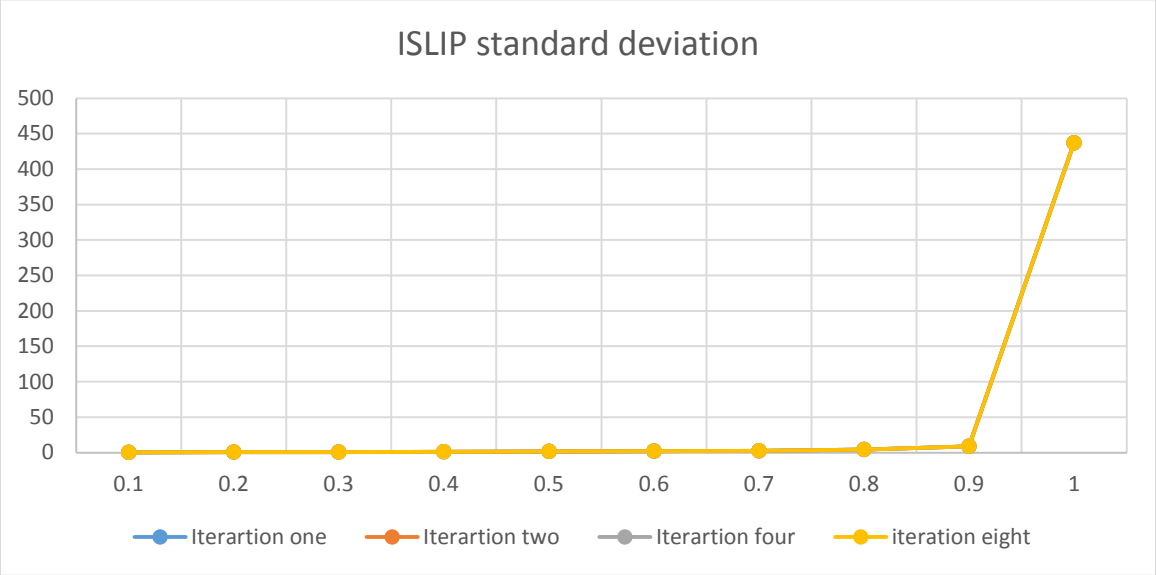
Switch size: 8
Switch Architecture: CIOQ with Speedup 2
Scheduling Algorithm: ISLIP, PIM, Maxsize and LQF (Longest Queue First).
Traffic Pattern: Bernoulli iid uniform
Iteration: 1,2,4,8 for PIM and ISLIP
Utilization: 0.1 to 1.0

ISLIP

		ISLIP		
		Latency		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.096966294	0.096966294	0.096966294	0.096966294
0.2	0.22187113	0.22187113	0.22187113	0.22187113
0.3	0.37395888	0.37395888	0.37395888	0.37395888
0.4	0.58323274	0.58323274	0.58323274	0.58323274
0.5	0.88013321	0.88013321	0.88013321	0.88013321
0.6	1.3200389	1.3200389	1.3200389	1.3200389
0.7	2.039507	2.039507	2.039507	2.039507
0.8	3.479742	3.479742	3.479742	3.479742
0.9	7.9290422	7.9290422	7.9290422	7.9290422
1	525.62265	525.62265	525.62265	525.62265

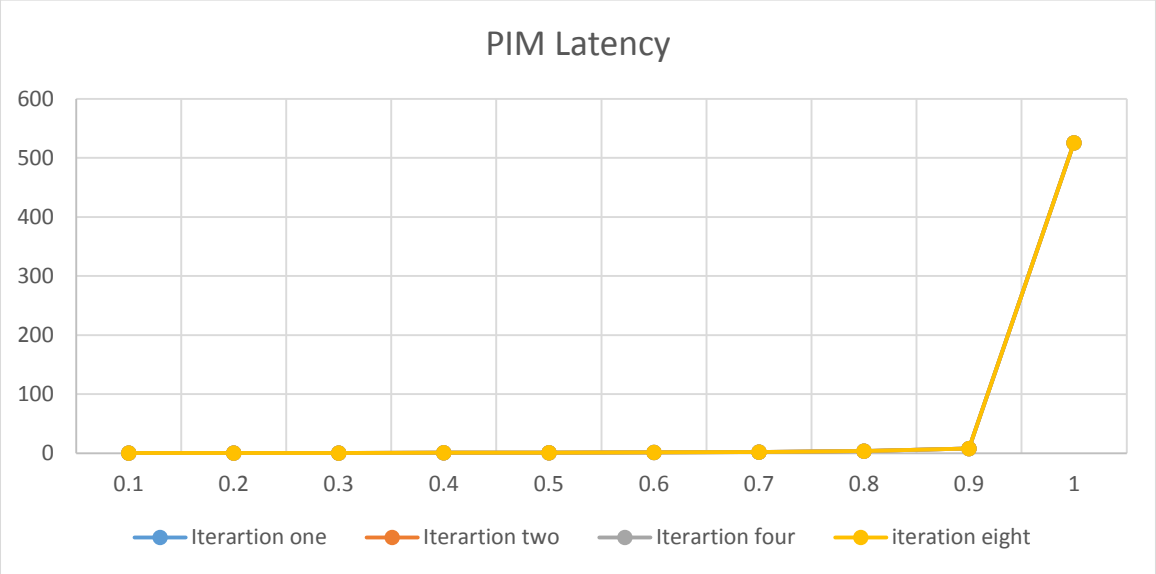


		standard deviation		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.4455172	0.4455172	0.4455172	0.4455172
0.2	0.68541224	0.68541224	0.68541224	0.68541224
0.3	0.89950879	0.89950879	0.89950879	0.89950879
0.4	1.1545821	1.1545821	1.1545821	1.1545821
0.5	1.4871555	1.4871555	1.4871555	1.4871555
0.6	1.9339135	1.9339135	1.9339135	1.9339135
0.7	2.6772471	2.6772471	2.6772471	2.6772471
0.8	4.1023163	4.1023163	4.1023163	4.1023163
0.9	8.6897241	8.6897241	8.6897241	8.6897241
1	436.82359	436.82359	436.82359	436.82359

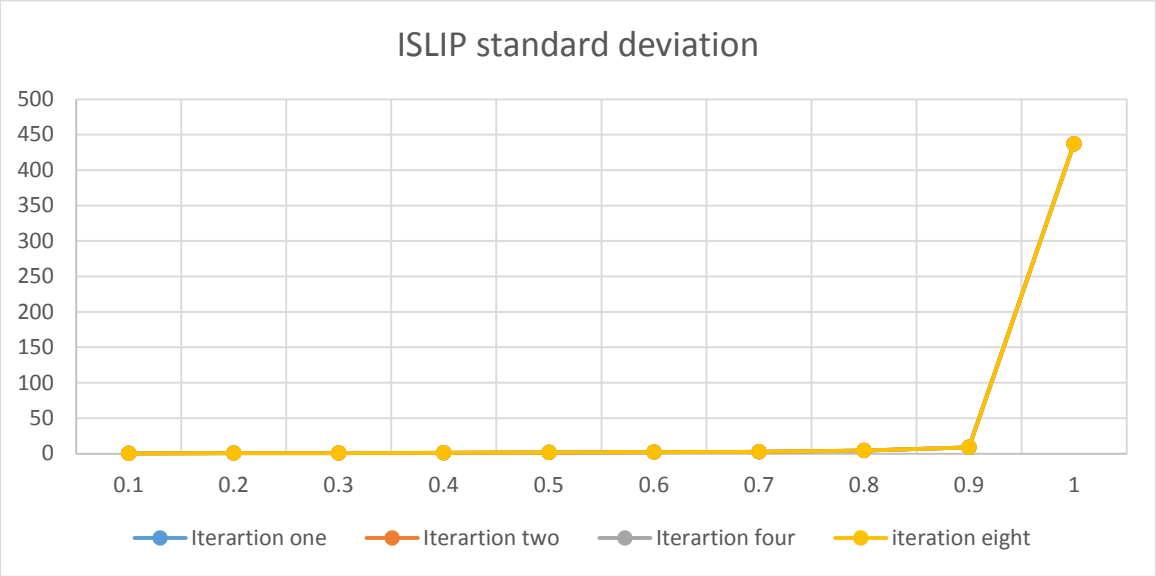


PIM

	PIM			
		Latency		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.096966294	0.096966294	0.096966294	0.096966294
0.2	0.22187113	0.22187113	0.22187113	0.22187113
0.3	0.37395888	0.37395888	0.37395888	0.37395888
0.4	0.58323274	0.58323274	0.58323274	0.58323274
0.5	0.88013321	0.88013321	0.88013321	0.88013321
0.6	1.3200389	1.3200389	1.3200389	1.3200389
0.7	2.039507	2.039507	2.039507	2.039507
0.8	3.479742	3.479742	3.479742	3.479742
0.9	7.9290422	7.9290422	7.9290422	7.9290422
1	525.62265	525.62265	525.62265	525.62265



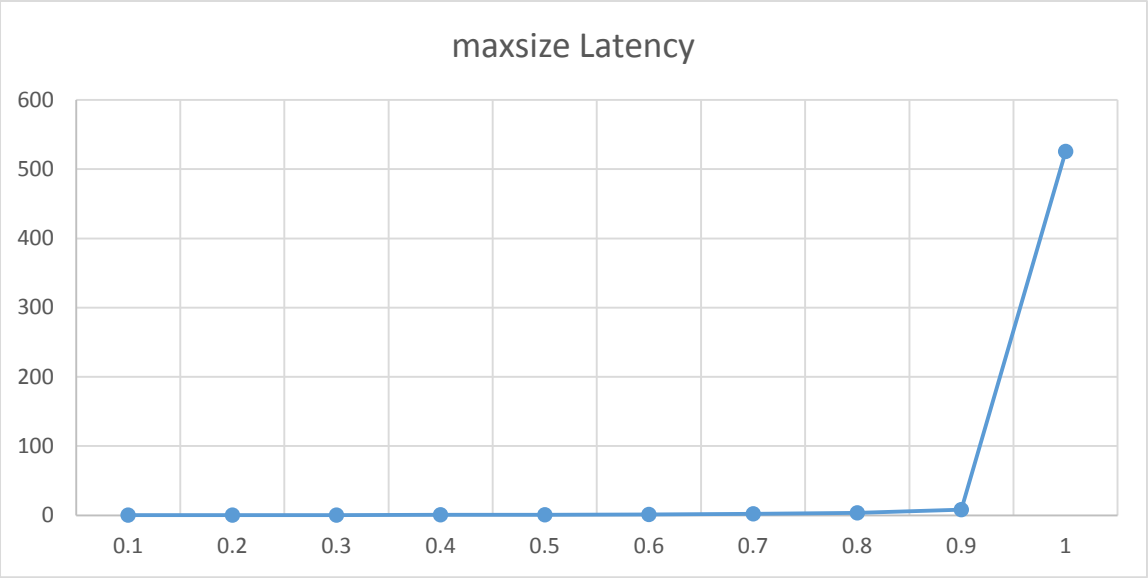
		standard deviation		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.4455172	0.4455172	0.4455172	0.4455172
0.2	0.68541224	0.68541224	0.68541224	0.68541224
0.3	0.89950879	0.89950879	0.89950879	0.89950879
0.4	1.1545821	1.1545821	1.1545821	1.1545821
0.5	1.4871555	1.4871555	1.4871555	1.4871555
0.6	1.9339135	1.9339135	1.9339135	1.9339135
0.7	2.6772471	2.6772471	2.6772471	2.6772471
0.8	4.1023163	4.1023163	4.1023163	4.1023163
0.9	8.6897241	8.6897241	8.6897241	8.6897241
1	436.82359	436.82359	436.82359	436.82359

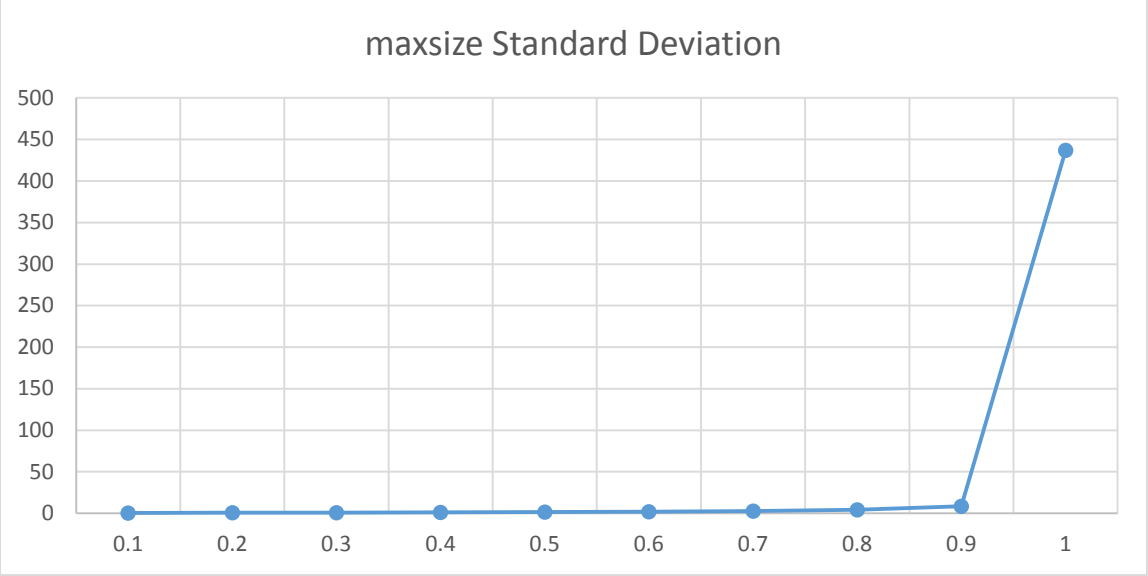


Maxsize

	maxsize
Load	Latency
0.1	0.096966294
0.2	0.22187113
0.3	0.37395888
0.4	0.58323274
0.5	0.88013321
0.6	1.3200389
0.7	2.039507
0.8	3.479742
0.9	7.9290422
1	525.62265

Load	Standard Deviation
0.1	0.4455172
0.2	0.68541224
0.3	0.89950879
0.4	1.1545821
0.5	1.4871555
0.6	1.9339135
0.7	2.6772471
0.8	4.1023163
0.9	8.6897241
1	436.82359

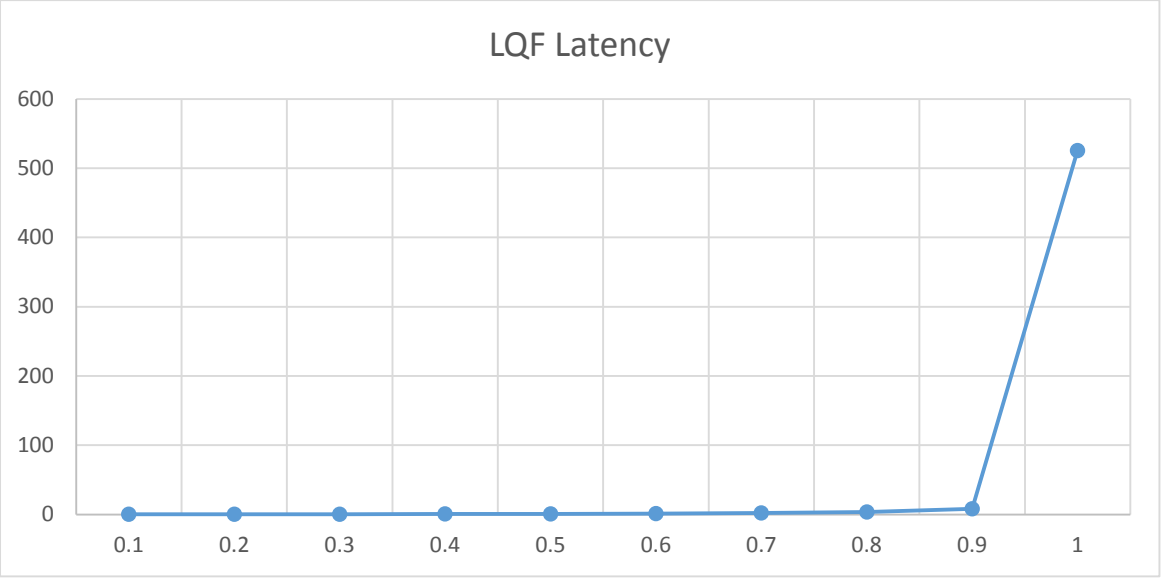


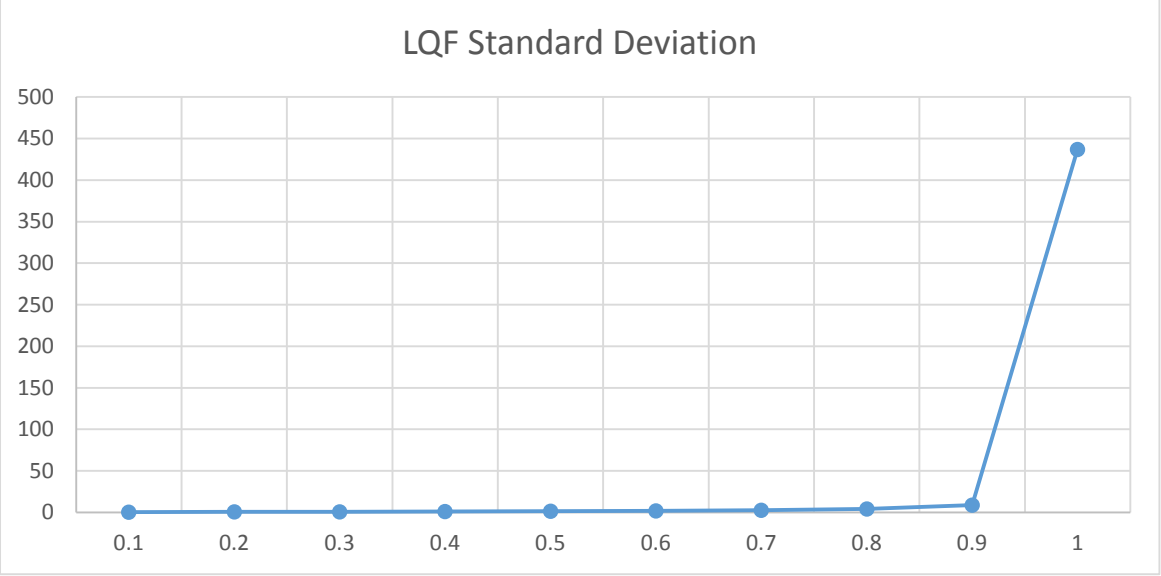


LQF

	LQF
Load	Latency
0.1	0.096966294
0.2	0.22187113
0.3	0.37395888
0.4	0.58323274
0.5	0.88013321
0.6	1.3200389
0.7	2.039507
0.8	3.479742
0.9	7.9290422
1	525.62265

Load	Standard Deviation
0.1	0.4455172
0.2	0.68541224
0.3	0.8995087
0.4	1.1545821
0.5	1.4871555
0.6	1.9339135
0.7	2.6772471
0.8	4.1023163
0.9	8.6897241
1	436.82359





Performance Analysis:

The switch architecture used here is CIOQ with speed up of 2. Looking at the curves it can be observed that the latency for ISLIP remains the same for different iterations. Performance is good for lower values of utilization it however degrades for large values of load.

The same can be observed from graphs of PIM, LQF and Maxsize. Also the performance of all the scheduling algorithms is more or less the same.

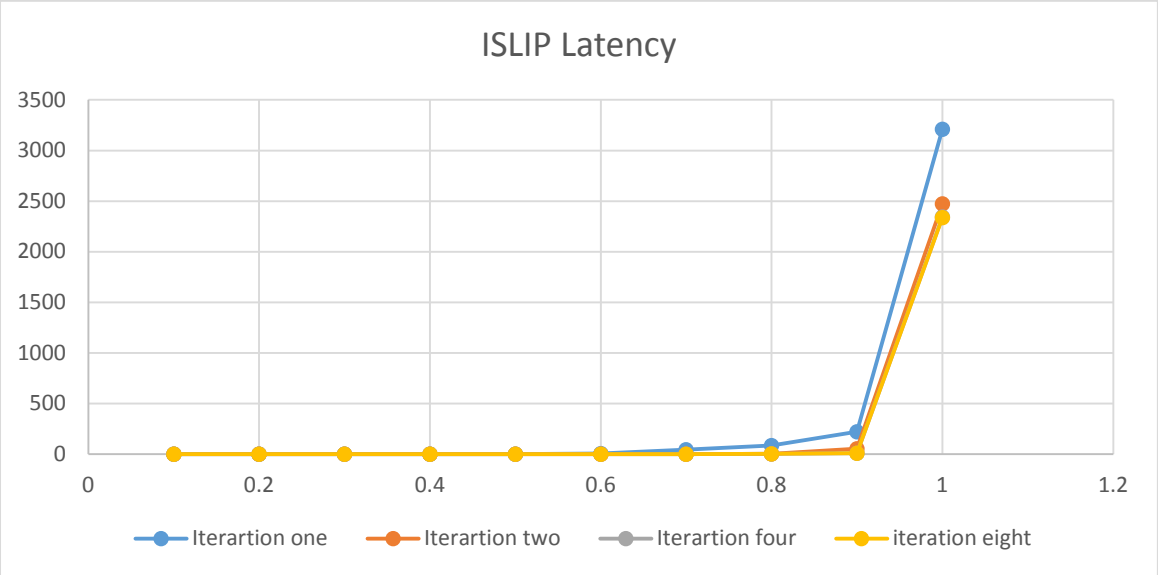
Standard deviation is the function of Latency has been plotted and is consistent for all values of iterations and any scheduling algorithms.

Combination C output:

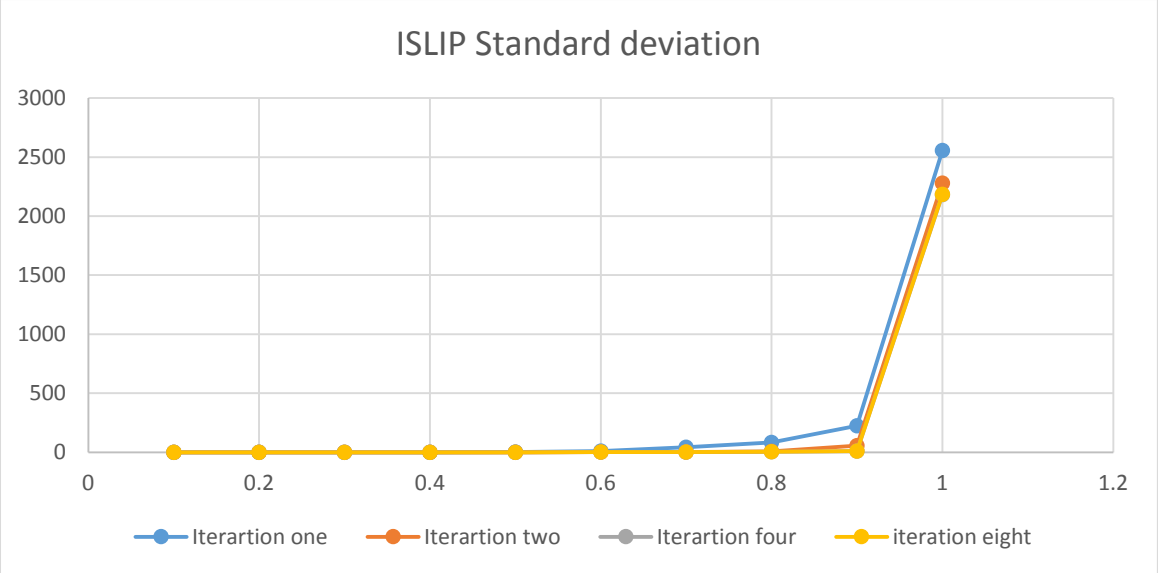
Switch size: 32
Switch Architecture: Input Queued with VOQ
Scheduling Algorithm: ISLIP, PIM, Maxsize and LQF (Longest Queue First).
Traffic Pattern: Bernoulli iid uniform
Iteration: 1,2,4,8 for PIM and ISLIP
Utilization: 0.1 to 1.0

ISLIP

		Latency		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.060039263	0.059138392	0.059138392	0.059138392
0.2	0.15530342	0.14551947	0.14551947	0.14551947
0.3	0.31813537	0.27096807	0.2709614	0.2709614
0.4	0.63847081	0.45792801	0.45779622	0.45779622
0.5	1.4644498	0.7458366	0.74435522	0.74435522
0.6	7.6295783	1.2196127	1.2077213	1.2077213
0.7	44.32604	2.1576458	2.0465177	2.0465177
0.8	88.101876	5.278788	3.8338392	3.8312581
0.9	222.02634	54.606787	9.6963609	9.6868669
1	3210.9421	2474.7963	2343.3282	2337.8653

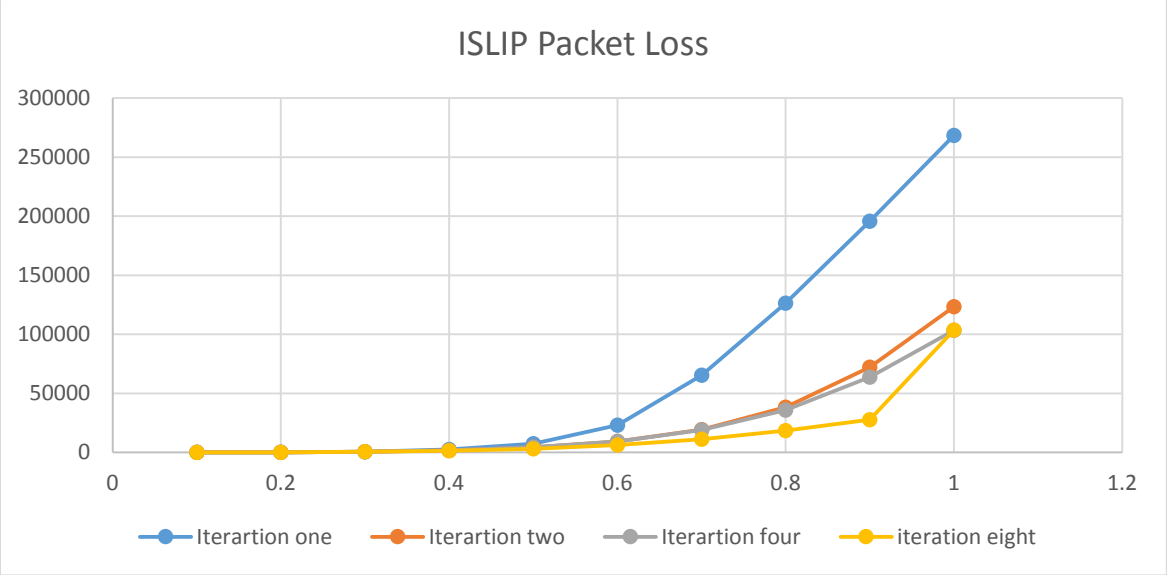


		standard deviation		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.26745867	0.26316192	0.26316192	0.26316192
0.2	0.47332299	0.44192149	0.44192149	0.44192149
0.3	0.75764418	0.64427465	0.64425677	0.64425677
0.4	1.248357	0.89869431	0.89835829	0.89835829
0.5	2.4199832	1.2516114	1.2485229	1.2485229
0.6	11.069096	1.7986627	1.7746959	1.7746959
0.7	42.036436	2.881195	2.6965093	2.6965093
0.8	85.277779	6.809815	4.6275785	4.6200726
0.9	225.82136	57.710729	11.088678	11.081522
1	2554.921	2279.7556	2181.4578	2183.7403



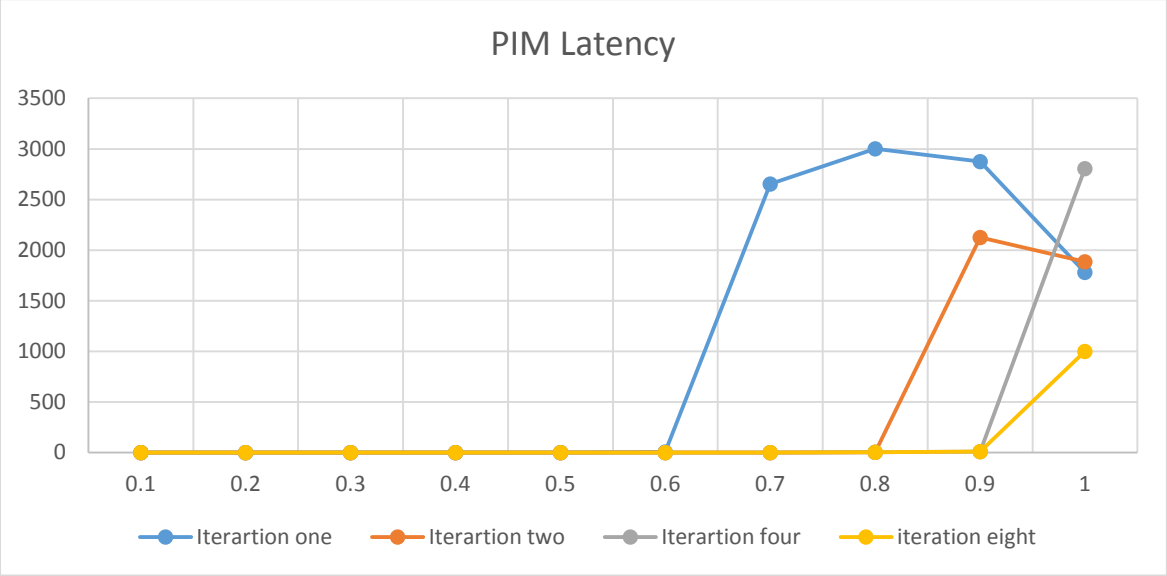
Number of Packets Lost

Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	22	21	21	12
0.2	147	131	131	134
0.3	650	570	570	454
0.4	2363	1722	1721	1350
0.5	7451	4339	4332	3097
0.6	23028	9345	9304	6321
0.7	65448	19194	18959	11217
0.8	126368	38144	35785	18490
0.9	195576	72065	63593	27779
1	268433	123416	103296	103439

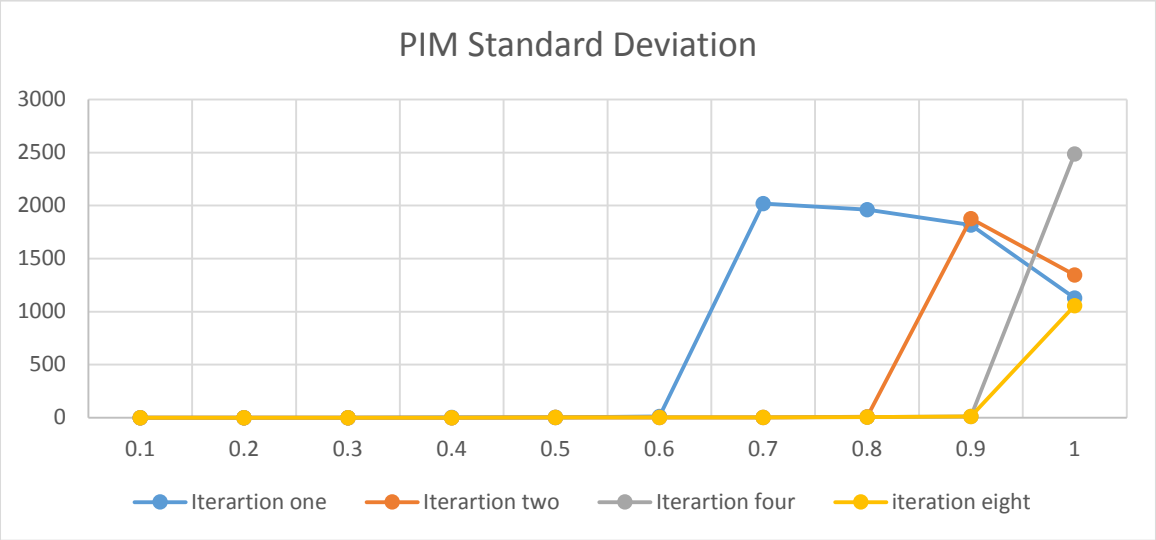


PIM

	PIM			
		Latency		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.059751485	0.059040798	0.059040798	0.059040798
0.2	0.1541888	0.14527569	0.14527569	0.14527569
0.3	0.313901	0.26884675	0.26951963	0.26951963
0.4	0.62862125	0.45431316	0.4538536	0.4538536
0.5	1.4393056	0.73741686	0.73548639	0.73548639
0.6	6.7772133	1.2036774	1.1921769	1.1921769
0.7	2655.5632	2.1234857	2.0190248	2.0190248
0.8	3002.5989	4.9867792	3.7900652	3.7900652
0.9	2875.3668	2125.6685	9.6696014	9.6885768
1	1781.2708	1885.6619	2806.659	1000.9329

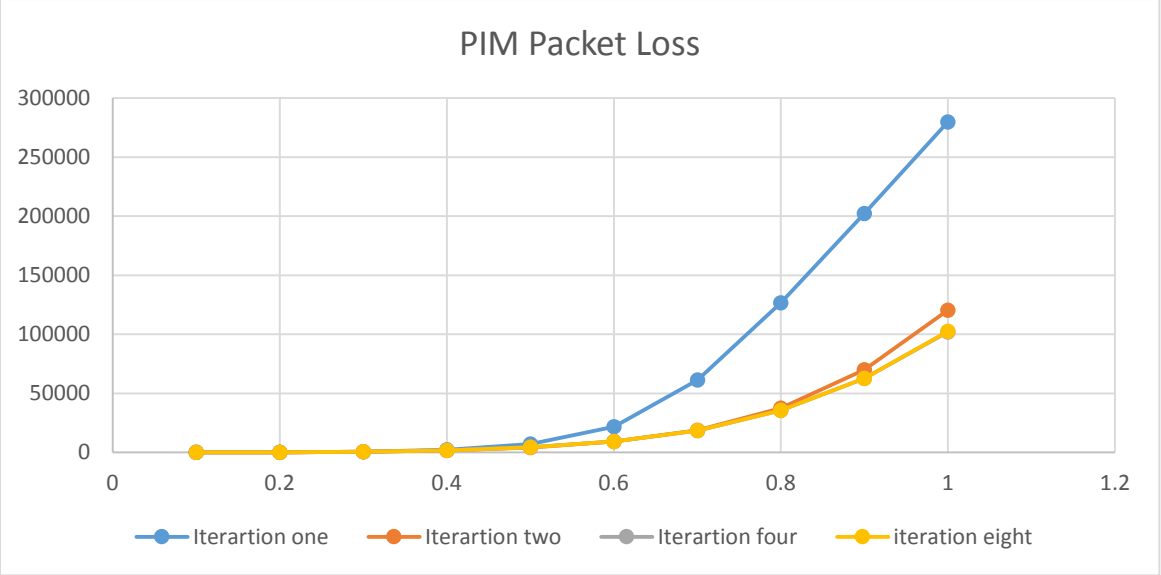


		standard deviation		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.27215074	0.2679238	0.2679238	0.2679238
0.2	0.49221953	0.45923866	0.45923866	0.45923866
0.3	0.80628624	0.68235674	0.68342425	0.68342425
0.4	1.3743851	0.97642094	0.97554315	0.97554315
0.5	2.7716278	1.3891248	1.3853416	1.3853416
0.6	12.01901	2.0377495	2.0121039	2.0121039
0.7	2020.1593	3.3002818	3.1044375	3.1044375
0.8	1962.7584	7.3750809	5.3487545	5.3487545
0.9	1815.9218	1879.0613	12.621752	12.679122
1	1128.9465	1344.9323	2487.5844	1057.1611



Number of Packets Lost

Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	25	19	19	19
0.2	142	134	134	134
0.3	636	545	546	546
0.4	2276	1748	1693	1693
0.5	7088	4212	4314	4314
0.6	21654	9199	9205	9205
0.7	61320	18838	18499	18499
0.8	126564	37482	35471	35471
0.9	202055	69902	62554	62554
1	279634	120370	102033	102384

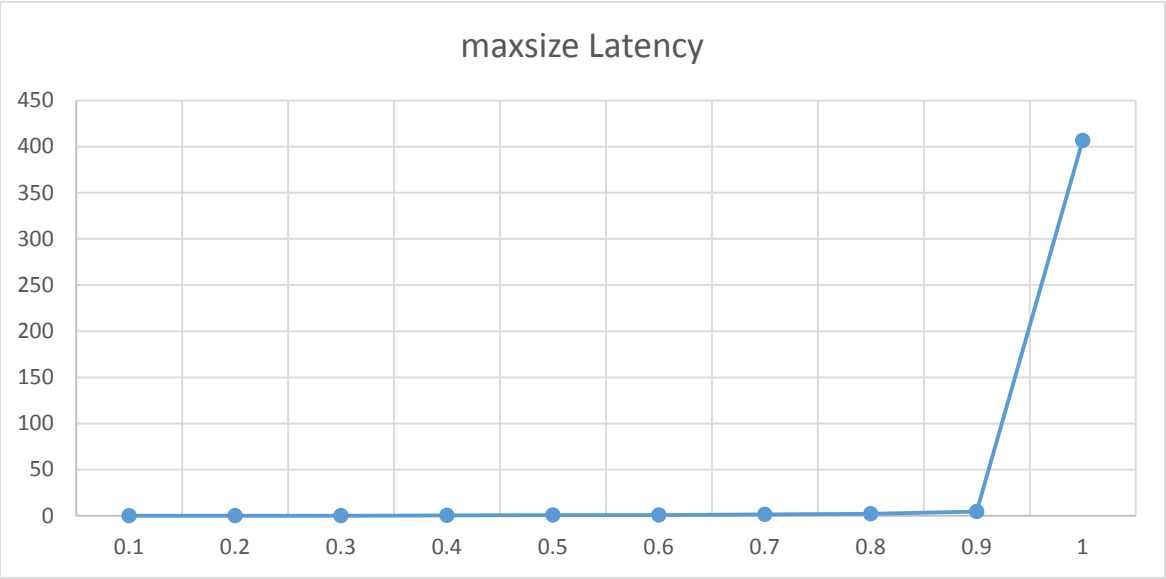


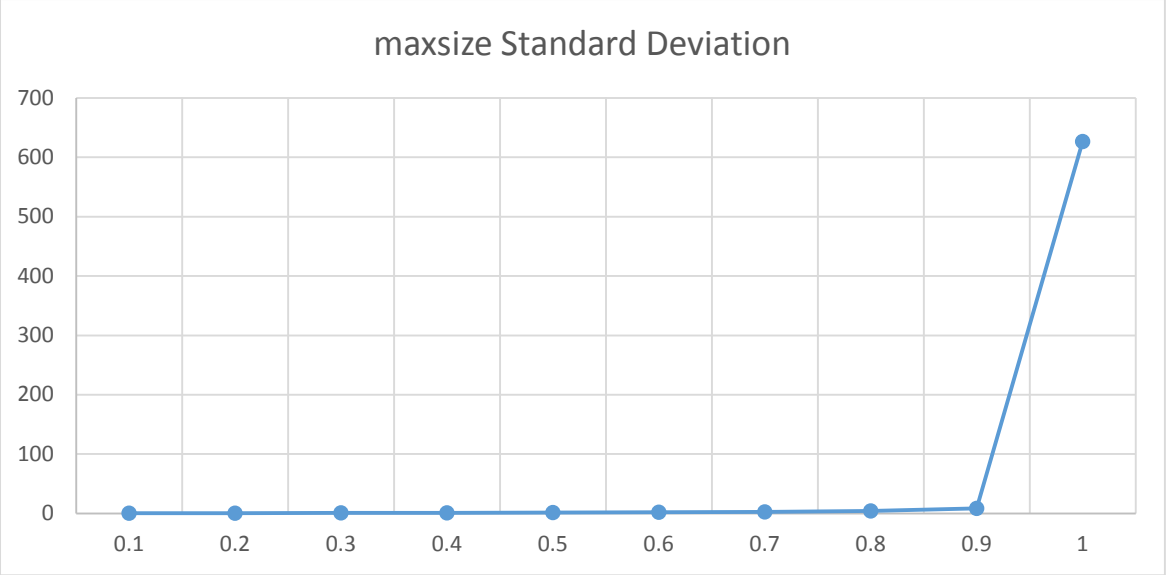
Maxsize

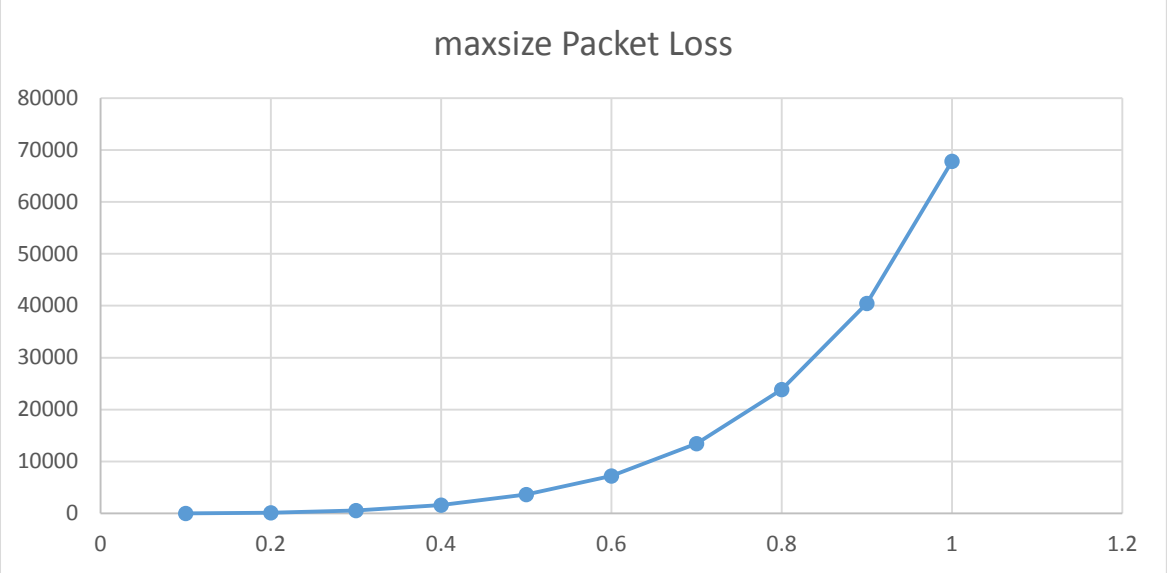
	maxsize
Load	Latency
0.1	0.058621643
0.2	0.14140016
0.3	0.25413379
0.4	0.40688746
0.5	0.61451003
0.6	0.90314993
0.7	1.3456339
0.8	2.1468808
0.9	4.537967
1	406.61067

Load	Standard Deviation
0.1	0.26654826
0.2	0.45242005
0.3	0.66484851
0.4	0.92363042
0.5	1.2649226
0.6	1.7411014
0.7	2.5124413
0.8	3.9870582
0.9	8.2565603
1	626.56671

Load	Packet Loss
0.1	17
0.2	119
0.3	533
0.4	1585
0.5	3619
0.6	7193
0.7	13471
0.8	23848
0.9	40428
1	67824





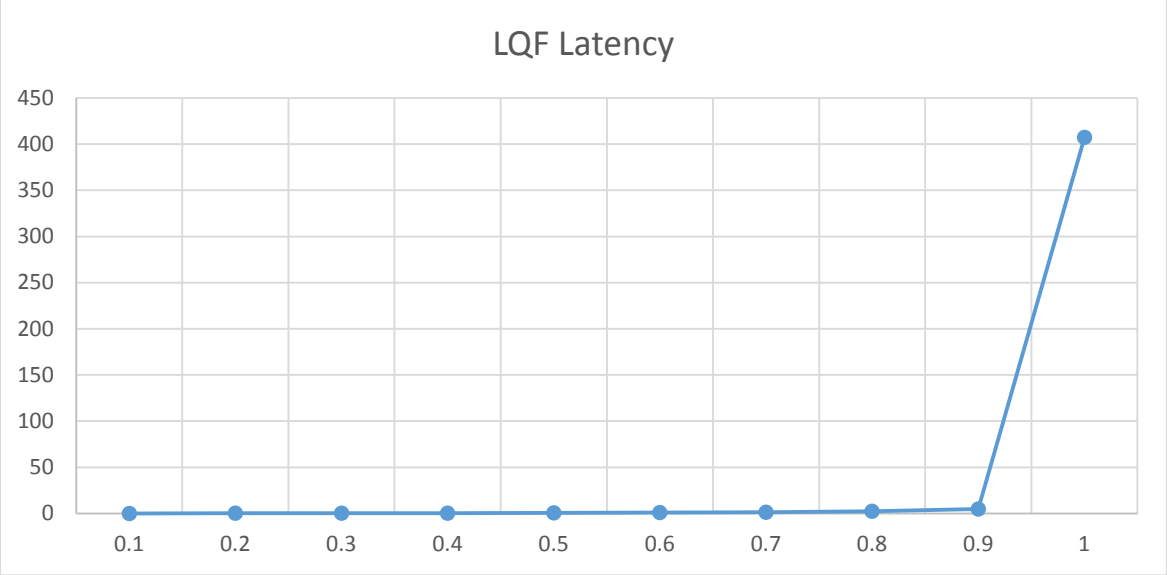


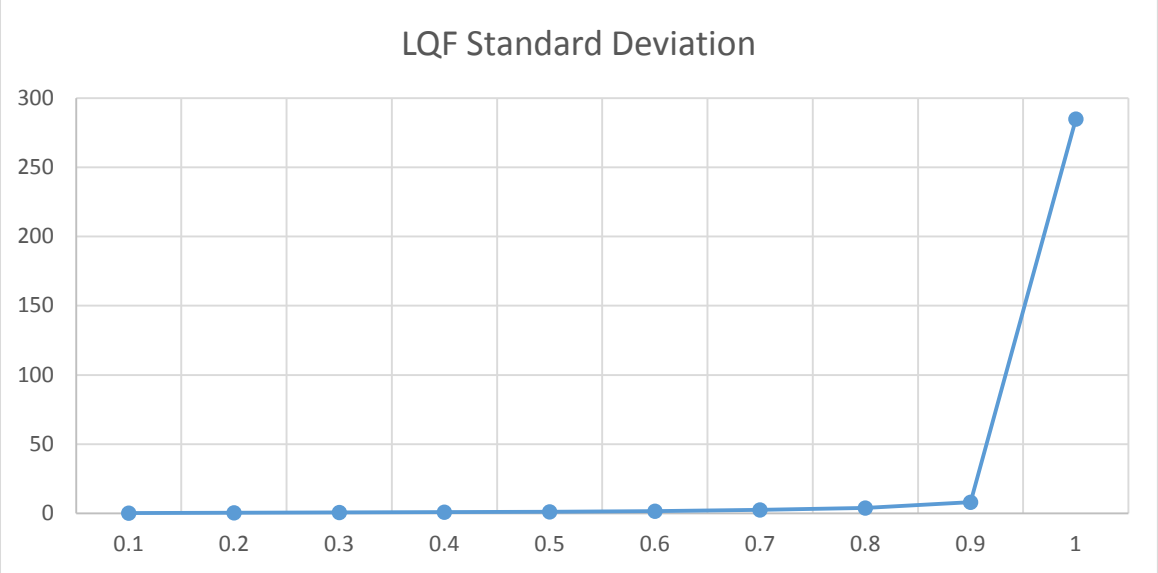
LQF

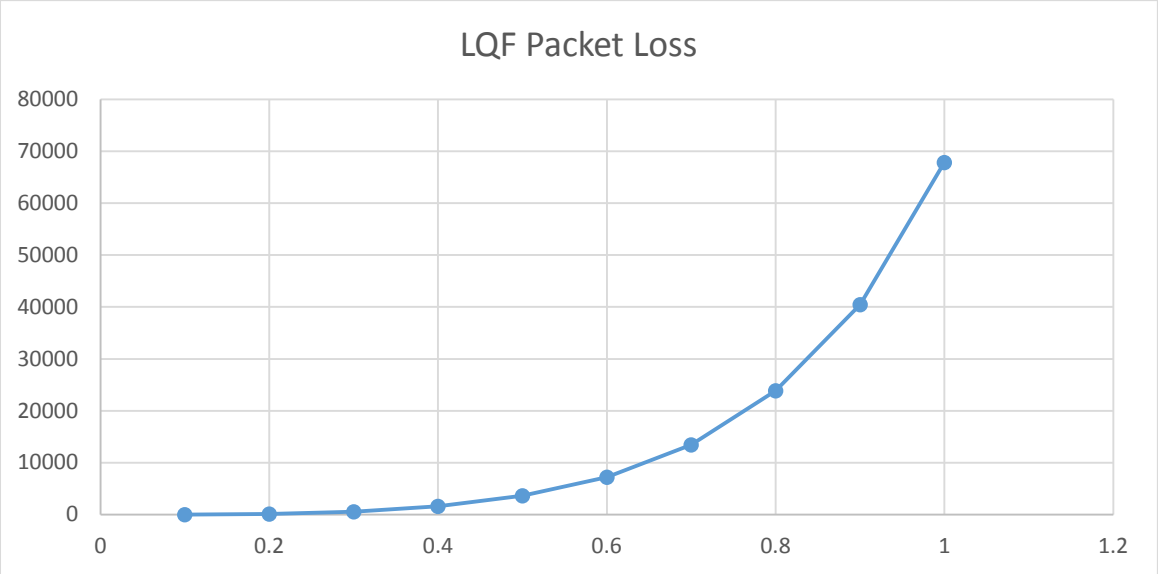
	LQF
Load	Latency
0.1	0.058619141
0.2	0.14137453
0.3	0.25392467
0.4	0.40636093
0.5	0.61318924
0.6	0.90231796
0.7	1.3504531
0.8	2.1699249
0.9	4.6188193
1	407.46047

Load	Standard Deviation
0.1	0.26647369
0.2	0.45214543
0.3	0.66347334
0.4	0.92047934
0.5	1.2567563
0.6	1.7277527
0.7	2.4911164
0.8	3.9233224
0.9	8.0488894
1	284.96124

Load	Packet Loss
0.1	17
0.2	119
0.3	533
0.4	1585
0.5	3619
0.6	7193
0.7	13471
0.8	23848
0.9	40428
1	67824


LQF Latency
450
400
350
300
250
200
150
100
50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


LQF Standard Deviation
300
250
200
150
100
50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


LQF Packet Loss
80000
70000
60000
50000
40000
30000
20000
10000
0
0
0.2
0.4
0.6
0.8
1
1.2

Performance Analysis:

Using ISLIP with Input Queued (with VOQ) and Bernoulli iid uniform traffic the Latency performance remains almost the same for all iterations when the load is less. However performance improves a bit when more iterations are employed for large values of load.

Using PIM the performance improves when more iterations are employed. High value of load however degrades performance. Iteration one and two shows unusual behavior where latency increases for load value 0.6 and 0.8 respectively and then gradually decreases for higher utilizations

For Maxsize and LQF as the utilization increases the latency also increases.High Latency values are seen for PIM and ISLIP. Maxsize and LQF however show low Latencies. LQF and Maxsize show better performance over ISLIP and PIM

For Packet Loss Rate, loss increases for low value of input buffer and large simulation times causes the buffer overflow. We have used a buffer of 7 and simulation length 50000.

For ISLIP Loss rate is high under one iteration it however decreases for higher value of iterations. Similar performance is observed for PIM, LQF and Max size. However Maxsize and LQF demonstrate lower Packet Losses. Also as the utilization increases the packet loss increases

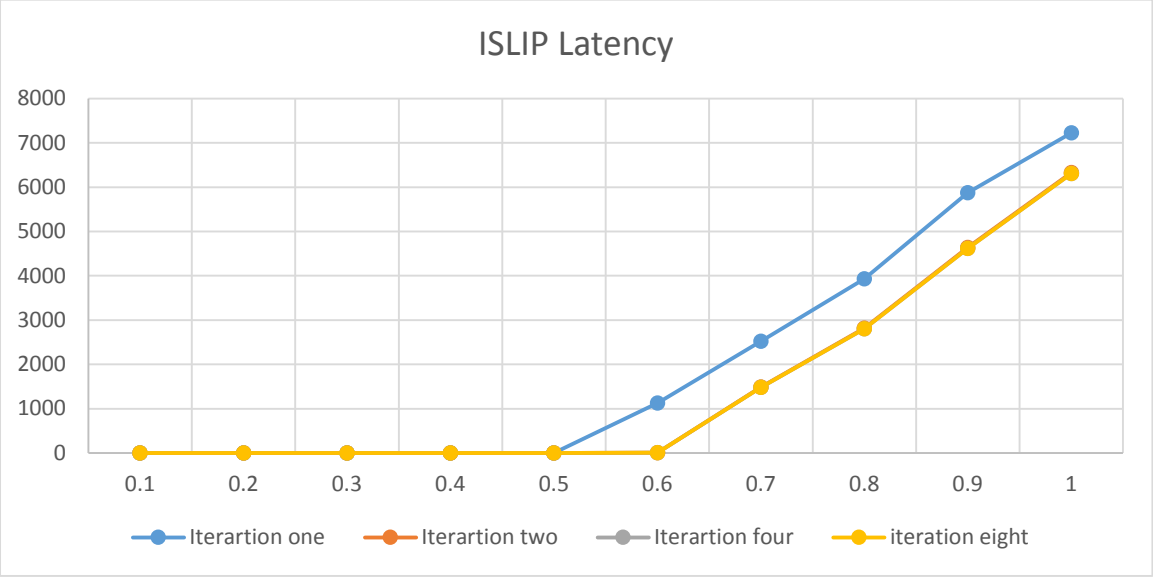
Combination D output

Switch size: 4
Switch Architecture: Input Queued with VOQ
Scheduling Algorithm: ISLIP, PIM, Maxsize and LQF (Longest Queue First).
Traffic Pattern: Bernoulli iid non-uniform
Iteration: 1,2,4,8 for PIM and ISLIP
Utilization: 0.1 to 1.0

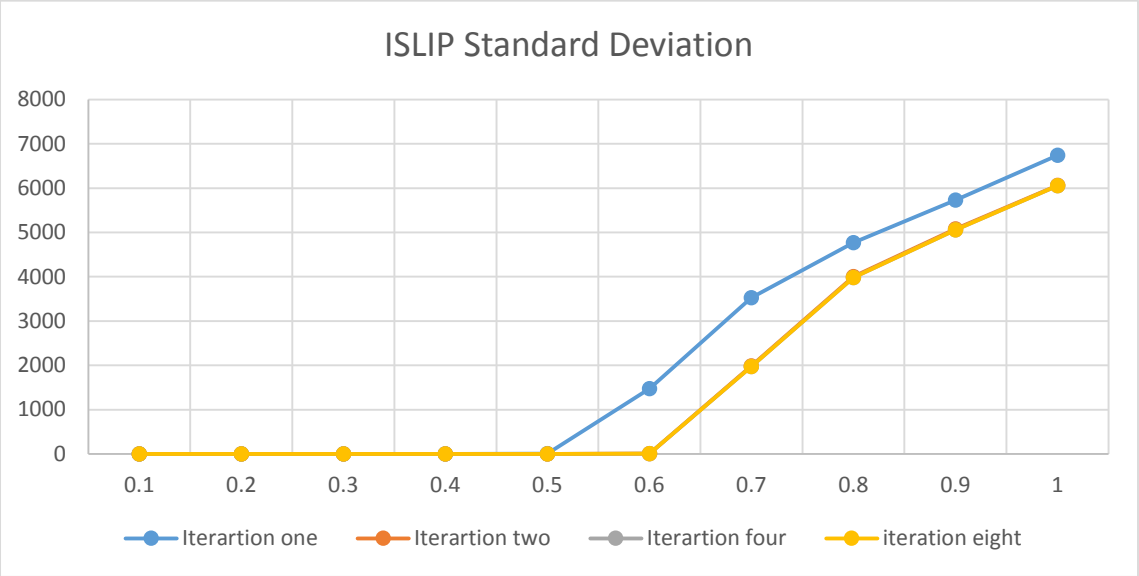
ISLIP

Latency

Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.052837377	0.052235813	0.052235813	0.052235813
0.2	0.15106576	0.14518399	0.14518399	0.14518399
0.3	0.33497752	0.28461177	0.28461177	0.28461177
0.4	0.72951498	0.5259807	0.5259807	0.5259807
0.5	2.658643	1.1288793	1.1288793	1.1288793
0.6	1128.0191	4.6021806	4.5442217	4.5442217
0.7	2522.1413	1489.6285	1477.7853	1477.7853
0.8	3933.1492	2815.2223	2801.1223	2801.1223
0.9	5877.3447	4642.2582	4615.4864	4615.4864
1	7224.5255	6328.3366	6312.0172	6312.0172

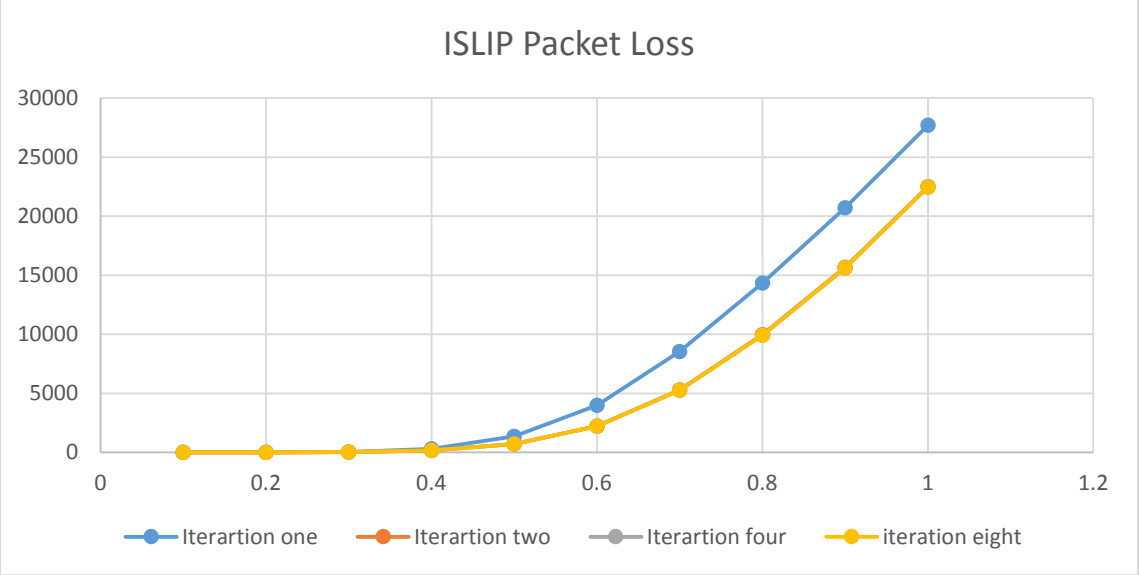


		standard deviation		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.2450952	0.2427586	0.2427586	0.2427586
0.2	0.45338991	0.43457479	0.43457479	0.43457479
0.3	0.80020213	0.66939387	0.66939387	0.66939387
0.4	1.479883	1.0360445	1.0360445	1.0360445
0.5	5.2747822	2.1132231	2.1132231	2.1132231
0.6	1473.0599	8.9269576	8.8008473	8.8008473
0.7	3529.7806	1986.7264	1969.2528	1969.2528
0.8	4767.248	4003.9131	3981.9679	3981.9679
0.9	5733.6366	5077.9109	5062.2772	5062.2772
1	6741.4659	6063.7164	6054.6811	6054.6811



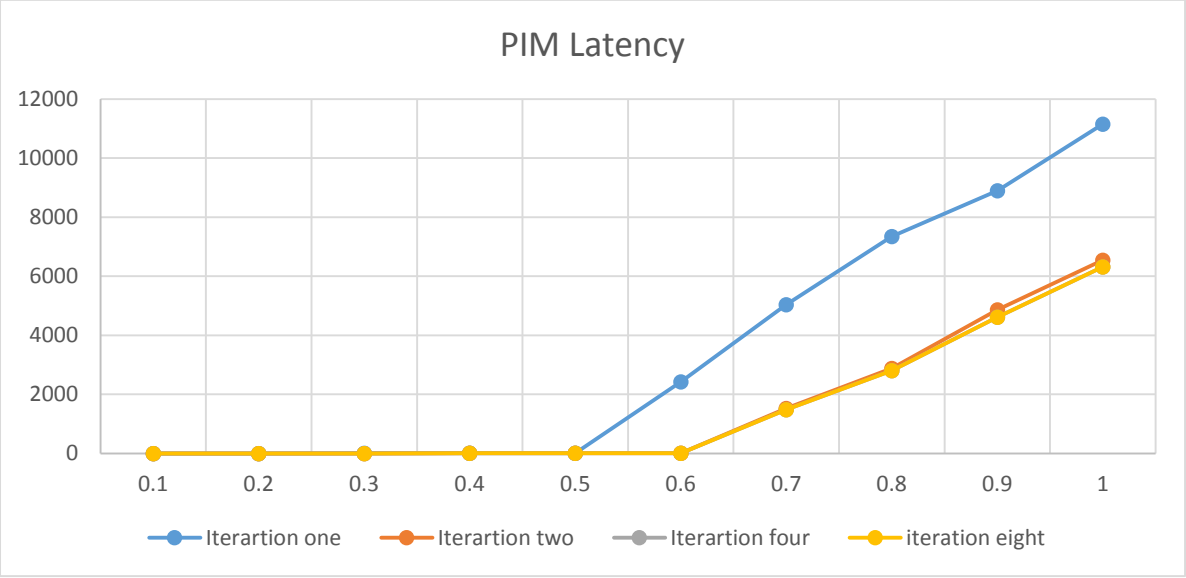
Number of Packets Lost

Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0	0	0	0
0.2	2	2	2	2
0.3	40	18	18	18
0.4	297	155	155	155
0.5	1358	705	705	705
0.6	3973	2220	2220	2220
0.7	8533	5283	5272	5272
0.8	14337	9964	9922	9922
0.9	20701	15663	15601	15601
1	27691	22484	22481	22481

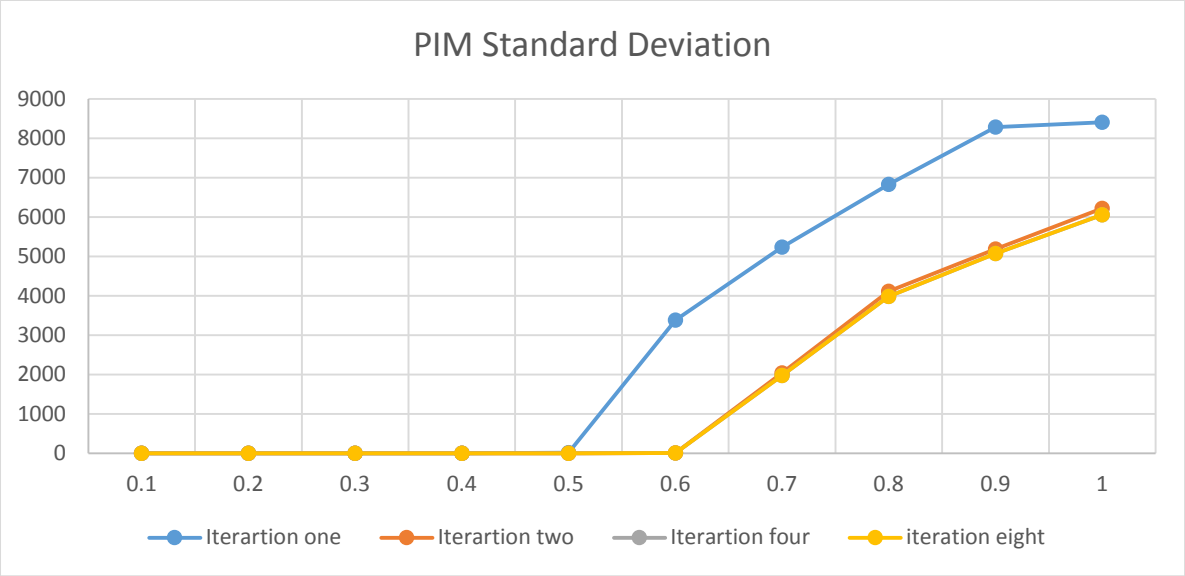


PIM

	PIM			
	Latency			
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.053138159	0.052837377	0.052837377	0.052837377
0.2	0.15111603	0.14483209	0.14483209	0.14483209
0.3	0.32048185	0.28276626	0.28276626	0.28276626
0.4	0.75191758	0.52516669	0.52516669	0.52516669
0.5	7.24995	1.1165513	1.1148682	1.1148682
0.6	2424.6266	4.5743119	4.3784091	4.3784091
0.7	5032.8013	1523.1128	1475.7647	1475.7647
0.8	7341.5868	2877.0481	2800.3625	2800.3625
0.9	8892.1873	4864.5845	4614.4037	4614.4037
1	11145.866	6538.7952	6311.2509	6311.2509

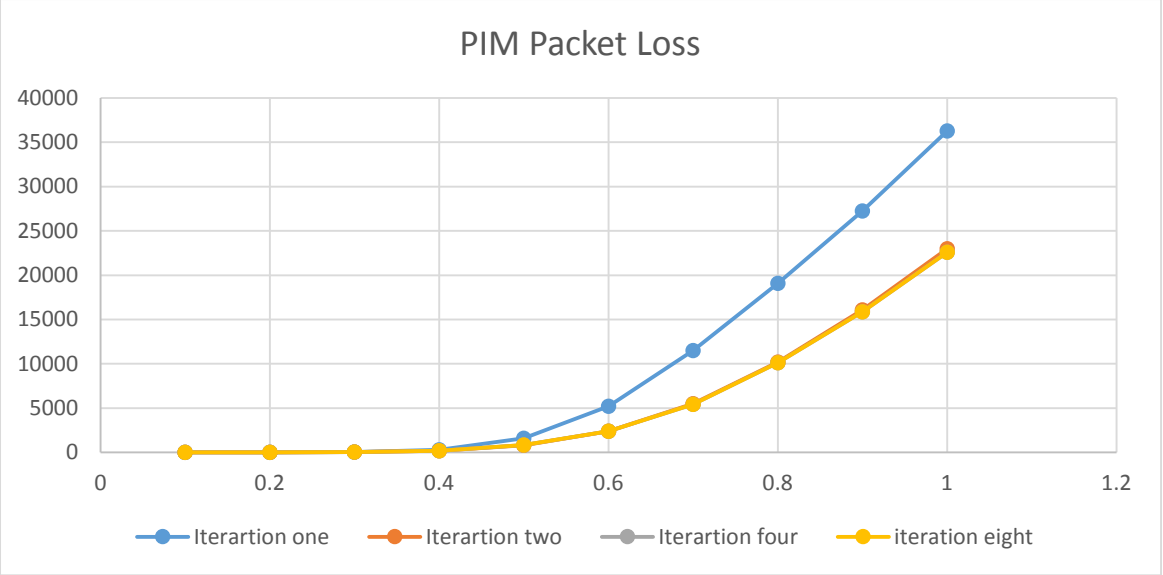


		standard deviation		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0.25089309	0.25035661	0.25035661	0.25035661
0.2	0.47497951	0.45453558	0.45453558	0.45453558
0.3	0.79690694	0.69757864	0.69757864	0.69757864
0.4	1.6480567	1.0981354	1.0981354	1.0981354
0.5	14.899316	2.2209845	2.2161709	2.2161709
0.6	3377.7605	9.2091661	8.5297398	8.5297398
0.7	5231.3345	2043.3708	1978.4035	1978.4035
0.8	6826.5743	4110.4093	3984.163	3984.163
0.9	8279.9434	5186.8166	5068.7973	5068.7973
1	8405.9884	6219.075	6056.0777	6056.0777



Number of Packets Lost

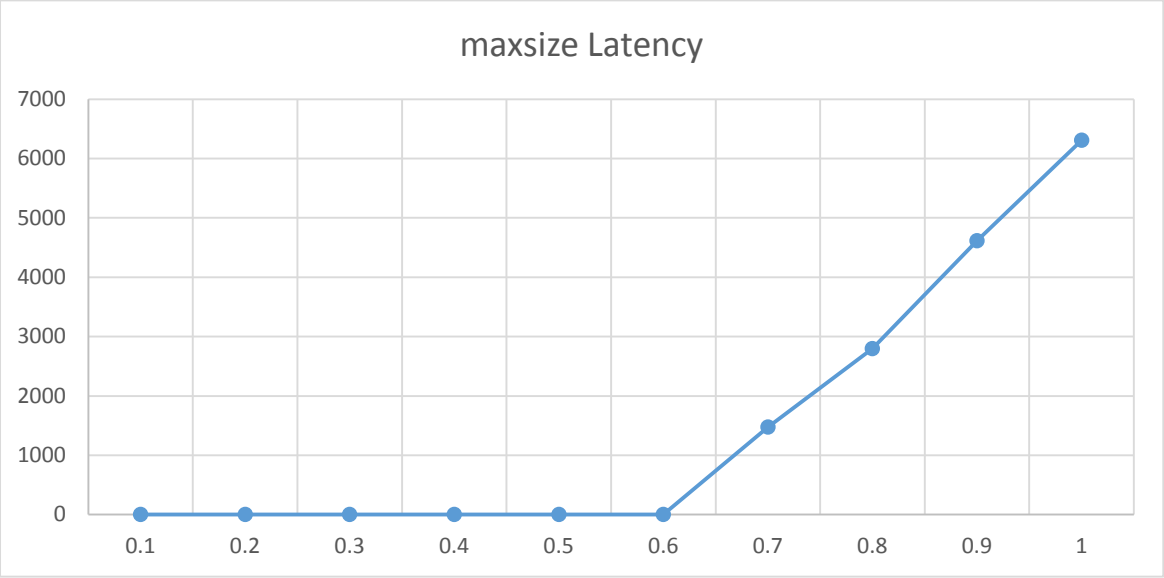
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	0	0	0	0
0.2	5	4	4	4
0.3	42	21	21	21
0.4	305	174	174	174
0.5	1595	785	823	823
0.6	5222	2370	2389	2389
0.7	11484	5509	5436	5436
0.8	19094	10178	10110	10110
0.9	27232	16083	15856	15856
1	36290	22984	22584	22584

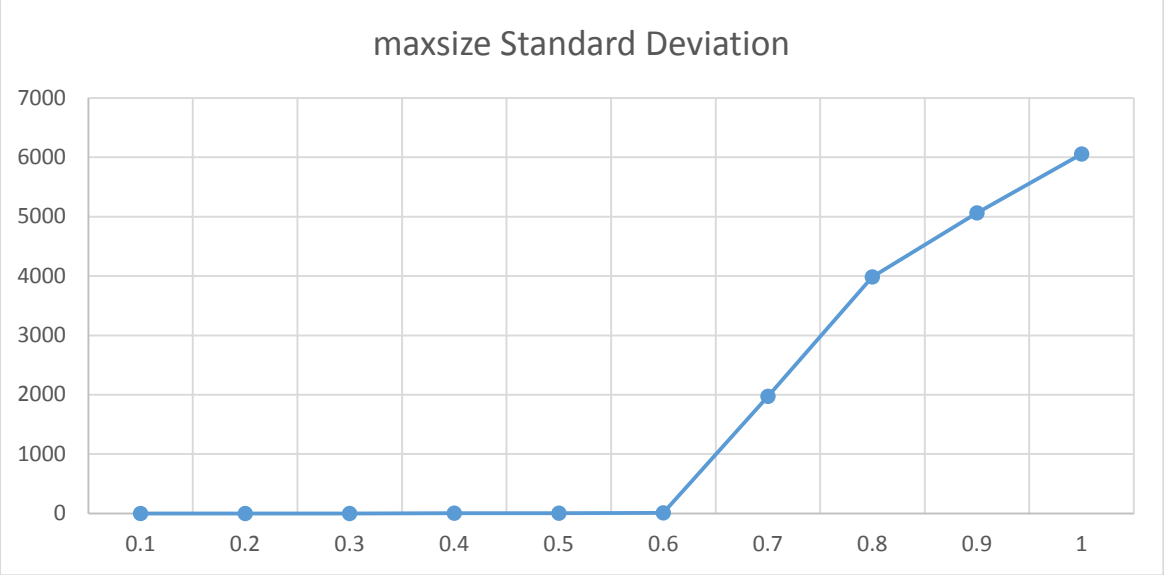


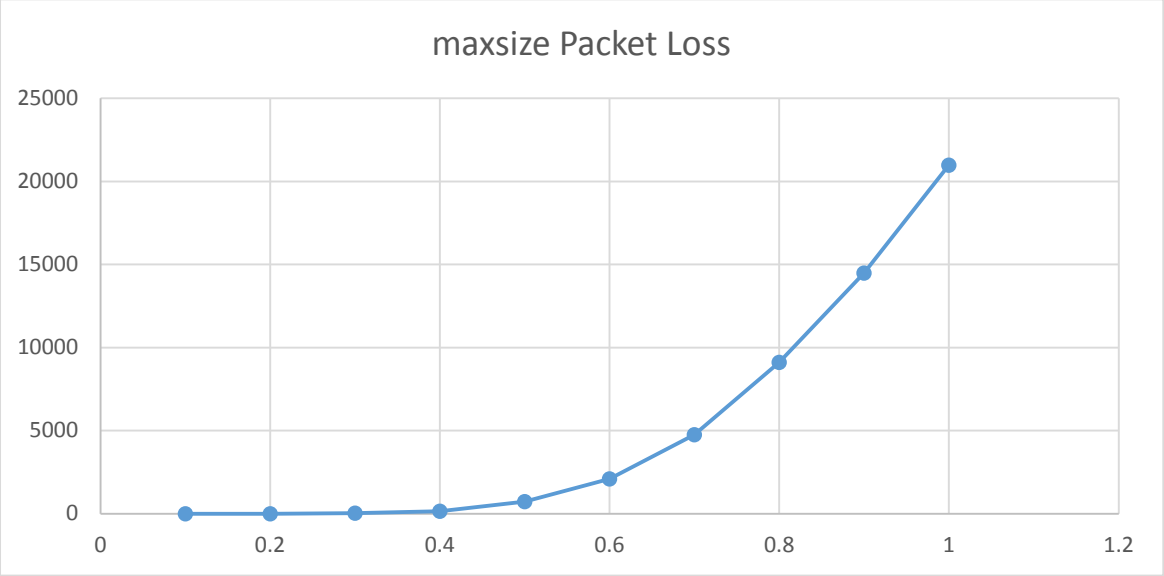
Maxsize

	maxsize	
Load	Latency	Standard Deviation
0.1	0.051935031	0.246308
0.2	0.14196662	0.447702
0.3	0.27350513	0.700735
0.4	0.48062365	1.056869
0.5	0.99279669	2.151232
0.6	3.8657737	8.565271
0.7	1475.8405	1971.19
0.8	2798.9213	3982.373
0.9	4613.9507	5062.298
1	6310.639	6056.481

Load	Packet Loss
0.1	0
0.2	2
0.3	26
0.4	157
0.5	731
0.6	2097
0.7	4755
0.8	9104
0.9	14492
1	20970



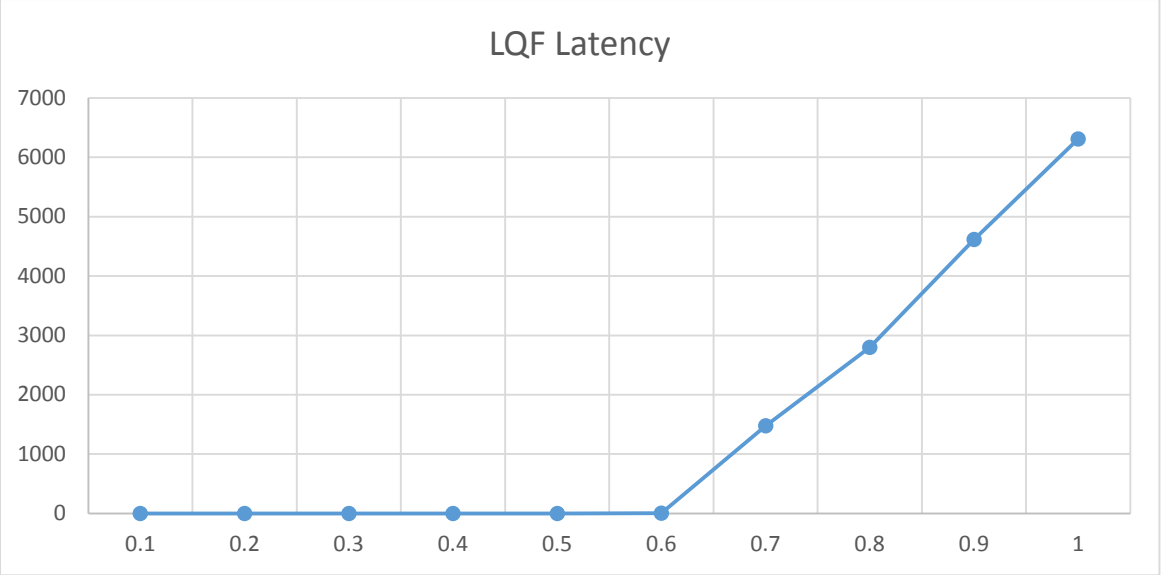


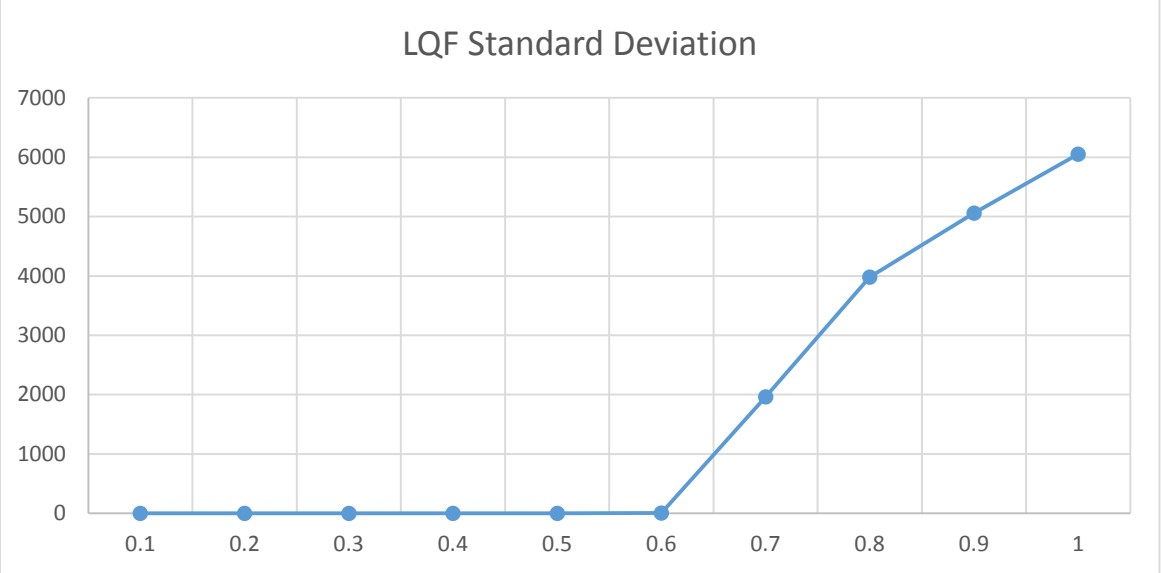


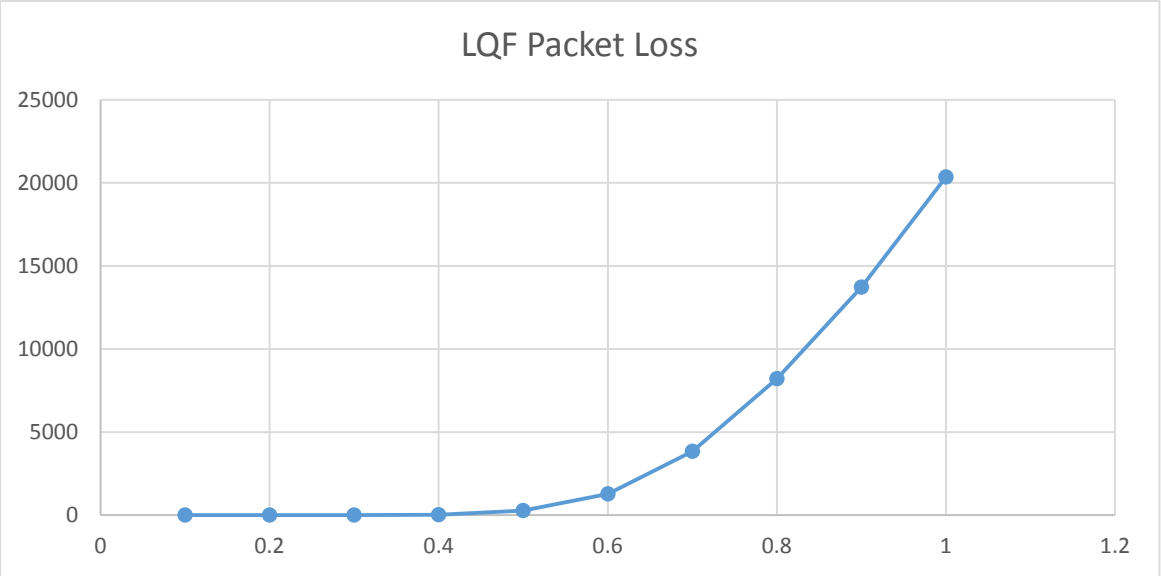
LQF

	LQF	
Load	Latency	Standard Deviation
0.1	0.051935031	0.24630774
0.2	0.14131309	0.44379273
0.3	0.27135763	0.68619144
0.4	0.47312879	0.99656871
0.5	0.95285831	1.8742984
0.6	3.6999766	6.6461378
0.7	1476.473	1965.3172
0.8	2798.8454	3982.1394
0.9	4614.1868	5058.798
1	6310.9779	6053.9669

Load	Packet Loss
0.1	0
0.2	0
0.3	2
0.4	36
0.5	281
0.6	1273
0.7	3844
0.8	8222
0.9	13731
1	20349


LQF Latency
7000
6000
5000
4000
3000
2000
1000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


LQF Standard Deviation
7000
6000
5000
4000
3000
2000
1000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


LQF Packet Loss
25000
20000
15000
10000
5000
0
0
0.2
0.4
0.6
0.8
1
1.2

Performance Analysis:

Using ISLIP with Input Queued (with VOQ) and Bernoulli iid non uniform traffic the Latency performance for lower value of load remains almost the same for all iterations. Performance under one iteration is not very efficient. Iteration two, four, eight have same performance and is better than under single iteration. Performance is good for load values less than 0.5 for single iteration and load values 0.6 for multiple iterations. Beyond these values performance degrades.

PIM also doesn't show good performance under single iteration, works well under multiple iterations. Performance is the same under 2, 4 and 8 iterations. Performance is good for load values less than 0.5 for single iteration and load values 0.6 for multiple iterations. Beyond these values performance degrades.
For Maxsize and LQF as the utilization increases the latency also increases. Performance is good for load values less than 0.6. Beyond this performance degrades.

For higher values of iterations in PIM and ISLIP say 8 performance is the same as LQF and Maxsize algorithms.

As far as Packet Loss Rate is concerned. Loss increases for low value of input buffer and large simulation times causes the buffer overflow. We have used a buffer of 7 and simulation length 50000.

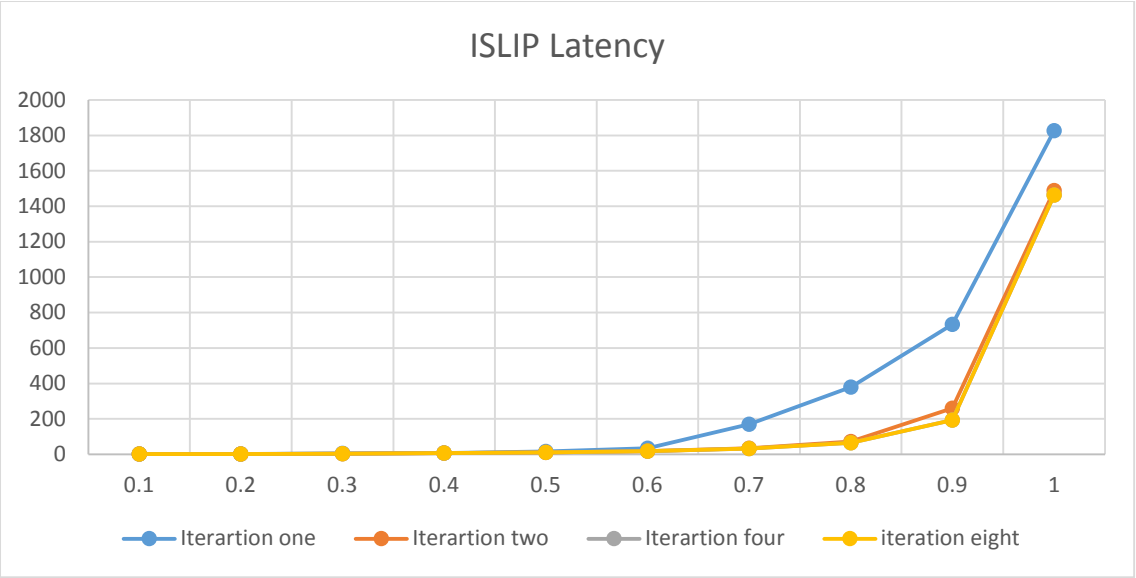
For ISLIP Loss rate is high under one iteration it however less for higher value of iterations. Similar performance is observed for PIM. Loss for higher values of iteration in case of PIM and ISLIP is the same as demonstrated by LQF and Maxsize. Also as the load increases the packet loss increases.

Combination E output

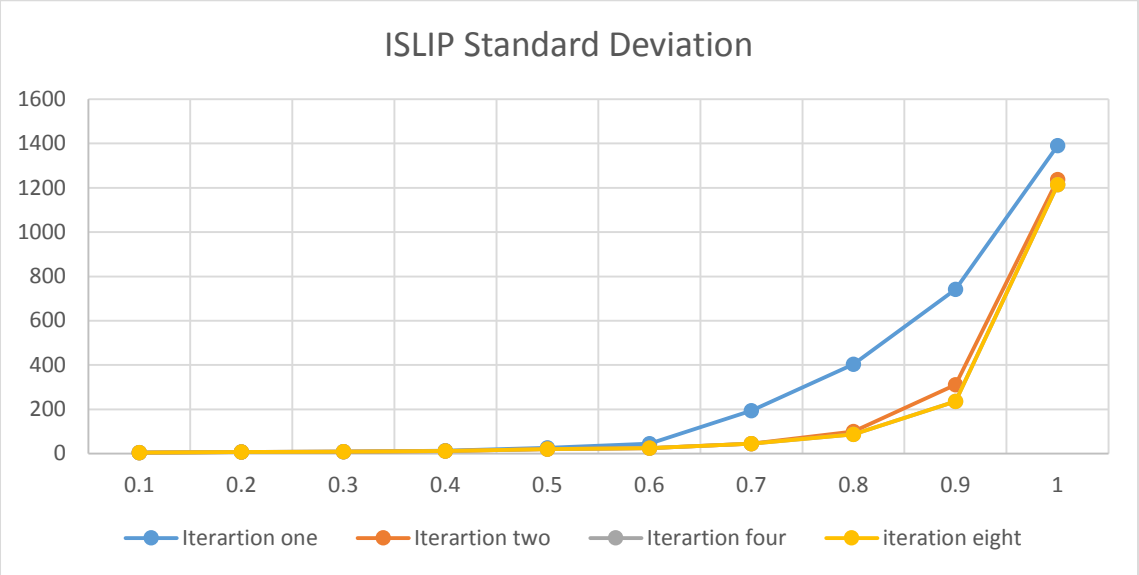
Switch size: 8
Switch Architecture: Input Queued with VOQ
Scheduling Algorithm: ISLIP, PIM, Maxsize and LQF (Longest Queue First).
Traffic Pattern: Bursty uniform
Iteration: 1,2,4,8 for PIM and ISLIP
Utilization: 0.1 to 1.0

ISLIP

		ISLIP		
		Latency		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	1.315475	1.3021065	1.3021065	1.3021065
0.2	2.5610447	2.5170613	2.5170613	2.5170613
0.3	4.5274403	4.3104315	4.3104315	4.3104315
0.4	7.7064931	6.8406054	6.8406054	6.8406054
0.5	15.561421	11.691392	11.691948	11.691948
0.6	35.008326	17.813565	17.765406	17.765406
0.7	170.58579	33.425264	32.880833	32.880833
0.8	378.59639	73.069215	64.533877	64.533877
0.9	733.18676	259.55058	193.84956	193.84837
1	1825.9511	1488.7072	1464.0859	1464.0859

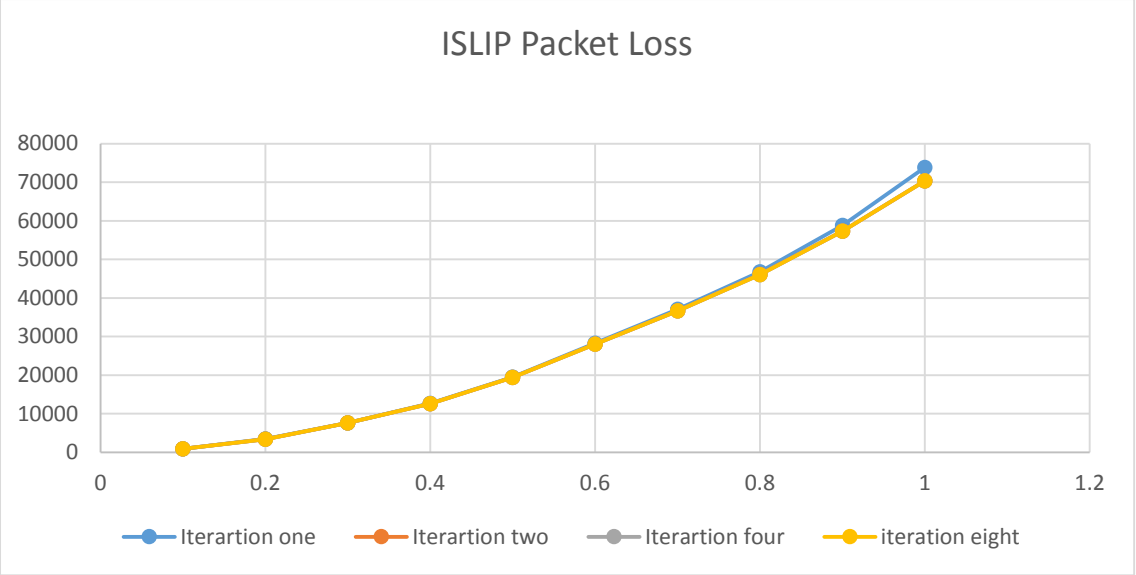


		standard deviation		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	4.1882033	4.1228577	4.1228577	4.1228577
0.2	6.7618505	6.6483128	6.6483128	6.6483128
0.3	8.4577314	8.0549609	8.0549609	8.0549609
0.4	13.543298	12.101161	12.101161	12.101161
0.5	25.437563	20.344824	20.346555	20.346555
0.6	45.05966	25.360189	25.244102	25.244102
0.7	194.23614	45.109933	44.384551	44.384551
0.8	402.65868	99.669419	86.943978	86.943978
0.9	741.99537	310.82107	235.00006	235.00067
1	1390.7781	1236.8551	1214.7039	1214.7039



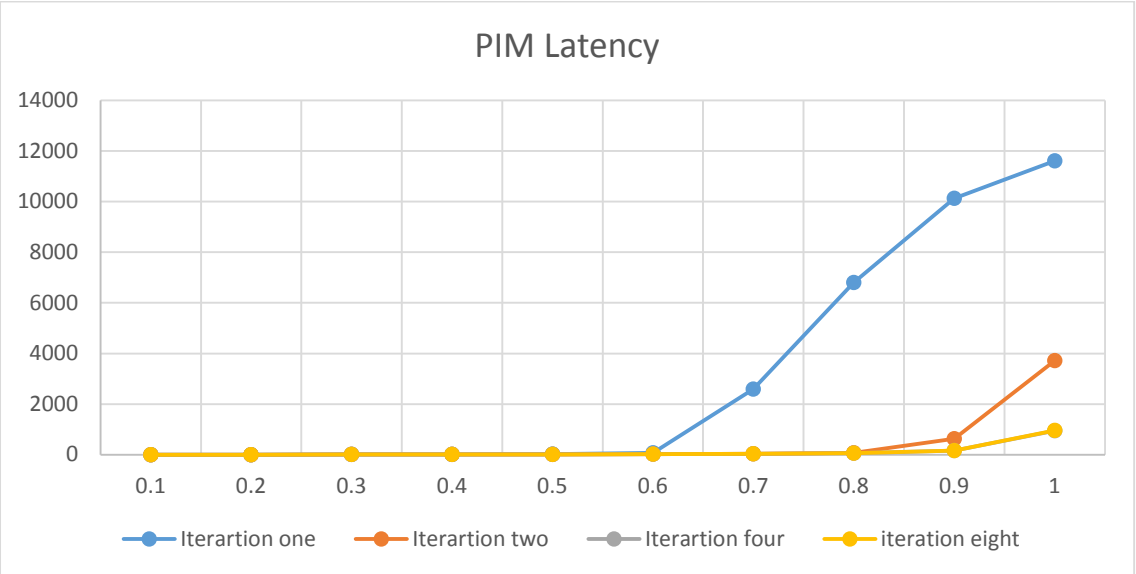
Number of Packets Lost

Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	927	926	926	926
0.2	3447	3444	3444	3444
0.3	7645	7619	7619	7619
0.4	12701	12650	12650	12650
0.5	19509	19398	19398	19398
0.6	28271	28072	28072	28072
0.7	37102	36692	36692	36692
0.8	46814	46092	46029	46029
0.9	58840	57300	57300	57300
1	73837	70342	70342	70342

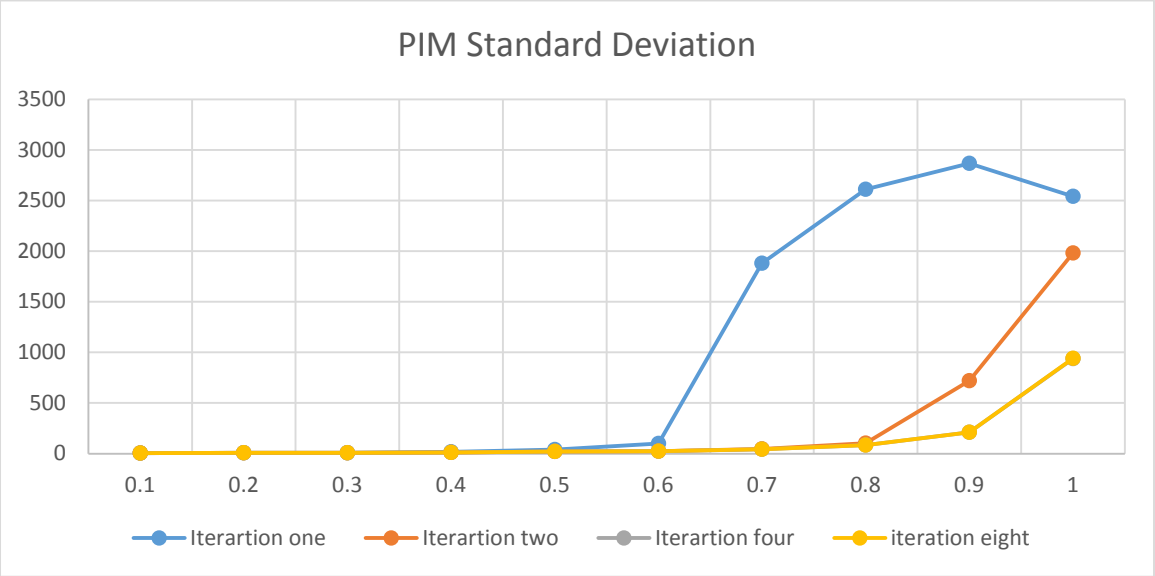


PIM

		PIM Latency		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	1.3225643	1.2997266	1.2997266	1.2997266
0.2	2.6576763	2.5153039	2.5153039	2.5153039
0.3	4.7867421	4.2383346	4.2383346	4.2383346
0.4	8.694485	6.6526011	6.6200812	6.6200812
0.5	20.861977	11.1863	11.18878	11.18878
0.6	69.538624	16.692045	16.556832	16.556832
0.7	2594.8956	31.590078	30.048578	30.048578
0.8	6801.6225	72.173308	57.735408	57.735408
0.9	10133.209	625.54151	163.58637	163.58637
1	11610.465	3710.543	944.47155	956.21072

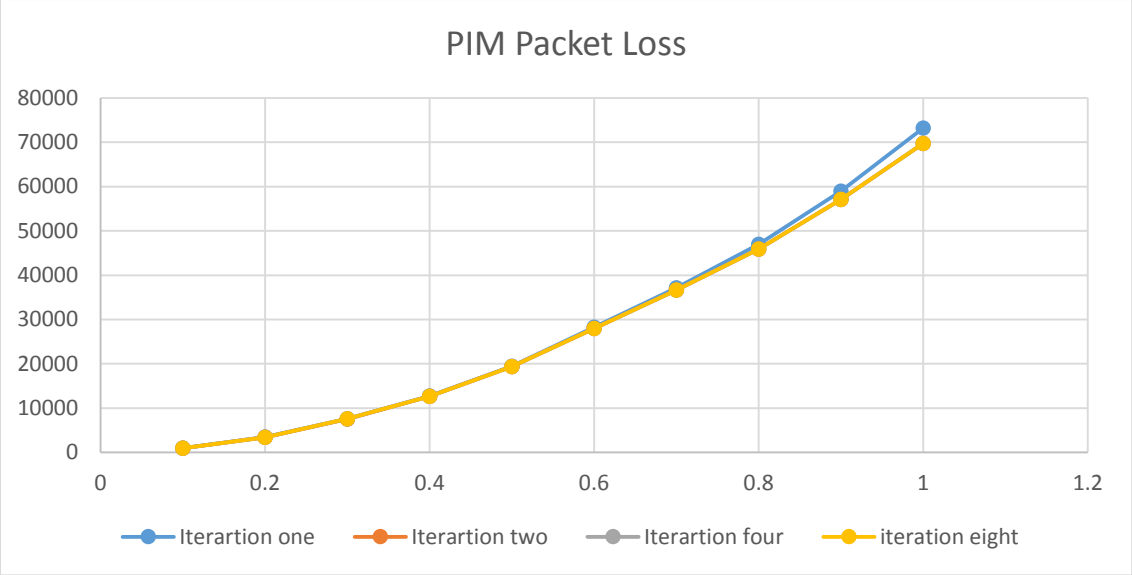


		standard deviation		
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	4.2502443	4.2187797	4.2187797	4.2187797
0.2	7.2949973	6.7198606	6.7198606	6.7198606
0.3	9.5349989	8.3964552	8.3964552	8.3964552
0.4	16.257401	12.468157	12.29528	12.29528
0.5	38.420089	20.433749	20.455899	20.455899
0.6	100.49124	25.356693	25.409826	25.409826
0.7	1879.8833	46.611233	44.005823	44.005823
0.8	2611.6774	103.92324	83.83681	83.83681
0.9	2865.7865	718.26678	209.9262	209.9262
1	2539.2726	1982.3912	937.64456	942.01647



Number of Packets Lost

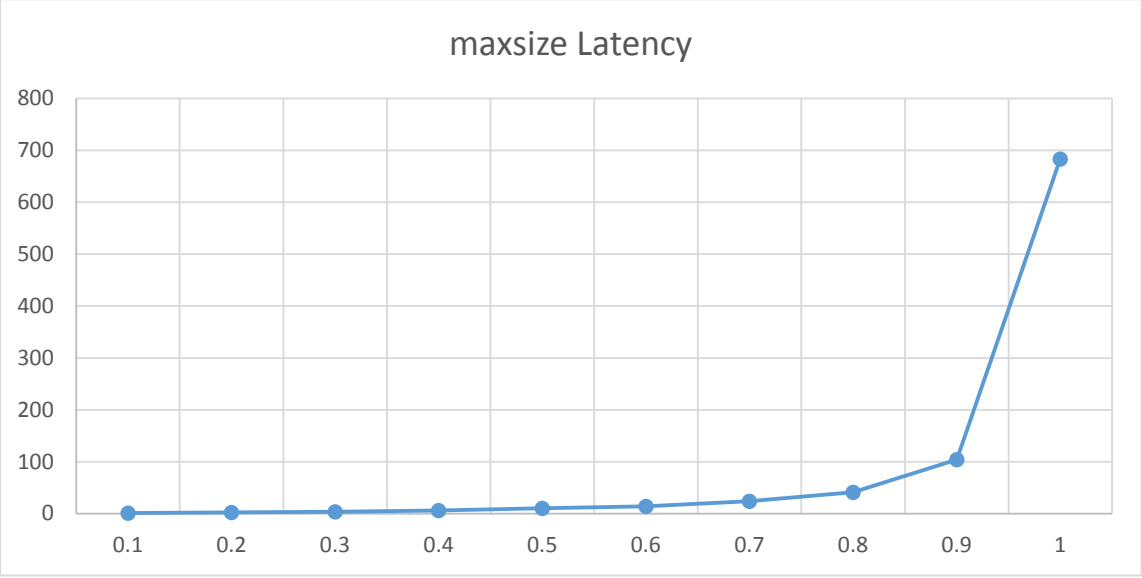
Load	Iterartion one	Iterartion two	Iterartion four	iteration eight
0.1	923	923	923	923
0.2	3443	3428	3428	3428
0.3	7628	7528	7582	7582
0.4	12692	12615	12615	12615
0.5	19463	19340	19340	19340
0.6	28296	27988	27988	27988
0.7	37154	36636	36636	36636
0.8	47000	45882	45882	45882
0.9	58951	57121	57111	57111
1	73178	69756	69736	69736

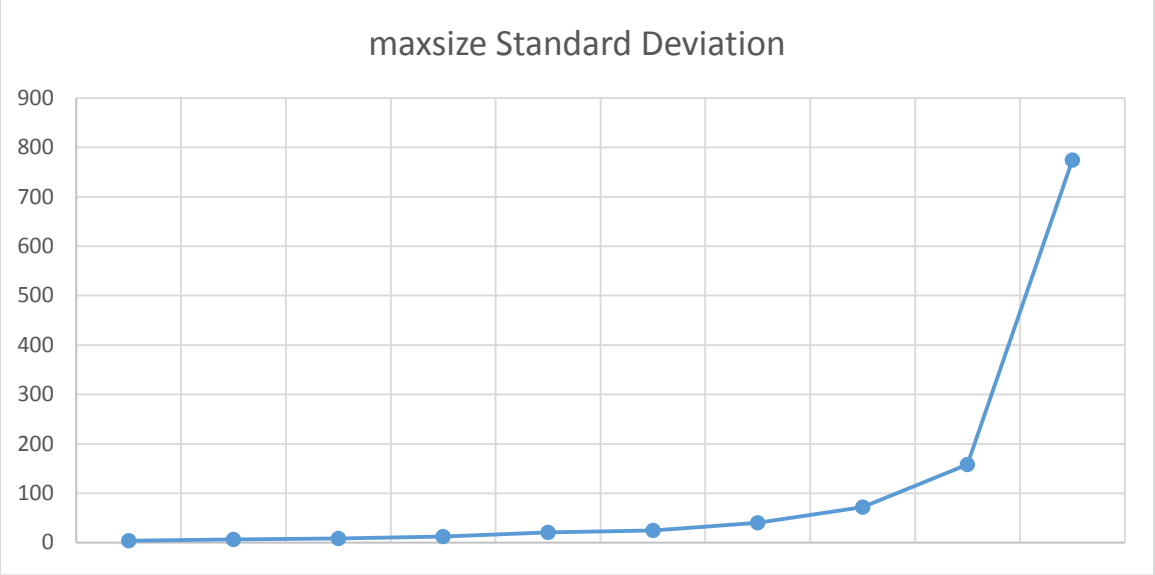


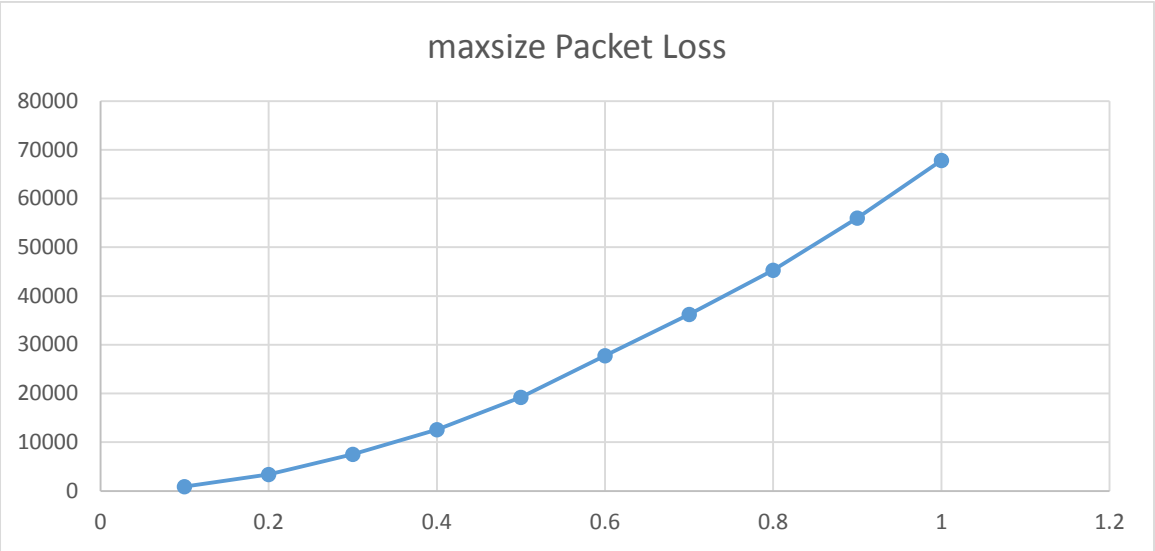
Maxsize

	maxsize	
Load	Latency	Standard Deviation
0.1	1.2978023	4.236057
0.2	2.4807908	6.780486
0.3	4.061502	8.405667
0.4	6.2504084	12.36369
0.5	10.283915	20.64472
0.6	14.384994	24.64273
0.7	24.317165	40.26862
0.8	41.433377	71.80362
0.9	104.3243	158.5249
1	683.4621	774.4554

Load	Packet Loss
0.1	916
0.2	3409
0.3	7543
0.4	12555
0.5	19205
0.6	27774
0.7	36242
0.8	45283
0.9	56013
1	67805



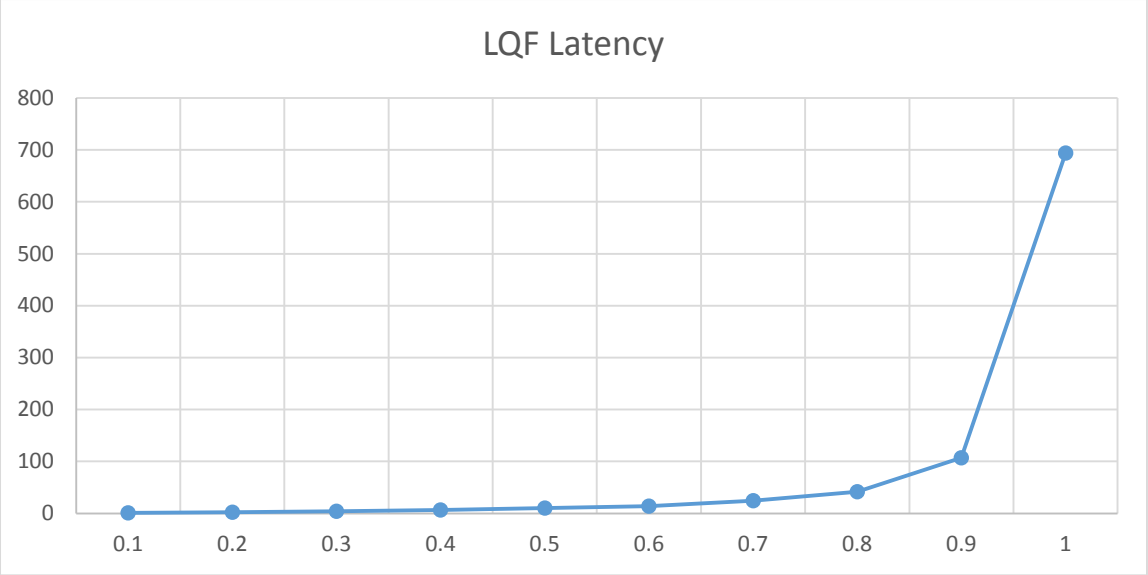


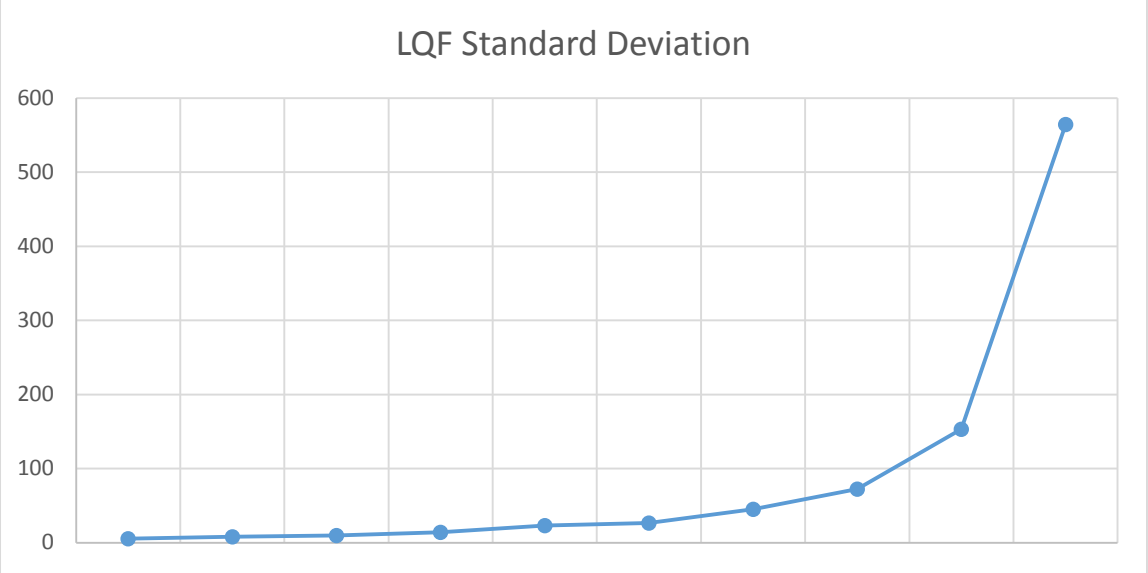


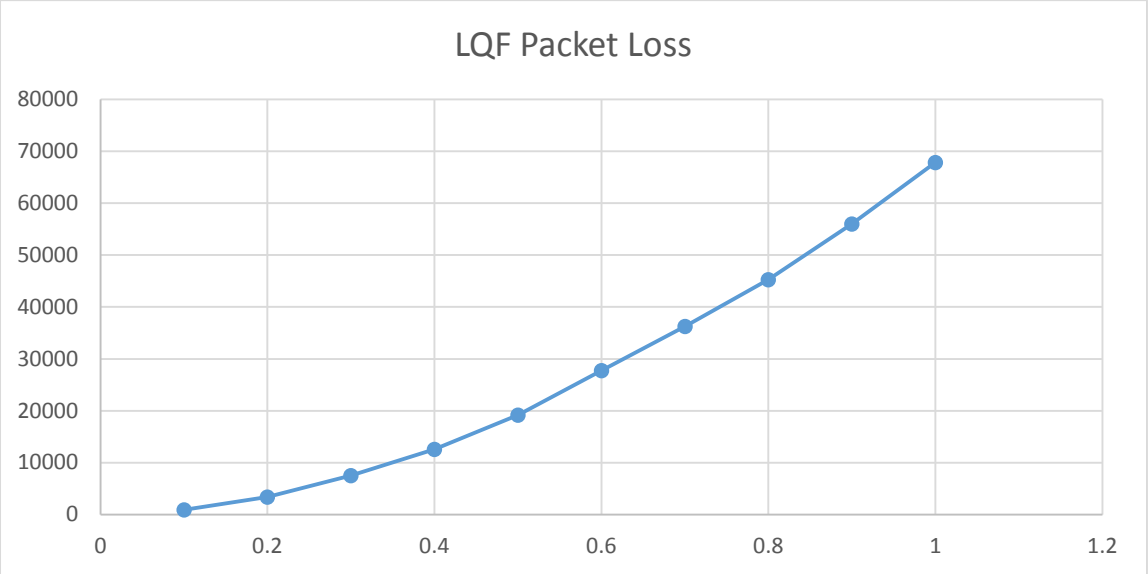
LQF

	LQF	
Load	Latency	Standard Deviation
0.1	1.2995746	5.3001834
0.2	2.5204784	7.9031101
0.3	4.0608746	9.7521359
0.4	6.285366	14.232051
0.5	10.222689	23.061188
0.6	14.167311	26.560071
0.7	24.279048	45.355647
0.8	41.483179	72.488096
0.9	106.88915	153.30944
1	694.10884	564.45783

Load	Packet Loss
0.1	916
0.2	3409
0.3	7543
0.4	12555
0.5	19205
0.6	27774
0.7	36242
0.8	45283
0.9	56013
1	67805


LQF Latency
800
700
600
500
400
300
200
100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


LQF Standard Deviation
600
500
400
300
200
100
0


LQF Packet Loss
80000
70000
60000
50000
40000
30000
20000
10000
0
0
0.2
0.4
0.6
0.8
1
1.2

Performance Analysis:

Using ISLIP with Input Queued (with VOQ) and Bursty uniform traffic the Latency performance remains almost the same for multiple iterations. Performance is not well under single iteration. However performance improves a bit for large value of load when more iterations are employed. Performance is good up to load values 0.6 and degrades for larger loads

PIM shows different behavior under single iteration then under multiple iteration. For load values greater than 0.6 latency increases drastically. Under multiple iterations however performance is good up to load value 0.8.

Maxsize and LQF show almost similar performance for lower values of load they work fine performance degrades for values greater than 0.7. They both demonstrate better performance than ISLIP and PIM.

As far as Packet Loss Rate is concerned. Loss increases for low value of input buffer and large simulation times causes the buffer overflow. We have used a buffer of 7 and simulation length 50000.

High packet loss is observed from load values 0.1 itself. All four PIM, ISLIP, Maxsize and LQF demonstrate high packet loss which increases as the utilization increases. Not much difference is observed between multiple iterations for ISLIP and PIM.

Samples of Configuration Files

Reference Combination A

```
# ../sim -l1000
Numswitches 1
Switch 0
      Numinputs    8
      Numoutputs   8
      InputAction  defaultInputAction
      OutputAction defaultOutputAction
      Fabric       crossbar
      Algorithm  pim -n 1
      0    bernoulli_iid_uniform  -u 0.1
      1    bernoulli_iid_uniform  -u 0.1
      2    bernoulli_iid_uniform  -u 0.1
      3    bernoulli_iid_uniform  -u 0.1
      4    bernoulli_iid_uniform  -u 0.1
      5    bernoulli_iid_uniform  -u 0.1
      6    bernoulli_iid_uniform  -u 0.1
      7    bernoulli_iid_uniform  -u 0.1
      Stats
            Arrivals    (0,3)
            Departures  (0,3)
            Latency     (*,1)
            Occupancy   (1,*)
      Histograms
            Arrivals    (0,3)
            Departures  (*,m)
            Latency
            Occupancy
```

Reference Combination B

```
# ../sim -l1000
Numswitches 1
Switch 0
      Numinputs    8
      Numoutputs   8
      InputAction  defaultInputAction -n 100
      OutputAction defaultOutputAction
      Fabric       outputQueued
      Algorithm  islip -n 4
      0    bernoulli_iid_uniform  -u 0.5
      1    bernoulli_iid_uniform  -u 0.5
      2    bernoulli_iid_uniform  -u 0.5
      3    bernoulli_iid_uniform  -u 0.5
      4    bernoulli_iid_uniform  -u 0.5
      5    bernoulli_iid_uniform  -u 0.5
      6    bernoulli_iid_uniform  -u 0.5
      7    bernoulli_iid_uniform  -u 0.5
      Stats
            Arrivals
            Departures
            Latency
            Occupancy
```

```
      Histograms
            Arrivals
            Departures
            Latency
            Occupancy
```

Reference Combination C

```
# ../sim -l1000
Numswitches 1
Switch 0
      Numinputs    32
      Numoutputs   32
      InputAction  defaultInputAction
      OutputAction defaultOutputAction
      Fabric       crossbar
      Algorithm  maxsize
      0     bernoulli_iid_uniform  -u 0.1
      1     bernoulli_iid_uniform  -u 0.1
      2     bernoulli_iid_uniform  -u 0.1
      3     bernoulli_iid_uniform  -u 0.1
      4     bernoulli_iid_uniform  -u 0.1
      5     bernoulli_iid_uniform  -u 0.1
      6     bernoulli_iid_uniform  -u 0.1
      7     bernoulli_iid_uniform  -u 0.1
       8    bernoulli_iid_uniform  -u 0.1
      9     bernoulli_iid_uniform  -u 0.1
      10    bernoulli_iid_uniform  -u 0.1
      11    bernoulli_iid_uniform  -u 0.1
      12    bernoulli_iid_uniform  -u 0.1
      13    bernoulli_iid_uniform  -u 0.1
      14    bernoulli_iid_uniform  -u 0.1
      15    bernoulli_iid_uniform  -u 0.1
      16    bernoulli_iid_uniform  -u 0.1
      17    bernoulli_iid_uniform  -u 0.1
      18    bernoulli_iid_uniform  -u 0.1
      19    bernoulli_iid_uniform  -u 0.1
      20    bernoulli_iid_uniform  -u 0.1
      21    bernoulli_iid_uniform  -u 0.1
      22    bernoulli_iid_uniform  -u 0.1
      23    bernoulli_iid_uniform  -u 0.1
      24    bernoulli_iid_uniform  -u 0.1
      25    bernoulli_iid_uniform  -u 0.1
      26    bernoulli_iid_uniform  -u 0.1
      27    bernoulli_iid_uniform  -u 0.1
      28    bernoulli_iid_uniform  -u 0.1
      29    bernoulli_iid_uniform  -u 0.1
      30    bernoulli_iid_uniform  -u 0.1
      31    bernoulli_iid_uniform  -u 0.1
      Stats
            Arrivals
            Departures
            Latency
            Occupancy
      Histograms
            Arrivals
```

```
            Departures
            Latency
            Occupancy
```

Reference Combination D

```
# ../sim -l1000
Numswitches 1
Switch 0
      Numinputs    4
      Numoutputs   4
      InputAction  defaultInputAction
      OutputAction strictPriorityOutputAction
      Fabric       crossbar
      Algorithm  lqf
      0    bernoulli_iid_nonuniform  -u 0.320 0.240 0.160 0.080

      1    bernoulli_iid_nonuniform  -u 0.320 0.240 0.160 0.080
      2    bernoulli_iid_nonuniform  -u 0.320 0.240 0.160 0.080
      3    bernoulli_iid_nonuniform  -u 0.320 0.240 0.160 0.080
           Stats
           Arrivals    (0,3)
           Departures  (0,3)
           Latency     (*,1)
           Occupancy   (1,*)
      Histograms
           Arrivals    (0,3)
           Departures  (*,m)
           Latency
           Occupancy
```

Reference Combination E

```
# ../sim -l1000
Numswitches 1
Switch 0
      Numinputs    8
      Numoutputs   8
      InputAction  defaultInputAction
      OutputAction defaultOutputAction
      Fabric       crossbar
      Algorithm  pim -n 2
      0    bursty  -u 0.4
      1    bursty  -u 0.4
      2    bursty  -u 0.4
      3    bursty  -u 0.4
      4    bursty  -u 0.4
      5    bursty  -u 0.4
      6    bursty  -u 0.4
      7    bursty  -u 0.4
           Stats
           Arrivals    (0,3)
           Departures  (0,3)
           Latency     (*,1)
           Occupancy   (1,*)
      Histograms
```

```
            Arrivals    (0,3)
            Departures  (*,m)
            Latency
            Occupancy
```

Output Sample file shown when Packet Loss Occurs

```
####################################################
./sim -f /home/jay/final/inputs/islip_itr_4_0.9 -l 50000 This is Sim
version 2.35, Released Sun April 8th 2001

# Date Wed Nov 11 03:39:10 2015
# Machine jay-VirtualBox
####################################################

Number of switches: 1

==========================================
================ Switch 0 ================
==========================================
Creating switch with 8 inputs, 8 outputs and 1 priorities
InputAction: defaultInputAction
    Max cells per input buffer: 7
    Max cells per input FIFO: 0
OutputAction: defaultOutputAction
Fabric: crossbar
Switch Scheduling Algorithm: islip
numIterations 4
Input: 0  Traffic model: bursty
 Using default priority levels
Levels of priority 1
priority 0   utilization 0.900000
    Using default mean burst length
    Burstlength 10.000000
    Using default burst-by-burst destination switching probability
    Burst-by-burst destination switching probability 1.000000
    Destination changed burst by burst.
Input: 1  Traffic model: bursty
 Using default priority levels
Levels of priority 1
priority 0   utilization 0.900000
    Using default mean burst length
    Burstlength 10.000000
    Using default burst-by-burst destination switching probability
    Burst-by-burst destination switching probability 1.000000
    Destination changed burst by burst.
Input: 2  Traffic model: bursty
 Using default priority levels
Levels of priority 1
priority 0   utilization 0.900000
    Using default mean burst length
    Burstlength 10.000000
    Using default burst-by-burst destination switching probability
    Burst-by-burst destination switching probability 1.000000
    Destination changed burst by burst.
```

```
Input: 3  Traffic model: bursty
 Using default priority levels
Levels of priority 1
priority 0   utilization 0.900000
    Using default mean burst length
    Burstlength 10.000000
    Using default burst-by-burst destination switching probability
    Burst-by-burst destination switching probability 1.000000
    Destination changed burst by burst.
Input: 4  Traffic model: bursty
 Using default priority levels
Levels of priority 1
priority 0   utilization 0.900000
    Using default mean burst length
    Burstlength 10.000000
    Using default burst-by-burst destination switching probability
    Burst-by-burst destination switching probability 1.000000
    Destination changed burst by burst.
Input: 5  Traffic model: bursty
 Using default priority levels
Levels of priority 1
priority 0   utilization 0.900000
    Using default mean burst length
    Burstlength 10.000000
    Using default burst-by-burst destination switching probability
    Burst-by-burst destination switching probability 1.000000
    Destination changed burst by burst.
Input: 6  Traffic model: bursty
 Using default priority levels
Levels of priority 1
priority 0   utilization 0.900000
    Using default mean burst length
    Burstlength 10.000000
    Using default burst-by-burst destination switching probability
    Burst-by-burst destination switching probability 1.000000
    Destination changed burst by burst.
Input: 7  Traffic model: bursty
 Using default priority levels
Levels of priority 1
priority 0   utilization 0.900000
    Using default mean burst length
    Burstlength 10.000000
    Using default burst-by-burst destination switching probability
    Burst-by-burst destination switching probability 1.000000
    Destination changed burst by burst.

Statistics Enabled for switch: 0
--------------------------------
    Arrival Statistics:
      Enabled for i/p buffer (0,3)
    Departures Statistics:
      Enabled for i/p buffer (0,3)
    Latency Statistics:
      Enabled for i/p buffers (*,1)
      Enabled for i/p buffers (*,1)
      Enabled for i/p buffers (*,1)
```

```
      Enabled for i/p buffers (*,1)
      Enabled for i/p buffers (*,1)
      Enabled for i/p buffers (*,1)
      Enabled for i/p buffers (*,1)
      Enabled for i/p buffers (*,1)
    Occupancy Statistics:
      Enabled for i/p buffers (1,*)
    Arrival Histogram:
      Enabled for i/p buffer (0,3)
    Departures Histogram:
      Enabled for all mcast i/p buffers
    Latency Histogram:
    Occupancy Histogram:
ResetStatsTime 25000
Resetting stats for switch: 0 at time 0
Resetting stats for switch: 0 at time 25000



============================================================
======================== RESULTS ===========================
============================================================
Simulation stopped at time: 50000
Maximum memory used: 491520 bytes
# Simulation runtime: 0 secs

=====================================================
====================== SWITCH    0 ==================
=====================================================
  Traffic Information
  -------------------
  I/P  model  Util
  0  bursty  0.902600
  (0,0)    0    0.122580
  1  bursty  0.900940
  2  bursty  0.902560
  3  bursty  0.901160
  4  bursty  0.904500
  5  bursty  0.899300
  6  bursty  0.899800
  7  bursty  0.901080


  OVERFLOWS AT EACH INPUT BUFFER:
  -------------------------------
  I/P    Num  Arrivals
  ---------------------
    0      7004
    1      7059
    2      7443
    3      7084
    4      7305
    5      7192
    6      7237
    7      6976
```

```
  INPUT BUFFER ARRIVAL STATS
  --------------------------
  I/P O/P   Pri  Avg   SD
  ----------------------
    0   3   0   0.00000 0.00000 (1974)

  INPUT BUFFER DEPARTURE STATS
  ----------------------------
  I/P O/P   Pri  Avg   SD
  ----------------------
    0   3   0   1.00000 0.00000 (1974)

  INPUT BUFFER LATENCY STATS
  --------------------------
  I/P O/P   Pri  Avg   SD
  ----------------------
    0   1   0   0.51920 0.82231 (1641)
    1   1   0   0.53028 0.75727 (1899)
    2   1   0   0.52271 0.78280 (2070)
    3   1   0   0.52987 0.79083 (1908)
    4   1   0   0.50560 0.79862 (2233)
    5   1   0   0.55062 0.81823 (1867)
    6   1   0   0.49799 0.80310 (1990)
    7   1   0   0.44434 0.76213 (2174)

  INPUT BUFFER TIME AVG OCCUPANCY STATS
  -------------------------------------
  I/P O/P   Pri  Avg   SD
  ----------------------
    1   0   0   0.03924 0.19417 (24999)
    1   1   0   0.04028 0.19662 (24999)
    1   2   0   0.04716 0.21199 (24999)
    1   3   0   0.03916 0.19398 (24999)
    1   4   0   0.04224 0.20114 (24999)
    1   5   0   0.03992 0.19578 (24999)
    1   6   0   0.03628 0.18699 (24999)
    1   7   0   0.04028 0.19662 (24999)
    1   X 0.325 0.470 (25000)


  INPUT BUFFER ARRIVAL HISTOGRAMS
  -------------------------------

------------------------------------------------------------
Histogram of "Occupancy seen by Arrivals" for list: Input Buffer
(0,3), pri=0
------------------------------------------------------------
As seen by ARRIVALS:
Histogram: Occupancy seen by Arrivals
  Bin               #    %Total  %Cumulative
-----------------------------------------------
0                1974 100.0000 100.0000
Total number counted: 1974
===============================================

  INPUT BUFFER DEPARTURE HISTOGRAMS
```

```
  ----------------------------

------------------------------------------------------------
Histogram of "Occupancy seen by Departures" for list: Input 0 mcast
buffer, pri=0
------------------------------------------------------------
As seen by DEPARTURES:
Histogram: Occupancy seen by Departures
  Bin               #    %Total  %Cumulative
-----------------------------------------------
Total number counted: 0
================================================

------------------------------------------------------------
Histogram of "Occupancy seen by Departures" for list: Input 1 mcast
buffer, pri=0
------------------------------------------------------------
As seen by DEPARTURES:
Histogram: Occupancy seen by Departures
  Bin               #    %Total  %Cumulative
-----------------------------------------------
Total number counted: 0
================================================

------------------------------------------------------------
Histogram of "Occupancy seen by Departures" for list: Input 2 mcast
buffer, pri=0
------------------------------------------------------------
As seen by DEPARTURES:
Histogram: Occupancy seen by Departures
  Bin               #    %Total  %Cumulative
-----------------------------------------------
Total number counted: 0
================================================

------------------------------------------------------------
Histogram of "Occupancy seen by Departures" for list: Input 3 mcast
buffer, pri=0
------------------------------------------------------------
As seen by DEPARTURES:
Histogram: Occupancy seen by Departures
  Bin               #    %Total  %Cumulative
-----------------------------------------------
Total number counted: 0
================================================

------------------------------------------------------------
Histogram of "Occupancy seen by Departures" for list: Input 4 mcast
buffer, pri=0
------------------------------------------------------------
As seen by DEPARTURES:
Histogram: Occupancy seen by Departures
  Bin               #    %Total  %Cumulative
-----------------------------------------------
Total number counted: 0
================================================
```

```
------------------------------------------------------------
Histogram of "Occupancy seen by Departures" for list: Input 5 mcast
buffer, pri=0
------------------------------------------------------------
As seen by DEPARTURES:
Histogram: Occupancy seen by Departures
  Bin               #    %Total  %Cumulative
-------------------------------------------
Total number counted: 0
===========================================

------------------------------------------------------------
Histogram of "Occupancy seen by Departures" for list: Input 6 mcast
buffer, pri=0
------------------------------------------------------------
As seen by DEPARTURES:
Histogram: Occupancy seen by Departures
  Bin               #    %Total  %Cumulative
-------------------------------------------
Total number counted: 0
===========================================

------------------------------------------------------------
Histogram of "Occupancy seen by Departures" for list: Input 7 mcast
buffer, pri=0
------------------------------------------------------------
As seen by DEPARTURES:
Histogram: Occupancy seen by Departures
  Bin               #    %Total  %Cumulative
-------------------------------------------
Total number counted: 0
===========================================

  INPUT BUFFER LATENCY HISTOGRAMS
  -------------------------
    No Histograms Enabled.

  INPUT BUFFER TIME AVG OCCUPANCY HISTOGRAMS
  ------------------------------------
    No Histograms Enabled.

  OUTPUT BUFFER ARRIVAL STATS
  --------------------------
  O/P   Avg   SD
  -------------
    No Stats Enabled.

  OUTPUT BUFFER DEPARTURE STATS
  ----------------------------
  O/P   Avg   SD
  -------------
    No Stats Enabled.

  OUTPUT BUFFER LATENCY STATS
  --------------------------
```

```
  O/P   Avg   SD
  --------------
    No Stats Enabled.

  OUTPUT BUFFER TIME AVG OCCUPANCY STATS
  --------------------------------------
  O/P   Avg   SD
  --------------
    No Stats Enabled.

Avg Number Synchronized Output Schedulers:    3.5974 1.423135
(25000)
Avg Number of Iterations:   1.06112 0.2395503    (25000)
Average Grant Latency    0.5441
Average Accept Latency   0.0000

  Latency statistics
  ------------------
                       Avg       SD     Number
                     -------------------------
     Input Latency:  0.53571487 0.78768983    (122890)
    Fabric Latency:         0        0    (122890)
    Output Latency:         0        0    (122890)
    Switch Latency:  0.53571487 0.78768983    (122890)



  Crossbar statistics
  -------------------
                       Avg       SD     Number
                     -------------------------
Match Size:            4.9156 0.92576273    (25000)

  OUTPUT BURSTINESS
  -----------------
   O/P  Avg   SD
  -----------------
    0    1.985   3.272
    1    2.114   3.689
    2    1.923   3.163
    3    2.029   3.335
    4    1.984   3.300
    5    1.984   3.273
    6    2.031   3.385
    7    2.078   3.529
-----------------------------
Total Latency over all cells:  0.53571487 0.78768983    (122890)
-----------------------------
```

Python Scripts for Generating Configuration files

Below are some python scripts that can be used to automate the process of generating configuration files. However the code should not be used directly since the paths to the configuration files are different for different systems. The code clears the logic of implementation.

Following script generates configuration files with different parameters like iterations, scheduling algorithms and utilization

```
import os
import sys
import fileinput

a=1
x=1
itr=1

for itr in range(0,4):
    for x in xrange(1,11):
        y = format (float(x/float(10)),'.1f')
        z = 2**itr

        f1 = open('ref','r')
        filedata = f1.read()
      newdata1 = filedata.replace('0.1',''+str(y))
      newdata2 = newdata1.replace('pim -n 1','pim -n '+str(z))
        g = open('pim_itr_'+str(z)+'_'+str(y),'w')
      g.write(newdata2)
        g.close()
        f1.close()

        f2 = open('ref','r')
        filedata = f2.read()
      newdata3 = filedata.replace('0.1',''+str(y))
      newdata4 = newdata3.replace('pim -n 1','islip -n '+str(z))
        s = open('islip_itr_'+str(z)+'_'+str(y),'w')
      s.write(newdata4)
        s.close()
        f2.close()

        x+=1
    itr+=1


for a in range(1,11):
    c = format (float(a/float(10)),'.1f')

    b1 = open('ref','r')
    filedatamax = b1.read()
    newdatamax1 = filedatamax.replace('0.1',''+str(c))
    newdatamax2 = newdatamax1.replace('pim -n 1','maxsize')
    d = open('max_size_'+str(c),'w')
    d.write(newdatamax2)
    d.close()
```

```
    b1.close()

    b2 = open('ref','r')
    filedatamax = b2.read()
    newdatalqf1 = filedatamax.replace('0.1',''+str(c))
    newdatalqf2 = newdatalqf1.replace('pim -n 1','lqf')
    e = open('lqf_'+str(c),'w')
    e.write(newdatalqf2)
    e.close()

    b2.close()
    a+=1
```

Following script generates an output text file with different commands that can be pasted in terminal to generate output files.

```
import os
import sys
import fileinput

x=1
a=1
itr=1

for itr in range(0,4):
    for x in xrange(1,11):
        y = format (float(x/float(10)),'.1f')
     z = 2**itr
        txtfile = open ("commands.txt","a")
        txtfile.write("./sim -f
/home/jay/final/inputs/islip_itr_"+str(z)+"_"+str(y)+" -l 500000 >
/home/jay/final/outputs/opt_islip_itr_"+str(z)+"_"+str(y)+".txt")
        txtfile.write("\n")
        txtfile.write("./sim -f
/home/jay/final/inputs/pim_itr_"+str(z)+"_"+str(y)+" -l 500000 >
/home/jay/final/outputs/opt_pim_itr_"+str(z)+"_"+str(y)+".txt")
        txtfile.write("\n")
txtfile.close()


for a in xrange(1,11):
    b = format (float(a/float(10)),'.1f')

    txtfile = open ("commands.txt","a")
    txtfile.write("./sim -f
/home/jay/final/inputs/max_size_"+str(b)+" -l 500000 >
/home/jay/final/outputs/opt_max_size_"+str(b)+".txt")
    txtfile.write("\n")
    txtfile.write("./sim -f /home/jay/final/inputs/lqf_"+str(b)+" -l
500000 > /home/jay/final/outputs/opt_lqf_"+str(b)+".txt")
    txtfile.write("\n")
txtfile.write("\n\n")
txtfile.close()
```

Once the output files are generated search script is used to generate a text file containing the latency data of different combinations which can later be used to plot graphs and perform analysis.

```
import os
import sys
import fileinput

x=1
itr=1
textfile = open("latency.txt","a")
for itr in range(0,4):
    textfile.write("******** SLIP iteration " +
str(2**itr)+"***********\n")
    for x in xrange(1,11):
        y = format (float(x/float(10)),'.1f')
      z = 2**itr
        searchfile = open
("opt_islip_itr_"+str(z)+"_"+str(y)+".txt","r")

        for line in searchfile:
            if "Total Latency over all cells:" in line:
textfile.write(line)

searchfile.close

x1=1
itr1=1

for itr1 in range(0,4):
    textfile.write("********** PIM iteration " +
str(2**itr1)+"***********\n")
    for x1 in xrange(1,11):
        y1 = format (float(x1/float(10)),'.1f')
     z1 = 2**itr1
        searchfile = open
("opt_pim_itr_"+str(z1)+"_"+str(y1)+".txt","r")

        for line in searchfile:
            if "Total Latency over all cells:" in line:
textfile.write(line)

searchfile.close


x3=1

textfile.write("********** maxsize iteration ***********\n")
for x3 in xrange(1,11):
    y3 = format (float(x3/float(10)),'.1f')
```

```
    searchfile = open ("opt_max_size_"+str(y3)+".txt","r")

    for line in searchfile:
        if "Total Latency over all cells:" in line:
textfile.write(line)

searchfile.close

x4=1

textfile.write("********** LQF iteration **********\n")
for x4 in xrange(1,11):
    y4 = format (float(x4/float(10)),'.1f')

    searchfile = open ("opt_lqf_"+str(y4)+".txt","r")

    for line in searchfile:
        if "Total Latency over all cells:" in line:
textfile.write(line)

searchfile.close

textfile.close
```

A slightly different script is used to generate configuration files in case of non-uniform traffic pattern

```
import os
import sys
import fileinput

a=1
x=1
l=4
m=3
n=2
o=1
p=100
itr=1

for itr in range(0,4):
    for x in xrange(1,11):

        y1 = format (float(x/float(10)),'.1f')


      u1= format(float(x*l/float(p)),'.3f')
      u2= format(float(x*m/float(p)),'.3f')
      u3= format(float(x*n/float(p)),'.3f')
      u4= format(float(x*o/float(p)),'.3f')

        z = 2**itr
```

```
        f1 = open('ref','r')
        filedata = f1.read()
      newdata1 = filedata.replace('0.1',''+str(u1)+' '+str(u2)+'
'+str(u3)+' '+str(u4))
      newdata2 = newdata1.replace('pim -n 1','pim -n '+str(z))
        g = open('pim_itr_'+str(z)+'_'+str(y1),'w')
      g.write(newdata2)
        g.close()
        f1.close()

        f2 = open('ref','r')
        filedata = f2.read()
      newdata3 = filedata.replace('0.1',''+str(u1)+' '+str(u2)+'
'+str(u3)+' '+str(u4))
      newdata4 = newdata3.replace('pim -n 1','islip -n '+str(z))
        s = open('islip_itr_'+str(z)+'_'+str(y1),'w')
      s.write(newdata4)
        s.close()
        f2.close()

        x+=1
    itr+=1


for a in range(1,11):
    c = format (float(a/float(p)),'.1f')
    c1 = format (float(a/float(10)),'.1f')

    u5= format(float(a*l/float(p)),'.3f')
    u6= format(float(a*m/float(p)),'.3f')
    u7= format(float(a*n/float(p)),'.3f')
    u8= format(float(a*o/float(p)),'.3f')


    b1 = open('ref','r')
    filedatamax = b1.read()
    newdatamax1 = filedatamax.replace('0.1',''+str(u5)+' '+str(u6)+'
'+str(u7)+' '+str(u8))
    newdatamax2 = newdatamax1.replace('pim -n 1','maxsize')
    d = open('max_size_'+str(c1),'w')
    d.write(newdatamax2)
    d.close()
    b1.close()

    b2 = open('ref','r')
    filedatamax = b2.read()
    newdatalqf1 = filedatamax.replace('0.1',''+str(u5)+' '+str(u6)+'
'+str(u7)+' '+str(u8))
    newdatalqf2 = newdatalqf1.replace('pim -n 1','lqf')
    e = open('lqf_'+str(c1),'w')
    e.write(newdatalqf2)
    e.close()

    b2.close()
    a+=1
```

Reference : http://read.pudn.com/downloads56/doc/196930/stanford%E5%A4%A7%E5%AD%A6%20Packet%20Switching%20%E8%AE%B2%E4%B9%89/Part%20I/SIM_mannul.pdf