4DK4 Lab 5

Caleb Gannon 400137271

Experiment Results and Analysis

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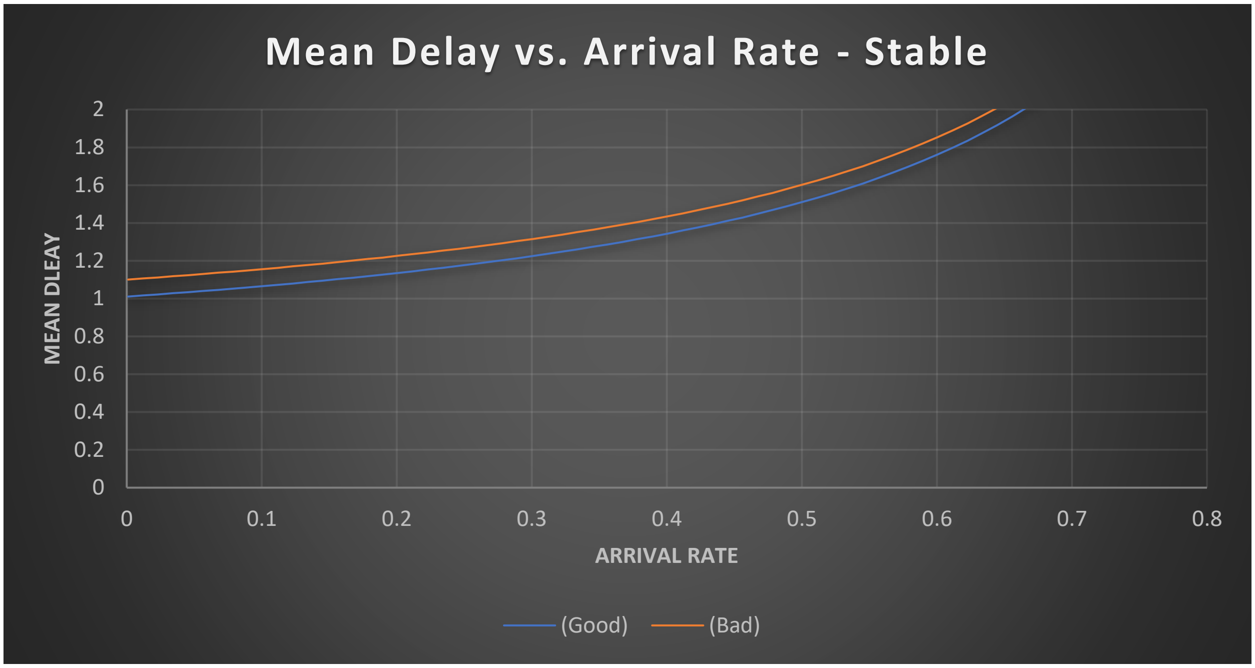
Section 1

To model this system, I used three servers and three FIFO queues. New jobs are created at the *arrival rate* λ. New jobs are assigned to the *good* mobile unit (M_g), or the *bad* mobile unit (M_b), with a 50/50 chance. If the mobile unit is busy, then the new job is placed in a FIFO queue designated to that unit. The mobile units will upload a job to a shared base station at upload time U_g and U_b, where $U_b = 10U_g$. In this simulation $U_g = 0.01u$ and therefore $U_b = 0.1u$, where u is a generic time unit.

The time to upload from the base station to the cloud server is negligible. As jobs arrive at the cloud server, they begin execution. The job times (J_g and J_b) are both fixed at $1u$. If a job is in progress when a new one arrives at the cloud server, it is placed in a FIFO queue at the cloud server.

These upload and job times were chosen to normalize U_g, and to allow *the cloud server* to bottleneck the system before the base station becomes bottlenecked.

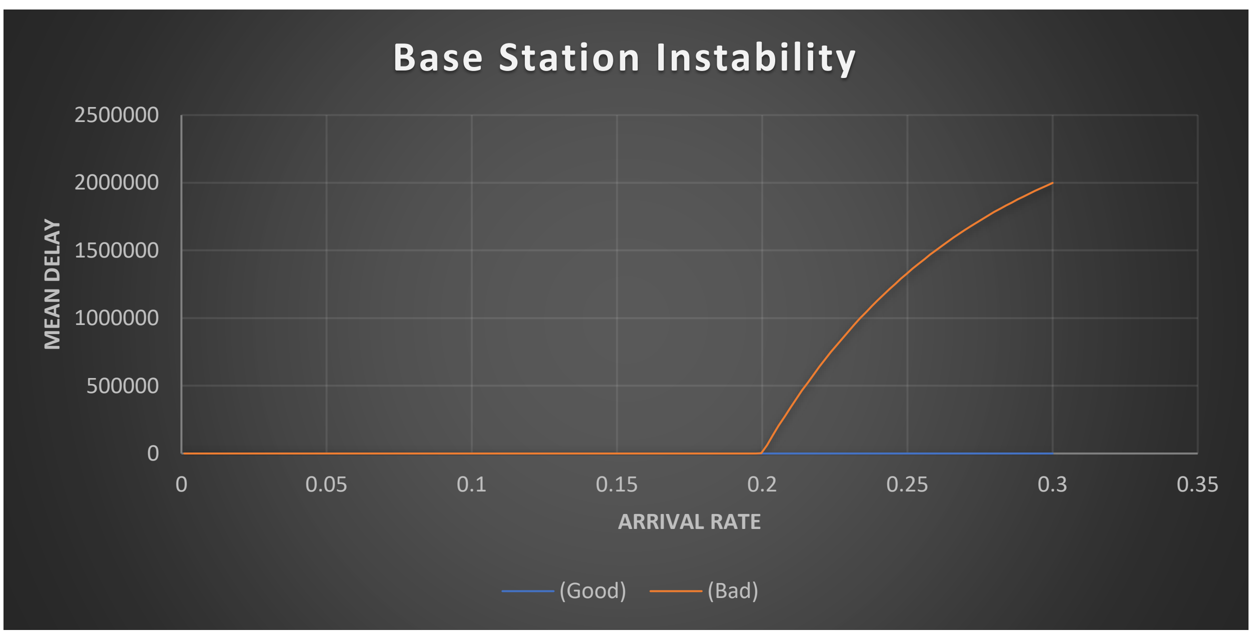
Mean delay is measured from job arrival to completion.



Data is in the appendix at <u>Mean Delay vs. Arrival Rate – Stable.</u>

In the above simulation, $J_g = J_b = 1$, $U_g = 0.01$, $U_b = 0.1$. We see the discrepancy between the slow and fast uploaded jobs, due to the extra delay in the slow upload process. This will be resolved in <u>Section 2.</u>

Base Station Instability



Data is in the appendix at <u>Base Station Instability.</u>

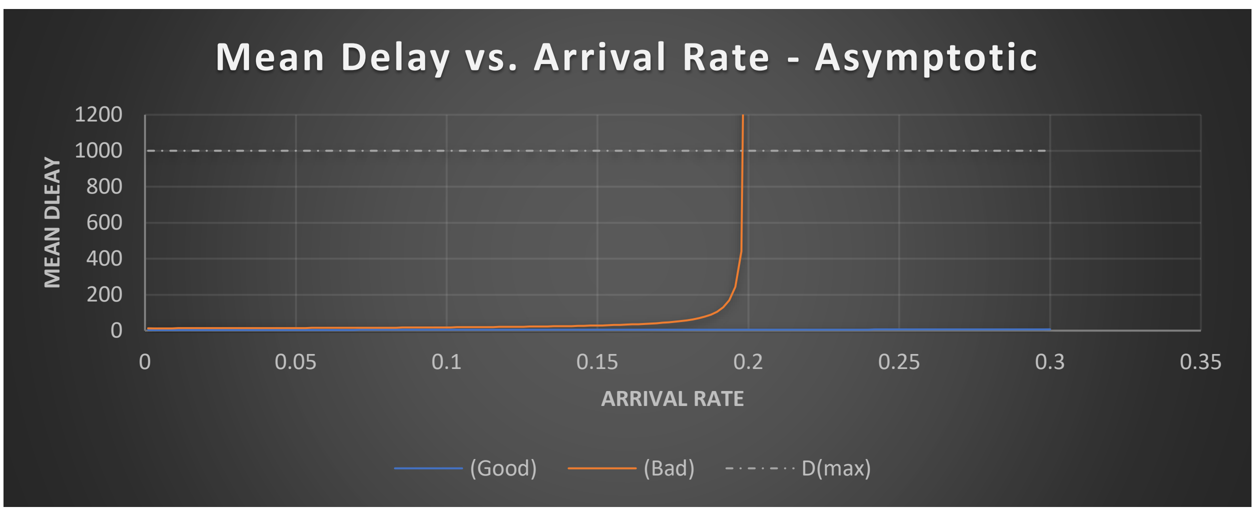
We see that as we vary the values of $J_g = J_b$, U_g, and U_b, we can observer different system behaviours. For example, we see above the instability of the slow-mobile to base station connection.

In the above simulation, $J_g = J_b = 1$, $U_g = 1$, $U_b = 10$. The cloud server is stable, and the fast upload mobile is stable, but we see at $\lambda = 0.2$ the slow upload mobile becomes unstable. This happens because $U_b = 10$, and the jops are split evenly between the mobile devices, therefore as $\lambda = 0.2, \lambda_b = 0.1$. At this arrival rate, the slow upload mobile connection is unstable. The delay of jobs from this mobile is bottlenecked at the connection to the *base station*, and therefore there is nothing the cloud server can do to increase the fairness (aside from idling to stall the fast upload packets, but this is not truly *fair*).

Dmax Analysis

The D_{max} is the maximum delay the system can support. A value of $100u$ was chosen for D_{max}. This is under the assumption that the cloud server can complete jobs ~100x more efficiently than the local mobile unit, and the cloud server completes the job in $1u$. If the delay exceeds $100u$ then the customer no longer is being more efficient by uploading to the cloud server.

This value of 100x was based on a review of mobile ARM based performance, with power usage as a metric. When running 3DMark benchmarks, mobile CPUs trend towards ~2.78Watts of active power usage using the ARM Cortex X1 as reference (link). The Intel® Xeon® Platinum 9282 Processor (77M Cache, 2.60 GHz) server CPU uses 400W of power (link). The server platform has 7x more cores than the mobile platform. The system that uses Mobile CPUs tend to be more efficient with power, but if this optimization is ignored as negligible, then we can assume the server CPU is ~1000x more efficient than the mobile unit.



Data is in the appendix at Mean Delay vs. Arrival Rate – Asymptotic.

We see the cloud server system become unstable around $\lambda = 1$.

This is because $\bar{X} = 1$ in the cloud server, and therefore the cloud server becomes unstable when the following inequality is violated.

$$0 < \texttt{ARRIVAL\_RATE} \times \texttt{SERVICE\_TIME} < 1$$

The arrival rate λ^* is the arrival rate where the D_{max} is exceeded. I calculate this by using a linear approximation based on the simulated data.

1.010286	51646.31
0.987857	43.22707

$$x = (y - y_1) \cdot \frac{x_1 - x_2}{y_1 - y_2} + x_1$$

$$x = (1000 - 51646.31) \cdot \frac{1.010286 - 0.987857}{51646.31 - 43.22707} + 1.010286$$

$$x = 0.988272856163 \frac{Jobs}{u}$$

Therefore $\lambda^* = 0.988272856163$.

Section 2

In order to increase that *fairness* between the good and bad connection, the cloud server can implement a *priority queue.* The cloud server would *detect* (via the base station) that the second device has a worse connection, and it would begin to prioritize those packets.

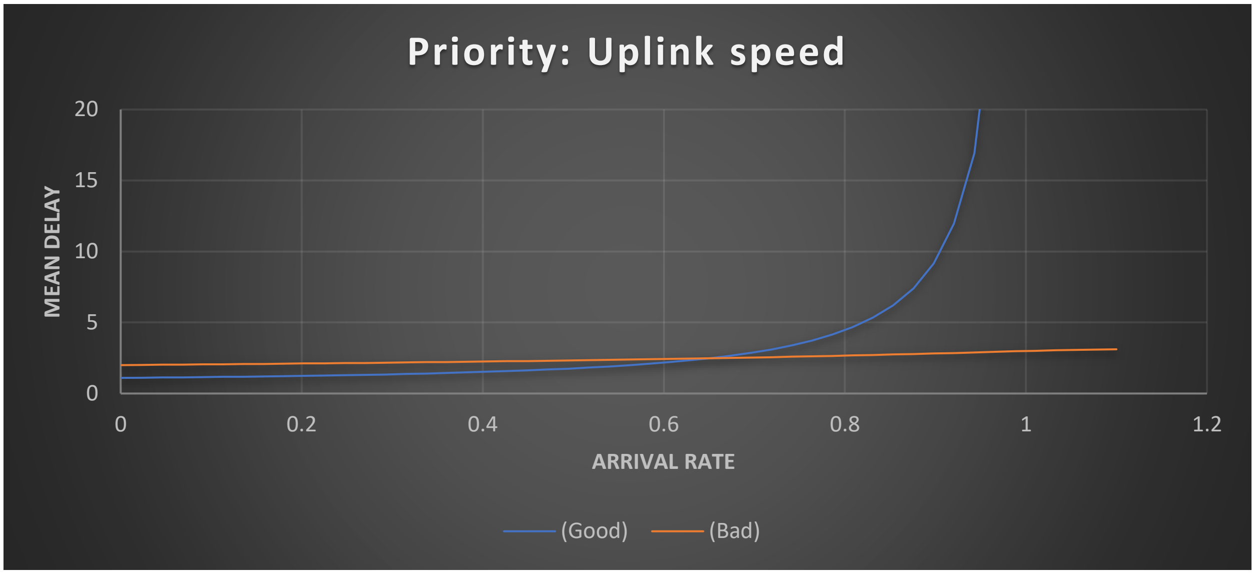
I Implemented this in simulation by using two FIFO queues, and conditional logic to deploy the priority queue.

I tested three variants of the priority queue: *uplink speed*, *non-preemptive delay detection*, and *preemptive delay detection.*

Uplink speed

I ran simulations that *always* prioritize packets with the slower uplink speed. These simulations demonstrate a high effectiveness when the system is stable, they are unfair once system instability (at either the base station or the cloud server) kicks in, and the fast uplink jobs will begin to face an extremely unfair advantage.

I ran the example below with $J_g = J_b = 1$, $U_g = 0.01$, $U_b = 0.1$, to clearly see the point of total system instability.



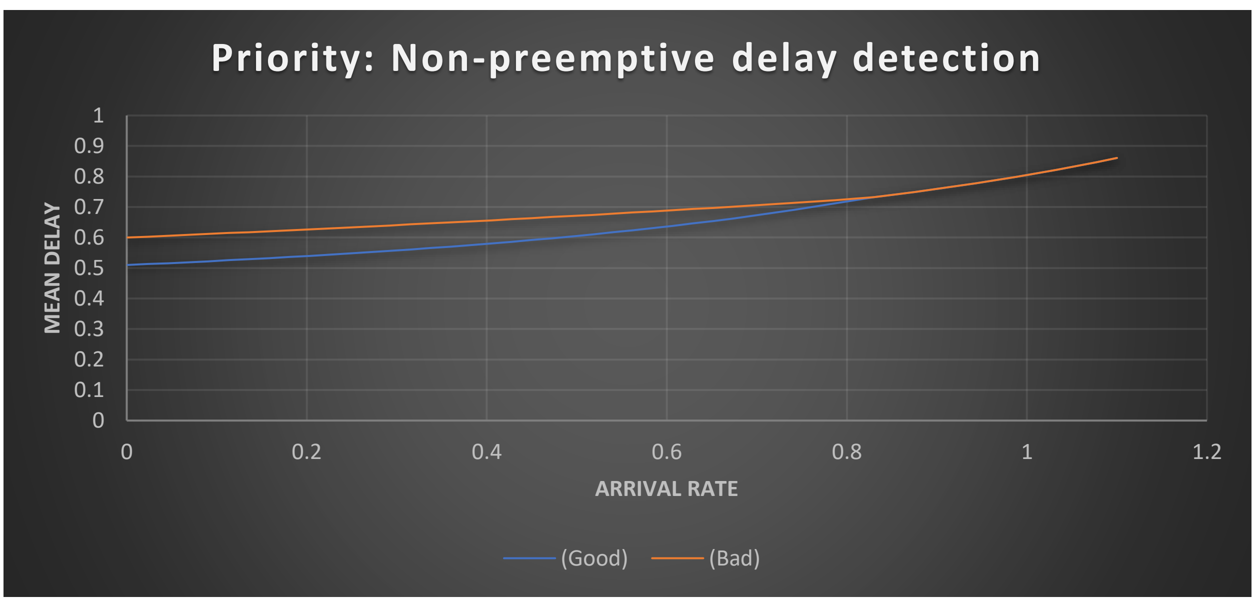
Data is in the appendix at Priority: Uplink speed.

We see that as the system is fairer when stable, as the offered load pressure is absorbed by the faster upload speed jobs. When the system becomes unstable, it becomes clear that the instability is entirely absorbed by the *good* jobs, as the priority is fixed on the slower upload speed jobs.

Non-preemptive delay detection

To increase fairness as system instability increases, I enabled the cloud server to track the current *mean delay* of the jobs delivered by the mobile users. The cloud server will prioritize packets delivered from a mobile unit seeing less overall mean delay.

I ran the example below with $J_g = J_b = 0.5$, $U_g = 0.01$, $U_b = 0.1$, to focus on the approach to instability, so we can see continuous fairness in stable and instable regions.



Data is in the appendix at Priority: Non-preemptive delay detection.

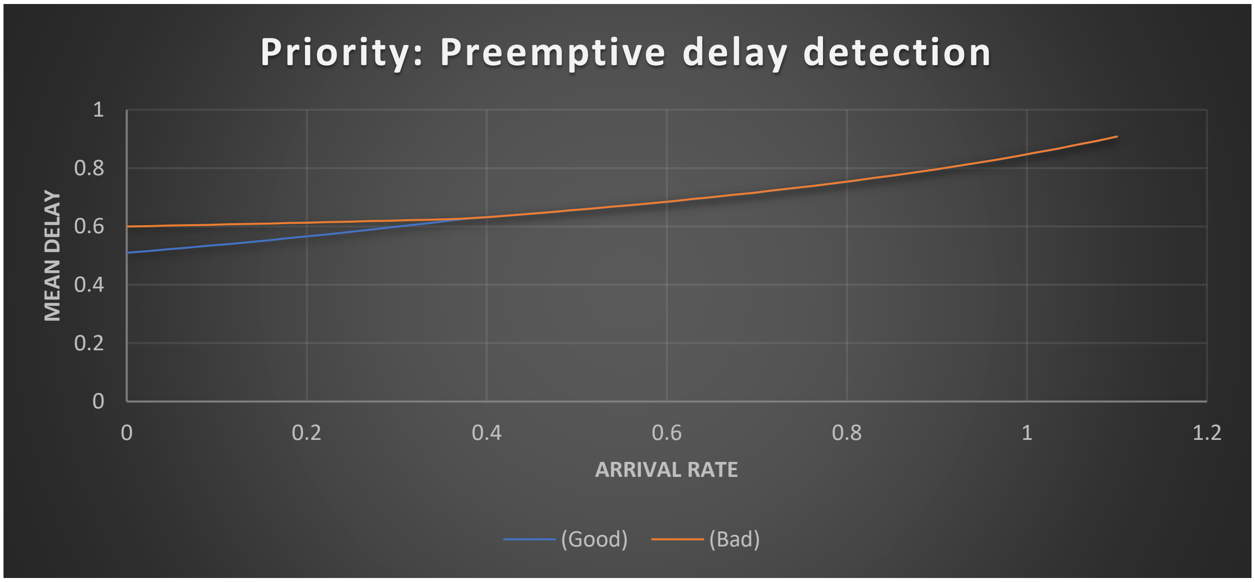
This solution can maintain a fair delay as the system approaches instability. However, this comes at the sacrifice of fairness during the stable region. This is because at stable arrival rates, there will often be **local instances** where the delay in the fast upload system exceeds the delay in the slow upload system. We will call the state of which mobile unit is locally experiencing more delay, the *delay state*. This will allow a fast upload job to run, despite slow upload jobs being available. While the fast upload job is running, the *delay state* of the system will shift to favor the slow upload system, but slow packets will have to wait for the fast upload jobs to finish.

To further increase fairness at low arrival rates, we can use *preemptive delay detection.*

Preemptive delay detection

To model this system, I check the *delay state* of the system upon every new arrival at the cloud server. If the new packet comes from a mobile that has been experiencing more delay, I pre-emptively stop execution of the current job (keeping track of how much time was remaining), and immediately begin to run the priority job.

I ran the example below with $J_g = J_b = 0.5$, $U_g = 0.01$, $U_b = 0.1$, to focus on the approach to instability, so we can see continuous fairness in stable and instable regions.



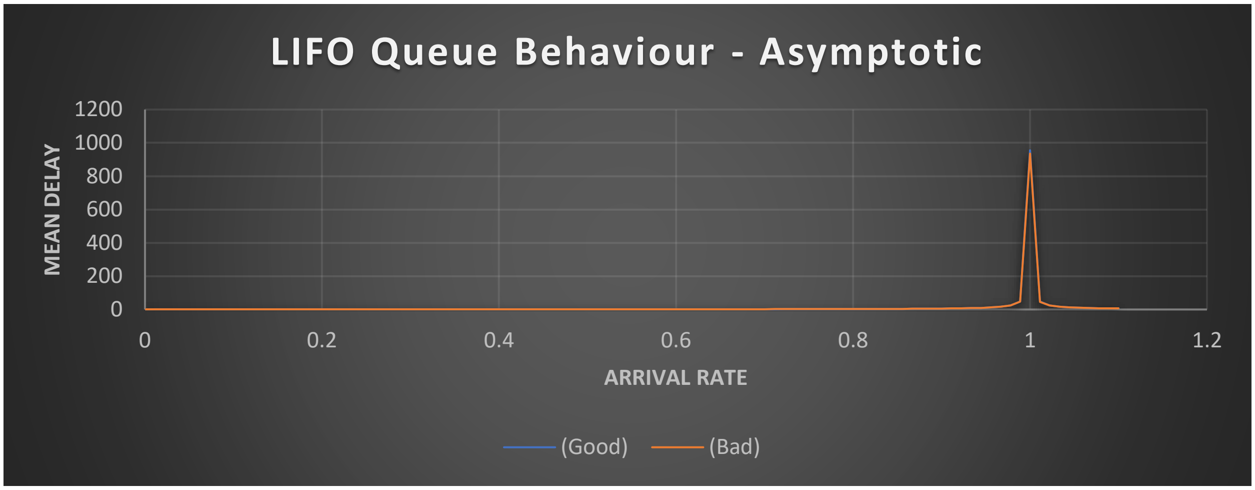
Data is in the appendix at Priority: Non-preemptive delay detection.

We see that with preemptive delay detection, the cloud server is able to increase fairness at both low (stable) and high (unstable) job creation rates.

Section 3

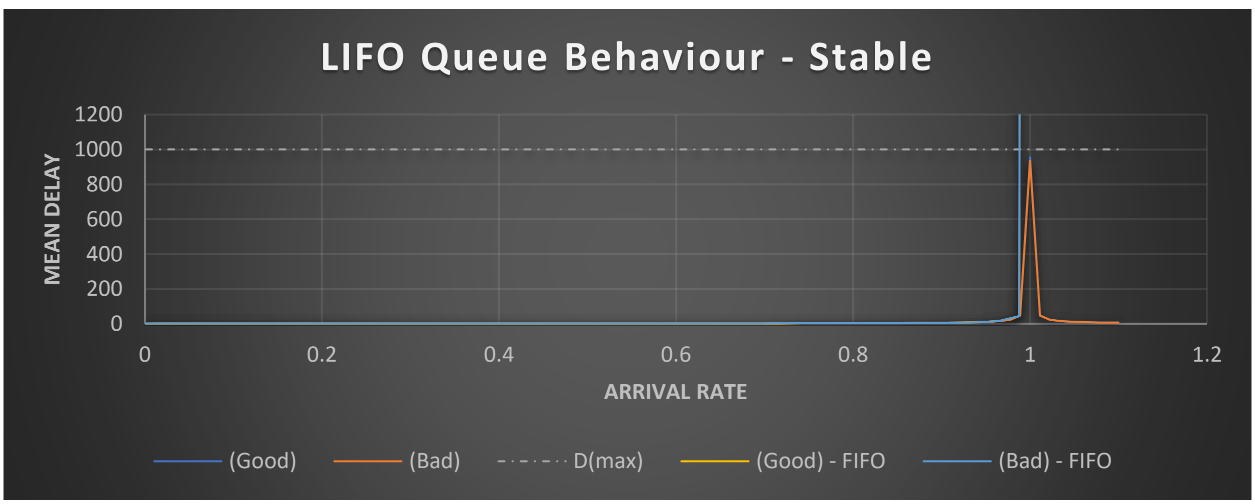
In Section 1, we calculated $\lambda^* = 0.988272$ in a system with parameters $J_g = J_b = 1$, $U_g = 0.01$, $U_b = 0.1$.

To increase λ^*, the cloud server can use LIFO queues, or stacks. LIFO queues prioritize low *mean delay*, at the cost of per-job reliability and *max* delay.



Data is in the appendix at LIFO Queue Behaviour.

We see that when using LIFO queues (stacks) the *mean delay* is greatly reduced. There is a spike in delya near the instability point. This is because the **reduction** in mean delay attributed to LIFO queues is applicable at low arrival rates, because packets will be served on average sooner, but with a **potential** to wait for a much larger max delay. When the system is unstable, the average packet must wait for nearly the *service rate*, while unfortunate packets must wait for extreme durations, but are so few they don't affect the mean. At the instability point, the push/pull job forces are balanced, and jobs that end up waiting longer in the queue have a moderate **potential to be served**, therefore the average delay spikes.



We can see that LIFO queuing is able to increase $\lambda^* = 1$ by ensuring that the system does not experience a large **mean delay** outside of the instability point. LIFO queues have a trade off in that the mobile user may have some jobs experience an extreme delay (and require a resubmit), but on average the system can support a larger λ^* while maintaining a fixed mean delay.

Modifications to code

For-loops were used to allow a range of arrival rates and seeds: to collect a fine range of data.

Data was exported en-masse to a .csv file, where the data was manipulated in excel to create the plots.

The code was modified throughout the lab to enable:

- Buffers were used for the base station and mobile devices. Base station buffer was shared with cloud server, as latency is negligible.
- The mobile devices and cloud server had links to track if a job is in transit or processing.
- For section 2, conditional logic was added to the start of cloud server jobs, to implement the prioritization schemes.
- For section 3, the simlib.c was modified to convert the fifoqueue methods to a LIFO queue format.

Appendix

Mean Delay vs. Arrival Rate – Asymptotic

Seed	arrival rate	(Good)	(Bad)
400137271	0.001	1.01049	1.100469
400137271	0.023429	1.022001	1.112029
400137271	0.045857	1.034036	1.12409
400137271	0.068286	1.046662	1.136721
400137271	0.090714	1.059934	1.149985
400137271	0.113143	1.073842	1.163942
400137271	0.135571	1.088457	1.178613
400137271	0.158	1.103836	1.194076
400137271	0.180429	1.120054	1.210388
400137271	0.202857	1.137195	1.227596
400137271	0.225286	1.155343	1.245789
400137271	0.247714	1.174552	1.265055
400137271	0.270143	1.194949	1.285485
400137271	0.292571	1.216657	1.307214
400137271	0.315	1.239806	1.330371
400137271	0.337429	1.264489	1.355117
400137271	0.359857	1.290931	1.381568
400137271	0.382286	1.3193	1.409947
400137271	0.404714	1.349763	1.440521
400137271	0.427143	1.382627	1.473431
400137271	0.449571	1.418128	1.509058
400137271	0.472	1.456696	1.547703
400137271	0.494429	1.498719	1.589758
400137271	0.516857	1.544648	1.63576
400137271	0.539286	1.595031	1.686216
400137271	0.561714	1.650517	1.741906
400137271	0.584143	1.712045	1.803694
400137271	0.606571	1.780685	1.872497
400137271	0.629	1.857564	1.94956

400137271	0.651429	1.94435	2.03649
400137271	0.673857	2.043124	2.13536
400137271	0.696286	2.156565	2.248776
400137271	0.718714	2.287949	2.380215
400137271	0.741143	2.442134	2.534568
400137271	0.763571	2.625982	2.718558
400137271	0.786	2.848738	2.941281
400137271	0.808429	3.123286	3.215646
400137271	0.830857	3.47066	3.56264
400137271	0.853286	3.924854	4.016317
400137271	0.875714	4.544569	4.635729
400137271	0.898143	5.438713	5.529759
400137271	0.920571	6.841325	6.930968
400137271	0.943	9.38339	9.46839
400137271	0.965429	15.21379	15.29454
400137271	0.987857	43.22707	43.28027
400137271	1.010286	51646.31	51651.05
400137271	1.032714	159109.3	159123.3
400137271	1.055143	262003.7	262026.6
400137271	1.077571	360614.8	360646.2
400137271	1.1	455204.6	455244.2

Mean Delay vs. Arrival Rate – Stable

Seed	arrival rate	(Good)	(Bad)
400137271	0.001	4.00437	13.02753
400137271	0.003007	4.013424	13.08348
400137271	0.005013	4.022659	13.14047
400137271	0.00702	4.032055	13.19892
400137271	0.009027	4.041429	13.25851
400137271	0.011034	4.050746	13.31948
400137271	0.01304	4.060133	13.38141
400137271	0.015047	4.069771	13.44435
400137271	0.017054	4.079788	13.50863
400137271	0.01906	4.089785	13.57433
400137271	0.021067	4.099355	13.64177
400137271	0.023074	4.109738	13.70994
400137271	0.025081	4.119549	13.78011
400137271	0.027087	4.129463	13.85154
400137271	0.029094	4.140176	13.92404
400137271	0.031101	4.15075	13.99879
400137271	0.033107	4.161334	14.07536

400137271	0.035114	4.172114	14.1535
400137271	0.037121	4.182732	14.23389
400137271	0.039128	4.193272	14.31618
400137271	0.041134	4.20397	14.40013
400137271	0.043141	4.214959	14.48605
400137271	0.045148	4.226706	14.57404
400137271	0.047154	4.238111	14.66468
400137271	0.049161	4.249545	14.75715
400137271	0.051168	4.260896	14.85226
400137271	0.053174	4.272765	14.9495
400137271	0.055181	4.284607	15.04939
400137271	0.057188	4.295985	15.15251
400137271	0.059195	4.30834	15.25787
400137271	0.061201	4.320562	15.36661
400137271	0.063208	4.333097	15.47833
400137271	0.065215	4.344793	15.59412
400137271	0.067221	4.35712	15.71246
400137271	0.069228	4.3695	15.83433
400137271	0.071235	4.382442	15.95968
400137271	0.073242	4.39514	16.08954
400137271	0.075248	4.407884	16.22385
400137271	0.077255	4.420802	16.36216
400137271	0.079262	4.434281	16.50422
400137271	0.081268	4.447739	16.65136
400137271	0.083275	4.46103	16.80401
400137271	0.085282	4.475114	16.96106
400137271	0.087289	4.489388	17.1241
400137271	0.089295	4.50356	17.29316
400137271	0.091302	4.518059	17.46842
400137271	0.093309	4.532246	17.65001
400137271	0.095315	4.54693	17.83788
400137271	0.097322	4.561527	18.03265
400137271	0.099329	4.576163	18.23457
400137271	0.101336	4.590695	18.44477
400137271	0.103342	4.606009	18.66276
400137271	0.105349	4.621834	18.89014
400137271	0.107356	4.637358	19.12767
400137271	0.109362	4.653495	19.375
400137271	0.111369	4.670156	19.63381
400137271	0.113376	4.686376	19.90471
400137271	0.115383	4.703035	20.18739
400137271	0.117389	4.719034	20.48411
400137271	0.119396	4.73634	20.79475

400137271	0.121403	4.753527	21.12161
400137271	0.123409	4.770421	21.46563
400137271	0.125416	4.787589	21.82744
400137271	0.127423	4.806068	22.20873
400137271	0.12943	4.824165	22.6114
400137271	0.131436	4.842512	23.03769
400137271	0.133443	4.860721	23.48854
400137271	0.13545	4.880359	23.96641
400137271	0.137456	4.899261	24.4748
400137271	0.139463	4.918124	25.01722
400137271	0.14147	4.937575	25.59583
400137271	0.143477	4.957148	26.2138
400137271	0.145483	4.976782	26.87669
400137271	0.14749	4.998314	27.59091
400137271	0.149497	5.019608	28.36027
400137271	0.151503	5.039484	29.18913
400137271	0.15351	5.061882	30.09068
400137271	0.155517	5.081927	31.07303
400137271	0.157523	5.104975	32.14838
400137271	0.15953	5.126834	33.32797
400137271	0.161537	5.150694	34.63567
400137271	0.163544	5.173053	36.08723
400137271	0.16555	5.195668	37.70639
400137271	0.167557	5.218702	39.51742
400137271	0.169564	5.241601	41.57297
400137271	0.17157	5.267065	43.89799
400137271	0.173577	5.291248	46.56964
400137271	0.175584	5.315332	49.66821
400137271	0.177591	5.342228	53.31883
400137271	0.179597	5.368815	57.69206
400137271	0.181604	5.394925	63.0222
400137271	0.183611	5.420317	69.61578
400137271	0.185617	5.447944	78.1641
400137271	0.187624	5.477691	89.44655
400137271	0.189631	5.506098	105.398
400137271	0.191638	5.533843	129.0253
400137271	0.193644	5.563247	168.5585
400137271	0.195651	5.592054	243.7645
400137271	0.197658	5.62299	441.7141
400137271	0.199664	5.653656	3410.375
400137271	0.201671	5.675544	62228.26
400137271	0.203678	5.697173	134477.2
400137271	0.205685	5.720265	204607.3

400137271	0.207691	5.739505	272703.4
400137271	0.209698	5.763691	338798.8
400137271	0.211705	5.78491	403000.5
400137271	0.213711	5.805407	465328.8
400137271	0.215718	5.829497	525870.8
400137271	0.217725	5.85416	584667.5
400137271	0.219732	5.873664	641806.3
400137271	0.221738	5.900579	697302.6
400137271	0.223745	5.922911	751181.4
400137271	0.225752	5.947718	803598.6
400137271	0.227758	5.974781	854504.6
400137271	0.229765	5.998873	904019.9
400137271	0.231772	6.025434	952153.7
400137271	0.233779	6.052229	998985.9
400137271	0.235785	6.078762	1044449
400137271	0.237792	6.106988	1088705
400137271	0.239799	6.134349	1131735
400137271	0.241805	6.16374	1173575
400137271	0.243812	6.193326	1214195
400137271	0.245819	6.221138	1253779
400137271	0.247826	6.253008	1292221
400137271	0.249832	6.282235	1329621
400137271	0.251839	6.313383	1366001
400137271	0.253846	6.34487	1401382
400137271	0.255852	6.37647	1435892
400137271	0.257859	6.411064	1469477
400137271	0.259866	6.443889	1502050
400137271	0.261872	6.478186	1533787
400137271	0.263879	6.512947	1564657
400137271	0.265886	6.546997	1594704
400137271	0.267893	6.584156	1623962
400137271	0.269899	6.624027	1652437
400137271	0.271906	6.660648	1680105
400137271	0.273913	6.698776	1707069
400137271	0.275919	6.737567	1733259
400137271	0.277926	6.77645	1758801
400137271	0.279933	6.817347	1783694
400137271	0.28194	6.858676	1807923
400137271	0.283946	6.902508	1831445
400137271	0.285953	6.944329	1854339
400137271	0.28796	6.986776	1876671
400137271	0.289966	7.035327	1898373
400137271	0.291973	7.08034	1919532

400137271	0.29398	7.12707	1940156
400137271	0.295987	7.173346	1960212
400137271	0.297993	7.223519	1979708
400137271	0.3	7.27503	1998755

Priority: Uplink speed

Seed	arrival rate	(Good)	(Bad)
400137271	0.001	1.100467	2.000491
400137271	0.023429	1.112063	2.011849
400137271	0.045857	1.124608	2.023508
400137271	0.068286	1.137935	2.035555
400137271	0.090714	1.152235	2.047804
400137271	0.113143	1.167526	2.060342
400137271	0.135571	1.184019	2.073146
400137271	0.158	1.201784	2.086246
400137271	0.180429	1.221057	2.099609
400137271	0.202857	1.241853	2.11332
400137271	0.225286	1.264307	2.12732
400137271	0.247714	1.288431	2.141738
400137271	0.270143	1.314377	2.156632
400137271	0.292571	1.34281	2.171749
400137271	0.315	1.373598	2.187369
400137271	0.337429	1.407108	2.203398
400137271	0.359857	1.443524	2.21997
400137271	0.382286	1.483234	2.237082
400137271	0.404714	1.526961	2.254473
400137271	0.427143	1.574791	2.272529
400137271	0.449571	1.627788	2.29081
400137271	0.472	1.686032	2.309909
400137271	0.494429	1.750746	2.329494
400137271	0.516857	1.823241	2.34943
400137271	0.539286	1.903616	2.370518
400137271	0.561714	1.993881	2.39193
400137271	0.584143	2.095461	2.414059
400137271	0.606571	2.210868	2.436833
400137271	0.629	2.341823	2.460622
400137271	0.651429	2.492365	2.484601
400137271	0.673857	2.665521	2.509681
400137271	0.696286	2.866836	2.535914
400137271	0.718714	3.103695	2.562905
400137271	0.741143	3.386625	2.590719

400137271	0.763571	3.72918	2.61911
400137271	0.786	4.148155	2.649624
400137271	0.808429	4.67206	2.680475
400137271	0.830857	5.338917	2.712875
400137271	0.853286	6.215615	2.745998
400137271	0.875714	7.412852	2.781967
400137271	0.898143	9.16343	2.817963
400137271	0.920571	11.94847	2.856148
400137271	0.943	16.9268	2.896755
400137271	0.965429	28.68211	2.936772
400137271	0.987857	83.88708	2.980229
400137271	1.010286	30423.47	3.01367
400137271	1.032714	94906.39	3.037977
400137271	1.055143	156626.7	3.062238
400137271	1.077571	215777.5	3.086962
400137271	1.1	272499.4	3.114724

Priority: Non-preemptive delay detection

Seed	arrival rate	(Good)	(Bad)
400137271	0.001	0.510124	0.600111
400137271	0.023429	0.512977	0.602944
400137271	0.045857	0.515939	0.605814
400137271	0.068286	0.519011	0.608694
400137271	0.090714	0.522184	0.611605
400137271	0.113143	0.525447	0.614574
400137271	0.135571	0.528834	0.617571
400137271	0.158	0.532348	0.620599
400137271	0.180429	0.535996	0.623658
400137271	0.202857	0.539761	0.626766
400137271	0.225286	0.54365	0.629917
400137271	0.247714	0.547685	0.633101
400137271	0.270143	0.551867	0.636325
400137271	0.292571	0.556201	0.639588
400137271	0.315	0.560728	0.642863
400137271	0.337429	0.56541	0.646194
400137271	0.359857	0.570285	0.649552
400137271	0.382286	0.575353	0.652944
400137271	0.404714	0.580589	0.656404
400137271	0.427143	0.586018	0.65992
400137271	0.449571	0.591683	0.663457
400137271	0.472	0.597573	0.667032

400137271	0.494429	0.603695	0.670658
400137271	0.516857	0.610072	0.674321
400137271	0.539286	0.616701	0.678039
400137271	0.561714	0.623583	0.681829
400137271	0.584143	0.630779	0.685644
400137271	0.606571	0.638305	0.68949
400137271	0.629	0.646119	0.693422
400137271	0.651429	0.654285	0.697386
400137271	0.673857	0.662776	0.701438
400137271	0.696286	0.671674	0.705511
400137271	0.718714	0.680956	0.709657
400137271	0.741143	0.690697	0.713823
400137271	0.763571	0.700841	0.718094
400137271	0.786	0.711423	0.722463
400137271	0.808429	0.722564	0.726834
400137271	0.830857	0.73274	0.732758
400137271	0.853286	0.741109	0.741115
400137271	0.875714	0.749812	0.749813
400137271	0.898143	0.758869	0.75887
400137271	0.920571	0.768304	0.768305
400137271	0.943	0.77814	0.778141
400137271	0.965429	0.7884	0.788401
400137271	0.987857	0.799121	0.799122
400137271	1.010286	0.810329	0.81033
400137271	1.032714	0.822058	0.82206
400137271	1.055143	0.834346	0.834348
400137271	1.077571	0.847219	0.847219
400137271	1.1	0.860728	0.860729

Priority: Preemptive delay detection

Seed	arrival rate	(Good)	(Bad)
400137271	0.001	0.510248	0.600058
400137271	0.023429	0.515927	0.601471
400137271	0.045857	0.521788	0.602907
400137271	0.068286	0.527729	0.604352
400137271	0.090714	0.53387	0.605814
400137271	0.113143	0.540091	0.607297
400137271	0.135571	0.546518	0.608794
400137271	0.158	0.553119	0.610307
400137271	0.180429	0.559929	0.611842
400137271	0.202857	0.566859	0.613396

400137271	0.225286	0.573888	0.614966
400137271	0.247714	0.581193	0.616554
400137271	0.270143	0.588674	0.618161
400137271	0.292571	0.596316	0.619785
400137271	0.315	0.604304	0.62143
400137271	0.337429	0.612478	0.623094
400137271	0.359857	0.620898	0.624781
400137271	0.382286	0.628021	0.628022
400137271	0.404714	0.633238	0.633238
400137271	0.427143	0.638589	0.638589
400137271	0.449571	0.644047	0.644047
400137271	0.472	0.649758	0.649758
400137271	0.494429	0.655526	0.655526
400137271	0.516857	0.66145	0.66145
400137271	0.539286	0.667577	0.667578
400137271	0.561714	0.673858	0.673858
400137271	0.584143	0.680343	0.680343
400137271	0.606571	0.687033	0.687034
400137271	0.629	0.693814	0.693815
400137271	0.651429	0.700939	0.700939
400137271	0.673857	0.708161	0.70816
400137271	0.696286	0.715708	0.715708
400137271	0.718714	0.723493	0.723493
400137271	0.741143	0.731451	0.731452
400137271	0.763571	0.739774	0.739774
400137271	0.786	0.748306	0.748306
400137271	0.808429	0.757226	0.757227
400137271	0.830857	0.7663	0.7663
400137271	0.853286	0.775751	0.775751
400137271	0.875714	0.785513	0.785514
400137271	0.898143	0.795684	0.795684
400137271	0.920571	0.806245	0.806246
400137271	0.943	0.817243	0.817244
400137271	0.965429	0.828686	0.828686
400137271	0.987857	0.840554	0.840554
400137271	1.010286	0.853076	0.853076
400137271	1.032714	0.866091	0.866091
400137271	1.055143	0.879526	0.879527
400137271	1.077571	0.89347	0.89347
400137271	1.1	0.908146	0.908147

Base Station Instability

Seed	arrival rate	(Good)	(Bad)
400137271	0.001	4.00437	13.02753
400137271	0.003007	4.013424	13.08348
400137271	0.005013	4.022659	13.14047
400137271	0.00702	4.032055	13.19892
400137271	0.009027	4.041429	13.25851
400137271	0.011034	4.050746	13.31948
400137271	0.01304	4.060133	13.38141
400137271	0.015047	4.069771	13.44435
400137271	0.017054	4.079788	13.50863
400137271	0.01906	4.089785	13.57433
400137271	0.021067	4.099355	13.64177
400137271	0.023074	4.109738	13.70994
400137271	0.025081	4.119549	13.78011
400137271	0.027087	4.129463	13.85154
400137271	0.029094	4.140176	13.92404
400137271	0.031101	4.15075	13.99879
400137271	0.033107	4.161334	14.07536
400137271	0.035114	4.172114	14.1535
400137271	0.037121	4.182732	14.23389
400137271	0.039128	4.193272	14.31618
400137271	0.041134	4.20397	14.40013
400137271	0.043141	4.214959	14.48605
400137271	0.045148	4.226706	14.57404
400137271	0.047154	4.238111	14.66468
400137271	0.049161	4.249545	14.75715
400137271	0.051168	4.260896	14.85226
400137271	0.053174	4.272765	14.9495
400137271	0.055181	4.284607	15.04939
400137271	0.057188	4.295985	15.15251
400137271	0.059195	4.30834	15.25787
400137271	0.061201	4.320562	15.36661
400137271	0.063208	4.333097	15.47833
400137271	0.065215	4.344793	15.59412
400137271	0.067221	4.35712	15.71246
400137271	0.069228	4.3695	15.83433
400137271	0.071235	4.382442	15.95968
400137271	0.073242	4.39514	16.08954
400137271	0.075248	4.407884	16.22385
400137271	0.077255	4.420802	16.36216
400137271	0.079262	4.434281	16.50422

400137271	0.081268	4.447739	16.65136
400137271	0.083275	4.46103	16.80401
400137271	0.085282	4.475114	16.96106
400137271	0.087289	4.489388	17.1241
400137271	0.089295	4.50356	17.29316
400137271	0.091302	4.518059	17.46842
400137271	0.093309	4.532246	17.65001
400137271	0.095315	4.54693	17.83788
400137271	0.097322	4.561527	18.03265
400137271	0.099329	4.576163	18.23457
400137271	0.101336	4.590695	18.44477
400137271	0.103342	4.606009	18.66276
400137271	0.105349	4.621834	18.89014
400137271	0.107356	4.637358	19.12767
400137271	0.109362	4.653495	19.375
400137271	0.111369	4.670156	19.63381
400137271	0.113376	4.686376	19.90471
400137271	0.115383	4.703035	20.18739
400137271	0.117389	4.719034	20.48411
400137271	0.119396	4.73634	20.79475
400137271	0.121403	4.753527	21.12161
400137271	0.123409	4.770421	21.46563
400137271	0.125416	4.787589	21.82744
400137271	0.127423	4.806068	22.20873
400137271	0.12943	4.824165	22.6114
400137271	0.131436	4.842512	23.03769
400137271	0.133443	4.860721	23.48854
400137271	0.13545	4.880359	23.96641
400137271	0.137456	4.899261	24.4748
400137271	0.139463	4.918124	25.01722
400137271	0.14147	4.937575	25.59583
400137271	0.143477	4.957148	26.2138
400137271	0.145483	4.976782	26.87669
400137271	0.14749	4.998314	27.59091
400137271	0.149497	5.019608	28.36027
400137271	0.151503	5.039484	29.18913
400137271	0.15351	5.061882	30.09068
400137271	0.155517	5.081927	31.07303
400137271	0.157523	5.104975	32.14838
400137271	0.15953	5.126834	33.32797
400137271	0.161537	5.150694	34.63567
400137271	0.163544	5.173053	36.08723
400137271	0.16555	5.195668	37.70639

400137271	0.167557	5.218702	39.51742
400137271	0.169564	5.241601	41.57297
400137271	0.17157	5.267065	43.89799
400137271	0.173577	5.291248	46.56964
400137271	0.175584	5.315332	49.66821
400137271	0.177591	5.342228	53.31883
400137271	0.179597	5.368815	57.69206
400137271	0.181604	5.394925	63.0222
400137271	0.183611	5.420317	69.61578
400137271	0.185617	5.447944	78.1641
400137271	0.187624	5.477691	89.44655
400137271	0.189631	5.506098	105.398
400137271	0.191638	5.533843	129.0253
400137271	0.193644	5.563247	168.5585
400137271	0.195651	5.592054	243.7645
400137271	0.197658	5.62299	441.7141
400137271	0.199664	5.653656	3410.375
400137271	0.201671	5.675544	62228.26
400137271	0.203678	5.697173	134477.2
400137271	0.205685	5.720265	204607.3
400137271	0.207691	5.739505	272703.4
400137271	0.209698	5.763691	338798.8
400137271	0.211705	5.78491	403000.5
400137271	0.213711	5.805407	465328.8
400137271	0.215718	5.829497	525870.8
400137271	0.217725	5.85416	584667.5
400137271	0.219732	5.873664	641806.3
400137271	0.221738	5.900579	697302.6
400137271	0.223745	5.922911	751181.4
400137271	0.225752	5.947718	803598.6
400137271	0.227758	5.974781	854504.6
400137271	0.229765	5.998873	904019.9
400137271	0.231772	6.025434	952153.7
400137271	0.233779	6.052229	998985.9
400137271	0.235785	6.078762	1044449
400137271	0.237792	6.106988	1088705
400137271	0.239799	6.134349	1131735
400137271	0.241805	6.16374	1173575
400137271	0.243812	6.193326	1214195
400137271	0.245819	6.221138	1253779
400137271	0.247826	6.253008	1292221
400137271	0.249832	6.282235	1329621
400137271	0.251839	6.313383	1366001

400137271	0.253846	6.34487	1401382
400137271	0.255852	6.37647	1435892
400137271	0.257859	6.411064	1469477
400137271	0.259866	6.443889	1502050
400137271	0.261872	6.478186	1533787
400137271	0.263879	6.512947	1564657
400137271	0.265886	6.546997	1594704
400137271	0.267893	6.584156	1623962
400137271	0.269899	6.624027	1652437
400137271	0.271906	6.660648	1680105
400137271	0.273913	6.698776	1707069
400137271	0.275919	6.737567	1733259
400137271	0.277926	6.77645	1758801
400137271	0.279933	6.817347	1783694
400137271	0.28194	6.858676	1807923
400137271	0.283946	6.902508	1831445
400137271	0.285953	6.944329	1854339
400137271	0.28796	6.986776	1876671
400137271	0.289966	7.035327	1898373
400137271	0.291973	7.08034	1919532
400137271	0.29398	7.12707	1940156
400137271	0.295987	7.173346	1960212
400137271	0.297993	7.223519	1979708
400137271	0.3	7.27503	1998755

LIFO Queue Behaviour

Seed	arrival rate	(Good)	(Bad)
400137271	0.001	1.01049	1.100469
400137271	0.012101	1.01613	1.106107
400137271	0.023202	1.021908	1.111884
400137271	0.034303	1.027773	1.117806
400137271	0.045404	1.033795	1.123834
400137271	0.056505	1.039962	1.130004
400137271	0.067606	1.046295	1.136303
400137271	0.078707	1.052758	1.142788
400137271	0.089808	1.059415	1.149406
400137271	0.100909	1.066171	1.156247
400137271	0.11201	1.073112	1.163232
400137271	0.123111	1.08024	1.170377
400137271	0.134212	1.087554	1.177698
400137271	0.145313	1.095096	1.18517

400137271	0.156414	1.102798	1.19288
400137271	0.167515	1.110724	1.200773
400137271	0.178616	1.118876	1.208871
400137271	0.189717	1.127218	1.217223
400137271	0.200818	1.135818	1.225771
400137271	0.211919	1.144634	1.234594
400137271	0.22302	1.15371	1.243657
400137271	0.234121	1.163063	1.252957
400137271	0.245222	1.172641	1.262579
400137271	0.256323	1.182538	1.272449
400137271	0.267424	1.192758	1.282595
400137271	0.278525	1.203275	1.293071
400137271	0.289626	1.214152	1.303857
400137271	0.300727	1.225351	1.315012
400137271	0.311828	1.237007	1.326439
400137271	0.322929	1.248998	1.338277
400137271	0.33403	1.261259	1.350642
400137271	0.345131	1.274037	1.363325
400137271	0.356232	1.287205	1.376495
400137271	0.367333	1.300742	1.390227
400137271	0.378434	1.314861	1.404348
400137271	0.389535	1.329552	1.418938
400137271	0.400636	1.344757	1.434092
400137271	0.411737	1.360504	1.449834
400137271	0.422838	1.376819	1.466217
400137271	0.433939	1.393758	1.483256
400137271	0.44504	1.411449	1.500901
400137271	0.456141	1.429973	1.519167
400137271	0.467242	1.44924	1.538234
400137271	0.478343	1.469305	1.558134
400137271	0.489444	1.490048	1.579104
400137271	0.500545	1.511959	1.600765
400137271	0.511646	1.534921	1.623367
400137271	0.522747	1.558744	1.647242
400137271	0.533848	1.583595	1.67233
400137271	0.544949	1.609889	1.698385
400137271	0.556051	1.63728	1.725987
400137271	0.567152	1.666211	1.754912
400137271	0.578253	1.696903	1.785159
400137271	0.589354	1.729243	1.817106
400137271	0.600455	1.763212	1.85096
400137271	0.611556	1.799181	1.886684
400137271	0.622657	1.836643	1.925108

400137271	0.633758	1.876701	1.965502
400137271	0.644859	1.919971	2.0077
400137271	0.65596	1.96538	2.053304
400137271	0.667061	2.013929	2.101821
400137271	0.678162	2.066212	2.153371
400137271	0.689263	2.122604	2.208201
400137271	0.700364	2.182611	2.267609
400137271	0.711465	2.246957	2.331762
400137271	0.722566	2.315965	2.401604
400137271	0.733667	2.390391	2.477589
400137271	0.744768	2.472287	2.559431
400137271	0.755869	2.561448	2.649092
400137271	0.76697	2.659802	2.746718
400137271	0.778071	2.768042	2.854162
400137271	0.789172	2.886684	2.973971
400137271	0.800273	3.020928	3.104353
400137271	0.811374	3.169918	3.25071
400137271	0.822475	3.335299	3.417761
400137271	0.833576	3.526838	3.603588
400137271	0.844677	3.742125	3.819761
400137271	0.855778	3.993402	4.066071
400137271	0.866879	4.28495	4.356346
400137271	0.87798	4.629571	4.70162
400137271	0.889081	5.042495	5.117084
400137271	0.900182	5.550726	5.620169
400137271	0.911283	6.184107	6.25328
400137271	0.922384	7.001013	7.070253
400137271	0.933485	8.122042	8.154812
400137271	0.944586	9.670425	9.697775
400137271	0.955687	11.99589	11.96127
400137271	0.966788	15.87298	15.87592
400137271	0.977889	23.86898	23.89078
400137271	0.98899	47.74123	47.7567
400137271	1.000091	955.3289	935.4839
400137271	1.011192	46.68478	46.44819
400137271	1.022293	23.83592	23.68232
400137271	1.033394	16.21645	16.22033
400137271	1.044495	12.44594	12.46897
400137271	1.055596	10.18364	10.21913
400137271	1.066697	8.696312	8.697812
400137271	1.077798	7.591912	7.649241
400137271	1.088899	6.779187	6.860263
400137271	1.1	6.166529	6.238653