Impact of random engines and multiple threads

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Abstract

The goal of this paper is to determine the effect of different random engines as well as the use of parallelism on the results obtained from the simulator.
Instead of running the simulator for all the seeds used in the original assignment, we decided to use the first 250 seeds of *random2.dat*. In the conclusion we will discuss the results for the following parallel configurations and random engines:

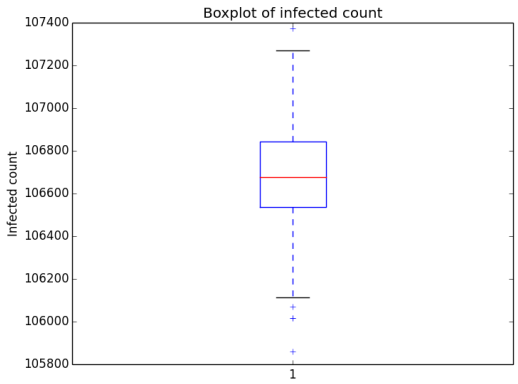
- No parallelism
- 2 threads
- 4 threads
- 8 threads
- 16 threads
- Lcg-64
- Lcg-64-shift
- Mrg-2
- Mrg-3
- Yarn-2
- Yarn-3

As allways for the Shapiro-Wilk test, we use (null hypothesis) H_0 = data is normally distributed, and just like before we will use a significance level α of 0.05. Thus if the p-value is smaller than 0.05 we reject the null hypothesis, meaning the data isn't normally distributed.

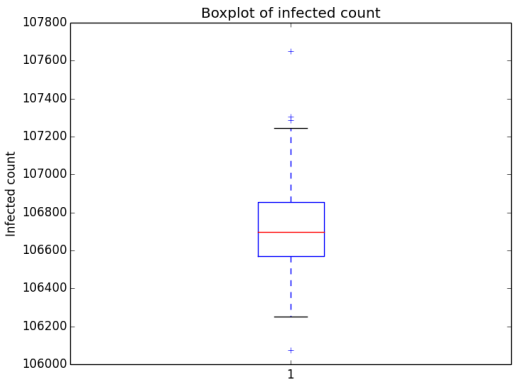
1 Impact of random engines

First we will compare results by changing the random engine while keeping the number of threads the same. The boxplots on the following pages were generated from the collected data. For the histograms, QQplots & scatterplots refer to the zip file. After all the boxplots we will summarize the data in tables for an easier comparison.

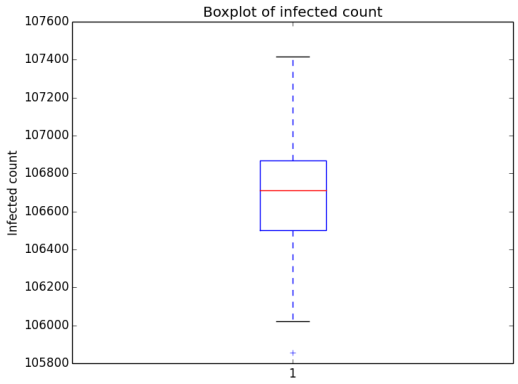
No parallelism



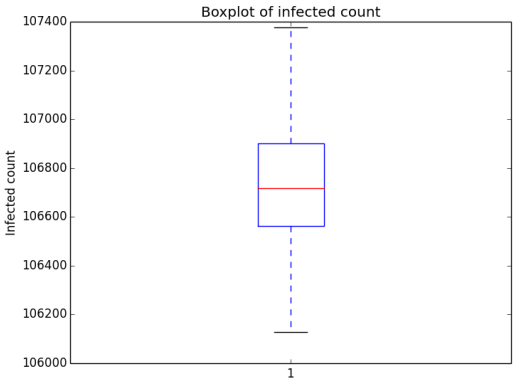
(a) Boxplot with lcg64 as random engine



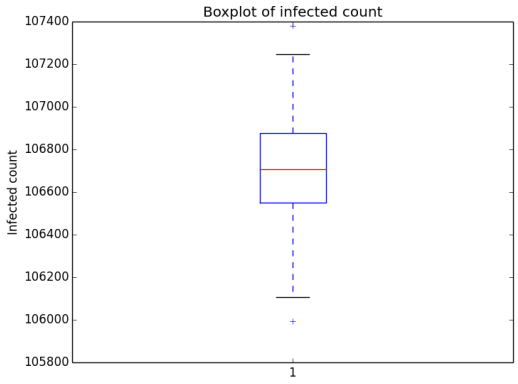
(b) Boxplot with lcg64shift as random engine



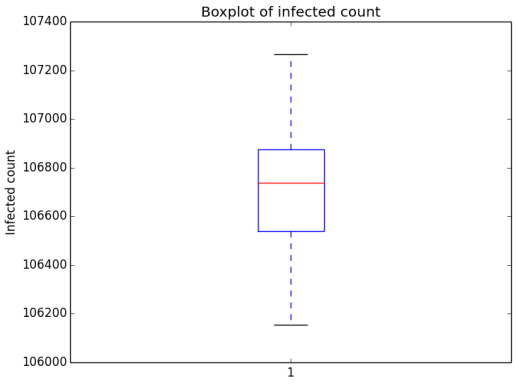
(c) Boxplot with mrg2 as random engine



(d) Boxplot with mrg3 as random engine



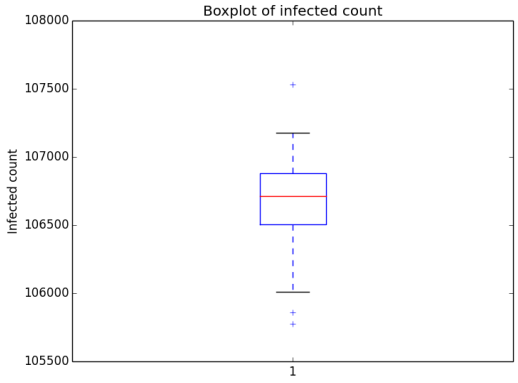
(e) Boxplot with yarn2 as random engine



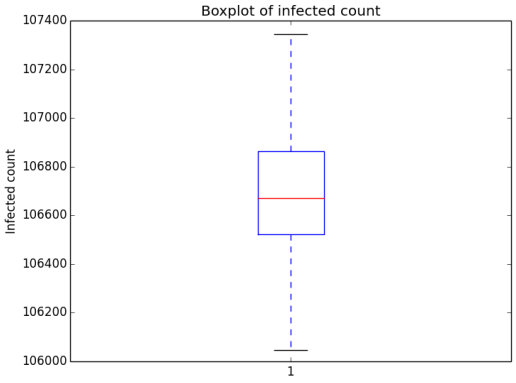
(f) Boxplot with yarn3 as random engine

Figure 1: Boxplots with no parallelism

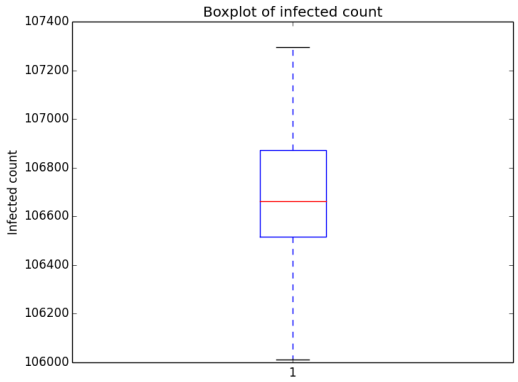
2 threads



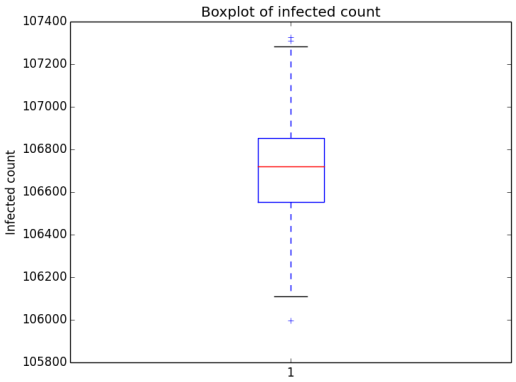
(a) Boxplot with lcg64 as random engine



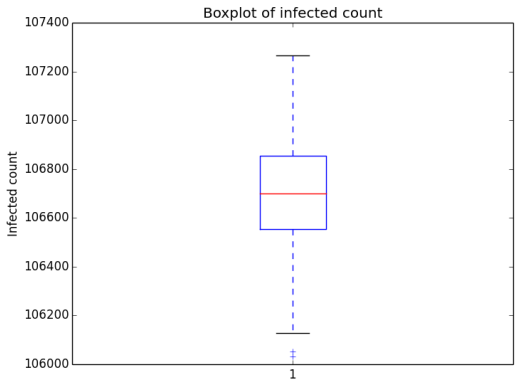
(b) Boxplot with lcg64shift as random engine



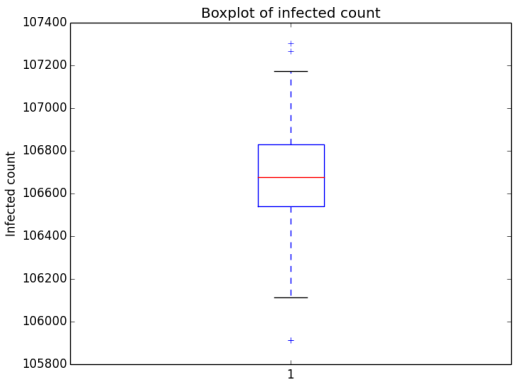
(c) Boxplot with mrg2 as random engine



(d) Boxplot with mrg3 as random engine



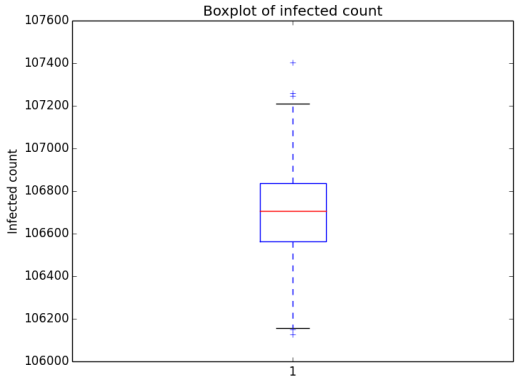
(e) Boxplot with yarn2 as random engine



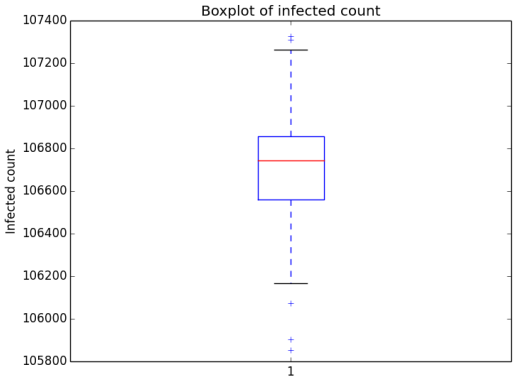
(f) Boxplot with yarn3 as random engine

Figure 2: Boxplots with 2 threads

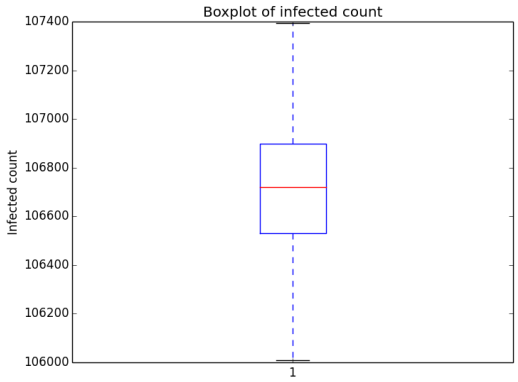
4 threads



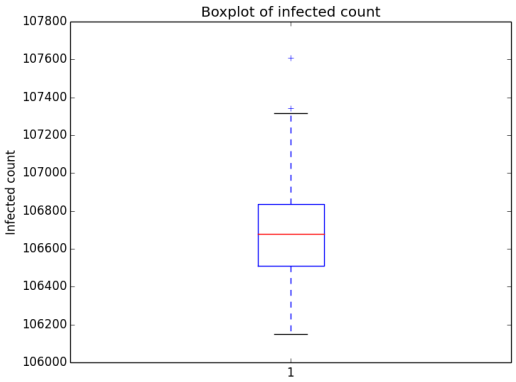
(a) Boxplot with lcg64 as random engine



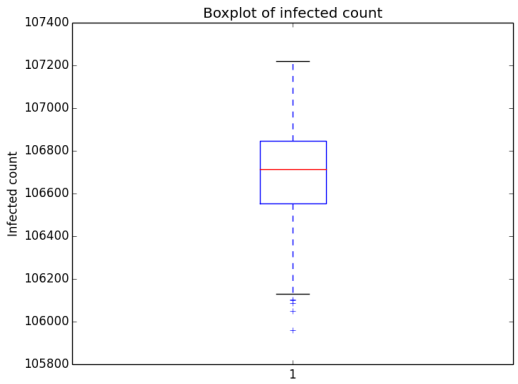
(b) Boxplot with lcg64shift as random engine



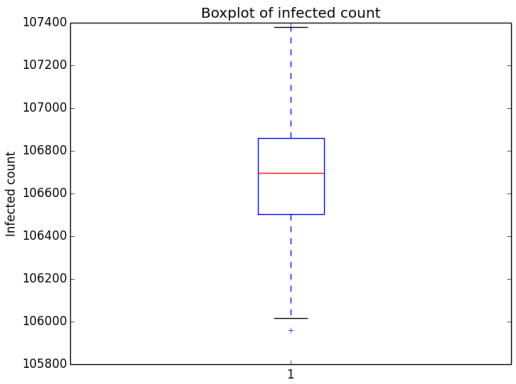
(c) Boxplot with mrg2 as random engine



(d) Boxplot with mrg3 as random engine



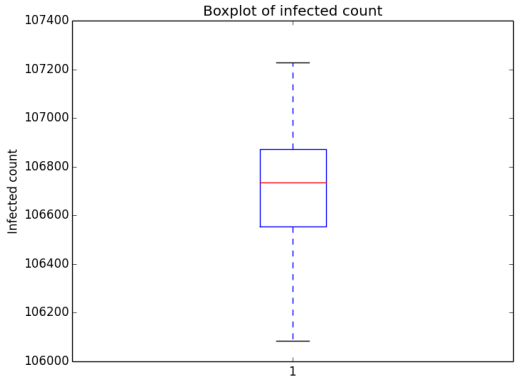
(e) Boxplot with yarn2 as random engine



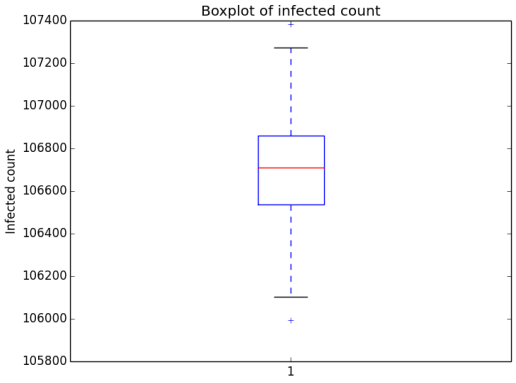
(f) Boxplot with yarn3 as random engine

Figure 3: Boxplots with 4 threads

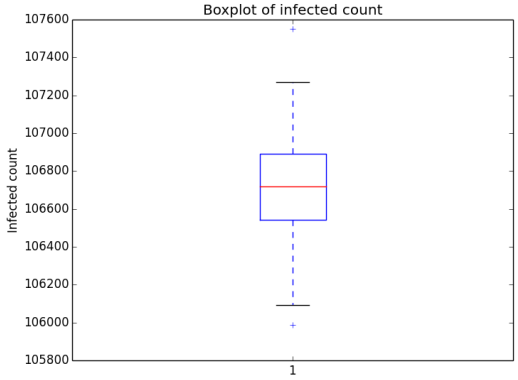
8 threads



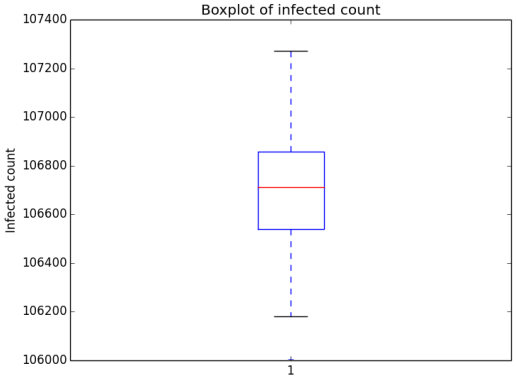
(a) Boxplot with lcg64 as random engine



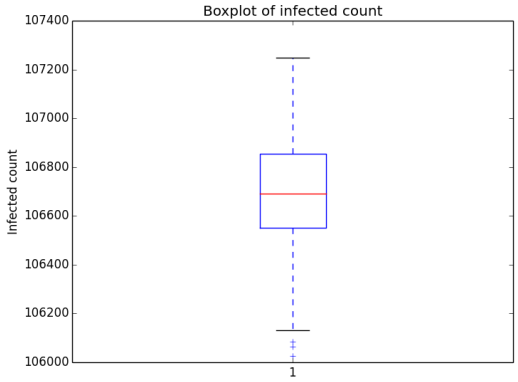
(b) Boxplot with lcg64shift as random engine



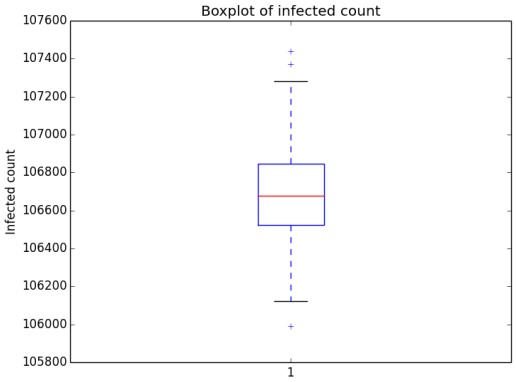
(c) Boxplot with mrg2 as random engine



(d) Boxplot with mrg3 as random engine



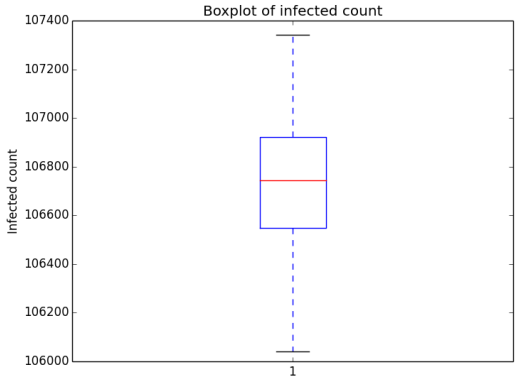
(e) Boxplot with yarn2 as random engine



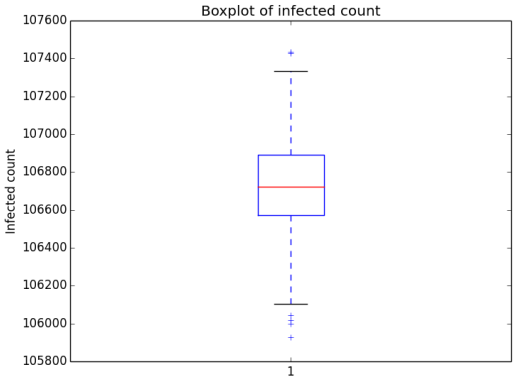
(f) Boxplot with yarn3 as random engine

Figure 4: Boxplots with 8 threads

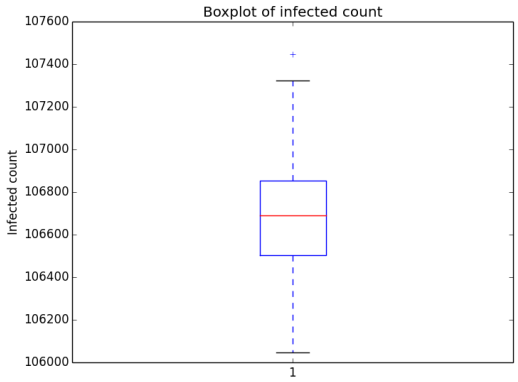
16 threads



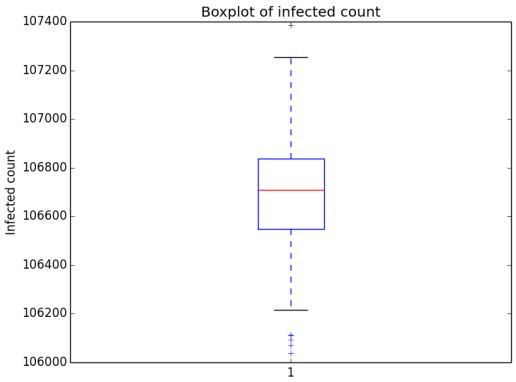
(a) Boxplot with lcg64 as random engine



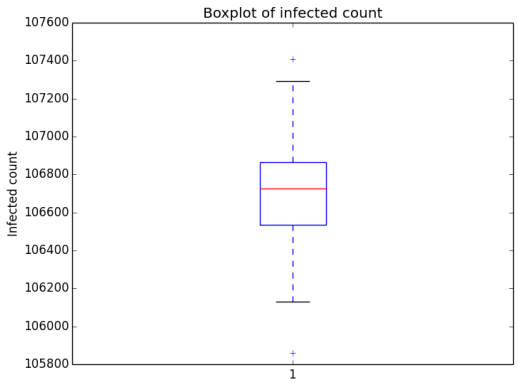
(b) Boxplot with lcg64shift as random engine



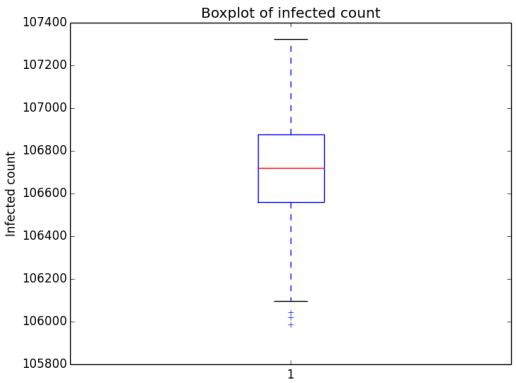
(c) Boxplot with mrg2 as random engine



(d) Boxplot with mrg3 as random engine



(e) Boxplot with yarn2 as random engine



(f) Boxplot with yarn3 as random engine

Figure 5: Boxplots with 16 threads

Summary for each parallel configuration

1 thread	lcg-64	lcg-64-shift	mrg-2	mrg-3	yarn-2	yarn-3
Mean (M)	106682	106710	106692	106719	106709	106712
Standard deviation	246.41	215.95	263.63	258.16	231.77	252.75
Lower bound	105861	106076	105856	106127	105993	106154
Upper bound	107374	107650	107417	107376	107379	107266
LB% from the mean	0.7697%	0.5944%	0.7833%	0.5548%	0.6706%	0.5225%
UB% from the mean	0.6485%	0.8805%	0.6798%	0.6155%	0.6283%	0.5195%
P(LB<X<UB)	99.71%	99.83%	99.63%	98.36%	99.71%	97.22%
Ceil(Max(LB%, UB%))	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
1% around mean	(105615, 107749)	(105643, 107777)	(105625, 107759)	(105652, 107787)	(105641, 107775)	(105644, 107779)
P(0.99M<X<1.01M)	99.9985%	99.9999%	99.9948%	99.9964%	99.9996%	99.9976%
3% around mean	(103481, 109883)	(103484, 109885)	(103491, 109892)	(103518, 109921)	(103507, 109910)	(103510, 109913)
P(0.97M<X<1.03M)	≈100%	≈100%	≈100%	≈100%	≈100%	≈100%
Shapiro-Wilk p-value	0.6197	0.0173	0.5810	0.3152	0.9896	0.0157

2 threads	lcg-64	lcg-64-shift	mrg-2	mrg-3	yarn-2	yarn-3
Mean (M)	106689	106685	106680	106700	106686	106681
Standard deviation	268.16	239.90	258.57	240.21	234.87	232.44
Lower bound	105778	106076	105856	106127	105993	106154
Upper bound	107532	107650	107417	107376	107379	107266
LB% from the mean	0.8544%	0.5970%	0.6274%	0.6595%	0.6123%	0.7196%
UB% from the mean	0.7896%	0.6187%	0.5762%	0.5880%	0.5443%	0.584%
P(LB<X<UB)	99.88%	99.31%	98.65%	99.38%	99.06%	99.59%
Ceil(Max(LB%, UB%))	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
1% around mean	(105623, 107756)	(105618, 107752)	(105614, 107747)	(105633, 107767)	(105619, 107753)	(105614, 107747)
P(0.99M<X<1.01M)	99.9931%	99.9991%	99.9963%	99.9991%	99.9994%	99.9996%
3% around mean	(103488, 109890)	(103484, 109885)	(103480, 109881)	(103499, 109901)	(103486, 109887)	(103480, 109881)
P(0.97M<X<1.03M)	≈100%	≈100%	≈100%	≈100%	≈100%	≈100%
Shapiro-Wilk p-value	0.0113	0.7737	0.2227	0.8678	0.2784	0.6173

4 threads	lcg-64	lcg-64-shift	mrg-2	mrg-3	yarn-2	yarn-3
Mean (M)	106704	106710	106710	106689	106705	106686
Standard deviation	233.82	247.91	259.32	252.89	238.16	242.69
Lower bound	106128	106710	106009	106150	105959	105961
Upper bound	107403	107327	107393	107608	107219	107381
LB% from the mean	0.5399%	0.8018%	0.6570%	0.5057%	0.6991%	0.6796%
UB% from the mean	0.6549%	0.5785%	0.6400%	0.8609%	0.4817%	0.6514%
P(LB<X<UB)	99.1730%	99.33%	99.23%	98.34%	98.37%	99.65%
Ceil(Max(LB%, UB%))	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
1% around mean	(105637, 107771)	(105643, 107777)	(105643, 107777)	(105623, 107756)	(105638, 107772)	(105619, 107753)
P(0.99M<X<1.01M)	99.9995%	99.9983%	99.9961%	99.9975%	99.9993%	99.9989%
3% around mean	(103503, 109905)	(103508, 109911)	(103508, 109911)	(103488, 109890)	(103504, 109906)	(103485, 109887)
P(0.97M<X<1.03M)	≈100%	≈100%	≈100%	≈100%	≈100%	≈100%
Shapiro-Wilk p-value	0.7314	0.0112	0.6241	0.0462	0.0566	0.3094

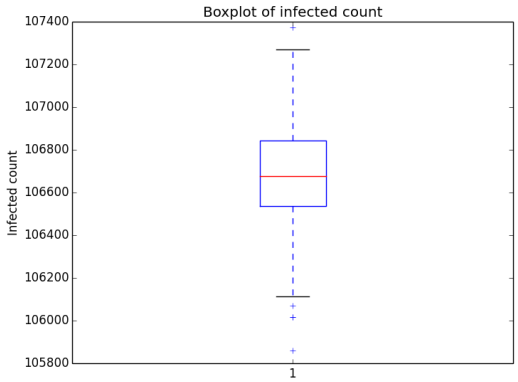
8 threads	lcg-64	lcg-64-shift	mrg-2	mrg-3	yarn-2	yarn-3
Mean (M)	106716	106700	106711	106698	106685	106683
Standard deviation	229.93	249.67	254.78	231.54	235.53	237.80
Lower bound	106084	105993	105989	106006	106025	105993
Upper bound	107228	107385	107553	107273	107249	107439
LB% from the mean	0.5918%	0.6624%	0.6769%	0.6488%	0.6185%	0.6471%
UB% from the mean	0.4802%	0.6422%	0.7887%	0.539%	0.5288%	0.7083%
P(LB<X<UB)	98.41%	99.46%	99.72%	99.21%	98.92%	99.74%
Ceil(Max(LB%, UB%))	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
1% around mean	(105648, 107783)	(105633, 107767)	(105644, 107778)	(105631, 107765)	(105618, 107752)	(05617, 107750)
P(0.99M<X<1.01M)	99.9997%	99.9981%	99.9972%	99.9996%	99.9994%	99.9993%
3% around mean	(103514, 109917)	(103499, 109901)	(103510, 109913)	(103497, 109899)	(103484, 109885)	(103483, 109884)
P(0.97M<X<1.03M)	≈100%	≈100%	≈100%	≈100%	≈100%	≈100%
Shapiro-Wilk p-value	0.2133	0.9108	0.8299	0.8538	0.0740	0.8036

16 threads	lcg-64	lcg-64-shift	mrg-2	mrg-3	yarn-2	yarn-3
Mean (M)	106730	106719	106694	106693	106700	106707
Standard deviation	259.11	262.26	244.09	237.15	248.64	248.06
Lower bound	106041	105928	106048	106037	105859	105986
Upper bound	107342	107436	107446	107384	107409	107400
LB% from the mean	0.6455%	0.7415%	0.6058%	0.6148%	0.7884%	0.6757%
UB% from the mean	0.5734%	0.6716%	0.7045%	0.6477%	0.6642%	0.6494%
P(LB<X<UB)	98.70%	99.56%	99.49%	99.54%	99.75%	99.56%
Ceil(Max(LB%, UB%))	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
1% around mean	(105663, 107797)	(105652, 107786)	(105627, 107761)	(105626, 107760)	(105633, 107767)	(105640, 107774)
P(0.99M<X<1.01M)	99.996%	99.9953%	99.9988%	99.9993%	99.9982%	99.9983%
3% around mean	(103528, 109931)	(103518, 109921)	(103493, 109895)	(103492, 109893)	(103499, 109901)	(103505, 109908)
P(0.97M<X<1.03M)	≈100%	≈100%	≈100%	≈100%	≈100%	≈100%
Shapiro-Wilk p-value	0.0822	0.5125	0.9113	0.1470	0.9195	0.5113

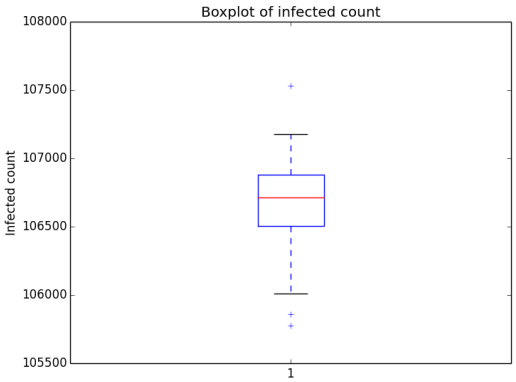
2 Impact of the number of threads

Now we will compare the effect of the number of threads for each random engine seperately. Once again, only the boxplots are present in this report, followed by tables that summarize all the data.

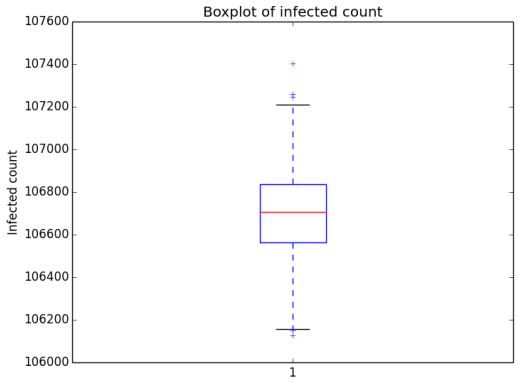
Lcg-64



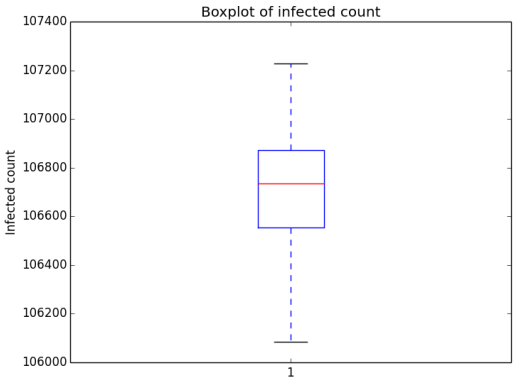
(a) Boxplot with No parallelism



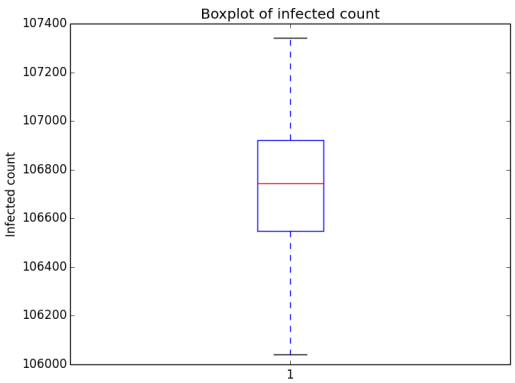
(b) Boxplot with 2 threads



(c) Boxplot for 4 threads



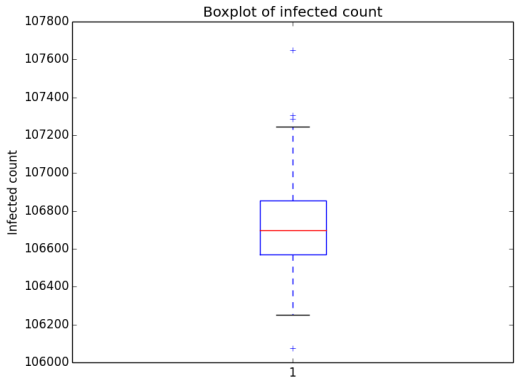
(d) Boxplot for 8 threads



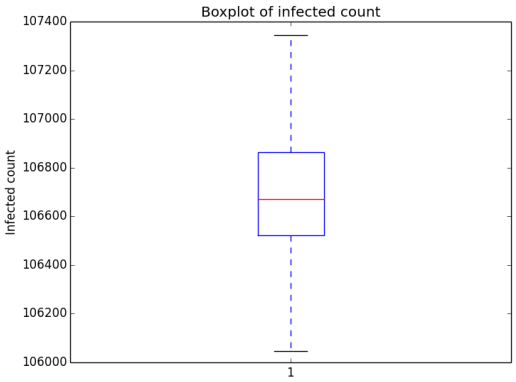
(e) Boxplot for 16 threads

Figure 6: Boxplots for lcg64 as random engine

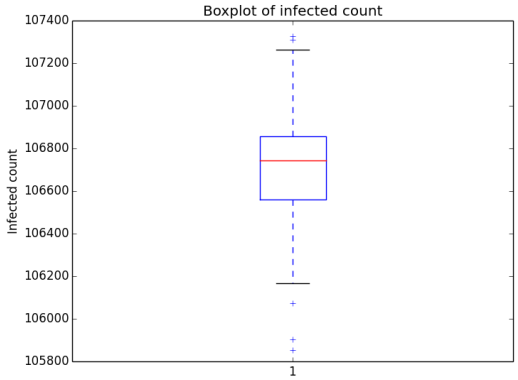
Lcg-64-shift



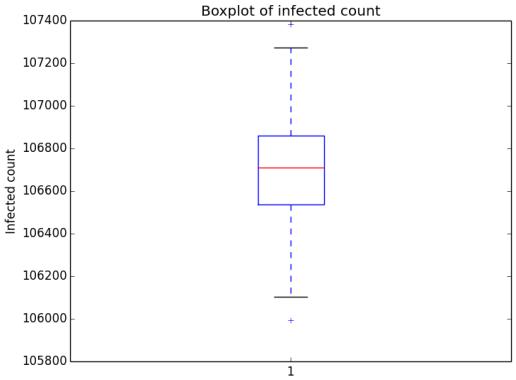
(a) Boxplot with No parallelism



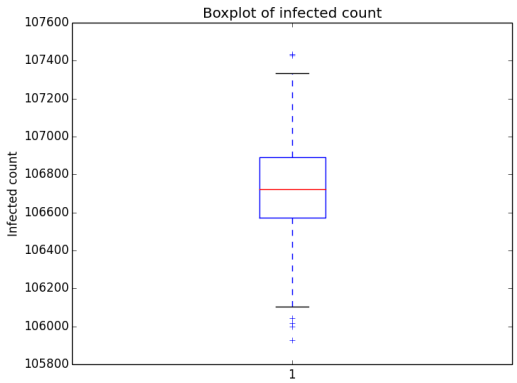
(b) Boxplot with 2 threads



(c) Boxplot for 4 threads



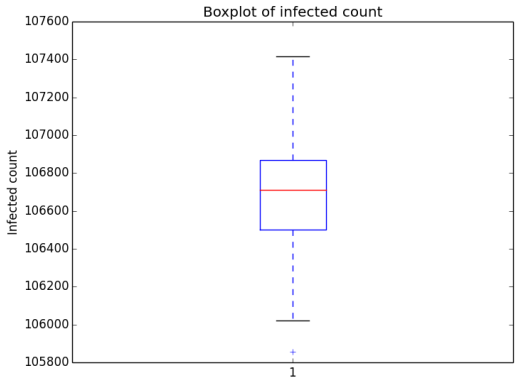
(d) Boxplot for 8 threads



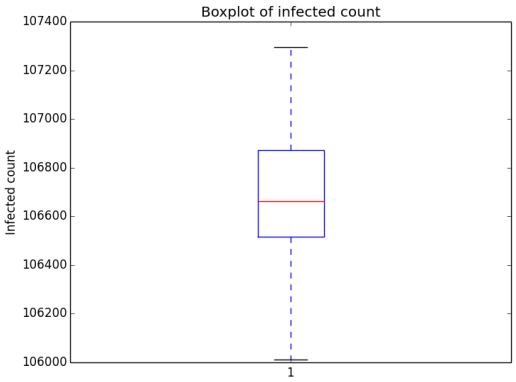
(e) Boxplot for 16 threads

Figure 7: Boxplots for lcg64-shift as random engine

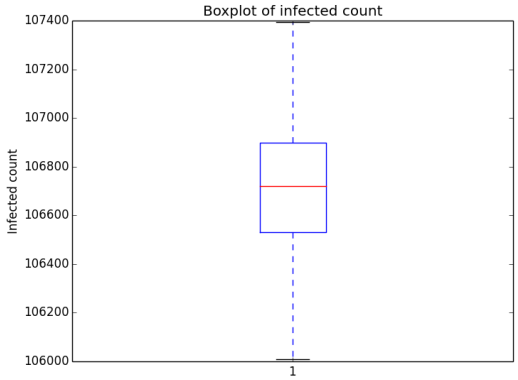
Mrg-2



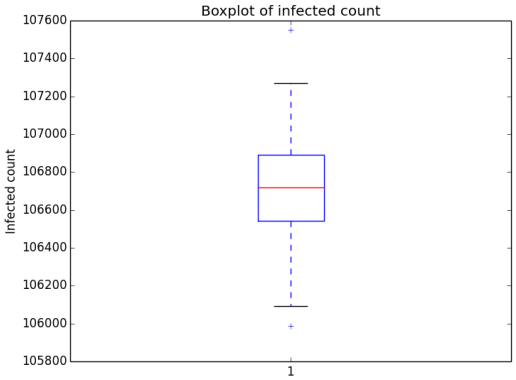
(a) Boxplot with No parallelism



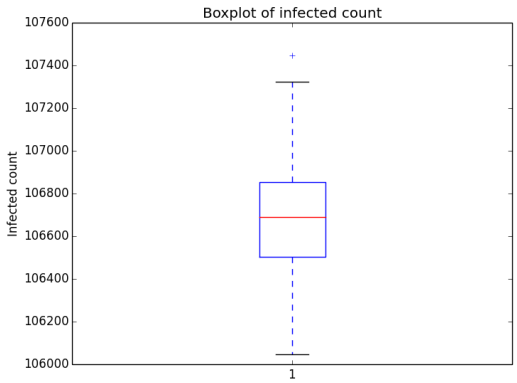
(b) Boxplot with 2 threads



(c) Boxplot for 4 threads



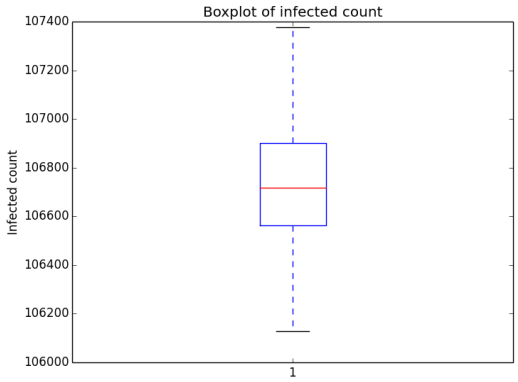
(d) Boxplot for 8 threads



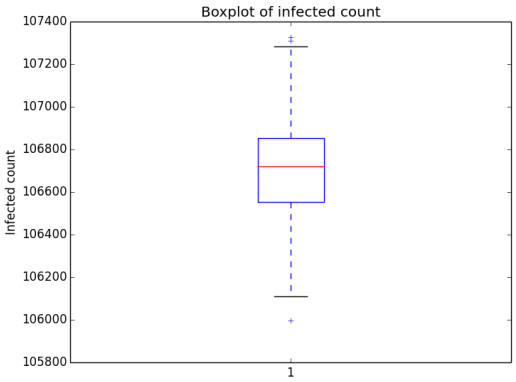
(e) Boxplot for 16 threads

Figure 8: Boxplots for mrg2 as random engine

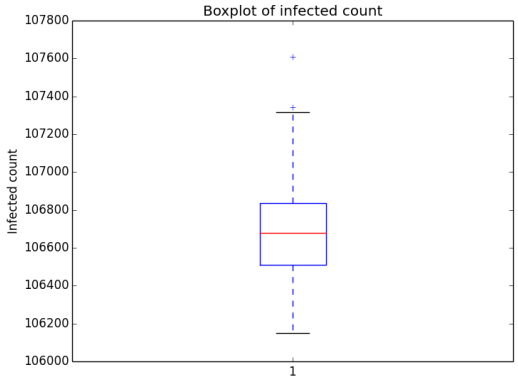
Mrg-3



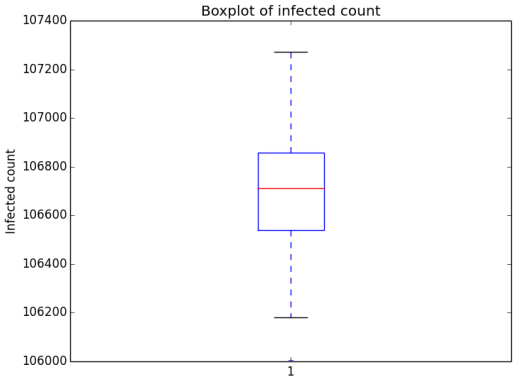
(a) Boxplot with No parallelism



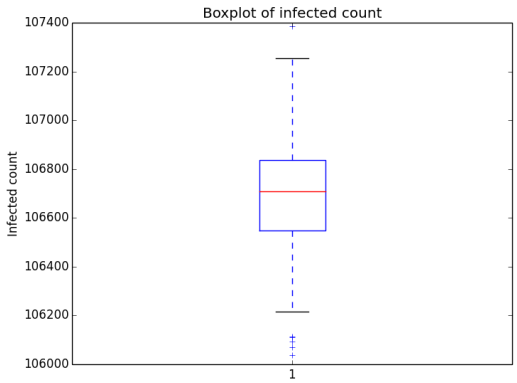
(b) Boxplot with 2 threads



(c) Boxplot for 4 threads



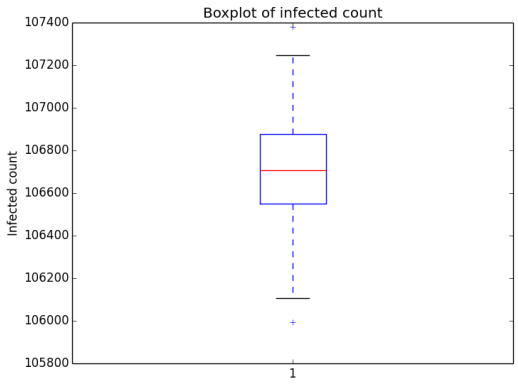
(d) Boxplot for 8 threads



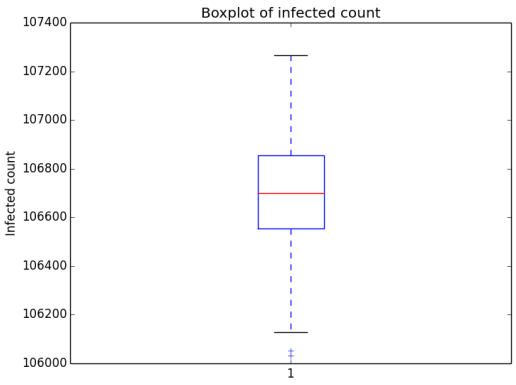
(e) Boxplot for 16 threads

Figure 9: Boxplots for mrg3 as random engine

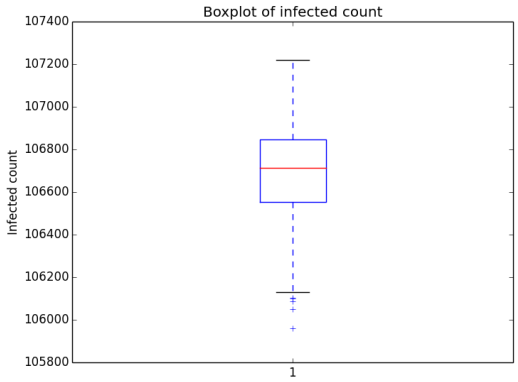
Yarn-2



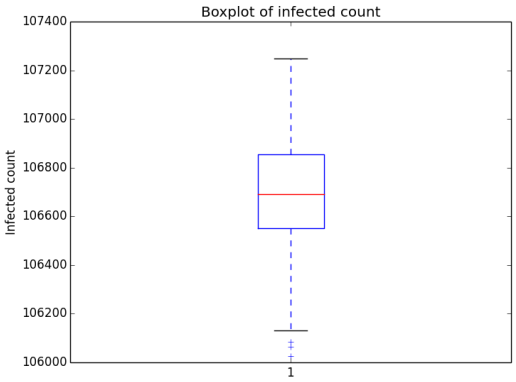
(a) Boxplot with No parallelism



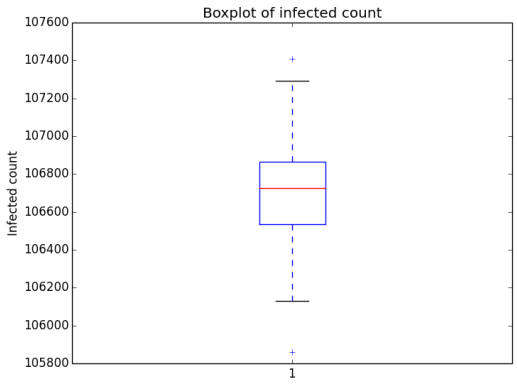
(b) Boxplot with 2 threads



(c) Boxplot for 4 threads



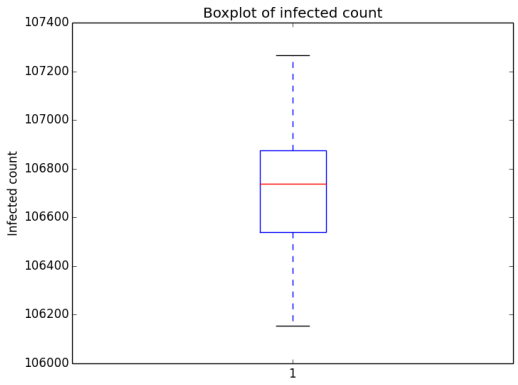
(d) Boxplot for 8 threads



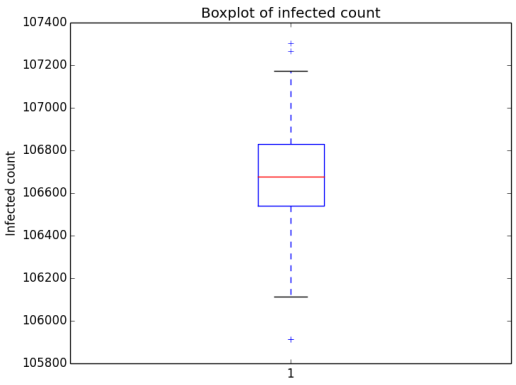
(e) Boxplot for 16 threads

Figure 10: Boxplots for yarn3 as random engine

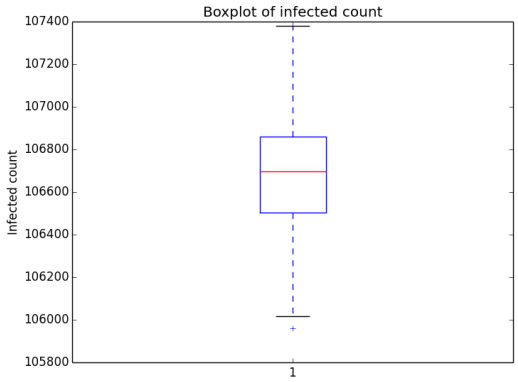
Yarn-3



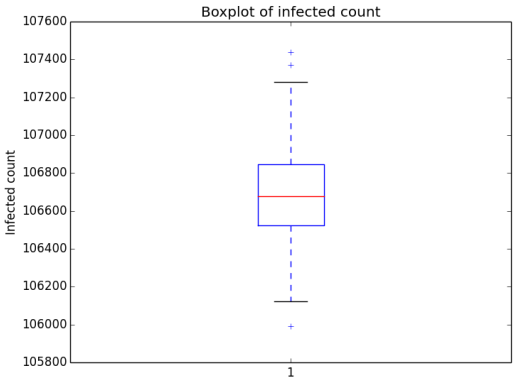
(a) Boxplot with No parallelism



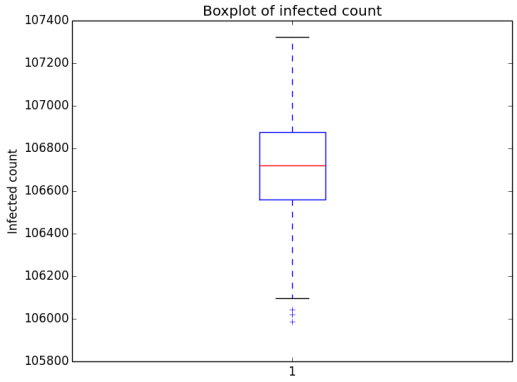
(b) Boxplot with 2 threads



(c) Boxplot for 4 threads



(d) Boxplot for 8 threads



(e) Boxplot for 16 threads

Figure 11: Boxplots for yarn3 as random engine

Summary for each random engine

LCG64	1	2	4	8	16
Mean (M)	106682	106690	106704	106716	106730
Standard deviation	246.41	268.16	233.82	229.93	259.11
Lower bound	105861	105778	106128	106084	106041
Upper bound	107374	107532	107403	107228	107342
LB% from the mean	0.7700%	0.5399%	0.6058%	0.5918%	0.6455%
UB% from the mean	0.6485%	0.7896%	0.6549%	0.4802%	0.5734%
P(LB<X<UB)	99.71%	99.88%	99.17%	98.41%	98.70%
Ceil(Max(LB%, UB%))	1.0%	1.0%	1.0%	1.0%	1.0%
1% around mean	(105615, 107749)	(105623, 107756)	(105637, 107771)	(105648, 107783)	(105663, 107797)
P(0.99M<X<1.01M)	99.9985%	99.9931%	99.9995%	99.9997%	99.9962%
3% around mean	(103482, 109883)	(103489, 109890)	(103503, 109905)	(103514, 109917)	(103528, 109932)
P(0.97M<X<1.03M)	≈100%	≈100%	≈100%	≈100%	≈100%
Shapiro-Wilk p-value	0.6198	0.0113	0.7315	0.2132	0.0822

LCG64-shift	1	2	4	8	16
Mean (M)	106710	106685	106710	106700	106719
Standard deviation	215.95	239.90	247.91	249.67	262.26
Lower bound	106076	106048	105854	105993	105928
Upper bound	107650	107345	107327	107385	107436
LB% from the mean	0.5944%	0.5970%	0.8018%	0.6624%	0.7415%
UB% from the mean	0.8806%	0.6187%	0.5785%	0.6422%	0.6716%
P(LB<X<UB)	99.83%	99.88%	99.33%	99.46%	99.56%
Ceil(Max(LB%, UB%))	1.0%	1.0%	1.0%	1.0%	1.0%
1% around mean	(105643, 107777)	(105618, 107752)	(105642, 107777)	(105633, 107767)	(105652, 107786)
P(0.99M<X<1.01M)	99.9999%	99.9991%	99.9983%	99.9981%	99.9953%
3% around mean	(103509, 109911)	(103484, 109885)	(103508, 109911)	(103499, 109901)	(103518, 109921)
P(0.97M<X<1.03M)	≈100%	≈100%	≈100%	≈100%	≈100%
Shapiro-Wilk p-value	0.0173	0.7737	0.01116	0.9108	0.5124

MRG2	1	2	4	8	16
Mean (M)	106692	106680	106710	106711	106694
Standard deviation	263.63	258.57	259.32	254.78	244.09
Lower bound	105856	106011	106009	105989	106048
Upper bound	107417	107295	107393	107553	107446
LB% from the mean	0.7833%	0.6274%	0.6570%	0.6769%	0.6058%
UB% from the mean	0.6798%	0.5761%	0.6400%	0.7887%	0.7045%
P(LB<X<UB)	99.63%	98.65%	99.23%	99.72%	99.49%
Ceil(Max(LB%, UB%))	1.0%	1.0%	1.0%	1.0%	1.0%
1% around mean	(105625, 107759)	(105643, 107777)	(105642, 107777)	(105644, 107778)	(105627, 107761)
P(0.99M<X<1.01M)	99.9948%	99.9963%	99.9961%	99.9972%	99.9988%
3% around mean	(103491, 109892)	(103509, 109911)	(103508, 109911)	(103510, 109913)	(103493, 109895)
P(0.97M<X<1.03M)	≈100%	≈100%	≈100%	≈100%	≈100%
Shapiro-Wilk p-value	0.5810	0.2227	0.6241	0.8299	0.9113

MRG3	1	2	4	8	16
Mean (M)	106719	106700	106690	106698	106693
Standard deviation	258.16	240.21	252.89	231.54	237.15
Lower bound	106127	105996	106150	106006	106037
Upper bound	107376	107327	107608	107273	107384
LB% from the mean	0.5549%	0.65945%	0.5057%	0.6488%	0.6148%
UB% from the mean	0.6155%	0.58796%	0.8609%	0.5387%	0.6477%
P(LB<X<UB)	98.36%	99.38%	98.34%	99.21%	99.54%
Ceil(Max(LB%, UB%))	1.0%	1.0%	1.0%	1.0%	1.0%
1% around mean	(105652, 107786)	(105633, 107767)	(105622, 107756)	(105631, 107765)	(105626, 107760)
P(0.99M<X<1.01M)	99.9964%	99.9991%	99.9975%	99.9996%	99.9993%
3% around mean	(103518, 109921)	(103499, 109901)	(103489, 109890)	(103497, 109899)	(103492, 109894)
P(0.97M<X<1.03M)	≈100%	≈100%	≈100%	≈100%	≈100%
Shapiro-Wilk p-value	0.3152	0.8678	0.0462	0.8538	0.1470

YARN2	1	2	4	8	16
Mean (M)	106708	106686	106705	106685	106700
Standard deviation	231.77	234.87	238.16	235.53	248.64
Lower bound	105993	106033	105959	106025	105859
Upper bound	107379	107267	107219	107249	107409
LB% from the mean	0.6706%	0.6123%	0.6991%	0.6185%	0.7885%
UB% from the mean	0.6283%	0.5443%	0.4817%	0.5288%	0.6642%
P(LB<X<UB)	99.71%	99.06%	98.37%	98.92%	99.75%
Ceil(Max(LB%, UB%))	1.0%	1.0%	1.0%	1.0%	1.0%
1% around mean	(105641, 107776)	(105619, 107753)	(105638, 107772)	((105618, 107752)	(105633, 107767)
P(0.99M<X<1.01M)	99.9996%	99.9994%	99.9993%	99.9994%	99.9982%
3% around mean	(103507, 109910)	(103486, 109887)	(103504, 109906)	(103484, 109885)	(103492, 109894)
P(0.97M<X<1.03M)	≈100%	≈100%	≈100%	≈100%	≈100%
Shapiro-Wilk p-value	0.9896	0.2780	0.0566	0.0740	0.9195

YARN3	1	2	4	8	16
Mean (M)	106712	106681	106686	106683	106707
Standard deviation	252.75	232.44	242.69	237.80	248.06
Lower bound	106154	105913	105961	105993	105986
Upper bound	107266	107304	107381	107439	107400
LB% from the mean	0.5225%	0.7196%	0.6795%	0.6471%	0.6757%
UB% from the mean	0.5195%	0.5843%	0.6514%	0.7083%	0.6494%
P(LB<X<UB)	97.22%	99.59%	99.65%	99.74%	99.56%
Ceil(Max(LB%, UB%))	1.0%	1.0%	1.0%	1.0%	1.0%
1% around mean	(105644, 107779)	(105614, 107747)	(105619, 107753)	(105617, 107750	(105640, 107774)
P(0.99M<X<1.01M)	99.9976%	99.9996%	99.9989%	99.9993%	99.9983%
3% around mean	(103510, 109913)	(103480, 109881)	(103485, 109887)	(103483, 109884)	(103506, 109908)
P(0.97M<X<1.03M)	≈100%	≈100%	≈100%	≈100%	≈100%
Shapiro-Wilk p-value	0.0157	0.6173	0.3095	0.8036	0.5114

3 Conclusion

3.1 Mean

As we can see the infected count's mean stays around 106700 cases. The following table sums up all the means for each random engine and parallel configuration, together with averages for each column/row. From this table we conclude that both the random engine as well as the number of threads don't affect the mean in a significant way.

Engine vs Threads	1	2	4	8	16	Avg.
LCG64	106682	106690	106704	106716	106730	106704.4
LCG64-shift	106710	106685	106710	106700	106719	106704.8
MRG2	106692	106680	106710	106711	106694	106697.4
MRG3	106719	106700	106690	106698	106693	106700
YARN2	106708	106686	106705	106685	106700	106696.8
YARN3	106712	106681	106686	106683	106707	106693.8
Avg.	106703.8	106687	106700.8	106698.8	106707.2	106699.5

3.2 Standard Deviation

The standard deviation behaves rather weird in the sense that we can't establish a consistent pattern. We're assuming this is simply the result of a limited sample set (250 seeds) where we have "bad luck". Furthermore we assume that the standard deviation will converge to a value between 215.95 and 268.16, being the smallest and largest standard deviations that we've found. The following table is the same as the last one, except now we're considering standard deviations instead of means.

Engine vs Threads	1	2	4	8	16	Avg.
LCG64	246.41	268.16	233.82	229.93	259.11	247.486
LCG64-shift	215.95	239.90	248.82	249.67	262.26	243.412
MRG2	263.63	258.57	259.32	254.78	244.09	256.078
MRG3	258.16	240.21	252.89	231.54	237.15	243.990
YARN2	231.77	234.87	238.16	235.53	248.64	237.794
YARN3	252.75	232.44	242.69	237.80	248.06	242.748
Avg.	244.855	245.692	245.950	239.875	249.885	245.251

3.3 Bounds

Again no consistent pattern can be found, however we do notice that all results fall within 1% of the mean. As we pointed out in the original assignment, we're only investigating a fraction of all possible seeds and thus it is probably better to take a more conservative value like 3%. Referring to the text files within the `summaries` folders we also see that the probability to fall within 3% around the mean is (still) practically 100%. Thus our original conclusion, i.e. 3% being a good margin, still holds for the measles disease which is used by the `run_default.xml`, being the default configuration.

3.4 Shapiro-Wilk tests

The data suggests that some combinations of random engines with a specific number of threads breaks the normal distribution. However we're assuming this is due to outliers since most of the time the data is in fact normally distributed. Aside from that the plots found in the zip file also suggest we're dealing with outliers. Needless to say (as we pointed out multiple times) the limited sample set of 250 seeds may also be a culprite as to why some of the p-values drop below our significance level.