A Comprehensive Study of Characterizing Program Execution Time

Young-Kyoon Suh
yksuh@cs.arizona.edu

January 19, 2016

1 Experiment Notes

Task Length	Description	Time Length
PUT1∼PUT64	A regular PUT experiment with runs of 1000 samples (on `sodb12`).	2013-10-14 ∼ 2013-10-15
PUT128∼PUT2048	A regular PUT experiment with runs of 300 samples (on `sodb12`).	2013-12-12 ∼ 2013-12-21
PUT4096	A regular PUT experiment with a run of 300 samples (on `sodb12`).	2014-06-23 ∼ 2014-07-10
PUT8192	A regular PUT experiment with a run of 40 samples (on `sodb12`).	2015-04-23 ∼ 2015-04-27
PUT8192	A regular PUT experiment with a run of 260 samples (on `sodb12`).	2015-10-31 ∼ 2015-11-24
PUT16384	A regular PUT experiment with a run of 40 samples (on `sodb12`).	2015-04-23 ∼ 2015-04-23
PUT16384	A regular PUT experiment with a run of 260 samples (on `sodb12`).	2015-11-25 ∼ 2016-01-14

Table 1: Notes on the PUT data used for the histograms

Task Length	Description	Time Length
PUT1	A regular PUT experiment with a run of 20,000 samples on `sodb9`.	2015-12-15 ∼ 2015-12-15
PUT2	A Regular PUT experiment with a run of 20,000 samples on `sodb10`.	2015-12-15 ∼ 2015-12-15
PUT4096	A dual PUT experiment with a run of 500 samples on `sodb8`. Used `gettimeofday()` for measuring the elapsed time of each half of every PUT4096 (same for the following PUT2 and PUT64).	2015-11-08 ∼ 2015-12-25
PUT2	A dual PUT experiment with a run of 1,000 samples on `sodb9`.	2015-12-27 ∼ 2015-12-27
PUT64	A dual PUT experiment with a run of 1,000 samples on `sodb10`	2015-12-27 ∼ 2015-12-27

Table 2: Notes on the new PUT experiments

2 Summary of the EMPv4 data

	Num. of Samples	Minimum (msec)	Maximum (msec)	Average (msec)	Std. Dev. (msec)
PUT1	1,000	999.0	1,005.0	1,002.4	0.73
PUT2	1,000	1,996.0	2,007.0	2,004.5	1.38
PUT4	1,000	4,004.0	4,012.0	4,008.6	1.64
PUT8	1,000	8,014.0	8,023.0	8,018.1	1.72
PUT16	1,000	16,029.0	16,041.0	16,034.3	1.86
PUT32	1,000	32,064.0	32,084.0	32,068.2	2.05
PUT64	1,000	64,129.0	64,145.0	64,135.0	2.27
PUT128	300	128,244.0	128,260.0	128,251.2	2.32
PUT256	300	256,494.0	256,523.0	256,502.3	3.29
PUT512	300	512,995.0	513,152.0	513,005.1	9.41
PUT1024	300	1,025,997.0	1,026,141.0	1,026,012.4	11.43
PUT2048	300	2,051,981.0	2,052,156.0	2,052,012.0	11.19
PUT4096	300	4,105,451.0	4,105,629.0	4,105,526.0	25.98
PUT8192	40 (last Apr)	8,207,870.0	8,207,967.0	8,207,918.0	21.03
PUT8192	260 (Nov)	8,210,940.0	8,211,196.0	8,211,049.0	36.60
PUT16384	40 (last Apr)	16,415,757.0	16,415,964.0	16,415,810.3	40.43
PUT16384	260 (Nov)	16,422,028	16,422,389	16,422,153.0	52.54

Table 3: PT statistics by EMPv4 (extension of Table VI in the EMP paper)

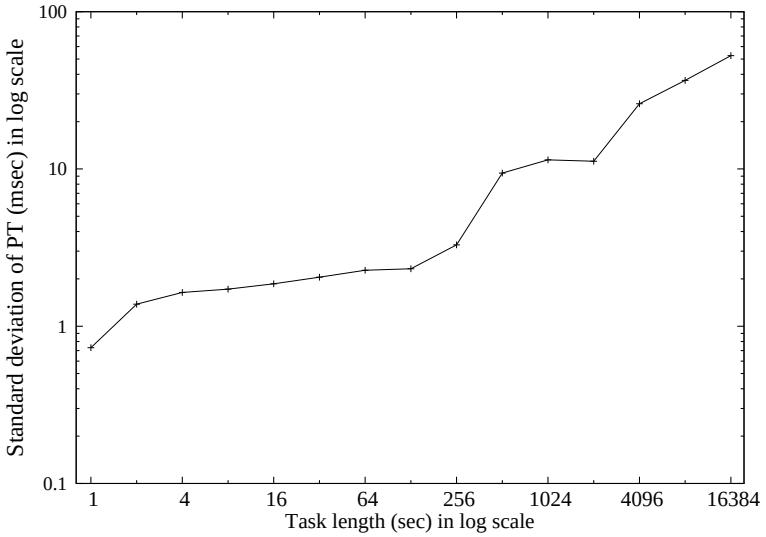
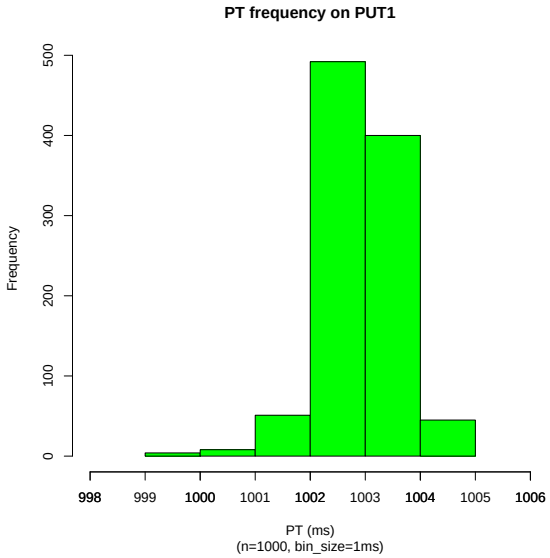
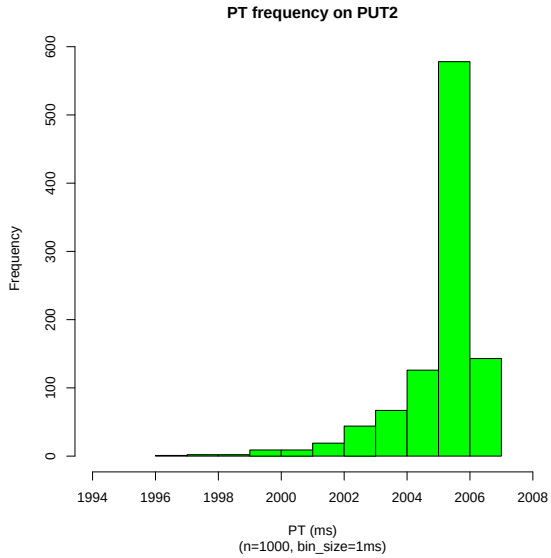


Figure 1: Std. dev. of PT over increasing task length

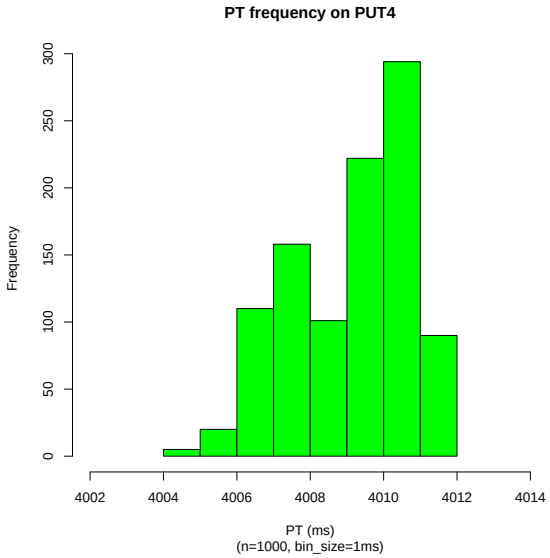
3 Histograms on the EMPv4 Data



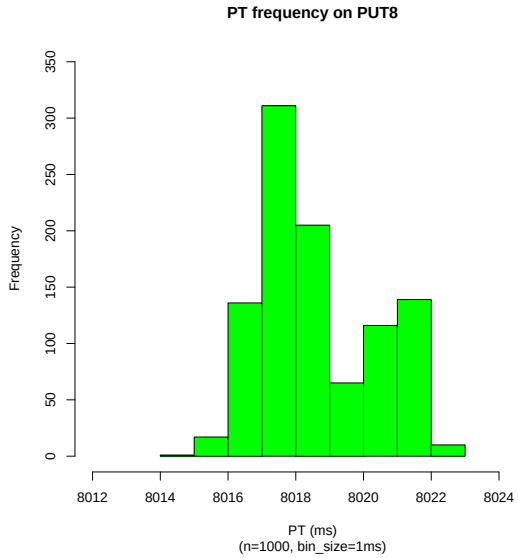
(a) PT frequency on PUT1



(b) PT frequency on PUT2

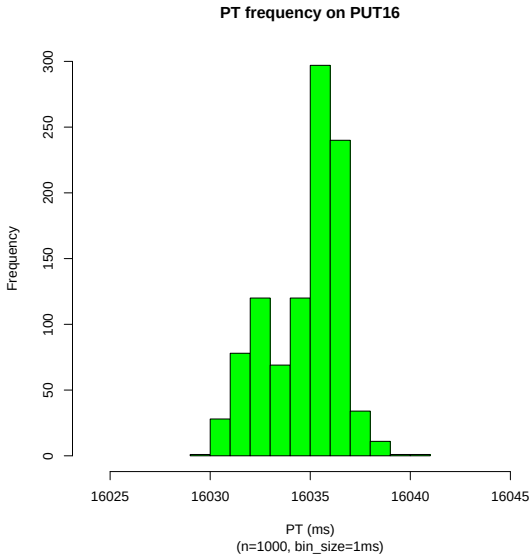


(c) PT frequency on PUT4

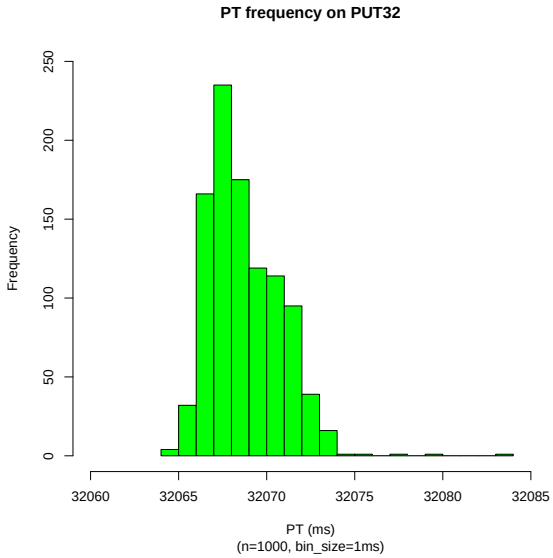


(d) PT frequency on PUT8

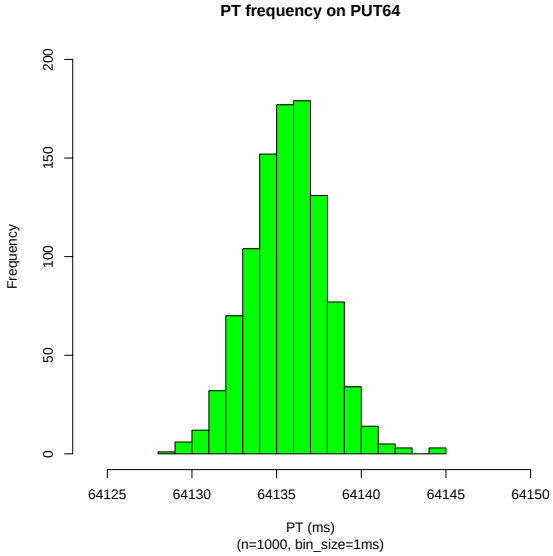
Figure 2: PT Histograms of PUT1 ... PUT8



(a) PT frequency on PUT16

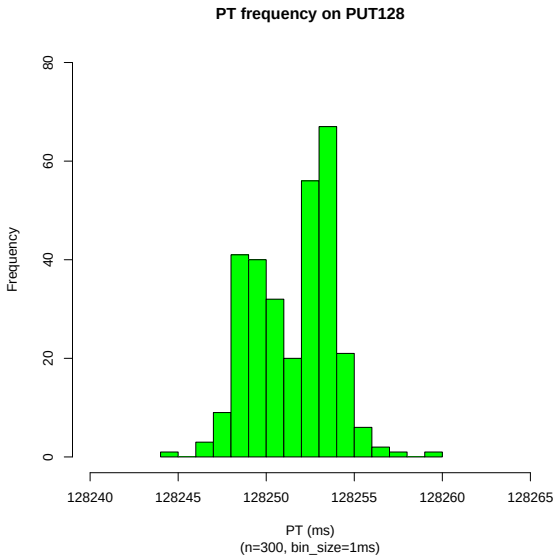


(b) PT frequency on PUT32

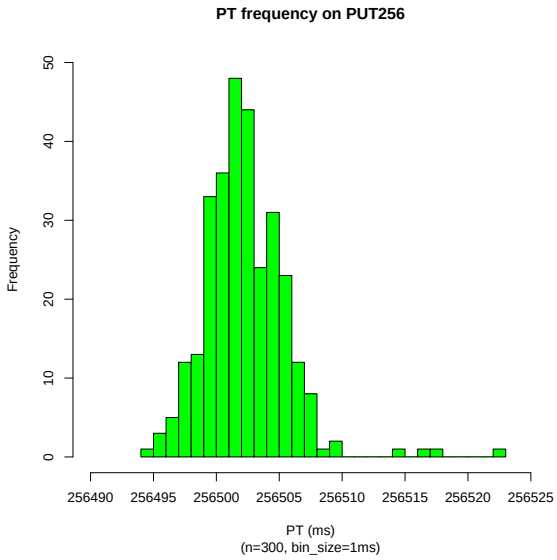


(c) PT frequency on PUT64

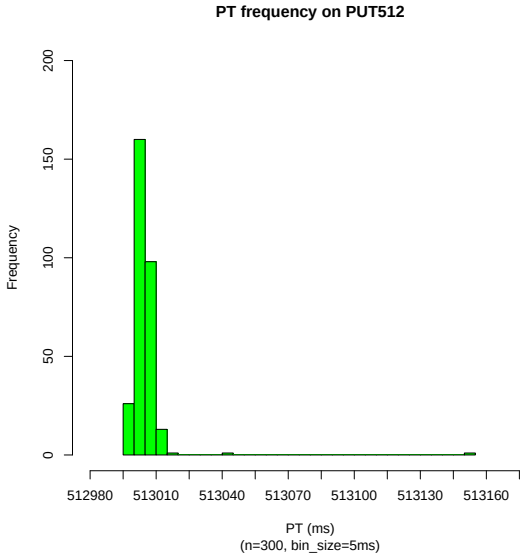
Figure 3: PT Histograms of PUT16 ... PUT64



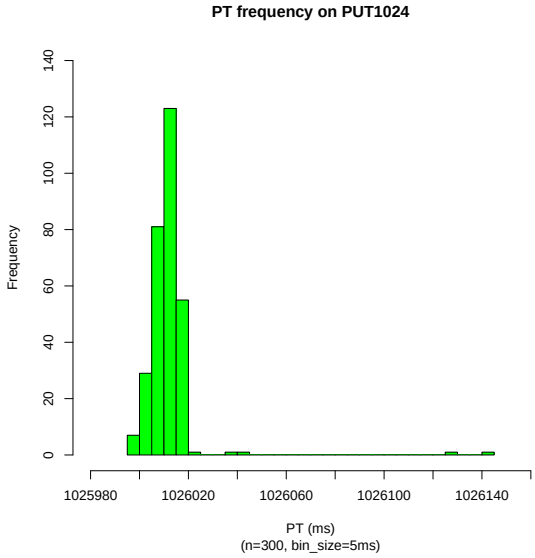
(a) PT frequency on PUT128



(b) PT frequency on PUT256

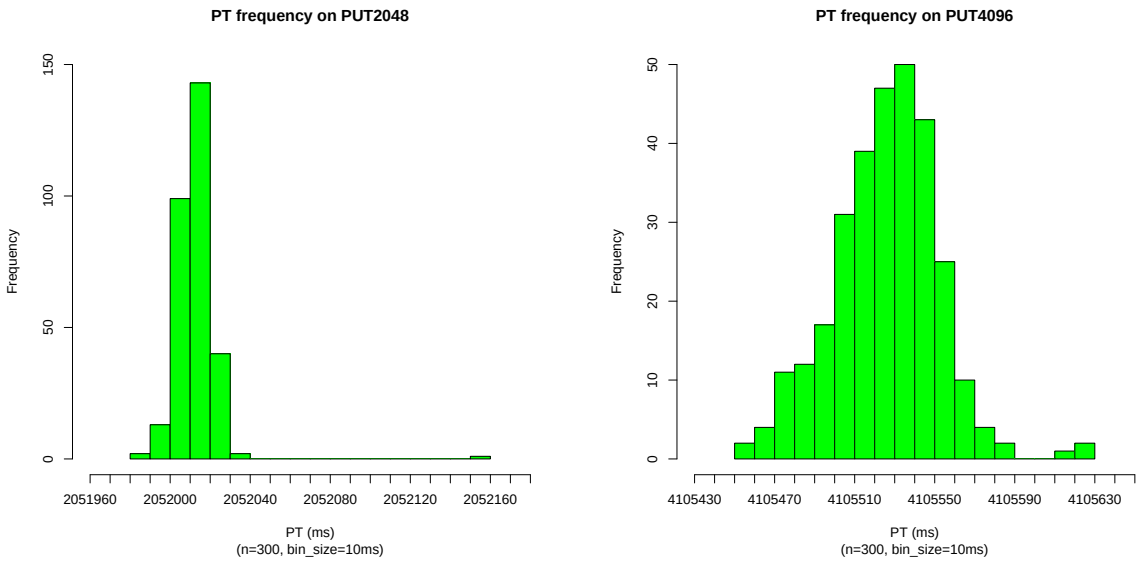


(c) PT frequency on PUT512



(d) PT frequency on PUT1024

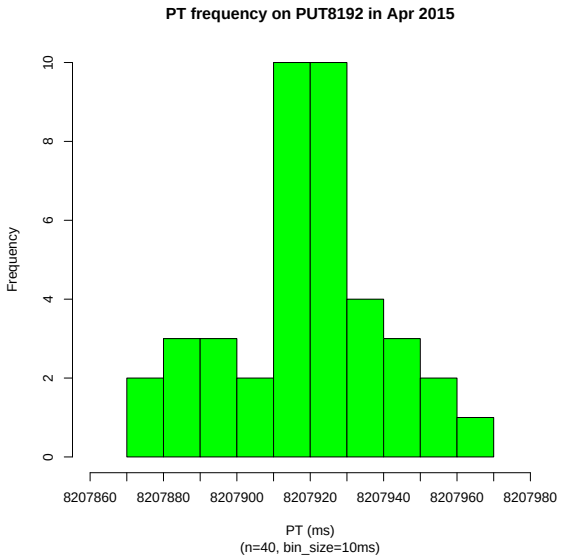
Figure 4: PT Histograms of PUT128 ... PUT1024



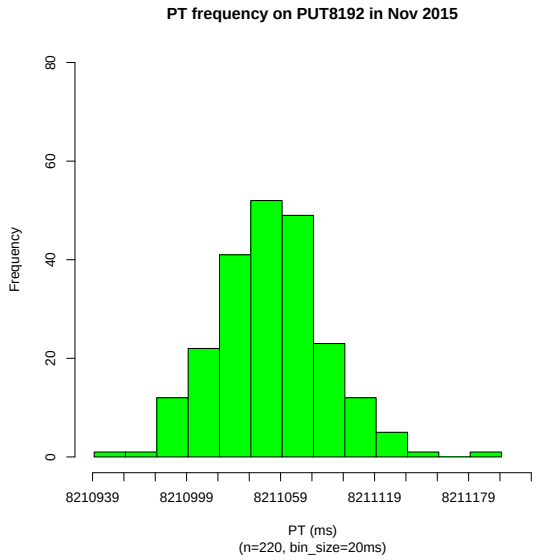
(a) PT frequency on PUT2048

(b) PT frequency on PUT4096

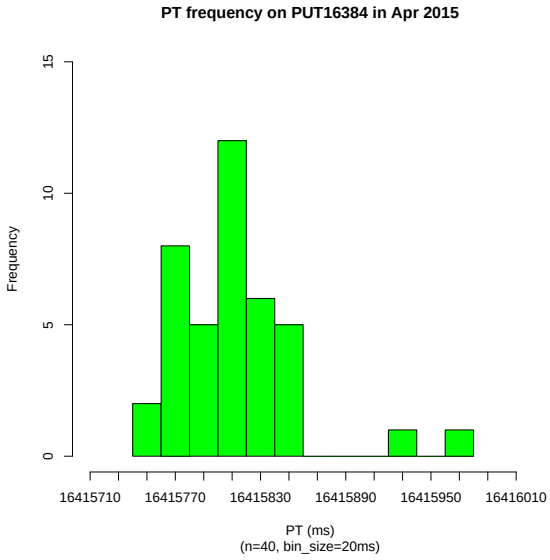
Figure 5: PT Histograms of PUT2048 and PUT4096



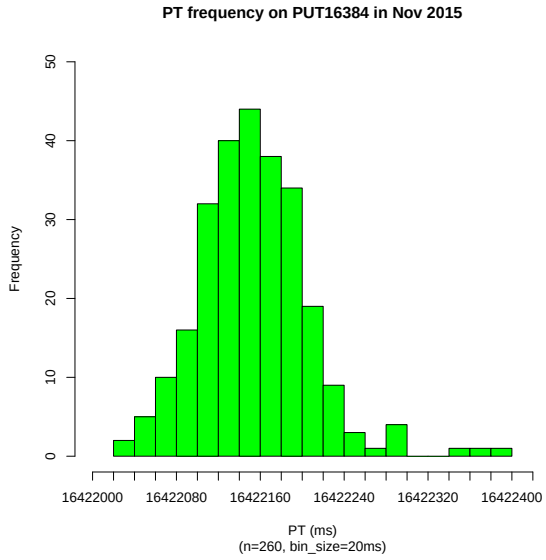
(a) PT frequency on PUT8192 with 40 samples (See Table 1.)



(b) PT frequency on PUT8192 with 260 samples (See Table 1.)



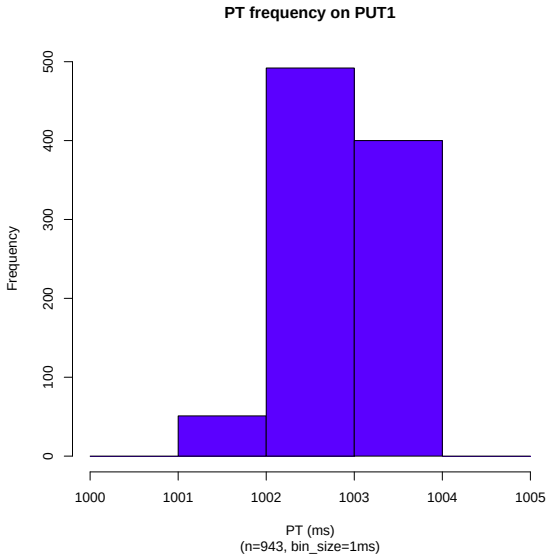
(c) PT frequency on PUT16384 with 40 samples (See Table 1.)



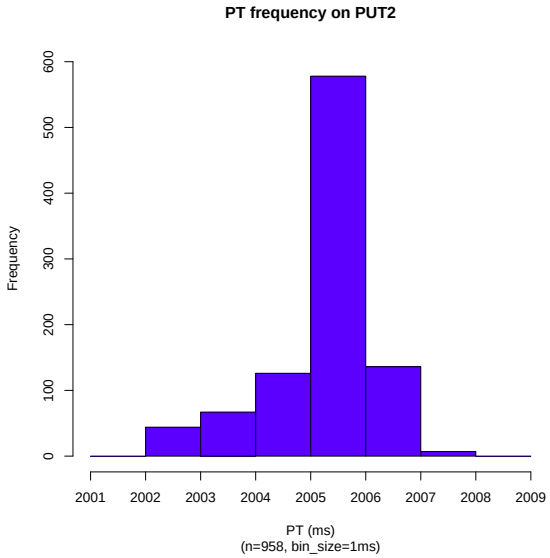
(d) PT frequency on PUT16384 with 260 samples (See Table 1.)

Figure 6: PT Histograms of PUT8192 and PUT16384

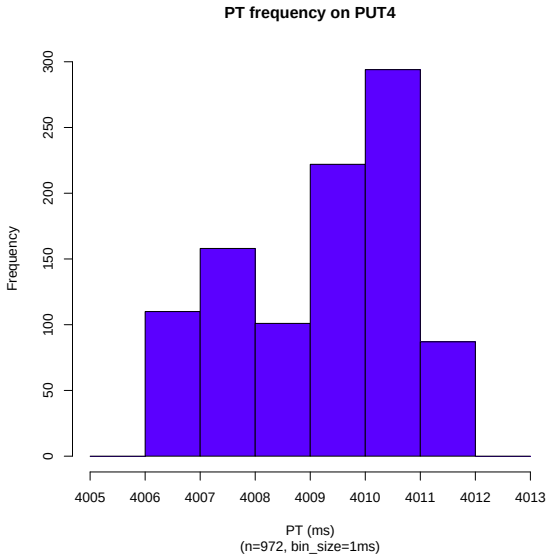
4 Histograms on the EMPv5 Data



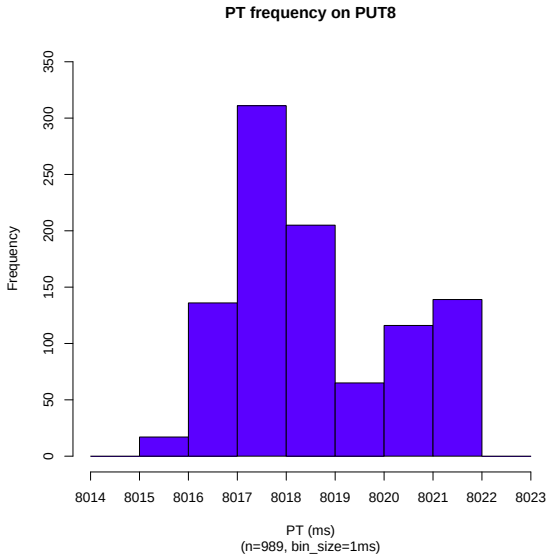
(a) PT frequency on PUT1



(b) PT frequency on PUT2

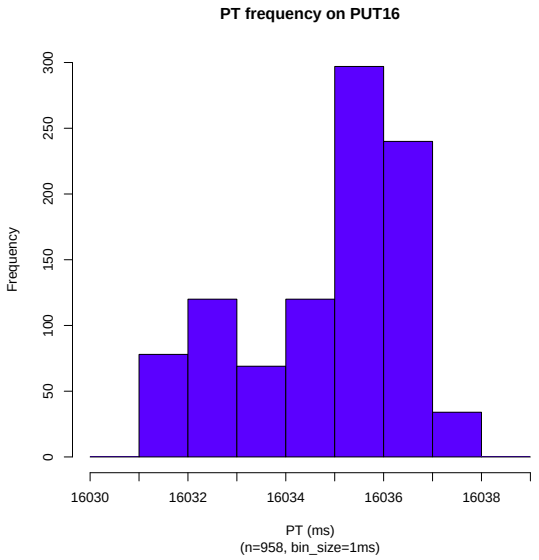


(c) PT frequency on PUT4

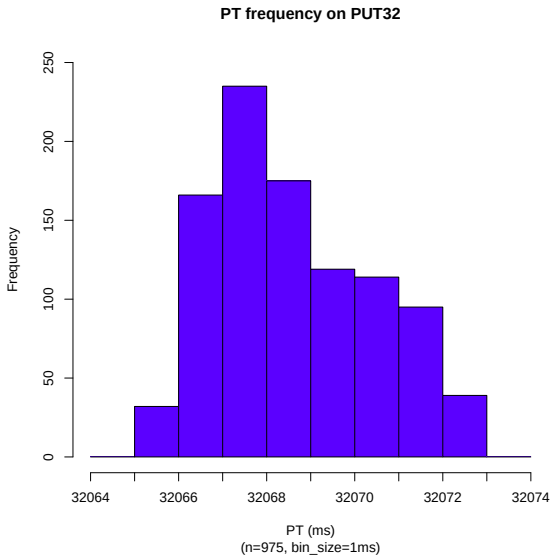


(d) PT frequency on PUT8

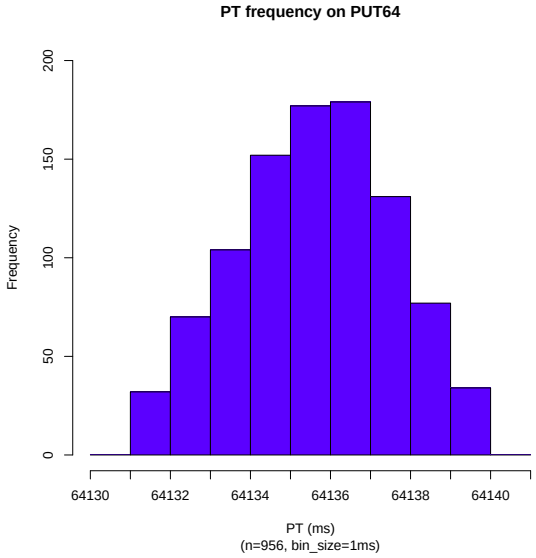
Figure 7: PT Histograms of PUT1 ... PUT8



(a) PT frequency on PUT16

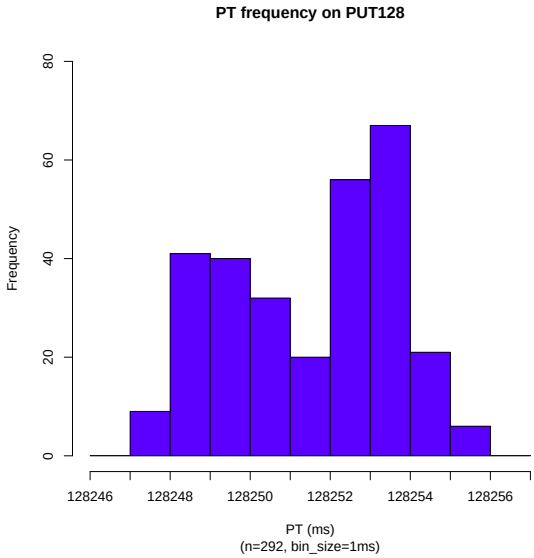


(b) PT frequency on PUT32

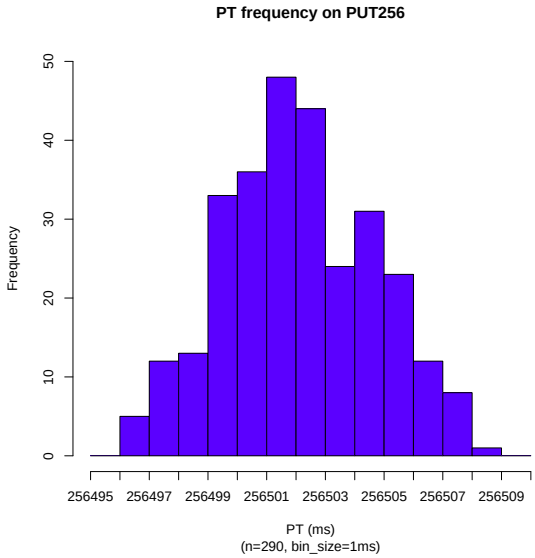


(c) PT frequency on PUT64

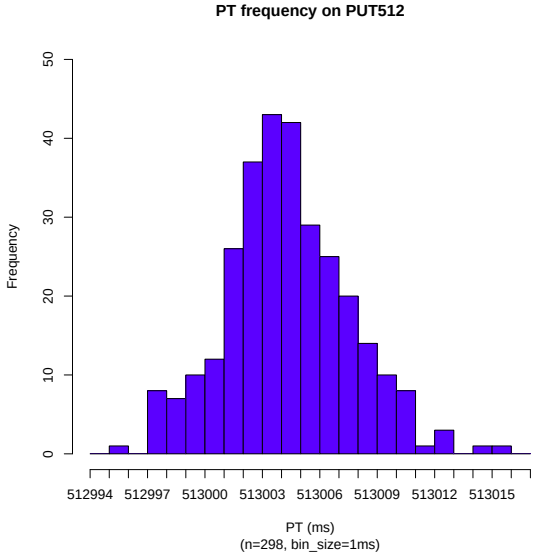
Figure 8: PT Histograms of PUT16 ... PUT64



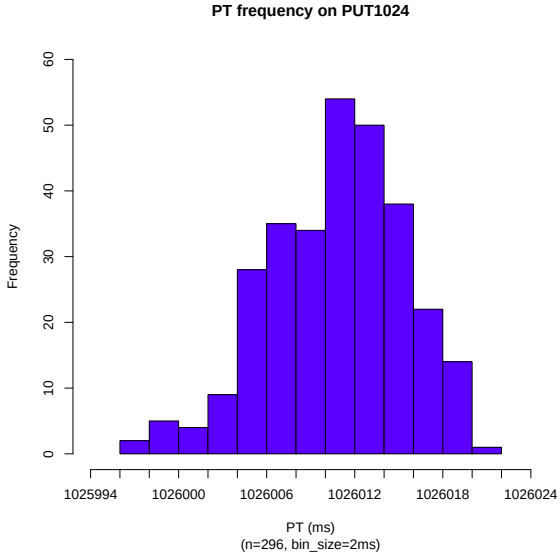
(a) PT frequency on PUT128



(b) PT frequency on PUT256

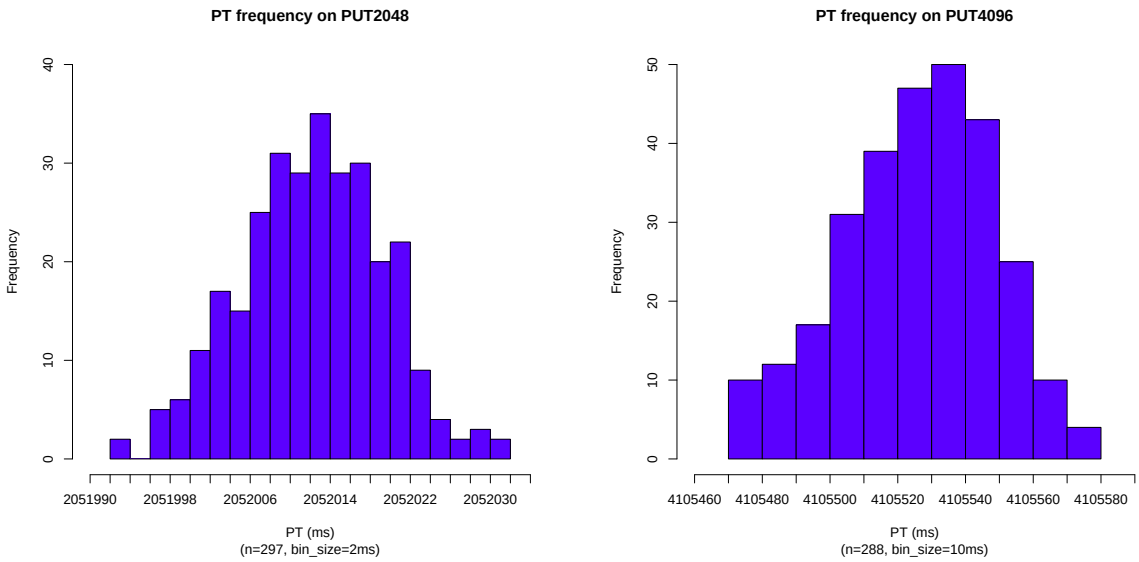


(c) PT frequency on PUT512



(d) PT frequency on PUT1024

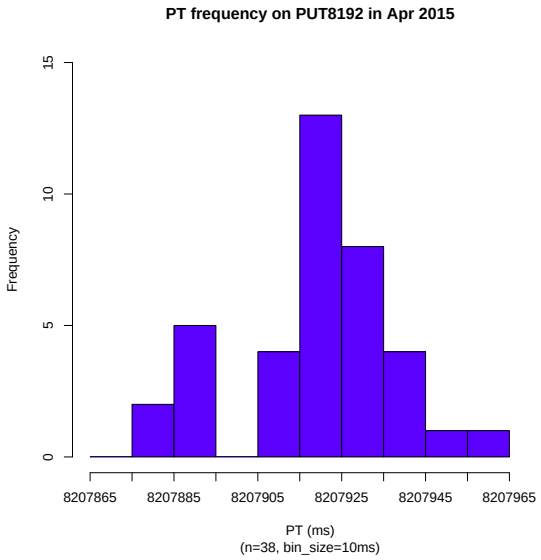
Figure 9: PT Histograms of PUT128 ... PUT1024



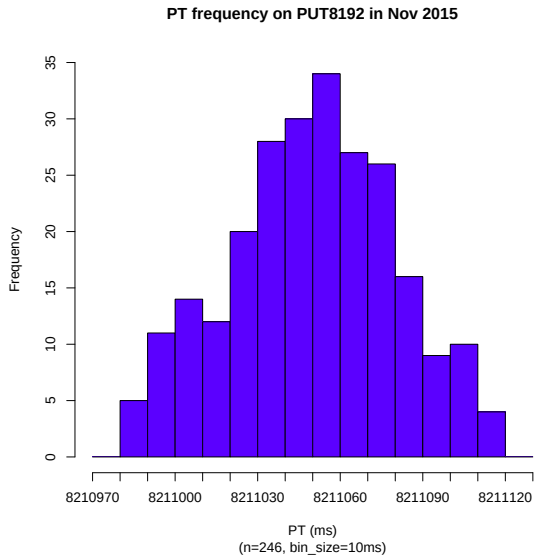
(a) PT frequency on PUT2048

(b) PT frequency on PUT4096

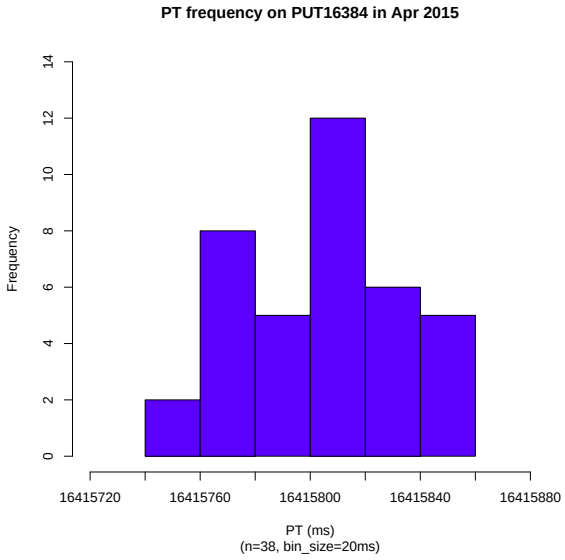
Figure 10: PT Histograms of PUT2048 and PUT4096



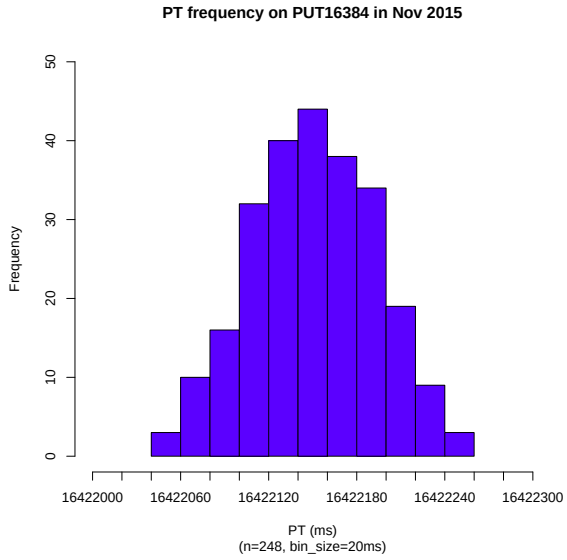
(a) PT frequency on PUT8192 with 40 samples (See Table 1.)



(b) PT frequency on PUT8192 with 260 samples (See Table 1.)



(c) PT frequency on PUT16384 with 40 samples (See Table 1.)



(d) PT frequency on PUT16384 with 260 samples (See Table 1.))

Figure 11: PT Histograms of PUT8192 and PUT16384

5 Sample Size vs. Standard Deviation of PT

Num. of Samples	Std. Dev. (msec)	
	PUT1	PUT2
1,000	1.07	1.40
2,000	1.06	1.39
3,000	1.07	1.38
4,000	1.07	1.37
5,000	1.07	1.40
6,000	1.06	1.70
7,000	1.06	1.65
8,000	1.07	1.62
9,000	1.07	1.60
10,000	1.07	1.58
11,000	1.08	1.57
12,000	1.08	1.56
13,000	1.08	1.54
14,000	1.08	1.53
15,000	1.08	1.52
16,000	1.08	1.51
17,000	1.08	1.50
18,000	1.08	1.50
19,000	1.08	1.50
20,000	1.08	1.49

Table 4: Std. Dev. of PUT1 and PUT2 over increasing sample size

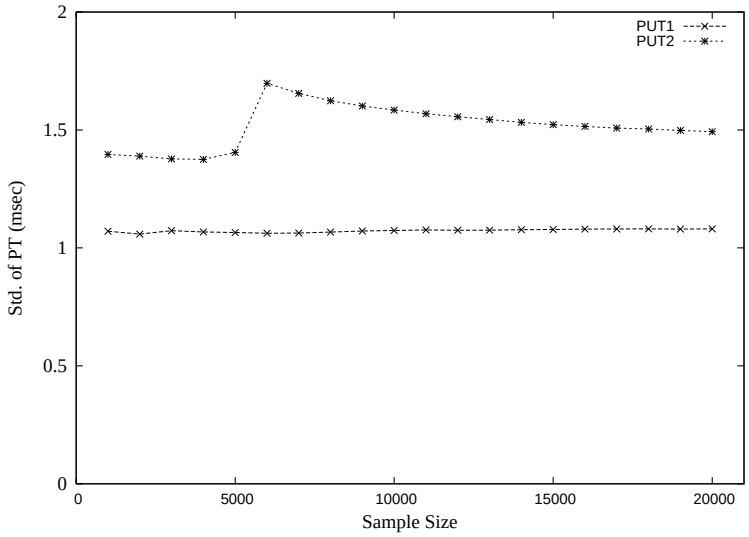


Figure 12: Std. dev. of PT on PUT1 and PUT2 over increasing sample size

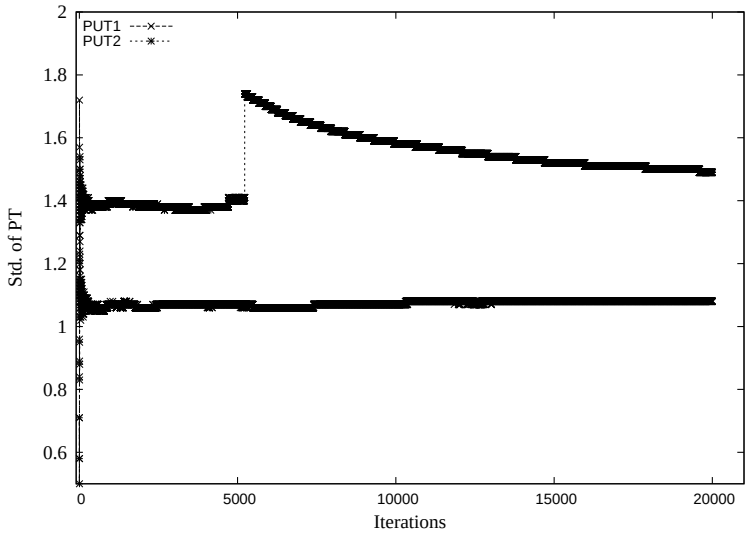
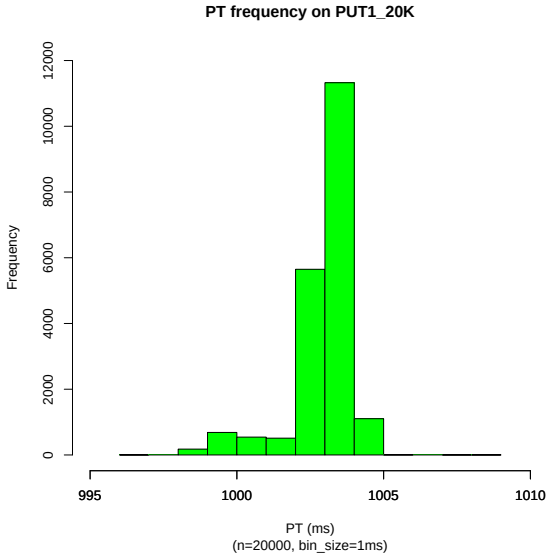


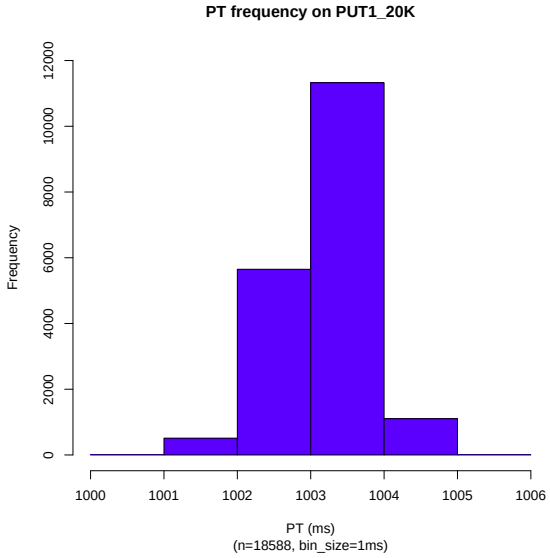
Figure 13: Std. dev. of PT on PUT1 and PUT2 over increasing sample size

PUT2	Program Time
`incr_work`	2078 msecs (at the 5276th iteration)
Daemon Processes	Program Time
`md0_raid1`	1 msec
`proc_monitor`	198 msecs
`rhn_check`	460 msecs
Total	659 msecs

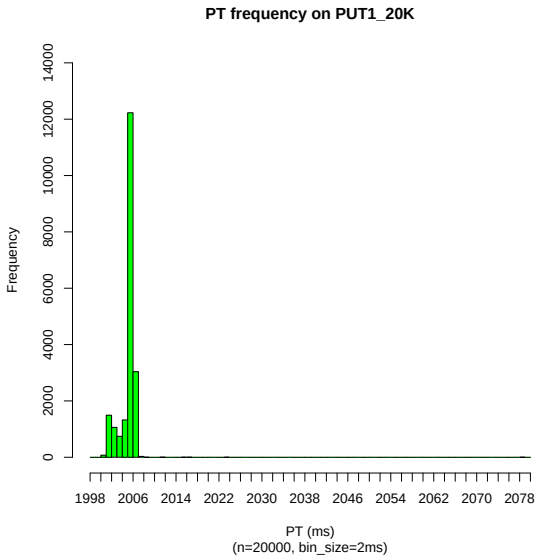
Table 5: The daemon processes captured at the hike of PUT2



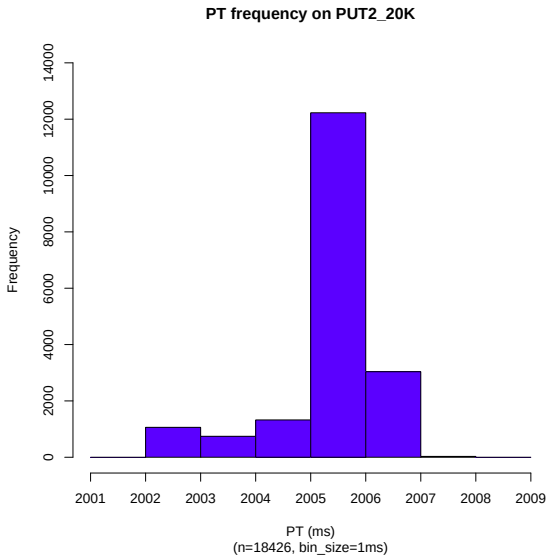
(a) PT frequency on PUT1 with 20,000 samples (See Table 2.)



(b) PT frequency on PUT1 excluding the outliers out of the 20,000 samples (See Table 2.)



(c) PT frequency on PUT2 with 20,000 samples (See Table 2.)



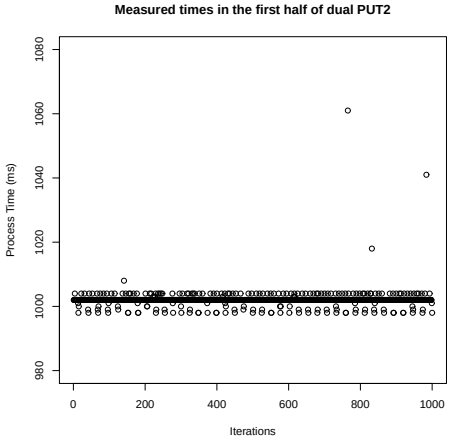
(d) PT frequency on PUT2 excluding the outliers out of the 20,000 samples (See Table 2.)

Figure 14: PT Histograms of PUT1 and PUT2 by 20,000 trials

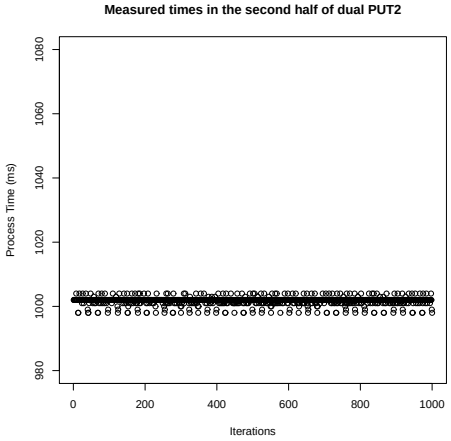
6 Dual PUT Experiments

Dual PUT	PUT2	PUT64	PUT4096
Correlation Coefficient	0.3	-0.01	-0.005

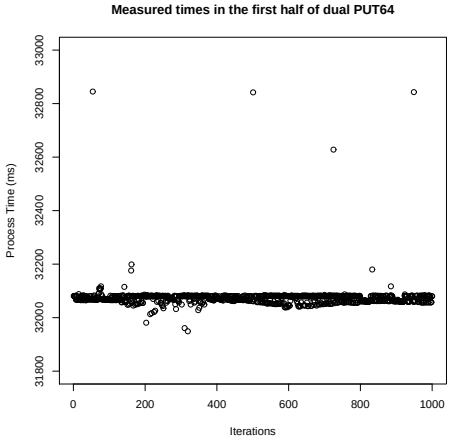
Table 6: Correlation Factors of Dual PUT Experiments



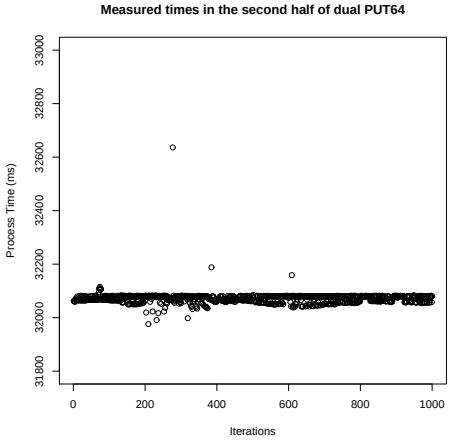
(a) 1st half's measured times on dual PUT2



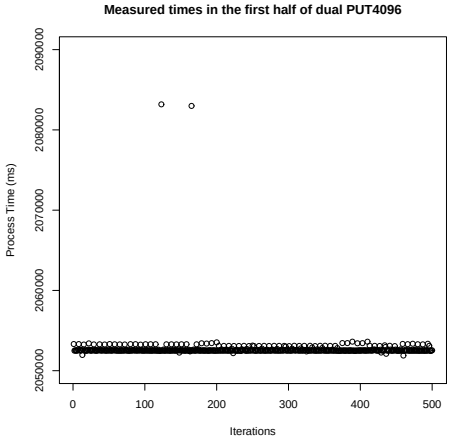
(b) 2nd half's measured times on dual PUT2



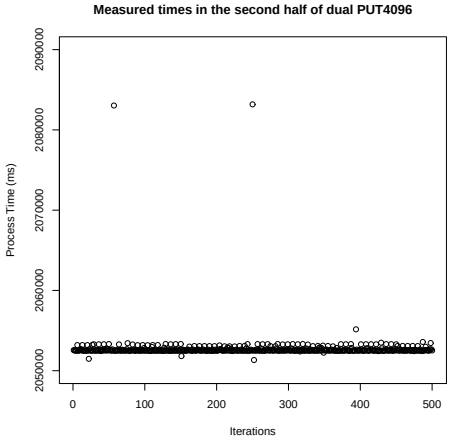
(c) 1st half's measured times on dual PUT64



(d) 2nd half's measured times on dual PUT64



(e) 1st half's measured times on dual PUT4096



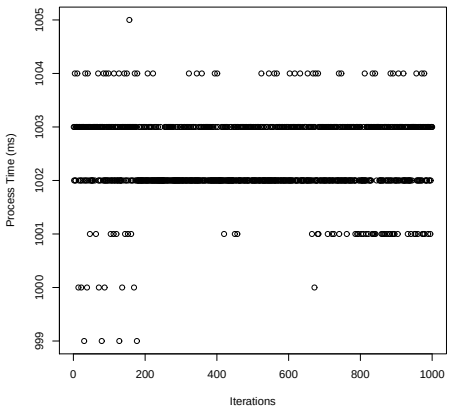
(f) 2nd half's measured times on dual PUT4096

Figure 15: Dual PUT data comparison

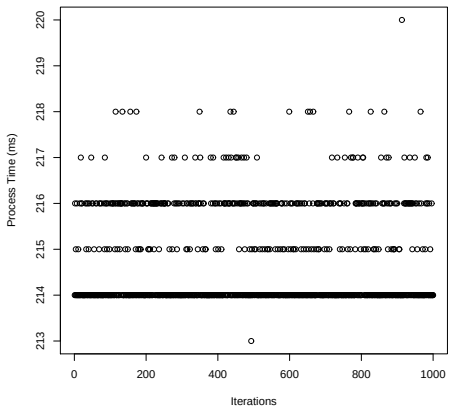
7 Correlations between the Program Times of Daemon Processes and PUT

PUT	Correlation Coefficient
PUT1	-0.2
PUT2	-0.005
PUT4	-0.05
PUT8	0.1
PUT16	0.1
PUT32	0.3
PUT64	0.2
PUT128	0.2
PUT256	0.4
PUT512	0.9
PUT1024	0.4
PUT256	0.4
PUT512	0.9
PUT1024	0.9
PUT2048	0.9
PUT4096	0.4
PUT8192 in Apr	0.4
PUT8192 in Nov	0.3
Combined PUT8192	1 (0.996)
PUT16384 in Apr	0.4
PUT16384 in Nov	0.5
Combined PUT16384	1 (0.999)

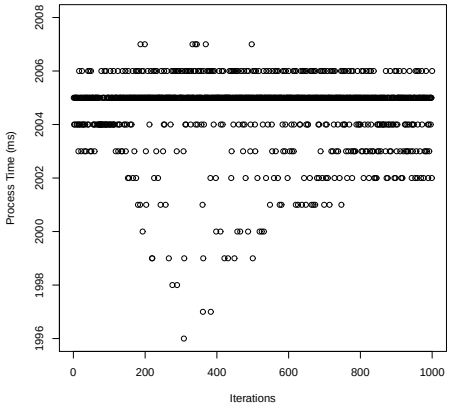
Table 7: Correlation Factors of Dual PUT Experiments



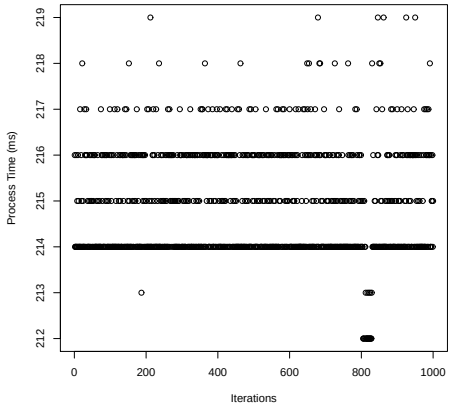
(a) PUT1's PTs



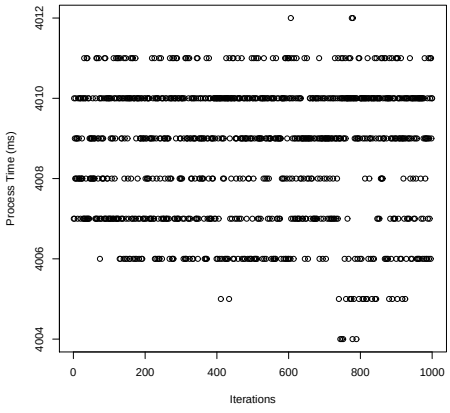
(b) PUT1's daemon PTs



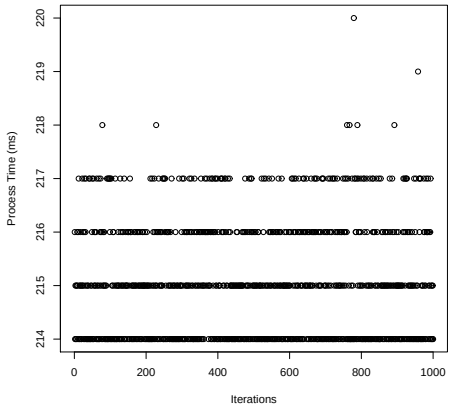
(c) PUT2's PTs



(d) PUT2's daemon PTs

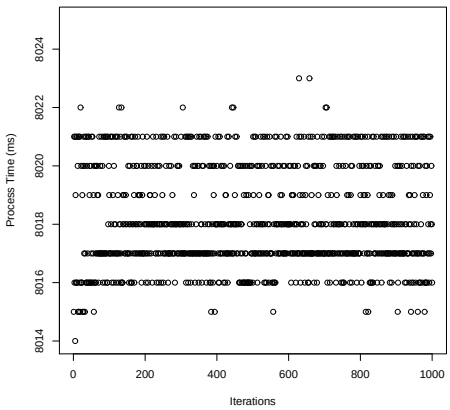


(e) PUT4's PTs

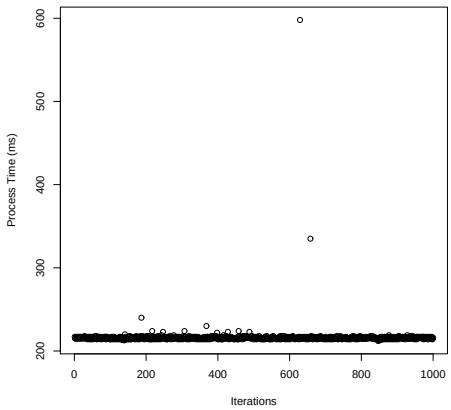


(f) PUT4's daemon PTs

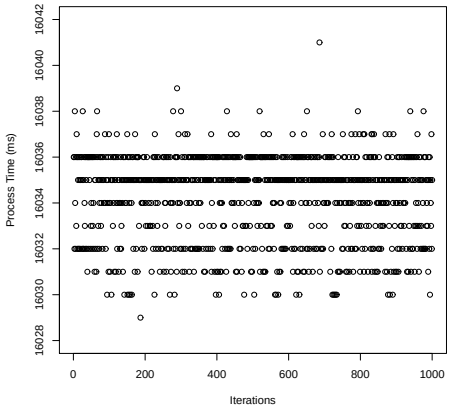
Figure 16: Program times between PUT1∼PUT4 vs. Daemon processes



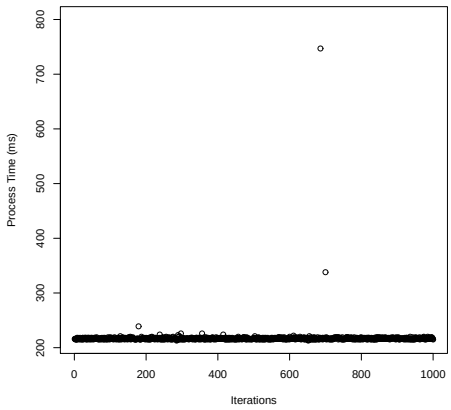
(a) PUT8's PTs



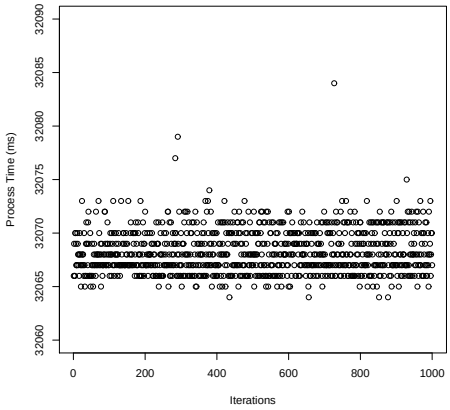
(b) PUT8's daemon PTs



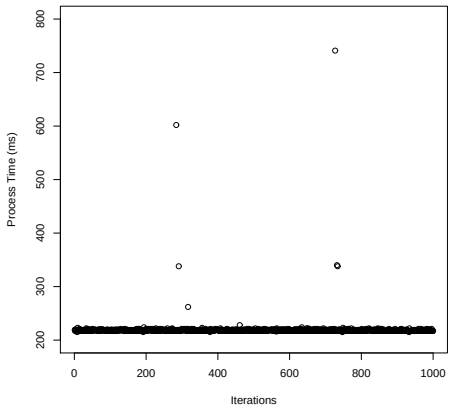
(c) PUT16's PTs



(d) PUT16's daemon PTs

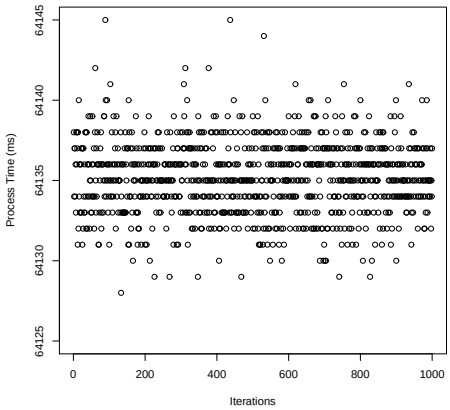


(e) PUT32's PTs

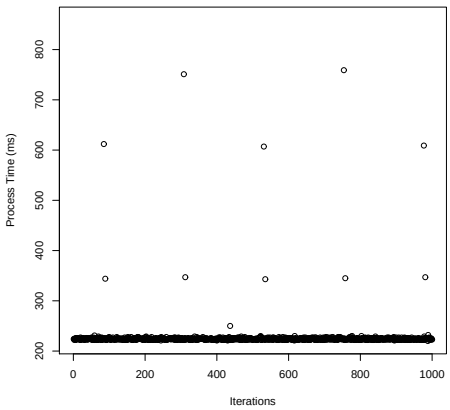


(f) PUT32's daemon PTs

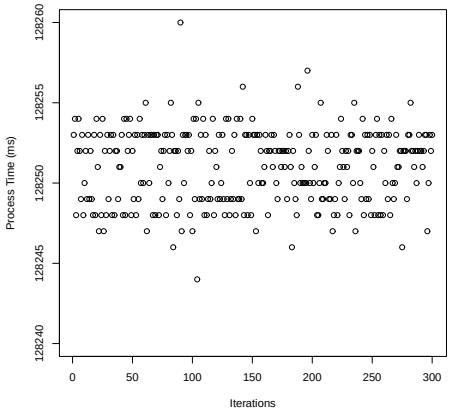
Figure 17: Program times between PUT8∼PUT32 vs. Daemon processes



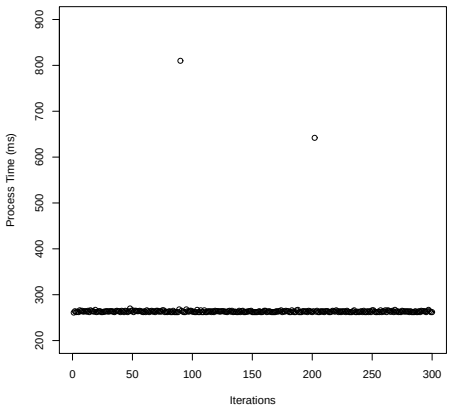
(a) PUT64's PTs



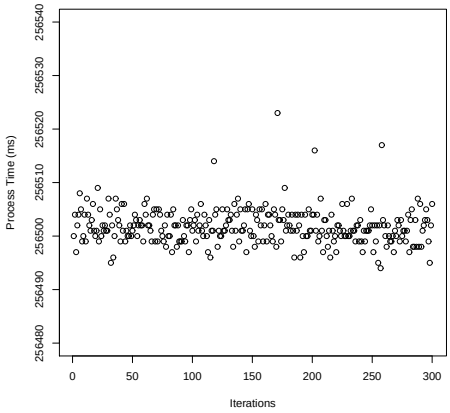
(b) PUT64's daemon PTs



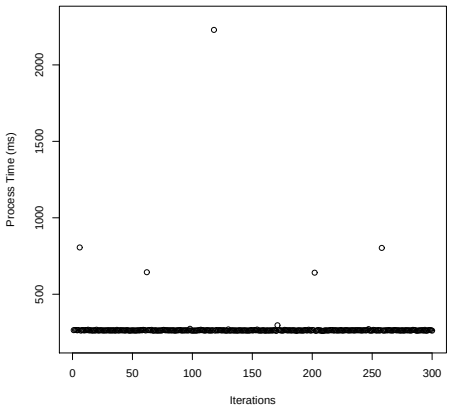
(c) PUT128's PTs



(d) PUT128's daemon PTs

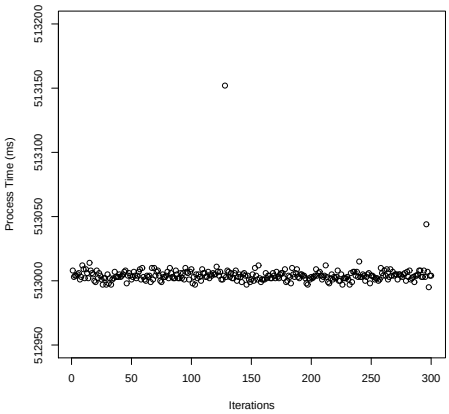


(e) PUT256's PTs

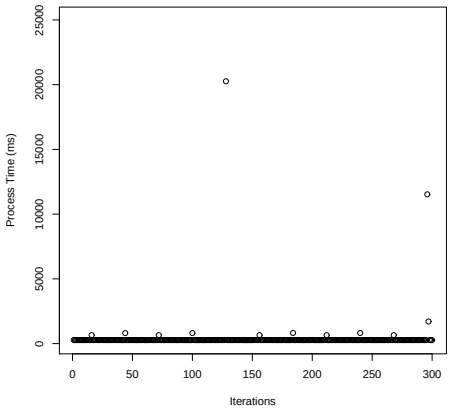


(f) PUT256's daemon PTs

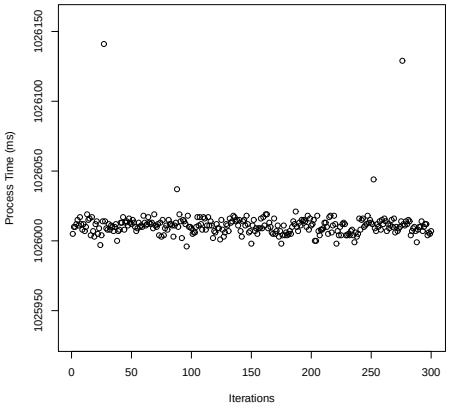
Figure 18: Program times between PUT64∼PUT256 vs. Daemon processes



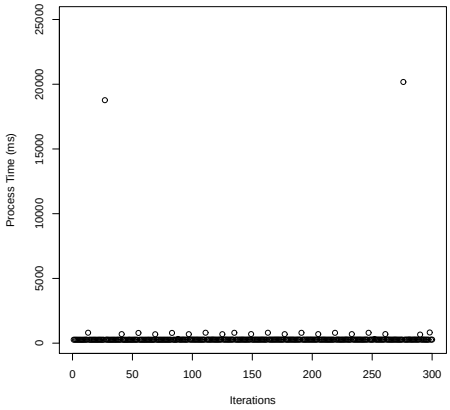
(a) PUT512's PTs



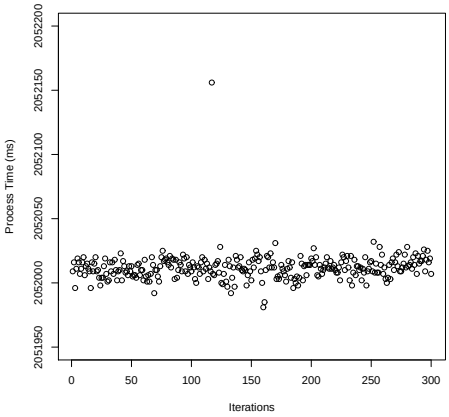
(b) PUT512's daemon PTs



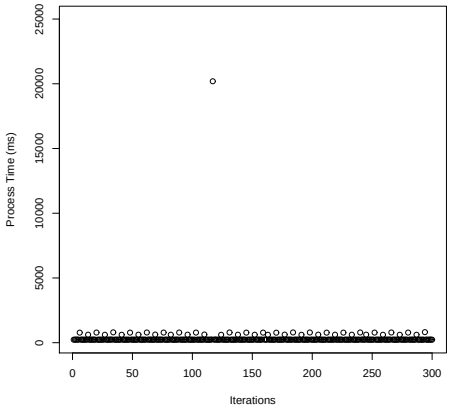
(c) PUT1024's PTs



(d) PUT1024's daemon PTs

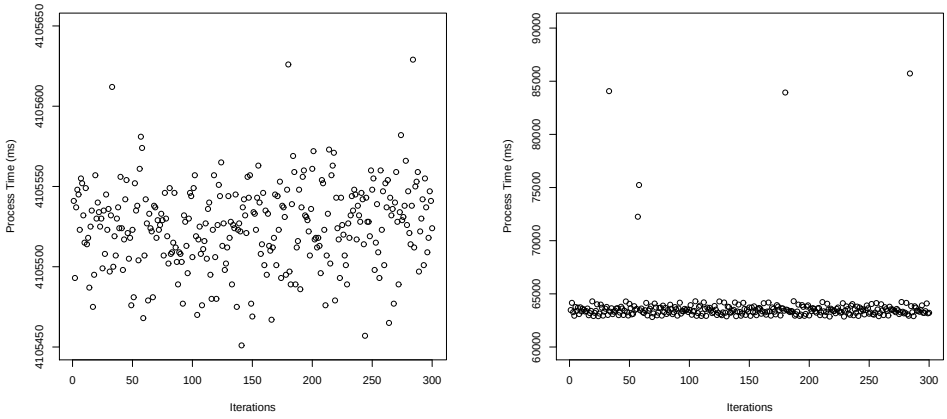


(e) PUT2048's PTs



(f) PUT2048's daemon PTs

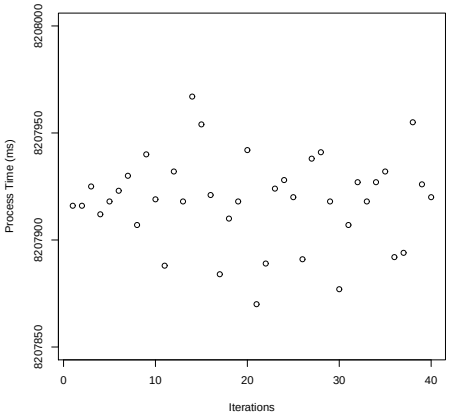
Figure 19: Program times between PUT512∼PUT2048 vs. Daemon processes



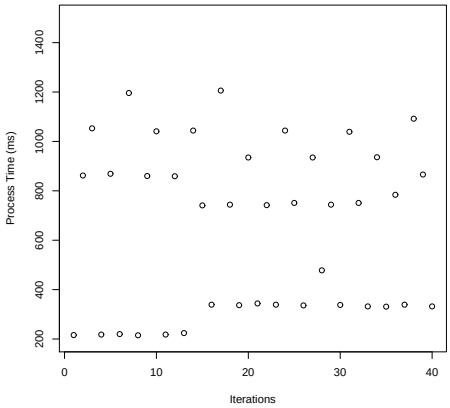
(a) PUT4096's PTs

(b) PUT4096's daemon PTs

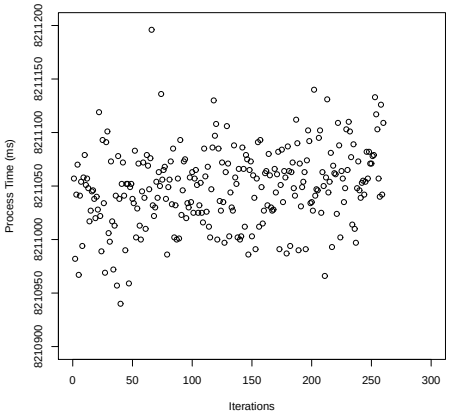
Figure 20: Program times between PUT4096 vs. Daemon processes



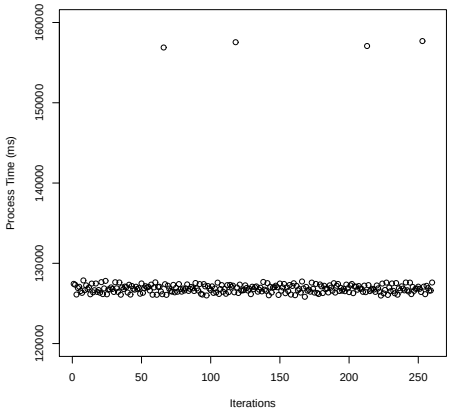
(a) PUT8192's PTs in Apr 2015



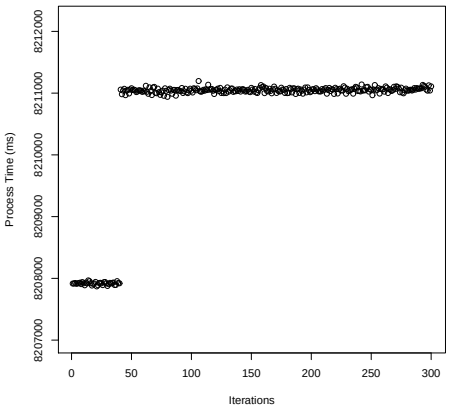
(b) PUT8192's daemon PTs in Apr 2015



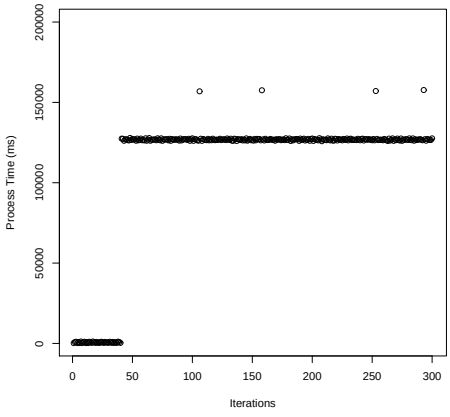
(c) PUT8192's PTs in Nov 2015



(d) PUT8192's daemon PTs in Nov 2015

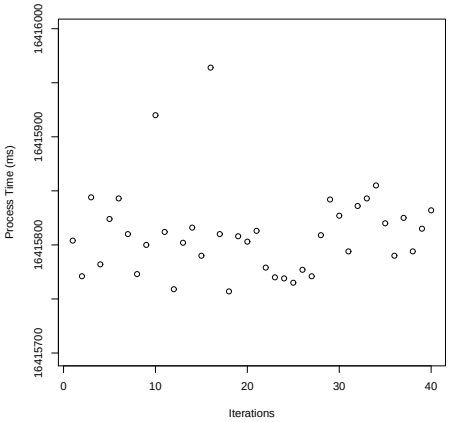


(e) Combined PUT8192's PTs

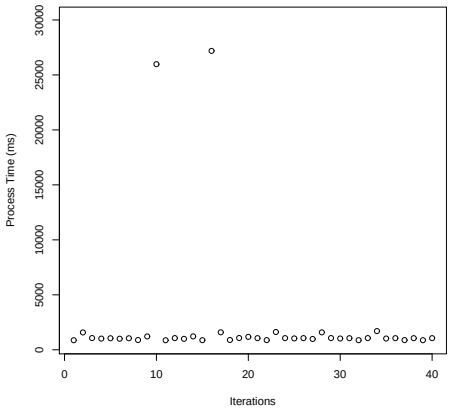


(f) Combined PUT8192's daemon PTs

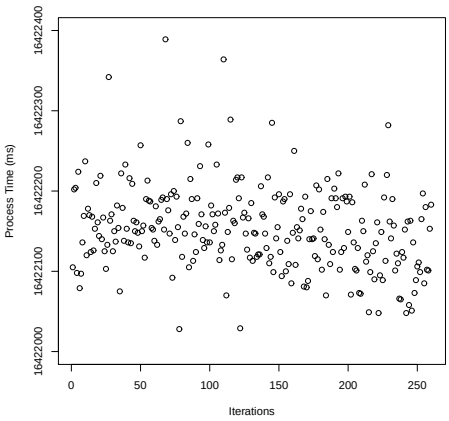
Figure 21: Program times between PUT8192 vs. Daemon processes



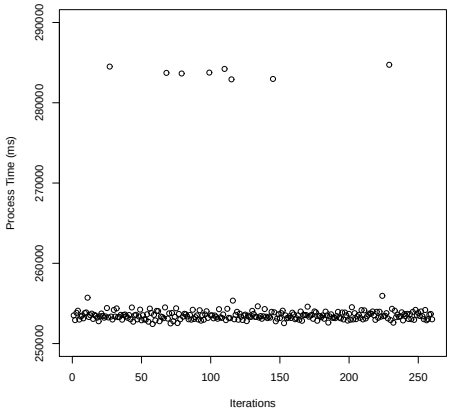
(a) PUT16384's PTs in Apr 2015



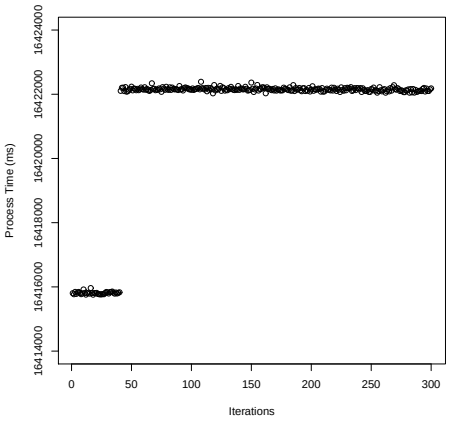
(b) PUT16384's daemon PTs in Apr 2015



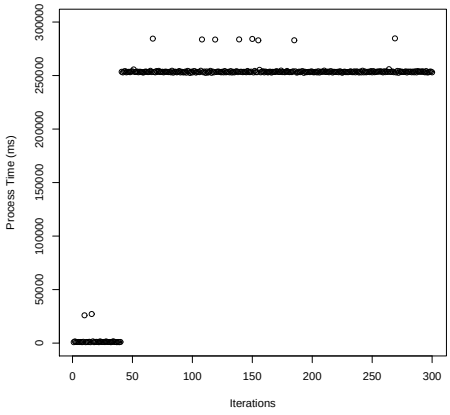
(c) PUT16384's PTs in Nov 2015



(d) PUT16384's daemon PTs in Nov 2015



(e) Combined PUT16384's PTs



(f) Combined PUT16384's daemon PTs

Figure 22: Program times between PUT16384 vs. Daemon processes

8 Appendix

8.1 Breakdown on Program Times of Daemon Processes

PUT256	Program Time
`incr_work`	256,514 msecs (at the 118th iteration)
Daemon Processes	Program Time
`java`	2 msecs
`md0_raid1`	4 msecs
`jbd2/md0-8`	1 msec
`flush-9:0`	10 msecs
`proc_monitor`	262 msecs
`rhnsd`	6 msecs
`rhn_check`	1,944 msecs
Total	2,229 msecs

Table 8: The daemon processes captured at the worst PT of PUT256

PUT256	Program Time
`incr_work`	513,152 msecs (at the 128th iteration)
Daemon Processes	Program Time
`java`	2 msecs
`md0_raid1`	51 msecs
`jbd2/md0-8`	27 msecs
`flush-9:0`	86 msecs
`proc_monitor`	270 msecs
`rhnsd`	6 msecs
`rhn_check`	19,820 msecs
Total	20,262 msecs

Table 9: The daemon processes captured at the worst PT of PUT512

PUT4096	Program Time
`incr_work`	4,105,629 msecs (at the 284th iteration)
Daemon Processes	Program Time
`events/0`	1 msec
`kblockd/0`	1 msec
`kslowd000`	31,710 msecs
`kslowd001`	31,782 msecs
`md0_raid1`	82 msecs
`jbd2/md0-8`	21 msecs
`flush-9:0`	79 msecs
`proc_monitor`	206 msecs
`rhnsd`	3 msecs
`ntpd`	1 msec
`java`	2 msecs
`rhn_check`	21,840 msecs
Total	85,728 msecs

Table 10: The daemon processes captured at the worst PT of PUT4096

PUT8192	Program Time
incr_work	8,207,884 msecs (at the 244th iteration)
Daemon Processes	Program Time
kblockd/0	3 msecs
kslowd000	31,710 msecs
kslowd001	31,782 msecs
md0_raid1	12 msecs
jbd2/md0-8	2 msecs
proc_monitor	204 msecs
rhnsd	6 msecs
java	1 msec
rhsmcertd-worke	114 msecs
rhsmcertd-worke	114 msecs
rhn_check	708 msecs
Total	64,656 msecs

Table 11: The daemon processes captured at the worst PT of PUT8192

Daemon Processes	Descriptions
kslowd000 (kslowd001)	A kernel threads for performing things that take a relatively long time. "Typically, when processing something, these items will spend a lot of time, blocking a thread on I/O, thus making that thread unavailable for doing other work." (http://www.mjmwired.net/kernel/Documentation/slow-work.txt)
rhn_check	An external program for check for updates, run by rhnsd
rhnsd	"A background daemon process that periodically polls the Red Hat Network to see if there are any queued actions available. Typically started from the initialization (init) scripts in /etc/init.d/rhnsd when its time to poll the Red Hat Network server for available updates and actions. The default interval is every 240 minutes. The minimum polling interval is 60 minutes. Any network activity is done via the rhn_check utility." (http://linuxcommand.org/man_pages/rhnsd8.html)

Table 12: Descriptions of some daemon processes