Breandan Kerin 1431016 30th November 2018

Advanced Computer Architecture

Tutorial 2

The aim of this assessment was to perform a comparison between the performance of:

- A Test-And-Test-And-Set lock
- Hardware-Lock-Elision (**HLE**)
- Restricted Transactional Memory (**RTM**)

Which performs concurrent updates to a Binary Search Tree (**BST**) implemented in C.

The code, screenshots and report can all be viewed on my github account: https://github.com/kerinb/CS4521---Advanced-Computer-Architecture/tree/master/Lock-lockless-comparison

Hardware Parameters:

In order to run this project, it is required to run on a system that provides the support for HLE and RTM - As I am not in possession of such a machine, I used a machine provided by the SCSS in TCD: namely Malbec - whose CPU specifications are shown below

```
kerinb@malbec:~/compArch/Lock-lockless-comparison$ lscpu
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Byte Order:            Little Endian
CPU(s):                16
On-line CPU(s) list:   0-15
Thread(s) per core:    2
Core(s) per socket:    8
Socket(s):             1
NUMA node(s):          1
Vendor ID:             GenuineIntel
CPU family:            6
Model:                 86
Model name:            Intel(R) Xeon(R) CPU D-1540 @ 2.00GHz
Stepping:              2
CPU MHz:               849.975
CPU max MHz:           2600.0000
CPU min MHz:           800.0000
BogoMIPS:              3999.87
Virtualization:        VT-x
L1d cache:             32K
L1i cache:             32K
L2 cache:              256K
L3 cache:              12288K
NUMA node0 CPU(s):     0-15
Flags:                 fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx pdpe1gb rdtscp lm constant_tsc arch_perfmon pebs
ts rep_good nopl xtopology nonstop_tsc aperfmperf eagerfpu pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2 ssse3 sdbg fma cx16 xtpr pdcm pcid dca sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_timer
es xsave avx f16c rdrand lahf_lm abm 3dnowprefetch epb invpcid_single kaiser tpr_shadow vnmi flexpriority ept vpid fsgsbase tsc_adjust bmi1 hle avx2 smep bmi2 erms invpcid rtm cqm rdseed adx smap intel_
 xsaveopt cqm_llc cqm_occup_llc cqm_mbm_total cqm_mbm_local dtherm ida arat pln pts
kerinb@malbec:~/compArch/Lock-lockless-comparison$
```

From the above image, the number of CPUs present on the Malbec machine is 16 – hence, the update mechanisms were tested on 5 different key ranges, for up to 2 * 16 = 32 threads.

- The number of operations measured for each of the tests run was equal to the number of operations attempted, and not necessarily associated with a successful insertion/deletion of a node in the binary search tree. This is because in one of these update operations, the effort really goes into searching the tree to find the insertion/deletion position: the actual update itself is trivial in comparison.

Random Key Generation:

The three update mechanisms used (Test And Test And Set - TATAS, Hardware Lock Elision - HLE and Restricted Transactional Memory - RTM) were tested for the following key ranges:

1. 16 -> [0 - 15]
2. 256 -> [0 - 255]
3. 4,096 -> [0 – 4095]

4. 65,536 -> [0 – 65535]
5. 1,048,576 -> [0-1048575]

The Random seed was generated using the c intrinsic function *std::_rdrand64_step.* This seed then underwent some binary operations - namely bit left and right shifts as well as ORs and multiplications:

```
r ^= r >> 12;   // a
r ^= r << 25;   // b
r ^= r >> 27;   // c
r * 2685821657736338717LL;
```

Optimisation

In order to ensure a high level of accurate measurement for the performance of each mechanism implemented in performing the concurrent updates, some optimisations were required to be applied so that any work that wasn't directly involved in the update of the BST itself was kept outside the body of the operation.

The following optimisation measures were implemented in the system:

- The BST lock variable used by the TATAS and HLE algorithms was declared to be aligned on a 64-byte cache line boundary:
  ALIGN(64) volatile long lock;
- The BST was pre-filled to half-capacity before running any updates on the structure (i.e. adding and removing nodes in the BST). This was necessary to ensure that the BST was in the approximate steady-state before performing any operations using the update mechanism (lock, HLE, RTM) on it. There is no point taking performance measurements when the tree is filling up, since it won't reflect the steady-state behaviour of updates to the BST.
- Because of the issues that arise from concurrently calling the malloc() and free() methods to allocate/deallocate memory for nodes, an alternative method of memory management was also implemented. This involved use of a variable RECYCLENODES, with which nodes are added to a *tmp* list when they are removed from the tree and from which nodes are reused (if any are available) when they are being added to the tree. This means that malloc() doesn't need to be called to allocate a node for instance, unless there are no spare nodes. All of these calls are done outside of the update operation itself.
- The read and write sets for the transaction are reduced by implementing iterative rather than recursive methods for the BST (reducing the number of stack frames generated).

Implementations:

1. No Threading and TATAS:
   a. This was pre-implemented by Prof. Jeremy Jones in the source code provided on his web site. Hence it was not re-implemented.
2. HLE

a. When the global variable METHOD == 2, the system is to update the BST structure using HLE TATAS implementation. The code for obtaining the *'lock'* is attached below, and as can be seen from the code below, it was the pessimistic TATAS that was implemented - meaning it assumes it won't receive the lock first time trying. The code for freeing the *'lock'* is also attached.

3. RTM
    a. When the global variable METHOD == 3, the system is to update the BST structure using RTM and if a maximum amount of aborts occur; tested on a range from 1 - 32, the system will use the HLE TATAS implementation instead to obtain a lock and try make progress. The code for obtaining the *'lock'* is attached below, and as can be seen from the code, it uses intrinsic functions such as _xbegin, _xabort and _xend to start, stop and abort the transaction. The lock implemented in the event of maxAborts being reached, is the pessimistic HLE TATAS.

Results:

No Lock - 1 Thread

- The results here are that:
    - As the key range increases, The number of operations and number of operations per second decreased: For example image M0 attached shows that for maxKey = 16, ops/sec = 22'450'274, while for maxKey = 1'048'576, ops/sec = 1'743'576. This is due to the fact that for a larger tree, there are more nodes to search to find the one on which we want to operate – hence, each operation takes longer to perform - thus the overall number of operations executed reduces.

TATAS Lock

- The results can be seen in image M1 - and shows that:
    - As the key range increases, the number of operations per second are seen to decrease. For instance, for 2 threads operating on key range 16 there are 17'349'000 operations performed per second. In contrast, 2 threads operating on key range 1,048,576 complete only 3'689'000 operations per second. This is due to the fact that for a larger tree, there are more nodes to search to find the one on which we want to operate on coupled with the fact that there will be a significant amount of contention for the lock to access the BST– hence, each operation takes longer to perform.
    - As the number of threads increase, the number of operations per second decrease roughly proportionally. This was expected for the TATAS lock, since it is expected that there would be significant contention for the lock resulting in fewer operations being performed for more threads.
    - Once the number of threads exceeds the number of logical CPUs, the number of operations per second performed is seen to decrease even further.

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Hardware Lock Elision (HLE)

- The results here are that:
    - As the number of threads is increased, the number of operations per second decreases roughly proportionally - This is to be expected as for the increase in the number of threads, there is an increases in the amount of contention for the lock which will inevitably stall the progress made by the overall system.
    - As the keyrange increases, the number of operations per second performed decreases.
    - In comparison to the Basic TATAS lock implementation, the HLE TATAS implementation drastically outperformed the previous method - for a maxKey of 1’048’576 and 32 threads, HLE TATAS performed 6’832’667 ops/s, while basic TATAS only performed 867,320 ops/s - which has approximately 8x times more throughput in operations.

Restricted Transactional Memory (RTM)

- The results here are that:
    - As the number of threads increases, the number of operations per second decreases roughly proportionally - much like above, this is expected as there will be an increase in contention for the lock since there will be more threads actively seeking the lock more often. Which will reduce the performance of the system.
    - Again, similar to the above other methods, as the key range increases, the number of operations per second performed decreases.
    - One thing that was expected from the RTM was that it would outperform all of the other methods, however the performance benifits of using the RTM was marginal for the max number of acceptable aborts before HLE was used of 1, and significantly better for when the maximum number of acceptable aborts was 8 or more which can be seen in the table below.

16 threads - 1’048’576 MaxKey	ops/sec
HLE	808’721
RTM - 1 aborts	866’728
RTM - 8 aborts	1’225’899
RTM - 32 aborts	3’704’885

From the above table, it shows that RTM is the superior method when the acceptable number of aborts is relatively large: 8 or more - but around 16+ aborts the perform increases dramatically since there are significantly less operations that operations that failed often enough to warrant the use of the HLE implementation.

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Method = 0 - No Threads

maxKey	nt	pft	rt	ops	ops/s	nMalloc	nFree	ntree	vmUse	memUse	avgD	maxD	tt
16	1	0.00	2.00	44,555,000	22,266,366	17	12	5	86.91MB	1.62MB	3.21	11	2.00
64	1	0.00	2.00	40,613,000	20,296,351	53	20	33	86.91MB	1.63MB	5.42	16	2.00
256	1	0.00	2.00	30,086,000	15,035,482	168	38	130	86.91MB	1.63MB	8.38	21	2.00
1,024	1	0.00	2.00	26,292,000	13,139,430	590	83	507	87.04MB	3.42MB	12.98	32	2.00
4,096	1	0.00	2.00	17,062,000	8,526,736	2,189	165	2,024	87.30MB	3.70MB	16.34	54	2.00
16,384	1	0.01	2.00	10,854,000	5,424,287	8,396	261	8,135	88.84MB	5.29MB	13.29	33	2.01
65,536	1	0.02	2.00	7,976,000	3,986,006	33,145	509	32,636	94.77MB	11.27MB	15.02	25	2.02
262,144	1	0.07	2.00	5,129,000	2,563,218	131,866	420	131,446	118.62MB	35.39MB	16.82	27	2.08
1,048,576	1	0.18	2.00	3,547,000	1,772,613	524,818	465	524,353	214.53MB	131.13MB	18.58	26	2.23

Method = 1

maxKey	nt	pft	rt	ops	ops/s	rel	nMalloc	nFree	ntree	vmUse	memUse	avgD	maxD	tt
16	1	0.00	2.00	40,990,000	20,484,757	[1.00]	17	8	9	86.91MB	1.66MB	3.21	11	2.00
16	2	0.00	2.00	18,077,000	9,033,983	[0.44]	7,732	7,725	7	158.92MB	3.04MB	3.21	11	2.00
16	4	0.00	2.00	11,983,000	5,988,505	[0.29]	12,205	12,195	10	302.93MB	5.18MB	3.22	10	2.00
16	8	0.00	2.00	9,531,000	4,763,118	[0.23]	11,923	11,919	4	558.93MB	8.33MB	3.21	11	2.00
16	16	0.00	2.00	10,867,000	5,428,071	[0.26]	10,175	10,168	7	1.05GB	9.67MB	3.22	11	2.00
16	32	0.00	2.00	5,970,000	2,977,556	[0.15]	7,459	7,452	7	2.05GB	10.56MB	3.22	10	2.01
64	1	0.00	2.00	37,403,000	18,692,153	[1.00]	52	24	28	2.05GB	10.57MB	5.43	15	2.00
64	2	0.00	2.00	18,102,000	9,046,476	[0.48]	2,021	1,995	26	2.05GB	10.67MB	5.43	15	2.00
64	4	0.00	2.00	11,545,000	5,769,615	[0.31]	3,633	3,597	36	2.05GB	10.85MB	5.42	15	2.00
64	8	0.00	2.00	8,536,000	4,263,736	[0.23]	5,261	5,233	28	2.05GB	11.46MB	5.43	14	2.00
64	16	0.00	2.00	9,691,000	4,840,659	[0.26]	5,747	5,718	29	2.05GB	11.96MB	5.42	15	2.00
64	32	0.00	2.00	4,875,000	2,432,634	[0.13]	6,776	6,738	38	2.05GB	12.49MB	5.43	15	2.00
256	1	0.00	2.00	31,501,000	15,742,628	[1.00]	167	42	125	2.05GB	12.49MB	8.39	20	2.00
256	2	0.00	2.00	16,245,000	8,118,440	[0.52]	1,527	1,402	125	2.05GB	12.56MB	8.39	22	2.00
256	4	0.00	2.00	11,362,000	5,678,160	[0.36]	3,616	3,490	126	2.05GB	12.77MB	8.41	21	2.00
256	8	0.00	2.00	8,890,000	4,442,778	[0.28]	4,782	4,656	126	2.05GB	13.04MB	8.40	20	2.00
256	16	0.00	2.00	8,372,000	4,181,818	[0.27]	6,085	5,972	113	2.05GB	13.11MB	8.37	20	2.00
256	32	0.00	2.00	4,151,000	2,070,324	[0.13]	6,175	6,059	116	2.05GB	13.23MB	8.47	20	2.00
1,024	1	0.00	2.00	25,807,000	12,897,051	[1.00]	585	62	523	2.05GB	13.23MB	13.04	33	2.00
1,024	2	0.00	2.00	14,252,000	7,122,438	[0.55]	2,637	2,123	514	2.05GB	13.23MB	12.82	33	2.00
1,024	4	0.00	2.00	11,170,000	5,582,208	[0.43]	3,956	3,427	529	2.05GB	13.40MB	12.69	31	2.00
1,024	8	0.00	2.00	7,827,000	3,911,544	[0.30]	3,966	3,474	492	2.05GB	13.60MB	12.95	33	2.00
1,024	16	0.00	2.00	7,259,000	3,624,063	[0.28]	5,900	5,378	522	2.05GB	13.64MB	12.56	30	2.00
1,024	32	0.00	2.01	4,152,000	2,069,790	[0.16]	6,475	5,954	521	2.05GB	13.73MB	12.68	33	2.01
4,096	1	0.00	2.00	15,974,000	7,983,008	[1.00]	2,189	132	2,057	2.05GB	13.98MB	15.60	49	2.00
4,096	2	0.00	2.00	12,433,000	6,213,393	[0.78]	4,439	2,376	2,063	2.05GB	14.37MB	14.79	50	2.00
4,096	4	0.00	2.00	9,879,000	4,937,031	[0.62]	4,728	2,673	2,055	2.05GB	14.62MB	13.50	41	2.00
4,096	8	0.00	2.00	7,762,000	3,879,060	[0.49]	5,422	3,432	1,990	2.05GB	14.86MB	13.11	42	2.00
4,096	16	0.00	2.00	7,007,000	3,498,252	[0.44]	7,262	5,191	2,071	2.05GB	15.03MB	12.89	40	2.00
4,096	32	0.00	2.00	3,679,000	1,835,828	[0.23]	8,100	6,044	2,056	2.05GB	15.16MB	11.79	32	2.01
16,384	1	0.00	2.00	10,766,000	5,380,309	[1.00]	8,453	297	8,156	2.05GB	16.18MB	13.27	29	2.00
16,384	2	0.01	2.00	9,536,000	4,765,617	[0.89]	10,373	2,185	8,188	2.05GB	17.89MB	13.31	31	2.01
16,384	4	0.01	2.00	8,830,000	4,412,793	[0.82]	11,443	3,348	8,095	2.05GB	19.36MB	13.26	29	2.01
16,384	8	0.00	2.00	7,390,000	3,691,308	[0.69]	12,363	4,131	8,232	2.05GB	20.77MB	13.21	28	2.00
16,384	16	0.00	2.00	6,393,000	3,191,712	[0.59]	14,032	5,776	8,256	2.05GB	22.12MB	13.20	27	2.01
16,384	32	0.00	2.01	3,279,000	1,634,596	[0.30]	13,969	5,731	8,238	2.05GB	23.05MB	13.09	25	2.01
65,536	1	0.01	2.00	7,769,000	3,882,558	[1.00]	33,199	391	32,808	2.06GB	28.26MB	15.03	24	2.01
65,536	2	0.02	2.00	7,352,000	3,674,162	[0.95]	34,432	1,842	32,590	2.06GB	34.44MB	15.02	24	2.02
65,536	4	0.02	2.00	6,979,000	3,487,756	[0.90]	35,869	3,135	32,734	2.07GB	40.58MB	15.01	25	2.02
65,536	8	0.02	2.00	6,329,000	3,162,918	[0.81]	36,807	3,887	32,920	2.08GB	46.60MB	15.01	25	2.02
65,536	16	0.01	2.00	5,564,000	2,776,447	[0.72]	37,841	5,266	32,575	2.08GB	52.45MB	14.99	26	2.01
65,536	32	0.01	2.02	3,126,000	1,545,229	[0.40]	37,532	4,718	32,814	2.09GB	57.83MB	14.92	24	2.03
262,144	1	0.03	2.00	6,060,000	3,028,485	[1.00]	131,666	855	130,811	2.11GB	81.05MB	16.85	25	2.03
262,144	2	0.06	2.00	5,054,000	2,525,737	[0.83]	132,522	2,001	130,521	2.13GB	104.87MB	16.82	26	2.07
262,144	4	0.06	2.00	5,228,000	2,612,693	[0.86]	133,196	2,467	130,729	2.15GB	128.80MB	16.83	25	2.07
262,144	8	0.06	2.00	4,800,000	2,397,602	[0.79]	133,979	2,924	131,055	2.18GB	152.65MB	16.81	25	2.07
262,144	16	0.03	2.00	4,467,000	2,229,041	[0.74]	135,473	4,388	131,085	2.20GB	176.40MB	16.81	27	2.04
262,144	32	0.03	2.01	2,243,000	1,117,031	[0.37]	135,069	4,205	130,864	2.22GB	199.92MB	16.71	25	2.04
1,048,576	1	0.10	2.00	3,483,000	1,740,629	[1.00]	525,372	1,159	524,213	2.32GB	295.24MB	18.58	27	2.15
1,048,576	2	0.15	2.00	3,450,000	1,724,137	[0.99]	525,883	898	524,985	2.41GB	391.16MB	18.58	26	2.19
1,048,576	4	0.14	2.00	3,425,000	1,710,789	[0.98]	525,382	2,219	523,163	2.50GB	486.86MB	18.58	25	2.19
1,048,576	8	0.16	2.00	3,350,000	1,672,491	[0.96]	527,449	2,143	525,306	2.60GB	583.06MB	18.58	26	2.19
1,048,576	16	0.10	2.01	3,143,000	1,566,799	[0.90]	529,081	5,756	523,325	2.69GB	679.24MB	18.57	26	2.14
1,048,576	32	0.10	2.01	1,824,000	907,462	[0.52]	528,418	3,985	524,433	2.78GB	774.54MB	18.50	25	2.14

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Method = 2

maxKey	nt	pft	rt	ops	ops/s	rel	nMalloc	nFree	ntree	vmUse	memUse	avgD	maxD	commit	tt
16	1	0.00	2.00	36,843,000	18,412,293	[1.00]	17	8	9	86.91MB	1.60MB	3.22	11	36,843,000	2.00
16	2	0.00	2.00	14,426,000	7,209,395	[0.39]	3,101	3,095	6	158.92MB	2.16MB	3.21	11	14,155,490	2.00
16	4	0.00	2.00	11,367,000	5,680,659	[0.31]	8,369	8,359	10	302.93MB	3.11MB	3.20	10	10,930,291	2.00
16	8	0.00	2.00	7,817,000	3,906,546	[0.21]	4,821	4,811	10	558.93MB	5.45MB	3.18	10	7,409,202	2.00
16	16	0.00	2.00	9,277,000	4,633,866	[0.25]	7,149	7,142	7	1.05GB	6.52MB	3.19	11	9,157,338	2.00
16	32	0.00	2.02	4,721,000	2,342,928	[0.13]	5,157	5,146	11	2.05GB	7.28MB	3.18	11	4,661,261	2.02
64	1	0.00	2.00	33,869,000	16,926,036	[1.00]	54	18	36	2.05GB	7.28MB	5.43	15	33,869,000	2.00
64	2	0.00	2.00	13,478,000	6,735,632	[0.40]	3,046	3,014	32	2.05GB	7.71MB	5.43	15	12,595,846	2.00
64	4	0.00	2.00	7,854,000	3,925,037	[0.23]	2,894	2,867	27	2.05GB	7.77MB	5.42	15	7,265,642	2.00
64	8	0.00	2.00	7,751,000	3,873,563	[0.23]	3,780	3,750	30	2.05GB	8.10MB	5.42	14	7,146,578	2.00
64	16	0.00	2.00	5,915,000	2,953,070	[0.17]	4,981	4,947	34	2.05GB	8.25MB	5.39	14	5,420,704	2.00
64	32	0.00	2.01	2,695,000	1,338,797	[0.08]	4,733	4,704	29	2.05GB	8.52MB	5.39	15	2,332,353	2.01
256	1	0.00	2.00	29,021,000	14,503,248	[1.00]	172	43	129	2.05GB	8.52MB	8.40	22	29,021,000	2.00
256	2	0.00	2.00	13,387,000	6,690,154	[0.46]	4,357	4,234	123	2.05GB	9.20MB	8.39	22	12,674,824	2.00
256	4	0.00	2.00	10,778,000	5,386,306	[0.37]	3,493	3,378	115	2.05GB	9.25MB	8.40	22	9,903,441	2.00
256	8	0.00	2.00	4,948,000	2,471,528	[0.17]	4,230	4,096	134	2.05GB	9.32MB	8.41	22	4,323,664	2.00
256	16	0.00	2.00	5,474,000	2,731,536	[0.19]	5,718	5,594	124	2.05GB	9.45MB	8.37	20	4,701,024	2.00
256	32	0.00	2.01	2,875,000	1,432,486	[0.10]	6,093	5,969	124	2.05GB	9.70MB	8.32	20	2,435,241	2.01
1,024	1	0.00	2.00	23,742,000	11,865,067	[1.00]	586	72	514	2.05GB	9.70MB	12.98	32	23,742,000	2.00
1,024	2	0.00	2.00	12,543,000	6,268,365	[0.53]	1,992	1,496	496	2.05GB	9.80MB	12.78	31	11,979,035	2.00
1,024	4	0.00	2.00	9,136,000	4,565,717	[0.38]	2,822	2,303	519	2.05GB	9.87MB	12.88	31	8,319,900	2.00
1,024	8	0.00	2.00	7,350,000	3,671,328	[0.31]	4,103	3,601	502	2.05GB	10.15MB	12.75	31	6,449,050	2.00
1,024	16	0.00	2.00	5,334,000	2,663,005	[0.22]	5,296	4,746	550	2.05GB	10.22MB	12.64	32	4,512,062	2.00
1,024	32	0.00	2.02	2,439,000	1,207,425	[0.10]	5,261	4,759	502	2.05GB	10.41MB	12.57	32	1,995,377	2.02
4,096	1	0.00	2.00	15,725,000	7,858,570	[1.00]	2,178	120	2,058	2.05GB	10.66MB	16.07	52	15,725,000	2.00
4,096	2	0.00	2.00	10,241,000	5,117,941	[0.65]	4,188	2,165	2,023	2.05GB	11.14MB	14.06	44	9,730,033	2.00
4,096	4	0.00	2.00	7,678,000	3,837,081	[0.49]	4,282	2,274	2,008	2.05GB	11.16MB	12.90	40	6,878,868	2.00
4,096	8	0.00	2.00	7,031,000	3,513,743	[0.45]	5,816	3,821	1,995	2.05GB	11.67MB	12.81	37	6,204,798	2.00
4,096	16	0.00	2.00	5,043,000	2,516,467	[0.32]	6,479	4,421	2,058	2.05GB	11.85MB	12.23	36	4,223,503	2.00
4,096	32	0.00	2.01	2,980,000	1,485,543	[0.19]	7,021	5,005	2,016	2.05GB	11.99MB	11.55	30	2,355,461	2.01
16,384	1	0.00	2.00	10,362,000	5,178,410	[1.00]	8,440	194	8,246	2.05GB	13.02MB	13.26	31	10,362,000	2.00
16,384	2	0.01	2.00	8,505,000	4,250,374	[0.82]	9,454	1,208	8,246	2.05GB	14.56MB	13.23	28	7,970,104	2.01
16,384	4	0.00	2.00	7,348,000	3,672,163	[0.71]	11,499	3,296	8,203	2.05GB	16.05MB	13.20	27	6,543,529	2.00
16,384	8	0.00	2.00	4,433,000	2,214,285	[0.43]	11,581	3,470	8,111	2.05GB	17.37MB	13.13	26	3,987,398	2.00
16,384	16	0.00	2.00	5,139,000	2,564,371	[0.50]	12,849	4,621	8,228	2.05GB	18.56MB	13.16	27	4,483,060	2.00
16,384	32	0.00	2.01	2,824,000	1,406,374	[0.27]	13,173	4,945	8,228	2.05GB	19.52MB	13.07	23	2,364,184	2.01
65,536	1	0.01	2.00	7,489,000	3,742,628	[1.00]	33,172	374	32,798	2.06GB	24.73MB	15.02	24	7,489,000	2.01
65,536	2	0.02	2.00	7,259,000	3,627,686	[0.97]	34,053	1,174	32,879	2.06GB	30.82MB	15.01	24	6,791,723	2.02
65,536	4	0.02	2.00	7,072,000	3,534,232	[0.94]	35,591	2,829	32,762	2.07GB	37.09MB	15.01	24	6,274,704	2.02
65,536	8	0.02	2.00	5,679,000	2,836,663	[0.76]	37,283	4,591	32,692	2.08GB	43.27MB	14.99	24	5,025,148	2.02
65,536	16	0.01	2.00	4,300,000	2,145,708	[0.57]	38,727	5,922	32,805	2.08GB	49.07MB	14.96	26	3,808,491	2.01
65,536	32	0.01	2.01	1,923,000	957,669	[0.26]	36,866	3,951	32,915	2.09GB	54.36MB	14.87	24	1,650,939	2.02
262,144	1	0.03	2.00	5,194,000	2,595,702	[1.00]	131,678	753	130,925	2.11GB	77.58MB	16.83	26	5,194,000	2.04
262,144	2	0.06	2.00	5,525,000	2,761,119	[1.06]	132,719	1,744	130,975	2.13GB	101.57MB	16.83	26	5,200,885	2.07
262,144	4	0.06	2.00	5,938,000	2,967,516	[1.14]	132,971	2,121	130,850	2.16GB	125.54MB	16.84	27	5,388,571	2.07
262,144	8	0.06	2.00	4,048,000	2,021,978	[0.78]	133,707	2,483	131,224	2.18GB	149.71MB	16.79	25	3,649,371	2.07
262,144	16	0.03	2.00	4,643,000	2,316,866	[0.89]	136,799	5,388	131,411	2.20GB	173.98MB	16.81	27	3,973,001	2.04
262,144	32	0.03	2.01	2,611,000	1,300,946	[0.50]	135,855	4,596	131,259	2.22GB	197.55MB	16.74	26	2,215,884	2.04
1,048,576	1	0.10	2.00	3,519,000	1,758,620	[1.00]	525,358	1,381	523,977	2.32GB	292.61MB	18.58	27	3,519,000	2.15
1,048,576	2	0.15	2.00	4,176,000	2,086,956	[1.19]	526,661	1,061	525,600	2.41GB	388.96MB	18.61	27	4,012,521	2.19
1,048,576	4	0.14	2.00	4,320,000	2,157,842	[1.23]	526,271	1,776	524,495	2.50GB	484.83MB	18.61	27	4,093,927	2.19
1,048,576	8	0.15	2.00	4,449,000	2,222,277	[1.26]	527,170	3,079	524,091	2.60GB	580.86MB	18.62	26	4,025,769	2.18
1,048,576	16	0.10	2.00	4,094,000	2,042,914	[1.16]	528,520	3,709	524,811	2.69GB	676.92MB	18.60	26	3,599,461	2.14
1,048,576	32	0.10	2.02	1,632,000	808,721	[0.46]	528,287	3,816	524,471	2.78GB	772.61MB	18.49	25	1,452,050	2.15

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Advanced Computer Architecture

Tutorial 2

Method = 3 - Attempts = 1

maxKey	nt	pft	rt	ops	ops/s	rel	nMalloc	nFree	ntree	vmUse	memUse	avgD	maxD	commit	tt	Commit%	Abort%
16	1	0.00	2.00	38,025,000	19,002,998	[1.00]	17	6	11	86.91MB	1.63MB	3.21	11	38,024,745	2.00	99.9993%	0.0007
16	2	0.00	2.00	14,382,000	7,187,406	[0.38]	3,345	3,338	7	158.92MB	2.23MB	3.21	11	7,355,268	2.00	51.1422%	48.8578
16	4	0.00	2.00	9,279,000	4,637,181	[0.24]	5,783	5,773	10	302.93MB	3.14MB	3.19	11	3,438,106	2.00	37.0525%	62.9475
16	8	0.00	2.00	5,407,000	2,700,799	[0.14]	3,509	3,503	6	558.93MB	5.18MB	3.19	10	1,138,673	2.00	21.0592%	78.9408
16	16	0.00	2.00	5,604,000	2,799,200	[0.15]	4,788	4,779	9	1.05GB	5.84MB	3.17	11	989,396	2.00	17.6552%	82.3448
16	32	0.00	2.01	2,756,000	1,372,509	[0.07]	5,509	5,502	7	2.05GB	6.66MB	3.17	10	173,329	2.01	6.2892%	93.7108
64	1	0.00	2.00	35,102,000	17,542,228	[1.00]	54	29	25	2.05GB	6.66MB	5.43	15	35,101,650	2.00	99.9990%	0.0010
64	2	0.00	2.00	15,128,000	7,560,219	[0.43]	2,182	2,155	27	2.05GB	6.96MB	5.42	14	7,686,035	2.00	50.8067%	49.1933
64	4	0.00	2.00	10,141,000	5,067,966	[0.29]	3,559	3,522	37	2.05GB	7.16MB	5.41	15	3,505,833	2.00	34.5709%	65.4291
64	8	0.00	2.00	5,665,000	2,831,084	[0.16]	3,447	3,413	34	2.05GB	7.40MB	5.42	15	1,036,329	2.00	18.2935%	81.7065
64	16	0.00	2.00	4,819,000	2,405,891	[0.14]	4,952	4,919	33	2.05GB	7.87MB	5.41	16	256,151	2.00	5.3154%	94.6846
64	32	0.00	2.01	2,495,000	1,238,828	[0.07]	4,828	4,797	31	2.05GB	8.24MB	5.41	14	130,282	2.01	5.2217%	94.7783
256	1	0.00	2.00	29,743,000	14,864,067	[1.00]	167	27	140	2.05GB	8.24MB	8.40	22	29,742,624	2.00	99.9987%	0.0013
256	2	0.00	2.00	12,237,000	6,115,442	[0.41]	2,535	2,399	136	2.05GB	8.26MB	8.40	20	4,739,727	2.00	38.7328%	61.2672
256	4	0.00	2.00	10,007,000	5,000,999	[0.34]	2,739	2,616	123	2.05GB	8.27MB	8.37	20	3,172,657	2.00	31.7044%	68.2956
256	8	0.00	2.00	4,170,000	2,082,917	[0.14]	2,979	2,838	141	2.05GB	8.32MB	8.42	21	331,247	2.00	7.9436%	92.0564
256	16	0.00	2.00	3,872,000	1,932,135	[0.13]	4,551	4,419	132	2.05GB	8.43MB	8.40	21	105,375	2.00	2.7215%	97.2785
256	32	0.00	2.01	2,495,000	1,243,148	[0.08]	4,535	4,406	129	2.05GB	8.60MB	8.39	19	97,270	2.01	3.8986%	96.1014
1,024	1	0.00	2.00	24,302,000	12,144,927	[1.00]	595	100	495	2.05GB	8.62MB	13.20	34	24,300,327	2.00	99.9931%	0.0069
1,024	2	0.00	2.00	11,527,000	5,760,619	[0.47]	3,788	3,240	548	2.05GB	9.05MB	12.90	32	4,167,887	2.00	36.1576%	63.8424
1,024	4	0.00	2.00	8,139,000	4,067,466	[0.33]	3,028	2,506	522	2.05GB	9.09MB	13.00	33	2,089,627	2.00	25.6742%	74.3258
1,024	8	0.00	2.00	4,169,000	2,083,458	[0.17]	3,204	2,672	532	2.05GB	9.29MB	12.63	30	289,279	2.00	6.9388%	93.0612
1,024	16	0.00	2.00	4,176,000	2,084,872	[0.17]	4,732	4,227	505	2.05GB	9.36MB	13.00	32	160,242	2.00	3.8372%	96.1628
1,024	32	0.00	2.02	2,198,000	1,088,118	[0.09]	5,079	4,543	536	2.05GB	9.48MB	12.17	30	29,230	2.02	1.3298%	98.6702
4,096	1	0.00	2.00	16,109,000	8,050,474	[1.00]	2,180	101	2,079	2.05GB	9.74MB	16.21	52	16,108,308	2.00	99.9957%	0.0043
4,096	2	0.00	2.00	10,038,000	5,016,491	[0.62]	3,830	1,742	2,088	2.05GB	10.09MB	13.79	45	3,203,724	2.00	31.9160%	68.0840
4,096	4	0.00	2.00	7,634,000	3,815,092	[0.47]	5,499	3,405	2,094	2.05GB	10.63MB	12.86	40	1,798,995	2.00	23.5656%	76.4344
4,096	8	0.00	2.00	3,935,000	1,965,534	[0.24]	4,823	2,795	2,028	2.05GB	10.80MB	11.96	36	160,851	2.00	4.0877%	95.9123
4,096	16	0.00	2.00	3,994,000	1,992,019	[0.25]	5,856	3,863	1,993	2.05GB	10.98MB	11.87	31	80,219	2.00	2.0085%	97.9915
4,096	32	0.00	2.01	2,247,000	1,118,466	[0.14]	6,931	4,847	2,084	2.05GB	11.19MB	11.50	30	36,745	2.01	1.6353%	98.3647
16,384	1	0.00	2.00	10,165,000	5,079,960	[1.00]	8,444	202	8,242	2.05GB	12.22MB	13.30	31	10,164,462	2.00	99.9947%	0.0053
16,384	2	0.01	2.00	8,408,000	4,201,899	[0.83]	10,117	1,963	8,154	2.05GB	13.94MB	13.24	31	3,302,479	2.01	39.2778%	60.7222
16,384	4	0.00	2.00	7,567,000	3,781,609	[0.74]	10,832	2,610	8,222	2.05GB	15.48MB	13.22	27	1,559,346	2.01	20.6072%	79.3928
16,384	8	0.01	2.00	5,504,000	2,749,250	[0.54]	12,292	3,962	8,330	2.05GB	17.10MB	13.16	26	642,641	2.01	11.6759%	88.3241
16,384	16	0.00	2.00	3,885,000	1,938,622	[0.38]	12,932	4,765	8,167	2.05GB	18.23MB	13.12	24	78,183	2.00	2.0124%	97.9876
16,384	32	0.00	2.01	2,032,000	1,009,940	[0.20]	12,177	3,924	8,253	2.05GB	19.22MB	13.04	22	8,030	2.01	0.3952%	99.6048
65,536	1	0.01	2.00	7,069,000	3,532,733	[1.00]	33,136	476	32,660	2.06GB	24.68MB	15.02	25	7,068,501	2.01	99.9929%	0.0071
65,536	2	0.02	2.00	6,832,000	3,414,292	[0.97]	34,513	1,705	32,808	2.07GB	30.87MB	15.01	24	1,961,315	2.02	28.7078%	71.2922
65,536	4	0.02	2.00	6,471,000	3,233,883	[0.92]	35,875	2,966	32,909	2.07GB	36.87MB	15.00	25	883,068	2.02	13.6465%	86.3535
65,536	8	0.02	2.00	4,118,000	2,057,971	[0.58]	35,608	2,758	32,850	2.08GB	42.68MB	14.95	24	138,932	2.02	3.3738%	96.6262
65,536	16	0.01	2.00	3,802,000	1,898,152	[0.54]	36,813	4,007	32,806	2.08GB	48.48MB	14.95	23	29,516	2.01	0.7763%	99.2237
65,536	32	0.01	2.01	1,998,000	993,041	[0.28]	36,751	4,006	32,745	2.09GB	54.02MB	14.87	24	11,578	2.02	0.5795%	99.4205
262,144	1	0.02	2.00	4,959,000	2,478,260	[1.00]	131,746	867	130,879	2.11GB	77.34MB	16.82	26	4,948,948	2.03	99.7973%	0.2027
262,144	2	0.06	2.00	5,789,000	2,893,053	[1.17]	133,016	1,718	131,298	2.13GB	101.66MB	16.84	26	1,507,575	2.07	26.0421%	73.9579
262,144	4	0.06	2.00	5,375,000	2,686,156	[1.08]	134,072	2,746	131,326	2.16GB	125.60MB	16.83	25	229,658	2.06	4.2727%	95.7273
262,144	8	0.02	2.00	4,637,000	2,316,183	[0.93]	134,515	3,319	131,196	2.18GB	149.77MB	16.81	26	167,172	2.03	3.6052%	96.3948
262,144	16	0.02	2.00	3,768,000	1,880,239	[0.76]	135,364	3,683	131,681	2.20GB	173.77MB	16.78	25	16,900	2.03	0.4485%	99.5515
262,144	32	0.02	2.01	2,133,000	1,061,194	[0.43]	135,280	4,281	130,999	2.22GB	197.46MB	16.71	24	1,870	2.04	0.0877%	99.9123
1,048,576	1	0.09	2.00	2,587,000	1,292,853	[1.00]	524,937	590	524,347	2.32GB	292.71MB	18.54	25	2,561,941	2.14	99.0313%	0.9687
1,048,576	2	0.14	2.00	3,595,000	1,796,601	[1.39]	525,119	701	524,418	2.41GB	388.70MB	18.59	26	717,893	2.19	19.9692%	80.0308
1,048,576	4	0.14	2.00	3,867,000	1,931,568	[1.49]	526,080	1,168	524,912	2.50GB	484.90MB	18.60	26	97,380	2.19	2.5182%	97.4818
1,048,576	8	0.14	2.00	3,640,000	1,817,274	[1.41]	526,819	3,430	523,389	2.60GB	581.04MB	18.59	27	16,042	2.17	0.4407%	99.5593
1,048,576	16	0.09	2.00	3,329,000	1,661,177	[1.28]	528,239	4,630	523,609	2.69GB	677.06MB	18.57	26	4,103	2.13	0.1233%	99.8767
1,048,576	32	0.09	2.03	1,749,000	860,728	[0.67]	528,052	4,712	523,340	2.78GB	772.78MB	18.50	25	712	2.15	0.0407%	99.9593

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Advanced Computer Architecture

Tutorial 2

Method = 3 - Attempts = 2

maxKey	nt	pft	rt	ops	ops/s	rel	nMalloc	nFree	ntree	vmUse	memUse	avgD	maxD	commit	tt	Commit%	Abort%
16	1	0.00	2.00	38,038,000	19,009,495	[1.00]	17	9	8	86.91MB	1.62MB	3.22	11	38,037,731	2.00	99.9993%	0.0007
16	2	0.00	2.00	13,857,000	6,925,037	[0.36]	1,670	1,662	8	158.92MB	1.93MB	3.21	10	6,691,329	2.00	48.2884%	51.7116
16	4	0.00	2.00	7,793,000	3,894,552	[0.20]	3,314	3,304	10	302.93MB	2.26MB	3.20	10	2,201,076	2.00	28.2443%	71.7557
16	8	0.00	2.00	4,006,000	2,000,999	[0.11]	3,685	3,679	6	558.93MB	4.47MB	3.19	10	376,627	2.00	9.4016%	90.5984
16	16	0.00	2.00	4,053,000	2,022,455	[0.11]	4,323	4,310	13	1.05GB	5.02MB	3.18	10	131,754	2.00	3.2508%	96.7492
16	32	0.00	2.01	2,454,000	1,222,720	[0.06]	4,285	4,278	7	1.98GB	5.67MB	3.18	11	68,563	2.01	2.7939%	97.2061
64	1	0.00	2.00	35,090,000	17,536,231	[1.00]	53	26	27	1.98GB	5.67MB	5.42	16	35,089,664	2.00	99.9990%	0.0010
64	2	0.00	2.00	13,564,000	6,778,610	[0.39]	1,920	1,892	28	1.98GB	5.86MB	5.43	15	5,861,039	2.00	43.2103%	56.7897
64	4	0.00	2.00	8,230,000	4,112,943	[0.23]	2,101	2,067	34	1.98GB	5.96MB	5.42	15	2,330,900	2.00	28.3220%	71.6780
64	8	0.00	2.00	4,163,000	2,079,420	[0.12]	4,216	4,175	41	1.98GB	6.37MB	5.41	15	347,755	2.00	8.3535%	91.6465
64	16	0.00	2.00	3,969,000	1,981,527	[0.11]	4,414	4,375	39	1.98GB	6.71MB	5.41	14	101,668	2.00	2.5616%	97.4384
64	32	0.00	2.01	2,184,000	1,084,409	[0.06]	4,535	4,498	37	2.05GB	7.14MB	5.41	14	46,772	2.01	2.1416%	97.8584
256	1	0.00	2.00	29,782,000	14,883,558	[1.00]	175	49	126	2.05GB	7.14MB	8.40	21	29,781,655	2.00	99.9988%	0.0012
256	2	0.00	2.00	12,597,000	6,295,352	[0.42]	1,822	1,704	118	2.05GB	7.24MB	8.39	22	4,878,925	2.00	38.7308%	61.2692
256	4	0.00	2.00	8,127,000	4,061,469	[0.27]	2,400	2,264	136	2.05GB	7.31MB	8.46	21	2,118,109	2.00	26.0626%	73.9374
256	8	0.00	2.00	4,280,000	2,137,862	[0.14]	3,841	3,720	121	2.05GB	7.57MB	8.36	21	369,324	2.00	8.6291%	91.3709
256	16	0.00	2.00	3,640,000	1,815,461	[0.12]	4,770	4,640	130	2.05GB	7.64MB	8.41	20	42,349	2.00	1.1634%	98.8366
256	32	0.00	2.01	2,539,000	1,265,072	[0.08]	4,862	4,741	121	2.05GB	7.90MB	8.39	20	102,405	2.01	4.0333%	95.9667
1,024	1	0.00	2.00	24,350,000	12,168,915	[1.00]	588	79	509	2.05GB	7.90MB	13.04	32	24,349,566	2.00	99.9982%	0.0018
1,024	2	0.00	2.00	11,850,000	5,922,038	[0.49]	2,679	2,128	551	2.05GB	8.16MB	12.87	33	4,392,464	2.00	37.0672%	62.9328
1,024	4	0.00	2.00	8,104,000	4,049,975	[0.33]	3,199	2,703	496	2.05GB	8.30MB	12.62	33	2,079,385	2.00	25.6587%	74.3413
1,024	8	0.00	2.00	5,676,000	2,835,164	[0.23]	3,581	3,047	534	2.05GB	8.49MB	12.76	32	790,077	2.00	13.9196%	86.0804
1,024	16	0.00	2.00	3,643,000	1,817,864	[0.15]	4,505	3,992	513	2.05GB	8.52MB	12.20	31	52,085	2.00	1.4297%	98.5703
1,024	32	0.00	2.02	2,401,000	1,189,202	[0.10]	5,375	4,870	505	2.05GB	8.61MB	12.25	29	54,242	2.02	2.2591%	97.7409
4,096	1	0.00	2.00	16,086,000	8,038,980	[1.00]	2,178	106	2,072	2.05GB	8.86MB	16.14	50	16,085,190	2.00	99.9950%	0.0050
4,096	2	0.00	2.00	10,093,000	5,043,978	[0.63]	4,074	2,036	2,038	2.05GB	9.27MB	14.08	44	4,193,153	2.00	41.5452%	58.4548
4,096	4	0.00	2.00	8,593,000	4,294,352	[0.53]	4,463	2,397	2,066	2.05GB	9.68MB	12.97	38	2,000,730	2.00	23.2833%	76.7167
4,096	8	0.00	2.00	5,350,000	2,672,327	[0.33]	4,658	2,623	2,035	2.05GB	9.88MB	12.09	35	385,072	2.00	7.1976%	92.8024
4,096	16	0.00	2.00	4,032,000	2,011,976	[0.25]	6,271	4,171	2,100	2.05GB	10.12MB	11.80	30	76,951	2.00	1.9085%	98.0915
4,096	32	0.00	2.02	2,202,000	1,087,944	[0.14]	6,693	4,618	2,075	2.05GB	10.24MB	11.43	28	20,868	2.02	0.9477%	99.0523
16,384	1	0.00	2.00	10,509,000	5,251,874	[1.00]	8,450	302	8,148	2.05GB	11.27MB	13.29	30	10,508,453	2.00	99.9948%	0.0052
16,384	2	0.01	2.00	8,486,000	4,240,879	[0.81]	9,917	1,814	8,103	2.05GB	12.94MB	13.26	30	3,371,298	2.01	39.7278%	60.2722
16,384	4	0.01	2.00	7,630,000	3,813,093	[0.73]	10,369	2,239	8,130	2.05GB	14.45MB	13.21	28	1,471,120	2.01	19.2807%	80.7193
16,384	8	0.00	2.00	5,131,000	2,562,937	[0.49]	11,629	3,429	8,200	2.05GB	15.84MB	13.15	26	309,840	2.00	6.0386%	93.9614
16,384	16	0.00	2.00	3,825,000	1,907,730	[0.36]	13,002	4,852	8,150	2.05GB	17.06MB	13.11	25	34,488	2.01	0.9016%	99.0984
16,384	32	0.00	2.01	1,889,000	940,737	[0.18]	11,753	3,523	8,230	2.05GB	18.00MB	13.03	22	10,469	2.01	0.5542%	99.4458
65,536	1	0.01	2.00	7,666,000	3,831,084	[1.00]	33,127	403	32,724	2.06GB	23.43MB	15.02	25	7,665,460	2.01	99.9930%	0.0070
65,536	2	0.02	2.00	7,200,000	3,598,200	[0.94]	34,014	1,489	32,525	2.07GB	29.53MB	15.01	25	2,559,829	2.02	35.5532%	64.4468
65,536	4	0.01	2.00	6,841,000	3,418,790	[0.89]	35,550	2,823	32,727	2.07GB	35.62MB	15.01	25	985,210	2.01	14.4015%	85.5985
65,536	8	0.01	2.00	4,893,000	2,444,055	[0.64]	35,705	2,993	32,712	2.08GB	41.57MB	14.98	24	220,501	2.01	4.5065%	95.4935
65,536	16	0.01	2.00	3,724,000	1,858,283	[0.49]	36,848	4,214	32,634	2.08GB	47.23MB	14.95	24	19,397	2.01	0.5209%	99.4791
65,536	32	0.01	2.02	1,997,000	989,103	[0.26]	37,177	4,564	32,613	2.09GB	52.89MB	14.88	24	8,674	2.03	0.4344%	99.5656
262,144	1	0.03	2.00	5,200,000	2,598,700	[1.00]	131,762	825	130,937	2.11GB	76.20MB	16.83	26	5,191,801	2.04	99.8423%	0.1577
262,144	2	0.06	2.00	5,771,000	2,884,057	[1.11]	132,370	1,540	130,830	2.13GB	100.03MB	16.84	26	1,789,585	2.08	31.0100%	68.9900
262,144	4	0.06	2.00	5,911,000	2,954,022	[1.14]	133,665	2,612	131,053	2.16GB	124.19MB	16.84	26	480,675	2.08	8.1319%	91.8681
262,144	8	0.06	2.00	4,524,000	2,259,740	[0.87]	134,482	3,279	131,203	2.18GB	148.24MB	16.81	25	122,462	2.07	2.7069%	97.2931
262,144	16	0.03	2.00	3,619,000	1,804,987	[0.69]	135,588	4,465	131,123	2.20GB	172.29MB	16.78	26	7,651	2.04	0.2114%	99.7886
262,144	32	0.03	2.02	1,961,000	968,873	[0.37]	135,528	4,380	131,148	2.22GB	196.00MB	16.70	26	3,597	2.06	0.1834%	99.8166
1,048,576	1	0.10	2.00	3,406,000	1,702,148	[1.00]	525,116	155	524,961	2.32GB	291.28MB	18.58	27	3,385,218	2.15	99.3898%	0.6102
1,048,576	2	0.15	2.00	4,580,000	2,288,855	[1.34]	526,587	1,759	524,828	2.41GB	387.59MB	18.62	27	1,129,857	2.19	24.6694%	75.3306
1,048,576	4	0.15	2.00	4,469,000	2,232,267	[1.31]	526,146	1,970	524,176	2.50GB	483.30MB	18.62	26	190,843	2.20	4.2704%	95.7296
1,048,576	8	0.16	2.00	4,092,000	2,043,956	[1.20]	526,850	2,479	524,371	2.60GB	579.53MB	18.60	26	37,250	2.19	0.9103%	99.0897
1,048,576	16	0.10	2.00	3,352,000	1,671,820	[0.98]	528,627	5,164	523,463	2.69GB	675.70MB	18.58	27	3,000	2.14	0.0895%	99.9105
1,048,576	32	0.10	2.01	1,926,000	958,208	[0.56]	529,167	3,760	525,407	2.78GB	771.47MB	18.51	25	1,332	2.14	0.0692%	99.9308

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Advanced Computer Architecture

Tutorial 2

Method = 3 - Attempts = 4

maxKey	nt	pft	rt	ops	ops/s	rel	nMalloc	nFree	ntree	vmUse	memUse	avgD	maxD	commit	tt	Commit%	Abort%
16	1	0.00	2.00	37,199,000	18,590,204	[1.00]	17	10	7	86.91MB	1.64MB	3.22	12	37,199,000	2.00	100.0000%	0.0000
16	2	0.00	2.00	15,129,000	7,560,719	[0.41]	3,486	3,480	6	158.92MB	2.27MB	3.20	11	12,781,188	2.00	84.4814%	15.5186
16	4	0.00	2.00	9,520,000	4,757,621	[0.26]	4,459	4,448	11	302.93MB	2.96MB	3.20	10	4,456,220	2.00	46.8090%	53.1910
16	8	0.00	2.00	4,482,000	2,239,880	[0.12]	2,945	2,938	7	494.93MB	4.96MB	3.19	10	818,422	2.00	18.2602%	81.7398
16	16	0.00	2.00	4,236,000	2,113,772	[0.11]	4,599	4,592	7	1.05GB	5.49MB	3.18	10	395,883	2.00	9.3457%	90.6543
16	32	0.00	2.01	2,385,000	1,187,749	[0.06]	4,809	4,802	7	2.05GB	6.25MB	3.18	10	214,902	2.01	9.0106%	90.9894
64	1	0.00	2.00	34,454,000	17,218,390	[1.00]	53	19	34	2.05GB	6.26MB	5.43	16	34,454,000	2.00	100.0000%	0.0000
64	2	0.00	2.00	14,822,000	7,407,296	[0.43]	1,447	1,411	36	2.05GB	6.50MB	5.42	15	12,566,390	2.00	84.7820%	15.2180
64	4	0.00	2.00	10,279,000	5,136,931	[0.30]	2,967	2,939	28	2.05GB	6.81MB	5.42	15	4,880,385	2.00	47.4792%	52.5208
64	8	0.00	2.00	4,762,000	2,378,621	[0.14]	3,105	3,077	28	2.05GB	6.90MB	5.42	14	911,018	2.00	19.1310%	80.8690
64	16	0.00	2.00	4,622,000	2,306,387	[0.13]	4,729	4,695	34	2.05GB	7.34MB	5.40	15	409,649	2.00	8.8630%	91.1370
64	32	0.00	2.01	2,379,000	1,185,351	[0.07]	4,702	4,668	34	2.05GB	7.78MB	5.41	14	199,319	2.01	8.3783%	91.6217
256	1	0.00	2.00	29,222,000	14,603,698	[1.00]	167	43	124	2.05GB	7.78MB	8.40	21	29,222,000	2.00	100.0000%	0.0000
256	2	0.00	2.00	14,415,000	7,203,898	[0.49]	4,379	4,252	127	2.05GB	8.39MB	8.38	22	12,134,791	2.00	84.1817%	15.8183
256	4	0.00	2.00	9,921,000	4,958,020	[0.34]	3,301	3,158	143	2.05GB	8.64MB	8.43	21	4,546,199	2.00	45.8240%	54.1760
256	8	0.00	2.00	6,242,000	3,119,440	[0.21]	3,984	3,858	126	2.05GB	8.85MB	8.41	21	1,291,833	2.00	20.6958%	79.3042
256	16	0.00	2.00	4,840,000	2,416,375	[0.17]	4,957	4,830	127	2.05GB	9.07MB	8.42	20	607,790	2.00	12.5576%	87.4424
256	32	0.00	2.01	2,630,000	1,310,413	[0.09]	5,635	5,514	121	2.05GB	9.31MB	8.34	20	184,238	2.01	7.0052%	92.9948
1,024	1	0.00	2.00	24,000,000	11,994,002	[1.00]	586	78	508	2.05GB	9.31MB	13.02	32	24,000,000	2.00	100.0000%	0.0000
1,024	2	0.00	2.00	12,549,000	6,271,364	[0.52]	2,054	1,531	523	2.05GB	9.41MB	13.12	32	10,692,120	2.00	85.2030%	14.7970
1,024	4	0.00	2.00	8,923,000	4,459,270	[0.37]	3,712	3,214	498	2.05GB	9.65MB	12.85	31	3,771,768	2.00	42.2702%	57.7298
1,024	8	0.00	2.00	4,744,000	2,369,630	[0.20]	4,074	3,561	513	2.05GB	9.87MB	12.84	32	711,516	2.00	14.9982%	85.0018
1,024	16	0.00	2.00	4,446,000	2,219,670	[0.19]	5,285	4,783	502	2.05GB	9.97MB	12.89	32	438,830	2.00	9.8702%	90.1298
1,024	32	0.00	2.03	1,903,000	938,362	[0.08]	4,356	3,853	503	2.05GB	10.09MB	12.31	31	93,399	2.03	4.9080%	95.0920
4,096	1	0.00	2.00	15,909,000	7,950,524	[1.00]	2,173	157	2,016	2.05GB	10.34MB	15.71	51	15,909,000	2.00	100.0000%	0.0000
4,096	2	0.00	2.00	10,855,000	5,424,787	[0.68]	4,196	2,062	2,134	2.05GB	10.83MB	13.86	43	8,956,911	2.00	82.5142%	17.4858
4,096	4	0.00	2.00	8,185,000	4,090,454	[0.51]	4,607	2,578	2,029	2.05GB	11.18MB	13.15	41	3,206,039	2.00	39.1697%	60.8303
4,096	8	0.00	2.00	5,937,000	2,965,534	[0.37]	5,652	3,631	2,021	2.05GB	11.48MB	12.33	36	1,244,815	2.00	20.9671%	79.0329
4,096	16	0.00	2.00	4,405,000	2,199,201	[0.28]	6,951	4,890	2,061	2.05GB	11.72MB	12.15	38	282,589	2.00	6.4152%	93.5848
4,096	32	0.00	2.02	2,565,000	1,268,545	[0.16]	6,543	4,495	2,048	2.05GB	11.84MB	11.46	31	157,548	2.02	6.1422%	93.8578
16,384	1	0.00	2.00	10,003,000	4,999,000	[1.00]	8,448	120	8,328	2.05GB	12.87MB	13.28	29	10,003,000	2.00	100.0000%	0.0000
16,384	2	0.01	2.00	8,079,000	4,037,481	[0.81]	9,006	867	8,139	2.05GB	14.42MB	13.25	29	6,426,283	2.01	79.5430%	20.4570
16,384	4	0.00	2.00	7,810,000	3,903,048	[0.78]	10,485	2,313	8,172	2.05GB	15.86MB	13.23	28	3,040,551	2.01	38.9315%	61.0685
16,384	8	0.00	2.00	5,319,000	2,658,170	[0.53]	12,216	4,107	8,109	2.05GB	17.50MB	13.14	24	779,460	2.00	14.6543%	85.3457
16,384	16	0.00	2.00	4,273,000	2,132,235	[0.43]	12,271	4,145	8,126	2.05GB	18.62MB	13.14	24	243,861	2.00	5.7070%	94.2930
16,384	32	0.00	2.01	2,038,000	1,014,435	[0.20]	12,220	4,037	8,183	2.05GB	19.77MB	13.03	22	34,033	2.01	1.6699%	98.3301
65,536	1	0.01	2.00	7,041,000	3,518,740	[1.00]	33,185	128	33,057	2.06GB	25.22MB	15.01	25	7,041,000	2.01	100.0000%	0.0000
65,536	2	0.02	2.00	6,959,000	3,477,761	[0.99]	34,405	1,601	32,804	2.07GB	31.30MB	15.02	27	5,958,024	2.02	85.6161%	14.3839
65,536	4	0.02	2.00	6,949,000	3,472,763	[0.99]	35,751	2,758	32,993	2.07GB	37.11MB	15.01	25	2,505,742	2.02	36.0590%	63.9410
65,536	8	0.01	2.00	4,656,000	2,325,674	[0.66]	35,540	2,766	32,774	2.08GB	43.00MB	14.97	24	475,617	2.02	10.2151%	89.7849
65,536	16	0.01	2.00	4,157,000	2,074,351	[0.59]	37,239	4,401	32,838	2.08GB	48.93MB	14.96	24	130,631	2.01	3.1424%	96.8576
65,536	32	0.01	2.03	1,995,000	984,698	[0.28]	37,400	4,617	32,783	2.09GB	54.57MB	14.87	25	18,505	2.03	0.9276%	99.0724
262,144	1	0.02	2.00	4,816,000	2,406,796	[1.00]	131,854	1,050	130,804	2.11GB	77.90MB	16.81	25	4,816,000	2.04	100.0000%	0.0000
262,144	2	0.05	2.00	6,180,000	3,088,455	[1.28]	132,332	1,310	131,022	2.13GB	101.84MB	16.85	26	5,768,021	2.06	93.3337%	6.6663
262,144	4	0.05	2.00	6,107,000	3,051,974	[1.27]	133,365	2,426	130,939	2.16GB	125.77MB	16.84	26	2,132,542	2.06	34.9196%	65.0804
262,144	8	0.05	2.00	5,058,000	2,526,473	[1.05]	133,847	3,053	130,794	2.18GB	149.82MB	16.82	26	383,593	2.06	7.5839%	92.4161
262,144	16	0.02	2.00	3,887,000	1,940,589	[0.81]	135,726	4,468	131,258	2.20GB	173.89MB	16.79	26	40,702	2.04	1.0471%	98.9529
262,144	32	0.02	2.01	2,071,000	1,031,374	[0.43]	135,498	4,273	131,225	2.22GB	197.45MB	16.71	24	29,456	2.04	1.4223%	98.5777
1,048,576	1	0.09	2.00	2,578,000	1,288,355	[1.00]	525,064	881	524,183	2.32GB	292.72MB	18.54	26	2,577,974	2.14	99.9990%	0.0010
1,048,576	2	0.14	2.00	3,874,000	1,936,031	[1.50]	525,503	1,331	524,172	2.41GB	388.74MB	18.60	26	3,762,058	2.18	97.1104%	2.8896
1,048,576	4	0.14	2.00	4,349,000	2,172,327	[1.69]	526,391	3,360	523,031	2.50GB	484.68MB	18.61	28	1,312,700	2.18	30.1840%	69.8160
1,048,576	8	0.14	2.00	3,976,000	1,985,022	[1.54]	527,486	3,027	524,459	2.60GB	580.64MB	18.60	26	148,803	2.18	3.7425%	96.2575
1,048,576	16	0.09	2.00	3,171,000	1,582,335	[1.23]	528,123	4,110	524,013	2.69GB	676.58MB	18.57	26	28,608	2.12	0.9022%	99.0978
1,048,576	32	0.09	2.03	1,881,000	928,430	[0.72]	529,145	4,017	525,128	2.78GB	772.53MB	18.51	25	6,076	2.14	0.3230%	99.6770

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Advanced Computer Architecture

Tutorial 2

Method = 3 - Attempts = 16

maxKey	nt	pft	rt	ops	ops/s	rel	nMalloc	nFree	ntree	vmUse	memUse	avgD	maxD	commit	tt	Commit%	Abort%
16	1	0.00	2.00	37,098,000	18,539,730	[1.00]	17	11	6	86.91MB	1.57MB	3.22	11	37,098,000	2.00	100.0000%	0.0000
16	2	0.00	2.00	21,843,000	10,916,041	[0.59]	4,893	4,883	10	158.92MB	2.45MB	3.20	11	21,685,783	2.00	99.2802%	0.7198
16	4	0.00	2.00	13,378,000	6,685,657	[0.36]	5,954	5,948	6	302.93MB	3.48MB	3.17	11	12,921,915	2.00	96.5908%	3.4092
16	8	0.00	2.00	7,681,000	3,836,663	[0.21]	5,472	5,461	11	558.93MB	5.96MB	3.15	10	6,366,416	2.00	82.8852%	17.1148
16	16	0.00	2.00	5,943,000	2,967,049	[0.16]	6,115	6,104	11	1.05GB	6.70MB	3.12	10	3,344,437	2.00	56.2752%	43.7248
16	32	0.00	2.01	3,867,000	1,927,716	[0.10]	6,219	6,209	10	2.05GB	7.42MB	3.12	10	2,165,373	2.01	55.9962%	44.0038
64	1	0.00	2.00	34,450,000	17,216,391	[1.00]	52	24	28	2.05GB	7.42MB	5.43	16	34,450,000	2.00	100.0000%	0.0000
64	2	0.00	2.00	18,988,000	9,489,255	[0.55]	2,112	2,076	36	2.05GB	7.64MB	5.42	16	18,904,056	2.00	99.5579%	0.4421
64	4	0.00	2.00	11,709,000	5,851,574	[0.34]	3,198	3,169	29	2.05GB	7.75MB	5.40	14	11,461,555	2.00	97.8867%	2.1133
64	8	0.00	2.00	7,771,000	3,883,558	[0.23]	5,116	5,087	29	2.05GB	8.12MB	5.38	15	6,674,770	2.00	85.8933%	14.1067
64	16	0.00	2.00	5,909,000	2,950,074	[0.17]	5,915	5,891	24	2.05GB	8.50MB	5.38	14	3,468,351	2.00	58.6961%	41.3039
64	32	0.00	2.01	4,125,000	2,056,331	[0.12]	6,544	6,509	35	2.05GB	9.02MB	5.38	14	2,493,750	2.01	60.4545%	39.5455
256	1	0.00	2.00	29,266,000	14,625,687	[1.00]	165	55	110	2.05GB	9.02MB	8.41	21	29,266,000	2.00	100.0000%	0.0000
256	2	0.00	2.00	16,773,000	8,382,308	[0.57]	2,588	2,471	117	2.05GB	9.40MB	8.41	20	16,736,884	2.00	99.7847%	0.2153
256	4	0.00	2.00	11,328,000	5,661,169	[0.39]	3,185	3,056	129	2.05GB	9.42MB	8.42	21	11,242,583	2.00	99.2460%	0.7540
256	8	0.00	2.00	8,715,000	4,355,322	[0.30]	4,166	4,032	134	2.05GB	9.55MB	8.39	20	8,162,568	2.00	93.6611%	6.3389
256	16	0.00	2.00	8,127,000	4,059,440	[0.28]	6,112	5,978	134	2.05GB	9.74MB	8.40	21	6,339,344	2.00	78.0035%	21.9965
256	32	0.00	2.00	4,384,000	2,186,533	[0.15]	7,206	7,088	118	2.05GB	10.00MB	8.36	20	2,883,917	2.01	65.7828%	34.2172
1,024	1	0.00	2.00	23,961,000	11,974,512	[1.00]	587	77	510	2.05GB	10.00MB	13.06	32	23,961,000	2.00	100.0000%	0.0000
1,024	2	0.00	2.00	13,480,000	6,736,631	[0.56]	2,249	1,739	510	2.05GB	10.14MB	12.79	33	13,463,733	2.00	99.8793%	0.1207
1,024	4	0.00	2.00	10,414,000	5,204,397	[0.43]	4,441	3,951	490	2.05GB	10.21MB	12.98	32	10,334,943	2.00	99.2409%	0.7591
1,024	8	0.00	2.00	9,098,000	4,546,726	[0.38]	5,148	4,674	474	2.05GB	10.54MB	12.79	33	8,662,555	2.00	95.2138%	4.7862
1,024	16	0.00	2.00	7,171,000	3,580,129	[0.30]	6,643	6,133	510	2.05GB	10.74MB	12.87	31	5,172,272	2.00	72.1276%	27.8724
1,024	32	0.00	2.00	5,195,000	2,592,315	[0.22]	7,643	7,122	521	2.05GB	10.84MB	12.66	30	3,730,233	2.00	71.8043%	28.1957
4,096	1	0.00	2.00	15,739,000	7,865,567	[1.00]	2,180	157	2,023	2.05GB	11.09MB	15.80	49	15,739,000	2.00	100.0000%	0.0000
4,096	2	0.00	2.00	11,296,000	5,645,177	[0.72]	3,690	1,676	2,014	2.05GB	11.35MB	14.16	44	11,286,042	2.00	99.9118%	0.0882
4,096	4	0.00	2.00	10,177,000	5,085,957	[0.65]	6,058	4,009	2,049	2.05GB	11.65MB	13.69	42	10,143,536	2.00	99.6712%	0.3288
4,096	8	0.00	2.00	7,612,000	3,804,097	[0.48]	6,667	4,560	2,107	2.05GB	12.06MB	12.84	37	7,105,477	2.00	93.3457%	6.6543
4,096	16	0.00	2.00	8,231,000	4,109,335	[0.52]	7,699	5,725	1,974	2.05GB	12.19MB	13.02	39	6,779,236	2.00	82.3622%	17.6378
4,096	32	0.00	2.00	7,060,000	3,521,197	[0.45]	9,574	7,499	2,075	2.05GB	12.25MB	12.94	40	5,924,488	2.01	83.9163%	16.0837
16,384	1	0.00	2.00	10,413,000	5,203,898	[1.00]	8,447	139	8,308	2.05GB	13.28MB	13.30	31	10,413,000	2.00	100.0000%	0.0000
16,384	2	0.01	2.00	9,085,000	4,540,229	[0.87]	9,620	1,473	8,147	2.05GB	14.91MB	13.24	27	9,084,949	2.01	99.9994%	0.0006
16,384	4	0.00	2.00	9,079,000	4,537,231	[0.87]	11,270	3,168	8,102	2.05GB	16.37MB	13.22	29	9,070,125	2.01	99.9022%	0.0978
16,384	8	0.01	2.00	8,765,000	4,380,309	[0.84]	12,705	4,405	8,300	2.05GB	17.74MB	13.27	32	8,639,577	2.01	98.5690%	1.4310
16,384	16	0.00	2.00	6,863,000	3,428,071	[0.66]	14,604	6,433	8,171	2.05GB	18.87MB	13.19	29	5,552,067	2.00	80.8985%	19.1015
16,384	32	0.00	2.00	5,433,000	2,709,725	[0.52]	15,505	7,236	8,269	2.05GB	19.67MB	13.19	27	4,388,326	2.01	80.7717%	19.2283
65,536	1	0.01	2.00	7,621,000	3,808,595	[1.00]	33,158	323	32,835	2.06GB	24.87MB	15.02	25	7,621,000	2.01	100.0000%	0.0000
65,536	2	0.02	2.00	7,660,000	3,828,085	[1.01]	34,971	2,371	32,600	2.06GB	31.11MB	15.02	24	7,659,187	2.02	99.9894%	0.0106
65,536	4	0.02	2.00	7,733,000	3,864,567	[1.01]	35,237	2,285	32,952	2.07GB	36.74MB	15.02	26	7,728,970	2.02	99.9479%	0.0521
65,536	8	0.01	2.00	8,355,000	4,173,326	[1.10]	37,918	5,077	32,841	2.08GB	43.26MB	15.04	25	8,264,906	2.01	98.9217%	1.0783
65,536	16	0.01	2.00	6,696,000	3,341,317	[0.88]	38,587	5,942	32,645	2.08GB	48.84MB	15.00	25	5,469,111	2.01	81.6773%	18.3227
65,536	32	0.01	2.00	7,232,000	3,606,982	[0.95]	40,427	7,575	32,852	2.09GB	54.50MB	15.02	24	6,599,643	2.01	91.2561%	8.7439
262,144	1	0.03	2.00	5,158,000	2,577,711	[1.00]	131,522	597	130,925	2.11GB	77.22MB	16.83	26	5,158,000	2.03	100.0000%	0.0000
262,144	2	0.06	2.00	6,556,000	3,276,361	[1.27]	132,369	1,314	131,055	2.13GB	101.40MB	16.85	26	6,556,000	2.07	100.0000%	0.0000
262,144	4	0.06	2.00	7,006,000	3,501,249	[1.36]	133,249	2,339	130,910	2.15GB	125.39MB	16.86	27	7,005,496	2.07	99.9928%	0.0072
262,144	8	0.03	2.00	7,641,000	3,816,683	[1.48]	135,216	3,784	131,432	2.18GB	149.54MB	16.87	26	7,587,419	2.04	99.2988%	0.7012
262,144	16	0.03	2.00	7,792,000	3,892,107	[1.51]	137,159	6,419	130,740	2.20GB	173.64MB	16.87	26	7,203,135	2.04	92.4427%	7.5573
262,144	32	0.03	2.00	7,310,000	3,645,885	[1.41]	139,160	8,434	130,726	2.22GB	197.45MB	16.86	28	6,719,199	2.04	91.9179%	8.0821
1,048,576	1	0.10	2.00	3,691,000	1,844,577	[1.00]	525,026	218	524,808	2.31GB	291.80MB	18.59	27	3,691,000	2.15	100.0000%	0.0000
1,048,576	2	0.15	2.00	4,964,000	2,480,759	[1.34]	526,100	862	525,238	2.41GB	387.94MB	18.63	27	4,964,000	2.20	100.0000%	0.0000
1,048,576	4	0.15	2.00	5,458,000	2,727,636	[1.48]	526,121	2,064	524,057	2.50GB	483.74MB	18.65	28	5,457,737	2.20	99.9952%	0.0048
1,048,576	8	0.14	2.00	6,354,000	3,173,826	[1.72]	528,272	4,221	524,051	2.59GB	580.16MB	18.67	27	6,291,106	2.18	99.0102%	0.9898
1,048,576	16	0.10	2.00	6,368,000	3,179,231	[1.72]	530,088	5,013	525,075	2.69GB	676.11MB	18.67	27	5,559,230	2.14	87.2995%	12.7005
1,048,576	32	0.10	2.01	5,643,000	2,813,060	[1.53]	531,376	6,955	524,421	2.78GB	772.26MB	18.65	27	4,889,309	2.14	86.6438%	13.3562

Breandan Kerin 1431016 30th November 2018

Advanced Computer Architecture

Tutorial 2

Method = 3 - Attempts = 32

maxKey	nt	pft	rt	ops	ops/s	rel	nMalloc	nFree	ntree	vmUse	memUse	avgD	maxD	commit	tt	Commit%	Abort%
16	1	0.00	2.00	37,104,000	18,542,728	[1.00]	17	9	8	86.91MB	1.69MB	3.21	11	37,104,000	2.00	100.0000%	0.0000
16	2	0.00	2.00	30,478,000	15,231,384	[0.82]	2,664	2,656	8	158.92MB	2.17MB	3.21	11	30,423,870	2.00	99.8224%	0.1776
16	4	0.00	2.00	16,757,000	8,374,312	[0.45]	7,052	7,044	8	302.93MB	3.04MB	3.19	11	16,651,442	2.00	99.3701%	0.6299
16	8	0.00	2.00	10,471,000	5,232,883	[0.28]	5,681	5,673	8	558.93MB	5.21MB	3.14	10	10,216,266	2.00	97.5672%	2.4328
16	16	0.00	2.00	7,391,000	3,691,808	[0.20]	6,348	6,340	8	1.05GB	6.03MB	3.06	10	6,973,506	2.00	94.3513%	5.6487
16	32	0.00	2.00	7,151,000	3,568,363	[0.19]	7,796	7,788	8	2.05GB	7.05MB	3.05	10	6,760,023	2.00	94.5326%	5.4674
64	1	0.00	2.00	34,483,000	17,232,883	[1.00]	54	25	29	2.05GB	7.05MB	5.43	16	34,483,000	2.00	100.0000%	0.0000
64	2	0.00	2.00	21,161,000	10,575,212	[0.61]	1,715	1,680	35	2.05GB	7.26MB	5.42	16	21,143,074	2.00	99.9153%	0.0847
64	4	0.00	2.00	13,922,000	6,957,521	[0.40]	8,170	8,140	30	2.05GB	8.59MB	5.41	15	13,883,533	2.00	99.7237%	0.2763
64	8	0.00	2.00	8,761,000	4,376,123	[0.25]	5,947	5,919	28	2.05GB	9.24MB	5.37	14	8,645,773	2.00	98.6848%	1.3152
64	16	0.00	2.00	7,344,000	3,668,331	[0.21]	5,514	5,483	31	2.05GB	9.49MB	5.34	14	7,063,961	2.00	96.1868%	3.8132
64	32	0.00	2.00	7,227,000	3,604,488	[0.21]	7,635	7,607	28	2.05GB	9.89MB	5.32	14	6,983,656	2.00	96.6328%	3.3672
256	1	0.00	2.00	29,272,000	14,628,685	[1.00]	169	45	124	2.05GB	9.90MB	8.36	21	29,272,000	2.00	100.0000%	0.0000
256	2	0.00	2.00	17,605,000	8,798,100	[0.60]	1,903	1,775	128	2.05GB	10.11MB	8.38	21	17,600,844	2.00	99.9764%	0.0236
256	4	0.00	2.00	12,534,000	6,263,868	[0.43]	2,697	2,557	140	2.05GB	10.25MB	8.41	20	12,522,884	2.00	99.9113%	0.0887
256	8	0.00	2.00	8,909,000	4,452,273	[0.30]	4,092	3,957	135	2.05GB	10.48MB	8.39	21	8,878,156	2.00	99.6538%	0.3462
256	16	0.00	2.00	6,851,000	3,422,077	[0.23]	5,572	5,421	151	2.05GB	10.71MB	8.32	20	6,684,803	2.00	97.5741%	2.4259
256	32	0.00	2.00	7,868,000	3,926,147	[0.27]	8,434	8,305	129	2.05GB	10.88MB	8.37	21	7,756,548	2.00	98.5835%	1.4165
1,024	1	0.00	2.00	23,983,000	11,985,507	[1.00]	591	85	506	2.05GB	10.88MB	13.08	32	23,983,000	2.00	100.0000%	0.0000
1,024	2	0.00	2.00	14,554,000	7,273,363	[0.61]	2,524	2,008	516	2.05GB	10.91MB	12.73	32	14,553,349	2.00	99.9955%	0.0045
1,024	4	0.00	2.00	10,897,000	5,445,777	[0.45]	2,922	2,430	492	2.05GB	10.91MB	12.92	31	10,893,175	2.00	99.9649%	0.0351
1,024	8	0.00	2.00	9,210,000	4,602,698	[0.38]	5,537	5,039	498	2.05GB	11.14MB	12.84	32	9,188,807	2.00	99.7699%	0.2301
1,024	16	0.00	2.00	8,768,000	4,379,620	[0.37]	6,165	5,680	485	2.05GB	11.18MB	13.11	32	8,616,601	2.00	98.2733%	1.7267
1,024	32	0.00	2.00	8,301,000	4,142,215	[0.35]	9,310	8,770	540	2.05GB	11.26MB	12.76	31	8,152,456	2.00	98.2105%	1.7895
4,096	1	0.00	2.00	16,012,000	8,001,999	[1.00]	2,182	150	2,032	2.05GB	11.51MB	15.25	51	16,012,000	2.00	100.0000%	0.0000
4,096	2	0.00	2.00	11,047,000	5,520,739	[0.69]	4,082	2,011	2,071	2.05GB	11.96MB	14.52	46	11,046,973	2.00	99.9998%	0.0002
4,096	4	0.00	2.00	10,258,000	5,126,436	[0.64]	5,388	3,320	2,068	2.05GB	12.56MB	13.40	40	10,256,870	2.00	99.9890%	0.0110
4,096	8	0.00	2.00	9,166,000	4,580,709	[0.57]	6,848	4,843	2,005	2.05GB	12.85MB	13.71	45	9,143,623	2.00	99.7559%	0.2441
4,096	16	0.00	2.00	8,544,000	4,265,601	[0.53]	8,919	6,801	2,118	2.05GB	13.03MB	12.96	41	8,404,491	2.00	98.3672%	1.6328
4,096	32	0.00	2.00	8,447,000	4,212,967	[0.53]	10,728	8,664	2,064	2.05GB	13.16MB	13.07	41	8,338,805	2.01	98.7191%	1.2809
16,384	1	0.00	2.00	10,409,000	5,201,899	[1.00]	8,462	332	8,130	2.05GB	14.18MB	13.31	31	10,409,000	2.00	100.0000%	0.0000
16,384	2	0.01	2.00	9,216,000	4,605,697	[0.89]	9,917	1,704	8,213	2.05GB	15.73MB	13.24	29	9,215,973	2.01	99.9997%	0.0003
16,384	4	0.01	2.00	9,047,000	4,521,239	[0.87]	12,406	4,164	8,242	2.05GB	17.04MB	13.26	28	9,046,999	2.01	100.0000%	0.0000
16,384	8	0.01	2.00	8,835,000	4,415,292	[0.85]	11,702	3,506	8,196	2.05GB	18.26MB	13.26	29	8,833,810	2.01	99.9865%	0.0135
16,384	16	0.00	2.00	8,666,000	4,328,671	[0.83]	14,960	6,738	8,222	2.05GB	19.45MB	13.26	29	8,655,576	2.01	99.8797%	0.1203
16,384	32	0.00	2.00	8,588,000	4,285,429	[0.82]	16,082	7,812	8,270	2.05GB	20.35MB	13.24	28	8,580,635	2.01	99.9142%	0.0858
65,536	1	0.01	2.00	7,599,000	3,797,601	[1.00]	33,200	413	32,787	2.06GB	25.50MB	15.03	25	7,599,000	2.01	100.0000%	0.0000
65,536	2	0.02	2.00	7,282,000	3,639,180	[0.96]	34,298	1,633	32,665	2.06GB	31.53MB	15.02	28	7,282,000	2.02	100.0000%	0.0000
65,536	4	0.02	2.00	7,966,000	3,981,009	[1.05]	35,344	2,581	32,763	2.07GB	37.60MB	15.02	25	7,966,000	2.02	100.0000%	0.0000
65,536	8	0.02	2.00	8,389,000	4,192,403	[1.10]	36,962	4,232	32,730	2.08GB	43.65MB	15.02	26	8,388,805	2.02	99.9977%	0.0023
65,536	16	0.01	2.00	8,432,000	4,209,685	[1.11]	39,097	6,482	32,615	2.08GB	49.39MB	15.03	25	8,427,365	2.01	99.9450%	0.0550
65,536	32	0.01	2.00	8,329,000	4,154,114	[1.09]	41,966	9,187	32,779	2.09GB	55.00MB	15.03	24	8,327,132	2.01	99.9776%	0.0224
262,144	1	0.03	2.00	5,124,000	2,560,719	[1.00]	131,688	404	131,284	2.11GB	77.52MB	16.82	26	5,124,000	2.04	100.0000%	0.0000
262,144	2	0.06	2.00	6,428,000	3,212,393	[1.25]	132,392	1,216	131,176	2.13GB	101.62MB	16.85	26	6,428,000	2.08	100.0000%	0.0000
262,144	4	0.06	2.00	6,991,000	3,493,753	[1.36]	133,749	2,616	131,133	2.15GB	125.77MB	16.86	25	6,991,000	2.07	100.0000%	0.0000
262,144	8	0.03	2.00	7,691,000	3,841,658	[1.50]	135,010	4,406	130,604	2.18GB	150.01MB	16.87	26	7,690,848	2.04	99.9980%	0.0020
262,144	16	0.03	2.00	7,978,000	3,983,025	[1.56]	137,736	6,331	131,405	2.20GB	174.00MB	16.87	26	7,977,012	2.04	99.9876%	0.0124
262,144	32	0.03	2.00	7,932,000	3,956,109	[1.54]	139,851	8,611	131,240	2.22GB	197.84MB	16.88	28	7,930,762	2.04	99.9844%	0.0156
1,048,576	1	0.10	2.00	3,439,000	1,718,640	[1.00]	524,885	659	524,226	2.31GB	292.30MB	18.58	27	3,439,000	2.15	100.0000%	0.0000
1,048,576	2	0.15	2.00	4,921,000	2,459,270	[1.43]	525,250	1,576	523,674	2.41GB	388.12MB	18.63	27	4,921,000	2.20	100.0000%	0.0000
1,048,576	4	0.15	2.00	5,809,000	2,903,048	[1.69]	527,535	3,699	523,836	2.50GB	484.33MB	18.66	27	5,809,000	2.20	100.0000%	0.0000
1,048,576	8	0.16	2.00	6,843,000	3,418,081	[1.99]	528,034	2,909	525,125	2.59GB	580.38MB	18.68	27	6,842,911	2.19	99.9987%	0.0013
1,048,576	16	0.10	2.00	7,419,000	3,703,944	[2.16]	530,079	6,044	524,035	2.69GB	676.73MB	18.69	27	7,418,618	2.14	99.9949%	0.0051
1,048,576	32	0.10	2.01	7,432,000	3,704,885	[2.16]	532,215	8,329	523,886	2.78GB	772.70MB	18.69	27	7,431,578	2.15	99.9943%	0.0057

Code Snippets:

The code snippets below are samples snippets taken from the “Contains” function - Only these sample snippets were used to prevent wasting paper - The full code can be viewed on my GitHub Account as illustrated on page 1.

HLE Acquire:

```
#elif METHOD == 2
    while (__atomic_exchange_n(&lock, 1, __ATOMIC_ACQUIRE | __ATOMIC_HLE_ACQUIRE)){
                do {
                        _mm_pause();
                } while (lock == 1);
        }
```

HLE Release:

```
#elif METHOD == 2
        __atomic_store_n(&lock, 0, __ATOMIC_RELEASE | __ATOMIC_HLE_RELEASE);
        commitNum++;
#endif
```

Breandan Kerin 1431016 30th November 2018

Advanced Computer Architecture

Tutorial 2

RTM Release:

```
#if METHOD == 3
	if(state == TRANSACTION){
		commitNum++;
		_xend();
	} else {
		abortNum++;
		__atomic_store_n(&lock, 0, __ATOMIC_RELEASE | __ATOMIC_HLE_RELEASE);
	}
#endif
```

RTM Acquire:

```
#elif METHOD == 3
	int state = TRANSACTION;
	int attempt = 1;
	while(1){ // while I dont have a lock/ ability to commit transaction
		UINT status = _XBEGIN_STARTED;
		if (state == TRANSACTION){ // If I can transact
			status = _xbegin();
		} else { // otherwise, grab a lock
			while (__atomic_exchange_n(&lock, 1, __ATOMIC_ACQUIRE | __ATOMIC_HLE_ACQUIRE)){
				do {
					_mm_pause();
				} while (lock == 1);
			}
		}
		if (status == _XBEGIN_STARTED){ // If I can transact
			if(state == TRANSACTION && lock){
				_xabort(0xA0); // abort if lock is already set
			} else {
				break;
			}
		} else {
			// the transaction aborted
			if(lock){
				do{
					_mm_pause();
				} while(lock);
			} else {
				volatile UINT64 wait = attempt << 4; // initialise wait and delay by ...
				while (wait--);
			}

			if (++attempt >= MAXATTEMPT) {
				state = LOCK; // execute non transactionally by obtaining lock
			}
		}
	}
#endif
```