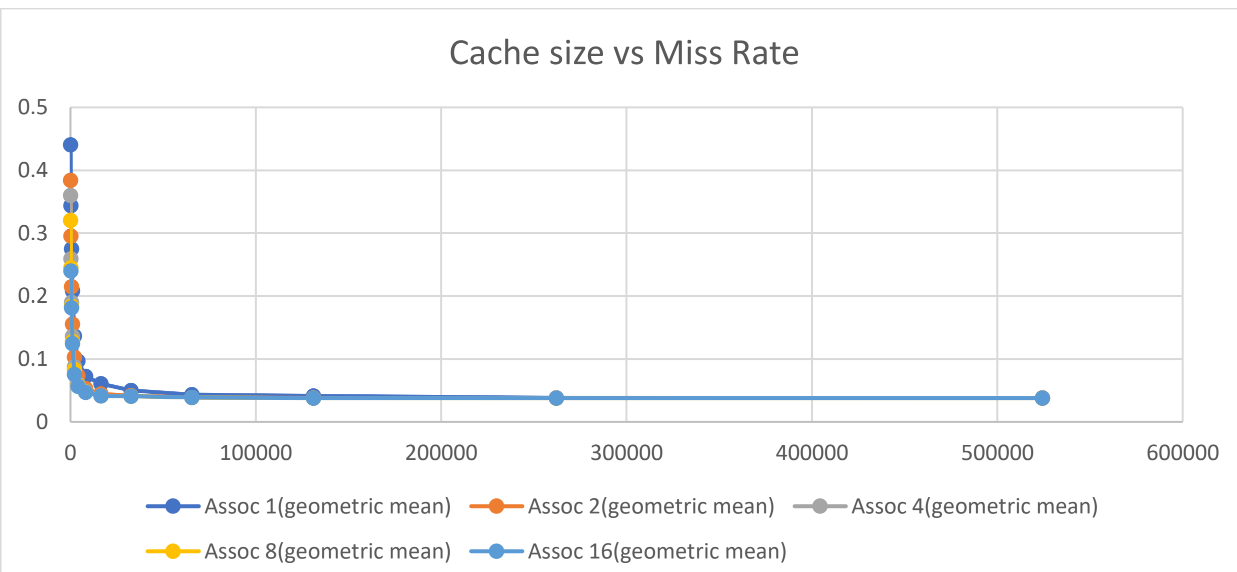
Flexible Cache – Performance Analysis

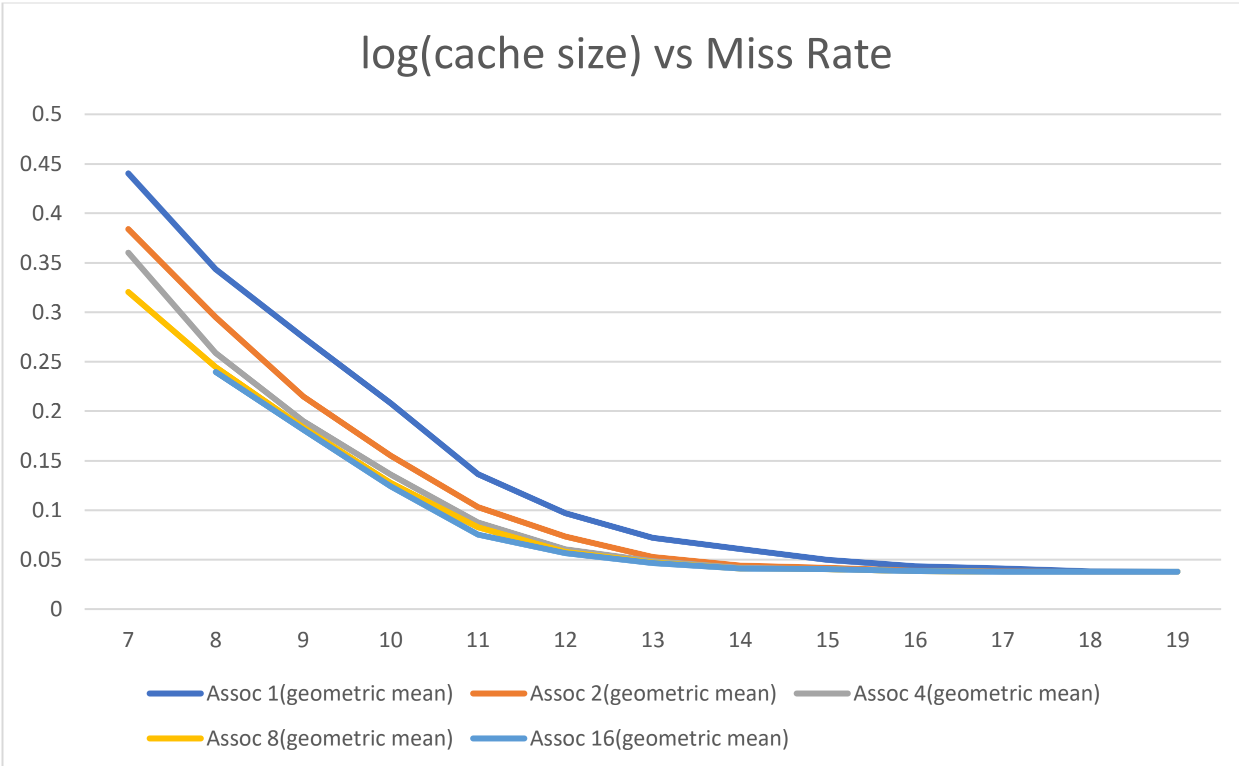
1.Effects of changing various parameters on miss rates

L1 cache size vs miss rate

Keeping constant block size = 16bytes, file – gcc_trace.txt

Cache Size	log(CacheSize)	Assoc 1(geometric mean)	Assoc 2(geometric mean)	Assoc 4(geometric mean)	Assoc 8(geometric mean)	Assoc 16(geometric mean)
128	7	0.440322687	0.384016666	0.360265425	0.320460867	
256	8	0.343506754	0.295211742	0.258967238	0.244707707	0.23958585
512	9	0.274747027	0.214831184	0.190169186	0.183656543	0.181405605
1024	10	0.208089131	0.155156748	0.135965735	0.127657052	0.124257626
2048	11	0.136317895	0.103007881	0.087739305	0.082907104	0.0751653
4096	12	0.096911328	0.073533261	0.060526542	0.057764125	0.056607402
8192	13	0.072120575	0.052851251	0.048394576	0.047213724	0.046651486
16384	14	0.060664405	0.044076945	0.041586674	0.041229021	0.041047319
32768	15	0.049737599	0.041705101	0.040546152	0.040510721	0.040499677
65536	16	0.043341306	0.038879463	0.038642451	0.038452323	0.038551036
131072	17	0.041052528	0.038013909	0.03786931	0.03786931	0.03786931
262144	18	0.038156576	0.037889394	0.03786931	0.03786931	0.03786931
524288	19	0.037932183	0.03786931	0.03786931	0.03786931	0.03786931





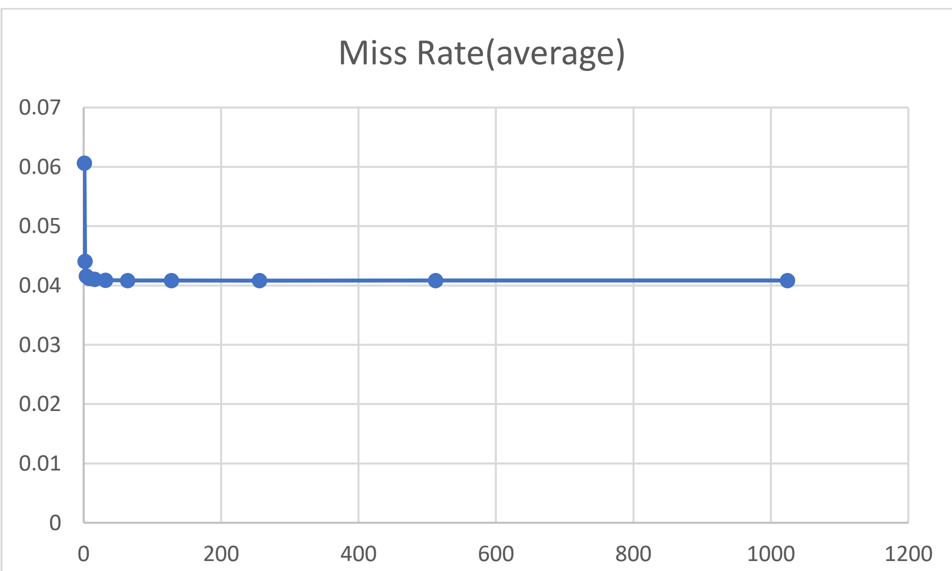
log(cache size) vs Miss Rate
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
8
9
10
11
12
13
14
15
16
17
18
19
Assoc 1(geometric mean)
Assoc 2(geometric mean)
Assoc 4(geometric mean)
Assoc 8(geometric mean)
Assoc 16(geometric mean)

Associativity vs miss rate

Keeping constant cache block size = 16384bytes and block size = 16.

Therefore, for full associativity associativity will be 1024

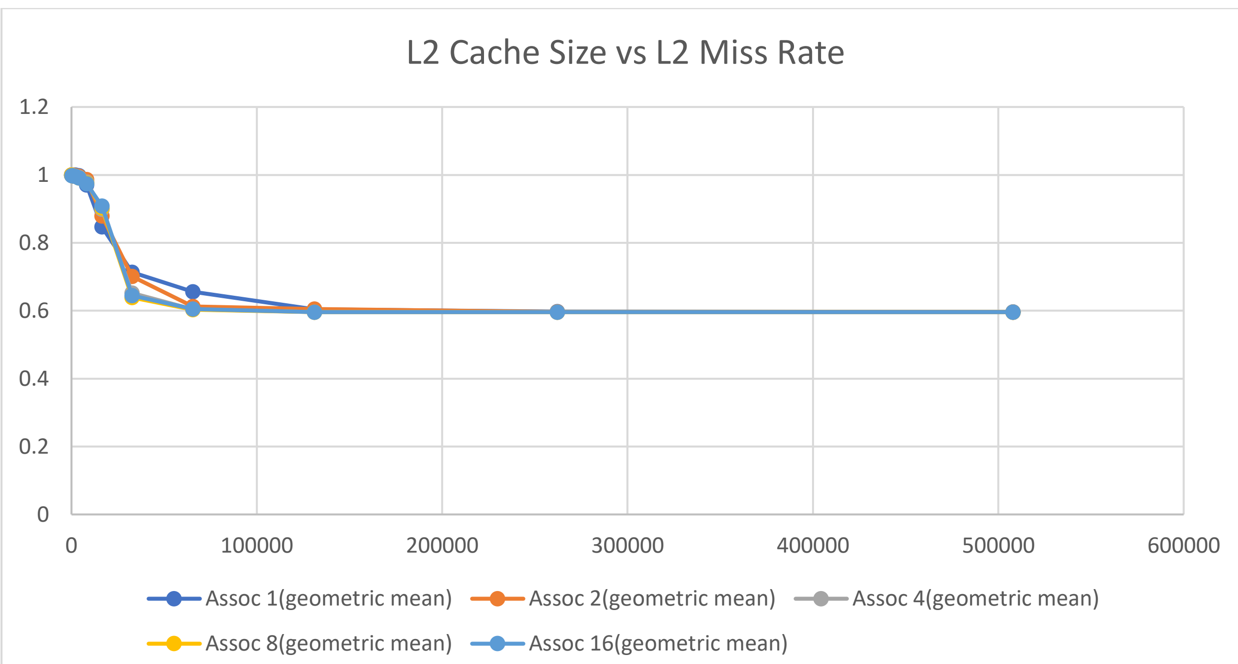
Associativity	Miss Rate(gcc_trace.txt)	Miss Rate (perl_trace.txt)	Miss Rate (go_trace.txt)	Miss Rate (vortex_trace.txt)	Miss Rate(average)
1	0.0672	0.0536	0.1033	0.0364	0.0606644
2	0.0525	0.0297	0.0984	0.0246	0.0440769
4	0.0482	0.0273	0.0984	0.0231	0.0415867
8	0.0477	0.027	0.0984	0.0228	0.041229
16	0.0476	0.0267	0.0984	0.0227	0.0410473
32	0.0476	0.0266	0.0984	0.0225	0.0409182
64	0.0475	0.0265	0.0984	0.0225	0.0408582
128	0.0475	0.0265	0.0984	0.0225	0.0408582
256	0.0475	0.0264	0.0984	0.0225	0.0408196
512	0.0475	0.0265	0.0984	0.0225	0.0408582
1024	0.0475	0.0265	0.0984	0.0225	0.0408582



L2 cache size vs miss rate

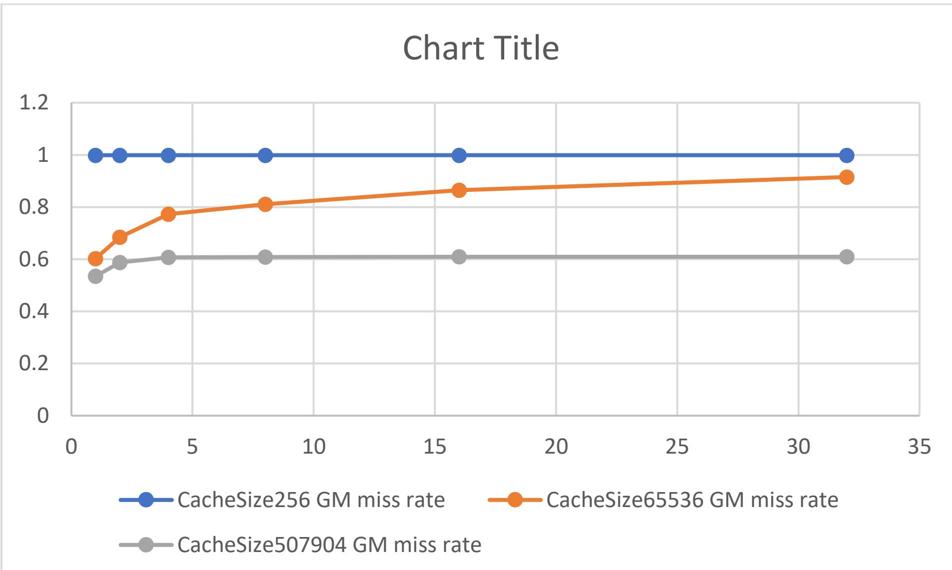
Setting L1 cache size = 16KB

Cache Size	log(CacheSize)	Assoc 1(geometric mean)	Assoc 2(geometric mean)	Assoc 4(geometric mean)	Assoc 8(geometric mean)	Assoc 16(geometric mean)
128	7	1	0.999825	0.99925	0.99965	
256	8	1	0.99975	0.998899	0.998975	0.997947
512	9	1	0.999325	0.997872	0.997822	0.997822
1024	10	0.999925	0.99895	0.997547	0.997148	0.997072
2048	11	0.99935	0.997874	0.996122	0.995521	0.995396
4096	12	0.997346	0.995619	0.992539	0.991233	0.990629
8192	13	0.970253	0.986003	0.978532	0.976178	0.973874
16384	14	0.847332	0.878599	0.898639	0.902777	0.907955
32768	15	0.713702	0.701201	0.651606	0.639295	0.64417
65536	16	0.655483	0.612349	0.604314	0.6027	0.604645
131072	17	0.603744	0.604968	0.595951	0.595951	0.595951
262144	18	0.597432	0.59626	0.595951	0.595951	0.595951
507904	~19	0.596476	0.595951	0.595951	0.595951	0.595951



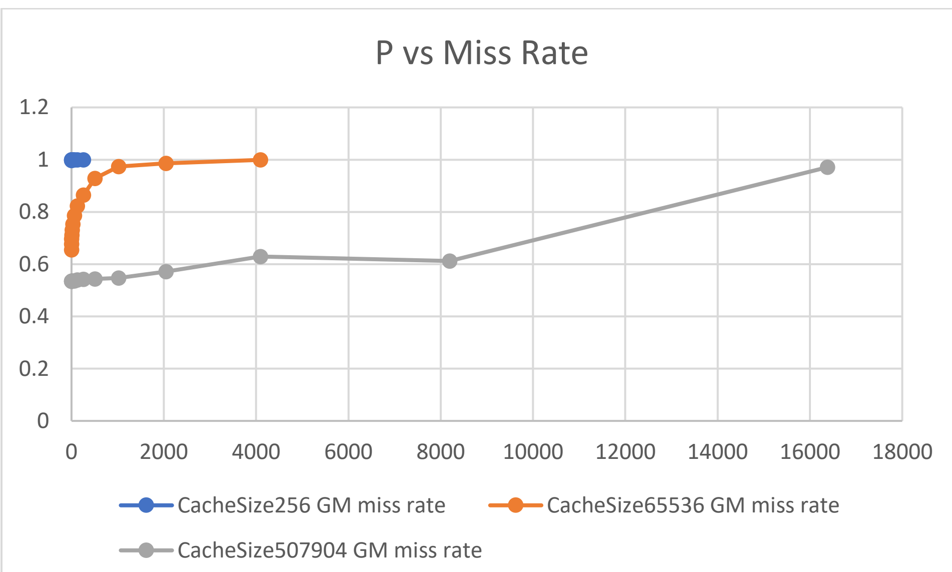
N vs miss rate

N	CacheSize256 GM miss rate	CacheSize65536 GM miss rate	CacheSize507904 GM miss rate
1	0.998799572	0.602699732	0.534637439
2	0.998799572	0.684104081	0.587437821
4	0.998799572	0.772823649	0.606757118
8	0.998799572	0.810663773	0.608395823
16	0.998799572	0.863977826	0.609130239
32	0.998799572	0.915064306	0.609130239



P vs miss rate

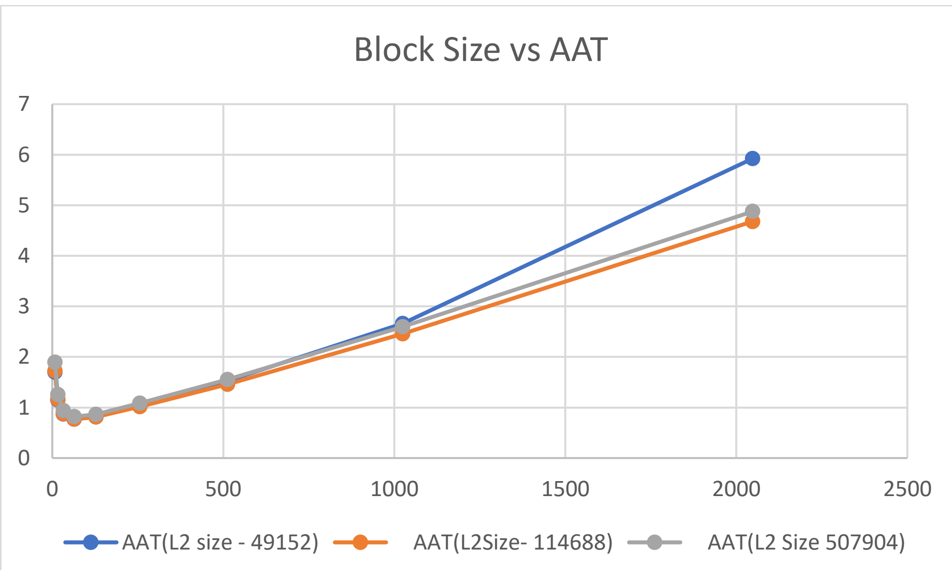
P	CacheSize256 GM miss rate	CacheSize65536 GM miss rate	CacheSize507904 GM miss rate
1	0.997346	0.655483	0.534637
2	0.999375	0.677565	0.534706
4	0.9999	0.696386	0.534797
8	1	0.711787	0.535024
16	1	0.731186	0.535523
32	1	0.752715	0.535975
64	1	0.786717	0.536394
128	1	0.822882	0.539247
256	1	0.863981	0.542722
512		0.928583	0.542788
1024		0.973329	0.547567
2048		0.985447	0.571491
4096		0.999149	0.629597
8192			0.612546
16384			0.970978



2. Design space and noteworthy trends

Block size vs AAT while keeping L2 size constant (for gcc_trace)

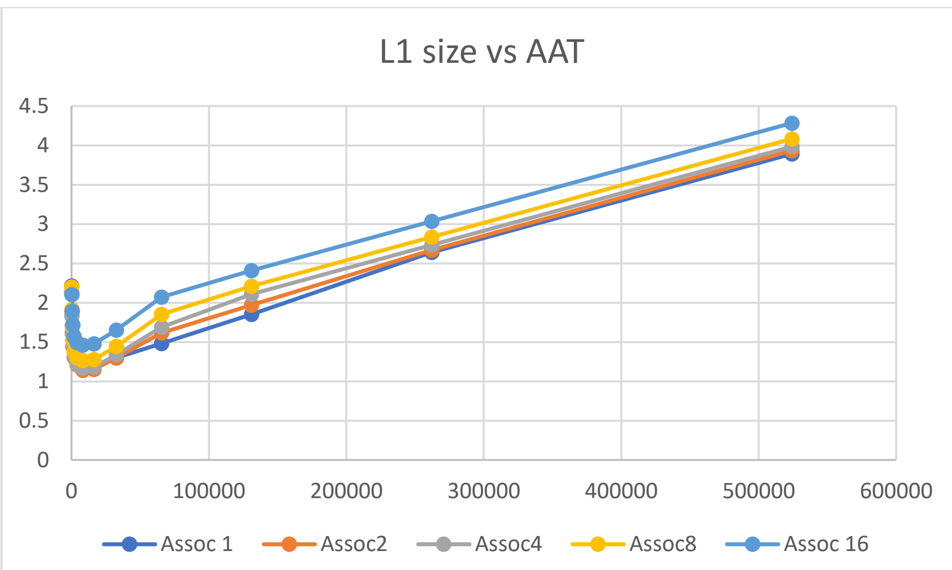
BlockSize	AAT(L2 size - 49152)	AAT(L2Size- 114688)	AAT(L2 Size 507904)
8	1.6974	1.7224	1.8927
16	1.148	1.1606	1.2591
32	0.8735	0.8793	0.9428
64	0.7683	0.7706	0.8194
128	0.8119	0.8135	0.867
256	1.0286	1.0141	1.086
512	1.5271	1.4605	1.5507
1024	2.6581	2.4606	2.5965
2048	5.9249	4.6805	4.8777



We can understand that there is a point(~64Bytes) after which increasing the block size is detrimental to AAT.

L1 size + Associativity vs AAT

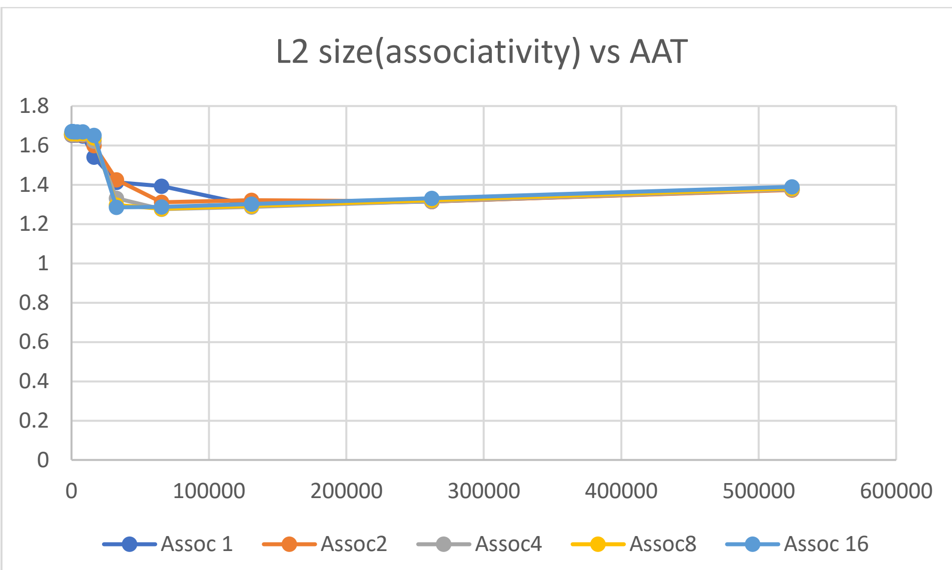
L1 size	Assoc 1	Assoc2	Assoc4	Assoc8	Assoc 16
128	2.2147	2.1324	2.1163	2.2025	
256	1.8952	1.8475	1.8323	1.9157	2.102
512	1.7084	1.6183	1.6139	1.7042	1.893
1024	1.529	1.4423	1.4465	1.5212	1.7168
2048	1.3945	1.3037	1.3131	1.3783	1.5681
4096	1.2711	1.2088	1.2144	1.3004	1.4957
8192	1.192	1.1408	1.1702	1.2663	1.461
16384	1.1918	1.1545	1.1814	1.2774	1.4767
32768	1.2989	1.3002	1.3406	1.446	1.6536
65536	1.4799	1.6152	1.6906	1.8512	2.0721
131072	1.8507	1.9694	2.1061	2.2093	2.4093
262144	2.6423	2.6709	2.7341	2.8343	3.0343
524288	3.8923	3.9343	3.9843	4.0843	4.2843



Similar to the observations for block size we see that the both associativity and L1 cachesize have a goldilocks area at around associativity 2 and cache size 8192

L2 size vs AAT

L2 size	Assoc 1	Assoc2	Assoc4	Assoc8	Assoc 16
128	1.6529	1.6541	1.6564	1.6612	
256	1.6529	1.6541	1.6565	1.6612	1.6708
512	1.653	1.6541	1.6565	1.6613	1.6705
1024	1.6531	1.6543	1.6565	1.6608	1.6701
2048	1.6533	1.6544	1.6557	1.6604	1.6696
4096	1.6527	1.6548	1.6559	1.6602	1.6697
8192	1.6477	1.6532	1.6564	1.6606	1.6699
16384	1.5404	1.5986	1.6215	1.6389	1.651
32768	1.4129	1.4261	1.3313	1.2975	1.2849
65536	1.3926	1.3107	1.2756	1.2774	1.2866
131072	1.2954	1.322	1.2865	1.2913	1.3009
262144	1.3148	1.3146	1.3164	1.3211	1.3307
524288	1.3744	1.3736	1.376	1.3808	1.3903



Similar to earlier observations we are able to see that we get the best AAT for L2 size ~= 64MB and L2 assoc =4

3. Best memory hierarchy configuration

Best memory hierarchy is assumed to be the configuration with the lowest access time. I will not be considering parameters such as size of the tag store as a factor contributing to “best”. ie. The best memory hierarchy regardless of price.

The simulation was run over a number of different configuration while keeping the values of L2 data_blocks=1 and L2 address_tags=1. This was done as an increase in miss rate was observed when the values of N and P are increased.

Therefore the best access time for gcc_trace.txt was observed to be 0.7671ns at block size 64 L1_size=16KB, L1_assoc=2, L2_size=64KB, L2_assoc=4 , N=1, P=1

Therefore the best access time for perl_trace.txt was observed to be 0.6720ns at block size 64 , L1_size=16KB, L1_assoc=2, L2_size=64KB, L2_assoc=4 , N=1, P=1(0.6718 was observed for 48KB)

Therefore the best access time for go_trace.txt was observed to be 0.7354ns at block size 128 ,L1_size=16KB, L1_assoc=2, L2_size=64KB, L2_assoc=4 , N=1, P=1(0.7348 was observed for 120KB size)

Therefore the best access time for vortex_trace.txt was observed to be 0.6534ns at block size 64 , L1_size=8KB, L1_assoc=2, L2_size=64KB, L2_assoc=4 , N=1, P=1

So in total this configuration seems to be best - block size 64, L1_size=16KB, L1_assoc=2, L2_size=64KB, L2_assoc=4 , N=1, P=1

The reason for this config being the best is that the tradeoff has been dome most effectively between the increase in access times due to a larger and more complex cache and the reduced miss rate which can be obtained from a larger and more complex(in terms of increased associativity) cache. Block size of 64bytes gives us the the right balance between spatial locality and effects of cache pollution.

4. Benchmark comparison

The best access time for gcc_trace.txt was observed to be 0.7671ns at block size 64 L1_size=16KB, L1_assoc=2, L2_size=64KB, L2_assoc=4 , N=1, P=1

The best access time for perl_trace.txt was observed to be 0.6720ns at block size 64 , L1_size=16KB, L1_assoc=2, L2_size=64KB, L2_assoc=4 , N=1, P=1(0.6718 was observed for 48KB)

The best access time for go_trace.txt was observed to be 0.7354ns at block size 128 ,L1_size=16KB, L1_assoc=2, L2_size=64KB, L2_assoc=4 , N=1, P=1(0.7348 was observed for 120KB size)

The best access time for vortex_trace.txt was observed to be 0.6534ns at block size 64 , L1_size=8KB, L1_assoc=2, L2_size=64KB, L2_assoc=4 , N=1, P=1

We are able to see that the go_trace gives better AAT for a bigger block size which might be due to it using bigger variable sizes by default or the higher spatial locality in the dataset.

5. Advantages of decoupled sectored cache

- The size of the tag store can be reduced if we use a sectored cache
- If we decouple the sectored cache we can decrease the miss rate to close to the levels shown by a set associative cache.
- To obtain a tag size comparable to that of a decoupled sectored cache in the scenario of a classical cache the block size would have to be increased. This would result in greater hit latency and seen in this perspective we can claim that the decoupled sectored cache helps reduce hit latency.

We implemented decoupled sectored cache in this project to explore the tradeoffs we would have to make to leverage a lower tag store size. We were able to understand that miss rate increases when we use a decoupled sectored cache.

Appendix

Data used for compiling this report can be found here as I was not able to include it in the report due to space constraints

https://github.com/GeoBK/cache_simulator/blob/sectored-decoupled-cache/Microarch-Proj%201B.xlsx