

NC State University
Department of Electrical and Computer Engineering
ECE 463/563: Fall 2021 (Rotenberg)
Project #1: Cache Design, Memory Hierarchy Design

by

Nandana Balachandran

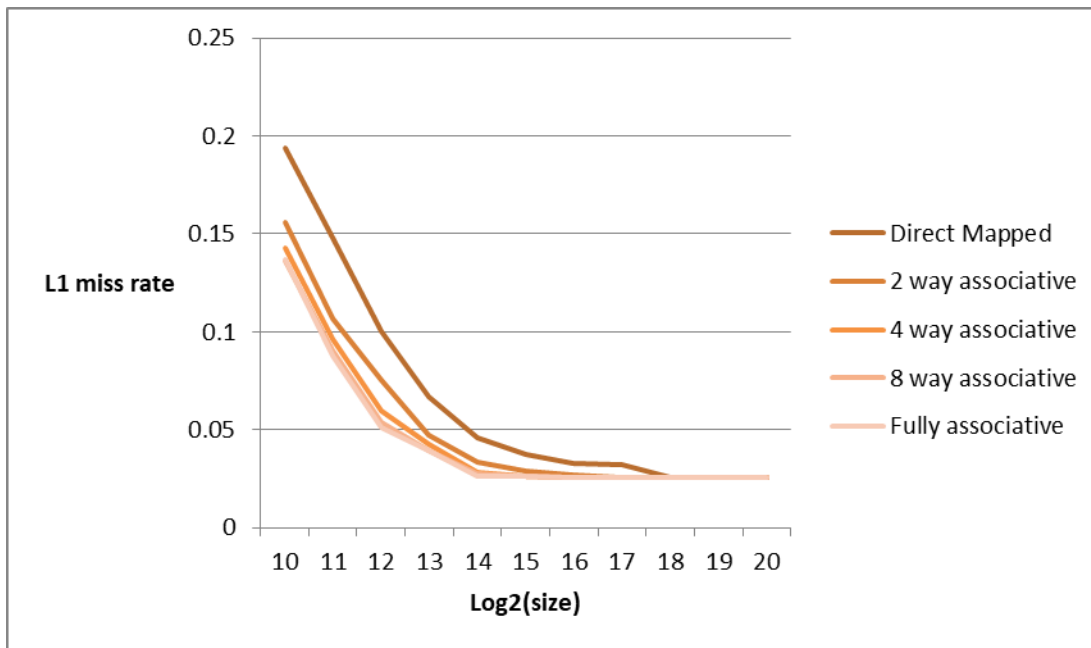
NCSU Honor Pledge: "I have neither given nor received unauthorized aid on this project."

Student's electronic signature: _____Nandana_____

Course number: _____563_____

Graph 1:

Size	Log2(Size)	Direct Mapped	2 way	4 way	8 way	Fully associative
1KB	10	0.1935	0.156	0.1427	0.1363	0.137
2KB	11	0.1477	0.1071	0.0962	0.0907	0.088
4KB	12	0.1002	0.0753	0.0599	0.0536	0.0512
8KB	13	0.067	0.0473	0.0425	0.0395	0.0394
16KB	14	0.0461	0.0338	0.0283	0.0277	0.0263
32KB	15	0.0377	0.0288	0.0264	0.0262	0.0262
64KB	16	0.0329	0.0271	0.0259	0.0259	0.0259
128KB	17	0.0323	0.0259	0.0258	0.0258	0.0258
256KB	18	0.0258	0.0258	0.0258	0.0258	0.0258
512KB	19	0.0258	0.0258	0.0258	0.0258	0.0258
1MB	20	0.0258	0.0258	0.0258	0.0258	0.0258

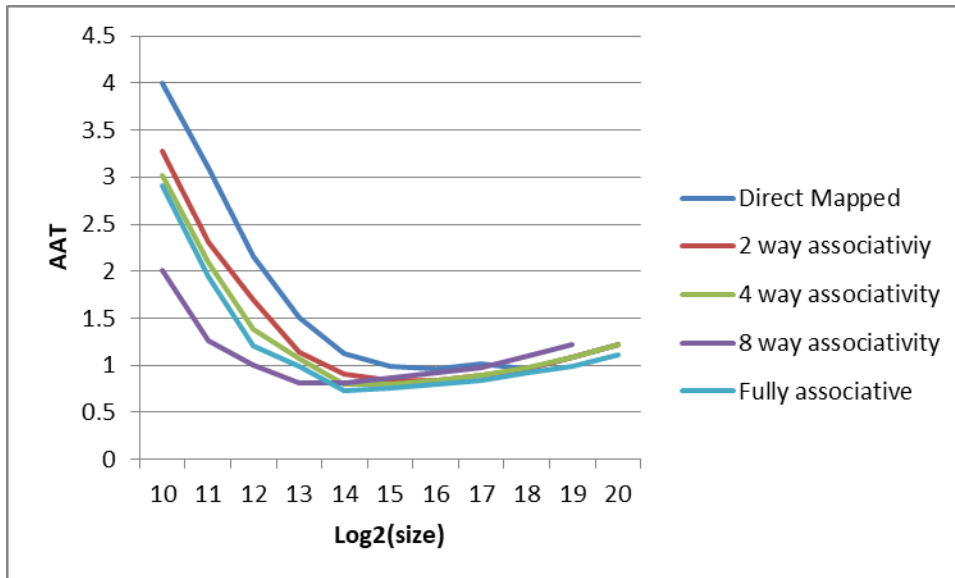


1. At a given time, when the associativity is constant and cache size increases, the miss rate decreases to reach a point where the conflict and compulsory misses are completely eliminated. The only miss that remains is the compulsory miss. Similarly, for a given cache size, increase in associativity tends to a decrease in the miss rate. The only miss cases remaining in this case will be that of compulsory and capacity miss and conflict miss is completely eliminated.
2. The compulsory miss rate is 0.0258 for all the set associativity.

3. The conflict miss rate is approximately 0.1935 for direct mapped, 0.156 for 2 way associative, 0.1427 for 3 way set associative, 0.137 for 8 way set associative and 0.137 for fully associative.

Graph 2:

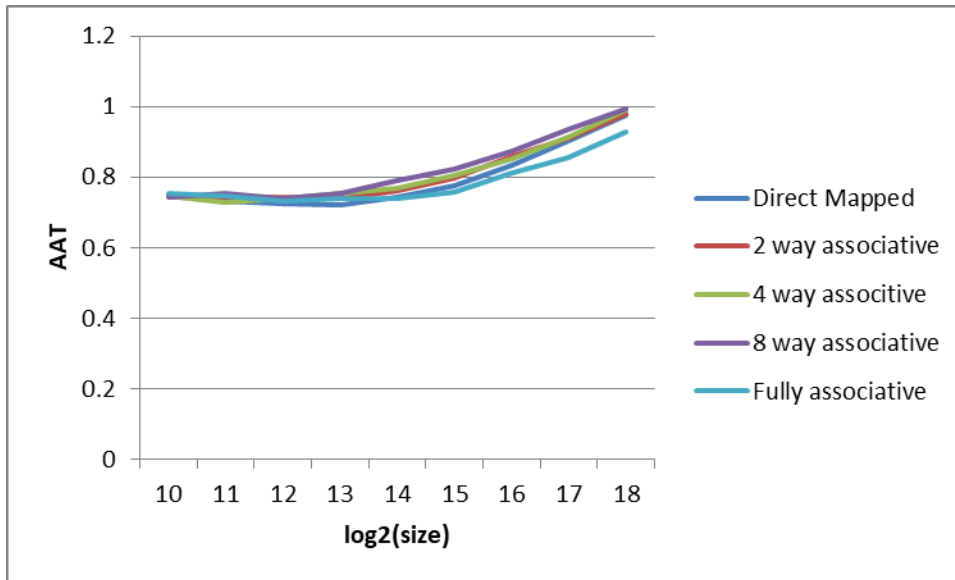
Size	Log2(Size)	Direct Mapped	2 way	4 way	8 way	associative
1KB	10	4.004147	3.275929	3.01509		2.909184
2KB	11	3.09786	2.314401	2.088116	2.003756	1.945315
4KB	12	2.161025	1.694661	1.389675	1.266425	1.212068
8KB	13	1.51053	1.144925	1.065423	1.006861	0.990521
16KB	14	1.125027	0.903297	0.802766	0.811124	0.734238
32KB	15	0.991123	0.841326	0.80189	0.815131	0.75136
64KB	16	0.955917	0.845437	0.840071	0.861803	0.796871
128KB	17	1.01603	0.895193	0.89886	0.919816	0.841066
256KB	18	0.962392	0.964509	0.976265	0.977505	0.914589
512KB	19	1.082031	1.086324	1.082998	1.096757	0.994308
1MB	20	1.21796	1.224626	1.218187	1.224399	1.107054



The minimum AAT that is achieved is “0.734238” which is for **fully associative set for 16 KB** cache size.

Graph 3:

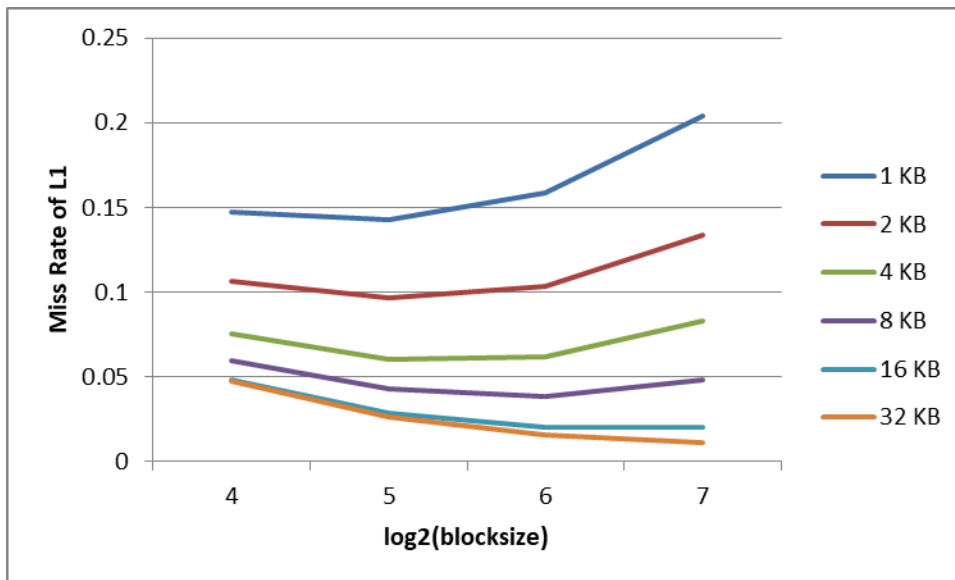
Size	Log2(Size)	Direct Mapped	2 way	4 way	8 way	Fully associative
1KB	10	0.745902	0.749466	0.748196	0.744785	0.753767
2KB	11	0.733428	0.742417	0.728907	0.752155	0.746537
4KB	12	0.724153	0.743809	0.739117	0.738589	0.731536
8KB	13	0.721586	0.740071	0.75513	0.754198	0.740874
16KB	14	0.744158	0.761826	0.768901	0.788611	0.73903
32KB	15	0.774374	0.79789	0.80548	0.821643	0.757872
64KB	16	0.832299	0.858382	0.852443	0.875372	0.811065
128KB	17	0.90395	0.908554	0.913777	0.934733	0.855983
256KB	18	0.976894	0.979011	0.991182	0.992422	0.929506



1. The configurations that yield AAT values close to the best value observed in Graph 2 is 0.731536 for the fully associative for a cache size of 4KB.
2. The lowest AAT value for L2 is 0.721586 for direct mapped cache with cache size of 8KB. This value is 0.00995 lesser than the minimum value of L1.
3. The total area under the graph for the optimal value of Graph 1 is 0.063446019 and for Graph 2 and for the Graph 1, it is 0.053293238.

Graph 4:

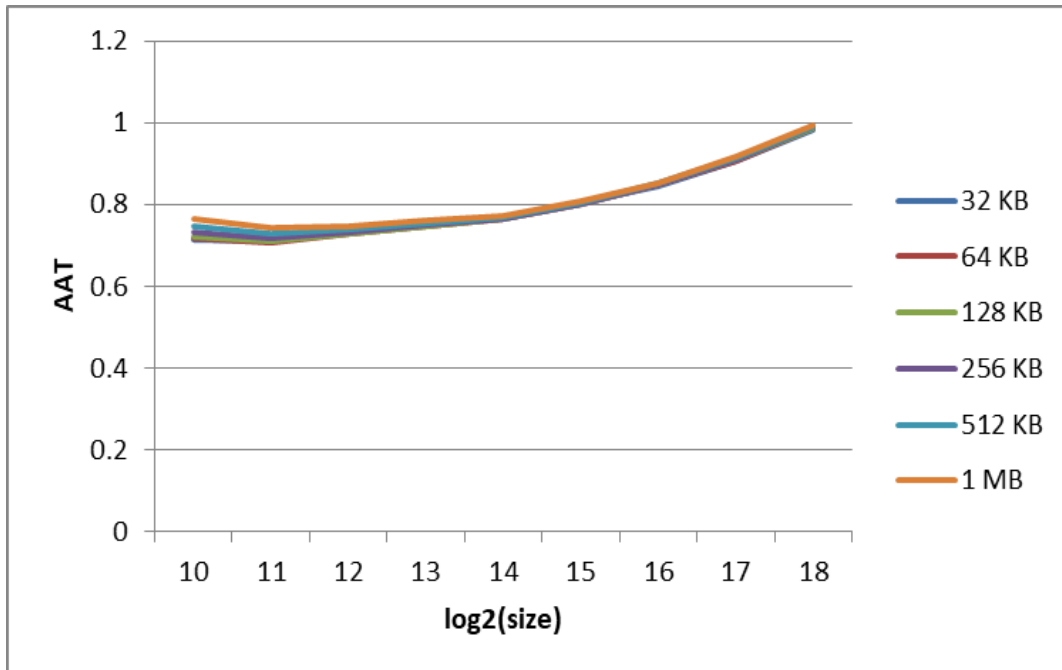
Size	Log2(Blocksize)	1KB	2KB	4KB	8KB	16KB	32KB
BLOCK SIZE 16	4	0.1473	0.1062	0.0755	0.0595	0.0482	0.0475
BLOCK SIZE 32	5	0.1427	0.0962	0.0599	0.04285	0.0283	0.0264
BLOCK SIZE 64	6	0.1584	0.1033	0.0619	0.0386	0.0204	0.0156
BLOCK SIZE 128	7	0.2036	0.1334	0.083	0.0483	0.0198	0.0111



1. The smaller cache size gives a more optimal value for smaller block size however, the larger cache sizes give a better value for larger block size. The larger block size will result in fewer unique blocks as compared to smaller blocks and so it will have lesser compulsory misses and the trade off is between hits on consecutive bytes and non-consecutive bytes. Yes, as the block size increases from 16 to 128, the tradeoff between exploiting more spatial locality vs. increasing cache pollution is evident in the graph. The tradeoff is less relevant for the larger cache size because cache pollution is less impactful on larger block size.

Graph 5:

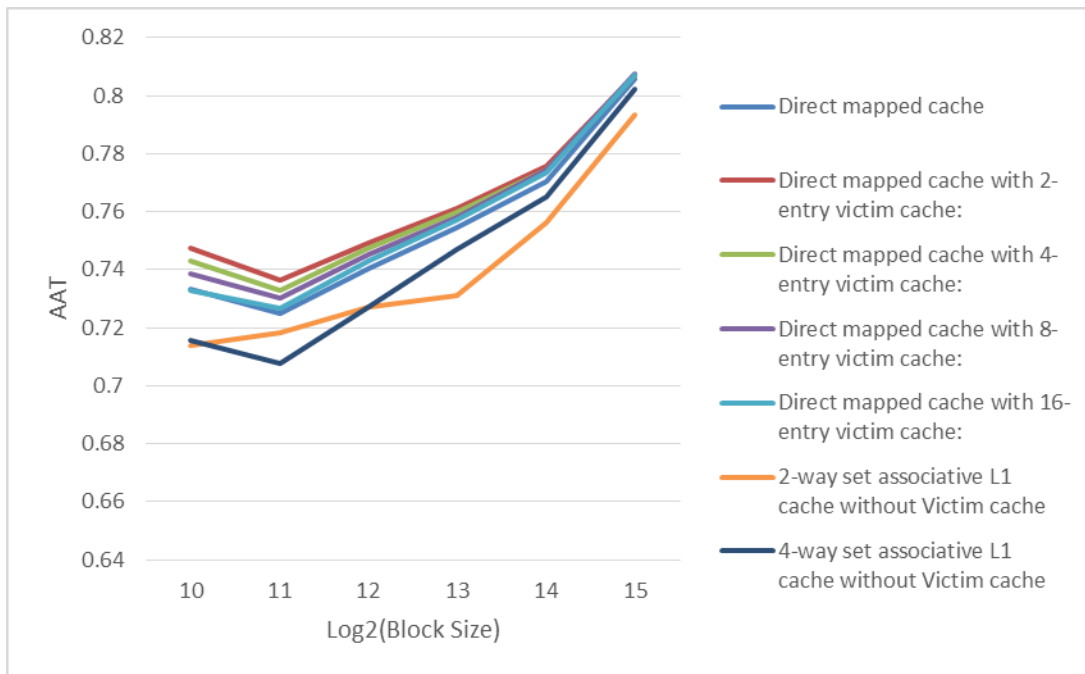
Size	32KB	64KB	128 KB	256 KB	512KB	1MB	Log2(Size)
1KB	0.715752	0.715815	0.722946	0.731179	0.748196	0.76641	10
2KB	0.709742	0.707658	0.711885	0.717435	0.728907	0.741186	11
4KB	0.730435	0.72697	0.728518	0.731974	0.739117	0.746763	12
8KB	0.751447	0.747194	0.74761	0.750061	0.75513	0.760554	13
16KB	0.769179	0.765039	0.763893	0.765526	0.768901	0.772513	14
32KB	0.8042	0.802461	0.800809	0.802332	0.80548	0.80885	15
64KB	0.84593	0.846514	0.84786	0.847308	0.850385	0.853678	16
128KB	0.906304	0.907663	0.909212	0.9107	0.913777	0.91707	17
256KB	0.983709	0.985068	0.986617	0.988105	0.991182	0.994475	18



1. The memory hierarchy that yields the best AAT is for cache size of 64KB and block size of 2KB and the value is 0.707658.
2. The smallest total area that produces an AAT within 5% of the best AAT is an area of 0.0187 for 2KB block size and cache size of 32KB.

Graph 6:

	Direct mapped cache	Direct mapped cache with 2-entry victim cache:	Direct mapped cache with 4-entry victim cache:	Direct mapped cache with 8-entry victim cache:	Direct mapped cache with 16-entry victim cache:	2-way set associative L1 cache without Victim cache	4-way set associative L1 cache without Victim cache	Log2(Blocksize)
Size	AAT	AAT	AAT	AAT	AAT	AAT	AAT	
1KB	0.73324	0.747407	0.742932	0.73858	0.733045	0.713754	0.715815	10
2KB	0.725022	0.736409	0.73284	0.73012	0.726645	0.71833	0.707658	11
4KB	0.740499	0.74936	0.747643	0.745438	0.743124	0.727327	0.72697	12
8KB	0.754399	0.761151	0.75983	0.758282	0.757403	0.731049	0.747194	13
16KB	0.770328	0.775728	0.774491	0.774291	0.773491	0.756399	0.765039	14
32KB	0.805611	0.807192	0.807024	0.807641	0.807163	0.793496	0.802461	15



1. Adding a Victim Cache to a direct-mapped L1 cache does yield performance comparable to a 2-way set-associative L1 cache of the same size. The cache size of 2 KB 16- entry victim cache.
2. The best AAT is for 2KB cache size for 4-way set associative cache without victim cache.
3. The smallest total area is for 1KB cache size which has a AAT value of 0.715815 and total area of 0.015115.