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CS 203 Computer Architecture

Assignment 3

1. Assuming a 512KB 4-way set associative cache with 16B block size, how many bits does the tag have?
   What is the total size, in bits, of the cache including tag bits and data blocks? (Assume 32-bit addressing).

   Main memory address space = 32 bits
   Cache size = 512 KB, block size = 16 B
   Block Offset size = (log2(16)) = 4 bits.
   # of set/index bits = 512KB/(16B*4)= 512K/64= log2(8K) = 13 bits
   Tag size = 32 - 4 - 13 = 15

   Total Tag size in bits = 15 * 4 * 8K= 480K bits
   Total size in bits = (512KB*8) + 480K = 4096K + 480K = 4576K bits.

2. What is the cache miss rate of the given traces and cache configuration?
   Assume we have a 512KB cache and 16B block size.

Trace	Direct mapped	2-way	4-way	Fully associative
gcc-10K.memtrace	7.62%	7.56%	7.56%	7.56%
gcc-650K.memtrace	1.35%	1.04%	1.03%	1.03%

3. For the following configurations, how many bits are for tag, index, and offset fields?
   a. *Assuming 32 bit addressing*

Configuration	Tag bits	Index bits	Offset bits
256KB cache, 16B block size, Direct mapped	14	14	4
256KB cache, 16B block size, 2-way	15	13	4
256KB cache, 16B block size, 4-way	16	12	4
256KB cache, 16B block size, Fully associative	28	0	4

4. Assuming a 256KB cache and 32B block size.
How does ***varying the number of ways*** affect cache miss rate?
Plot the number of ways (1,2,4,8,16) vs miss rate for the two traces.
What do you observe and why?

Trace	1	2	4	8	16
gcc-10K.memtrace	4.90%	4.79%	4.79%	4.79%	4.79%
gcc-650K.memtrace	0.95%	0.68%	0.61%	0.61%	0.61%

Our observation:
it seems that the number of ways for set associative does affect in most of the cases. Which means that most cases will be better than direct mapping (1 w) due to reducing conflict misses when increasing associativity. That is, increasing the number of ways won't make the cache more accurate. So, it could not affect the cold misses that much.

5. Assuming a 256KB 2-way set associative cache.
How does ***varying the size of the block*** affect cache miss rate?
Plot the block size (2B, 4B, 8B, 16B, 32B, 64B) vs miss rate for the two traces.
What do you observe and why?

Trace	2B	4B	8B	16B	32B	64B
gcc-10K.memtrace	10.96%	10.84%	10.70%	7.56%	4.79%	3.14%
gcc-650K.memtrace	1.50%	1.48%	1.43%	1.13%	0.68%	0.41%

Our observation:
when block size increased, the miss rate decreased. This is because the large blocks usually take the benefit of spatial locality which is a component of the locality.

6. Assuming a 2-way set associative cache and 32B block size.
How does ***varying the size of the cache*** affect cache miss rate?
Plot the cache size (64K, 128K, 256K, 512K, 1M, 2M) vs miss rate for the two traces.
What do you observe and why?

Trace	64K	128K	256K	512K	1M	2M
gcc-10K.memtrace	5.00%	4.79%	4.79%	4.79%	4.79%	4.79%

gcc-650K.memtrace	1.46%	0.86%	0.68%	0.62%	0.61%	0.61%

Our observation:
it seems that there is a big difference between the two files in the miss rates. for the 10K file, the miss rate doesn't improve after (2 w) associative. In contrast, the 650K file improved with higher associativity. This may happen because the cold misses are independent of cache size, whereas the capacity/conflict misses decrease as capacity/associativity increases.

7. Measuring cold, capacity, and conflict misses. (See "Measuring/Classifying Misses" in slides). In this problem, we will identify the types of misses for an 8KB, 4-way set associative cache with block size of 32B. For the gcc-650K trace, provide a breakdown of the type of cache misses. You can provide the breakdown in terms of the miss rate. For example, if the 8KB, 4-way cache has a 20% miss rate, an infinite size cache have a 1% miss rate, and a fully associative cache have a 10% miss rate, then 1% is due to cold misses, 9% is due to capacity misses, and 10% is due to conflict misses.

    a. Target cache: -c 8KB -b 32B -w 4
        i. 10K.memtrace: 7.43%, 650K.memtrace: 6.21%
    b. Infinite cache: -c 2048KB -b 32B -w 4
        i. 10K.memtrace: 4.79% , 650K.memtrace: 0.61%
    c. Fully Associative: -c 2048KB -b 32B -w 32768
        i. 10K.memtrace: 4.14%, 650K.memtrace: 0.48%

Trace	Cold miss	Capacity miss	Conflict miss
gcc-10K.memtrace	4.79%	0.65%	3.29%
gcc-650K.memtrace	0.61%	0.13%	5.73%