# 605.611 - Foundations of Computer Architecture

# Assignment 09 - Caching

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1. The main memory of a computer has 2 cm blocks while the cache has 2c blocks. If the cache uses the set associative mapping scheme with 2 blocks per set, then block k of the main memory maps to the set.

   ☐ (a) $(k \ mod \ m)$ of the cache

   ■ (b) $(k \ mod \ c)$ of the cache

   ☐ (c) $(k \ mod \ 2c)$ of the cache

   ☐ (d) $(k \ mod \ 2cm)$ of the cache

   **Answer:** Number of sets in cache

   $$= \text{Number of blocks in cache/Number of blocks in one set}$$
   $$= 2 \cdot c/2$$
   $$= c$$

2. In a k-way set associative cache, the cache is divided into v sets, each of which consists of k lines. The lines of a set placed in sequence one after another. The lines in set s are sequenced before the lines in set (s+1). The main memory blocks are numbered 0 on wards. The main memory block numbered 'j' must be mapped to any one of the cache lines from-

   ■ (a) $(j \ mod \ v) \cdot k$ to $(j \ mod \ v) \cdot k + (k-1)$

   ☐ (b) $(j \ mod \ v)$ to $(j \ mod \ v) + (k-1)$

☐ (c) $(j \ mod \ k)$ to $(j \ mod \ k) + (v - 1)$

☐ (d) $(j \ mod \ k) \cdot v$ to $(j \ mod \ k) \cdot v + (v - 1)$

**Answer:**

- 2-way set associative mapping is used, then $k = 2$
- Number of sets in cache is 4, then $v = 4$
- Block number 3 has to be mapped, then $j = 3$

Substituting these values:

(a) $(3 \ mod \ 4) \cdot 2$ to $(j \ mod \ 4) \cdot 2 + (2 - 1) = 6$ to 7

(b) $(3 \ mod \ 4)$ to $(3 \ mod \ 4) + (2 - 1) = 3$ to 4

(c) $(3 \ mod \ 2)$ to $(3 \ mod \ 2) + (4 - 1) = 1$ to 4

(d) $(3 \ mod \ 2) \cdot 4$ to $(3 \ mod \ 2) \cdot 4 + (4 - 1) = 4$ to 7

Within set number 3, block 3 can be mapped to any of the cache lines and can therefore be mapped to cache lines ranging from 6 to 7.

3. A block-set associative cache memory consists of 128 blocks divided into four block sets . The main memory consists of 16,384 blocks and each block contains 256 eight bit words.

(a) How many bits are required for addressing the main memory?

(b) How many bits are needed to represent the TAG, SET and WORD fields?

**Answer:** Main memory

$$= 16384 \text{ blocks}$$

$$= 16384 \cdot 256 \text{ bytes}$$

$$= 2^{22} \text{ bytes}$$

$$= 22 \text{ bits}$$

Block size:

$$= 256 \text{ bytes}$$
$$= 2^8 \text{ bytes}$$
$$= 8 \text{ bits}$$

Number of sets in cache:

$$= 128/4 \text{ blocks}$$
$$= 32 \text{ sets}$$
$$= 2^5 \text{ sets}$$
$$= 5 \text{ bits}$$

Number of bits in tag

$$= 22 - (5 + 8) \text{ bits}$$
$$= 22 - 13 \text{ bits}$$
$$= 9 \text{ bits}$$

8. Consider a direct mapped cache with 8 cache blocks (0-7). If the memory block requests are in the order-

$$3, 5, 2, 8, 0, 6, 3, 9, 16, 20, 17, 25, 18, 30, 24, 2, 63, 5, 82, 17, 24$$

Which of the following memory blocks will not be in the cache at the end of the sequence?

☐ (a) 3

■ (b) 18

□ (c) 20

□ (d) 30

Also, calculate the hit ratio and miss ratio.

**Answer:**

$$3 \ mod \ 8 = 3$$

$$5 \ mod \ 8 = 5$$

$$2 \ mod \ 8 = 2$$

$$8 \ mod \ 8 = 0$$

$$0 \ mod \ 8 = 0$$

$$6 \ mod \ 8 = 6$$

$$3 \ mod \ 8 = 3 \text{ (hit)}$$

$$9 \ mod \ 8 = 1$$

$$16 \ mod \ 8 = 0$$

$$20 \ mod \ 8 = 4$$

$$17 \ mod \ 8 = 1$$

$$25 \ mod \ 8 = 1$$

$$18 \ mod \ 8 = 2$$

$$30 \ mod \ 8 = 6$$

$$24 \ mod \ 8 = 0$$

$$2 \ mod \ 8 = 2$$

$$63 \ mod \ 8 = 7$$

$$5 \ mod \ 8 = 5 \text{ (hit)}$$

$$82 \ mod \ 8 = 2$$

$$17 \ mod \ 8 = 1$$

$$24 \ mod \ 8 = 0 \text{ (hit)}$$

| **Line** | **Requests** |
|---|---|
| 0 | 8, 0, 16, 24 |
| 1 | 9, 17, 25, 17 |
| 2 | 2, 18, 2, 82 |
| 3 | 3 |
| 4 | 20 |
| 5 | 5 |
| 6 | 6, 30 |
| 7 | 63 |

The hit ratio is 3/20 and the miss ratio is 17/20.