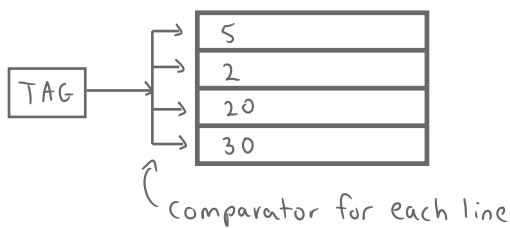


# Cache Mapping Strategies

## Associative Mapping

- A main memory block can go into any line in the cache
- The block number serves as the tag, and so this is known also as **Fully Associative**
- Cache contains
  - Valid/Invalid bit
  - Tag (block number)
  - Data (could be multiple words)
- Searches are done in parallel, requiring one comparator per line
  - fast but expensive due to hardware complexity
- Associativity here means we can "associate" a block with any line

## Cache lines



x indicates a miss

MM blocks: <sup>x</sup>5, <sup>x</sup>2, <sup>x</sup>20, <sup>x</sup>30, 15

Since 15 is a miss and we have no room in the cache for it, it needs to replace one of the lines (the least recently used)

## Problem Statement

Find the number of misses with a **fully associative mapping**, consisting of 8 one-word blocks given the following sequence of block addresses:

2, 4, 2, 6, 8, 0, 6, 2, 4, 6, 0, 7, 9, 6, 9, 9, 9, 7, 9, 6, 7, 1, 8, 1

0	2
1	4
2	6
3	8
4	0
5	7
6	9
7	1

<sup>x</sup>2, <sup>x</sup>4, <sup>✓</sup>2, <sup>x</sup>6, <sup>x</sup>8, <sup>x</sup>0, <sup>✓</sup>6, <sup>✓</sup>2, <sup>✓</sup>4, <sup>✓</sup>6, <sup>✓</sup>0, <sup>x</sup>7, <sup>x</sup>9, <sup>✓</sup>6, <sup>✓</sup>9, <sup>✓</sup>9, <sup>✓</sup>9, <sup>✓</sup>7, <sup>✓</sup>9, <sup>✓</sup>6, <sup>✓</sup>7, <sup>x</sup>1, <sup>✓</sup>8, <sup>✓</sup>1 → 8 misses

## Direct Mapping

- Each memory block maps to exactly one cache line
  - Cache line =  $(\text{Block Number}) \bmod (\text{Cache Size})$
- Cache structure includes:
  - Tag (to differentiate blocks with same index)
  - Line Index
  - Word offset (if multiple words per block)
- Simple and inexpensive, but prone to higher rate of cache misses

## Problem Statement

Find the number of misses with Direct Mapping, consisting of 8 one-word blocks given the following sequence of block addresses:

2, 4, 2, 6, 8, 0, 6, 2, 4, 6, 0, 7, 9, 6, 9, 9, 9, 7, 9, 6, 7, 1, 8, 1

0	<del>8</del> 8
1	<del>9</del> 1
2	2
3	
4	4
5	
6	6
7	7

\* Block goes into line:

$$(\text{block \#}) \bmod (\text{\# of cache lines})$$

x x ✓ x x x ✓ ✓ ✓ ✓ ✓ x x ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ x x ✓ → 9 misses

2, 4, 2, 6, 8, 0, 6, 2, 4, 6, 0, 7, 9, 6, 9, 9, 9, 7, 9, 6, 7, 1, 8, 1

## Set Associative Mapping

- Combines aspects of both fully associative and direct mapping
- Cache is divided into sets, each with multiple lines
  - eg. 8 lines and 2 sets = 4 lines per set  $\rightarrow$  4-way associative
- Block mapping:
  - Set index =  $(\text{Block \#}) \bmod (\text{\# of sets})$
  - Block can go into any line within its assigned set
  - Lines within a set are searched in parallel
- Requires fewer comparators than fully associative
- Examples:
  - 8 lines, 2 sets  $\rightarrow$  4-way associative (4 lines per set)
  - 8 lines, 4 sets  $\rightarrow$  2-way associative (2 lines per set)

## Problem Statement

Find the number of misses with 4 way Set Associative Mapping, consisting of 8 one-word blocks given the following sequence of block addresses:

2, 4, 2, 6, 8, 0, 6, 2, 4, 6, 0, 7, 9, 6, 9, 9, 9, 7, 9, 6, 7, 1, 8, 1

0	<del>2</del> 8	} $S_0$
1	<del>4</del> 0	
2	6	
3	<del>8</del> 4	
4	7	} $S_1$
5	9	
6	1	
7		

$$\begin{aligned} \# \text{ of sets} &= \frac{\# \text{ of lines}}{\# \text{ of lines per set}} \\ &= 8/4 = 2 \text{ sets} \end{aligned}$$

$$\text{set index} = (\text{block \#}) \bmod (\# \text{ of sets})$$

~~x~~ ~~x~~  $\checkmark$  ~~x~~ ~~x~~ ~~x~~  $\checkmark$   $\checkmark$  ~~x~~  $\checkmark$   $\checkmark$  ~~x~~ ~~x~~  $\checkmark$   $\checkmark$   $\checkmark$   $\checkmark$   $\checkmark$   $\checkmark$   $\checkmark$   $\checkmark$  ~~x~~ ~~x~~  $\checkmark$   $\rightarrow$  10 misses