COA

Chapter 04: |Set Associative Mapping

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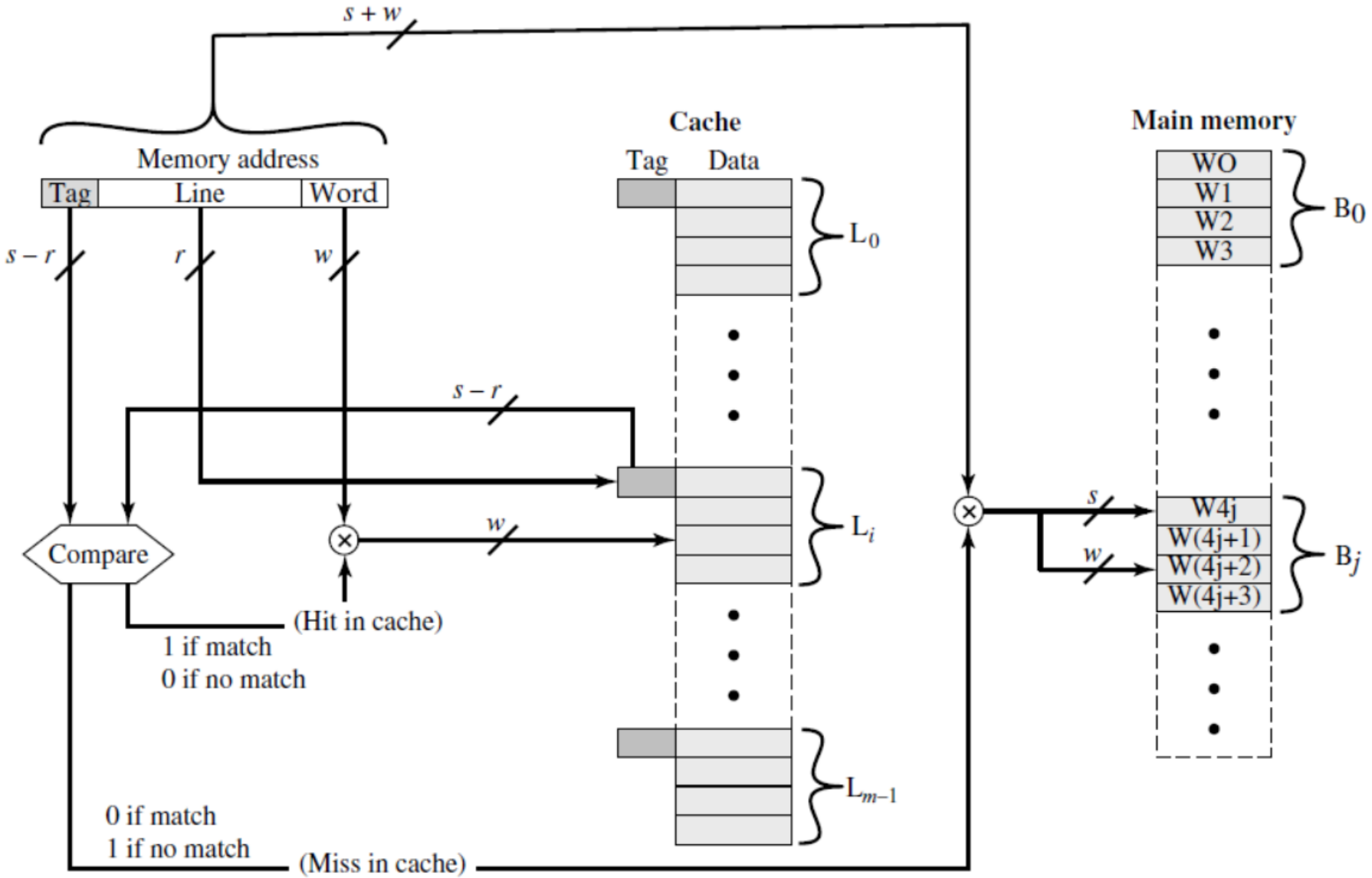
AGENDA

Elements of Cache Design

- Mapping Function
  - Direct
  - Associative
  - Set Associative

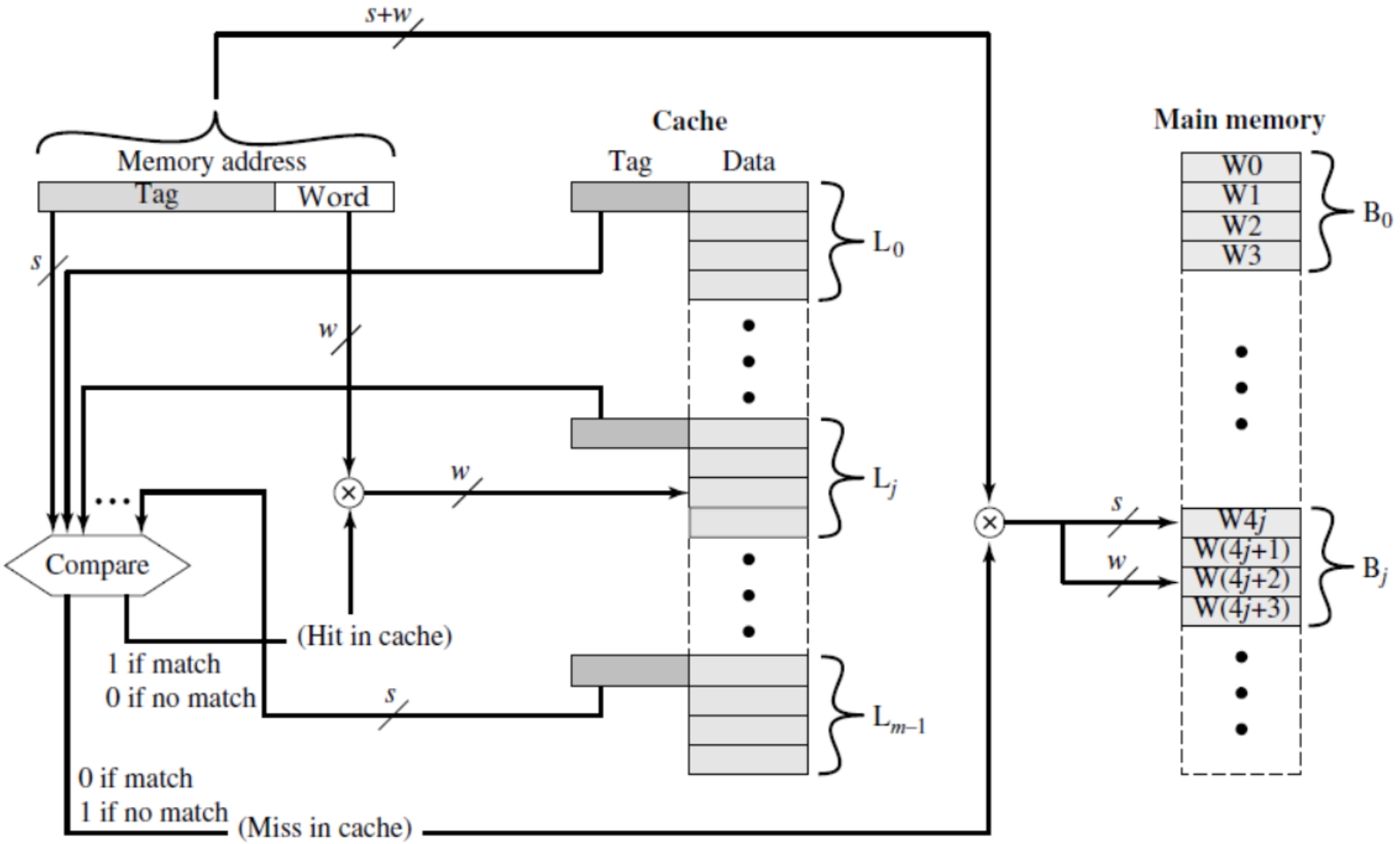
Direct Mapping



Direct Mapping

Cache line	Main memory blocks assigned
0	$0, m, 2m, \ldots, 2^s - m$
1	$1, m + 1, 2m + 1, \ldots, 2^s - m + 1$
⋮	⋮
$m - 1$	$m - 1, 2m - 1, 3m - 1, \ldots, 2^s - 1$

Associative Mapping



Set Associative Mapping

- **Compromise** that exhibits the strengths of both the **direct** and **associative** approaches while reducing their disadvantages
- The cache consists of several **sets**, each of which consists of several **lines**

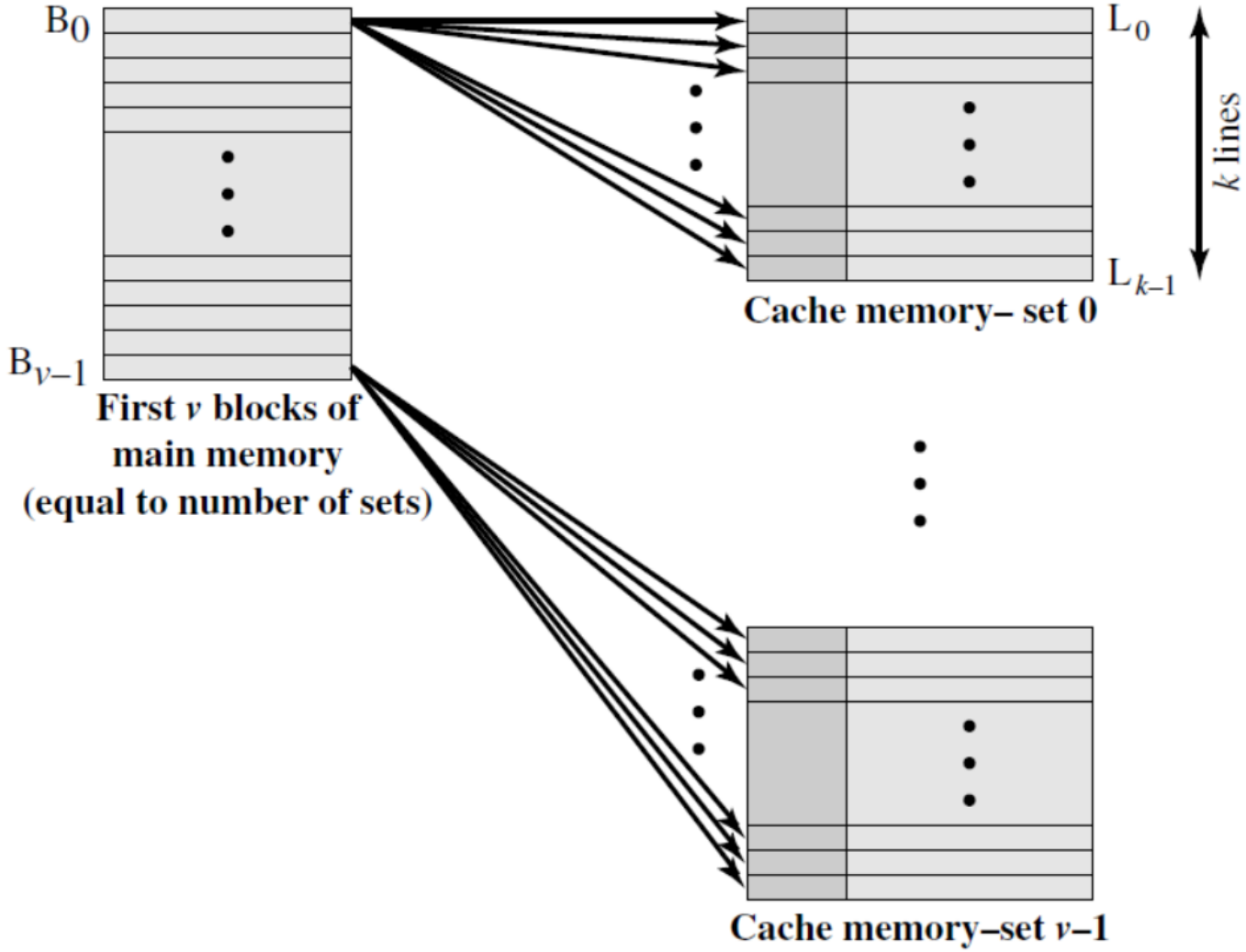
$$m = v \times k$$

$$i = j \; modulo \; v$$

- $\boldsymbol{i}$ cache set number $\boldsymbol{j}$ main memory block number
- $\boldsymbol{m}$ number of lines in the cache $\boldsymbol{v}$ number of sets
- $\boldsymbol{k}$ number of lines in each set

Set Associative Mapping

- Each word maps into all the cache lines in a specific set
- Set-associative cache can be physically implemented as associative caches



Set Associative Mapping

- Cache size : 64 Kbytes.
- Block size: 4 bytes.
- Cache is organized as $16\ K = \ 2^{14}$ lines of 4 bytes each.
- Memory Size: 16 Mbytes, with each byte directly addressable by a 24-bit address ($2^{14} = 16\ M$).
  - Main memory: 4M blocks of 4 bytes each

Set Associative Mapping

- Memory address as three fields: **Tag**, **Set**, and **Word**.
- The d set bits specify one of $v = 2^d$ sets
- The $\boldsymbol{s}$ bits of the Tag and Set fields specify one of the 2^s blocks of main memory.

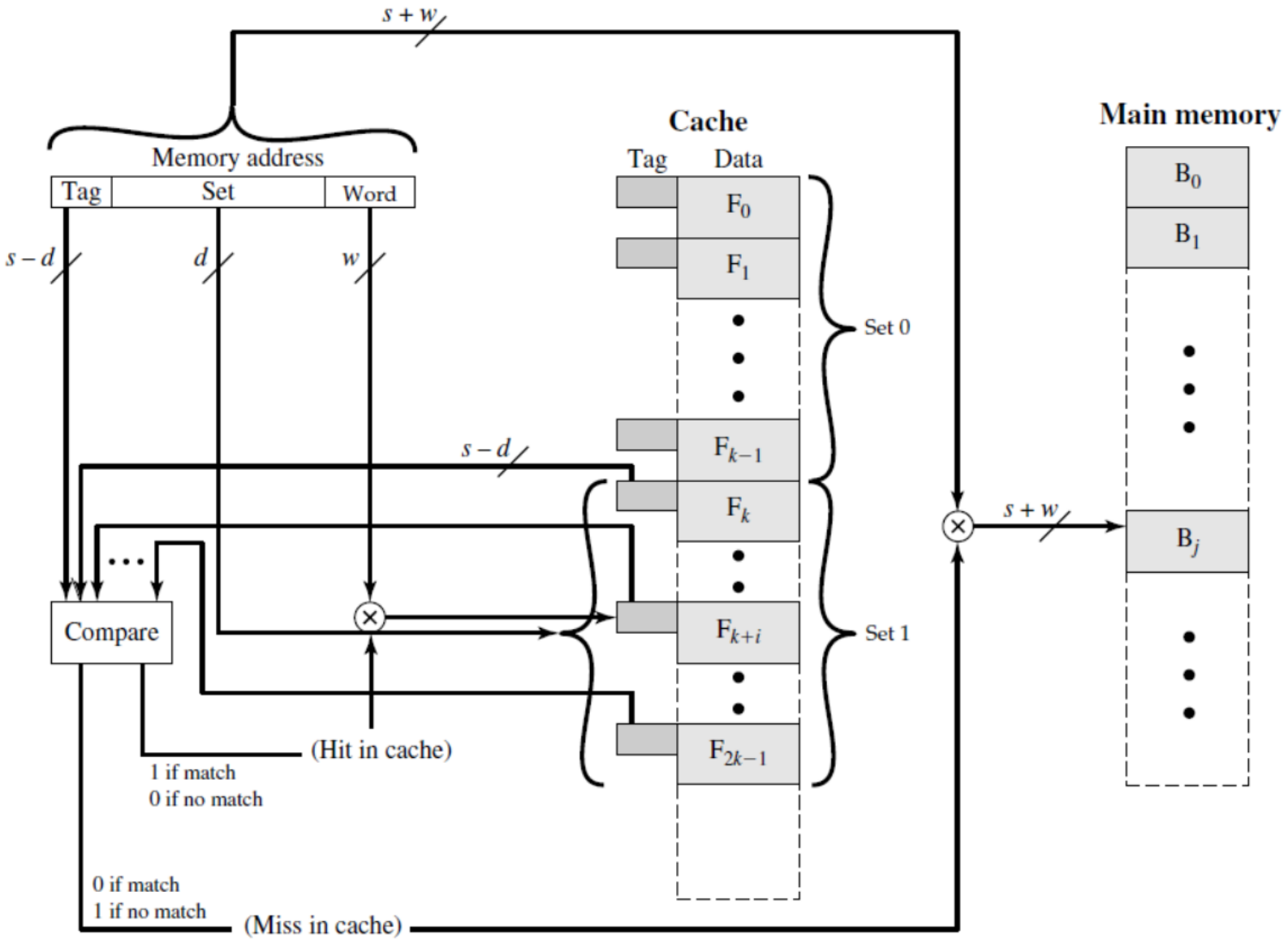


Figure 4.14 *K*-Way Set Associative Cache Organization

Set Associative Mapping

To Summarize:

- Address length: $s + w$ bits
- Number of addressable units: 2^{s+w} words or bytes
- Block size = line size = 2^{w} words or bytes
- Number of blocks in main memory: $\frac{2^{s+w}}{2^{w}} = 2^{s}$
- Number of lines in set = k
- Number of sets = $v = 2^{d}$
- Number of lines in cache = $m = kv = k \times 2^{d}$
- Size of cache = $k \times 2^{d+w}$ words or bytes
- Size of tag = $(s - d)$ bits

Set Associative Mapping

- In the extreme case of $v = m$, $k = 1$, the set-associative technique reduces to direct mapping
- for $v = 1$, $k = m$, it reduces to associative mapping.
- The use of two lines per set (v = m/2, k = 2) is the most common set-associative organization