Cache Mapping | Cache Mapping Techniques

📁 Computer Organization and Architecture

Cache Memory-

Before you go through this article, make sure that you have gone through the previous article on **Cache Memory**.

We have discussed-

> Cache memory bridges the speed mismatch between the processor and the main memory.

When cache hit occurs,

- The required word is present in the cache memory.
- The required word is delivered to the CPU from the cache memory.

When cache miss occurs,

- The required word is not present in the cache memory.
- The page containing the required word has to be mapped from the main memory.
- This mapping is performed using cache mapping techniques.

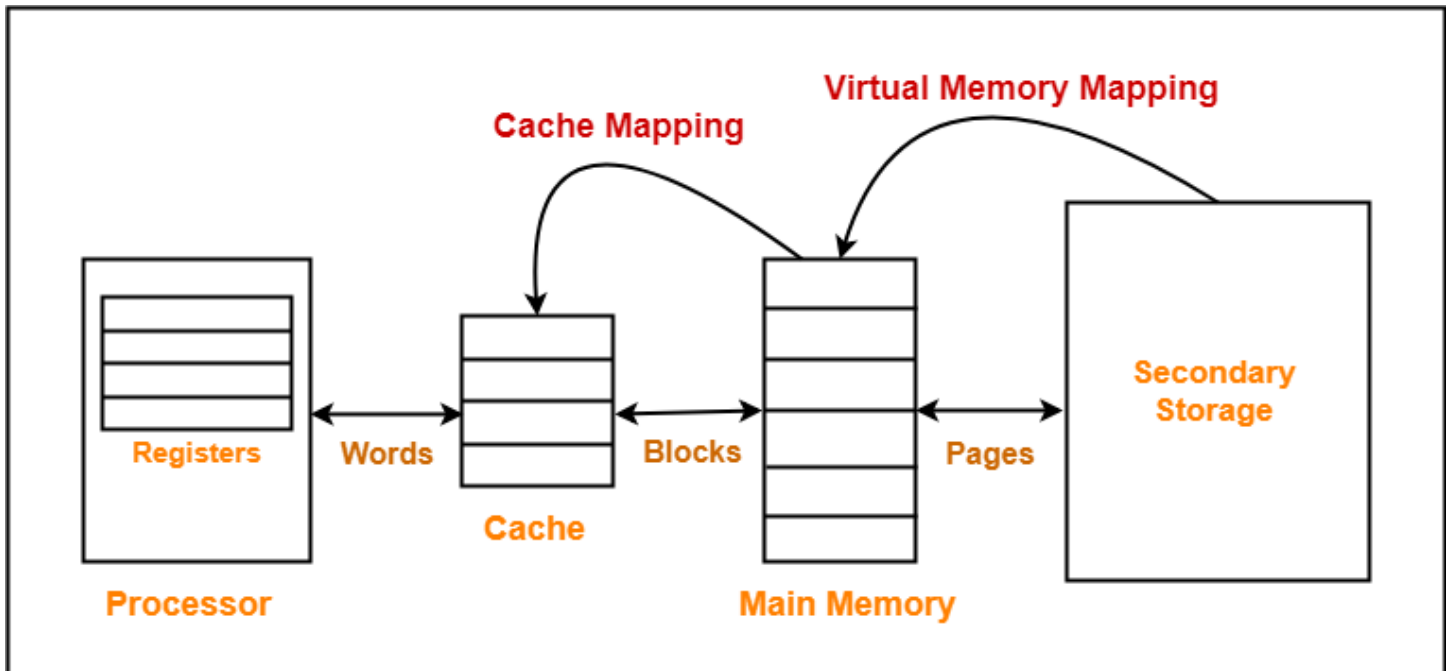In this article, we will discuss different cache mapping techniques.

Cache Mapping-

- Cache mapping defines how a block from the main memory is mapped to the cache memory in case of a cache miss.

OR

- Cache mapping is a technique by which the contents of main memory are brought into the cache memory.

The following diagram illustrates the mapping process-

Now, before proceeding further, it is important to note the following points-

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NOTES

- Main memory is divided into equal size partitions called as **blocks** or **frames**.
- Cache memory is divided into partitions having same size as that of blocks called as **lines**.
- During cache mapping, block of main memory is simply copied to the cache and the block is not actually brought from the main memory.

Cache Mapping Techniques-

Cache mapping is performed using following three different techniques-

Cache Mapping Techniques

Direct Mapping **Fully Associative Mapping** **K-way Set Associative Mapping**
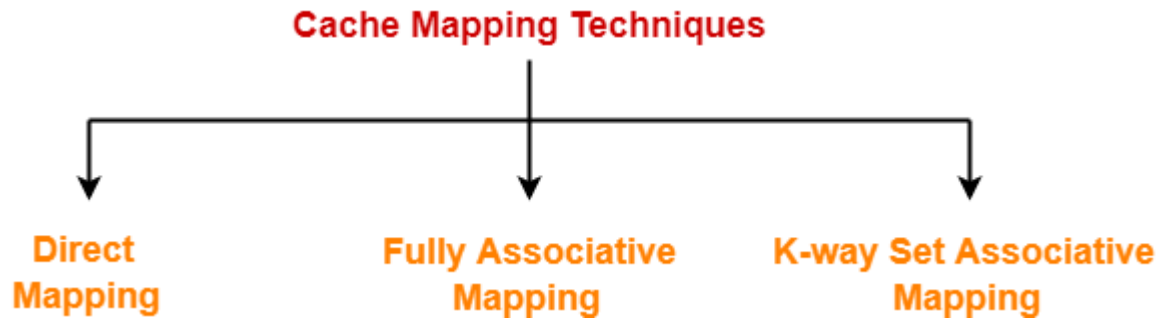
1. Direct Mapping

2. Fully Associative Mapping

3. K-way Set Associative Mapping
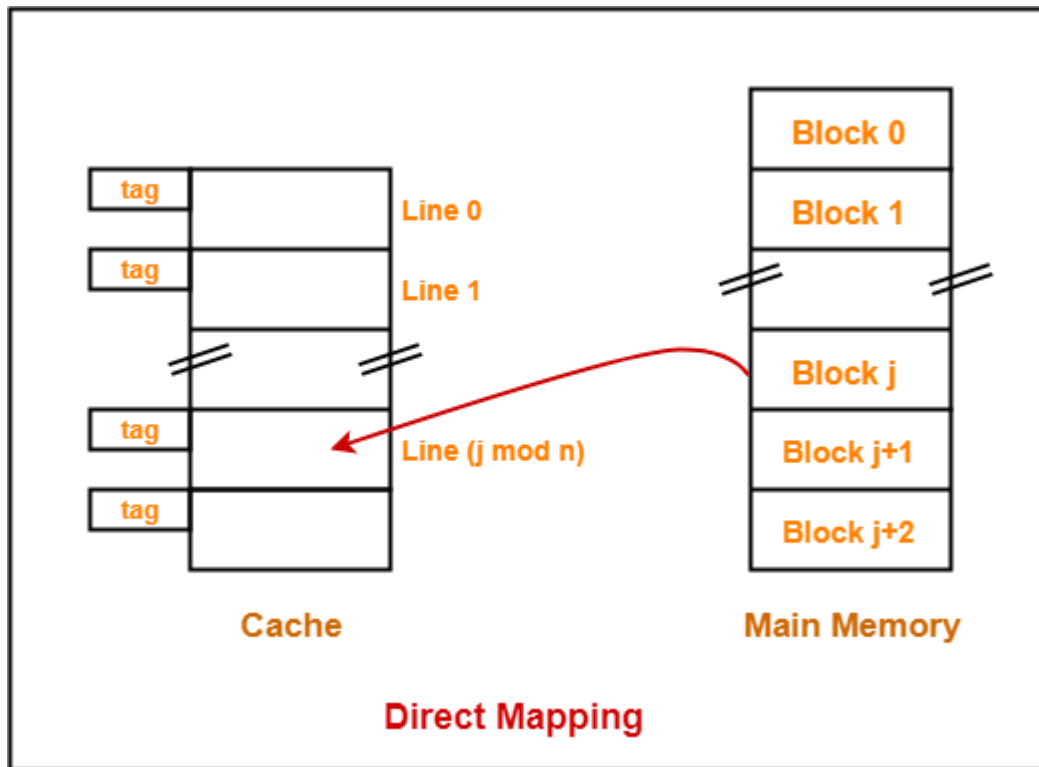
1. Direct Mapping-

In direct mapping,

- A particular block of main memory can map only to a particular line of the cache.
- The line number of cache to which a particular block can map is given by-

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Cache line number

= (Main Memory Block Address) Modulo (Number of lines in Cache)

Example-

- Consider cache memory is divided into 'n' number of lines.
- Then, block 'j' of main memory can map to line number (j mod n) only of the cache.
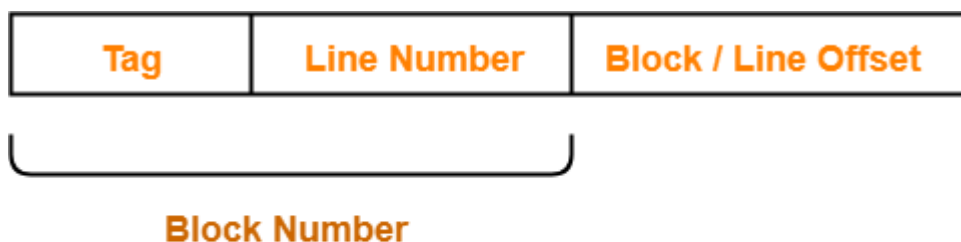
Direct Mapping

Need of Replacement Algorithm-

In direct mapping,

- There is no need of any replacement algorithm.
- This is because a main memory block can map only to a particular line of the cache.
- Thus, the new incoming block will always replace the existing block (if any) in that particular line.

Division of Physical Address-

In direct mapping, the physical address is divided as-

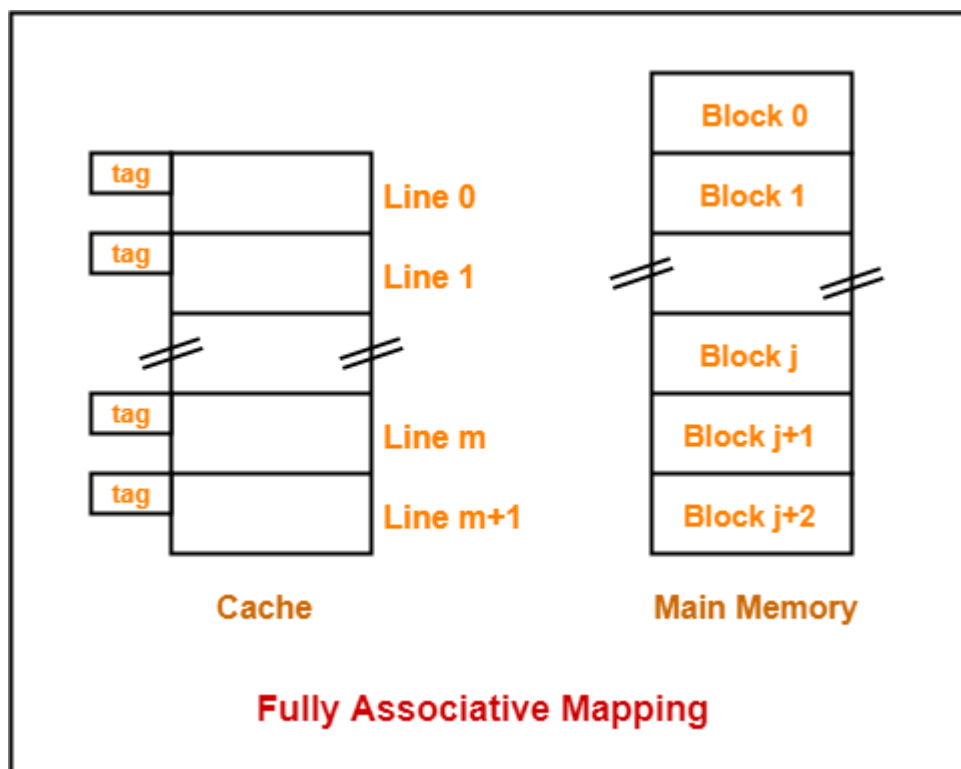Division of Physical Address in Direct Mapping

2. Fully Associative Mapping-

In fully associative mapping,

- A block of main memory can map to any line of the cache that is freely available at that moment.
- This makes fully associative mapping more flexible than direct mapping.

Example-

Consider the following scenario-

Fully Associative Mapping

Here,

- All the lines of cache are freely available.
- Thus, any block of main memory can map to any line of the cache.
- Had all the cache lines been occupied, then one of the existing blocks will have to be replaced.

Need of Replacement Algorithm-

In fully associative mapping,

- A replacement algorithm is required.
- Replacement algorithm suggests the block to be replaced if all the cache lines are occupied.
- Thus, replacement algorithm like FCFS Algorithm, LRU Algorithm etc is employed.

Division of Physical Address-

In fully associative mapping, the physical address is divided as-

Block Number / Tag	Block / Line Offset

Division of Physical Address in Fully Associative Mapping

3. K-way Set Associative Mapping-

In k-way set associative mapping,

- Cache lines are grouped into sets where each set contains k number of lines.
- A particular block of main memory can map to only one particular set of the cache.
- However, within that set, the memory block can map any cache line that is freely available.
- The set of the cache to which a particular block of the main memory can map is given by-
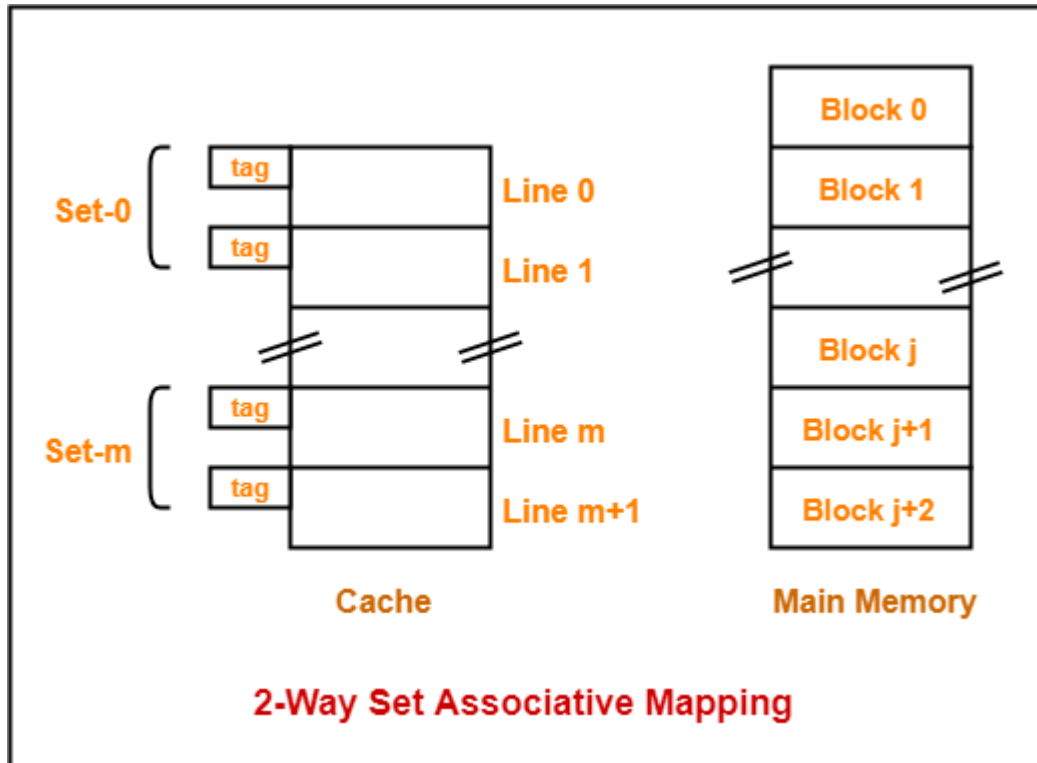
> **Cache set number**
>
> **= (Main Memory Block Address) Modulo (Number of sets in Cache)**

Also Read- Set Associative Mapping | Implementation and Formulas

Example-

Consider the following example of 2-way set associative mapping-

Here,

- k = 2 suggests that each set contains two cache lines.
- Since cache contains 6 lines, so number of sets in the cache = 6 / 2 = 3 sets.
- Block 'j' of main memory can map to set number (j mod 3) only of the cache.
- Within that set, block 'j' can map to any cache line that is freely available at that moment.
- If all the cache lines are occupied, then one of the existing blocks will have to be replaced.

Need of Replacement Algorithm-

- Set associative mapping is a combination of direct mapping and fully associative mapping.
- It uses fully associative mapping within each set.
- Thus, set associative mapping requires a replacement algorithm.

Division of Physical Address-

In set associative mapping, the physical address is divided as-

Tag	Set Number	Block / Line Offset

Division of Physical Address in K-way Set Associative Mapping

Special Cases-

- If k = 1, then k-way set associative mapping becomes direct mapping i.e.
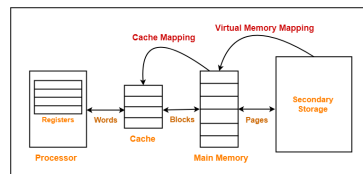
1-way Set Associative Mapping ≡ Direct Mapping

- If k = Total number of lines in the cache, then k-way set associative mapping becomes fully associative mapping.

Next Article- Direct Mapping | Implementation & Formulas

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Summary

Article Name	Cache Mapping	Cache Mapping Techniques
Description	Cache mapping is a technique that defines how contents of main memory are brought into cache. Cache Mapping Techniques- Direct Mapping, Fully Associative Mapping, K-way Set Associative Mapping.
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