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Impact of Cache Memory on CPU Performance

Computer Organisation

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Abstract

This case study analyzes the impact of cache memory on CPU performance in modern computer systems. Cache memory acts as a high-speed buffer between the processor and main memory, reducing memory access time and improving overall system efficiency. The study focuses on cache memory organization, levels of cache, and their role in minimizing latency and increasing throughput. Performance parameters such as cache hit ratio, miss rate, and access time are examined to understand how cache memory enhances processor execution speed. The relevance of cache memory in real-world applications such as high-performance computing, multitasking systems, and embedded devices is also discussed. The analysis shows that efficient cache design significantly improves CPU performance by reducing memory bottlenecks. This makes cache memory a critical component in computer organization and modern processor architecture.

Keywords

(Cache Memory, CPU Performance, Memory Hierarchy, Latency, Throughput)

1. Introduction

Cache memory is a vital component of modern computer systems that helps bridge the speed gap between the processor and main memory. As CPU speeds have increased rapidly, accessing data directly from main memory has become a major performance bottleneck. Cache memory solves this problem by storing frequently accessed instructions and data closer to the processor. In computer organization, cache memory plays an important role in determining system performance, efficiency, and responsiveness. The motivation for choosing this case study is to understand how cache memory improves CPU performance in real- world systems such as personal computers, servers, and mobile devices. Studying cache behavior is essential for designing efficient processors and optimizing system performance.

2. Problem Statement / Objective

Problem Statement

The speed difference between the CPU and main memory causes delays in instruction execution, reducing overall system performance.

Objectives

- To study the role of cache memory in CPU performance
 - To understand cache memory organization and hierarchy
 - To analyze performance parameters such as hit rate and latency
 - To evaluate advantages and limitations of cache memory
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3. System Overview / Architecture Description

Cachememoryis organized as partofthe memoryhierarchy and is located between the CPU and main memory. It is divided into multiple levels such as L1, L2, and L3 cache, each differing in size and speed.

Major Components

- L1 Cache: Smallest and fastest cache, located inside the CPU
 - L2 Cache: Larger than L1, slightly slower
 - L3 Cache: Shared cache, larger and slower than L2
 - Cache Controller: Manages data transfer between cache and main memory
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4. Working Principle / Methodology

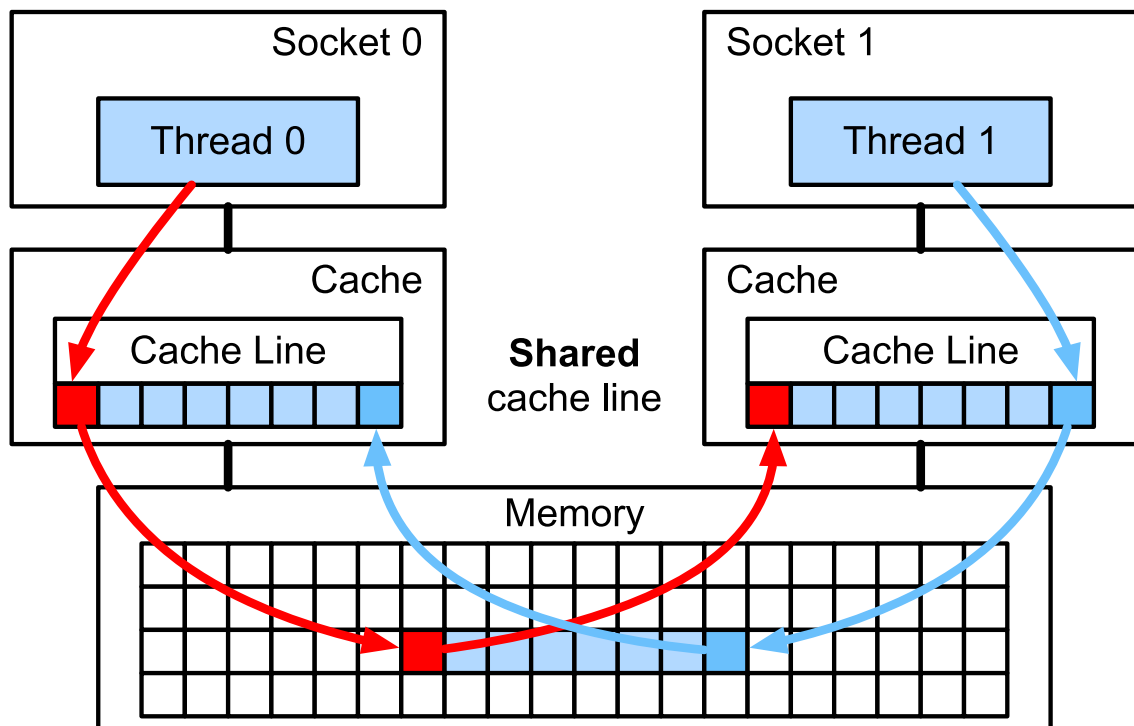
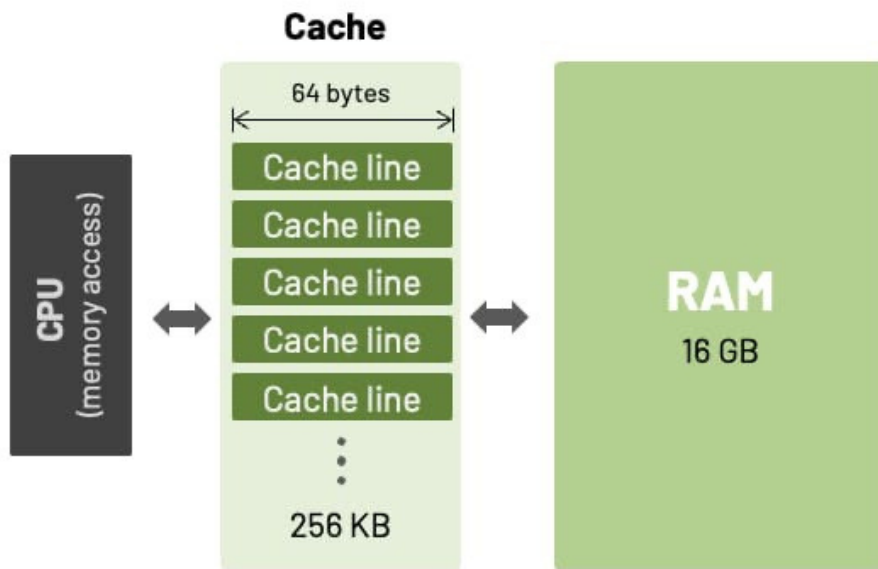
When the CPU requests data, the cache memory is checked first. If the required data is found in the cache, it is called a cache hit, resulting in fast access. If the data is not found, it is called a cache miss, and the data is fetched from main memory and stored in the cache for future use.

This process reduces memory access time and improves instruction execution speed. Cache replacement policies such as Least Recently Used (LRU) help manage limited cache space efficiently.

5. Case Study Analysis

Performance Parameters

- Speed: Fasterdata access improves CPU execution
- Latency: Reduced memory access delay
- Throughput: Increased number of instructions per second
- Power Consumption: Efficient cache usage reduces energy consumption



Advantages

- Improves system performance
- Reduces memory bottlenecks
- Enhances multitasking efficiency

Limitations

- Limited cache size
- Cache coherence issues in multiprocessor systems

6. Results and Discussion

The analysis shows that cache memory significantly improves CPU performance by reducing memory access time. Higher cache hit rates lead to faster instruction execution and better system responsiveness. Multi-level cache architectures further optimize performance by balancing speed and storage capacity. However, poor cache design can lead to increased miss rates and reduced efficiency.

Conclusion

Cache memory is a critical component in modern processor architecture and computer organization. By minimizing the speed gap between the CPU and main memory, cache memory enhances system performance, efficiency, and reliability. Effective cache design plays a major role in achieving high-performance computing systems, making it an essential topic of study in computer organization.