

A SYSTEMATIC REVIEW OF RECENT ADVANCEMENTS IN COMPUTER ARCHITECTURE

¹Ms. Priyanka Arora, ²Mr. Khushwinder Singh, ³Mr. Prince kumar

¹Assistant Professor in Computer Science, ³MBA Student, Department of Business Studies,
Baba Farid College of Engineering & Technology, Bathinda

²MSC- IT Student, Khalsa College, Patiala

Abstract

Computer architecture has undergone significant transformation over the past decade due to rapid advancements in semiconductor technology, increasing computational demands, and the emergence of data-intensive applications such as artificial intelligence, cloud computing, and big data analytics. Traditional performance scaling approaches based on clock frequency improvements have reached physical and power limitations, prompting researchers to explore alternative architectural designs and optimization strategies. This systematic review paper examines recent advancements in computer architecture with a focus on performance enhancement, energy efficiency, scalability, and security. The study analyzes contemporary architectural trends including multicore and manycore processors, heterogeneous computing, memory hierarchy innovations, hardware accelerators, and security-aware architectural designs. By synthesizing findings from recent scholarly literature, this review highlights key developments, identifies prevailing challenges, and outlines future research directions. The paper aims to provide researchers, academicians, and practitioners with a comprehensive understanding of modern computer architecture advancements in a structured and accessible manner.

Keywords: Computer Architecture, Multicore Processors, Heterogeneous Computing, Memory Hierarchy, Hardware Accelerators, Energy-Efficient Architecture

Introduction

Computer architecture serves as the foundation of computing systems, defining the structure, organization, and behavior of computer hardware components. Over the years, architectural design has evolved to meet the growing demands for higher performance, reduced power consumption, and improved reliability. Earlier advancements were primarily driven by increases in clock speed and transistor density, following Moore's Law. However, physical constraints such as power dissipation, heat generation, and diminishing returns from frequency scaling have limited this approach. In response, modern computer architecture research has shifted toward parallelism, specialization, and efficiency. Multicore and manycore processors, heterogeneous architectures, and domain-specific accelerators have become central to system design. Additionally, the rapid growth of cloud computing and artificial intelligence workloads has introduced new requirements for scalability, memory bandwidth, and security. This paper presents a systematic review of recent advancements in computer architecture, focusing on key trends and technological innovations that define contemporary computing systems.

Objectives of the Study

- To analyze recent advancements in computer architecture reported in scholarly literature.
- To examine emerging architectural trends addressing performance and energy efficiency challenges.
- To study innovations in processor design, memory systems, and specialized hardware accelerators.
- To identify security and reliability considerations in modern architectural designs.
- To highlight research gaps and suggest future directions in the field of computer architecture.

Research Methodology

This study adopts a systematic literature review methodology to ensure comprehensive and unbiased analysis. Peer-reviewed research articles, conference papers, and review papers published in reputed journals and digital libraries were considered. Sources include IEEE Xplore, ACM Digital Library, Springer, and Elsevier databases. The selection criteria focused on publications from recent years that discuss advancements in processor architecture,

memory hierarchy, energy-efficient computing, and architectural support for emerging applications. The review process involved identifying relevant studies, categorizing them based on architectural themes, and synthesizing their findings. Emphasis was placed on analyzing design approaches, performance benefits, and limitations discussed in the literature. This structured methodology ensures that the review reflects current research trends and technological progress in computer architecture.

Recent Advancements in Computer Architecture

1) Multicore and Manycore Architectures

One of the most significant advancements in computer architecture is the widespread adoption of multicore and manycore processors. Instead of increasing clock frequency, modern processors integrate multiple processing cores on a single chip to improve parallel execution. This approach enhances performance while maintaining manageable power consumption. Manycore architectures, which include dozens or even hundreds of cores, are particularly beneficial for high-performance computing and data-parallel applications. Research has focused on efficient core communication, cache coherence mechanisms, and parallel programming models to fully exploit multicore systems. Despite their advantages, challenges such as workload balancing and synchronization overhead remain active areas of research.

2) Heterogeneous Computing Architectures

Heterogeneous architectures combine different types of processing units, such as CPUs, GPUs, and specialized accelerators, within a single system. This design allows workloads to be executed on the most suitable processing element, thereby improving performance and energy efficiency. Graphics Processing Units (GPUs) are widely used for parallel workloads, particularly in artificial intelligence and scientific computing. Recent advancements emphasize seamless integration and efficient task scheduling across heterogeneous components. These architectures are increasingly adopted in modern computing platforms, including mobile devices, cloud data centers, and embedded systems.

3) Memory Hierarchy and Storage Innovations

Memory systems play a critical role in overall system performance. As processor speeds continue to increase, the gap between computation and memory access latency has become a major bottleneck. Recent research has focused on improving memory hierarchy through advanced cache designs, non-volatile memory technologies, and memory-centric architectures. Innovations such as 3D-stacked memory, high-bandwidth memory (HBM), and near-memory computing aim to reduce latency and increase bandwidth. These approaches enhance data access efficiency, particularly for data-intensive applications such as big data analytics and machine learning.

4) Hardware Accelerators and Domain-Specific Architectures

Domain-specific hardware accelerators are designed to efficiently execute specific types of workloads. Examples include tensor processing units for machine learning, encryption accelerators for security applications, and network processing units for data centers. These accelerators offer significant performance and energy efficiency gains compared to general-purpose processors. Recent architectural research emphasizes the integration of accelerators into system-on-chip designs and the development of programming models that simplify their use. Such architectures are critical for meeting the performance demands of emerging applications.

5) Energy-Efficient and Green Computing Architectures

Energy efficiency has become a primary design objective in modern computer architecture. Power-aware techniques such as dynamic voltage and frequency scaling, power gating, and energy-efficient core designs are widely adopted. Research also explores architectural approaches that balance performance with sustainability, contributing to green computing initiatives. Energy-efficient architectures are particularly important in large-scale data centers and mobile devices, where power consumption directly impacts operational costs and battery life.

6) Security-Aware Architectural Designs

With the increasing frequency of hardware-level security threats, modern computer architecture incorporates security features at the design stage. Techniques such as secure enclaves, trusted execution environments, and

hardware-based encryption enhance system security. Architectural support for secure computation helps mitigate vulnerabilities and protect sensitive data. Recent studies highlight the importance of integrating security mechanisms without significantly affecting performance, making security-aware architecture a critical research area.

Analysis of Recent Advancements

The analysis of recent advancements in computer architecture is based on a comparative evaluation of existing architectural approaches discussed in the reviewed literature. The analysis focuses on performance improvement, energy efficiency, scalability, and security as the key evaluation parameters. Multicore and manycore architectures demonstrate significant performance gains by exploiting instruction-level and thread-level parallelism. However, the analysis indicates that these gains are highly dependent on efficient parallel programming models and workload characteristics. Applications with limited parallelism fail to fully utilize available cores, leading to suboptimal performance.

Heterogeneous computing architectures show superior performance and energy efficiency for specialized workloads such as artificial intelligence, graphics processing, and data analytics. The analysis reveals that GPUs and domain-specific accelerators outperform general-purpose processors in compute-intensive tasks. Despite these benefits, challenges related to programming complexity, data movement overhead, and interoperability between heterogeneous components remain prominent.

Memory hierarchy innovations, including high-bandwidth memory and non-volatile memory technologies, significantly reduce memory access latency and improve throughput. The analysis highlights that memory-centric architectures effectively address the processor-memory gap, especially for data-intensive applications. However, cost, integration complexity, and compatibility with existing systems limit their widespread adoption.

Energy-efficient architectural techniques such as dynamic voltage and frequency scaling and power-aware core designs contribute to reduced power consumption without severely impacting performance. The analysis confirms that energy efficiency has become a critical design constraint, particularly for data centers and mobile computing platforms. Security-aware architectural designs enhance system resilience against hardware-level attacks. The analysis indicates that while hardware-based security mechanisms improve protection, they may introduce additional performance overhead, requiring careful architectural trade-offs.

Findings and Discussion

The systematic review reveals that modern computer architecture has shifted from performance-centric designs to balanced approaches emphasizing efficiency, scalability, and security. Multicore and heterogeneous architectures dominate current research, while memory and accelerator innovations address emerging workload demands. However, challenges related to programmability, interoperability, and security persist. The findings suggest that collaborative research across hardware and software domains is essential to fully leverage architectural advancements.

Future Research Directions

Future research in computer architecture is expected to focus on intelligent and adaptive systems that dynamically optimize performance and energy consumption. Greater emphasis on AI-driven architectural optimization, advanced memory technologies, and secure-by-design frameworks is anticipated. Additionally, simplifying programming models for heterogeneous systems remains a critical research challenge.

Conclusion

This systematic review has examined recent advancements in computer architecture, highlighting key trends and innovations shaping modern computing systems. The transition toward multicore, heterogeneous, and energy-efficient architectures reflects the need to overcome physical and technological limitations of traditional designs. By synthesizing recent research, this paper provides valuable insights into current developments and future directions in computer architecture. The findings can serve as a reference for researchers and practitioners aiming to design efficient, scalable, and secure computing systems.

References

1. Hennessy, J. L., & Patterson, D. A. Computer Architecture: A Quantitative Approach. Morgan Kaufmann.
2. Sze, V., Chen, Y. H., Yang, T. J., & Emer, J. S. Efficient Processing of Deep Neural Networks. Proceedings of the IEEE.
3. Hill, M. D., & Marty, M. R. Amdahl's Law in the Multicore Era. IEEE Computer.
4. Jouppi, N. P., et al. In-Datacenter Performance Analysis of a Tensor Processing Unit. ACM/IEEE ISCA.
5. Asanović, K., et al. The Landscape of Parallel Computing Research. Communications of the ACM

Use for Citation: Ms. Priyanka Arora, Mr. Khushwinder Singh, Mr. Prince kumar.
(2025). A SYSTEMATIC REVIEW OF RECENT ADVANCEMENTS IN
COMPUTER ARCHITECTURE. International Journal of Multidisciplinary Research
and Technology, 6(12), 95–98. <https://doi.org/10.5281/zenodo.18016072>