

# Multicore Processor Architectures: A brief survey

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**Abstract**—Multicore processors are common in contemporary computing systems because they enhance speed through parallel computation. This survey provides a synopsis of history and present-day patterns associated with multicore processor architecture. The research starts with an overview of multicore processor history and the different architectures that have evolved over time. It then discusses major issues that multicore processors face, such as power consumption, memory bandwidth, and scalability. This study also emphasizes new apps that are pushing the need for more efficient and powerful multicore processors. The research closes with a discussion of two of the most popular multicore processors based on current market patterns. Recent advancements in multicore CPU architecture are also discussed. In summary, this survey provides a detailed overview of multicore processor architecture, covering key trends, challenges, and opportunities for further research and development.

**Keywords**—bandwidth, multicore, parallelism, scalability

## I. INTRODUCTION

Multicore processors have transformed the design and use of computer systems in the modern era. These processors integrate multiple processing cores onto a single chip, allowing for parallel task processing and significantly improved processing speed and efficiency. Multicore processors have evolved to meet the need for increased system performance while reducing power consumption. Initially, they were developed for high-end server systems in the late 1990s, but they soon found a wider market in the early 2000s. Chip manufacturers continued to increase the number of cores, with some processors now having dozens of cores, to meet the demand for more processing power, especially in data-intensive applications.

Alongside the increase in core counts, manufacturers also focused on improving power efficiency to reduce energy consumption in computing systems and extend battery life in mobile devices. Today, multicore processors are widely used in personal computers, servers, mobile devices, and high-performance computing applications. Intel's Core processors, AMD's Ryzen processors, Qualcomm Snapdragon processors, Apple's A-series processors, and Nvidia Tegra processors are some of the most popular multicore processors used worldwide. The design of multicore processors has also impacted software development and optimization. Developers must now consider parallelism in their applications, requiring them to design algorithms and software that can use multiple cores in a multicore processor. This has led to the development of new programming paradigms and tools, such as parallel programming frameworks and libraries.

In conclusion, multicore processors have significantly impacted the computing industry by offering a way to improve system performance while reducing power consumption. As the demand for processing power and parallelism continues to grow, the evolution of multicore processors is likely to have a significant impact on the computing industry in the future.

## II. LITERATURE REVIEW

The previous works are reportable in the literature study in order to get to know more and more about the multicore processor architectures. The paper titled "Multicore processors: challenges, opportunities, emerging trends" [1] by Christian Martin was presented at the 2014 Embedded World Conference. It provides a synopsis of the challenges and opportunities related with multicore processors and highlights emerging trends in this field. The paper discusses the advantages of using multicore processors and the challenges faced in their design and implementation. It also presents emerging trends in multicore processor architecture and their potential impact on the computing industry. Another paper provides a comprehensive survey of multicore processors [2], including their history, design, and implementation. The authors discuss the benefits and challenges of using multicore processors and analyze different types of multicore processor architectures. The paper also covers emerging trends in multicore processor design, such as heterogeneous computing and specialized accelerators, and provides insights into the future of multicore processors. Schauer et al. [3] argued that the use of multicore processors is necessary to achieve increased processing power, improved system performance, and reduced power consumption. Overall, the paper highlights the importance of multicore processors in meeting the growing demands of modern computing systems. A yet another paper [4] discusses the advantages of multi-core processors over single-core processors, including higher performance and reduced power consumption. The authors also discuss the challenges of multi-core processor design, such as inter-core communication and memory access. An other paper provides a comprehensive survey of the techniques used for designing and managing asymmetric multicore processors (AMPs). AMPs are a type of multicore processor where the cores are not identical in terms of their performance, power consumption, or other parameters. The paper [5] covers the design of AMPs, the various techniques for task scheduling and load balancing on these processors, and the challenges in managing AMP-based systems. The survey also includes a review of the applications that can benefit from AMPs and the future research directions in this field.

### III. MULTICORE PROCESSOR ARCHITECTURES

Computer architecture encompasses the design and organization of both hardware and software components within a computer system. This involves specifying the instruction set architecture (ISA), microarchitecture, memory hierarchy, and other important aspects. The ISA defines the set of instructions that a computer can execute and the data types, registers, and memory organization used by the hardware. Common ISAs include x86, ARM, and PowerPC.

Microarchitecture is the implementation of the ISA in a specific processor design. It specifies the arrangement of functional units, the number of registers, and the organization of the memory hierarchy. The memory hierarchy, on the other hand, is the arrangement of different levels of memory storage in a computer system, from the fastest (but smallest) level (e.g., cache) to the slower (but larger) level (e.g., main memory).

Input/ Output (I/O) systems are responsible for managing the communication between the computer and its external environment (e.g., keyboard, mouse, storage devices). The design of I/O systems is important as it affects the performance, reliability, and security of the system. Pipelining and parallelism are techniques used in computer architecture to improve the performance of processors by allowing multiple instructions to be processed in parallel. Other important aspects of computer architecture include power management, security, and interconnects. It is essential for computer scientists, software engineers, and hardware engineers to understand computer architecture as it enables them to design and build efficient, reliable, and secure computer systems.

#### A. Multicore concepts in computers

A multi-core processor is a computer processor that integrates multiple processing cores (i.e., processing units) on a single chip. The primary objective of a multicore processor is to improve the performance of computer systems by allowing them to perform multiple tasks in parallel. This results in a significant increase in processing speed and overall system efficiency. Multicore processors are designed to take advantage of parallelism in applications by allowing multiple tasks to run simultaneously on different cores. The operating system schedules the tasks to run on the available cores, and the cores communicate with each other as needed to exchange data and coordinate their activities. This approach enables the system to complete tasks much faster than a single-core processor, as multiple cores can work together to solve complex problems. They are also widely used in high-performance computing and data-intensive applications, where the need for processing power and parallelism is high.

Overall, the concept of multicore processors has revolutionized the computing industry by providing a way to improve the performance of computer systems while also reducing power consumption. This has enabled the development of more powerful and efficient computer systems that can meet the increasing demands of modern applications and services. Multicore processors are computer processors that integrate multiple processing cores (i.e., processing units) on a single chip. This architecture has become increasingly popular in recent years as a way to improve the performance of computer systems while also

reducing power consumption. There are several different architectures that can be used to implement multicore processors, including:

1) *Symmetric Multiprocessing Architecture*: Symmetric multiprocessing, also known as shared-memory multiprocessing (SMP), is a computer architecture that involves multiple processors connected to a shared main memory. All Processing Units have full access to all I/O devices and are equally managed by a single operating system instance, with no resources allocated for specialised applications. Nowadays, SMP architecture is commonly used in multiprocessor systems. In the case of multi-core processors, each core is treated as a separate processor and the SMP architecture is applied to them.

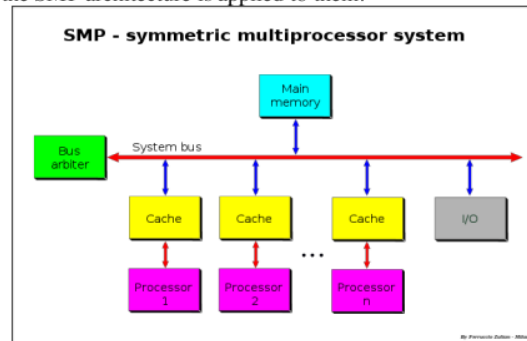


Fig. 1. SMP Architecture

SMP is particularly useful in time-sharing and server systems, where multiple parallel processes are typically running, as different processes can be assigned to different processors, without requiring modifications to applications. In these systems, SMP can be easily employed, without the need for significant changes to the software.

On the other hand, SMP has limited usefulness in personal computers, where unmodified applications rarely run more than one process at a time. SMP can be beneficial in such systems only for applications that have been adapted to support multithreaded processing. To take advantage of multiple processors, custom software can be developed or modified to use multiple threads, enabling applications to run faster and more efficiently. In time-sharing and server systems that support multithreading, multithreaded programs can be used to make more efficient use of multiple processors, further enhancing performance and efficiency. By utilizing SMP technology, such systems can provide faster and more responsive service to users, making them ideal for applications that require high levels of performance and scalability.

In modern SMP systems, all processors are closely connected within the same enclosure using a bus. In earlier SMP systems, a single CPU occupied an entire cabinet. Shared components include global memory, disks, and I/O devices. A single copy of an operating system runs on all the processors, and the OS must be designed to exploit this architecture. Some of the primary benefits of SMP include cost-effective methods for increasing throughput. To address various problems and tasks, SMP employs multiple

processors for a single problem, which is referred to as parallel programming. However, SMP's scalability is restricted by cache coherence and shared objects.

**2) Asymmetric multiprocessing Architecture:** Asymmetric multiprocessing (AMP or ASMP) is a form of multiprocessor computer system in which not all interconnected CPUs receive identical treatment. In some instances, either at the hardware or operating system level, only one CPU is permitted to run operating system code or conduct I/O tasks. Other AMP systems may enable any CPU to perform these duties, but devices may be connected to specific CPUs, resulting in peripheral asymmetry. Before symmetric multiprocessing (SMP), AMP was the main technique for managing multiple CPUs. It's also been used to provide less expensive alternatives on platforms with SMP.

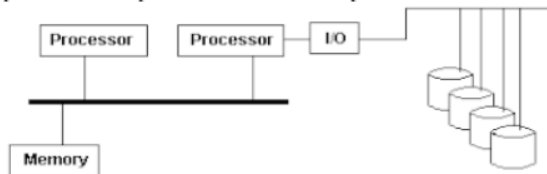


Fig. 2. AMP Architecture

**3) Chip-Multiprocessor Architecture:** Chip multiprocessors (CMPs) have become the preferred approach for building high-performance microprocessors due to several factors. Large uniprocessors of the past are no longer capable of achieving higher performance since extracting parallelism from a standard instruction stream using traditional superscalar instruction techniques is challenging. Furthermore, increasing clock speeds on today's processors will result in higher power dissipation, making it impractical for all but water-cooled systems. The problem is compounded by the high cost of designing and debugging ever-larger processors every few years as microprocessors continue to become more complex with the increasing number of transistors. CMPs address these issues by using multiple simpler processor cores instead of one large core. Core sizes in CMPs can vary, ranging from basic pipelines to moderately complex superscalar processors. Once a core is chosen, CMP performance can be increased across silicon process generations by replicating more high-speed processor core copies in each subsequent chip generation. This approach reduces the design cost and time to market, making it possible to achieve high-performance microprocessors more quickly and cost-effectively.

In addition, running multiple threads of execution across various cores through parallel code execution can deliver considerably better performance than using a single core. The use of CMPs allows for more efficient utilization of processor resources, resulting in improved system performance and lower power consumption. CMPs have become a standard in the industry, and modern microprocessors use multi-core designs to deliver the high-performance computing required by demanding applications, such as gaming, machine learning, and scientific simulations.

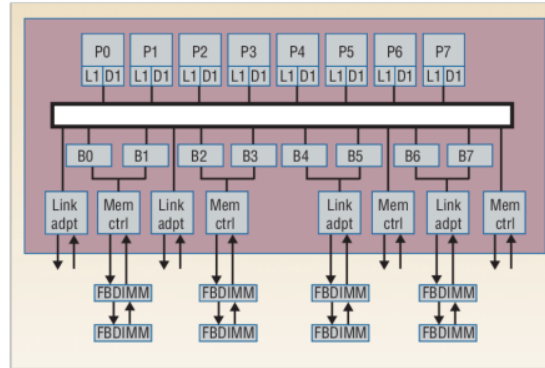


Fig. 3. CMP Architecture

There are several examples of multicore processors that are commonly used in computers. Intel's Core processors are widely used in personal computers and laptops and are available in various configurations, with up to 18 cores. AMD's Ryzen processors are another popular choice for consumers and are known for their high performance and competitive price. Qualcomm Snapdragon processors are widely used in mobile devices, such as smartphones and tablets, and are designed for power efficiency to extend battery life. Apple's A-series processors are used in the company's iPhone and iPad devices, and Nvidia Tegra processors are used in a variety of devices, including automotive systems, gaming devices, and mobile devices. These multicore processors use advanced microarchitecture and process technologies to deliver high performance and efficiency in a small and power-efficient package. The specific type of multicore processor architecture used in a computer will depend on its intended use case, performance requirements, and other factors.

Multicore Processor	Architecture Used	Number of cores
Intel Xeon Scalable Processor	Hybrid architecture (SMP + AMP)	40 cores
AMD Ryzen Threadripper	Symmetric Multiprocessing	64 cores
Qualcomm Snapdragon 870	Asymmetric Multiprocessing	8 cores
Nvidia Tegra Xavier	Heterogeneous architecture	8 cores
Apple A14 Bionic	Heterogeneous architecture	4 cores
Samsung Exynos 2100	Hybrid architecture (SMP + AMP)	8 cores
IBM Power9	Coherent Multicore Processor	24 cores



MediaTek Dimensity 1200	Heterogeneous architecture	8 cores
Fujitsu A64FX	Coherent Multicore Processor	64 cores

Table.1. Types of Multicore Processor Architecture modern multicore processor uses

## B. Current market trends

Now let's look at the two leading processors according to the current market trends:

### 1) AMD Ryzen

AMD Ryzen is a line of CPUs produced by Advanced Micro Devices (AMD). The Ryzen family of processors was introduced in 2017 and is known for its high performance and power efficiency. Ryzen CPUs are designed to compete with Intel's Core processors in the consumer and commercial markets. The Ryzen processors are based on AMD's Zen microarchitecture, which offers improved performance compared to AMD's previous generation of CPUs. The Ryzen processors come in various models with different core counts, clock speeds, and power consumption levels. Some of the most popular Ryzen CPUs include the Ryzen 3, Ryzen 5, Ryzen 7, and Ryzen 9 series, which cater to different market segments and user needs. These processors have been well received by users and industry experts for their high performance, power efficiency, and competitive pricing, making them a popular choice for gamers, content creators, and professionals who need high-performance computing.

The specifications of AMD Ryzen processors can vary depending on the model, but they offer several common features that enhance their performance. Ryzen processors come with up to 16 cores and 32 threads, allowing for efficient multitasking and high performance. The processors have a base clock speed and a boost clock speed that can go higher depending on the workload. They also have a large amount of cache memory, including a smaller L1 and L2 cache and a larger L3 cache, which improves their performance. The TDP (Thermal Design Power) indicates the maximum amount of power the processor can consume and how much heat it generates. Ryzen processors use the AM4 socket for desktops and the TR4 socket for high-end desktops. Some Ryzen processors have integrated graphics, while others require a separate graphics card. Ryzen processors support DDR4 memory with varying maximum speeds. They are manufactured using a 7nm process, which improves their power efficiency and performance. Finally, many Ryzen processors can be overclocked to improve their performance, but this requires specialized knowledge and can void warranties.

	<b>13</b> Ryzen 9 7950X	Ryzen 9 7900X	Ryzen 7 7700X	Ryzen 5 7600X
<b>Cores</b>	16/32	12/24	8/16	6/12

<b>2</b> Cache (L2+L3)	80MB	76MB	40MB	38MB
<b>Base clock</b>	4.5GHz	4.7GHz	4.5GHz	4.7GHz
<b>Boost clock</b>	5.7GHz	5.6GHz	5.4GHz	5.3GHz
<b>TDP</b>	170W	170W	105W	105W
<b>Price</b>	\$699	\$549	\$399	\$299

Table. 2. The specifications of some of the processors of AMD Ryzen

### 2) Intel Core

Intel Core is a line of CPUs (Central Processing Units) produced by Intel Corporation. The Core family of processors was introduced in 2006 and is known for its high performance and power efficiency. The Core processors are based on Intel's x86 architecture and are used in a wide range of devices, including desktops, laptops, and servers. The Core processors come in various models with different core counts, clock speeds, and power consumption levels. Some of the most popular Core CPUs include the Core i3, Core i5, Core i7, and Core i9 series, which cater to different market segments and user needs.

Intel Core processors offer several features that enhance their performance, making them a popular choice for users with varying performance needs and budgets. Turbo Boost Technology is a feature available on many Intel Core processors that dynamically increases the processor's clock speed when needed, depending on the workload. Quick Sync Video is another feature available on many Intel Core processors that accelerates video encoding and decoding, making it useful for tasks such as video editing and streaming. Intel Optane Memory is a high-speed memory that can be used in conjunction with a traditional hard drive or SSD to speed up system performance. Thermal Velocity Boost is a feature available on some Intel Core processors that further increases the processor's clock speed when operating below a certain temperature threshold. Intel vPro Technology is designed for business users, with features that include hardware-based security, remote management capabilities, and virtualization support. The Intel Core X-series processors are high-end desktop processors that offer even higher core counts and clock speeds than the standard Intel Core processors. They are designed for users who require maximum performance for tasks such as video editing, 3D rendering, and gaming. Finally, the Intel Core H-series processors are designed for high-performance laptops and offer a balance of power and efficiency, commonly used in gaming laptops, content creation laptops, and mobile workstations. Overall, the Intel Core processor family offers

a wide range of options for users, making it a popular choice in the market.

	Core i9-13900K	Core i7-13700K	Core i5-13600K
Cores	24/32	16/24	14/20
Cache (L2+L3)	68MB	54MB	44MB
Base Clock	3GHz(P-core), 2.2GHz (E-core)	3.4GHz(P-core), 2.5GHz (E-core)	3.5GHz(P-core), 2.6GHz (E-core)
Boost Clock	5.8GHz	5.4GHz	5.1GHz
TDP	125W/153W	125W/153W	125W/181W
Price	\$590	\$410	\$320

Table. 3. The specifications of some of the processors of Intel Core

3) *AMD vs Intel: Which one is Better in current scenerio?*  
The choice between Intel Core and AMD Ryzen processors depends on your specific needs and budget. Ryzen offers more cores and threads for better multi-threaded performance, while Core has higher single-threaded performance, making it better for gaming and single-threaded tasks. Ryzen is generally more affordable, while Core is the premium option for the highest-end performance.

	AMD Ryzen	Intel Core
CPU pricing and value	1	0
Gaming Performance	1	0
Content Creation	1	0
Specifications	1	0
Overlocking	1	0
Power consumption	0	1
Drivers and software	1	0
Process Node	0	1
Architecture	1	1
Security	0	1
Winner Total: Intel	7	4

Table. 4. The comparison between AMD's Ryzen and Intel Core

In the world of CPUs, Intel is considered the best option for overall everyday use, while AMD is preferred for high-end workstations with their high core counts. According to CPU stress tests, Intel's clock speeds usually outperform AMD's, and their processors tend to be more flexible and reliable. AMD is gaining ground as a strong competitor with its Ryzen 9 processor, which boasts 8+ cores and a multithreaded Zen architecture that excels in high-end workstations. When choosing a CPU, it's important to look for deals that match your desired specifications, and if an AMD chip can meet your needs at a better price than an Intel chip, it's worth

considering. The intense rivalry between Intel and AMD is prompting both companies to produce cutting-edge hardware, resulting in outstanding choices for consumers. To summarize, Intel still dominates the CPU market, providing the best balance between price and performance. However, AMD is a close competitor, particularly for high-end workstations.

## IV. CONCLUSION

A multicore architecture has become an important aspect of computer architecture in recent years as a way to improve the performance and efficiency of computer systems. It involves integrating multiple processing cores on a single chip and utilizing parallelism to perform tasks simultaneously. There are several different architectures that can be used to implement multicore processors, including SMP, AMP, CMP, and hybrid multiprocessing, each with its own advantages and disadvantages. The interconnect architecture, memory hierarchy, and operating system and software used to manage the processors are also important factors that impact the performance and efficiency of multicore processors. Understanding these concepts is essential for computer scientists, software engineers, and hardware engineers as they design and build efficient, reliable, and secure computer systems.

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