A Comprehensive Review of The Specification Evaluation of High-Performance Cloud-Based Graviton3 Processors

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Abstract: In the 4.0 industrial era, the internet is a dynamically changing environment, acting as the backbone of technological enlargement. For deploying, processing, and storing data at a low cost, users and businesses require fast and scalable options. This can only be achieved by having high computing power. AWS announced Graviton 3, which provides much better performance. In the future, tech giants will be tasked with managing the workload, providing better performance, and reducing the time complexity of computing as industry 4.0 and smart-healthcare applications become even more complicated. Graviton3, the new cloud-based processor, boasts the latest architecture and higher performance than its predecessors and competitors. The cloud is a scalable, secure, and affordable way to access computing power compared to a private server. Efficient and cheap cloud processors are essential to sustainable cloud computing. Cloud computing is rapidly improving to provide the best performance/cost ratio. Compared to its previous generation, AWS Graviton 2, this delivers 25% higher compute performance, 2x float performance, 2x cryptography performance, 50% higher memory bandwidth, and 3x faster machine learning workloads. The AWS Graviton series of processors dominate cloud computing processors today. In some metrics, the AWS Graviton even outperforms the Intel x86-based CPU. ARM-based processors have changed the dynamics of cloud computing. An extensive technical review of cloud-based processors is presented in this paper, including how it'll help solve problems of modern-day cloud computing and comparison with other competitors. The paper discusses and analyzes the implications of ARM in cloud computing, including its challenges, open issues, related works, and its applications.

Keywords: Graviton 3, Advanced RISC Machine (ARM), Amazon Web Services (AWS), Internet of Things, Industry 4.0, Cloud Computing.

1 Introduction

Cloud-based systems are increasing their hold into industry 4.0, and with the increasing demand for a company's systems to be on online mode cloud systems applications are also increasing, hence requiring more computing power. So, to tackle this issue AWS launched its new generation of processors "AWS Graviton 3". The ARM-based graviton cloud-based processors are challenging the traditional x86 market of personal and server-based processors. Industry 4.0 is fully embracing cloud-based processors like graviton2, especially for reducing costs and boosting efficiency [1]. According to Statista the Market capital of Cloud Market share has risen at a very exponential rate from 2017 to 2020 shown in Figure 1. Amazon Web Services, a cloud computing technology company, introduced its latest Intel Graviton3 processor and also revealed EC2 C7g preview instances. Amazon's AWS platform uses the Graviton ARM-based CPU as a central processing unit.

A Graviton series of processors are intended to meet the demands of better computing, low prices, and high performance [2]. Graviton2 delivered up to 7x higher performance than Graviton1 and featured 4x more cores, twice as many caches, and 5x quicker memory than the first-generation Graviton processors from AWS. Graviton2 was 40% more performant than x86 architecture [3]. Application Servers, Micro Services, Video Encoding, Open-Source Databases, in-memory caching, accelerated computation, and Machine Learning may all be operated on a Graviton2-powered EC2. Graviton2 can operate Linux-based operating systems such as Amazon Linux 2, RedHat, Ubuntu, and essential AWS services as a result of these features [4, 8]. According to Graviton3 the latest CPU in the Graviton series, it delivers up to 25% better performance, as well as 2x higher floating-point performance as well as 2x faster for cryptographic

workloads when compared with AWS Graviton2 processors. And compared to Graviton2, Graviton3 processors have up to 3x better performance for Machine Learning workloads, and support for bfloat16 has also been added [6]. With help of these powerful benchmarks, Graviton 3 is a huge breakthrough in the Cloud Computing domains, and hence it's solving the huge level of time and efficiency problem in industry 4.0, wherein everything is connected and act as a node. The Graviton3 processor performs up to 3x faster for Machine Learning workloads than Graviton2, and it supports bfloat16 as well [7]. DDR5 memory offers a 50% increase in bandwidth over DDR4, so Graviton3 supports it. Before the advent of ARM-based CPUs, low-end devices such as phones and computers were powered by ARM-based processors. High-performance ARM-based CPUs like Graviton are used in cloud computing where they can run high-performance applications that provide benefits of ARM architecture which are low power consumption and less heat generation [10]. The cloud can be operated at a lower cost, providing more access to cloud technology for a lower price for a wider audience [5].

The infrastructure as a service (IaaS) is growing at a very rapid pace as a by-product of the COVID-19 pandemic which saw a steep rise in online network traffic after the schools, colleges, offices, and industries were shut down. The worldwide distributed computing business is supposed to develop at a Compound Annual Growth Rate (CAGR) of 16.3 percent from USD 445.3 billion in 2021 to USD 947.3 billion in 2026, as indicated by Report Linker [9].

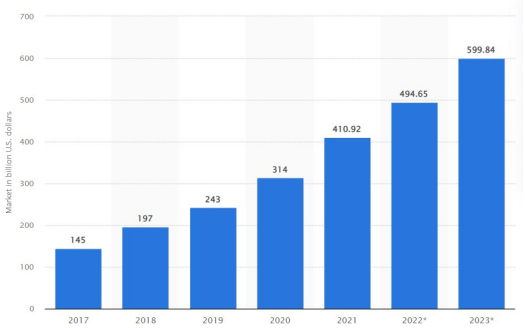

Figure 1. Global cloud computing market size from 2017 to 2021 (Billions of dollars), data from Statista

With the increase in cloud market capital, big enterprises are pouring funds into the research and development of new cloud-based CPUs. The ARM-based CPU like the graviton is storming the market. The competition between ARM-based and x86-based CPUs was already stiff. Alibaba also launched their ARM-based Yitian 710 CPU for the cloud. It is very exciting to see ARM dominating cloud computing taking a leapfrog jump from mobile computing devices direct to the cloud.

The cloud-based CPU market is diversified by various choices presented by the leading semiconductor vendors. The table below shows the development of the cloud-based CPU market over the years. It is evident from the table that the market is seeing rapid innovations regarding ARM-based CPUs in the previous year [5].

Processor	Release Date	Architecture
Graviton 3	Nov 2021	ARM
Yitian 710	Oct 2021	ARM
Intel Xeon 3rd Gen	April 2021	x86
AMD EYPC 3rd Gen	March 2021	x86
Graviton 2	Dec 2019	ARM
AMD EYPC 2nd Gen	Aug 2019	x86
Intel Xeon 2nd Gen	April 2019	x86
Graviton 1	Nov 2018	ARM

Table 1. Developments in cloud-based processors

The role of cloud computing is essential for sustainable Industry 4.0. The industries will look for cheap and secure alternatives to maintain a private cloud for themselves. The innovation in the cloud-based CPU can help enable and meet the requirements of these industries. The cost to performance, scalability, privacy, and security will remain a great challenge for cloud computing. The new security features like pointer authentication in AWS Graviton are necessary for the security of the cloud.

In this paper, we'll analyze the impact and role of ARM-based CPUs in the future of cloud computing. The paper presents a comprehensive review of cloud-based processors, it discusses and analyzes the impact of the ARM in cloud computing covering the prospects of ARM in cloud computing, its challenges, open issues, related works, and its applications. The research aims to provide a background study and comprehensive literature review of Graviton 3, including comparisons with other manufacturers as well as performance comparisons and experimentations.

This paper is organized as follows: Section 2 discusses literature reviews. Section 3 highlights a general overview along with the scenario of EC2 instances. Section 4 discusses the relevance and quality assistance in Industry 4.0 and its applications. Section 5 highlights ARM architecture and its microarchitecture Neoverse V1. Section 6 elaborates on features of graviton3 in contrast with the ARM-based processors. Section 7 highlights comparative analysis & Improvements of graviton3 with other industry-leading cloud-based processors. Section 8 outlines cloud-based processor instances. And finally, we discussed future research and related work and then concluded the paper.

2. Literature Review

The review provides the information in a systematic manner that helps further in exploring and uncovering the areas of interest and advancing the knowledge. In this paper, we aim to provide a systematic approach for reviewing the literature regarding the advancement in cloud-based processors its prospects, challenges, and open issues.

2.1 Literature Search Process

The AWS documentation and various articles were queried for the literature search process for this review paper. Other similar cloud-based processors were also queried to present a brief overview of the cloud-based processor domain. The cloud-based CPU were classified in the ARM and x86 category. The paper provides a dense informative overview of the latest trends in ARM Cloud Computing [8].

2.2 Classification

Cloud computing-based processors can be broadly classified based on the architecture. The AMD EYPC and Intel Xeon are based on x86 architecture while Alibaba's Yitian 710 and AWS Graviton are based on ARM [8, 11]. The classification of cloud processors is shown in Figure 2.

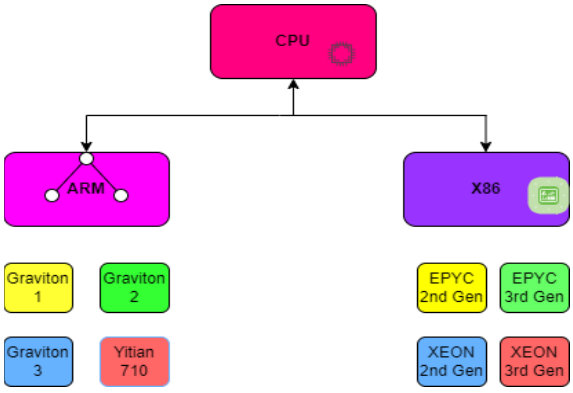

Figure 2. Classification of Cloud-Based Processors

3 Overview

AMD has the biggest latencies in all scenarios and for all EC2 instances. Since we will not repeat this information in future overviews, we exclude it from comparisons in percentages and numbers of values with other CPUs. On EC2, an instance with 8 vCPU Intel shows an advantage only in scenarios that have threads using less or equal amounts of vCPU. A Graviton advantage started to emerge on EC2 with eight vCPU. As the number of threads is 8 and 16 times bigger than the number of virtual CPUs, it grows up to 15 percent in high-concurrency scenarios. Graviton started to show an advantage on EC2 with eight vCPUs when threads outnumbered vCPUs [12].

4 Relevance and quality assistance in Industry 4.0, smart healthcare, and IoT applications

Artificial intelligence (AI), Internet of Things (IoT) devices, data analytics, and other technologies are generating increasingly resource-intensive cloud workloads that demand higher performance, scalability, and security. They are also driving up cloud costs, spurring a need for more cost-efficient cloud computing options. Furthermore, as we know

healthcare 4.0 saves the data from the medical IoT devices to the cloud-based services which also requires high computation power since parameters of healthcare-related data are increasing and hence increasing the space and time requirement for storing the data autonomously [5, 8]. The Graviton processors deliver on both fronts. Here are four of its key benefits:

4.1 Extensive Ecosystem Support

Graviton-based instances have been around for three years, and Red Hat, Ubuntu, and SUSE are all part of an Arm-centric ecosystem. Arm developers may use this environment to create cloud-native apps, removing the requirement for time-consuming and error-prone emulation and cross-compilation. Furthermore, many of AWS' and ISVs' most popular apps and services, including those used in Machine Learning and other resource-intensive applications, are compatible with Graviton2-powered instances. Among the services provided are Amazon ECS, Amazon CodeBuild, Amazon EKS, Amazon CloudWatch, Amazon CodeCommit, Amazon CodePipeline, Amazon ECR, Amazon CodeDeploy, NGINX, Jenkins, TensorFlow, NodeJS, and Docker. Not unexpectedly, AWS provides the same degree of support for its Arm-based Graviton silicons as it does for x86-based CPUs [13].

4.2 Enhanced Security

Numerous organizations are worried about cloud security, yet AWS' Graviton2 processors assist with easing a portion of the risks. Graviton2 permits generally 256-cycle DRAM encryption and 50 percent quicker per center encryption execution than past-age silicon. They are based on the AWS Nitro System, which gives expanded security by persistently observing, protecting, and guaranteeing the cases' equipment and firmware. This includes the Nitro security chip, which has specialized security hardware and software and by default supports encrypted EBS storage volumes. The Graviton2 processors additionally benefit from a set of architecture security features developed by Arm to protect against speculative execution attacks such as control flow, data-access, and side-channel assaults [14].

4.3 Reusability

The Arm architecture of the Graviton2 processors is responsible for several benefits that reduce cloud app development time. All that is required to migrate server-side workloads is to recompile code for the Arm architecture that is naturally supported in modern languages and frameworks like Python/Django, PHP/Symfony, or C#/.NET. For managed services like Amazon RDS, nothing has to be done with the code when modernizing a cluster from 4th to 5th generation instances. Just select the *g instance type, run Multi-AZ failover, and then allow your app to auto-connect using the same settings as before. With no need for routine, often error-prone activities such as syncing the logic between platforms, development teams can focus on achieving the highest levels of user satisfaction and, consequently, business value.

5 Graviton3 based on Advanced RISC Machines (ARM)

The ARM processor series is an assortment of chips in view of Advanced RISC Machines' RISC engineering (diminished guidance set PC) (ARM). ARM produces RISC multi-center processors notwithstanding 32-bit and 64-bit variations. With a large number of directions each second (MIPS), the RISC processor is intended to perform fewer sorts of PC guidelines. A RISC processor provides exceptional performance while consuming a fraction of the power that CISC (complex instruction set computing) processors do. Consumer electronics products like smartphones, tablets, multimedia players, and wearables use ARM processors. ARM processors are well suited to progressively smaller electronics due to their small size, low complexity, and low power consumption. The reduced instruction set allows them to have a smaller integrated circuit (IC) die size since fewer transistors are required.

Graviton3 has a slightly faster clock, but it makes up for it by extracting more instructions per cycle (IPC). The majority of the 30 to 50 billion transistors went into the cores. We increased the size of the core. It features a 2x wider front end, a considerably larger branch predictor that predicts branches for greater workloads, almost 2x wider dispatch, a 2x larger instruction window, twice the SIMD performance, and SVE and bfloat16 support. There are twice as many memory operations, including some upgraded prefetchers, as well as twice as many outstanding transactions from each core. As a result, things like RSA TLS session negotiations are significantly faster. Pointer Auth is a mechanism that allows you to sign pointers and authenticate that they were signed, which prevents attacks like return-oriented programming. Enhancements of Graviton2 and Graviton3 from their previous generation block architectural diagram wise is shown in Figures 3 and Figure 4.

6 Features of Graviton3 based on ARM

The industry has seen a huge number of applicational with a new generation of cloud-based processors Graviton3 here are some key features of the ARM-based architectures.

- Load/store architecture: Main burden/store (LDR and STR) directions can get to memory thanks to heap/store engineering. Before

working on an ARM processor, information needs to be relocated from memory to registers.

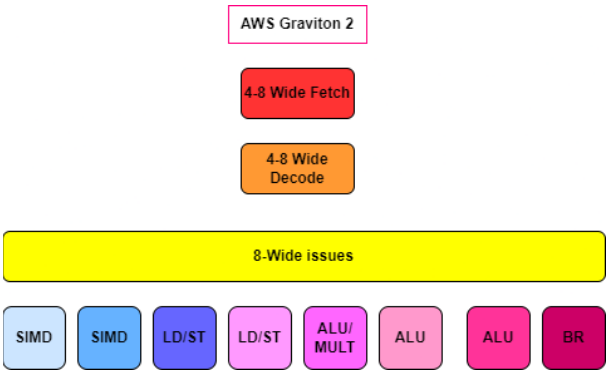

Figure 3. Graviton 2 CPU enhancements.

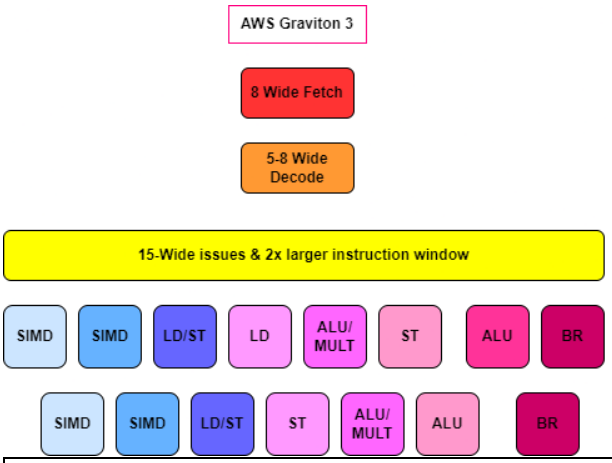

Figure 4. Graviton's CPU enhancements.

- Orthogonal instruction set: A symmetrical guidance set is one in which all guidance types are capable to utilize all tending to modes. It is "symmetrical" as in the instruction type and tends to strategy contrast from each other.
- Single-cycle execution: The single-cycle execution is the process of executing only one instruction per execution cycle.
- Power Saving.

The ARM is based on the RISC architecture which consists of a small instruction set compared to the CISC architecture. This implies that RISC needs fewer transistors and thus less power consumption occurs.

- For scalable high-performance 64 and 32-bit execution states.
- Hardware/Equipment virtualization support.
- Virtualization is the strategy used to make virtual forms of actual work areas and working frameworks.

Graviton3 has two different enhancements for machine learning the first is bfloat16, which gives you the same width as an FP32 number, but less precision. And we have twice the SIMD width. So, if we combine those, we end up seeing about two and a half x higher performance on this BERT workload. And if you were looking at a CNN like ResNet, it's closer to 3x or even over 3x. The above improvements in the Graviton 3 are summarized in table 2 below.

Parameters or types	Feature
Architecture	Neoverse V2
Process	5nm
Data width	wide data width (5-8)
Memory	DDR5
PCI Slot	PCI-Express 5.0
Security	Pointer authentication
Data	bfloat16

Table 2: Graviton 3 feature improvements

7 Comparative analysis & Improvements of graviton3 with other industry-leading cloud-based processors

The AWS Graviton 3 comes with significant improvements compared to the AWS Graviton 2 processors. Though the number of cores same in the AWS Graviton 3 and Graviton 2. But there is a significant increase in the number of transistors and the L3 cache is double the size of Graviton 2. The improvements of graviton 3 over Graviton 2 are 25% higher compute, 2x Float Performance, 2x Cryptography Performance, up to 60% less power consumption, 50% higher memory bandwidth, and 3x faster ML workloads.

7.1 Comparison: Graviton1 vs Graviton 2 vs graviton 3

The Graviton 2 also has 64 cores and a 2.5 GHz clock speed, but the new processor is wider, which means that twice as much data can be processed in a single clock cycle and the number of instructions that each core can operate on concurrently has doubled from 5 to 8 each cycle. Support for bfloat16, a

truncated 32-bit floating-point value appropriate for machine learning when speed is more critical than precision, is another feature of Graviton 3. Security is further improved with the addition of a new pointer authentication function. "Return addresses are signed with a secret key and extra context information, including the current value of the stack pointer, before being placed into the stack. When signed addresses are retrieved from the stack, they are verified before being utilized. If the address is invalid, an exception is thrown, preventing attacks that operate by overwriting the stack contents with the address of malicious code."

AWD Graviton Chips	Graviton 1	Graviton2	Graviton3
Architecture	64 bits	64 bits	64 bits
Codename	“Alpine”	“Alpine+”	-
Model	AL73400	ALC12B00	-
Process	16nm	7nm	5nm
Transistors (Billion)	5	30	55
Arm Architecture	ARMv8	ARMv8.2	ARMv8.5
Clock Speed	2.3 GHz	2.5GHz	2.6GHz
L1 Cache/Chip	1.25MB	8MB	8MB
L2 Cache/Chip	8MB	64MB	64MB
L3 Cache/Chip	-	32MB	64MB
Memory Type	DDR4-1600	DDR4-3200	DDR5-4800
Microarchitecture	Cortex-A72	Neoverse N1	Neoverse N2
Cores	16	64	64
PCI-Express Generation	3.0	4.0	5.0
PCI-Express Lanes	32	64	32
Memory Bandwidth	51.2 GB/s	204.8 GB/s	300 GB/s
Power (TDP)	95W	110W	100W

Table 3: Graviton1, Graviton2, Graviton3 Comparison

The chips will power new Amazon Web Services (AWS) EC2 C7g instances. The chips and instances will be the first to employ DDR5 memory, which has a 50% greater bandwidth than DDR4 but consumes far less power. The new Graviton processors, like existing Graviton processors, will use the AWS Nitro System and will have dedicated cores and caches for each vCPU. According to Matthew Wilson, VP and distinguished engineer at AWS, broadening memory access is part of improving speed. Graviton3 is the first public cloud instance to use DDR5 memory, which boosts memory bandwidth substantially [14]. AWS Graviton3 processors are more energy-efficient than equivalent EC2 instances, requiring up to 60% less energy for the same performance. This is a significant step toward a more sustainable cloud. Figure 5 shows

comparisons in form of a bar graph. Figure 5(a) shows real-time workload, Figure 5(b) shows improvement in performance from the previous generation, Figure 5(c) shows, memory bandwidth per VCPU.

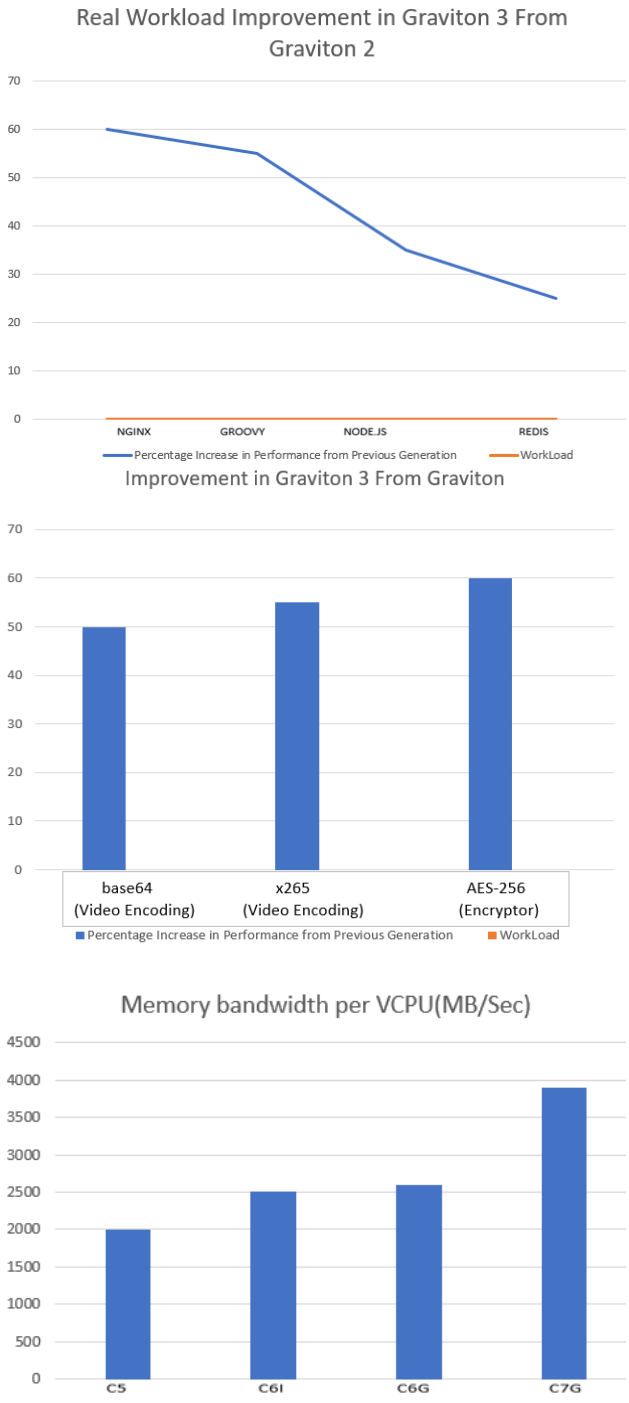

Figure 5(a). Real Workload (Graviton 3 improvements over Graviton 2), **5(b).** Graviton 3 improvement over Graviton 2 in percentage; **5(c).** Memory bandwidth per VCPU(MB/Sec)

9 Future research & Related Work

Power consumption by machine farms has become a significant adequacy concern [1, 3]. There have been two main approaches to dealing with processor plans. One approach is to employ low-power CISC processors, such as those in the Intel Atom thing family, which are referred to as "weak focus foci" in [4, 12]. This helps manage I/O-intensive but computationally light applications, such as key-respect capacity, but it has limitations when the applications are not enrolled [4, 12, 17]. Another approach is to use RISC processors, such as those from the ARM family. The majority of such drives employed 32-cycle Cortex-A7/A8/A9 CPUs, with testing done on a single computer [14, 17, 18]. Because the above-mentioned research activities, most of them were centered on a single point of confluence. Rajovic et al. [15] proposed Tibidabo, the main test HPC load with 128 Cortex-A9 focal concentrates. The specific model group achieved 120 MFLOPS/W on HPL with a fixed number of 256 CPU conditions. When it came to AMD Procedure 6128 and Intel Xeon X5660-based structures, the developers admitted to Tibidabo that they were "tough." Aakash et al. [16] propose an assessment program that runs on an ARM64 system, which most people would consider usual for changed name validation and city scene collection. Jayanth et al. [17] look at the combination of an ARM64 machine (AMD Opteron A1100 SoC) with an x64 server (AMD Opteron 3380) for large data tasks. Adrian et al. [18] used a benchmarking approach to estimate the capacity of incorporating ARM processors in HPC systems. HPE Apollo 70, an ARMv8-based pack with up to 1024 PROCESSOR cores and 4096 GB RAM, was under scrutiny. The designers estimated that the presentation of HPE Apollo seventy was comparable to, if not superior to, that of grounded phases with Intel Xeon processors. This is much above the greatest PROVIDE group that has been depicted in the composition. Daniel et al. [19] conducted a comprehensive writing evaluation of previous projects involving ARM processors in HPC. There is already a substantial collection of writing on surveying the presentation of PERSONAL COMPUTER architectures in general [9, 10, 20Tudor et al. [19] concentrated on high-performance computing, web servers, and financial lawful prospects. They discovered that low-power CPU focuses did not guarantee energy-efficient executions for machine occupations. In HPC, in contrast to the traditional longer performance time and greater energy costs, resource imbalanced character types were seen.

Conclusion

In this research work, we provide an in-depth examination of the AWS Graviton 3 processor. In this

evaluation, we compare the Amazon Graviton Processor against the Intel Xeon, AMD MI 200, AMD EYPC, NVIDIA Bluefield, and YITIAN 710 CPUs. We evaluated and studied the important aspects of all of the main firms' cloud-based processors, as well as the processors that are currently being discussed in the market. Likewise, for the enormous scope procedure on AWS EC2, contrast the A1 thing family with the I3 and M5 thing families. Far-reaching testing included 1600 vCPU focuses, making it the quickest ARM64 bunch of all time. Utilizing a blend of microbenchmarks and OS execution counters, we show that the Amazon Graviton Processor's absence of L3 reserve and more slow memory access speed can disallow it from arriving at unrivaled execution for figuring serious jobs with high memory interest. In any case, flat scaling can be utilized to accomplish satisfactory handling limits. We've observed that the A1 item family conveys a similar cost exhibition in multi-level web benefits, expense reserve funds of up to 37% in video transcoding, and expense reserve funds of up to 66% in terabyte-scale arranging. Furthermore, we discussed graviton architecture, microarchitecture, reviewing methodology and relevance assistance, features, and comparative analysis of graviton3 and its instances as well along with the future scope of the same and how these open the door for further optimization for workloads with both cost and deadline constraints of cloud-based processors like Graviton3 and its competitors.

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