Performance Evaluations on Various Virtual Machines for different Cloud-Based Workloads.

A

MINOR PROJECT REPORT

Submitted by

Parth Ahuja(36014802718),

Ishaan Kalra(35414802718),

Shruti Aggarwal(36314802718)

BACHELOR OF TECHNOLOGY

IN

COMPUTER SCIENCE AND ENGINEERING

Under the Guidance of

Dr. Ashish Khanna (Professor,CSE)

Department of Computer Science and Engineering

Maharaja Agrasen Institute of Technology,

PSP area, Sector – 22, Rohini, New Delhi – 110085 (Affiliated to Guru Gobind Singh Indraprastha, New Delhi)

(DEC 2021)

CERTIFICATE

This is to Certified that this MINOR project report **Cloud Comparison and Performance Evaluation of Virtual Machine Configurations** is submitted by **Parth Ahuja(36014802718), Ishaan Kalra(35414802718), Shruti Aggarwal(36314802718)** who carried out the project work under my supervision.

I approve this MINOR project for submission.

Prof. Namita Gupta	Dr. Ashish Khanna(Professor, CSE)
(HoD, CSE)	(Project Guide)

ACKNOWLEDGEMENT

It gives me immense pleasure to express my deepest sense of gratitude and sincere thanks to my respected guide **Dr. Ashish Khanna(Professor,CSE)** MAIT Delhi, for their valuable guidance, encouragement and help for completing this work. Their useful suggestions for this whole work and cooperative behavior are sincerely acknowledged.

I also wish to express my indebtedness to my parents as well as my family member whose blessings and support always helped me to face the challenges ahead.

Place: Delhi

Parth Ahuja(36014802718)
Shruti Aggarwal(36314802718)
Ishaan Kalra(35414802718)

Date: 15th December 2021

TABLE OF CONTENTS

List of Figures

Performance Evaluations on Various Virtual Machine for different Cloud-Based Workloads.

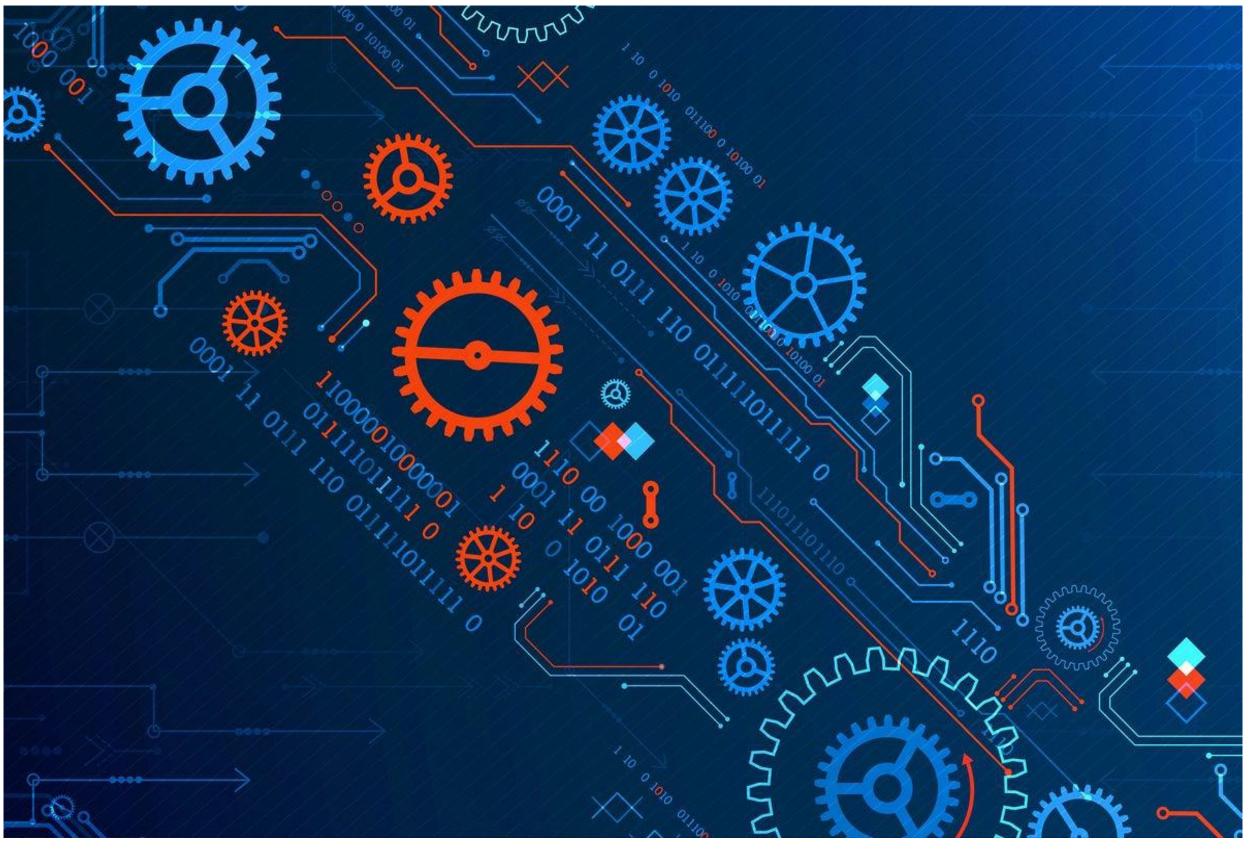

Figure 1

Submitted by	Mr. Parth Ahuja, Mr. Ishaan Kalra
Mentor	Dr. Ashish Khanna
College/University	Maharaja Agrasen Institute of Technology
Branch	Bachelors of Technology
Specialization	Computer Science Engineering
Enrollment Number	36014802718,35414802718
Email	aryaanahuja14@gmail.com
Contact Number	9891510043

Abstract

Cloud computing manages system resources such as processing, storage, and networking by providing users with multiple virtual machines (VMs) as needed. It is one of the rapidly growing fields that come with huge computational power for scientific workloads. Currently, the scientific community is ready to work over the cloud as it is considered as a resource-rich paradigm. The traditional way of executing scientific workloads on cloud computing is by using virtual machines.

Picking up public cloud service providers is now becoming a harder task in an enterprise organization. This paper will help in reducing more hesitation to choose a public cloud service provider. This paper is highlighting computation, storage, and infrastructure is important to service features that have an impact when choosing cloud service providers. Compare these three (AWS, Microsoft Azure, GCP) CSPs concerning service, price, advantages, and highlight significant service features.

Studies discuss the primary reason to choose a CSP that normally enhances features, familiarity with the brand, suitable for organization and security parameters considered when choosing CSP. Amazon Web Services proved its leadership by maintainingabout 33% share in the market throughout for several quarters irrespective of the market size increased by a factor of 3. Microsoft has shown prominent performance in SaaS. Since 2008, after introducing PaaS in the form of Google App Engine, Google is continuously enhancing its cloud computing services of Google Cloud Platform.

The latest emerging concept of containerization is growing more rapidly and gained popularity because of its unique features. Containers are treated as lightweight as compared to virtual machines in cloud computing. In this regard, a few VMs/containers-associated problems of performance and throughput are encountered because of middleware technologies such as virtualization or containerization. In this paper, we introduce the configurations of VMs and containers for cloud-based scientific workloads in order to utilize the technologies to solve scientific problems and handle their workloads. This paper also tackles throughput and efficiency problems related to VMs and containers in the cloud environment and explores efficient resource provisioning by combining four unique methods: hyperthreading (HT), vCPU cores selection, vCPU affinity, and isolation of vCPUs. The proposed solution is to implement four basic techniques to reduce the effect of virtualization. Additionally ,these techniques are used to make virtual machines and containers more effective and powerful for scientific workloads. The results show that allowing hyperthreading, isolation of CPU cores, proper numbering, and allocation of vCPU cores can improve the throughput and performance of virtual machines and.

What Is Multithreading?

Multithreading is a form of parallelization or dividing up work for simultaneous processing. Instead of giving a large workload to a single core, threaded programs split the work into multiple software threads. These threads are processed in parallel by different CPU cores to save time.
Depending on how they're built, games may be lightly threaded or heavily threaded. Some older game engines are known for their reliance on single-threaded performance, meaning they mostly use a single CPU core and get a major boost from higher clock speeds.
Today, game engines like Unreal Engine 4 utilize multiple cores when creating complex scenes2. Engines may also use multithreading to handle different parts of "draw calls" — instructions sent from the CPU to the GPU about in-game objects, textures, and shaders to draw.

What Is Hyper-Threading?

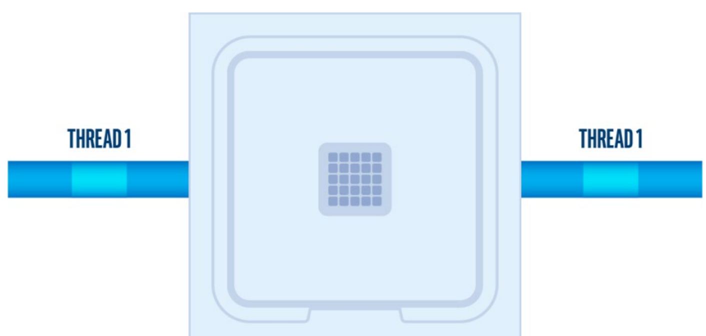

Figure 2

Intel® Hyper-Threading Technology is a hardware innovation that allows more than one thread to run on each core. More threads means more work can be done in parallel.
How does Hyper-Threading work? When Intel® Hyper-Threading Technology is active, the CPU exposes two execution contexts per physical core. This means that one physical core now works like two "logical cores" that can handle different software threads. The ten-core Intel® Core™ i9-10900K processor, for example, has 20 threads when Hyper-Threading is enabled. Two logical cores can work through tasks more efficiently than a traditional single-threaded core. By taking advantage of idle time when the core would formerly be waiting for other tasks to complete, Intel® Hyper-Threading Technology improves CPU throughput (by up to 30% in server applications).

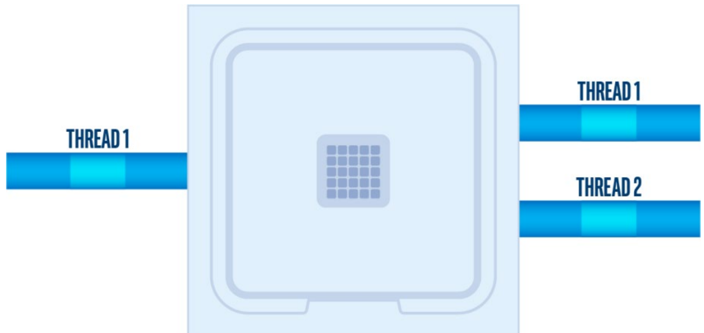

Figure 3

Wondering how to enable Hyper-Threading? It’s enabled by default, but it can be switched on and off from the BIOS environment by setting “Hyper-Threading Technology” to “Enable” or “Disable.”

What Benefits Will I See from Hyper-Threading?


Figure 4

With CPU Hyper-Threading, a PC can process more information in less time and run more background tasks without disruption. Under the right circumstances, the technology lets CPU cores effectively do two things at once. Multitaskers, streamers, and professionals running heavily threaded programs can boost their computing experience.

Literary Review

Nicolo Maria Calcavechia, Ofer Biran, Erez Hadad, and Yosef Moatti [1] discussed different strategies of placing Virtual Machines for Clouds. Although there has been lot of research done on the problem of placing Virtual Machine in cloud infrastructure but the dynamic nature of incoming stream of virtual machine deployment stream has been ignored. A practical model of cloud management system under stream of requests has been discussed in this paper. Moreover, an innovative technique named Backward Speculative Placement is also debated. BSP technique is discussed in two algorithms. Handling the stream of deployment requests and periodic optimization are two aspects of BSP technique which are thoroughly discussed in this paper. Authors have used generic MIP solver to compare the results, which shows the benefits of BSP technique. In short, authors have monitored historical demand traces of deployed VMs and BSP projects, and found VMS correlation aspect in most efficient way.

Minder Chen, and Yiching Liou [2] have discussed various virtualization techniques and their benefits. Authors have also identified and discussed various impacts of virtualization on IT industry. ITIL, an Information Technology standard, has been used to analyze virtualization technologies and to assess impacts of virtualization on IT industry. Authors have concluded virtualization will result in improved IT infrastructures and improved IT services. It will also help IT companies in reducing their costs and expenditures. Moreover, advanced and improved IT services are also identified as impacts of virtualization. It can be concluded from report that virtualization will result in improvement of IT infrastructure and creation of new advanced dynamic IT infrastructures.

Yashpalnish Jadeja, and Kirit Modi [3] have discussed cloud computing and challenges to cloud computing. Landmarks in IT history such as parallel computing to distributive computing to grid computing and now most recent cloud computing have been briefly discussed. Authors have thoroughly discussed the concepts of Cloud Computing. A different narrative regarding the definition of cloud computing is visible in this paper. Moving forward, authors have discussed the architecture of cloud computing. Advantages of cloud computing are precisely identified. Moreover, the challenges to cloud computing has also been discussed. Different advantages of cloud computing such as cost efficiency, uninterrupted services, easy management, and green computing are also discussed. In the end, authors have put light on issues with cloud computing. In short, this paper authors have discussed the basic concepts of cloud computing, its architecture and challenges to cloud computing.

Kangkang Li, Huanyang Zheng, and Jie Wu [4] have debated the concept of migration-based virtual machine placement in cloud systems. Authors have started with defining the basic concept of cloud computing. Moving forward, they have discussed the working time of physical and virtual machines. The research of authors is based on how to decrease the total job completion time of input virtual machine request through a proper virtual machine channel. Authors have proposed an offline virtual machine placement method through emulated VM migration. The migration algorithm is taken as heuristic approach. Moreover, hybrid scheme where a batch is engaged to accept upcoming virtual machines is also studied and discussed in this paper.

Malhotra, D. Agarwal, and A. Jaiswal [5] has discussed Virtualization in Cloud Computing. This papers starts with basic introduction, definition and history of cloud computing. Moving forward, the concept of virtualization is thoroughly discussed. Architecture of virtualized technology has also been debated and thoroughly explained. Moreover, basic concepts like virtual servers, types of virtualization, benefits of virtualization technologies, and benefits of cloud computing are also discussed. In the end, future scope of virtualization and cloud computing, and challenges to cloud computing are discussed. Authors have methodically discussed different challenges to cloud computing such as infected application, mass data loss, and data integrity are discussed.

Peter Mell, and Timothy Grance [6] gave a comprehensive and thorough definition of Cloud Computing which covers important aspects of Cloud Computing. Authors have discussed essential characteristics and service models of cloud computing. Moreover, they've also discussed deployment models such as private cloud, public cloud, community cloud and hybrid cloud.

PD Patel, Miren Karamta, M.D. Bhavasar, and M.B. Potdar [7] have discussed migration techniques in cloud computing. Authors have discussed the process of live migration. Furthermore, they've included a detailed survey on live migration of virtual machines in cloud computing. Authors have covered different migration categories such as Load Balancing Migration Techniques, Fault Tolerating Migration Techniques, and Energy Efficient Migration Techniques. Moreover, performance metrics are also discussed. A thorough analysis on live virtual machine migration in cloud is also given. In the end, authors have discussed different challenges and issues.
R.M. Sharma [8] has given a different narrative regarding impacts of virtualization in cloud computing in his paper. Author has discussed basic idea regarding cloud computing, virtualization, and their interconnectedness. Paper describes the impacts of virtualization in cloud computing. Paper also gives the idea about architecture of virtualization and levels of abstraction. Author has also presented different advantages of virtualization. These advantages include maximization of resources, flexibility, availability, scalability, hardware utilization and improved security. Author has also differentiated between traditional server and virtual server. It also gives brief idea about popular cloud services. It can be briefly concluded that this paper gives detailed information regarding different aspects of virtualization.

Yuping Xing and Yongzhao Zhan [9] have wrote about virtualization and cloud computing. They have discussed the general ideas regarding both virtualization and cloud computing. Moving forward, they have discussed different challenges and issues with cloud computing. Paper analyzes the issues and give possible solution to these solutions.

R Suchitra et al. [10] have presented a technique to place a virtual machine in a virtual cloud. Server consolidation technique is used to decrease number of physical servers. Authors have discussed how this technique is helpful in reducing costs and energy conservation. Consolidation approach requires efficient migration of VMs. Unfortunately, migration of virtual machines is a costly process which make it complicated to place virtual machine efficiently. Authors have used the idea of bin packed algorithm to propose an effective virtual machine placement algorithm. Authors have used multiple test cases to verify the feasibility of algorithm. Their research shows that their proposed algorithm minimizes the required number of needed virtual machine migration. In short, authors have proposed an algorithm which can be used to achieve efficient virtual machine placement in cloud environment.

Shilpa et al. [11] did a survey on load balancing in cloud computing. Authors have selected various new load balancing techniques and presented a comprehensive analysis. The motivation of this survey is to encourage amateur research towards more efficient algorithm of load balancing. Authors have discussed a cloud model and they presented a thorough debate on load balancing. Several challenges to load balancing such as virtual machine migration, energy management, stored data management, automated service provisioning are discussed. Moving forward, different categories of load balancing algorithm are discussed. Authors have included different surveys in the literature on load balancing and tried to differentiate between them. They have presented detailed information of these surveys. Briefly we can conclude that this paper presents basic concepts of cloud computing along with the challenges in load balancing.

Xiong et al. [12] wrote paper on selection of virtual machine and its placement for dynamic consolidation in cloud computing environment. Authors have discussed that dynamic consolidation is an effective way to decrease energy consumption and improve physical source utilization. Authors have discussed how different scenarios can cause the violence of service level of agreement delivered by service providers and users. To cater this issue, authors have proposed considering CPU utilization and also defining a variable which represents degree of resource satisfaction in selecting virtual machines. Authors have also presented a novel virtual machine placement policy. It suggests that a host which has minimum correlation coefficient will be preferred to place a virtual machine. Authors have used CloudSim to run simulations. Results of these simulations shows that technique proposed by authors have better outcomes then existing techniques. The technique proposed by authors is better in terms of virtual machine migration time, service level of agreement violation and energy consumption. Authors have presented an effective approach for dynamic consolidation in cloud computing environment and their approach is supported by data collected using CloudSim simulations.

Kono et al. [13] wrote paper which provides a guideline for selecting live migration policies and implementation in clouds. Live migration approach is extensively used for maintaining cloud platforms. Authors have recognized that live migration can cause performance inferences on cloud services. They have also highlighted that migration time and downtime are used to measure live migration performance. However, cloud administrators must consider live migration performance inference. It is necessary that cloud administrator selects suitable migration policy. Authors have presented a thorough analysis as a guideline for selecting live migration policies. They have conducted many experiments and compared many migration methods. Their experimental results shows trade-offs of different migration policies. Authors have used these results to present guidelines for cloud administrators. In short, authors have conducted researches to present guidelines for selecting appropriate policies and proper implementation.

Mills et al. [14] have wrote this paper to give a comparison of different virtual machine placement algorithms for on demand clouds. In recent times, a lot of VM placement algorithms have been presented and it is difficult for cloud administrators to select appropriate one. Authors have observed that many of these algorithms only address specific issues such as consolidation and initial placement. Moreover, these algorithms are focused on specific VMs and PMs. Authors have proposed an objective method to compare virtual machine placement algorithms in large clouds. Their research covers large number of VMs and PMs. They have used 18 algorithms for comparison. They have compared algorithms inspired by open-source code for infrastructure cloud. So, authors have presented an objective method to compare resource allocation algorithms in simulation of large distributed systems. Authors have also found out small quantitative differences in different algorithms.

Peng et al. [15] have wrote this paper on how to improve load balancing in Virtual Machine environment. Load balancing is considered as one of the most challenging issue in cloud computing. It is difficult to balance load while avoiding overloading a subset of machines. Authors have presented an effective load balancing strategy which is based on virtual machine live migration. They have applied a workload adaptive live migration algorithm. This algorithm is helpful in minimizing virtual machine downtime and improving user experience. Authors have found out that their approach is more efficient than previous approaches. Their algorithm is based on these steps: collecting load values on each computational load, determining whether to trigger live migration, checking live migration history and scheduling live migration. Authors have also used workload adaptive migration mechanism to provide minimal downtime for different applications which improves the user experience. In short, this article covers maximum aspects of use of adaptive live migration to improve load balancing in virtual environment.

Kukade et al. [16] have presented survey of load balancing and scaling approaches in cloud computing. In cloud computing, scaling is a term referred to ability of providing services without lagging. The cloud system must be designed in such a way that it could adapt to request of customer to increase or decrease resources. This is required to create a balance between cost, effectiveness and performance. Authors have suggested that for scaling the application, we need to increase or decrease the instances of the application. Authors have also found out that physical machines also need to be taken into consideration to increase performance. Moreover, authors have discussed different approaches used for scaling in cloud computing such as horizontal and vertical scaling.

Kansaal et al. [17] have discussed cloud load balancing techniques. Load balancing is considered as major challenge in cloud computing. Load balancing is dividing workload on different nodes to ensure that no single node is overwhelmed. Authors have pointed that goal of load balancing is minimizing resource consumption. Authors have also deeply discussed existing load balancing techniques in cloud computing. They have discussed different load balancing techniques such as: decentralized content aware load balancing, server based load balancing for internet distributed services, join idle-queue, scheduling strategy of load balancing on virtual machine, ACCLB, and two phased load balancing algorithm. Authors have presented a table which discuss and compare all these techniques. It gives readers a better idea about which technique to use in specific environment. This report also tell readers which technique is more suitable for green computing. In short, this paper gives details regarding load balancing and different existing load balancing techniques.

Tushar et al. [18] have presented survey of different existing load balancing techniques and challenges in cloud computing. Authors have stated that now more people are using cloud computing which demands that better services must be provided. Moreover, better implementation of load balancing techniques is required. There are several challenges to existing load balancing techniques. This paper discuss different existing techniques, challenges to these techniques and their solutions. Authors have started with the basic concepts of cloud computing architecture, virtualization and types of virtualization. Furthermore, authors have discussed load balancing and its types. In the end, authors have discussed challenges for load balancing. They have put light on issues like response time, resource utilization, scalability, migration time and fault tolerant. In short, various load balancing techniques, challenges to these techniques and their solutions are discussed.

Clark et al. [19] have wrote this paper on live migration of virtual machines. Authors have started with discussion regarding migration and its advantage. They have found out that migrating operating system is useful for administrators because it helps in clean separation between software and hardware. Moreover, it also helps in load balancing, low level system maintenance and fault management. Paper also shows that live migration can be used to achieve best service with minimal service downtime. Moreover, authors have also discussed design options for migrating Oses running services with live constraints. The concept of writable working set is also analyzed and discussed in detail. Authors have used different experiments which revealed that by integrating live OS migration into Xen virtual machine monitor, rapid movement of workloads within clusters and data centers can be enabled.

Agarwal et al. [20] present ideas about live migration of virtual machines in cloud. They have stated that live migration is simply shifting virtual machine from source node to target node. This process is completed without disturbing any active network connections. It is considered live because the original virtual machine is operating while this process is executed. Authors have stated that benefit of live migration is small downtime. Furthermore, authors have discussed the load balancing phenomenon. The basic idea of live migration and why it is used is thoroughly discussed in this paper. Moreover, the five stage process of live migration is also explained. In the last part of this paper, authors have presented benefits of live migration. These benefits include reduction in IT costs, improved flexibility with server consolidation, decrease in downtime, exploitation of resource locality, and simplified system administration. It can be briefly concluded that this paper gives details about live migration, whole process, different challenges with this process and advantages of this process.

Introduction

The internet is revolutionizing the mode in which we run our businesses and deliver them to the general public. Mostly,software and hardware both are completely available within a client's PC. In this manner, the client's information and projects are stored within his or her PC . The responsibility of securing data as well as keeping application and system software up to the standards lies upon the shoulders of the concerned department and the user inside the organization . The term 'the cloud' is used to refer to the Internet. 'Computing' is a process in which computer technology is utilized to perform a task in order to achieve a goal, including the Design and development of software and hardware. When the term 'the cloud' is appended with Computing It gives multi-dimensional meaning to computing. In contrast to placing away all the information and programming, one is from a computer or server, and it is placed 'in the cloud'. It can be composed of applications, databases, email, record administrations, processing power, memory, processing time, and other services. According to some analysts and vendors, cloud computing is like a conventional outsourcing process where computer resources are being consumed beyond the organization's firewall, and the process is being referred to as computing 'in the cloud' . In cloud computing, an organization with a speciality in cloud computing provides the client with a limited amount of IT resources (concerning server space, access to programming, or both) via the cloud. In this way, the customer gets his or her IT requirements fulfilled by leasing them from an organization providing cloud computing services by spending only those hardware/software resources that are most important for the client. It enables smaller organizations to have access to resources that can only be bought as a whole by large organizations due to their high buying, running, and maintenance costs. Eventually, it helps businesses, from small to large scale, to flourish through the concept of varying IT capabilities of the organization on the spot using the Internet . Thus, the profit margin can be maintained and improved with ease without making heavy investments in building up from scratch a strong IT infrastructure, training new staff, and licensing new software. Cloud computing has three models (IaaS, PaaS, and SaaS) with variations in access and security levels. Each model is mainly used for computation, storage, and infrastructure services, so it is very difficult for a consumer to choose a cloud computing model. There is not a single model that fits best for every company and information handling requirements, thus if any organization chooses to model how they know which model uses which service feature . It is required by the client to make a proper decision while choosing the model. Cloud computing overview is shown in figure. Studies highlight important service features of each service that will help the organization in choosing the cloud computing model and service.

Recently, cloud computing has become the most promising computing paradigm that provides flexible and on-demand infrastructure to scientific workloads. It has evolved from grid and utility computing. Being emerged from these computing paradigms, cloud computing is recently considered as an alternative to grid, cluster, and supercomputing for scientific workloads because of the characteristics of cloud computing such as scalability, on-demand self-service, elasticity, and availability. In cloud environments, users do not need to worry about system implementation and administration, cloud computing becomes a desired tool that works as infrastructure-as-a-service (IaaS) and fulfills the necessity of computing resources . Scientific workloads manipulated using high performance computing (HPC), high throughput computing (HTC), and many-task computing (MTC) can be executed in virtualized computing environment.
High performance tasks require a huge amount of computing power for a short period of time. In contrast, high throughput computing involves an enormous amount of computing power over a longer period of time, such as months or years. Multitask computing acts as a consensus solution to bridging the gap between HTC and HPC. It can perform many independent and dependent tasks using huge computing in shorter time. In MTC, task-parallel applications are performed on large-scale distributed systems. The major concerns related to scientific workloads are higher throughput and enhanced performance of virtualization or in a cloud environment. In order to address these concerns, some techniques need to be proposed to improve the overall performance.
The Virtual Machine Monitor (VMM) or hypervisor is a software abstraction layer that was introduced by virtualization technology. Cloud computing that uses virtual machines (VMs) for enabling a complete system with resource virtualization becomes most popular among other technologies. It makes physical infrastructures easy to manage and virtualizes full software stacks effectively with its operating system. The VM is a computer system mirroring that provides real machines with functionality. It is regarded as the cloud environment's basic logical tool that provides computing facilities. VMM is an abstraction layer of the physical hardware and tracks virtual machines. It works with physical resources and logical resources. In addition, it also provides a complete view of heterogeneous underlying hardware that allows VMs to run on any computing system without considering the dependencies between software and hardware.
On the other hand, today's cloud service providers are also offering container deployment (e.g., Docker, LXC, etc.), which is becoming more popular than the VMs. The concept of container is similar to VM, but it consumes comparatively less time and resources. It is considered more as an application-specific solution in cloud environments. In containerization, the same kernel is being shared for containers and the host operating system; that is the key enabling feature of containers that make it lightweight as compared to VMs. In containerization, the hardware and software components are being shared between host the operating system (OS) and containers' applications. The host OS is mainly responsible for ensuring the isolation among the applications of containers. Because of single host OS,

containers help to reduce the overhead of management as well. Performance of non-virtualized environment differs from virtualized environment because of the interactions of virtual machines with the abstraction layer called VMM. Comparing the container's performance with bare metal is also different because of shared kernel. The main important factor for optimizing the VMs/containers is the efficiency and availability for scientific workloads. Many scientific tasks require successful preparation and fast execution to achieve useful scientific results. In order to obtain advantages of cloud computing, the issues related to efficiency and throughput need to be addressed directly in virtualized and containerized scientific cloud environments.
With the goal of addressing aforementioned challenges, this article proposes a method for solving these issues—performance and throughput. Currently, the scientific community is ready to work over the cloud as it is considered as a resource-rich paradigm. Cloud computing enables users to work anywhere by providing logical resources such as virtual machines or containers. However, it should be noted that there are a few VM/container associated issues regarding performance and throughput. In this paper, in order to utilize virtualization technologies, we evaluated the different configurations of VMs and containers, which are the main computing actors for scientific workloads. We also take into consideration the problems of throughput and efficiency related to VMs and containers, and explore efficient resource provisioning by combining four unique methods: hyperthreading (HT), Vcpu cores selection, Vcpu affinity, and isolation of vCPUs. The scope of this research is mainly focused on scientific workloads. Furthermore, a balanced view of performance and throughput is also given. A renowned cloud computing platform, OpenStack , has been adopted to configure the computing environment for logical setup and to run scientific applications. The HEPSPEC06 benchmark that is produced by the HEPiX CPU Benchmark Group is used for performance evaluation of virtual machines and containers. Realistic issues regarding the performance of VMs/containers and throughput degradation are also investigated. In this paper, we use the combination of four famous techniques to achieve real-time performance and higher throughput of virtual machines and containers. These techniques are: hyperthreading technology, the selection of Vcpu cores per virtual machine/container, physical CPU isolation, and pinning of Vcpu cores of a virtual machine/container in a multicore NUMA (non uniform memory access) architecture. Our proposed solution shows that a fine combination can work very efficiently to achieve higher performance and enhanced throughput of VMs and containers in a cloud-based environment for scientific computing.

Comparison with previous studies/researches

Researchers have produced several papers on the significance of cloud services. The importance of IoT in cloud computing is increasing tremendously. Cloud services like Google Compute Engine, Azure IoT Edge, Amazon Web Services, as well as their integration with IoT and the field of data science, have been highlighted in studies . Due to the increasing demand for deploying a web application with reduced cost and optimum scalability of cloud computing, a comparison of monolithic with microservice architectures have also been thoroughly studied.

Currently, many studies have been actively conducted by many researchers, addressing the performance evaluation of virtual machines. In literature, many articles work on increased performance of virtual machines. Most of the literature have used VMM abstraction layer in general to measure the overhead of VMs. In the article , the authors reported the degradation of performance in virtual machines. They worked on NUMA architectures, based on the effects of virtualization and tested the architecture with the hypervisors such as KVM and Xen. In , the authors measured one of the performance factors, i.e., startup-time of virtual machines in cloud environments. Those time measurements are performed and analyzed among three well-known cloud providers: Amazon EC2, Rackspace, and Microsoft Azure. The authors presented a systematic detailed analysis of cloud computing application efficiency evaluations for scientific workloads . The result said that reliability and cloud efficiency are inadequate for scientific workloads. Infrastructure-as-a-service is the main feature for adopting cloud to cope with scientific workload. In , the authors presented a survey on performance overhead of virtual machines. They also discussed how the performance varies from single server virtualization to geo-distributed datacenters. The authors in illustrated the impact of type of workload, processor pinning, configuration, and partial background CPU load. They also investigated and addressed the issues of paired colocated compute-intensive workloads that create interference and reduce the overall performance. OpenStack cloud platform for IaaS implementation evaluates energy efficiency in high-performance computing . In this article, performance impact was evaluated, which is produced by the underlying hypervisors and the IaaS solution by using the HPCC (High-Performance Computing Cluster) and HPL (High-Performance Linpack) , and Graph500 benchmarks. The author in evaluated performance of virtual machines and organization of scientific workflow on virtual systems. They conducted a complete benchmark to test the CMS (Compact Muon Solenoid) scientific workloads on virtual machines. In , performance of virtual machines in the cloud is compared with usage in the cloud. Virtual machines and Linux containers are compared in terms of network performance and reduction of potential performance overhead. Some literature work quantifies the overhead efficiency of VMs by using a VMM or Xen virtualization layer. To improve the resource utilization in cloud computing environments, swarm optimization based workload optimization (SOWO) technique is proposed in. In the research, they also used the OpenStack platform and claimed that resource utilization is increased by 50 percent in cloud computing environments. Operating containers on top of virtual machines technique was examined in. In the paper, they followed an observational approach to measure the overhead efficiency provided by the additional virtualization layer in virtual machines by performing different benchmarking tests and implementing programs with the real-world-use case scenarios. In , the authors compare the performance of a typical KVM hypervisor to a Docker Linux container by contrasting the performance of Vmware Server with the actual physical servers. The extended paravirtualization (XPV) is another approach evaluated for effective virtualization of NUMA architecture. XPV consists of revisiting the interface between the hypervisor and the host OS, and between the host OS and the device runtime libraries (SRLs), so that they can automatically take into account changes in the NUMA topology. The authors in proposed an empirical overview of the success impact of the different resource affinities. They proposed a performance prediction model called resource affinity function effect estimation (RAIE). The RAIE model takes into account the real effect of resource affinity dependent on VM activities that can be tracked online without VM alteration. The proposed model tried to increase the average prediction accuracy of VMs.

It is difficult to find a study that analyzes the latest techniques for enhancing virtual machine efficiency and throughput. The major purpose of our research is to enhance overall efficiency and throughput of VMs and containers, so that scientific workloads can run more efficiently. The series of four well-known techniques is used to reduce the impact of results on virtual machines and containers.

Serverless computing is a much better service; that is the reason organizations move towards the cloud to enhance their services because the cloud is cheaper as compared to an organization's self-infrastructure. . Function as a Service (FaaS), also referred to as Cloud Functions, used for running distributed applications, has been analyzed by researchers by evaluation major cloud function providers, including Microsoft, Google. Cloud supports heterogeneous functions and heterogeneous components. Cloud computing has many functions, which are a support to all small, medium, and large organizations. Because of heterogeneous nature, every vendor component can participate in cloud computing infrastructure . Researchers have also published the paper on rising privacy, trust, and security issues while using resources through cloud computing. Security is man's concern because cloud services are available to the organization through the internet, and several security threats are present on the internet in different ways. If an organization wants to use different CSPs services is also a challenge for this organization because of security, privacy, and trust issues between two clouds. Furthermore, it is a drawback of cloud computing CSPs give support to organizations from security, privacy, and trust perspective, but still, CSPs need to improve. Several cloud computing providers have been compared with each other using several factors by researches like IaaS, PaaS, and SaaS cloud computing environments in order to search for the most suitable cloud service concerning customer's varying requirements. Every CSP has a different approach for his user; that is, the reason when an organization goes for select CSP is a little confusing because he has to first understand about facilities provided by CSPs than decide. IaaS, PaaS, and SaaS all are service models of cloud computing, but every CSP has different features for these service models . It is also shown by the study that enterprise serverless cloud computing platforms are gaining in popularity; there are several use cases and researches on these platforms, requiring further research to reduce the existing challenges as well as extend their application in various areas. Serverless cloud computing is good for organizations because organizations have to pay as they use resources, not fixed amounts. CSPs try to improve services with every going day, and both consumers and CSPs are benefits of this. Serverless computing now becomes popular because it is cheaper . Research also indicates that cloud computing in the form of Cloud function (FaaS) is gaining global fame in running distributed applications, and researchers have presented a benchmarking framework for its performance evaluation. Cloud computing support heterogeneous functions and work with multiple vendors at the same time. Cloud computing support consumers from many service models and design service concerning organizations or consumers. Researchers have also indicated the emerging requirement of more research and development related to cloud event services present in cloud computing using real-world applications. Research is going on event services on cloud computing perspective of applications that how cloud computing support much better to multiple applications of organizations, and in this regard, many researchers are researching the analysis of cloud computing for applications. A study has been carried out in demonstrating the fact that, by using patterns found in common cloud computing, mobile cloud computing can be optimized to use fewer resources. Cloud computing use resources to give services to the consumer but how cloud computing uses fewer resources and give more services to consumers, that is why multiple ways to use for optimization in cloud computing. Several researchers have highlighted the benefits of R&D in the cloud computing domain through their workshop conference papers like software engineering challenges in cloud-based applications, benefits of applying cloud computing in oceanographic data distribution on a global scale, software engineering towards developing applications for the broking of cloud storage services. A study done by researches indicates that there has been a rapid increase of CSPs in the market due to the popularity of cloud computing, and comparison of these services based on various parameters has also been presented. Comparisons of many CSPs have presented concerning services that service is better of which CSP. Every CSP has some advantages as well as some disadvantages with all aspects like price, computation, infrastructure, storage. An author has highlighted the fact that cloud computing advantages are not always related to monetary benefits but can be in other forms as well, like, easily increased scalability, security, redundancy. Sometimes organizations choose CSP from economic suitability.

BACKGROUND OF CSPs

Amazon Web Services (AWS)

An individual, organization (public, private, and government) can acquire AWS in the form of on-demand computing resources based on the pay-as-you-go style of billing. Cloud-based web administrations offer several different, focused frameworks and suitable building blocks and apparatuses for processing needs. From Amazon, Amazon Elastic Compute Cloud provides such facilities it allows clients to get continuous access to a virtual bunch of PCs with the help of the Internet. In this mode, client gets features as if he or she has quality PC hardware owned by himself/herself together with equipment (CPU and GPU for processing needs, RAM for memory requirements, hard-circle, SSD for information storing); a choice of working frameworks; establishing; and pre-stacked application program design, for instance, CRM, databases, servers to host websites, etc.. AWS servers throughout the world are kept up by the Amazon backup system. The cost of acquiring their services varies with the combination of different options like utilization of the tools, OS, program design, organizing features chosen via the sponsor, required the level of approachability, security, and tools set of administrative tasks. A client can pay for a dedicated virtual AWS PC, a dedicated physical PC, or a combination of each type. Amazon's vital aspect of membership agreement provides security to the client's framework. AWS is spread over various geological locales in the world.AWS achieved above ninety administrations in 2017, spanning over different fields like information database management, stockpiling, application administrations, equipment utilized in engineering, apparatus related to the Internet of Things (IoT), examination. The mainline of products include AS3 and EC2. End clients do not get most of the administration directly, but through APIs so that engineers can utilize them in their applications to achieve the task. Now, AWS has spanned up to HTTP, and it is making use of REST structural style and SOAP convention. Amazon markets AWS to endorsers as a method for getting expansive scale figuring limits more rapidly and economically than structure a genuine physical server farm. All administrations are charged depending upon utilization, yet each administration estimates use in differing ways. AWS possesses an overall dominance cloud, while Microsoft and Google are after AWS.

Google Cloud Platform

As the name suggests, GCP is provided by Google, and it is a set of cloud computing administrations. It works on the same platform, which is being utilized by Google itself to run its end-client services like YouTube, Google Search. Through the platform, the client can perform various cloud administrative tasks easily, such as information stockpiling, figuring of information, examining data, and machine learning. A charging card or ledger detail required for the registration process. GCP gives the foundation a management stage and serverless registering conditions.

Google introduced App Engine in April 2008, which served as a stage to create and facilitate web applications in Google-oversaw server farms. It dealt mainly with distributed computing administration. Due to its rising popularity, it was found to be used commonly in November 2011, and as a result, Google got involved in introducing various cloud administrations in this stage. Google Cloud Platform is a unit of Google that combines the GCP open cloud framework, just employing G Suite, industry adaptations of Android and Chrome OS, plus application programming interfaces (APIs) aimed at Artificial intelligence (AI) and undertaking mapping administrations.

Microsoft Azure Cloud

Microsoft Azure Cloud is for the administration of a cloud computing prepared by Microsoft for making arrangements, analysis, deploying, and managing applications by Microsoft-managed data centre. It offers SaaS, PaaS, and IaaS and supports a wide range of program design languages, machines, and structures, together with Microsoft explicit and outcast program design and frameworks. In October 2008, Microsoft Azure was started as a project by the name "Project Red Dog". Microsoft Azure has spent money on cloud computing, for instance, hundreds of millions of dollars, for providing several scalable cloud solutions to assist consumers and allowing them to fulfil their requirements and hopes. Microsoft Azure allows application owners to use their product on a network along with a virtually unlimited resource pool through almost no upfront investment as well as by limited operating expenditures. Cloud computing is network-established computing, link up dissimilar machines in various categories of a network like private, public, and hybrid infrastructure. The search trend of AWS, GCP and Microsoft Azure shown.

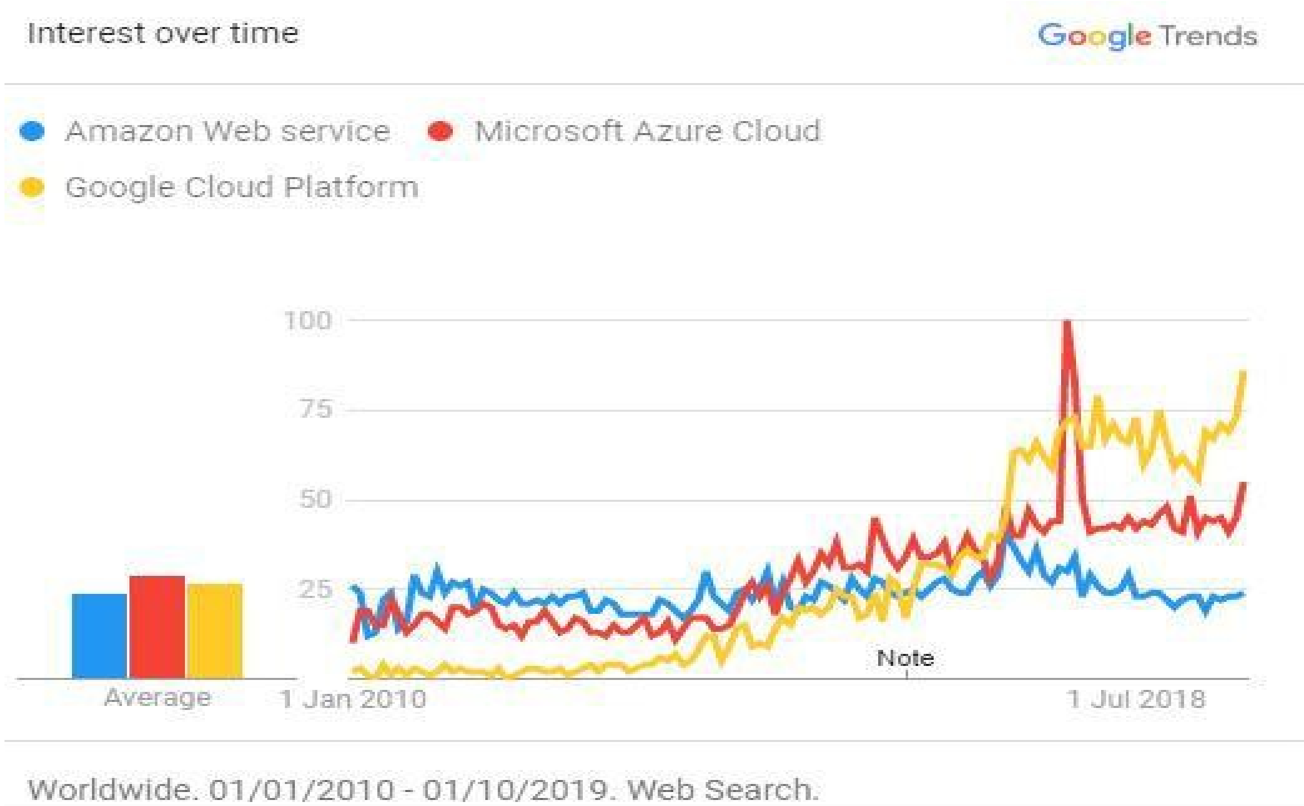

Figure 5

COMPARISON OF CLOUD SERVICE PROVIDERS

Service

Cloud computing is a go-faster technology that permits the use of IT skills up to the user's need or according to the corporate requirements, everywhere. Amazon is a major provider of open cloud benefits and is the pioneer in the Distributed computing market. Amazon AWS offers practically everything with regards to Distributed computing. AWS is dominant in numerous places of interest, like design and monitoring. AWS is, for the most part, preferred in the business for its broad and massive contributions, venture helpful administrations, worldwide achieve, open and adaptable features. AWS, Azure similarly offers a full variety of administrations and answers for people and associations regarding groundwork, process capacity, storing, organizing, and so forth. Microsoft Azure's quality is its registering power. Microsoft enables to send and manage virtual machines as a scale that can figure at whatever limit need inside minutes. It is a novel element over Amazon and Google. Microsoft Azure additionally enables to incorporate effectively with Microsoft instruments, offers open-source backing, and half-breed cloud benefits too. Google's specialized skill is significant, and its industry-driving devices in profound learning and computerized reasoning, Regard, and information investigation are critical preferences. Google Cloud offers a collection of cloud administrations for engineers. Google Cloud gives open source support, moving ability, discounts, and adaptable contracts. Google Cloud is uniquely intended for cloud-based organizations and has the talent of DevOps to support groups. As Google originates from an analytical groundwork, GCP gives more highlights and adaptability towards investigation and scientific devices.

Pricing

Amazon costs are exceptionally focused on all other cloud gives. Amazon offers every hour instalment reason for the highlights use. Amazon also gives a free arrangement constrained capacity and registering ability, which could be valuable for people and new companies before they buy. The Estimating model is on interest, sport, and held. Can pay month to month for the administration's use on an hourly premise. It can likewise ascertain evaluation with their estimating adding machine. Microsoft is evaluating differs and is dependent on the sorts of items utilized by the development team. Microsoft offers Paid ahead of time, or regularly scheduled instalment alternatives at a cost determined on every moment of utilization. As should be obvious, Microsoft is very versatile, and the valuing is on-request on momentary responsibilities. Google Cloud has the best valuing among the three specialist organizations. GCP has a compensation as-you-go valuing charged on per-minute or per-second of use.

Advantages

An unavoidable favourable position of Amazon is the experience. Amazon has been in this Cloud advertises for about 14 years, and it has the world's ideal and experienced developers and architects. AWS is owing to a large number of developments in these devices. Amazon Web services offer tough competition to its competitors. Nevertheless, the cost of the infrastructure of AWS can be confusing. This experience makes Amazon the most undertaking generous cloud specialist co-op, which enables anybody to take a shot at AWS effortlessly. Microsoft Azure is the quickest cloud arrangement accessible at this point. It is reasonable for big business advancement as it has high figuring capacity, and the other Microsoft highlights it incorporated into one framework and procedure, offering more power. Another good competitor of AWS is Microsoft Azure. Microsoft Azure has an endeavour foundation (supporting Windows). It endeavours to get interoperability with them. GCP offers one of the best cloud security in the business. It offers another dimension of cloud security than the remainder of its rivals and has more than 500 security engineers taking a shot at it. For top security activities, for example, banking, finance, defence applications, GCP will be the best decision.

REASON TO CHOOSE CLOUD SERVICE PROVIDER

After too much review on the cloud service provider, this paper endeavours to sum up primary reasons for each of the services that focused before choosing a service provider.

Enhanced Features

When choosing any service provider, one has to know about the enhanced features of each service provider because as it has been discussed earlier that out of the three CSPs till now, according to the best of knowledge that has gathered through thorough literature review, AWS has good features as compared to Microsoft Azure and GCP.

Familiarity with Brand

Microsoft Azure and GCP take advantage of this because both are familiar as compared to AWS.

Security

As know, security is the main concern nowadays, that is why all CSPs try to enhance their security regularly, but GCP security is much better than AWS and Microsoft Azure.

Suitable for Organization

It is sure that when one chooses any cloud service, one has to keep in mind the CSP,

Which is better and gives suitable service from one's organization's perspective. Normally, many organizations use hybrid cloud services, but if comparison among AWS, Microsoft Azure, and GCP made, all are not much suitable for every type of organization because every organization has its requirements, but AWS somehow possesses more suitable services as compared to Microsoft Azure and GCP.

SERVICE FEATURES FOR CSPS

Storage Features

Cloud computing is a location, and the resources of computing are used from this location. It is a pool of resources available for the clients on-demand. This section throws light over important service features that have an impact when choosing a CSP. First, the author will discuss storage features through this research paper.

Object storage: It takes a part of information then entitles it as an object. Information is preserved in distinct storehouses as opposed to files in folders and is rushed through related metadata and an exclusive identifier to process a storing group.

File storage: It stores information about a particular portion of data in a folder to create relationships with other information. It is similarly known as categorized storage, duplicating the technique that by paper files are put in storage. While wanting access to information, the workstation system wants to distinguish the pathway to discover it.
Block storage: It takes a folder separately into particular blocks of information as well as formerly stores these blocks, for instance, unconnected portions of information/data. For each portion of information takes a dissimilar address. Therefore they do not want to remain put in storage in a file arrangement [55].

Disaster recovery: It is very useful feature of cloud because nowadays mostly all small and medium-sized organizations' data is on cloud and if by mistake or because of malicious traffic, data gets corrupted or lost then, through the disaster recovery, organizations can restore the data easily, a facility that permits the backup as well as rescue of remote technologies on a cloud-centred stage. A cloud centred disaster recovery answer permits the consumer to measure the whole cloud DRP solution as of more or less-to-various. [56].

Backup: It is also a significant feature of cloud from CSPs a facility is available that every consumer can back up his data, and multiple options are available like hourly backup, daily backup, weekly backup. Backup, also well-known as online backup or remote backup, is an approach intended for transfer a copy of a virtual database to a subordinate, off-site place for safeguarding in a situation of apparatus disaster or failure. A secondary server, as well as, storage methods are frequently accommodated through a third-party facility provider, which provides the consumer a payment based scheduled storage capacity, data communication bandwidth, the number of consumers, the number of servers or amount of time data access.

Archiving: It is an approach of cloud when some data which is not using this time, so organizations use archiving technique make a separate storage device and archive this data in this device. The procedure of moving information that is certainly no longer aggressively use to a distinct storage device for long-standing. Archived information is put in storage on a minor-cost level of storage, helping as an approach to decrease the most important storage consumption plus associated expenses. A significant characteristic of a company's data archiving approach is to record that one data and recognize what data is an applicant for archiving [57]. Below is a table of important storage features concerning CSPs.

Computation Features

Virtual server: It is also a significant feature of the cloud nowadays. Generally, organizations use virtual servers (VS) because of some benefits. Today's technology era not completed without cloud services. Cloud is a need of every organization with a different perspective like

SaaS, PaaS, and IaaS. The VS distributes hardware and software resources by the new OS, as opposed to dedicated servers. One of the benefits of the VS is they less expensive and deliver quicker resource control, and VSs are common in Web hosting. Preferably, a VS imitates committed server functionalities. Somewhat than execute numerous committed servers, many VSs executed on a single server [58].
Highlight the Features of AWS, GCP and Microsoft Azure that Have an Impact when Choosing a Cloud Service
Provider

Platform as a Service: It is a good feature of cloud in which if anyone wants to develop any application, do not worry about infrastructure or platform. Arrange for cloud apparatuses to definite software even though being used mostly for functions. PaaS delivers a structure to designers that they are capable of construct upon and used to produce modified applications. Whole servers, storage, and networking be able to be administered through an organization or a third-party provider, whereas the developers can preserve the administration of the application. A platform with Tools to test provides by PaaS, in the same environment develop and host applications. No need to bother regarding primary infrastructure facilitates companies to concentrate on growth: security, operating systems, server software, and backups managed by providers[59].

Scaling: It is also a significant feature. Because without scaling how an organization knows about resources that an organization needed which time and how much resources required. The ability of an IT resource towards manage expanding or else reducing challenges capably is called scaling. It is one of best admired as well as helpful aspects of cloud, as corporations know how to measure higher or lay down to come across needs based upon season, plans, development, and further. Enable resources to expand as business or company expands, by implementing cloud scalability, and vice versa [60].

Virtual Private Servers: It is a very commonly used feature because VPS is not expensive, and also CSPs give 24/7 support to customers. Organizations that are not able to manage private cloud because of expensive infrastructure use CSP services and CSP manages many VPS on a single physical server. Sometimes hosting, also recognized as “Private Cloud,” is dependent on servers which are made by virtualization mechanism. VPS has multiple individual dedicated slots on the same virtual machine with one architecture. Dedicated resources can be assigned to each slot. However, generally, the technology mechanism is based on a time-shared or resource-shared trend. Usually, VPS is less costly than cloud servers. File or data access not occurs between VPS consumers on the shared server. If required, single VPS can be restarted without disturbing other VPSs on a shared server [61].

Infrastructure Features

After storage and computation, features now will present important management or infrastructure features as follows.

Server Management Services: It is an infrastructure feature of cloud computing. Usually, cloud administration mentions to on-demand facilities suggested throughout the IaaS model. The simple distribution pattern of the cloud is IaaS that allows access to configurable resources of shared pools. Computer, servers, networks, storage, applications & services all are included in configurable resources. Sharing and storing data is a cloud function. Through network or internet, all the information, resources, and networks are shared and stored on physical servers. CSPs maintain and control these physical servers, through the assistance of Cloud Management Services (CMS), industry owners might have a deep concentration on their organization aims. CMS is the precise solution for performing good quality service on cloud infrastructure [62].

Cloud deployment: It is a feature which is used for cloud deployment as per organizations need or organizations hierarchy. Cloud deployment talks about the deployment of IaaS, PaaS, SaaS, or answers that may perhaps retrieve on-demand through consumers. The cloud implementation pattern talks about the category of cloud computing architecture; a cloud result will apply. Cloud deployment comprises whole compulsory configuration and installation phases that need to be applied before consumer provisioning can take place. When cloud deployment has finished for an IaaS, SaaS, or PaaS solution, consumer provisioning can take place based on consumer approvals, wherever access offered for cloud resources relay on the user's taxonomy as moreover a reliable or unreliable object. Reliable objects might obtain access approval to managed cloud, hybrid cloud, or private cloud resources [63].

Logging: A feature used by all organizations because of their critical need, All logs from which know about computation history may see from the logging feature. Logging is information technology or network architectural model in place of centrally ingesting and gathering any record, log files coming from any particular location or source, such as applications, servers, devices. Records are normalized or clarified for reorganizing and sending to other needy systems to be handled as native records, which are able to be handled formerly, presented, and finally prepared according to a pre nominated holding program based on any of criteria.

Monitoring: Also, an important feature from monitoring; data and records monitored and through this feature information collected from every node. It is a structure that enables the placement of monitoring functionalities for several other facilities and applications inside the cloud. Online state monitoring is a very common application, which constantly tracks reliable conditions of networks, applications, systems, events, or any part that might organize able inside the cloud [64].

Server Automation: It is a requisite basic feature of cloud computing. Server automation assists the consumer to operate or manage a system or network with good decisions. It is an incorporated solution that systematizes or automates specifications, patching, as well as the configuration of operating systems, application components, and storage resources through public, virtual, and physical cloud systems. It also simplifies workflows towards productively accomplishing the complication of constantly varying virtualized environments [65].

Features have an impact when choosing CSP

Based on the concentrated analysis carried throughout this research, a broad list of important constraints that have serious impacts on choosing CSPs has created. For example, if one wants to select cloud service IaaS for one's organization, one needs to know that among AWS, Azure, or GCP, which service provider has the best solution for IaaS from one's organization's or industry's perspective? One also has to bear in mind about the service provider's features that are more suitable for his / her requirements, available according to Storage, Computation, and Infrastructure services. All three cloud service providers use different service features. After reviewing many papers, some service features which are used by cloud service providers have been outlined properly in this work. This study work divides all service features into three tables, i.e., 1) Storage Features 2) Computations Features 3) Management Features.

Methodology/Experimental Setup

The experimental setup and connectivity of Virtual Machines in a cloud based platform is shown below. The different nodes in the CPU are aggregated as a compute node.

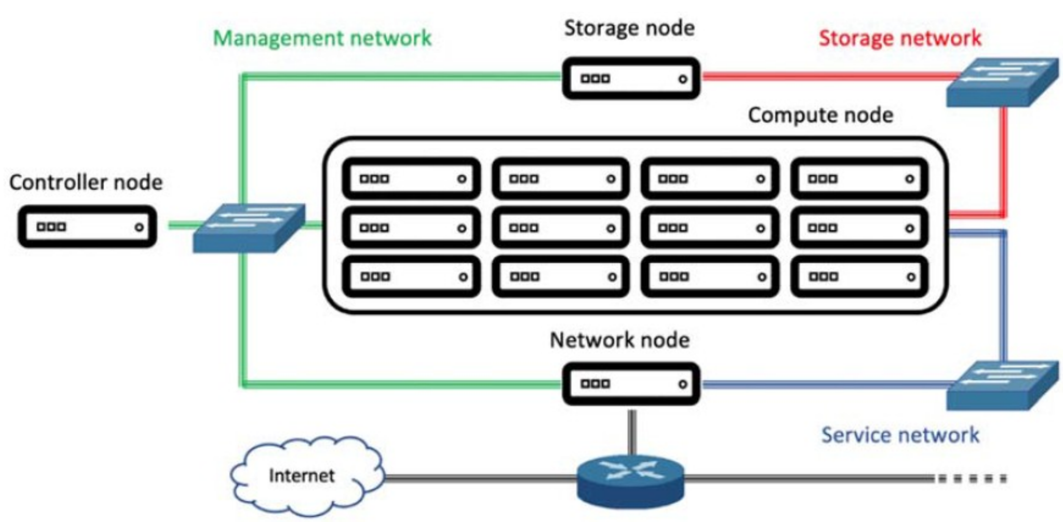

Figure 6

The operational private cloud environment is used for this experimental setup to test the efficiency and output of virtual machines and containers. For our all experiments, we utilized the cloud virtual machine monitoring system, which is an abstraction layer source cloud management solution.

The test is carried out on the following virtual machines –

Cloud Provider	Machine Type	CPUs	Memory(in GB)
AWS	t4g.nano	2	0.5
AWS	t4g.micro	2	1
AWS	t4g.small	2	2
AWS	t4g.medium	2	4
AWS	t4g.large	2	8
AWS	t4g.xlarge	4	16
AWS	t4g.2xlarge	8	32
Azure	B1ls	1	0.5
Azure	B1s	1	1
Azure	B1ms	1	2
Azure	B2s	2	4
Azure	B2ms	2	8
Azure	B4ms	4	16
Azure	B8ms	8	32
GCP	e2-standard-2	2	8
GCP	e2-standard-4	4	16
GCP	e2-standard-8	8	32

Figure 7

The aim of this procedure is to measure the CPU performance of a particular worker node in our cloud computing environment for scientific workloads.

According to HEPiX recommendation, we should use the recommended version of OS and kernel (CentOS 7 or Scientific Linux 7 and Kernel v3.1) to achieve better performance but we have used the default operating system and kernel available for the virtual machine.

The system is composed of network, controller, storage, and several compute nodes. The central management is provided by the controller node in this cloud setup environment. The storage node provides capacity to store images and instances and the network node provides the services related to communication and networking in this environment These nodes play an essential role for our all experiments because each virtual machine or container uses their computing resources in order to work as a physical machine for scientific jobs.

Results and Discussions

Below table comprises the details of all the configurations of the first test. In this result section, performance difference of configurations can be seen clearly.

GCP

Machine Type	CPU	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
e2-standard-2	2	8	1	5	0.61	1.05gb	<6 seconds	Successful
e2-standard-2	2	8	10	5	0.61	1.05gb	<6 seconds	Successful
e2-standard-2	2	8	100	5	2.92	1.05gb	<6 seconds	Successful
e2-standard-2	2	8	1000	5	15.27	1.05gb	<20 seconds	Successful
e2-standard-2	2	8	10000	5	86.66	1.5gb	<2 minutes	Successful
e2-standard-2	2	8	100000	5	99.64	1.87gb	<20 minutes	Successful
e2-standard-2	2	8	1000000	5	99.7	1.81gb	<4 hours	Successful
e2-standard-2	2	8	1	10	0.67	1.06gb	<6 seconds	Successful
e2-standard-2	2	8	10	10	0.67	1.06gb	<6 seconds	Successful
e2-standard-2	2	8	100	10	3.12	1.06gb	<6 seconds	Successful
e2-standard-2	2	8	1000	10	16.36	1.08gb	<25 seconds	Successful
e2-standard-2	2	8	10000	10	99.68	1.28gb	<3 minutes	Successful
e2-standard-2	2	8	100000	10	99.66	1.35gb	<21 minutes	Successful
e2-standard-2	2	8	1000000	10	99.56	2.09gb	<4 hours 10 minutes	Successful
e2-standard-2	2	8	1	15	0.66	0.48gb	<16 seconds	Successful

Machine Type	CPU	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
e2-standard-2	2	8	10	15	0.66	0.48gb	<16 seconds	Successful
e2-standard-2	2	8	100	15	3.27	0.48gb	<16 seconds	Successful
e2-standard-2	2	8	1000	15	16.39	0.48gb	<30 seconds	Successful
e2-standard-2	2	8	10000	15	87.45	1.26gb	<3 minutes	Successful
e2-standard-2	2	8	100000	15	99.49	1.44gb	<22 minutes	Successful
e2-standard-2	2	8	1000000	15	99.66	1.46gb	<4 hours 10 minutes	Successful
ec2-standard-4	4	16	1	5	0.17	1.08	<10 seconds	Successful
ec2-standard-4	4	16	10	5	0.17	1.08	<10 seconds	Successful
ec2-standard-4	4	16	100	5	2.5	1.08	<10 seconds	Successful
ec2-standard-4	4	16	1000	5	6.14	1.08	<15 seconds	Successful
ec2-standard-4	4	16	10000	5	42.77	1.77	<1 minute	Successful
ec2-standard-4	4	16	100000	5	99.73	2.29	<9 minutes	Successful
ec2-standard-4	4	16	1000000	5	99.78	2.33	<1 hour 40 minutes	Successful
ec2-standard-4	4	16	1	10	0.76	1.09	<15 seconds	Successful
ec2-standard-4	4	16	10	10	0.76	1.09	<15 seconds	Successful
ec2-standard-4	4	16	100	10	0.86	1.09	<15 seconds	Successful
ec2-standard-4	4	16	1000	10	5.93	1.09	<20 seconds	Successful
ec2-standard-4	4	16	10000	10	57.6	1.1	<1 minute	Successful
ec2-standard-4	4	16	100000	10	99.94	2.56	<9 minutes	Successful
ec2-standard-4	4	16	1000000	10	99.81	2.57	<1 hour 40 minutes	Successful

Machine Type	CPU	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
ec2-standard-4	4	16	1	15	0.16	1.09	<20 seconds	Successful
ec2-standard-4	4	16	10	15	0.16	1.09	<20 seconds	Successful
ec2-standard-4	4	16	100	15	0.23	1.09	<20 seconds	Successful
ec2-standard-4	4	16	1000	15	5.52	1.09	<22 seconds	Successful
ec2-standard-4	4	16	10000	15	53.25	1.41	<1 minute 10 seconds	Successful
ec2-standard-4	4	16	100000	15	99.8	2.54	<9 minutes	Successful
ec2-standard-4	4	16	1000000	15	99.8	2.56	<1 hour 40 minutes	Successful
ec2-standard-8	8	32	1	5	0.11	1.15	<7 seconds	Successful
ec2-standard-8	8	32	10	5	0.11	1.16	<7 seconds	Successful
ec2-standard-8	8	32	100	5	0.31	1.17	<7 seconds	Successful
ec2-standard-8	8	32	1000	5	2.32	1.17	<20 seconds	Successful
ec2-standard-8	8	32	10000	5	17.67	1.3	<2 minutes	Successful
ec2-standard-8	8	32	100000	5	96.64	2.87	<5 minutes	Successful
ec2-standard-8	8	32	1000000	5	98.78	2.89	<53 minutes	Successful
ec2-standard-8	8	32	1	10	0.11	1.19	<13 seconds	Successful
ec2-standard-8	8	32	10	10	0.11	1.19	<13 seconds	Successful
ec2-standard-8	8	32	100	10	0.32	1.19	<13 seconds	Successful
ec2-standard-8	8	32	1000	10	2.12	1.19	<15 seconds	Successful
ec2-standard-8	8	32	10000	10	20.65	1.19	<40 seconds	Successful
ec2-standard-8	8	32	100000	10	98.09	2.91	<5 minutes	Successful

Machine Type	CPU	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
ec2-standard-8	8	32	1000000	10	98.16	2.86	<53 minutes	Successful
ec2-standard-8	8	32	1	15	0.12	1.18	<20 seconds	Successful
ec2-standard-8	8	32	10	15	0.25	1.18	<20 seconds	Successful
ec2-standard-8	8	32	100	15	0.25	1.19	<20 seconds	Successful
ec2-standard-8	8	32	1000	15	3.92	1.21	<20 seconds	Successful
ec2-standard-8	8	32	10000	15	22.08	2.49	<40 seconds	Successful
ec2-standard-8	8	32	100000	15	97.78	2.88	<5 minutes	Successful
ec2-standard-8	8	32	1000000	15	98.88	2.9	<53 minutes	Successful

AWS

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
t4g.nano	2	0.5	1	5	0.141	124mb	<10 seconds	Successful
t4g.nano	2	0.5	10	5	0.141	124mb	<10 seconds	Successful
t4g.nano	2	0.5	100	5	0.141	124mb	<10 seconds	Successful
t4g.nano	2	0.5	1000	5	0.141	97.7mb	<1 minute	Successful
t4g.nano	2	0.5	10000	5	89.2	389mb	<8 minutes	Successful
t4g.nano	2	0.5	100000	5	90.1	389mb	<14 minutes	Unsuccessful
t4g.micro	2	1	1	5	26.69	111mb	<6 seconds	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
t4g.micro	2	1	10	5	26.69	112mb	<6 seconds	Successful
t4g.micro	2	1	100	5	26.69	112mb	<6 seconds	Successful
t4g.micro	2	1	1000	5	26.69	112mb	<1 minute	Successful
t4g.micro	2	1	10000	5	96.98	908mb	<4 minutes	Successful
t4g.micro	2	1	100000	5	96.8	920mb	<31 minutes	Successful
t4g.micro	2	1	1	10	0.603	145mb	<11 seconds	Successful
t4g.micro	2	1	10	10	0.603	145mb	<11 seconds	Successful
t4g.micro	2	1	100	10	0.862	145mb	<11 seconds	Successful
t4g.micro	2	1	1000	10	45.3	145mb	<1 minute	Successful
t4g.micro	2	1	10000	10	97.1	918mb	<5 minutes	Successful
t4g.micro	2	1	100000	10	98.4	924mb	<52 minutes	Unsuccessful
t4g.small	2	2	1	5	1.475	114mb	<6 seconds	Successful
t4g.small	2	2	10	5	1.475	114mb	<6 seconds	Successful
t4g.small	2	2	100	5	1.475	114mb	<6 seconds	Successful
t4g.small	2	2	1000	5	12.2	114mb	<13 seconds	Successful
t4g.small	2	2	10000	5	87.8	696mb	<2 minutes	Successful
t4g.small	2	2	100000	5	99.6	1.30gb	<13 minutes	Successful
t4g.small	2	2	1000000	5	99.1	1.33gb	<2 hours 10 minutes	Successful
t4g.small	2	2	1	10	0.35	117mb	<11 seconds	Successful
t4g.small	2	2	10	10	0.44	117mb	<11 seconds	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
t4g.small	2	2	100	10	1.44	121mb	<11 seconds	Successful
t4g.small	2	2	1000	10	11.94	270mb	<20 seconds	Successful
t4g.small	2	2	10000	10	89.925	970mb	<2 minutes	Successful
t4g.small	2	2	100000	10	99.1	1.45gb	<12 minutes	Successful
t4g.small	2	2	1000000	10	99.13	1.45gb	<2 hours	Successful
t4g.small	2	2	1	15	0.466	108mb	<16 seconds	Successful
t4g.small	2	2	10	15	0.466	108mb	<16 seconds	Successful
t4g.small	2	2	100	15	1.525	108mb	<16 seconds	Successful
t4g.small	2	2	1000	15	13.175	108mb	<25 seconds	Successful
t4g.small	2	2	10000	15	82.625	781mb	<2 minutes	Successful
t4g.small	2	2	100000	15	99.15	1.57gb	<12 minutes	Successful
t4g.small	2	2	1000000	15	99.19	1.57gb	<2 hours	Successful
t4g.medium	2	4	1	5	0.28	113mb	<21 seconds	Successful
t4g.medium	2	4	10	5	0.28	113mb	<6 seconds	Successful
t4g.medium	2	4	100	5	0.28	113mb	<6 seconds	Successful
t4g.medium	2	4	1000	5	2.87	113mb	<13 seconds	Successful
t4g.medium	2	4	10000	5	18.3	1.29gb	<2 minutes	Successful
t4g.medium	2	4	100000	5	99.1	1.34gb	<13 minutes	Successful
t4g.medium	2	4	1000000	5	98.9	1.32gb	<2 hours	Successful
t4g.medium	2	4	1	10	0.44	111mb	<11 seconds	Successful
t4g.medium	2	4	10	10	0.44	111mb	<11 seconds	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
t4g.medium	2	4	100	10	1.46	111mb	<11 seconds	Successful
t4g.medium	2	4	1000	10	11.8	730mb	<18 seconds	Successful
t4g.medium	2	4	10000	10	83.1	1.33gb	<2 minutes	Successful
t4g.medium	2	4	100000	10	98.1	1.41gb	<13 minutes	Successful
t4g.medium	2	4	1000000	10	100	1.55gb	<2 hours	Successful
t4g.medium	2	4	1	15	0.36	118mb	<16 seconds	Successful
t4g.medium	2	4	10	15	0.36	118mb	<16 seconds	Successful
t4g.medium	2	4	100	15	1.63	118mb	<16 seconds	Successful
t4g.medium	2	4	1000	15	12.06	154mb	<25 seconds	Successful
t4g.medium	2	4	10000	15	87.6	1.58gb	<2 minutes	Successful
t4g.medium	2	4	100000	15	100	1.59gb	<12 minutes	Successful
t4g.medium	2	4	1000000	15	100	1.61gb	<2 hours	Successful
t4g.large	2	8	1	5	46		<6 seconds	Successful
t4g.large	2	8	10	5	0.965	112mb	<6 seconds	Successful
t4g.large	2	8	100	5	1.23	114mb	<6 seconds	Successful
t4g.large	2	8	1000	5	11.8	111mb	<16 seconds	Successful
t4g.large	2	8	10000	5	92	1.25gb	<2 minutes	Successful
t4g.large	2	8	100000	5	98.3	1.35gb	<13 minutes	Successful
t4g.large	2	8	1000000	5	100	1.42gb	<13 minutes	Successful
t4g.large	2	8	1	10	0.35	114mb	<11 seconds	Successful
t4g.large	2	8	10	10	1.51	135mb	<11 seconds	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
t4g.large	2	8	100	10	1.51	135mb	<11 seconds	Successful
t4g.large	2	8	1000	10	11.8	330mb	<20 seconds	Successful
t4g.large	2	8	10000	10	91.88	1.46gb	<2 minutes	Successful
t4g.large	2	8	100000	10	96.8	1.51gb	<12 minutes	Successful
t4g.large	2	8	1000000	10	99.5	1.61gb	<2 hours 2 minutes	Successful
t4g.large	2	8	1	15	0.1	120mb	<16 seconds	Successful
t4g.large	2	8	10	15	0.2	219mb	<16 seconds	Successful
t4g.large	2	8	100	15	0.2	221mb	<16 seconds	Successful
t4g.large	2	8	1000	15	11.1	696mb	<25 seconds	Successful
t4g.large	2	8	10000	15	97.2	1.45gb	<2 minutes	Successful
t4g.large	2	8	100000	15	97.8	1.57gb	<13 minutes	Successful
t4g.large	2	8	1000000	15	98.5	1.65gb	<2 hours 2 minutes	Successful
t4g.xlarge	4	16	1	5	3.3	170mb	<6 seconds	Successful
t4g.xlarge	4	16	10	5	3.3	170mb	<6 seconds	Successful
t4g.xlarge	4	16	100	5	5.64	178mb	<6 seconds	Successful
t4g.xlarge	4	16	1000	5	3.82	170mb	<10 seconds	Successful
t4g.xlarge	4	16	10000	5	34.91	1.69gb	<40 seconds	Successful
t4g.xlarge	4	16	100000	5	98.72	1.82gb	<6 minutes	Successful
t4g.xlarge	4	16	1000000	5	98.75	1.85gb	<56 minutes	Successful
t4g.xlarge	4	16	1	10	0.081	165mb	<11 seconds	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
t4g.xlarge	4	16	10	10	0.162	165mb	<11 seconds	Successful
t4g.xlarge	4	16	100	10	0.646	165mb	<11 seconds	Successful
t4g.xlarge	4	16	1000	10	5.66	166mb	<15 seconds	Successful
t4g.xlarge	4	16	10000	10	32.3	1.92gb	<45 seconds	Successful
t4g.xlarge	4	16	100000	10	99.2	1.88gb	<6 minutes	Successful
t4g.xlarge	4	16	1000000	10	99.2	1.89gb	<56 minutes	Successful
t4g.xlarge	4	16	1	15	0.522	166mb	<16 seconds	Successful
t4g.xlarge	4	16	10	15	0.12	184mb	<16 seconds	Successful
t4g.xlarge	4	16	100	15	0.558	166mb	<16 seconds	Successful
t4g.xlarge	4	16	1000	15	5.795	1.69gb	<20 seconds	Successful
t4g.xlarge	4	16	10000	15	42.45	1.87gb	<1 minute	Successful
t4g.xlarge	4	16	100000	15	98.5	1.88gb	<6 minutes	Successful
t4g.xlarge	4	16	1000000	15	98.92	1.90gb	<56 minutes	Successful
t4g.2xlarge	8	32	1	5	0.06	180mb	<10 seconds	Successful
t4g.2xlarge	8	32	10	5	0.08	181mb	<10 seonds	Successful
t4g.2xlarge	8	32	100	5	0.328	184mb	<10 seconds	Successful
t4g.2xlarge	8	32	1000	5	2.91	2.60gb	<10 seconds	Successful
t4g.2xlarge	8	32	10000	5	18	10.7gb	<1 minute	Successful
t4g.2xlarge	8	32	100000	5	87.76	14.7gb	<4 minutes	Successful
t4g.2xlarge	8	32	1000000	5	92.2	18.4gb	<40 minutes	Successful
t4g.2xlarge	8	32	1	10	0.06	207mb	<11 seconds	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
t4g.2xlarge	8	32	10	10	0.09	207mb	<11 seconds	Successful
t4g.2xlarge	8	32	100	10	0.29	207mb	<11 seconds	Successful
t4g.2xlarge	8	32	1000	10	2.96	210mb	<15 seconds	Successful
t4g.2xlarge	8	32	10000	10	23.64	5.27gb	<37 seconds	Successful
t4g.2xlarge	8	32	100000	10	88.46	10.5gb	<4 minutes	Successful
t4g.2xlarge	8	32	1000000	10	91.64	14.3gb	<40 minutes	Successful
t4g.2xlarge	8	32	1	15	0.058	174mb	<16 seconds	Successful
t4g.2xlarge	8	32	10	15	0.066	177mb	<16 seconds	Successful
t4g.2xlarge	8	32	100	15	0.091	179mb	<16 seconds	Successful
t4g.2xlarge	8	32	1000	15	2.97	1.92gb	<20 seconds	Successful
t4g.2xlarge	8	32	10000	15	27.295	5.85gb	<42 seconds	Successful
t4g.2xlarge	8	32	100000	15	81.02	12.0gb	<4 minutes	Successful
t4g.2xlarge	8	32	1000000	15	90.12	12.9gb	<40 minutes	Successful

Microsoft Azure

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
B1ls	1	0.5	1	5	0.141	124mb	<10 seconds	Successful
B1ls	1	0.5	10	5	0.141	124mb	<10 seconds	Successful
B1ls	1	0.5	100	5	0.141	124mb	<10 seconds	Successful
B1ls	1	0.5	1000	5	0.141	97.7mb	<1 minute	Successful
B1ls	1	0.5	10000	5	89.2	389mb	<8 minutes	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
B1ls	1	0.5	100000	5	90.1	389mb	<14 minutes	Unsuccessful
	1							
B1s	1	1	1	5	26.69	111mb	<6 seconds	Successful
B1s	1	1	10	5	26.69	112mb	<6 seconds	Successful
B1s	1	1	100	5	26.69	112mb	<6 seconds	Successful
B1s	1	1	1000	5	26.69	112mb	<1 minute	Successful
B1s	1	1	10000	5	96.98	908mb	<4 minutes	Successful
B1s	1	1	100000	5	96.8	920mb	<31 minutes	Successful
	1							
B1s	1	1	1	10	0.603	145mb	<11 seconds	Successful
B1s	1	1	10	10	0.603	145mb	<11 seconds	Successful
B1s	1	1	100	10	0.862	145mb	<11 seconds	Successful
B1s	1	1	1000	10	45.3	145mb	<1 minute	Successful
B1s	1	1	10000	10	97.1	918mb	<5 minutes	Successful
B1s	1	1	100000	10	98.4	924mb	<52 minutes	Unsuccessful
B1ms	1	2	1	5	1.475	114mb	<6 seconds	Successful
B1ms	1	2	10	5	1.475	114mb	<6 seconds	Successful
B1ms	1	2	100	5	1.475	114mb	<6 seconds	Successful
B1ms	1	2	1000	5	12.2	114mb	<13 seconds	Successful
B1ms	1	2	10000	5	87.8	696mb	<2 minutes	Successful
B1ms	1	2	100000	5	99.6	1.30gb	<13 minutes	Successful
B1ms	1	2	1000000	5	99.1	1.33gb	<2 hours 10 minutes	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
B1ms	1	2	1	10	0.35	117mb	<11 seconds	Successful
B1ms	1	2	10	10	0.44	117mb	<11 seconds	Successful
B1ms	1	2	100	10	1.44	121mb	<11 seconds	Successful
B1ms	1	2	1000	10	11.94	270mb	<20 seconds	Successful
B1ms	1	2	10000	10	89.925	970mb	<2 minutes	Successful
B1ms	1	2	100000	10	99.1	1.45gb	<12 minutes	Successful
B1ms	1	2	1000000	10	99.13	1.45gb	<2 hours	Successful
B1ms	1	2	1	15	0.466	108mb	<16 seconds	Successful
B1ms	1	2	10	15	0.466	108mb	<16 seconds	Successful
B1ms	1	2	100	15	1.525	108mb	<16 seconds	Successful
B1ms	1	2	1000	15	13.175	108mb	<25 seconds	Successful
B1ms	1	2	10000	15	82.625	781mb	<2 minutes	Successful
B1ms	1	2	100000	15	99.15	1.57gb	<12 minutes	Successful
B1ms	1	2	1000000	15	99.19	1.57gb	<2 hours	Successful
B2s	2	4	1	5	0.28	113mb	<21 seconds	Successful
B2s	2	4	10	5	0.28	113mb	<6 seconds	Successful
B2s	2	4	100	5	0.28	113mb	<6 seconds	Successful
B2s	2	4	1000	5	2.87	113mb	<13 seconds	Successful
B2s	2	4	10000	5	18.3	1.29gb	<2 minutes	Successful
B2s	2	4	100000	5	99.1	1.34gb	<13 minutes	Successful
B2s	2	4	1000000	5	98.9	1.32gb	<2 hours	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
B2s	2	4	1	10	0.44	111mb	<11 seconds	Successful
B2s	2	4	10	10	0.44	111mb	<11 seconds	Successful
B2s	2	4	100	10	1.46	111mb	<11 seconds	Successful
B2s	2	4	1000	10	11.8	730mb	<18 seconds	Successful
B2s	2	4	10000	10	83.1	1.33gb	<2 minutes	Successful
B2s	2	4	100000	10	98.1	1.41gb	<13 minutes	Successful
B2s	2	4	1000000	10	100	1.55gb	<2 hours	Successful
B2s	2	4	1	15	0.36	118mb	<16 seconds	Successful
B2s	2	4	10	15	0.36	118mb	<16 seconds	Successful
B2s	2	4	100	15	1.63	118mb	<16 seconds	Successful
B2s	2	4	1000	15	12.06	154mb	<25 seconds	Successful
B2s	2	4	10000	15	87.6	1.58gb	<2 minutes	Successful
B2s	2	4	100000	15	100	1.59gb	<12 minutes	Successful
B2s	2	4	1000000	15	100	1.61gb	<2 hours	Successful
B2ms	2	8	1	5	46		<6 seconds	Successful
B2ms	2	8	10	5	0.965	112mb	<6 seconds	Successful
B2ms	2	8	100	5	1.23	114mb	<6 seconds	Successful
B2ms	2	8	1000	5	11.8	111mb	<16 seconds	Successful
B2ms	2	8	10000	5	92	1.25gb	<2 minutes	Successful
B2ms	2	8	100000	5	98.3	1.35gb	<13 minutes	Successful
B2ms	2	8	1000000	5	100	1.42gb	<13 minutes	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
B2ms	2	8	1	10	0.35	114mb	<11 seconds	Successful
B2ms	2	8	10	10	1.51	135mb	<11 seconds	Successful
B2ms	2	8	100	10	1.51	135mb	<11 seconds	Successful
B2ms	2	8	1000	10	11.8	330mb	<20 seconds	Successful
B2ms	2	8	10000	10	91.88	1.46gb	<2 minutes	Successful
B2ms	2	8	100000	10	96.8	1.51gb	<12 minutes	Successful
B2ms	2	8	1000000	10	99.5	1.61gb	<2 hours 2 minutes	Successful
B2ms	2	8	1	15	0.1	120mb	<16 seconds	Successful
B2ms	2	8	10	15	0.2	219mb	<16 seconds	Successful
B2ms	2	8	100	15	0.2	221mb	<16 seconds	Successful
B2ms	2	8	1000	15	11.1	696mb	<25 seconds	Successful
B2ms	2	8	10000	15	97.2	1.45gb	<2 minutes	Successful
B2ms	2	8	100000	15	97.8	1.57gb	<13 minutes	Successful
B2ms	2	8	1000000	15	98.5	1.65gb	<2 hours 2 minutes	Successful
B4ms	4	16	1	5	3.3	170mb	<6 seconds	Successful
B4ms	4	16	10	5	3.3	170mb	<6 seconds	Successful
B4ms	4	16	100	5	5.64	178mb	<6 seconds	Successful
B4ms	4	16	1000	5	3.82	170mb	<10 seconds	Successful
B4ms	4	16	10000	5	34.91	1.69gb	<40 seconds	Successful
B4ms	4	16	100000	5	98.72	1.82gb	<6 minutes	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
B4ms	4	16	1000000	5	98.75	1.85gb	<56 minutes	Successful
B4ms	4	16	1	10	0.081	165mb	<11 seconds	Successful
B4ms	4	16	10	10	0.162	165mb	<11 seconds	Successful
B4ms	4	16	100	10	0.646	165mb	<11 seconds	Successful
B4ms	4	16	1000	10	5.66	166mb	<15 seconds	Successful
B4ms	4	16	10000	10	32.3	1.92gb	<45 seconds	Successful
B4ms	4	16	100000	10	99.2	1.88gb	<6 minutes	Successful
B4ms	4	16	1000000	10	99.2	1.89gb	<56 minutes	Successful
B4ms	4	16	1	15	0.522	166mb	<16 seconds	Successful
B4ms	4	16	10	15	0.12	184mb	<16 seconds	Successful
B4ms	4	16	100	15	0.558	166mb	<16 seconds	Successful
B4ms	4	16	1000	15	5.795	1.69gb	<20 seconds	Successful
B4ms	4	16	10000	15	42.45	1.87gb	<1 minute	Successful
B4ms	4	16	100000	15	98.5	1.88gb	<6 minutes	Successful
B4ms	4	16	1000000	15	98.92	1.90gb	<56 minutes	Successful
B8ms	8	32	1	5	0.06	180mb	<10 seconds	Successful
B8ms	8	32	10	5	0.08	181mb	<10 seconds	Successful
B8ms	8	32	100	5	0.328	184mb	<10 seconds	Successful
B8ms	8	32	1000	5	2.91	2.60gb	<10 seconds	Successful
B8ms	8	32	10000	5	18	10.7gb	<1 minute	Successful
B8ms	8	32	100000	5	87.76	14.7gb	<4 minutes	Successful

Machine Type	CPUs	Memory(in Gib)	Number of Concurrent requests	Average Sleep time in seconds	CPU(max) %	Memory Used	Average Duration	Status of request
B8ms	8	32	1000000	5	92.2	18.4gb	<40 minutes	Successful
B8ms	8	32	1	10	0.06	207mb	<11 seconds	Successful
B8ms	8	32	10	10	0.09	207mb	<11 seconds	Successful
B8ms	8	32	100	10	0.29	207mb	<11 seconds	Successful
B8ms	8	32	1000	10	2.96	210mb	<15 seconds	Successful
B8ms	8	32	10000	10	23.64	5.27gb	<37 seconds	Successful
B8ms	8	32	100000	10	88.46	10.5gb	<4 minutes	Successful
B8ms	8	32	1000000	10	91.64	14.3gb	<40 minutes	Successful
B8ms	8	32	1	15	0.058	174mb	<16 seconds	Successful
B8ms	8	32	10	15	0.066	177mb	<16 seconds	Successful
B8ms	8	32	100	15	0.091	179mb	<16 seconds	Successful
B8ms	8	32	1000	15	2.97	1.92gb	<20 seconds	Successful
B8ms	8	32	10000	15	27.295	5.85gb	<42 seconds	Successful
B8ms	8	32	100000	15	81.02	12.0gb	<4 minutes	Successful
B8ms	8	32	1000000	15	90.12	12.9gb	<40 minutes	Successful

Figure below shows the result. The primary goal of this test was to enhance the overall throughput of the physical system. Since the hyperthreading doubles the number of cores, we often allowed HT on a physical system with 16 cores; it doubles the cores up to 32. As illustrated in the fugure, the efficiency of HEPSPEC06 on the physical host (bare metal) is improved by up to 16%. As shown in the results, using the HEPSPEC06 benchmark, the performance loss of VM is 18% and containers is up to 14% of configuration 1 compared to the physical machine. The size of the virtual machine or container can vary according to scientific workload so that throughput and performance can be balanced according to requirements.

It clearly shows that the containers can give much better and near-real-time performance in a cloud environment.

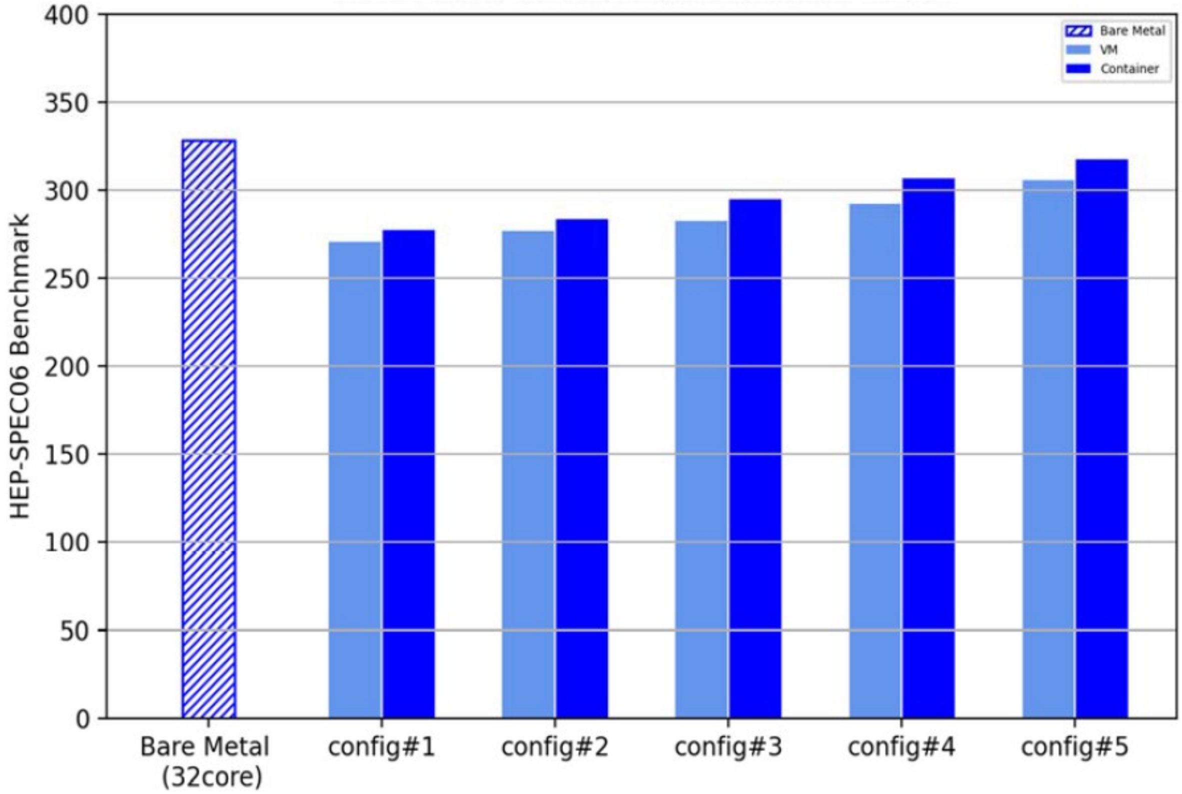

Figure 8

Every consumer has his / her priorities, and every CSP has its services. With different features, it is very difficult for the consumer to know the features that Azure is offering from storage perspective similar problems are present regarding finding the features provided by AWS from the computation perspective and also for Google's available features from an infrastructure perspective. Based on the review of many research papers are collected and divided into groups of all features concerning computation, storage, and infrastructure. It has been a big challenge to discuss every feature of the table individually and suggest the CSP, which offers good service features. That is why, based on many papers reviewed, some findings have been given as per the best of knowledge and understanding.

AWS

If talking about AWS then it has more and good features as compared to Azure and Google, AWS is more dominant in IaaS service than Azure and Google but as compared to Google and Azure, AWS is somewhat more expensive, and security of AWS is also not much better.

Microsoft Azure

It also has good features, especially in all services. Microsoft Azure is a bit cheaper as compared to AWS. Microsoft is dominant in SaaS, and also in PaaS, service features are good as compared to AWS. Microsoft is a familiar name for people, and AWS is not much familiar as compared to Microsoft and Google.

Google cloud platform

It is a good competitor of AWS and Microsoft azure because of good security and low price. Google is dominant in PaaS as compared to AWS and Microsoft Azure. Also, in SaaS, Google is going up. As discussed earlier, AWS, Microsoft Azure, and GCP all are giving good services in all domains. In the cloud, all services use the same domain mostly, for example, SaaS, PaaS, and IaaS. All three services use storage, computation, and infrastructure, so that is the reason for making tables of features from the domain's perspective and not from the service perspective. Highlighted are the CSP service features that businesses or organizations bring into consideration. These choices are shown in tables 1, 2, and 3.

Table- I: Storage features

Features	Cloud Service Providers		
	AWS (Amazon)	*Azure (Microsoft)*	*GCP (Google)*
Object Storage	Amazon S3	Blob Storage	Google Cloud Storage
Block Storage	Amazon Elastic Block Store	Azure Managed Disk (Built-in Service)	Persistent Disk
File Storage	Amazon Elastic File System	Azure Files	Cloud Filestore
Disaster Recovery	Pilot light to Hot standby environment	Enterprise Scale or SMB DR	Not good DR or backup service
Backup	S3 is used often for backup	Backup service	
Archive Storage	S3 or S3 Glacier	Azure Archive Storage	Archival Cloud Storage
Bulk Data Transfer	AWS Import/Export and Snowball	Azure Import/Export and Data Box Disk Service	STS (Storage Transfer Service)

Figure 9

Table. III: Infrastructure features

Features	Cloud Service Providers		
	AWS (Amazon)	***Azure (Microsoft)***	***GCP (Google)***
Server Management Services	Systems Manager	Operational Insights	N/A
Cloud Deployment	Cloud Formation	Resource Manager	Resource Manager and Cloud Deployment Manager
Logging and Monitoring	CloudWatch and CloudTrail	Azure Monitor with Log Analytics and Application Insights	StackDriver
Server Automation	OpsWorks, Lambda and Service Catalog	Automation and VM Extension	N/A

Figure 10

Conclusions

In this paper, we discuss the issues which are related to efficiency and throughput of virtual machines and containers and also compared different virtual machine tiers in three of the most popular cloud providers, Amazon, Google & Microsoft. Also features offered by CSP companies are discussed as well as AWS, GCP, and Microsoft Azure are compared. The purpose of CSPs comparison and highlighting service features of Microsoft Azure, Google Cloud Platform, and Amazon Web Services are to answer the questions, which are important for organizations when choosing CSP. Just significant service features have been pointed out, namely storage service features, computation service features, and infrastructure service features. All three service features have an impact on the decision to choose CSP.

The performance overhead problems to scientific workloads in a cloud computing environment are evaluated with our configuration scenarios. We propose an approach that combines the four techniques and improves the overall throughput and performance of virtual machines and containers. We present a balanced view of efficiency and throughput for virtualization and containerization. Our analysis and experience can enable VMs or containers to create a cloud-based environment that can deliver the scientific workloads. One of the most promising pinning benchmarks, HEPSPEC06, is not used for performance evaluation, enhancements, and accomplishments in cloud computing environments, instead we rely on time consumed and CPU performance.

Our experimental results show that the overall performance and efficiency of VMs and containers can be enhanced only when we choose the minimum cores for a VM or container, and overall throughput of CPU cores is also able to be maximized when we make hyperthreading enabled. Pinning and isolation of physical hosts' CPU cores can further enhance performance in the cloud environment, especially for containerization. This research finds that there is a need for tuning in the virtualization layers that directly affect the performance in order to achieve the best performance and increase the throughput of a virtual machine.

Limitations & Future Scope

Although our benchmarking is valuable in a data-intensive cloud computing environment, it should be noted that our benchmarking has a limitation. The experimental results described in this paper are evaluating the differences among bare metal and VM in a cloud-based scientific computing environment on the basis of time consumed and CPU utilization and not any approved benchmarking like HEPSPEC06. Since HEPSPEC06 mainly focuses on science-oriented computing, applications of benchmarking may be limited when comparing with other similar benchmarks that do not seriously consider a data-intensive environment like high energy physics. Therefore, meaningful future research would be to find and evaluate specific working applications that show performance gaps.

Also we have just taken one factor into consideration (hyperthreading) but there are many researches that show that containerisation with docker and kubernetes/OpenStack along with CPU isolation and CPU pinning can help in improving HEPSPEC06 score to near real time scores.

Also our research focuses on general purpose VM's and not dedicated VMs for storage/computation.

References

1. Armbrust, M.; Fox, A.; Griffith, R.; Anthony, D.J.; Katz, R.; Konwinski, A.; Lee, G.; Patterson, D.; Rabkin, A.; Stoica, I.; et al. A view of cloud computing. Commun. ACM 2010, 53, 50–58. [CrossRef]
2. Ostermann, S.; Iosup, A.; Yigitbasi, N.; Prodan, R.; Fahringer, T.; Epema, D. A performance analysis of EC2 cloud computing
services for scientific computing. In Cloud Computing; Springer: Berlin/Heidelberg, Germany, 2010; pp. 115–131.
3. Foster, I.; Zhao, Y.; Raicu, I.; Lu, S. Cloud computing and grid computing 360-degree compared. In Proceedings of the 2008 Grid
Computing Environments Workshop, Austin, TX, USA, 12–16 November 2008; pp. 1–10.
4. Wang, L.; Zhan, J.; Shi, W.; Liang, Y.; Yuan, L. In cloud, do mtc or htc service providers benefit from the economies of
scale? In Proceedings of the 2nd Workshop on Many-Task Computing on Grids and Supercomputers, Portland, OR, USA,
16 November 2009; Association for Computing Machinery: New York, NY, USA, 2009; p. 7.
5. Beloglazov, A.; Buyya, R. Optimal online deterministic algorithms and adaptive heuristics for energy and performance efficient
dynamic consolidation of virtual machines in cloud data centers. Concurr. Comput. Pract. Exp. 2012, 24, 1397–1420. [CrossRef]
6. Vecchiola, C.; Pandey, S.; Buyya, R. High-performance cloud computing: A view of scientific applications. In Proceedings
of the 10th International Symposium on Pervasive Systems, Algorithms, and Networks (ISPAN), Kaohsiung, Taiwan,
14–16 December 2009
7. OpenStack an Open Source Cloud Management Platform. Available online: https://www.openstack.org (accessed on
12 December 2014).
8. HEPSPEC06 Benchmark. Available online: https://w3.hepix.org/benchmarking (accessed on 15 October 2015).

9. Rao, J.; Wang, K.; Zhou, X.; Xu, C.Z. Optimizing virtual machine scheduling in NUMA multicore systems. In Proceedings
of the IEEE 19th International Symposium on High Performance Computer Architecture (HPCA2013), Shenzhen, China,
23–27 February 2013; pp. 306–317.
10. Ibrahim, K.Z.; Hofmeyr, S.; Iancu, C. Characterizing the Performance of Parallel Applications on Multi-socket Virtual Machines.
In Proceedings of the 11th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing, Newport Beach, CA,
USA, 23–26 May 2011; pp. 1–12.
11. Mao, M.; Humphrey, M. A performance study on the vm startup time in the cloud. In Proceedings of the IEEE Fifth International
Conference on Cloud Computing, Honolulu, HI, USA, 24–29 June 2012.
12. Xu, F.; Liu, F.; Jin, H.; Vasilakos, A.V. Managing performance overhead of virtual machines in cloud computing: A survey, state of
the art, and future directions. Proc. IEEE 2013, 102, 11–31. [CrossRef]

13. Podzimek, A.; Bulej, L.; Chen, L.; Binder, W.; Tuma, P. Analyzing the Impact of CPU Pinning and Partial CPU Loads on
Performance and Energy Efficiency. In Proceedings of the 15th IEEE/ACM International Symposium on Cluster, Cloud and Grid
Computing (CCGrid), Shenzhen, China, 4–7 May 2015; pp. 1–10.
14. Varrette, S.; Plugaru, V.; Guzek, M.; Besseron, X.; Bouvry, P. HPC Performance and Energy-Efficiency of the OpenStack Cloud
Middleware. In Proceedings of the 43rd International Conference on Parallel Processing Workshops (ICCPW), Minneapolis, MN,
USA, 9–12 September 2014; pp. 419–428.
15. High-Performance Linpack (HPL). Available online: http://www.netlib.org/benchmark/hpl/ (accessed on 8 July 2020).
16. Graph500. Large Scale Benchmarks. Available online: https://graph500.org/ (accessed on 1 August 2020).
17. Wang, L.; Kunze, M.; Tao, J. Performance evaluation of virtual machine based Grid workflow system. Concurr. Comput. Pract. Exp.
2008, 20, 1759–1771. [CrossRef]
18. Jackson, K.R.; Ramakrishnan, L.; Muriki, K.; Canon, S.; Cholia, S.; Shalf, J.; Wasserman, H.J.; Wright, N.J. Performance analysis of
high performance computing applications on the amazon web services cloud. In Proceedings of the IEEE Second International
Conference on Cloud Computing Technology and Science (CloudCom), Indianapolis, IN, USA, 30 November–3 December 2010;
pp. 159–168.
19. Barik, R.K.; Lenka, R.K.; Rao, K.R.; Ghose, D. Performance analysis of virtual machines and containers in cloud computing.

In Proceedings of the International Conference on Computing, Communication and Automation (ICCCA), Noida, India,
29–30 April 2016.
20. Yan, J.; Zhang,H.; Xu,H.; Zhang, Z. Discrete pso-basedworkload optimization in virtualmachine placement. Pers. Ubiquitous Comput.
2018, 22, 589–596. [CrossRef]
21. Mavridis, I.; Karatza, H. Combining containers and virtual machines to enhance isolation and extend functionality on cloud
computing. Future Gener. Comput. Syst. 2019, 94, 674–696. [CrossRef]
22. Chae, M.; Lee, H.; Lee, K. A performance comparison of linux containers and virtual machines using Docker and KVM.
Clust. Comput. 2019, 22, 1765–1775. [CrossRef]
23. Bui, B.; Mvondo, D.; Teabe, B.; Jiokeng, K.;Wapet, L.; Tchana, A.; Depalma, N. When extended para-virtualization (xpv) meets
numa. In Proceedings of the Fourteenth EuroSys Conference, Dresden, Germany, 25–28 March 2019; Association for Computing
Machinery: New York, NY, USA, 2019; pp. 1–15.
24. Li, J.; Qian, J.; Guan, H. A Holistic Model for Performance Prediction and Optimization on NUMA-based Virtualized Systems.
In Proceedings of the INFOCOM 2019—IEEE Conference on Computer Communications, Paris, France, 29 April–2 May 2019;
pp. 352–360.
25. Intel Hyper-Threading Technology: Technical User Guide 2013. Available online: https://www.utdallas.edu/~{}edsha/parallel/
2010S/Intel-HyperThreads.pdf (accessed on 5 April 2020).
26. Integer Component of SPEC CPU2000. Available online: https://www.spec.org/cpu2000/CINT2000/ (accessed on 10 March 2020).

PROOF OF RESEARCH PAPER PUBLISHING

From: **ICICC 2022** <icicc.ui@gmail.com>
Date: Thu, 23 Dec 2021 at 17:41
Subject: ICICC 2022 - Paper Notification 508
To: Aryaanahuja <aryaanahuja14@gmail.com>

International Conference on Innovative Computing and Communication (ICICC) – A Flagship Conference

Dear Author(s),

Greetings from ICICC 2022!

We congratulate you that your paper with submission ID **508** and Paper Title '**Performance Evaluations on Various Virtual Machine for different Cloud Based Workloads.'** has been shortlisted to be considered for Elsevier SSRN Reputed Series. This means that your paper is among the top 25% of the papers received/reviewed. The reviews have been found below. Our registration process has started. Kindly submit your registration fees as early as possible.

Details regarding Elsevier SSRN can be find here: https://www.elsevier.com/about/press-releases/science-and-technology/elseviers-scopus-expands-to-include-ssrn-preprints

You are requested to do the registration as soon as possible and submit the following documents to icicc.ui@gmail.com at the earliest.
1. Revised Final CRC as per the Elsevier format. (See "Elsevier Word Template" at http://icicc-conf.com/downloads_page)
2. The final revised copy of your paper should also be uploaded via Microsoft CMT