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PERFORMANCE EVALUATION OF A COMPUTER NETWORK IN A CLOUD COMPUTING ENVIRONMENT

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Abstract. *The cloud service platforms number has increased and this resulted in an increased number of its providers. This emphasizes the investigation of the factors which influence its services and overall performance. Therefore, this study explores the performance evaluation of the cloud services which are critical provisioning quality services and distribution of the workload. A performance evaluation method has been designed to assess the cloud computing services used for the computer network. The performance of 1.76 GFLOPS was achieved through the cluster with one node to advertise the peak performance as depicted by Amazon (66%). A total of 52.4 GFLOPS or 39.87% has been obtained for 16 instances from the 85% efficiency and the theoretical peak. The experiment performed in this study showed that the reliability and performance of the investigated clouds are beneath the expectations. Therefore, this cloud is inadequate and inefficient for scientific computation comprehensively, although it shows a dire adaptation based on temporarily and immediate resources.*

Keywords: Performance evaluation, Computer network, Cloud computing environment, Models, Infrastructure, Metrics

1. **Introduction.** In the modern world, working dynamics of the computer system have significantly changed. One main contributor to this change is the expansion of the data centers and the clouding environments where the computing services are delivered on the Internet [1]. It is evident from the increased traffic of the users on Amazon, Alibaba and more such platforms. Given this, there are a variety of tools which are being utilized for regulating and monitoring these services, such as large infrastructures. The primary motive behind the utilization of such infrastructure is to bridge the capability gap which impedes the deliverance of the quality integrated services enabled through the dynamic working of the cloud technology [2]. Cloud computer follows a distributed and parallel system for providing connectivity and facilitating the distribution of these services. The resources and the infrastructure required for cloud computing are accessible to every user [3]. Presently, the content over the Internet can be accessed by every user regardless of the infrastructure he hosts. This accessibility has been provided by the data centers, which are constantly sustained and monitored by the providers. The emergence of the computing environment was mainly driven to facilitate the application of business services through a network. The network enables the providers to be continuously connected with the consumer improving its nurturance on their needs, its profitable opportunities and eradicating the increased cost which occurs when the services are delivered in-house.

The integration of cloud services with the routine operations of the business enhances the firms' overall performance [4]. This is because of the increased use of network and

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telecommunication system their challenges, and users demand. This emphasizes improvement in firms' capabilities and enlargement of the computing application [4]. The profitable projection of the cloud services in the coming years has advanced its aggressive investment. This increased investment has emerged to instill high quality in the offered services [3]. Given the escalated development of cloud computing and the network technologies, the networks are associated with individuals' daily tasks, i.e., e-commerce, business, education or leisure and more. Since its deployment and complexity continues to exceed with the constant emergence of new protocols, architects and applications, it is in a constant process of adaptation.

Moreover, the periodical increase in the network systems and application for catering to the demands of the massive real-time user and with the global IT spending of US $3.5 trillion further stresses towards its performance evaluation [5,6]. The earlier findings further emphasize the evaluation of the performance. For example, Lee and Zomaya [7] investigated the consumption and efficiency in a cloud computing environment in terms of costs and highlighted various challenges. Likewise, Tudoran et al. established that on-demand provision of the resource along with the utility providers initiated cost assist in acquiring maximum gain, which is also facilitated by reducing the operational cost [8]. Vineetha highlighted that the monitoring tools of the cloud computing performance should be considered for the cloud provider along with the cloud users' perspective [9].

Consequently, the present study assumes that assessment of the network performance will assist in developing an understanding of its functionality which significantly impacts the future performance of these infrastructure. Also, it helps provider optimize their infrastructures while simultaneously meeting its user's performance necessities. This will assist the consumers by providing methods which help them compare various cloud services based on the offers made assisting in its selection and composition at an optimal level.

Given the changing landscape of cloud computing and network, Gorelik [10] asserted that this structure has provided the organization with various choices in terms of infrastructure, cost, and delegation of liabilities to third-party provider. This network has improved the business models and enables fast adaptation to new technological strategies at both individual and organizational level. The primary comparisons of networking technology with the computation grid further amplify its advantages where previously many servers up-front were used for carrying out large computational jobs [10]. The benefit of the cloud is based on its scaling which can be done as per demand. This provides potential and existing users with more elasticity, i.e., an environment which requires few servers to commence its functioning to efficiently develop more serves while also scaling down to its initial size if necessary. Therefore, the study aims to evaluate the performance of cloud networking which provides the users with the necessary performance measures to augment the efficiency and productivity achieved through this application.

The paper is divided into various sections. Section 2 of the paper shares the related work of various authors whereas Section 3 provides a review analysis of the methods concerning the various aspects of the cloud computing network and its performance. Section 4 summarizes the results of the experiment whereas implications are presented in Section 5. Lastly, Section 6 briefly summarizes the findings and provides a direction to the future researches and the issues and challenges, which can be experienced by them.

2. **Literature Review.** According to Garg et al. [11], the primary aim of the cloud computing networks is to assess the performance of cloud computing and provide the attributes which must be present in a system. The Amazon Elastic Cloud (EC2), GoogleApps Engine, Microsoft Windows Azure, Sales-force and Dropbox are characterized as the leading providers of the cloud services in the commercial market [12]. These providers have gained significant popularity among the other users based on their responsible services providing

feasibility and accessibility [12]. In the same context, Zhang et al. [13] compared four cloud platforms part of the commercial market highlighting that each platform provides different services and various abstraction level. It emphasizes that end users must choose more than one platform based on their business requirements to meet their needs in the best possible way [13].

Buyya et al. [14] illuminated that there exists a need to innovate the cloud computing practices for risk management and for meeting customer satisfaction. The features of cloud computing were classified by Höfer and Karagiannis [15]. It highlighted that system working proficiency is achieved through its various characteristics such as service model, its license type, cost, and the language for providing system along with the system operations. These classifications of the features were also assessed by Rimal et al. [16]. They considered the provider's attributes and compared them for their interoperability and security, infrastructure, virtualization, instruments for the load balancing, and assistance for software and programming languages [16].

Ostermann et al. [17] used micro-benchmarks such as LM bench, HPC Challenge (HPC-C), kernels, and Cache Bench, Bonnie for analyzing EC2 performance. It showed that low performance of virtualized resources in the public cloud, specifically for the application of computation and networking. It also compared the private cloud visualized capabilities to a nonvirtualized capability for the Single Instance. This target was achieved using the I/O, CPU, and memory hierarchy metrics on the benchmarks for evaluation of the performance.

Few studies also have evaluated the performance of the computing network providers in a quantitative manner where a framework named as Cloud Comp for comparing the performance of the multiple providers in the market [18]. The study has also performed a comparison of four cloud providers' servers which serve the commercial markets using the components of computing, database, network, and storage as the base. The commercial markets include Google App Engine, Windows Azure, Amazon EC2, and Rackspace. The study of Mao and Humphrey further enlightened various concerns, which impacted the start-up time of the virtual machine integrated into the cloud serves across the three clouds provides, i.e., Amazon EC2, Windows Azure Google Apps Engine, and Rackspace [19]. Li et al. [18] conducted performance and cost evaluation by comparing the four public clouds, which cater to the diversified user. The measures used for the assessment included the operative capacity of the clouds, which include elastic computing, the network used for intra-cloud, persistent storing, and Wide range network [18].

3. **Methodology.** A performance evaluation method has been designed to assess the cloud computing services used for the computer network. To this end, the evaluation process for a computer network is divided merely into the cloud-specific evaluation.

3.1. **Assessment of cloud-specific aspects.** Clouds can be achieved at any time regardless of additional waiting time as it is always based on unused resources. In contrast, other large-scale systems' loads differ timely concerning the submission trends. Therefore, it is important to investigate the period required for resource acquisition and release over short and long time periods. To this end, one and more instances of the same time are usually obtained during a few minutes for the short-time periods. A Poisson process with arrival rate ($\lambda = 1$s) is requested for the resource acquisition. Moreover, an instance is obtained and released every 1 minute over one week for the long periods. This process is also segregated into hourly averages taken over one month from the 2-minute samples.

3.2. **Performance metrics.** The HPCC benchmarks have been used in this study as performance metrics. The High-Performance Linpack (HPL) efficiency is used on the basis of instance Type (T) for a real virtual cluster. A standard formula for operation count helps solve a constant and random system of linear equations and accounts time and floating-point execution rate. The expression of instance type T is presented in the form of percentage and computed from the ratio between the performance of a real environment formed with one instance of the same type and the HPL benchmark performance of the cluster. Following expression is used to satisfy the benchmark:

$$\frac{||A_x - b||}{||A||||x||n\epsilon} \leq O(1) \tag{1}$$

where ϵ is the precision of the machine and n is the problem size, x is the number of nodes in the system whereas 'A' and 'b' in the formula are the cluster nodes. $O(1)$ refers to the big-O notation.

In contrast, gigaflops measure the computer's floating point unit's performance. It denotes one billion floating point operations per second or FLOPS. Gigaflops serve as a better indicator of a raw performance of a processor since it measures how many millions of floating point calculations a processor can execute per second.

3.3. **Environment.** All the measurements were performed in the (EC2) environment. Despite the fact that it is an outdated version, the measurement in this environment will not bound the results of the study as (HPCC) is specifically used to perform single-job benchmarks. Homogeneous environments are developed with 1 to 64 cores on the basis of the four (EC2) instance types in the experiments. Table 1 has presented the 32 and 64-bit instances computed through Fedora Core 6 operating system with a Linus 2.6 Kernel.

TABLE 1. Performance of the single and multiple instance types

Instance type	Sequence output			Sequence input		Random input
	Characters	*Block*	*Rewrite*	*Characters*	*Block*	
M1.small (M1 General Purpose Small)	*20.27*	*50.15*	*23.17*	*15.14*	*63.36*	*64.3*
M1.large (M1 General Purpose Large)	*40.78*	*54.18*	*14.14*	*25.82*	*53.10*	*114.2*
M1.xlarge (M1 General Purpose Extra Large)	*46.88*	*77.74*	*23.25*	*31.18*	*64.41*	*357.7*
C1.medium (C1 High-CPU Medium)	*39.08*	*48.57*	*22.70*	*37.34*	*64.85*	*62.3*
C1.xlarge (C1 High-CPU Extra Large)	*54.75*	*77.57*	*19.96*	*34.89*	*64.36*	*273.5*
01 Ext3 (third extended filesystem)	*10.14*	*28.65*	*15.96*	*10.57*	*163.58*	
02 RAID5	*12.25*	*14.28*	*12.17*	*13.40*	*63.03*	
07 RAID5	*28.78*	*30.25*	*27.03*	*31.81*	*102.59*	*172.5*

Moreover, the study has used two instance types of families, which include the general purpose and compute optimized family. From the general purpose family, the study has selected *m1.small*, *m1.large*, and *m1.xlarge* whereas *c1.medium* and *c1.xlarge* were selected from compute optimized family. The notion of general purpose instances is to provide a balance of memory, networking resources, and computation for different workloads. In contrast, compute optimized instances are beneficial for compute-bound applications that rely on high-performance processors. Following applications are well-suited for the compute optimized instances.

3.3.1. *Media transcoding.* The media transcoding application provides a cost-effective, scalable as well as an easier way to transform the media source format file to the versions which can be run on the various devices and smartphones.

3.3.2. *High-Performance Computing (HPC).* This application aggregates the computing power effectively improving the performance which an individual achieves at the typical desktop for solving complex science, engineering, or business queries [20].

3.3.3. *High-performance web servers.* It effectively hosts websites and infuses such software which allows easy access to the hosted web pages. These allow effective transmission rate for the accessing data [21].

3.3.4. *Scientific modeling.* This modeling integrates with an activity which improves the understanding by referring a particular novel feature with something which is universally or generally accepted. This provides the tool for better prediction, explanation, and change of information [22].

3.3.5. *Batch processing workloads.* This improves the system ability to process the terabyte data from a high-speed storage device and provides valuable information such as financial reports, quarterly stock statements and more [23].

3.3.6. *Dedicated gaming servers and ad serving engines.* These servers and serving engines transmit the data in its internal form which allow its associated customers and clients to sustain an accurate version for their usage.

3.3.7. *Compute-intensive applications that include machine learning inference.* The learning machine interface allows the applications to make accurate predictions about the user preference and needs to the provider.

4. **Results.** A total of three resource acquisition and release scenarios have been investigated in this experiment based on a short and long time period.

4.1. **Single instances.** The five instance types were repeated for 20 times that was followed by a release after the resource status was installed. The resource acquisition time was computed by combining the sum of the Install and Boot times. From the results, it has been observed that the ($c1.*$) instances were easy to be acquired, whereas the ($m1.*$) instances require higher time expectation for the resource acquisition. Both the Release times and Virtual Machine (VM) Boot are stable to present a quarter of total each regardless of any occasional outlier as shown in Table 1.

4.2. **Multiple instances.** The acquisition of multiple resources was requested for 2, 4, 8, 16 and 20 resources at the same time for investigating the performance of the computer network at multiple instances. Constructing a homogenous cluster using Amazon cloud computing resources corresponds as a practical example. In the cases, acquisition and release times were recorded when the resources were recorded for bulk. For instance, as compared to a single instance, the expectation and the variability are higher as shown in Table 1.

4.3. **HPL performance.** The *m1.small* instance is achieved to compute the performance of the HPL benchmark based on assorted virtual clusters as portrayed in Table 2. The performance of 1.76 gigaflops per second (GFLOPS) was achieved through the cluster with one node to advertise the peak performance as depicted by Amazon (66%). A total of 52.4 GFLOPS or 39.87% has been obtained for 16 instances from the 85% efficiency and the theoretical peak. The HPL performances benchmark for different instance types in the Amazon Elastic Compute Cloud (EC2) are shown in Table 3. Better performance has been achieved from the (*c1.xlarge*), whereas the theoretical peak performance was not highly achieved in other instance types. Due to the reliability issues, a low performance has been depicted from one instance (*c1.medium*). A total of 54.6 (GFLOPS/$) has been achieved through the cost-wise: (*c1.xlarge*) instance. This instance has achieved a better peak performance in the experiment (based on the assumption that an already existing

TABLE 2. HPCC performance for different platforms

Provider, system	Peak performance	HPL	STREAM	RandomAc.	Latency	Bandwidth
EC2, m1.small	*3.20*	*1.76*	*2.19*	*9.51*		
EC2, m1.large	*15.20*	*5.15*	*2.18*	*34.35*	*18.18*	*0.50*
EC2, m1.xlarge	*25.10*	*10.18*	*2.47*	*154.54*	*15.78*	*0.78*
EC2, 16 × m1.small	*12.00*	*2.91*	*2.84*	*34.59*	*11.18*	*1.07*
EC2, 16 × c1.xlarge	*78.00*	*41.38*	*11.55*	*65.82*	*58.14*	*1.39*

TABLE 3. Performance and cost comparison of HPL with instances

Name	Peak performance	GFLOPS	GFLOPS/ECU	GFLOPS/$1
M1.small (M1 General Purpose Small)	*2.4*	*1.76*	*1.76*	*15.5*
M1.large (M1 General Purpose Large)	*15.1*	*5.15*	*1.59*	*15.8*
M1.xlarge (M1 General Purpose Extra Large)	*25.1*	*10.28*	*1.25*	*12.2*
C1.medium (C1 High-CPU Medium)	*12.0*	*2.81*	*0.57*	*17.5*
C1.xlarge (C1 High-CPU Extra Large)	*66.0*	*39.87*	*1.50*	*52.4*

is present) which is the preeminent measured value in the present study assessment. The best ratio between achieved performance and its Amazon ECU (Elastic Compute Unit) rating is investigated through this instance.

4.4. **HPCC performance.** The HPCC benchmarks were executed on unit clusters to acquire the virtual EC2 performance consisting of one instance and two instances for 16-core clusters. The results have shown that the performance of (*.xlarge*) is achievable and comparable than the HPC system for HPL performance. In contrast, the performance of the cloud computing services is similar or effective as compared to the performance of the HPC clusters for Random Access, DGEMM (Double-precision General Matrix-Matrix multiply), and STREAM. The cloud computing services have shown higher latency, emphasizing a meaningful influence on the HPL benchmark performance concerning the network behavioral characteristics. The cloud computing clusters can drive to the lower performance for large system sizes for scientific computing applications as compared to HPL.

5. **Implication.** With the dynamic changes in the cloud computing system, the assessment of the service performance is integral. By the evaluation of the cloud service and network performance, the companies will be able to lower their cost, as low capital expenditure is required [16,24-26]. It reduces firms' investment on the physical infrastructure. The stakeholder does not have to struggle with the purchasing of the goods on hardware or software, as the efficient network provides it all, proposed by Reixa et al. [27]. It further contributes towards the green movement as the rack space is not used, which results in a lower cost of utility. The use of cloud service allows the fast deployment of the service as there is no need for purchasing and installing the equipment as the providers make it all available. This reduces the time used in the installation, which can be done in minutes, hours, and days. Moreover, the performance evaluation is essential as it contributes to the workforce enhancement, which allows the firms to focus on other tasks as compared

to the configuration or maintenance related to the cloud networking service. An effective system allows accessibility from every place requiring just the presence of Internet capability. The response time increases which improves the instant actions as per the user-generated request within minutes and second.

There has been an incentive of experimental evidence in the evaluation of performances associated with cloud computing services. The targeted computational cloud resources for scientific computing have been evaluated based on the size and scope as compared to other studies by Moura and Hutchison [28], Höfer and Karagiannis [15]. Therefore, the peak performance of the computer network gives a comprehensive evaluation of the services of the cloud with other clusters. Moreover, the applications aim to inline to the mainstream HPC scientific community as used in this study. An assessment of file transfer between cloud services and computer network is investigated from the instances used in this experiment. In contrast, scientific computing is evaluated through the implementation of cloud infrastructure by Giangrande et al. [29], Höfer and Karagiannis [15]. The structure is executed by computing the cloud infrastructure, executing major workflows from conventional clouds and grids, and extending clusters based on demand with IaaS resources. This eventually stems the increasing role of the cloud computing environment for computer network evaluation and the pre-requisite to have performance estimates for distinct offerings.

6. **Conclusion.** E-Scientists are experiencing a plethora of challenges with a new platform option in which scientific computation is attempted when required from big data centers on leased resources. In contrast, the preliminary target of the cloud computing environment does not show any meaningful stance towards the computer network evaluation. Therefore, this study has investigated the performance of a computer network using a cloud computing environment. The experiments performed in this study showed that the reliability and performance of the investigated clouds are beneath the expectations. Therefore, this cloud is inadequate and inefficient for scientific computation comprehensively, although it shows a dire adaptation based on temporarily and immediate resources. The enhancement of existing clouds concerned with computer networks and the identification of a novel research direction has been analyzed by the present study. Future work can extend this work by implementing other cloud services such as a database, private cloud, queue service, and storage. By performing similar experiments on other IaaS offerings, this experiment can be extended for assessing the performance evaluation. This study aims to assess the novel research areas as raised in the review of needed cloud enhancements in the long-run.

A realistic system is required which evaluates the performance of the cloud infrastructure which should further be investigated. The future studies are suggested to conduct end user's perception of the performance for the end-to-end service that is likely to involve the infrastructure and network present within the cloud environment. It also provides a change in the application and diversity of cloud services. This generates different patterns in terms of workloads requiring the development of suitable and flexible models, which accurately projects the generated traffic arriving from a different application, to be studied by the future work.

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