Cloud Computing Simulators: A Detailed Survey and Future Direction

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***Abstract*—Cloud computing is one of the emerging technologies with its ease of access and diverse applicability, letting customers attracted to it and thus posing many challenging issues that need to overcome in this field. Since the evolution of cloud computing: Load balancing, power constrains, program offloading, cost modelling and security issues are the popular research topic in this field. Deploying real cloud for testing or for commercial use is very costly. Cloud simulator helps to model various kinds of cloud application by creating Data Centre, Virtual Machine and many Utilities which can be added to configure it, thus making it very easy to analyse. Till now, many cloud simulators have been proposed and also available to use. These simulators are built for specific purpose, and have varying features in each of them. In this paper we presented a comprehensive study of major cloud simulators by highlighting their important features and analysing their pros and cons. we made a comparison among the simulators by considering their important attributes and finally concluded with our future direction.**

Keywords—Cloud Computing; Cloud Computing Simulator; Data Centre; Load Balancing; Virtual Machine.

I. INTRODUCTION

Cloud Computing is an emerging topic with its unique services such as on-demand self-service, broad network access, resource pooling, rapid elasticity, measured services etc.[1,4]. The fundamental idea of Cloud Computing that differs from the Grid Computing is the unique service level abstractions and virtualization. The services are categorized as (i) Software as a Service (SaaS), which completely deals with applications, management, and user interfaces e.g. Microsoft Office 365 [39], Salesforce [40], Dropbox [49] etc. (ii) Platform as a service (PaaS), which provides environment for application development framework, Operating Systems, virtual machines etc. e.g. Google App Engine [9], Aneka [10] etc. (iii) Infrastructure as a Service (IaaS) which provides the computing hardware, virtual storage, virtual Infrastructure etc. e.g. Amazon EC2 [7], Eucalyptus [8]. With the evolution of cloud computing, IT companies don't need to worry about infrastructure deployment for hosting web, application, and data storage. According to Rajkumar Buyya "A Cloud is a type of parallel and distributed system consisting of a collection of inter-connected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resource(s) based on service-level agreements established through negotiation between the service provider and consumers [2]".

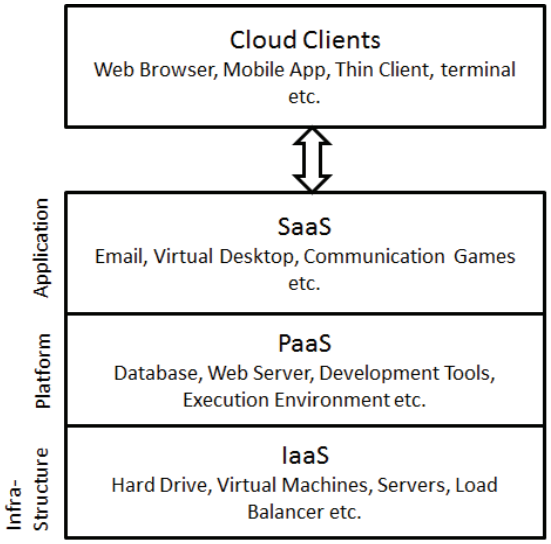

Figure 1.Cloud Computing Layers[50]

A recent report shows that, Cloud Computing will control active enterprise market within the next two to five years [3]. With the increase in cloud's popularity, providing the cloud services with minimal cost and low power consumption is becoming a challenge. The major challenges that preventing cloud as being a standard platform are [2, 43],

(i) *Security:* since all the storage and computations are processed in cloud servers, the importance of confidentiality, data integrity and non-repudiation issues are predominant.

(ii) *Cost Modeling:* cloud computing has a unique pay-as-you-go service model; through which organizations pay only for what is being used and no more. For example, it might be highly beneficial for a company if a brand new high powered server farm could be obtained to introduce a new web based market offering with zero upfront capital.

(iii) *Energy Management:* due to fluctuation of workload, the average load is only 30% of data center resources and rest of the 70% account putting resources in sleep mode, so main goal is to run an application with minimum set of computing resources and maximize the resources to be in sleep mode [44, 12].

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(iv) *Virtual Machine Migration:* since cloud computing is a distributed system, when workload is increased in a particular data center, virtual machine migration helps to prevent performance degradation of the system.

The cost of deploying and testing a real cloud needs lot of effort including hardware resources and eventually cost for its hugely distributed systems integration. But, this drawback can be eliminated with the help of Cloud Simulator. There are lots of benefits of using Simulators particularly in cloud such as, (i) *Minimal Cost:* since this is just software, cost is very less comparing to hardware, (ii) *Repeatable and controllable: we* can test more than a number of time until we get the desirable output does, (iii) *Environment-* It provides evaluation for different scenario under different workload and cost measurement [6].

To develop and analyze in any new cloud computing environment with the help of simulators, it is required to understand about the existing cloud simulators with their pros and cons. In this paper we are presenting some of the latest and popular cloud simulators available by highlighting the important characteristics of each simulator. The main goal of this paper is to demonstrate a clear understanding of existing cloud simulators that will be helpful in choosing a simulator for any specific type of application. The rest of the paper is organized as per the following. Section 2 describes information about related work on cloud simulators. Section 3 covers various kinds of cloud simulators available, section 4 gives a detail comparison by analyzing the available cloud simulators on the basis of important attributes and section 5 concludes the paper by highlighting new features to be added that can be added in existing cloud simulators as future work.

II. Related Work

Since Cloud Computing is still in infancy state, research work is booming in this field. A detail of cloud computing architectures, state-of-art implementation and challenging issues are discussed in [1, 2]. According to [46] author mentioned the benefits of mobile cloud computing and different challenging issues [46]. In the literature, many cloud simulators exist such as CloudSim [11], GreenCloud [12], iCanCloud [37], CloudAnalyst [13] and many others. However because of the varieties of challenging issues of cloud computing, one particular existing cloud simulators does not solve the entire problem for example GreenCloud [12] which is specifically build for calculating energy consumption; CloudAnalysis is favorable for testing the performance of social networking sites such as facebook, twitter etc. In a recent cloud simulator survey, the author mentioned only the overview of cloud simulators without discussing the features available in each simulator [5]. Kumar compared the features taking only three simulators [47]. Infect, it is necessary to draw a conclusion which simulator is suitable for what type of work. In our work we first discussed major problems do exist in the cloud then we focus on the available simulators with great detail about their capabilities to simulate. At the end we define valuable attributes and compared the simulator on basis of those attributes.

III. Cloud Simulators

In this section we describe cloud simulators on the basis of their popularity, publication paper and useful researches and for having their unique features.

A. CloudSim

CloudSim [11] is the most popular simulator tool available for cloud computing environment. It is an event driven simulator, built upon the core engine of grid simulator GridSim [14]. Java the most powerful object oriented programming language is being used in CloudSim, because of OOP feature, CloudSim modules can be easily extendable with the user's requirement. CloudSim has feature of modeling and creating a huge data center, unlimited number of virtual machines, introducing brokering policy and support the important feature of cloud computing pay-as-you-go model. One of its unique features is federated policy, which is rarely available to any other simulators.

Because of extendibility nature of CloudSim its popularity is being increased day by day. Due to the lack of many important features in new cloud simulators, CloudAnalyst [13], NetworkCloudSim [48], EMUSIM [15], CDOSim [17] are developed integrating new features to the CloudSim Modules. Currently, in HP labs (Palo Alto) and Duke University (U.S.A.) researchers are using CloudSim for evaluation of resource algorithms and energy-efficient management of data centers.

Later on many works have been done for the improvement of CloudSim. Yuxiang Shi proposed an energy scheme using "Linear Predicting Method" (LPM) and "Flat Period Reservation-Reduced Method" (FPRRM) based on CloudSim that will reduce the energy consumption of cloud [18]. G. Belalem had made an approach to improve resource allocation scheme in CloudSim [19]. Y. Shi added file stripping and functions for data replication management in CloudSim, Thus a new simulation framework is proposed for data storage processing and computation [38]. One of the drawbacks of CloudSim is lack Of GUI.

B. CloudAnalyst

In 2009, Wickremasinghe [13] developed a new simulator called CloudAnalyst based upon CloudSim [11], adding new features to it. CloudAnalyst is basically made for evaluating performance and cost of large-scale geographically distributed cloud system that is having huge user workload based on different parameters. It has very attractive GUI and huge flexibility to configure any geographical distribute system such as setting hardware parameters (storage, main memory, bandwidth limit, network delays etc.) of a virtual machine or data center. New service brokering policy can be added easily that control the users of any geographical location based on services done by which Data Center at any particular given time. In CloudAnalyst, analysis can be done repeatedly and can generate output in the form of chart and table that summarize the huge amount user, system statistic during the simulation time. In 2012, Rawat [20] has evaluated performance of social networking adding new brokering policy using this simulator.

C. GreenCloud

GreenCloud [12] is a packet level cloud simulator developed by extending network simulator ns-2[21]. This is quite different from CloudSim, and is specially made for energy-aware environment. GreenCloud is designed so that it can calculate energy consumption at any particular data center components such as link, switch, gateway etc. as well as communication between the packet levels. Further, it offers to know the workload distribution in the system. DENS [22] scheduler is used to minimize the resources during job selection by taking consideration of workload and communication capability of data center [23] . It has no feature for finding energy consumption on the basis of storage area network techniques.

One of the drawbacks of GreenCloud is that it takes minutes of time for simulating a model and huge memory [24]. Because of time consuming, its scalability is only restricted to small data center. User of this simulator needs to learn both of the programming languages i.e. C++ and Otcal to use this simulator, which is a noticeable drawback. This simulator is useful with only the work related to calculating energy computation in the cloud.

D. MDCSim

In 2009, Seung-Hwan Lim proposed MDCsim cloud simulator featuring the design and analysis for large scale multi-tier data center [24]. MDCsim allows to measure power and analyze each layer of 3-layer architecture model and can modify any layer without affecting other layer of the architecture. It can also model hardware characteristic such as links between two communication node and switches connected with those node. The simulator featured IBA and Ethernet communication protocols over TCP/IP and support many functions of IBA. There is no restriction in adding any new communication protocol.

To use this simulator, user must know C++/Java language. The drawback of this simulator is that it is commercial [37]; so users need to buy it for full functionality. Functional overview of MDCsim is shown in the below figure 2.

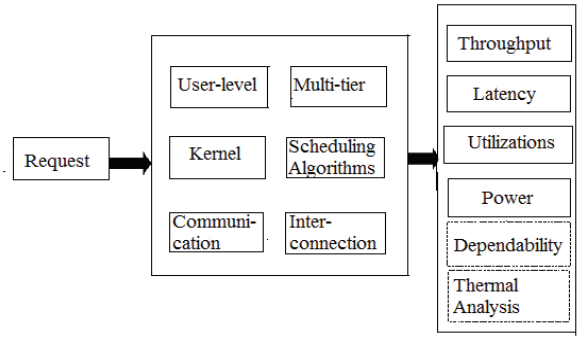

Figure 2. Overview of MDCsim Simulator[24].

E. iCancCloud

iCanCloud [37] is developed by considering the drawbacks of the previous cloud simulators as CloudSim[11], GreenCloud[12] and MDCsim[24]. This simulator is developed based on SIMCAN [25] and can simulate many experiments. It's very flexible and unique feature is that the user can customize the core hypervisor class, which in turn is the core of iCanCloud. There is also one public cloud model Amazon that instances type integrated with the simulator. This provides extra features for comparison with a corporate model. The programming language used in this simulator is C++; user can extend and add new features by inheriting the hypervisor class.

iCanCloud allows to add many adapted MPI library and POSIX based API for simulating new applications. Many new brokering policies can be integrated in this simulator. Using iCanCloud, A. Núñez built new flexible hypervisor and proposed new brokering policies to minimize user cost for public cloud infrastructure based on classical scheduling heuristic [26].

F. NetworkCloudSim

NetworkCloudSim [48] is proposed by Saurabh Kumar Garg and Rajkumar Buyya extending features of CloudSim. CloudSim [11], GreenCloud [12] are basically built for single server architecture and become insufficient for real cloud model, deploying different type of applications from different customer.[24]In MDCsim only applications can communicate among each other. To overcome above drawback NetworkCloudSim supports communication between the application element and various network elements. In NetworkCloudSim, there are two level of scheduling as, Host level and VM level. Thus, VM scheduler is accounts communication and computational stages of each application stages. NetworkCloudSim support real cloud application such as e-commerce, HPC and real work flow. NetworkCloudSim is appropriate for simulating any networking protocol within the cloud.

G. EMUSIM

EMUSIM [15] is not only simulator; it provides both simulation and emulation of a cloud application. It is developed for software as a service (SaaS), applications having huge CPU-intensive and which are very costly for actual deployment. For these types of applications, customer needs to analyze before taking rent of the resources. When a simulation is performed it depends only upon the software and hardware characteristics. But, in emulation, the software model is tested in the actual hardware itself. Thus, in comparing to simulation, emulation is more dependent on software. This simulator is built based upon the CloudSim [11] and AEF [27]. For improving the accuracy, relevant information of the application are taken out during emulation and is used during the simulation.

H. GroudSim

GroudSim [28] is a discrete event simulation platform for both cloud and grid computing. It is specially made for simulating scientific application in cloud and grid computing. GroudSim has Java as an underlying programming language. It is flexible, focused on IaaS service. GroudSim can be extended very easily by adopting probability distribution packages. One unique feature is that, GroundEntity in the GroudSim [28] has own definition error behaviors, user can change this

configuration during each error occurrence. In [29] author used GroudSim framework as a back-end part of the Grid Computing environment ASKALON [30].

I. DCSim

DCSim [34] simulator basically developed for simulating virtualized data center deployed in Infrastructure as a service (IaaS) model. It has multiple interconnected hosts and each host having own CPU scheduler and resource managing policy. It supports VM migration between the host and replication of it. It also supports sharing of workload between multiple VMs that are running multi-tier applications. DCSim simulates data center with the centralized management system. It neglects data center network topology for higher scalability [42].

In [41], the author proposed a model in which order of VMs and hosts are to be migrating during stress situation. The author uses DCSim simulation framework to conduct the experiment.

J. MR-CloudSim

Most recently, MR-CloudSim [31] is developed by extending feature of CloudSim [11]. The above cloud simulators we discussed, notably not a single support for big data processing analysis technique. Due to the increase of data consumption and high network bandwidth, now a day's data center stores huge amount of information. MapReduce [32] is distributed computing model, which solve most problems that exist in parallel and distributed computing. CloudSim simulator does not have the feature for file processing, and cost and time related with it. In MR-CloudSim [31], author changes some of the classes of CloudSim and so as MapReduce is implemented in the framework. This simulator is appropriate for work related with data processing task that uses MapReduce protocol. The above framework is not tested with the existing real MapReduce model Hadoop [33] which is popular in industry [31]. The execution flow diagram of this simulator is shown in figure 3.

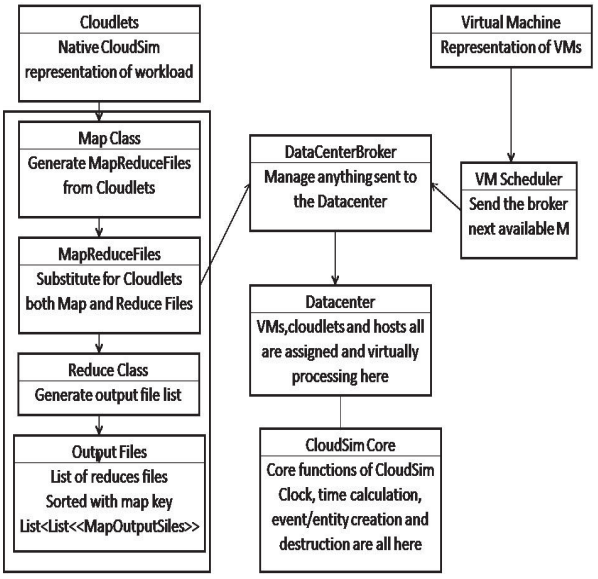

Figure 3. Execution Flow Diagram in MR-CloudSim[31].

K. SmartSim

SmartSim [16] is uniquely built for Mobile Cloud Computing and this is the first ever simulator that support simulation of various application of Mobile Cloud Computing. It has feature for modeling mobile cloud application running in mobile. The system takes resource provision, evaluation method for resource utilization in SMD as an attributing for system application processor and memory modeling [16]. Block diagram of SmartSim is shown in figure 4. It does not support simulation most of the mobile cloud problems.

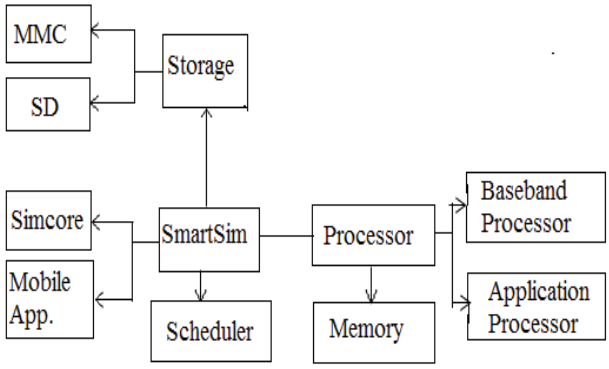

Figure 4. Block Diagram of SmartSim Simulator[16].

L. SimIC

In 2013, Stelios Sotiriadis proposed SimIC framework for simulating various inter-cloud activities [35]. It is a discrete event simulator built upon the SimJava package. Recently, many inter-cloud activities are evolved, thus exchanging many services between different cloud data centers and eventually increasing quality of services. None of the above simulators can implement inter-cloud activities without extending distribution package. It has the entities of inter-cloud such as users, data center, host, hypervisor, meta-brokers, local brokers and virtual many important features such as energy model for reducing power consumption during message distribution, host-scheduling policy for time sharing, benchmarking with machines (VMs) [35]. SimIC uses ICMS algorithm for inter-cloud scheduling which depends upon most of the distributed parameters. It also gives as-per-as-you go facility. Using SimIC, Sotiriadis analyzes the performance of ICMS that depend on the varying amount of job submission in related with computational requirement [36]. The authors also tried to use the result for future inter-cloud benchmarking analysis. many important features such as energy model for reducing power consumption during message distribution, host-scheduling policy for time sharing, benchmarking with CloudSim are still author expected in future work. This simulator is currently not available under distribution.

IV. Analysis of Cloud Simulators

In the above section we have discussed some of the popular cloud simulators including few latest one. From a user point of view it is very important to choose appropriate simulator to get

efficient with minimum cost. Here we will compare some of the important attributes from the above simulator. We have also mentioned features available in each simulator. Some of the simulators are made for special purpose – SmartSim is for mobile computing, MR-CloudSim is for Big Data Processing, DCSim help VMs migration during workload etc.

The attributes selected for comparison (given in Table 1) between various Cloud Simulators are:

a) Underlying Platform: Some of the simulators are built upon any existing simulation framework. The features of existing platform are inherited in the new simulation framework. Other

Table 1. Comparison between cloud Simulators

Simulator	Underlying Platform	Available	Programming Language	Cost Modeling	GUI	Communication Model	Simulation Time	Energy Model	Federation Policy
CloudSim	SimJava	Open Source	Java	yes	No	Limited	second	yes	yes
CloudAnalyst	CloudSim	Open Source	Java	yes	yes	Limited	second	yes	yes
GreenCloud	NS-2	Open Source	C++, otcel	No	Limited	Full	Minute	yes	no
MDCsim	CSIM	Commercial	JAVA/C++	No	No	Limited	second	Rough	no
iCanCloud	SIMCAN	Open Source	C++	yes	yes	Full	second	No	no
NetworkCloudSim	CloudSim	Open Source	Java	yes	No	Full	second	yes	yes
EMUSIM	CloudSim, AEF	Open Source	Java	yes	No	Limited	second	yes	no
GroudSim	-	Open Source	Java	No	Limited	No	second	No	no
MR-CloudSim	CloudSim	Still not available	Java	yes	No	Limited	-	yes	yes
DCSim	-	Open Source	Java	yes	No	No	Minute	No	no
SimIC	SimJava	Still not available	Java	yes	No	Limited	second	Rough	Yes

than GroudSim and DCSim, all are built on a particular framework.

b) Availability: This is important to know the availability of a simulator is commercial or open source. MR-CloudSim and SimIC is not available but the author mentioned any interested person can contact to get the simulation software.

c) Programming Language: Most of simulator uses Java language for scripting or modeling any system. This is very important, since user have to learn the language first to use the simulator.

d) Cost Modeling: Since pay-as-you model go is one of fundamental service of cloud computing, or utility computing and one of the challenging issue of cloud simulator. User can model any new policy by using the simulator that has this module.

e) Graphical User Interface: Graphical user interface is for visual purpose and for simplicity when modeling. Many of the above simulators have interactive GUI.

f) Communication Model: Communication Model is one of the important in cloud computing especially for networking within the data center and message passing between applications.

g) Simulator Time: This is the execution time of simulator during testing. This will determine whether simulator is heavy. GreenCloud takes minutes during execution.

h) Energy Modeling: Energy modeling is very important in cloud computing research because of huge energy consumption in the data center and various networking elements (router, switch etc.). GreenCloud is specially built for this purpose.

i) Federation Policy: Since, cloud is distributed system. Many cloud service providers are located in different geographical location. Federation policy allows coordinating different cloud service provider that supports internetworking of application and workload migration to benefit high quality of service [45].

V. CONCLUSION

After the evolution of cloud computing, IT services are growing faster. Cloud is helping to serve computing utilities like electric and a phone service. In this paper we have presented importance of cloud computing and its available simulators. But, the above simulators have many limitations that force to the attention in adding more features in the above

simulators. Mobile Cloud Computing is one of the emerging brands of cloud computing due to immense increase of mobile users [46]. But, from the above discussion, we have clearly seen none of the simulators except SmartSim [16] have the feature to simulate mobile cloud computing issues. Major Mobile Cloud issues are computational offloading, Network access management, Energy awareness, Privacy policy, mobility of users etc. Our future work is to create a simulation framework that can simulate major issues of Mobile Cloud Computing.

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