A Critical Review & Analysis of Cloud Computing Simulators

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Abstract- The Cloud computing service is a computing elucidation, where resources are provided just like water and electricity to the users. It is the rung towards the development of on-demand computing solution that delivers IT as a service. With the help of cloud computing, users can access their files and use their software from any computer with internet access. Since it is very difficult for the researchers to perform experiments or implement their algorithms in real cloud computing environment, the simulators play an important role to model the system and evaluate the results as per the requirements. Moreover, simulating a cloud environment can reduce the time, cost and effort required for configuring a real cloud scenario. The paper presents a critical review & analysis of the various cloud computing simulators available in the computer world. The review will act as a good reference source for researchers or academicians to find out the appropriate cloud simulator. Results show that the CloudSim is the pedestal of many cloud computing simulation algorithms and is being heavily used by most of the researchers.

Keywords- Cloud computing simulators; GreenCloud; iCanCloud; CloudSim; NetworkCloudSim; CloudAnalyst; DCSim; MDCSim;.

I. INTRODUCTION

In the older days, most of the households, towns, farms or villages had its own water well. Afterwards, the governments started sharing water tanks to the public by giving access to water through the taps. Similarly, electricity is being provided to the public on a pay-per-use basis. These are the on-demand services that can be turned ON or OFF as per the requirements and the users will be charged accordingly. Though the billing is based upon the usage, the concept of providing water and electricity in this way is basically implemented to reduce the wastage. The notion of cloud computing arises in a similar fashion. The Cloud computing service is a computing elucidation where resources are provided just like water and electricity to the users. It is the rung towards the development of on-demand computing solution that delivers IT as a service. With the help of cloud computing users can access their files and use their software from any computer with internet access. The NIST (National Institute of Standards and Technology) defined cloud computing as "A model for enabling ubiquitous, convenient; on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [1]. Because of its potential to minimize power consumption and enhance user experience the model has gained popularity with high pace. The low cost, highly secured and location independent cloud computing model leads the educators and businesses to migrate from the conventional computing to cloud computing.

Since it is very difficult for the researchers to perform experiments or implement their algorithms in real cloud computing environment, the simulators play more viable and attractive role to design the system and analyze the results as per the requirements. They enable the option of evaluating the assumption in the desired situation where the results can be easily reproduced. Today many IT companies are significantly benefited by these simulation-based approaches by testing their services in convenient and well managed environment with different scenarios [4]. Starting from the network simulators such as packet tracer, the researchers are now proceeding towards the development of the advanced cloud computing simulation tools.

The paper presents a critical review & analysis of the different cloud computing simulators. It is separated into different sections where section II provides the background of different simulating environments. Next in section III, different Cloud simulators have been explored, such as CloudSim, Cloud Analyst, Green Cloud, and iCanCloud etc. Finally in the section IV, evaluation of different cloud computing simulators in terms of platform, availability, language, graphical support etc is given. The conclusion and future work is given in the last section.

II. BACKGROUND

Cloud computing is the result of natural progression of many years of evolution dating back from the centralized mainframe computers to the distributed client-server computing. The researchers define cloud computing as a metered service that is provisioned of providing online shared storage and computational services in a simple and scalable manner. There are generally seven phases of computing known as Mainframe computing, PC computing, Network computing, Internet computing, Grid computing, Cloud Computing and Mobile Cloud Computing. The mobile cloud computing is called as the future of cloud computing where the users can use their portable, handheld devices for accessing the cloud.

In the earlier period, "the Grid" has evolved as the computing infrastructure that is used for distributed networking environment. So for the development of Grid computing and testing of Grid model with its components, several Grid simulators have been proposed namely such as SimGrid, GangSim, GridSim and OptorSim. Out of these, SimGrid provides the basic framework for the Grid platform simulation. Similarly, GangSim is another simulation tool that provides support for designing the Grid-based environments. Another simulator called as GridSim have been developed that can be used for comprehensive modeling of grid entities that includes users, network components and network traffic. Though the aforesaid simulation tools are capable of designing and simulating Grid environments, none of them are capable of segregating the services such as SaaS, PaaS, and IaaS; that is definitely required by cloud computing infrastructures. Moreover, there is very little or even no shore up in these tools for implementing the concept of virtualization. Hence with the development of cloud computing infrastructures, the researchers are shifted towards the development of Cloud based simulators. That is why cloud computing modeling and simulation toolkits are developing with a high pace.

III. CLOUD SIMULATION TOOLS

The simulation toolkits are developed by using the set of mathematical formulas to model the real scenario. In other words, these are the programs that allow users to model or implement the situation without actually performing that operation [9]. The simulators have been actively participating for a long time in several different fields such as computer networks, robotics, medical sciences etc. There are different cloud simulation toolkits available in the computer world. This section explores some of the most accepted cloud simulation toolkits.

3.1 CloudSim

The existing Grid-based simulation tools were not able to segregate the services such as SaaS, PaaS, and IaaS. To bridge this gap, a Java-based simulation framework called as CloudSim have been introduced at CLOUDS Laboratory, University of Melbourne, Australia. It is probably the most famous & popular simulator for cloud environments & parameters [9]. The CloudSim can be used by researchers to model and simulate the cloud infrastructure and analyze the performance of the application service in a controlled environment [1]. It is an extensible simulator that provides basic classes for describing users, computational resources, virtual machines, data centers, cloudlets and many other strategies for the management of different elements of the infrastructure. The main features of CloudSim are:

- Very less time or effort is required for the implementation of cloud computing environments.
- Enables modeling and simulation of large scale data centers.
- Allows the developers to create heterogeneous cloud environments and analyze the performance of their application services in it.
- It provides the shore up for designing and simulation of energy-aware computational resources [9].
- Support for dynamic inclusion of simulation elements, over and above stopping and resuming simulation.
- Provide support for different user defined policies for the allocation of hosts to VM's.
- Provides the flexibility to allocate different processing cores to virtualized services by sharing time and space.

The major limitation of CloudSim is the lack of a GUI. However, it is the base of many other cloud computing simulation algorithms. Most of the researchers and academicians are still using CloudSim for the development of more advanced cloud simulators. Figure 1 shows the different layers and the architectural components of the CloudSim toolkit [1].

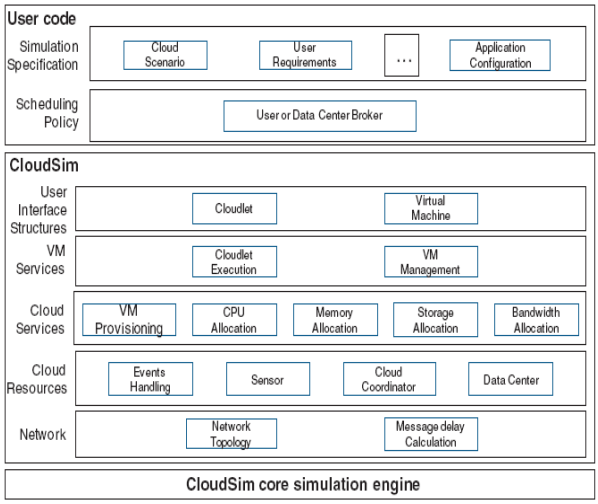

Figure 1: Multi-layered Design of CloudSim

The topmost layer is the "User Code" that handles the issues related to simulation specifications and scheduling policies. So this layer implements the user requirements such as considering number of machines, assigning hosts to VMs. Moreover the application configuration such as number of tasks of virtualized data center including the configuration for VMs is also handled by this layer. Furthermore this layer is also involved in scheduling policies for user or data center broker.

The middle layer provides support for the creation and simulation of cloud-based environments that includes interfaces for Virtual machines, storage and bandwidth. The user interface structures such as cloudlet and VM implementation is given in this layer. The cloudlet execution and the management of VM can also be done using this layer.

The lowest layer is called as the "Simulation Engine" that includes the main job required for high-level simulation environments such as queuing events, creation of components, communications among these components, and administration of the simulation timer.

3.2 GreenCloud

The GreenCloud is an extension of network simulator known as NS2. It is a refined, CloudSim based, open source cloud computing simulator that let the researchers to interact, watch and determine the cloud performance. This tool has been developed to bear out the green cloud computing revolution by provisioning an option for analyzing energy efficiency of the clouds. It has been detailed in the perspective of the GreenIT project. It provides sophisticated packet-level information about the energy consumed by the equipments used in data centers. Specially, the tool differentiates the energy consumption components related to physical infrastructure, communicational and computing energy of a data center.

GreenCloud can be used to develop new scenarios of allocating resource, scheduling workload, optimizing network infrastructures and communication protocols [9]. Some of the important features of GreenCloud toolkit are:

- Enlighten the issue of energy awareness.
- Simulation base environment is provided for energy-aware cloud data centers.
- All communication processes related to storage and processing can be simulated.
- User friendly, Graphical User Interface is available.

The major disadvantage of GreenCloud is that it limits to only small data centers [9].

3.4 CloudAnalyst

It is a CloudSim based simulator that provides the powerful simulation framework for deploying real time data centers. It was developed to study the behavior of large scale cloud applications under various deployment conditions [9]. The CloudAnalyst is a graphical simulator that can be used to model and to perform simulations repeatedly with trivial variations of parameters in a simple and quick manner. Moreover the user need not to worry about the programming language, rather he could simply use the graphical environment to examine the behavior of large scale cloud. The CloudAnalyst have been developed using Java and Java Swing. The CloudAnalyst let the

users to save their simulation design information as an "xml" file and the outcome into the "PDF" file format. The main features of CloudAnalyst are [12]:

- Offers a good control over the experimentation with the help of different design options such as Data Center configuration, virtual machine specification, Internet dynamics and Service Broker Policies.
- Offers an easy to use graphical environment to perform experiment in an easy manner.
- Performs different types of experiments with repetitions.

Figure 2 shows the architecture if CloudAnalyst [14].

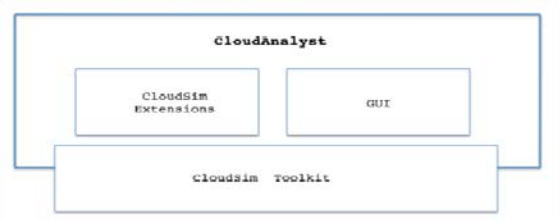

Figure 2: Architecture of CloudAnalyst

3.5 NetworkCloudSim

The NetworkCloudSim [3] is an extension of CloudSim that is capable of implementing network layer in CloudSim. The generalized applications that include workflows and real cloud data centers can be implemented using NetworkCloudSim. It provides a topology file which contains number of nodes with different entities required in simulation [9]. The NetworkCloudSim offers to configure most of the parameters that allows the practitioners to undertake the varied network topologies. However, the NetworkCloudSim limits its functionality to only small data centers due to the large simulation time and high memory requirements. Moreover, the power efficient resource management schemes can be rapidly implemented by using this simulator. Figure 3 shows the architecture of NetworkCloudSim [14].

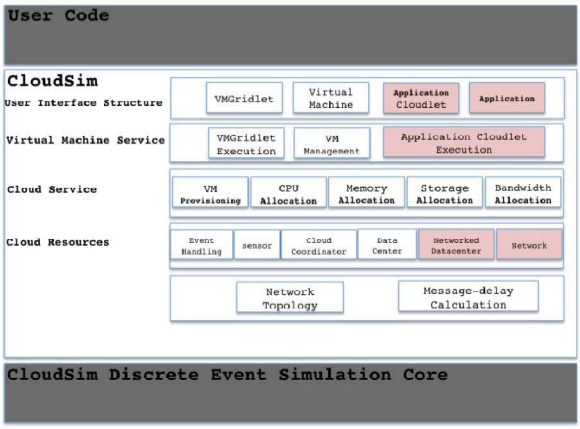

Figure 3: Architecture of NetworkCloudSim

3.6 EMUSIM

It is an integrated architecture that is built on AEF (Automated Emulation Framework) for emulation and CloudSim for simulation. So the EMUSIM come together with both the emulation as well as simulation techniques in a single package. It is used to model an environment that is closer to the real computing resources and patterns. The EMUSIM does not require the information such as location of virtual machines and number of virtual machines per host in a given time. The main limitation of EMUSIM is that it is less scalable may be due to the hardware restriction or difficulty in producing large and real networks. Figure 4 depicts architecture of EMUSIM [15]:

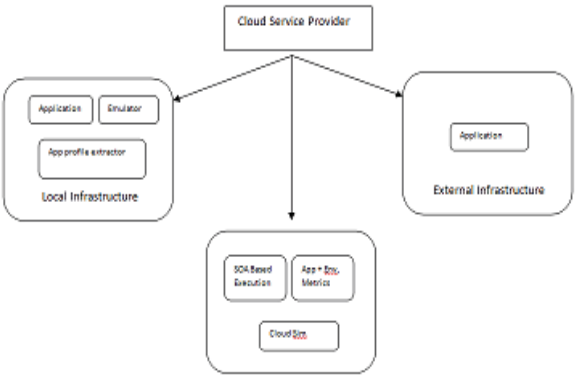

Figure 5: Architecture of EMUSIM

3.7 DCSim

It is an extensible Data Centre Simulator (DCSim) that is implemented in Java and is designed to provide a simple framework for the development of cloud environment [5]. The Data Centre Simulator (DCSim) concentrates on the creation and evaluation of virtualized data centers. It provides the extra ability of designing replicated virtual machines for sharing incoming workload as well as dependencies between these machines [7]. The main focus is to model the internet based environments such as a web server. Figure 5 depicts the architecture of DCSim [14].

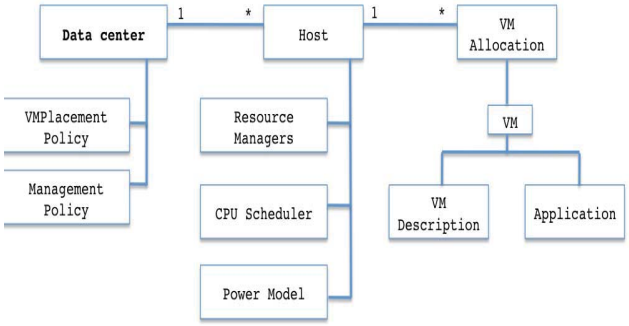

Figure 5: Architecture of DCSim

The architecture is primarily concerned with the Data Centre that contains different management components that includes Hosts and VMs. It is used to develop and evaluate dynamic resource management techniques very easily and quickly. The key features that are added in this simulator include multi-tier application model and VM replication for handling increased workload.

3.8 GDCSim

The Green Data Center Simulator (GDCSim) is a simulator that was developed for studying the energy efficiency of data centers. This can be implements under different geometries, characteristics, platforms, power management schemes, and scheduling algorithms of various data centers. The users can design green data centers and repeat different experiments over the simulator. Moreover the GDCSim is has the feature of online analysis.

3.9 MDCSim

The Multi-tier Data Center Simulation (MDCSim) is a discrete, event based simulator that was developed at the Pennsylvania State University. The tool is used to model the hardware characteristics of different components of data center such as communication links and servers, etc. [2]. It is the tool having low simulation overhead [9] that are mainly used for the simulation of large scale, multi-tier data centers. The MDCSim preserve a data center topology in terms of directed graph. The data centre architecture and cluster configuration are used to measure the performance. It supports three-tiered web applications, with the ability to modify and evaluate the configuration of each tier [7].

3.10 iCanCloud

The iCanCloud [8] is a simulation platform that is basically used to find out the relation between the cost and throughput of a given set of application on a particular hardware configuration. It is developed over SIMCAN which is a simulation tool used to analyze high performance input/output architectures [16]. Figure 6 shows the structural design of iCanCloud [8].

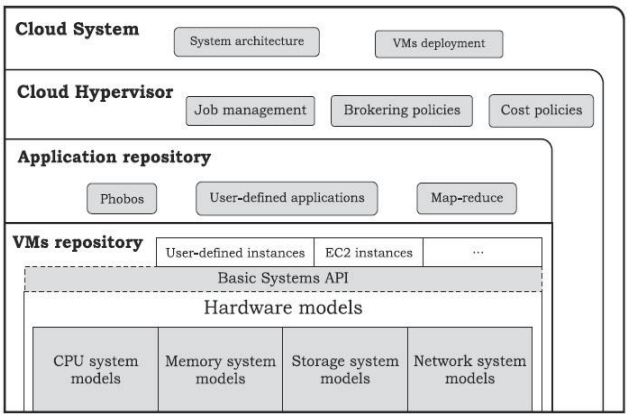

Figure 6: Architecture of iCanCloud

Moreover, various simulation instances are provided by Amazon, so the simulation framework is provided with model of such simulating instances. Main features of iCanCloud are as follow:

- Flexible cloud hypervisor module.
- Provides the facility to simulate uni-core as well as multi-core systems by customizable VMs.
- Large distributed models can be generated and customize easily using user-friendly GUI.
- The new components can be added to the repository for increasing the functionality of iCanCloud.

3.11 SPECI

SPECI stands for "Simulation Program for Elastic Cloud Infrastructures". It is a simulation toolkit that allows the examination of scaling attributes of large data centers. The main aim of SPECI project is to monitor the performance and behavior of data centers, with size and middleware design policy being specified as input [23]. SPECI is a simulation tool that allows the exploration of different aspects of scaling and performance attributes for future Data Centers. The experimental portion of the simulator is based on SimKit, which offers the ability to schedule events as well as the functionality of random distribution drawing [9]. It is responsible for analyzing the various scalability and performance aspects of future Data centers. A second version, SPECI-2 has also been introduced with some enhancements that include a system for analytical simulation modeling of large-scale data-centers.

3.12 CDOSim

CDOSim stands for "Cloud Deployment Option Simulator". It can be used to simulate the response times and Software Level Agreement (SLA) costs of a CDO. A CDO is a simulator that is basically concerned decision making for the selection of a cloud service provider, some runtime strategies, deployment of VMs and the configuration of its instances. The CDOSim is the best example of a simulator for comparing runtime reconfiguration strategies or for determining the tradeoff between the costs and performance [13]. It is developed to address the main limitations of other cloud computing simulators. Some of the main features of CDOSim are:

- Rather than revealing fine-grained elements of a cloud platform, it is leaned towards the cloud user viewpoint.
- Concentrates on cloud platform structure and diminish the user's unawareness.
- The Simulation does not depend upon the existing programming languages.
- Pre-employed profiles can be used to repeat user's behavior for simulating CDOs.

3.13 TeachCloud

It was introduced by University of California at Berkeley for providing advanced workload modeling capabilities. The Rain workload generator framework has been introduced in TeachCloud. It is a complete, simple, and competent cloud computing modeling and simulation tool that is specifically built for educational purposes. It provides a graphical environment to build cloud environment and presents the results in the form of charts. Moreover, it allows a user to customize different features of cloud environment from the host computers to the

networking topologies. So, users can edit or modify the components and their attributes to run varied simulations and analyze results [6]. The CloudSim is the base of this tool with some enhancements such as:

- Graphical interface.
- Introduced the cloud workload generator.
- Added a monitor for most of the cloud resources.
- Introduced a module that enables students to reconfigure the cloud system.

IV. COMPARISON OF VARIOUS CLOUD SIMULATORS

The cloud computing simulation tools are very helpful for setting up the virtual network and monitoring the performance of the network. The paper discusses the working of some cloud computing simulators. As they are similar in many aspects, there exist a lot of differences between these simulators. The Table 1 highlights some of the most important differences between these simulators which would be very helpful for researchers and academicians for the selection of appropriate simulator for the implementation of their work.

Table 1: Comparison of various Simulators

Simulator	**Platform**	**Programming Language**	**Open Source**	**GUI Support**
CloudSim	GridSim	Java	Yes	No
GreenCloud	NS2	C++	Yes	No
CloudAnalyst	CloudSim	Java	Yes	Yes
NetworkCloudSim	CloudSim	Java	Yes	No
EMUSIM	AEF, CloudSim	Java	Yes	No
GDCSim	BlueTool	C++/XML	Yes	No
CDOSim	CloudSim	Java	No	No
DCSim	None	Java	Yes	No
MDCSim	CSIM	C++/Java	No	No
iCanCloud	SIMCAN	C++	Yes	Yes
SPECI	SimKit	Java	Yes	No
TeachCloud	CloudSim	Java	Yes	Yes

V. CONCLUSIONS & FUTURE WORK

Cloud computing is one of the emerging pasture in IT business. Moreover, simulation based approaches helps researchers to create the virtual networks and monitor the performance of these networks. This paper has explored some of the most popular cloud simulation tools such as CloudSim, GreenCloud, CloudAnalyst, iCanCloud, TeachCloud etc. For implementing cloud computing infrastructure, all of these simulators are fine, each having its own advantages & disadvantages. Some are based on any other predecessors, while others are made from scratch. Most of the available simulators are “Open Source” and are freely available; however, some are commercially available simulators. It’s a very difficult task to choose one over many others, as all are having some benefits & limitations. Thus, after analyzing almost all the cloud computing simulation tools, we have concluded that the CloudSim is regarded as the “Pedestal” of most of the simulators. Due to its extensible and generalized simulation framework, using it as a base simulation tool would be very helpful for the researchers to develop any other customized simulator. The future research may extend the CloudSim framework to develop a simulator for another emerging field known as Mobile Cloud Computing (MCC).

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