

# A Comparative Study of Cloud Simulation Tools

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**Abstract**—Cloud technology is rapidly gaining popularity in computing world. Cloud services are generally offered to clients in three different flavors: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Cloud service environment is a large and complex environment involving various entities and their interactions with each other. Testing of various aspects of cloud environment in a real environment is a complex and costly task. Hence simulations tools and techniques are employed to test various aspects of cloud environment in a controlled manner. Simulation tools allow the researcher to test the behavior of the cloud under various circumstances. These tools enable the user to perform repeated experimentation on cloud behavior by changing various parameters. In this review paper, we would explore various cloud simulation tools available in the market. We would discuss various open source and proprietary cloud simulation tools. We would also compare cloud simulation tools on different parameters.

**Keywords**-Cloud simulation tools, CloudSim, CloudAnalyst, GreenCloud, iCanClou, CloudExp, CloudReports.

## I. INTRODUCTION

Cloud computing is an emerging technology. The success of cloud technology is attributed to the expansion of internet and internet users. According to internet world statistics [1], Internet users have grown manifold from 16 million in December 1995 to 3,732 million in March 2017. Around 49.6% of the world population today has an internet connection. The growth of internet technology, development of smart-phones and electronic gadgets has provided a very conducive environment for the success of cloud technology. Cloud services are offered to clients in three different flavors: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Under IaaS service, Infrastructure is provided to customers on a subscription basis. The tenant can subscribe for infrastructure as per requirement and pay as per usage. Cloud service providers (CSP) like Amazon EC2, Microsoft Azure, and IBM Smart Cloud etc. offer IaaS service to users. In PaaS service model, CSP offers development platform to customers. The development platform allows the users to develop, run, and manage applications without building and knowing the underlying details of the infrastructure. CSPs like Google App Engine, and salesforce.com etc. offer PaaS service to clients. SaaS service model is the most popular service model of cloud computing. In SaaS service model, software or application (App) is provided to clients on a subscription basis. The client uses the App of the provider to interact with resources of the CSP. SaaS service providers include Facebook, Twitter, and WhatsApp etc. Besides the above services, various novel types of services are emerging [2] like Business process as a Service (BPaaS), Governance as a Service (GaaS), Storage as a Service (StaaS), Integration as a Service (InaaS), Testing as service (TaaS), and Anything as a Service (XaaS). These emerging services provide a new dimension to the growth of cloud technology.

The cloud environment is a large and complex environment. The environment is large and complex as it encompasses of cloud users, cloud service provider, datacenters, service broker policy for datacenter selection, scheduling algorithms to schedule user requests, internet bandwidth, internet latency, and storage technology etc. The interactions and communication among all these entities make it large and complex environment. Testing the behavior of cloud in a real environment is a difficult task as it involves huge cost, setup of cloud, and other issues. To address this issue, Simulation tools and techniques are employed to test the cloud behavior before actual implementation of the cloud. The simulation tools allow the researcher to test the behavior of cloud by performing experiments in a repeated manner by changing different parameters and conditions. Cloud simulation tools can be open source or proprietary. In this review paper, we would discuss various simulation tools and explore their usage and features. The simulation tools provide a cloud test blueprint before the actual implementation of the cloud and enable the CSP to make necessary changes before actual implementation of the

cloud. The rest of the paper is organized as follows: In section II, literature is reviewed within the context of cloud simulations tools and techniques. In section III, we explore various cloud simulation tools. In section IV, comparison of various simulation tools is discussed, and in section V, conclusion and future scope are listed.

## II. LITERATURE REVIEW

In this section, literature is reviewed within the context of cloud simulation tools. Researchers need to perform experiments to test the behavior of cloud. Testing the behavior in a real environment is a difficult task. Modeling and simulation techniques enable the researchers to perform experiments to test the behavior and performance of cloud in a monitored way. The Performance of cloud can be analysed and improved by using simulation tools and techniques. In this section, we discuss the work already carried out in this area.

In [3] authors had discussed simulation tools for efficient cloud computing applications. They had discussed the integration of mobile devices and cloud computing applications. Experimental comparison of various cloud simulation tools like CloudSim, CloudAnalyst, CloudReports, CloudExp, GreenCloud, and iCanCloud was carried out. The simulation tools were compared on the basis of platform, availability, language used, graphical support, communication models, and power consumption modeling.

In [4] authors had explored various cloud simulation tools like SPECI, DCSim, GDCCSim, MDCSim, EMUSim, TeachCloud, NetworkCloudSim, and CloudAnalyst etc. They discuss the pros and cons of various tools and compared tools on the basis of language and platform used. They also compare cloud computing and grid computing simulators and found that cloud simulators are better than grid simulators.

In [5] authors had discussed various cloud simulation tools like CloudSim, CloudAnalyst, Network CloudSim, DCSim, GroundSim, and MDCSim. They compare the various simulation tools on the basis of the underlying platform, programming language, event or packet based, networking facility, and open source or proprietary based simulation tools. They explore that the choice of simulation tools depends upon the circumstances and needs.

In [6] authors had explored CloudAnalyst simulator in detail. They explore the various packages and classes of CloudAnalyst simulation tool. They explain the purpose of each class in the simulator and also discuss the methodology to perform modifications in the source code of the simulation tool as per requirement of the user. They use the tools to configure cloud computing environment. Finally, they analyse the performance of SaaS cloud using the CloudAnalyst simulation tool.

In [7] authors had proposed CloudSim simulation tool. The CloudSim simulation framework enables seamless modeling and experimentation of emerging cloud computing services. The proposed simulation tool had the support for modeling of large-scale cloud computing environment, self-contained platform for modeling data centers, service brokers, scheduling and allocation policies, the virtualization engine, and flexibility to switch between space-shared and time-shared processing cores.

In [8], the author presents a critical evaluation of the state-of-the-art modeling and simulation tools available for cloud computing environment. The tools are compared on the basis of API features, programming flexibility, operating system requirements, supported services, licensing needs, and popularity. The author also provides recommendations regarding the choice of the most appropriate simulation tool for cloud computing environment.

In [9], authors had reviewed the existing modeling and simulation tools of cloud computing. They indicate that there exist two types of cloud computing simulators, first, simulators just based on software, and second simulators based on both software and hardware. They analyse and compare features of the existing cloud computing simulators. They explore Open Cloud Testbed (OCT), NetworkCloudSim, Open Cirrus, EMUSIM, and GroundSim etc.

In [10], authors had explored the use of cloud simulators for computational research. They explore the features, suitability, and adaptability of the existing cloud simulation tools in the research domain. They discuss the suitability of CloudSim, SPECI, Green Cloud, and future systems for data science research. They explore CloudSim simulation and its extensions like CloudSimEx, WorkflowSim, Cloud2Sim, RealCloudSim, CloudReports, CloudAuction, CloudMIG Xpress, and CloudAnalyst.

## III. CLOUD SIMULATION TOOLS

In this section, Cloud simulation tools and techniques are explored. These tools are discussed and explored across various dimensions like some simulation tools are event based or packet level and open source or proprietary based etc. These simulation tools enable the researchers to test the cloud behavior and performance before actual implementation of the cloud.

### III.1 CloudSim

CloudSim simulation toolkit was developed by the GRIDS laboratory of the University of Melbourne in 2009. CloudSim project is the most popular cloud simulator used by researchers and industry to simulate large-scale cloud computing environment. In its initial version, CloudSim uses GridSim as underlying platform, but in its

upgraded versions, it includes a full implementation of its own kernel. CloudSim [7] enables seamless modeling, simulation, and experimentation of cloud computing based system and application provisioning environment. The researchers can focus and investigate on the specific system design issues without going into low-level details. CloudSim framework is an open source framework. This toolkit is programmed using java language. The researchers can modify the source code as per their requirement and can do simulation and experimentation to test the various characteristics of cloud computing environment. The core features of CloudSim toolkit are:

- It supports modeling and simulation of large scale cloud computing environment.
- It provides a virtualization engine that enables to create an environment of virtual resources.
- It supports space-shared and time-shared allocation of processing cores.
- It supports modeling of service brokers, provisioning and allocation policies of virtual resources.
- It provides the facility to simulate and model federated clouds.

Figure 1. Shows the main entities in the CloudSim. These are

- I. **Cloudlets** : Cloudlets are the tasks executed by virtual machines (VM) in the data center.
- II. **Service Broker**: Service broker entity would decide submission of Cloudlets to a specific data center.
- III. **Data Center**: Data center entity includes host and virtual machines. The VMs would execute the allotted cloudlets.
- IV. **Cloud Information Service (CIS)**: The CIS entity is responsible for registering all the entities in the cloud environment.

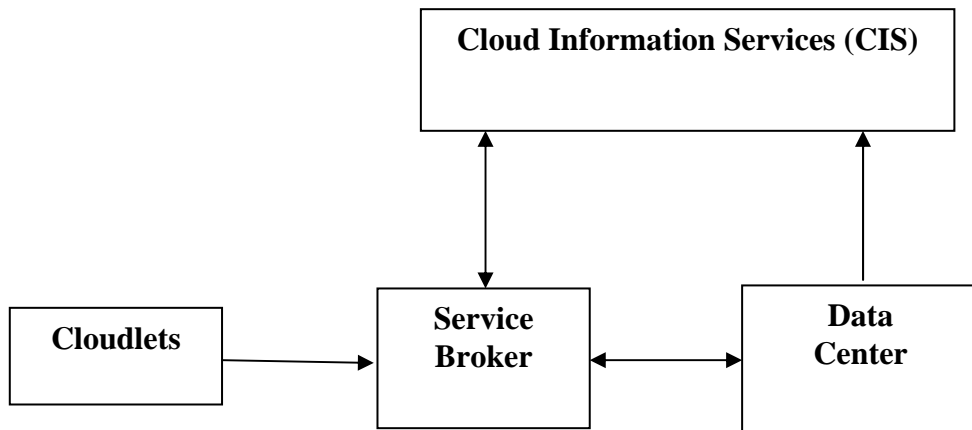


Figure 1. Main Entities in CloudSim

The various tasks submitted by the user in the cloud environment are modeled in the form of Cloudlets in the CloudSim project. These Cloudlets are received by the service broker entity. The cloud environment consists of various datacenters, the broker entity would decide the passage of the cloudlet to a specific datacenter by considering the load on various datacenters. The tasks got executed on the VMs in the data center. VM allocation policy allocates the tasks to VMs by considering the load on the VMs. The cloud information service entity would register all the entities in the cloud environment. As the cloud environment is a dynamic environment, CIS keeps on updating as new entities registers.

### III.2 CloudAnalyst

CloudAnalyst [11] simulation tool is a visual modeler to analyse the performance of large-scale cloud computing application. The main objective of CloudAnalyst tools is to separate the programming exercise from the simulation exercise. The graphical user interface (GUI) capability of the tool enables the researchers to set up simulations without going into underlying details of programming. This tool is an open source and developed using java programming language. The researcher can alter the source code as per requirement and can add and remove entities as per demand. Figure 2. Shows the basic architecture of CloudAnalyst tool. The underlying platform of CloudAnalyst is CloudSim toolkit. Some new packages as CloudSim extensions are added on top of CloudSim toolkit. These extensions allow the researcher to focus on simulation exercise without getting into to the details of programming part. The GUI capability enables the researcher to perform repeated experimentation by changing the various parameters of the simulation.

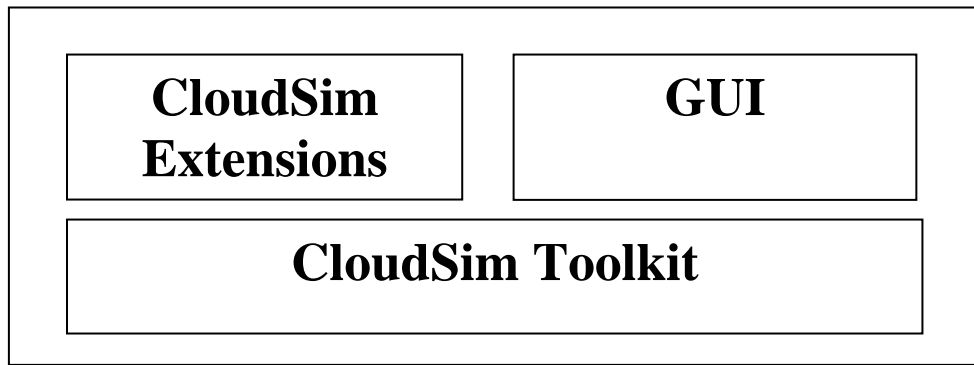


Figure 2. CloudAnalyst Basic Architecture

The main features of the CloudAnalyst simulation tools are:

- Graphical user interface (GUI) for setting up simulations in repeated manner
- Enables the researcher to define simulation with high degree of configurability and flexibility
- The output of the simulation tool is graphical in the form of tables, charts, and graphs.
- It is open source tool and enables the researcher to add new extensions as per requirement.

CloudAnalyst simulation tool is easy to install and set up. This tool can be used to analyse various performance parameters like response time i.e. the time taken to fulfill the user request, data center request processing time i.e. the time taken by the data center to process a user request, and cost i.e. the cost involved in providing services to the user. Generally, this tool is used to analyse the performance of large-scale cloud computing application like a social networking application (App). The performance of the application depends upon the placement of App at various datacenters of the cloud service provider and the distribution of users in the cloud environment. This tool enables the researcher to perform experiments by changing the data center locations, service broker policies, and virtual machine allocation policies to find the ideal solution in terms of placement of datacenters in the cloud environment.

### III.3 GreenCloud

GreenCloud [12] simulation tool is an extension of the NS2 network simulator. This tool was developed using C++ language and Tool Command language (TCL). This tool is used for energy-aware cloud computing datacenters with a focus on cloud communications. It provides fine-grained modeling of energy consumption of computing servers, network switches, and communication links etc. in a datacenter. It can be used to simulate energy consumption of existing data center and helps in the decision making of enhancement in the capacity of existing data centers and designing future data centers. GreenCloud can be used to optimize communication protocols and network infrastructure. This tool enables the datacenter administrator to generate the energy profile of the datacenter and take decisions to lower down the energy consumption and develop eco-friendly datacenters. As shown in Figure 3 [13], the results of simulation tool are graphical and it aids the datacenter administrator to analyse the results in a comprehensive manner. The energy summary depicts the energy consumed by various devices in the data center. This tool is supported on both Windows and Linux operating system.

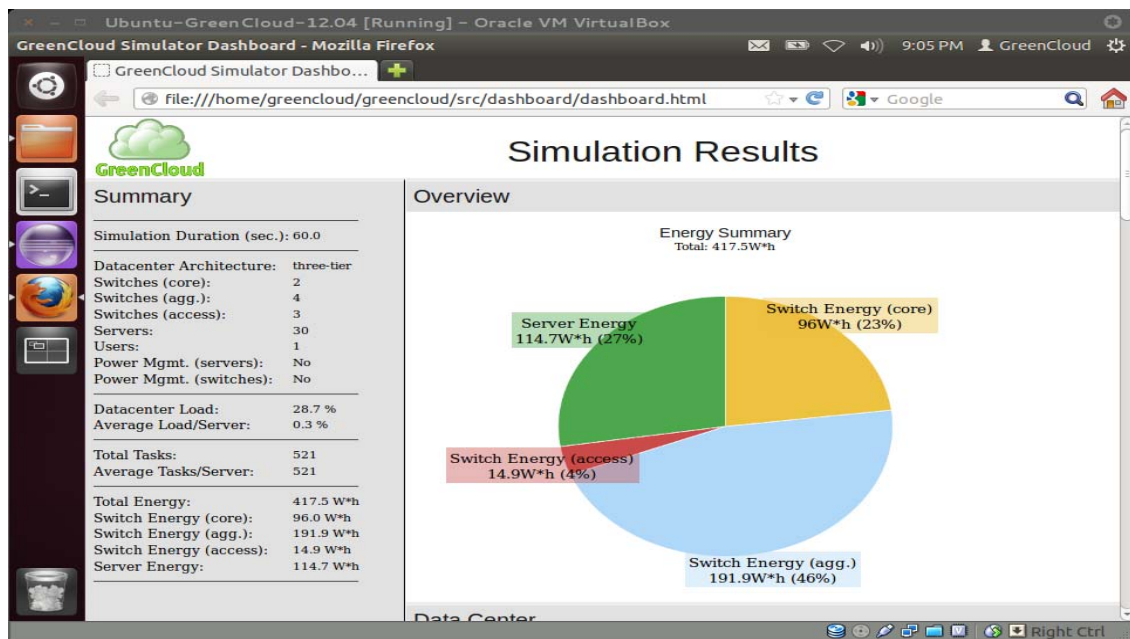


Figure 3. GreenCloud Simulation Results

### III.4 iCanCloud

iCanCloud [14] simulator is used to simulate cloud environment with a diversity of users. The users can be normal users or advance users i.e. developers of large distributed applications. It is used to find the linkage between the cost and the performance of the application. iCanCloud simulation tool is a flexible tool as it allows the user to customize the code to add new cloud brokering policy. It is a scalable tool as it allows simulation of large-scale cloud application without losing performance. The Graphical user interface (GUI) enables the user to configure and launch the simulations in an easy way. Moreover, the results produced are also graphical and can be easily analysed and interpreted. Figure 4. Shows the configuration screen of iCanCloud simulation tool.



Figure 4. iCanCloud Simulation Tool

### III.5 CloudExp

CloudExp [15] simulation tool is used to model cloud environment with emphasis on mobile cloud computing environment. CloudExp simulation tool can be used to evaluate various cloud components like data centers, storage, networking, and processing elements etc. Its MapReduce processing model is used to handle scenarios related to big data and Rain workload generator generates real workloads in a simulated cloud environment. It

allows the researcher to study the communication cost between the users and clouds. It can also be used to create mobility scenarios for mobile devices. The user can configure the various properties of the simulated cloud environment like the number of users, the number of cloudlets in a region, and cloudlet types etc. The results produced are in the form of excel sheets which can be easily analysed and interpreted. Figure 5. [13], show the configuration screen of CloudExp simulation tool. The graphical user interface enables the user to configure the various components of the cloud system like storage, networking, processing elements, and data centers etc.

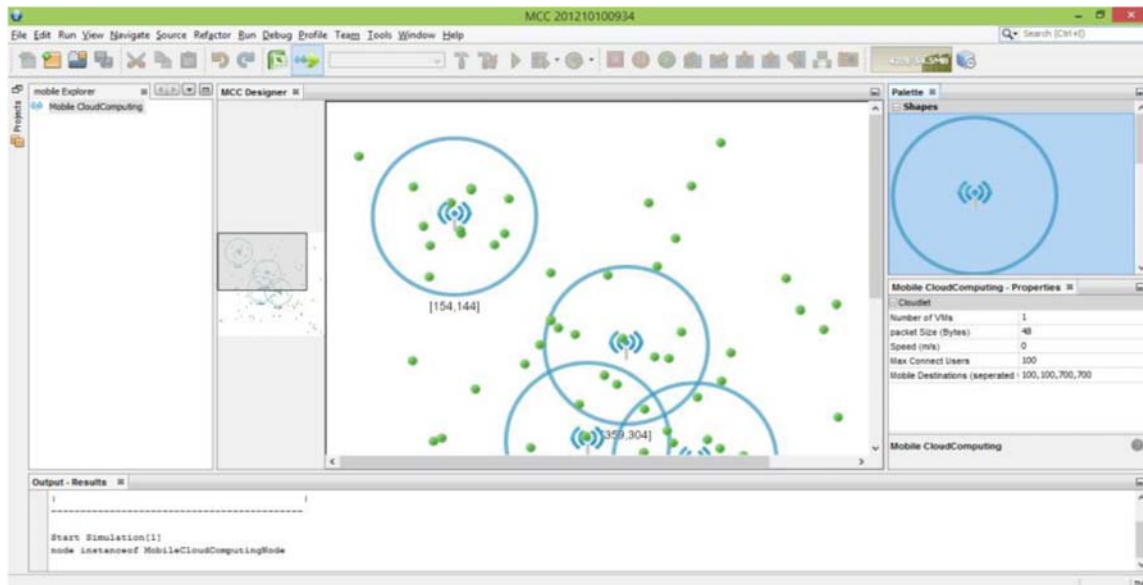


Figure 5. CloudExp Simulation Tool

### III.6 CloudReports

CloudReports simulation tool is built on top of CloudSim framework. The user-friendly graphical user interface allows the researcher to set up simulations in an easy way. Moreover, it allows the execution of multiple simulations at the same time. The results of CloudReport tool are in the form of tables and charts which can be easily analysed and interpreted. This simulation tool can be used to simulate Infrastructure as a Service (IaaS) provider. The researcher can configure the various properties of IaaS provider like the number of datacenters, memory, storage, processing capacity and various other parameters pertaining to a datacenter. The clients of IaaS provider and resource allocation policy can also be easily configured. The results obtained after simulation are graphical and can be easily processed. Figure 6[13] shows the architecture of CloudReports based on CloudSim.



Figure 6. CloudReport Architecture

## IV. COMPARISON OF CLOUD SIMULATION TOOLS

Table 1.below provides the summary of cloud simulation tools discussed in this article. The various cloud simulation tools like CloudSim, CloudAnalyst, GreenCloud, iCanCloud, CloudExp, and CloudReports are compared on the basis of different parameters like underlying platform, the programming language used, open source or commercial, event-based or packet-level simulator, and graphical support. The comparison shows that the choice of a simulation tool depends upon the cloud entity to be explored e.g. for energy modeling and efficiency, GreenCloud should be the best option, for testing of social networking App and placement of datacenters, CloudAnalyst is the best option etc.

Table 1. Cloud computing simulation tools comparison

Simulator	Underlying Platform	Programming Language	Open Source or Proprietary	Simulator Type	Graphical Support
CloudSim	GridSim	Java	Open Source	Event Based	Limited
CloudAnalyst	CloudSim	Java	Open Source	Event Based	Full
GreenCloud	NS2	C++Tool Command Language (TCL)	Open Source	Packet Level	Limited
iCanCloud	OMNET, MPI	C++	Open Source	Event Based	Full
CloudExp	CloudSim	Java	Proprietary	Event Based	Full
CloudReports	CloudSim	Java	Open Source	Event Based	Full

## V. CONCLUSION AND FUTURE SCOPE

With the ever increasing popularity of cloud computing systems to deliver services to the users, cloud simulation tools became an important choice to test the behavior and characteristics of the cloud environment before actual implementation of the cloud. These simulation tools provide insights into the trade-offs between cost and performance of cloud applications. In this article, we discuss various cloud simulation tools like CloudSim, CloudAnalyst, GreenCloud, iCanCloud, CloudExp, and CloudReports. We explore their features and compare them on the basis of various parameters like underlying platform, the programming language used, open source or commercial, simulator type, and graphical support. The choice of cloud simulation tool depends upon the requirements of the researcher. GreenCloud is the best option for energy modeling and efficiency of datacenters. CloudAnalyst can be used for performance testing of large scale cloud computing environment like social networking App. In future, we would experimentally use the simulation tools explained in this article and would explore other simulation tools.

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