Various Cloud Simulators: A Comparative Study

Priyanka[1], Anita Ganpati[2]
Department of Computer Science
[1,2]Himachal Pradesh University, Shimla, India

Abstract-*A cloud consists of several elements such as clients, data center, and distributed servers. It includes fault tolerance, high availability, scalability, legibility, and the reduced overhead for users, reduced cost of ownership, on-demand services etc. Cloud computing is a type of computing that relies on sharing computing resources rather than having local servers or personal devices to handle applications. Use of cloud computing is increasing at a very fast pace everywhere because it turns the capital expenditure cost into operational cost. In addition to that, use of simulation tools is considered a better option in spite of being on the real cloud as performing experiments in a controlled and dependent environment is difficult and costly to handle. The real deployment of the cloud is very expensive if we need it for personal use because efficient resource utilization is not possible. Research scholars need to test their algorithms in a cloud environment. Various cloud simulators have come up to handle the issue. The solution is cloud simulation tools. The simulation tools contemplate a better option in spite of being a real cloud as dispatch experiment is difficult and costly to execute. In this paper 25 simulators are discussed and compare on the basis of different parameters so, one can easily choose which simulator is to be use according to the work.*

Keywords:Cloud computing, Cloud simulators.

I. INTRODUCTION

A cloud consists of several elements such as clients, data center, and distributed servers. It includes fault tolerance, high availability, scalability, legibility, and the reduced overhead for users, reduced cost of ownership, on-demand services etc. Cloud computing is a phrasethat means different things to different people. For some, it's just another way of describing IT (information technology) "outsourcing"; others use it to mean any computing service provided over the Internet or a similar network, and some define it as any bought-in computer service you use that sits outside your firewall. However we define cloud computing, there's no doubt it makes most sense when we stop talking about abstract definitions and look at some simple, real examples so let's do just that.

The term cloud computing was born between 2007 not to talk about a new trend, but to generalize the direction of information infrastructure which has been taking place since the past few years. This concept can be interpreted in a simple way: the enormous computing resources such as software, services, and the services will be located at the virtual server **(cloud)** on the Internet rather than in computer and family office **(on the ground)** for people to connect and use whenever they need to. With these services available on the Internet, businesses are not buying and maintaining hundreds or even thousands of computers and software. Most people already use popular cloud services with e-mail, photo albums and digital maps [15].

Cloud computing is a type of computing that relies on *sharing computing resources* rather than having local servers or personal devices to handle applications. In cloud computing, the word cloud(also phrased as "*the cloud*") is used as a metaphor for "*the Internet*," so the phrase *cloud computing* means "a type of Internet-based computing," where different services — such as servers, storage, and applications — are delivered to an organization's computers and devices through the Internet [16]. Cloud computing is comparable to grid computing, a type of computing where unused processing cycles of all computers in a network are harnesses to solve problems too intensive for any stand-alone machine.

The National Institute of Standards and Technology (NIST) 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. This cloud model is composed of five essential characteristics, three service models, and four deployment models [1].

From a customer perspective, the public cloud offers a way to gain new capabilities on demand without investing in new hardware or software. Instead, customers pay their cloud provider a subscription fee or pay for only the resources they use.

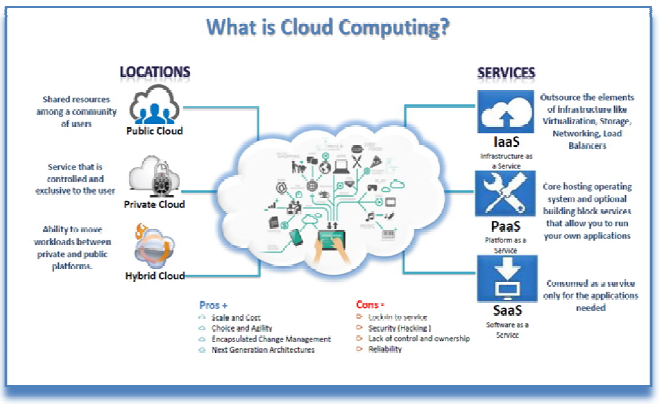

Figure 1.1: The concept of cloud computer [17].

Figure 1.1 depicts the concept of cloud computing that is explained further in this study. While there are incalculable different definitions, but there are most remarkable features are Pay-per-utilize (no continuous duty, utility costs); versatile limit and the dream of infinite resources; Self-benefit interface and resources that are disconnected or virtualized.

II. RESEARCH

Cloud computing is defined by the US National Institute of Standards and Technology (NIST) "a model for user convenience, on-demand network access contribute the computing resources (e.g. networks, storage, applications, servers, and services) that can be rapidly implemented with minimal management effort or service provider interference [1]".

According to Maria et al. [2], simulation is a way of evaluating a proposed system for various parameters within a specific period of time.

Open Cloud Testbed (OCT) was proposed by Grossman et al. [3] to mainly benchmark different cloud computing systems, to investigate their interoperability. It also supports experimental studies using non-Transmission Control Protocol (TCP) protocols, such as UDT, and with dynamic services based on flexible compute node and network provisioning capabilities.

As Rodrigo et al. [4] explained quantifying the performance of scheduling and allocation policy on a Cloud infrastructure for different application and service models under varying load, energy performance, and system size is an extremely challenging problem to tackle in cloud computing. So, they proposed CloudSim, a new generalized and extensible simulation framework that enables seamless modeling, simulation, and experimentation of emerging Cloud computing infrastructures and management services.

In MEDC project report Bhathiya et al. [5] introduced a novel tool, CloudAnalyst, along with a new approach to simulate such large-scale applications on the Cloud with the purpose of studying the behavior of such applications under various deployment configurations.

Ostermann et al. [6] presented grounds, a grid and simulation toolkit for scientific applications based on a scalable simulation independent discrete event core GroudSim provides a comprehensive set of features for complex simulation scenarios from simple job execution on leased computing resources to the calculation of costs, and background load on resources.

As in cloud computing, energy efficiency and cost are two major factors of concern so Kliazovich et al. [7] presented a simulation environment for energy-aware cloud computing data centers. GreenCloud is designed to capture details of the energy consumed by data center components as well as packet-level communication patterns between them.

Garg et al. [8] extended a popular Cloud simulator (CloudSim) with a scalable network and generalized application model, which allows more accurate evaluation of scheduling and resource provisioning policies to optimize the performance of a Cloud infrastructure.

Alberto et al. [9] introduced and validated iCanCloud, a novel simulator of cloud infrastructures with remarkable features such as flexibility, scalability, performance, and usability.

Li et al. [10] developed an enhanced cloud simulating system DartCSim based on CloudSim with a more user-friendly interface, which allows a user to configure all the data of the simulation environment with a visual interface, including the configurations of network cloudlets, network topology, and the algorithms for managing the cloud center.

III. OVERVIEW OF CLOUD SIMULATORS

The real deployment of the cloud is very expensive if we need it for personal use because efficient resource utilization is not possible. Research scholars need to test their algorithms in a cloud environment. Various cloud simulators have come up to handle the issue. The solution is cloud simulation tools. The simulation tools contemplate a better option in spite of being a real cloud as dispatch experiment is

difficult and costly to execute. Simulators offer a dependent and controlled cloud environment for conducting experiments.

There are various simulation tools for cloud, some of which are as follows:

- **CloudSim**

  CloudSim is a Java-Based Simulation Toolkit for Cloud computing environment was developed in the CLOUDS Laboratory, at the Computer Science and Software Engineering Department of the University of Melbourne, Australia [11]. Cloudsim allows extension and definition of policies in all the components of the software stack, which makes it suitable as a research tool that can handle the complexities arising from simulated environments.

- **CloudAnalyst**

  Cloud Analyst: A GUI Based simulator supports the evaluation of social network tools according to the geographic distribution of users and data centers. Cloud Analyst provides powerful simulation framework via Map Interface for deploying real-time data centers and monitoring load balancing, cloud cluster monitoring, and data center data flow in real time [11].

- **GreenCloud**

  GreenCloud is designed to capture details of the energy consumed by data center components as well as packet-level communication patterns between them. GreenCloud is quite different from CloudSim [12]. It is built by extending network simulator NS-2. Basically, it is used for the energy-aware environment. It offers to know about the workload distribution of the data center. One of the drawbacks is that it takes minutes for simulation. Due to this, it is applicable only for the small data center.

- **iCanCloud**

  This is the case of public cloud infrastructures, where a given number and type of virtual machines are instantiated during a specified time, is this reflected in the final budget. In order to develop new proposals aimed at different topics related to cloud computing, This simulator was developed based on SIMCAN(a simulation tool to analyze high performance I/O architectures)[18].

- **A Multi-Tier Data Center Simulation, Platform (MDCsim)**

  MDCSim is a variant of CloudSim tools.it is the most famous tool having low simulation overhead and used to preserve a data center topology in the form of a directed graph. It is designed to simulate large-scale, multi-tier data centers. To measure performance it focuses on data center architecture and cluster configuration. It supports three-tiered web applications, with the ability to modify and evaluate the configuration of each tier. [13]

- **NetworkCloudSim**

  Network CloudSim is an extension of CloudSim, which supports more realistic and complex applications with communicating tasks as a simulation framework that. Network CloudSim provides scalable and fast simulation. NetworkCloudSim supports communication between application elements and various networks.[8]

- **CloudReports**

  CloudReports uses CloudSim as its simulation engine. The application simulates an Infrastructure as a Service (IaaS) provider with an arbitrary number of data centers. Each data center is entirely customizable.

- **DynamicCloudSim**

  As an entry point for research on workflow scheduling, DynamicCloudSim provides the functionality to simulate the execution of scientific workflows using different well-established schedulers.

- **WorkFlowSim**

  Workflow simulator WorkflowSim assists researchers to evaluate their workflow optimization techniques with better accuracy and wider support than existing solutions.

- **EMUSIM**

  EMUSIM combines emulation and simulation to extract information automatically from the application behavior via emulation and uses this information to generate the corresponding simulation model.

- **GroudSim**

  GroudSim [9], (Gr-Grid and oud-Cloud Simulator) is a discrete event simulation platform for both cloud and grid computing environments. It is specifically developed for simulating scientific applications in grid and cloud environments. Base programming language for GroudSim

is Java. GroudSim can be extended very easily by adopting probability distribution packages. One unique feature is that Ground Entity in the GroudSim has its own definition for error behaviors; the user can change this configuration during each error occurrence.

- **DCSim**

  DCSim is a data center simulation tool for dynamic resource provisioning. DCSim consists of multiple interconnected hosts and each host consists of scheduler and resource management policy, which simulates data center with a central management system.

- **Cloud2Sim**

  Cloud2Sim presents an architecture that enables the execution of larger simulations in a cluster that cannot be run on single nodes due to the requirement of huge heap space and long execution times.

- **GDCSim**

  GDC is a Green Data Center Simulator. It combines both modular and large-scale entities. Green Datacenter if constructed to run as economically as possible.

- **SPECI Sim**

  Simulation Program for Elastic Cloud Infrastructures (SPECI) is a simulation tool which allows analyzing and exploration of scaling properties of large data center behavior under the size and design policy of the middleware as inputs. The aim of SPECI is to simulate the performance and behavior of data centers, given the size and middleware design policy as inputDiscrete event simulations (DES) are a type of simulation where events are ordered in time maintained in a queue of events by the simulator and each processed at given simulation time [14]. SPECI uses an existing package for DES in Java. SPECI is built with SimKit which in turn is developed in Java. SPECI does not provide any support for VMs, load balancing, security and job scheduling.

  .**opencirus**

  Open Cirrus is a cloud computing testbed that, unlike existing alternatives, federates distributed data centers. It aims to spur innovation in systems and applications research and catalyze the development of an open source service stack for the cloud.

- **CDOSim**

  CDOSim can simulate cost and performance properties of those CDOs. It builds upon and significantly extends the cloud simulator CloudSim and integrates into our cloud migration framework CloudMIG. Additionally, CDOSim utilizes reverse-engineered architectural models and can employ actual monitored workload.

- **SimIC**

  Simulating the Inter-Cloud' (SimIC) is a discrete event simulation toolkit based on the process-oriented simulation package of SimJava. The SimIC aims of replicating an inter-cloud facility wherein multiple clouds collaborate with each other for distributing service requests with regards to the desired simulation setup.

- **CloudsimSDN**

  CloudSimSDN, a simulation framework for SDN-enabled cloud environments based on CloudSim. This paper develops and presents the overall architecture and features of the framework and provides several use cases. Moreover, we empirically validate the accuracy and effectiveness of CloudSimSDN through a number of simulations of a cloud-based three-tier web application.

- **CEPSim**

  It is a simulator for cloud-based Complex Event Processing systems. CEPSim extends CloudSim, an existing cloud computing simulator, with a new application model based on DAGs and an engine that can simulate the execution of CEP queries. Moreover, CEPSim enables its user to customize the simulation by creating alternative operator placement and scheduling strategies. Experimental results have shown that CEPSim can simulate a real system (Apache Storm) with high precision and accuracy. By using the simulator, system architects and researchers can experiment with different environment configurations and strategies without incurring the costs of running large-scale tests on cloud environments.

- **PICS**

  PIC is a Public IaaS Cloud Simulator and is designed for evaluating the performance of both public IaaS clouds and cloud applications without the actual deployment of cloud applications.

- **Secure Cloud Simulator (secCloudSim)**

  SecCloudSim is an extension of existing iCanCloud simulator, which provides the basic security features of authentication and authorization.secCloudSim has a low-performance impact as compared to iCanCloud. The low-performance impact of secCloudSim is due to the integration of security features to iCanCloud architecture. The security issue was not immediate concerns of existing simulators. security features in terms of authentication and authorizationare the novel approach in the field of Cloud security simulators.

- **CloudExP**

  CloudSimEx is the extension of CloudSim to simulate MapReduce applications. CloudExp can be used to evaluate a wide spectrum of cloud components such as processing elements, data centers, storage, networking, Service Level Agreement (SLA) constraints, web-based applications, Service Oriented Architecture (SOA), virtualization, management and automation, and Business Process Management (BPM). MapReduce processing model is integrated intoCloudExp in order to handle the processing of big data problems.

- **TeachCloud**

  TeachCloud is an extension of CloudSim, a research-oriented simulator used for the development and validation of cloud computing. TeachCloud is a modeling and simulation environment for cloud computing. TeachCloud can be used to experiment with different cloud components such as processing elements, data centers, networking, Service Level Agreement (SLA) constraints, web-based applications, Service Oriented Architecture (SOA), virtualization, management and automation, and Business Process Management (BPM).

- **VirtualCloud**

  VirtualCloud, a simulator for cloud computing environment helps developers to model and test, their policies to utilize the cloud computing resources efficiently. It is multi-layered architecture, help to make decisions, to maintain the service level agreements with minimum effort and efficient way.

IV. OBJECTIVES OF STUDY

The objective of this study is to analyze the various cloud simulators in detail. However, the specific objectives are.

1. To study the basic concept of cloud computing and simulators.
2. To compare various cloud simulators.

V. ANALYSIS

The main problem for researchers is to choose the correct simulator for their cloud research as there are cloud simulators for a specific purpose. In this work, several attributes (on the basis of their characteristics and their performance) are introduced based on which comparative analysis of the cloud simulators is performed.

Table 1:VariousCloudSim simulators description according to their characteristics.

Simulator	Platform	Availability	Language	Cost Modeling	GUI
Cloudsim	Gridsim	Open Source	Java	Yes	Limited
Cloud analyst	Cloudsim	Open Source	Java	No	Limited
Greencloud	NS2	Open Source	C++/OTCL	No	Limited
Icancloud	SIMCAN	Open Source	Omnet,MPL,C++	Yes	Full
Mdcsim	CSIM	Commercial	C++/Java	No	No
NetworkCloudSim	Cloudsim	Open Source	Java	Yes	None
CloudReport	Ant, Maven, Java Development Kit (Cloudsim)	Open Source	Java	No	Full
DynamicCloudSim	Cloudsim	Open Source	Java	Yes	No
Workflowsim	Cloudsim	NA	Java	No	No
EMUSIM	AEF /Cloudsim	Open Source	Java	Yes	Limited
GroudSim	NA	NA	Java	No	None
Dcsim	NA	Open Source	Java	Yes	None
Cloud2Sim	Cloudsim	Open Source	Java	Yes	None
Gdcsim	Bloetool	Open Source	C++/XML	No	None
SPECI Sim	Simkit	Open Source	Java	No	Limited
Open Cirus	FederationOf Heterogeneous Data Center	Limited	NA	No	None
Cdosim	Gridsim	Commercia	Java	Yes	None
Simic	Simjava	Still Not Available	Java	Yes	No
Cloudsim SDN	Cloudsim	Open Source	Java	Yes	Yes
CEP Sim	Cloudsim	NA	Java	Yes	Yes
PICS	IAAS	Open Source	Python	Yes	No
See Cloudsim	Icancloud	NA	C++	Yes	Yes
Cloudexp	Cloudsim	No	Java	Yes	Full
Teachcloud	Cloudsim	Yes	Java	Yes	Yes
virtualCloud	-	NA	Xml	No	Yes

Table 2: Various CloudSim Simulators Description According To Their Performance

Simulator	Simulation Time	Federation Policy	Power saving mode	Simulator type	Communication Model (N/W)	Energy Modeling
Cloudsim	Seconds	Yes	DVFS	Event-based	Limited	Yes
Cloudanalyst	Seconds	Yes	DVFS	Event-based	Full	Yes
Greencloud	Minutes	No	DVFS, DNS and both	Packet-level	Full	Yes
Icancloud	Seconds	No	NO	Event-based	Full	No
Mdcsim	Seconds	No	No	Event based	Limited	Rough
Networkcloudsim	Seconds	Yes	Yes	Packet-level	Full	Yes
Cloud reports	Seconds	No	Limited	Event-based	Limited	No
Dynamiccloudsim	Seconds	Yes	Yes	Event-based	Limited	Yes
Workflows	Seconds	No	Yes	Event-based	No	Yes
EMUSIM	Seconds	No	Yes	Event-based	Limited	Yes
Groudsim	Seconds	No	Yes	Event based	No	No
Dcsim	Minutes	No	Yes	Event based	No	No
Cloud2Sim	seconds	Yes	Yes	Event-based	No	Yes
Gdcsim	seconds	No	Yes	Event-based	Full	Yes
SPECI Sim	Seconds	No	No	Event based	Yes	No
Open Cirus	Seconds	Yes	Yes	Event-based	No	No
CDO Sim	seconds	Yes	Yes	Event based	LIMITED	Yes
Simic	Seconds	Yes	No	Event based	Limited(Yes)	No
Cloudsim SDN	Seconds	Yes	Yes	Packet-level	Limited	Yes
CEP Sim	Seconds	Yes	Yes	Event-based	Limited	Yes
PICS	Minutes	No	No	Event based	No	No
Sec Cloudsim	Seconds	No	No	Event based	Full	No
Cloudexp	Seconds	No	Yes	Event based	Full	Yes
Teachcloud	Seconds	Yes	No	Event-based	Limited	Yes
virtualCloud	Seconds	No	Yes	Event based	Limited	No

VI. CONCLUSION

Cloud computing is growing at a much faster rate. To carry out a fundamental research in cloud computing, cloud simulators are considered to be a better option rather than real deployment of the cloud. In this study, brief descriptions of 25 cloud simulators are discussed. The novel work done in this study is consideration of latest cloud simulators like Opencirus, CloudSimSDN, secCloudSim, CEPSim, and PICS and TeachCloud etc. All the 25 cloud simulators have been compared based on 12 evaluation criteria namely: base platform, availability, programming language, cost model, GUI, hardware/software companion, simulation time, federation model, power saving mode, simulator type, communication model, and energy model. The results and explanation of the comparative analysis have been presented.

Although there are several cloud simulators available, it is concluded that choosing a simulator depends on the type of problem as there are several simulators geared for certain types of research problems. As a general purpose simulator CloudSim is recommended based on its features and popularity in the research community.

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