

Overview of Cloud Simulation Tools: A Comparison of Cloud Computing Simulators

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Abstract. Cloud computing comprises of transferring of secure, maintainable, dependable, scalable and fault tolerant infrastructures for simplifying web oriented application facilities. These applications consists of different deployment, setup and composition requirements. When cloud computing deployment and adoption expands, its distinguishing to obtain cloud computing environs performance. Simulation and modeling feasible for obtaining security and performance issues. For testing of cloud framework, cloud simulators required to diminishing complication and sift out quality concerns. Some cloud simulators specifically made for testing of cloud computing environs performance. This paper presents review and compare characteristics of different kinds of cloud computing simulators.

Keywords: Cloud simulators, GroudSim, Green Cloud, CloudSim, EMUSIM, OCT, SPECI, ICANCLOUD, MDOSIM, CDOSIM, DCSIM, GDCSIM, TeachCloud, CloudAnalyst, CloudReports.

1 Introduction

In every day's life, the origin of digital technology and Internet extremely transformed mode people act and interrelate in both specialized and personal situations. Family, work and social life are becoming gradually intertwist with the Internet, sometimes even blurred together. The office no more uses only for workplace, people mostly used to deal with personal problems, through instant messaging, e-mails or social media. Inversely, proficient and professional actions spread all over the day while traveling, during lunch break either at home or at office, or after completing work, people don't feel hesitation to complete their work and to check their e-mails.

Without direct access to their computer, from any place and at any time, people are capable enough to achieve their professional or personal documents. Thus, Internet has become a necessity, in most advanced and developed countries.

Ubiquitous computing is an effort to fulfill or to answer user's need for ubiquity. Without trying to resolve any specific technical or business problem, UC shows struggle to describe new opportunities based on connectivity and pervasive computing. Computing has become fundamental part of our everyday life, nowadays. In the computing industry, technological advances like electronic devices are used and placed in the environment in such manner that it is invisible to end user's.

CC (Cloud computing) is the next evaluation step in computing [28]. For the internet, cloud is a metaphor, focused on how it is illustrated in computer system graphs and is a notion for the difficult or complex structure it covers. It is a form of computing in which IT-related capabilities are sold as a kit, enabling customers to obtain technologically-enabled services over the internet without know how of the expertise or technology infrastructure that supports them. When you store your pictures online using social networks, websites rather than using home computer and laptop, basically you are using a service called cloud computing.

Cloud computing offers shared pool of resources, including networks, data storage space, user applications and computers processing power. Cloud services are famous because they could decrease the cost of owning and operating networks and computers. Cloud users do not need to buy cloud infrastructure, get software license etc. Clouds provides everything as a service.

Hence there exist three types of services, one of them is (SAAS), 2nd is (IAAS) and the 3rd one is (PAAS). In IAAS providers offer virtual machines and other resources. In SAAS, providers provide access of databases and application software's to the users. In PAAS, providers offers the operating platform involves operating system, programming languages environment etc. [27, 38].

Just like cloud services there are different deployment models with deviations in physical position and distribution which have been accepted by the cloud computing. A cloud can be categorized as public, hybrid, private and community based on the deployment model. Cloud provides potential benefits but clouds faced several information security issues and risks. Issues can be differ according to the sensitivity of data how it will be stored and processed and how will choose the cloud service providers. Cloud computing main power is delivered by the grouping of data centers, for offering computing environment, which has been used to be installed with 100 to 1000's of servers. At the higher level there exists application services such as data processing, webhosting, social networking etc.

The lower level comprises of storage server and these servers are used to be managed by the higher level virtualization services and these services provide the opportunity of fault tolerance and security. The main difference b/w data center and cloud is that data center is an on premise hardware which keeps data store inside organization's local network, cloud, on the other hand, is an off-premise mode of computation which stores data or information by using internet.

In research areas, now-a-days cloud computing is an interesting and beneficial field and quickly gained fame of scholars, researchers and industries. On the internet, it is basically the distribution of computing resources and facilities. There are several firms which are running in cloud computing atmosphere and supply facilities and resources firms such as IBM, Microsoft and Amazon etc. With the advancement of cloud technologies, new possibilities for internet based applications are emerging. These new application prototypes might be assembled into two classes. On one hand, there are

Cloud Applications	Social Networking	Webhosting	Data Processing
Virtual Machines	Windows	Virtual Machine Mac OS	Linux OS
Application Server	Virtual Machine Monitor		
Storage Server	Storage Virtualization Management		

Fig. 1. Cloud Based Typical Data Center.

large scale programming framework suppliers that produce applications, cloud service providers, on the other hand, exist. To reduce overheads, these applications can get profit from cloud infrastructure administration.

To minimize complication and separate quality issues, cloud simulators are needed for cloud structure testing [1]. Simulation-based approaches support Information Technology organizations by helping them to analyze their services in a managed and repeatable environment, as well as experiment with various task configurations and resource performance scenarios on virtual systems for designing and testing adaptive application provisioning strategies.

Available distributed system simulators does not provide an atmosphere which we can directly use for sculpting cloud computing atmosphere, CloudSim, on the other hand, is a simplified simulation tool that gives the permission of experimentation of evolving application services and cloud infrastructures. On cloud computing there exists two types of simulators, one is software-based, and the other is software-and-hardware-based. Number of cloud simulators are increasing day by day and they have been specially designed for performance analysis of cloud computing atmosphere. Cloud simulators' several capabilities will hasten the development and introduction of new technologies.

The remainder of the parts are organized as follows: Section 2 focuses on background about several available simulators. Section 3 define and explore numerous cloud simulators such as CloudSim and many others. Section 4 provides the comparison of various cloud simulators and the paper comes to a close with section 5.

2 Background

In earlier days, Grids developed an infrastructure to provide high performance services for the computing of scientific operations. To facilitate research numerous grid simulators proposed, analysis and growth of new grid modules and policies. Some of them are GridSim, GangSim, MicroSim, SimGrid, OptorSim and CloudSim. 1st 3 emphasis on Grid computing based systems. For studying cloud systems, CloudSim is the only framework or simulation toolkit. Hence, in cloud infrastructure gridsim is used to calculate costs of implementing distributed applications. For the simulation of distributed applications, SimGrid is mostly useful. For modeling of grid based resources and organizations, GangSim provides support. For various grid resources, GridSim is the simulation toolkit and it provide support for forming of grid objects

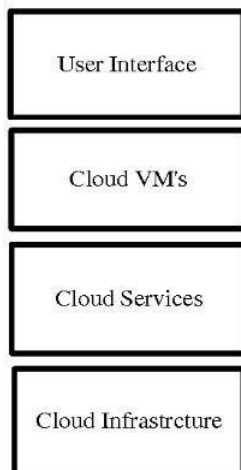


Fig. 2: CloudSim Components.

users, networks and machines etc, but no one is capable to support infrastructure and application level requests.

For providing real time exchanging of services, cloud simulation toolkit provide support for economic objects like cloud dealers and exchange. Between the currently existing simulators discussed above, to provide support for application scheduling simulation and resource management, GridSim is the only simulator [9,12].

3 Cloud Simulators

Simulators for grid computing are useful, but they can't accurately model the cloudframework. Simulation now a days suppose the growing portion in the evaluation and believable results and atmosphere condition testing. It is a weakness of the real-world solution and system's operation. Simulation is the direction how to explore the model. Simulation is the method of producing and discovering d/f directions about a computerized mathematical model of a physical structure or framework. Developers and researchers can quickly monitor and verify the performance of newly built software using cloud simulators. Cloud simulators help new applications develop faster. We offer an overview of the various cloud computing simulators in this section, which are mostly used to assess the stability and security of cloud computing systems as well as provide cloud environment support [10, 34].

3.1 CLOUDSIM

CloudSim is generalized simulation application, for single and internetworked clouds, which supports modeling, cloud operating platforms, application services, and infrastructures are being tested [9, 5]. Using a distributed system simulator to estimate and calculate the performance of cloud systems, policies, and server workload under a variety of system usage needs and configurations is challenging. CloudSim may be used

to overcome this difficulty. To put it simply, we can say for the simulation of cloud scenarios, CloudSim is a development toolkit [25]. CloudSim toolkit provide support both behavior and system modeling of cloud constituents like data centers, virtual machines, and resource provisioning plans are also things to consider. These elements may be combined to allow users to quantify new policies, routing, algorithms, and scheduling, among other things. It's important to mention that CloudSim is a database, not a ready-to-use solution, for creating desired scenarios and collecting results for cloud application success and security review. CloudSim needs to write a java program using its components. Through message passing all components communicate with each other. Without observing low level details associated with applications and cloud services, by using CloudSim users can analyze system problems [42].

In the University of Melbourne, Australia, CloudSim is developed as CloudBus project. Gazebo is an open source web framework that incorporates preconfigured devices plotted to run popular open-source robotic tools and simulators [4].

All CloudSim components communicate with one another through message passing. CloudSim framework's multi-layered architecture or design, lower level or 1st layer called simulation engine which is responsible for the communication between components and it supports numerous essential functionalities like processing of events, construction of cloud system objects like virtual machines, hosts, servers, and data centers, as well as simulation clock control. CloudSim is a simulation layer that aids in the design of cloud based data center environments with interfaces for virtual machines, storage, bandwidth, and memory. This layer is responsible for basic tasks such as VM hosting, monitoring complex system state (condition), and managing programme execution. Top-most layer is user code layer which depicts basic objects for number of tasks, hosts, number of users and their applications, number of VM's [23]. WorkFlowSim, CloudSimEx, RealCloudSim, Simpleworkflow, CloudAnalyst, CloudAuction, CloudMIG, CloudReports, and Xpress are some of the other simulation tools that help to extend CloudSim power [16, 8, 29, 21].

3.2 CLOUDANALYST

CloudAnalyst is a simulator with a graphical user interface that was derived from CloudSim and enhances some of its capacitances and functionality [4]. It distinguishes between simulation analysis and programming activities. In a cloud environment, CloudAnalyst is applied to analyze performance of large scale internet application. It permits users to store simulation results in the PDF format. CloudAnalyst allow users to run experiments speedily and efficiently.

It has the ability to display interactive simulation outcomes as graphs and tables. CloudAnalyst is created using a variety of techniques. a) Java (with java) The CloudAnalyst simulator is written entirely in Java. b) Java Swing, which makes use of swing components a graphical user interface component has been developed c) SimJava, CloudAnalyst mostly used some features of SimJava tool [19] d) CloudSim, CloudAnalyst used CloudSim features for designing data centers. CloudAnalyst's main features include: a) an intuitive graphical user interface (GUI); b) the ability to express simulations with a high degree of usability and configurability; c) experiment replication; d) fortify technologies and ease of extension; and e) graphical performance [36, 41].

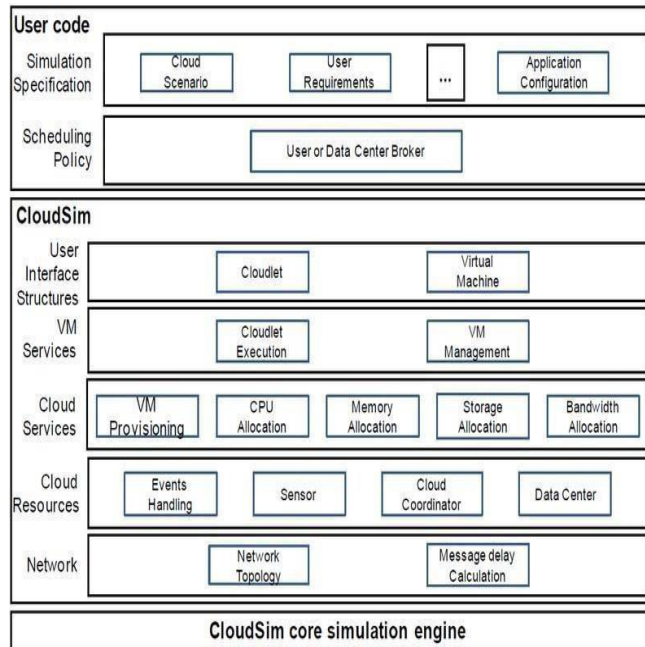


Fig. 3. Layered Architecture of CloudSim.

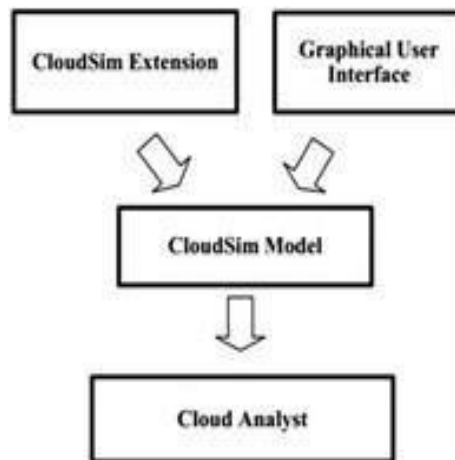


Fig. 4. Pictorial View of CloudAnalyst.

3.3 CLOUDREPORTS

CloudReports tool simulates distributed computing environs depend on cloud computing. In simple terms, CloudReports is a graphical representation of CloudSim provides easy and friendly atmosphere [4]. CloudReports offers various facets for scholars to play part of users and service providers. It is same as CloudAnalyst offer

Table 1. Comparison on basis characteristics.

Factors of Comparison	CloudAnaLyst	CloudReports	CloudSim
Accuracy	Higher	Higher	Higher
Adaptability	Mid	Mid	Higher
Speed of simulation	Higher	Higher	Mid
Efficiency	Mid	Mid	Higher
Scalability	Mid	Mid	Higher
Reliability	Higher	Higher	Higher
Consumptionmemory Overlap	Mid	Mid	Low
Repeatability	Higher	Higher	Higher

atmosphere for simulating cloud computing model without programming abilities and generation characteristic shapes it simpler to comprehend simulation outcomes via exhibiting charts and simulated environs features lists [35]. In CloudReports, supported kinds of extensions are: VM's provision strategies, broker strategies, VM's resource consumption models and schedulers and power consumption models. Ability of user are set quantity of VM's every consumer owns, broker is liable for assigning these resource utilization algo's and VM's set quantity of hosts (computational nodes) and their resource configuration, that contains RAM amount, execution time, processing capacity, resource utilization and available bandwidth and facilitate service providers to estimate their cloud atmosphere before hiring facilities to consumers [37, 6].

Given below tables demonstrates comparison among characteristics and parameters of CloudAnalyst, CloudSim and CloudReports.

3.4 GREENCLOUD

With attention on cloud communication, GreenCloud is established as an innovative packet or carton level cloud network simulator. In simple words, with minimal environmental damage, the principle of planning, producing, and ordering computational resources is known as GreenCloud [22]. It is a supercomputing initiative at Notre Dame University. It provides a computer software environment or network that reduces running costs. It offers a modelling platform for energy- conscious cloud storage data centers. GreenCloud differentiates 3 energy consumption constituents, 1st is communicational energy, 2nd is computing energy and the third is an energy aspect that is connected to the data center's physical infrastructure. GreenCloud basic purposes include, to develop high level computing systems like clouds, clusters and data centers that assign resources to application hosting internet facilities or services to fulfill user needs. GreenCloud extracts, collects and makes information fine grained about the

Table 2. Comparison of simulation parameters.

Simulation Parameters	CloudSim	CloudAnaLyst	CloudReports
Data center	√	√	√
Regulation on allocation	√	√	√
Simulation time	√	√	√
Simulate host	√	√	√
Load balancing	√	√	×
Cost estimate	√	√	√
VM's Option	√	√	√
Request and response time	√	√	√
Social network	√/×	√	×
Federal cloud	√	√	×
Extend service broker algo	√	√	√
Cloudlet options	√	√	√
VM Migration	√/×	×	×
Resources management	√	√	√
Topologies in data centers	√	√	×
User base modeling	√	√	√
Power consumption	√	×	√
Task scheduling	√	√	√
Energy Efficiency	√	√	√
Security in cloud	×	×	×
SLA Modeling	√	√	√
PaaS Modeling	√	×	×
SaaS Modeling	√	√	√
IaaS Modeling	√	√	√

communication elements of the data center like network switches, communication links, computing servers etc.



Fig. 5. User view of GreenCloud.

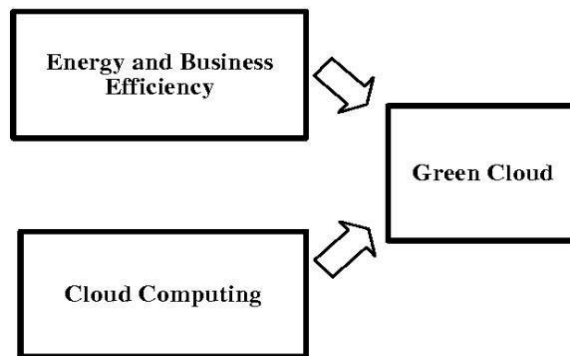


Fig. 6. Pictorial View of GreenCloud.

GreenCloud simulator is an extension or we can say new version of network simulator (NS2) simulator. Disadvantage of GreenCloud tool is that due to its higher simulation time and huge memory requests, it restricts its scalability to only fewer number of data centers [42].

3.5 MDCSIM

MDCSIM stands for multi-tier data center simulation. It is a CloudSim tool that has been tweaked. It assists the customer in predicting and examining data center hardware constraints such as switches, servers, and routers. MDCSIM is developed at Pennsylvania state university [36].

In the architecture of MDCSIM, in a server node, CPU has devices such as a network access card and a disc, as well as procedures. It is assumed that the NIC, CPU, and disc are the essential computational resources in a node that are responsible for processing requirements. Simulation is constructed in 3 layers a) user-level b) kernel-

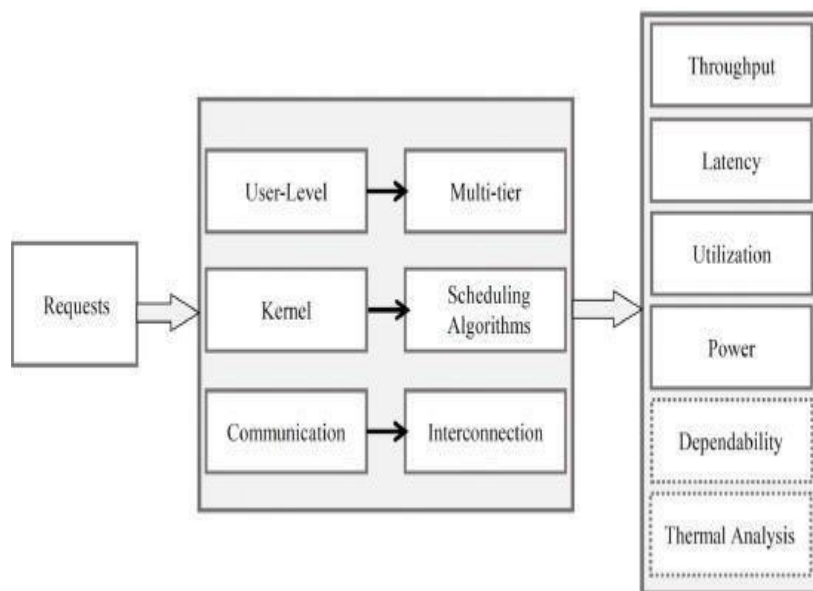


Fig. 7. Multi-tier data center simulation.

level c) communication level layers. To analyze design, 3 layer abstraction provides scalability and flexibility. It is used as a most prominent tool due to its low overhead simulation and in the form of directed graph its network platform keep maintains a data center topology [24, 13, 26].

3.6 TEACHCLOUD

TeachCloud is an extended form of CloudSim. It is comprehensive, efficient and easy to use simulation toolkit. For cloud computing TeachCloud is a simulation and modeling atmosphere. It is basically a research based tool used for the development and justification of research theories in CC (cloud computing). TeachCloud is used by students to do experiments using the d/f cloud modules like datacenters, networking, processing of elements, web-based application, virtualization, business process management and management of resources. Users easily update various cloud system components and their parameters, examine results and can run simulations. TeachCloud was developed primarily for educational purposes. Scholars and students will conduct tests using a basic graphical user interface [20].

3.7 GROUDSIM

Ostermann recommended GroudSim as an event-based simulator for science applications [34]. For complex simulation set-ups, GroudSim offers a comprehensive set of features. SimEngine is the key part of CloudSim which implements the time advance, keeps track of the recorded objects used for tracing during simulation and

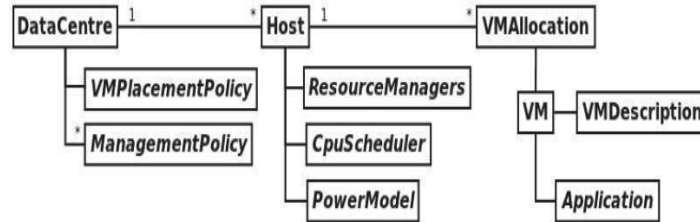


Fig. 10. DCSIM Architecture.

creates a predicted case list. While it is mostly based on Infrastructure as a Commodity, it can quickly be expanded to support other utilities such as DAAS and PAAS. Simulations can be easily parameterized. It offers some research views and statistics after runtime to enable users to quickly write more complicated analyses.

SPECI referred to as simulation program for elastic cloud infrastructures. It simulates the behavior and performance of data centers [39].

It is a type of simulator which scale up the performance of future data centers. It deals with inconsistencies that arise after failures happen.

Discrete event simulations (DES) are simulations in which events are ordered in time and held in a catalogue. SPECI uses currently package for DES in java. SPECI is a combination of 2 packages, topology and data center layout and the constituents for experiment implementation and measuring. The simulator's Experiment section is based on SimKit that provides random distribution drawing as well as event scheduling [2, 3].

3.8 DCSIM

DCSIM stands for data center simulator. It is a Java-based extended data center simulator that's designed to make experimenting and evolving data center management algorithms and methodologies easy. It is focused on developing a simulator to analyze and improve data center management technology in a virtualized data center that provides IAAS. It focuses on continuous workloads, but it can easily be expanded to model other types of workloads. Primary class is data center, which comprises of VM's, hosts, servers, polices and several management components. VM replication is a method for managing which workloads and combining capabilities. It allows research scholars to easily design, develop and estimate dynamic resource management methodologies. It includes new technologies not found in other simulators, such as a multi- tier application model. With the expansion of computing power, data center costs and operating expenses are increasingly rising. Data centers are becoming more well-known for the provisioning of computational services [40].

3.11 ICANCLOUD

SIMCAN is used to create ICanCloud, which is a kind of simulator. It is a device modelling platform for massive storage networks. ICanCloud provides a complete graphical user interface (GUI) for performing and executing tests, but available software systems can only be demonstrated manually. It enables the concurrent execution of a single experiment through several devices [31]. ICanCloud can predict

the cost and performance of different applications on different hardware's and notify users about the cost. On huge storage networks, it is basically used for simulating high level MPI applications [30]. In this tool, there is no need to change the code to examine numerous applications or architectures. This can be accomplished by merely generating anew configuration file [32].

3.12 NETWORKCLOUDSIM

S.K. Garg and Rajkumar suggested it as an expanded version of CloudSim. It is a generalized application model and scalable network. To enhance performance of cloud framework, it permits more precise calculation of scheduling. NetworkCloudSim makes use of the network topology class, which runs the CloudSim network layer, reads a BRITE disc and produces topological based network. In network CloudSim, file holds nodes, no of objects in the simulation and without changing the topology file, it allow users to increase scale of simulation. At any given time, each BRITE node can only be plotted to one object (entity). For the designing of the real cloud sim data centers and plotting d/f strategies, NetworkCloudSim structure provide support. In network traffic of CloudSim, network CloudSim info utilized for simulating latency. In the NetworkCloudSim, there are 3 main entities: NetworkDatacenterBroker, Network Datacenterand Switch. NetworkCloudSim aids in the production of more efficient and advantageous resource management strategies in theconstruction of network systems and complexsoftware that works within cloud datacenters. NetworkCloudSim helps in the modeling of cloud datacenters for the fast simulations [14].

3.13 OCT

Grossman suggested Open Cloud Testbed (OCT). It provides standards to examine d/f cloud computing systems and their interoperability. Cloudcomputing applications and networks are modelled using OCT. OCT framework comprises of 4 datacenters located at the Uni of Illinois (Chicago), John Hopkins Uni (Baltimore), Starlight(Chicago) and the Uni of California. Every rack contains thirty two vertices. Every node comprises of dual-dual core. 2 Cisco switches connect the 32 nodes. At all levels, the framework of OCT contains infrastructure, services and high performance protocols. Rather than using the internet, it employs a high-performance 10 GB network that is built on fast transport protocols. To make OCT more user-friendly, to research requirements, and to build network libraries and monitoring systems to support the experimental studies and development of CC stacks, d/f cloud services and systems are fixed containing CloudStore, Hadoop, Thrift and Sector [15].

3.14 FTCLLOUDSIM

It is a CloudSim based framework for estimating and designing cloud services reliability improvement apparatus. To support scholars in executing new methodologies easily, an expandable interface is provided in FTCloudSim. FTCloudSim can examine failures to analyze the behavior of every mechanism. After implementation, it will create statistics and data to highlight the advantages of the mechanism. Replication and check pointing are the 2 mostly used mechanisms. FTCloudSim study the performance of new planned technologies. FTCloudSim has been added new six segments into CloudSim: results generation, fat-tree data center network construction, checkpoint based cloudlet

recovery, checkpoint image storage and generation, failure and repair event triggering [43].

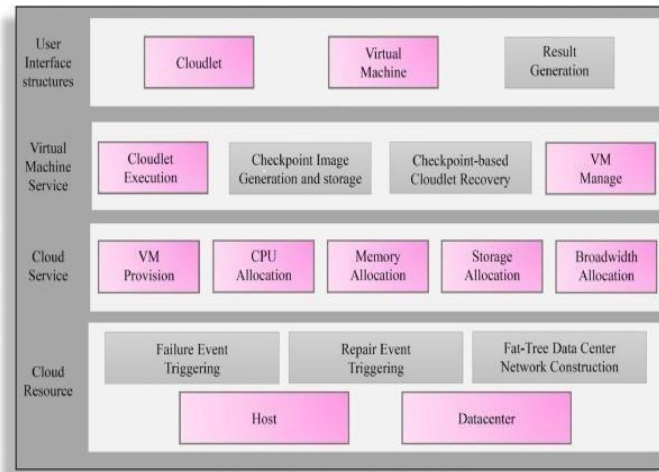


Fig. 11. FTCloudSim Framework.

3.15 GDCSIM

Green Data Center (GCD) Simulator is a type of simulator, under several data center graphs, scheduling algorithms and resource management strategies, it is use for the study of energy effectiveness of datacenters. GDCSIM is efficient to model green datacenters. It is appropriate for online data analysis. GDCSIM consists of different components like BlueSim, resource management and Simulator. Modularization guarantees that d/f constituents of GDCSIM can be used freely (independently) [17].

3.16 CDOSIM

CDOSim stands for cloud deployment option simulator. It simulates SLA contraventions, response times and CDO costs. CDO is considered to be a decision based simulator and takes decision regarding cloud provider selection, precise runtime adaptation tactics, and modules deployment of VM and configuration of its instances. Module deployment of VM instances contains probability of developing new modules of already present modules. It is a simulator which permits incorporation of fine grained models. It is a good illustration for relating runtime reconfiguration policies and for defining trade off among performance and costs. CDO simulator made to address main deficiencies of other simulators like: for simulating CDO's, from production monitoring data, workload outline should be utilized to rerun real consumer conduct; alleviates cloud consumers deficiency of knowledge and control relating structure of cloud platform and accordingly oriented to cloud user viewpoint rather than revealing fine grained internals of cloud platform [11].

3.17 EMUSIM

EMUSIM (integrated emulation and simulation) [18] integrates simulation and emulation to automatically excerpt info from application conduct via emulation and

Table 3. Comparison of different Cloud Simulators.

Cloud Simulators	Platform	Programming Language	GUI Support	Open Source	TCP/IP Support	H/W or S/W
CloudSim	GridSim	Java	Limited	√	None	S/W
Network CloudSim	CloudSim	Java	None	√	None	S/W
GreenCloud	NS2	OTCL/C++	Limited	√	Full TCP/IP support	S/W
EMUSIM	AEF	Java	Limited	√	None	S/W
CloudAnalys t	CloudSim	Java	√	√	None	S/W
CDOSIM	CloudSim	Java	None	NA	No TCP/IP support	S/W
MDCSIM	CSIM	Java/C++	No	Commercial	None	S/W
GDCSIM	BlueTool	XML/C++	No	√	None	S/W
TeachCloud	CloudSim	NA	√	√	None	S/W
ICanCloud	SIMCAN	MPL,C++, OMNet	√	√	None	S/W
DCSIM	NA	Java	None	√	No TCP/IP support	S/W
GroudSim	NA	Java	None	NA	Full TCP/IP support	S/W
SPECI	Simkit	Java	Limited	√	None	S/W
OCT	Four data centers make up a geographically dispersed cloud testbed	NA	Limited	Limited	NA	Both S/W and H/W

utilizes this info to create simulation model. In request patterns and application computing resources, simulation model utilized to body a simulated state which is near to real target manufacture atmosphere. EMUSIM is a software framework built on top of two software systems: CloudSim for simulation and AEF (automated simulation framework) for emulation [25]. EMUSIM is suitable when tester unaware on the performance of software below various stages of parallelism and adequacy that obstruct use of simulation [7, 16, 36].

4 Comparison of CloudSimulator Tools

For simulation and modeling of cloud computing (CC) virtualized domain hosts, data centers and data center network topologies, cloud simulator are beneficial to use. The table below illustrates some of the most significant variations among simulators, which will be very useful for researchers when choosing best simulator for their project.

5 Conclusion

In the IT (information technology) sector, cloud computing has been the fastest growing domain. It is compulsory to evaluate security risks and performance that are integral part of CC, as consumers are concerned about encryption and other cost-related concerns that come with widespread cloud computing adoption. For performance analysis of cloud computing environments, numerous simulators designed such as CloudSim, GroudSim, GreenCloud, EMUSIM, OCT, SPECI, ICANCLOUD, MDCSIM and CDOSIM etc.

In this review paper, different cloud simulation tools were discussed. Every simulation tool has limitations and advantages over the other. Thus, users can choose tools according to their needs.

References

1. Singh, Ch., Shet Gaba, N., Kaur, B.: Comparison of different CI/CD tools integrated with cloud platform. In: 9th International Conference on Cloud Computing, Data Science & Engineering (Confluence), (2019). doi: 10.1109/ CONFLUENCE.2019.8776985.
2. Akarvardar, K., Wong, P.: Technology Prospects for Data-Intensive Computing. Proceedings of the IEEE, 111(1), pp. 92–112 (2023). doi:10.1109/JPROC.2022. 3218057.
3. van Renen, A., Leis, V.: Cloud Analytics Benchmark. In: Proceedings of the VLDB Endowment, 16(6), pp. 1413–1425, (2023). doi: 10.14778/3583140. 3583156.
4. Chafi, S.-E., Younes, B., Mazer, S., Fattah, M.: Cloud computing services, models and simulation tools. In: International Journal of Cloud Computing, 10(5-6), pp. 533–547, (2021). doi: 10.1504/IJCC.2021.120392.
5. Ahmad, M.O., Zaman Khan, R.: Cloud computing modeling and simulation using CloudSim environment. In: International Journal of Recent Technology and Engineering (IJRTE), 8(2), (2019). doi: 10.35940/ijrte.B3669.078219.
6. Mansouri, N., Ghafari, R., Hasani Zade, B.M.: Cloud computing simulators: A comprehensive review. Simulation Modelling Practice and Theory, 104(2), (2020). doi: 10.1016/j.simpat.2020.102144.
7. Singh Rajput, R.K., Goyal, D., Hussain, R., Pant, A.: Modeling and Simulation of Scalable Cloud Environment using iDR. In: International Conference on Smart Generation Computing, Communication and Networking (SMART GENCON). IEEE (2021)
8. Le, D.-N., Pal, S., Pattnaik, P.K.: Cloudsim: A simulator for cloud computing environment. Cloud Computing Solutions, pp. 269–285, (2022). doi:10.1002/ 9781119682318.ch16.
9. Ahmad, M.O., Khan, R.Z.: Cloud computing modeling and simulation using CloudSim environment. International Journal of Recent Technology and Engineering (IJRTE), 8(2), (2019). doi:10.35940/ijrte.B3669.078219.
10. Tchernykh, A., Feoktistov, A., Gorsky, S., Sidorov, I.: Orlando tools: development, training, and use of scalable applications in heterogeneous distributed computing environments. High Performance Computing, pp. 265–279, (2019). doi:10.1007/978-3-030-16205-4_20.

11. Bassam Talib, S.: A Cutting-Edge Data Mining Approach for Dynamic Data Replication That also Involves the Preventative Deletion of Data Centres That are Not Compatible with One Other. In: *International Journal of Intelligent Systems and Applications in Engineering*, 10(3s), pp. 88–99 (2022)
12. Begy, V., Barisits, M., Lassnig, M., Schikuta, E.: Forecasting network throughput of remote data access in computing grids. *Journal of Computational Science*, 44, (2020). doi:10.1016/j.jocs.2020.101158.
13. Oladimeji, O., Oyeyiola, D., Oladimeji, O., Oyeyiola, P.: A comprehensive survey on cloud computing simulators. *Scientific journal of informatics*, 8(1), pp. 51–59, (2021). doi:10.15294/sji.v8i1.28878.
14. Boubakeur, A., Alti, A., Ghazali, O.: SecNetworkCloudSim: An extensible simulation tool for secure distributed mobile applications. In: *International Journal of Communication Networks and Information Security*, 12(1), pp. 47–62, (2020)
15. Zink, M., Irwin, D., Cecchet, E., Saplakoglu, H., Krieger, O., Herbordt, M.: The Open Cloud Testbed (OCT): A platform for research into new cloud technologies. *IEEE 10th International Conference on Cloud Networking (CloudNet)* (2021)
16. Perez Abreu, D., Velasquez, K., Curado, M., Monteiro E.: A comparative analysis of simulators for the cloud to fog continuum. *Simulation Modelling Practice and Theory*, 101(6), (2020). doi:10.1016/j.simpat.2019.102029.
17. Emad, O.: Data center simulator for sustainable data centers. MS thesis. (2019)
18. Gustedt, J., Jeannot, E., Quinson, M.: N 6859—version 2.
19. Pelosi, M.: CAST: A Declarative Language and its Execution Platform for Large-Scale Cloud Simulations. Diss. University of Illinois at Chicago (2021)
20. Cosimo, A., Canonico, M., Guazzone, M.: Teaching cloud computing: Motivations, challenges and tools. In: *IEEE International Parallel and Distributed Processing Symposium Workshops (IPDPSW)* (2020)
21. Soumya Ranjan, J., Shanmugam, R., Saini, K., Kumar, S.: Cloud computing tools: inside views and analysis. *Procedia Computer Science*, 173, pp. 382–391 (2020). doi:10.1016/j.procs.2020.06.045.
22. Ahuja, S.P., Muthiah, K.: Advances in green cloud computing. *Research Anthology on Architectures, Frameworks, and Integration Strategies for Distributed and Cloud Computing*. IGI global, pp. 2651–2662, (2021). doi:10.4018/978-1-7998-5339-8.ch128.
23. Vijay, V., Nanda, R.: A Systematic Review and Comparative Analysis of Cloud Simulation Tools. *Journal of Information and Computational Science*, 11(2), pp. 180 (2021)
24. Bambrik, I.: A survey on cloud computing simulation and modeling. *SN Computer Science*, 1(5), (2020). doi:10.1007/s42979-020-00273-1.
25. Reddy Manasa, D.: Cloud Computing and Security using CloudSim. 3rd International Conference on Smart Data Intelligence (ICSMDI) (2023)
26. Kumar, M.: A comprehensive survey for scheduling techniques in cloud computing. *Journal of Network and Computer Applications*, 143, pp: 1–33 (2019)
27. Aaqib, R., Chaturvedi, A.: Cloud computing characteristics and services: a brief review. *International Journal of Computer Sciences and Engineering* 7.2 pp. 421–426 (2019)
28. Sunyaev, A.: Cloud computing. *Internet Computing: Principles of Distributed Systems and Emerging Internet-Based Technologies*. pp. 195–236 (2020)
29. Bendeche, M.: Modelling and simulation of ElasticSearch using CloudSim. *IEEE/ACM 23rd International Symposium on Distributed Simulation and Real Time Applications (DS-RT)* (2019)
30. Ali, M.: An approach for realistically simulating the performance of scientific applications on high performance computing systems. *Future Generation Computer Systems*, 111, pp. 617–633 (2020)
31. Talha, U., Nadeem, M., Sajid, M.: Simulation Tools for Cloud Computing: A Comparative Study. *Advances in Data-driven Computing and Intelligent Systems: Selected Papers from ADCIS, 2*, Springer Nature Singapore, pp. 239–251 (2023)

32. Bohu, Li, Zhang Lin, Chai Xudong: Introduction to cloud manufacturing. *Zte Communications*, 8(4), pp. 6–9 (2020)
33. Zulfiqar, A.: Scientific workflows management and scheduling in cloud computing: taxonomy, prospects, and challenges. *IEEE Access* 9, pp. 53491–53508 (2021)
34. Bellavista, P.: A simulation framework for virtualized resources in cloud data center networks. *IEEE Journal on Selected Areas in Communications*, 37(8) pp. 1808–1819 (2019)
35. Reza Pakize, S., Masood Khademi, S.: Comparison of cloudsim, cloudanalyst and cloudreports simulator in cloud computing (2014)
36. Pawan, K., Rakesh, K.: Issues and challenges of load balancing techniques in cloud computing: A survey. *ACM Computing Surveys (CSUR)* 51(6), pp. 1–35 (2019)
37. Taskeen, Z.: Analysis of energy consumption on iaas cloud using simulation tool. *Proceedings of the 4th International Conference: Innovative Advancement in Engineering & Technology (IAET)* (2020)
38. Mohd, A.: A Compendium of Cloud Forensics. *Critical Concepts, Standards, and Techniques in Cyber Forensics*. IGI Global, pp. 215–227 (2020)
39. Sriram, I.: Speci, a simulation tool exploring cloud-scale data centres. In *IEEE International Conference on Cloud Computing*, pp. 381–392, Springer (2009)
40. Bukhtawar, E.: Toward scalable cloud data center simulation using high-level architecture. *Software: Practice and Experience*, 50(6), pp. 827–843 (2020)
41. Hassaan, M.: A comparative study between cloud energy consumption measuring simulators. *Int J Educ Manage Eng*, 10(2), pp. 20 (2020)
42. Wei Zhao, Yong Peng, Feng Xie, Zhonghua Dai: Modeling and simulation of cloud computing: A review. In: *IEEE Asia Pacific cloud computing congress (APCloudCC)*, pp. 20–24 (2012)
43. Punit, G.: Tools for fault and reliability in multilayered cloud. *Trust & Fault in Multi Layered Cloud Computing Architecture*, pp. 181–194 (2020)