

**Edu World 2016**  
**7th International Conference**

**ENERGY AWARE OF CLOUD COMPUTING DEVELOPMENT  
USING CLOUD SIMULATORS**

Ionel Gordin (a)\*

\*Corresponding author

(a) University of Stefan cel Mare, Suceava, Romania, ionel@usv.ro

**Abstract**

Cloud Computing its a hot topic nowadays, a concept that permits the organizations to access high performance computing and storage infrastructure at reduced cost through internet. With the fast development of cloud computing, the data center is becoming larger in scale and consumes more energy. From this situation comes the immediate need to develop cost-efficient energy saving methods to reduce the huge energy consumption in the cloud data center. The first solution to reduce the power consumption is to plan and test the optimal cloud data center structure before it is in production. We have achieved this goal through intensive testing of various well known cloud simulators (CloudSim, GreenCloud, Cloud Analyst, EMUSIM, GroudSim, DCSim). During this article we take in consideration both software based respectively software and hardware based simulators. Finally, we analyse and compare features of the existing cloud computing simulators and we take in consideration the most effective cloud solution for our project.

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**Keywords:** Cloud Simulators; *CloudSim*; *GreenCloud*; *Cloud Analyst*; *EMUSIM*; *GroudSim*

**Abbreviations:** Graphical User Interface (GUI); Automatic Emulation Framework (AEF); Data Center (DC); Network Simulator 2 (NS2); Virtual Machine (VM); Infrastructure as a Service (IaaS); Service Level Agreement (SLA);

## 1. Introduction

Although cloud computing started to be used in production more than a decade ago, we still have many challenging situations that requires a significant amount of research to be done. A physical cloud for conducting research it is not practical for medium to small sized educational institutions.



A physical cloud requires a considerable investment in necessary equipment (servers, networking devices, air conditioning). A solution for this situation is to use cloud simulators which can create a virtual cloud infrastructure without the considerable investments of a real cloud.

A cloud simulator assists at creating various model of cloud applications by making data centers, virtual machines and other utilities that can be configured appropriately, thus making it easier to analyze. Until today many cloud simulators had been developed and have been actively used to conduct cloud research. These simulators have different features like GUI, base programming languages, extensibility through plugins or modules, etc.

The academic websites and journals includes now many articles comparing different cloud solutions. This article takes a deeper approach on cloud simulators. In this article I present a comprehensive study of multiple cloud simulators by highlighting their features and analyzing advantages and disadvantages. A conclusion with the best cloud simulator for a certain project is provided at the end of the article.

A comparative analysis of various cloud simulators is presented on table 1.

Benefits of using cloud simulators over physical cloud are as follows:

- *Low Cost*: The cost of a cloud simulator software is much less when compared to purchasing hardware and proprietary software (OS, VM and cloud software, etc). Many simulators are available free of charge this making cloud simulators more convenient. Free cloud simulators are usually also open source. This opens the possibility of developing custom features that haven't been designed in the original software.
- *Repeatable and Controllable*: Our test results are not affected in any way by hardware limitations, background load of other processes or network speed as in real world. This permits developing of the desired model without any other variables involved. The model can be tested as many times we want, until we get the desirable output.
- *Environment*: A simulator provides environment for testing of various scenarios under different workloads.

## 2. Cloud Simulators

This section takes in consideration various cloud simulators that are mostly used to conduct cloud research simulations. We have described in this section 6 cloud simulators.

### 2.1 CloudSim

CloudSim is one the most popular simulation tool available for cloud computing environment. CloudSim it is a library for simulation of Cloud computing environments. Software has been developed at the Computer Science and Engineering Department of the University of Melbourne, Australia at CLOUDS Laboratory. The classes provided within library permits describing data centers, virtual machines (VM), applications, computational resources, and policies necessary for management of different parts of the system. The simulation tool can be adapted to our requirements by simply extending or replacing the classes built in. As we have mentioned before, CloudSim is not a ready to use solution where we set parameters and gather results necessary to use for our project. Being a library, CloudSim

requires that we write a Java application using its components following our desired scenario and then collect the obtained results for the analysing the performance of Cloud applications. (“CloudSim Simulation Framework - Superwits Academy”, 2016) (Umang, S. & Ayushi ,S. 2016).

The layered architecture of CloudSim is outlined on Fig. 1.

Cloudsim contains the following features:

- Support for modelling and simulation of large scale Cloud computing systems
- Permits modelling and simulation of virtualized server hosts
- Support for simulation of network connections together with the simulated system components
- Support for simulation of federated cloud environment that includes also inter-network resources for both private and public domains
  - Permits user-defined policies for allocation of hosts to virtual machines and policies for allocation of host resources to virtual machines
  - Support for user-defined policies at allocation of hosts and host resources to virtual machines
  - Permits simulation of electric energy consumption for desired model
  - Support for modelling and simulation of application modules
  - permits insertion of simulation elements and also stop and resume of simulation
  - Open source

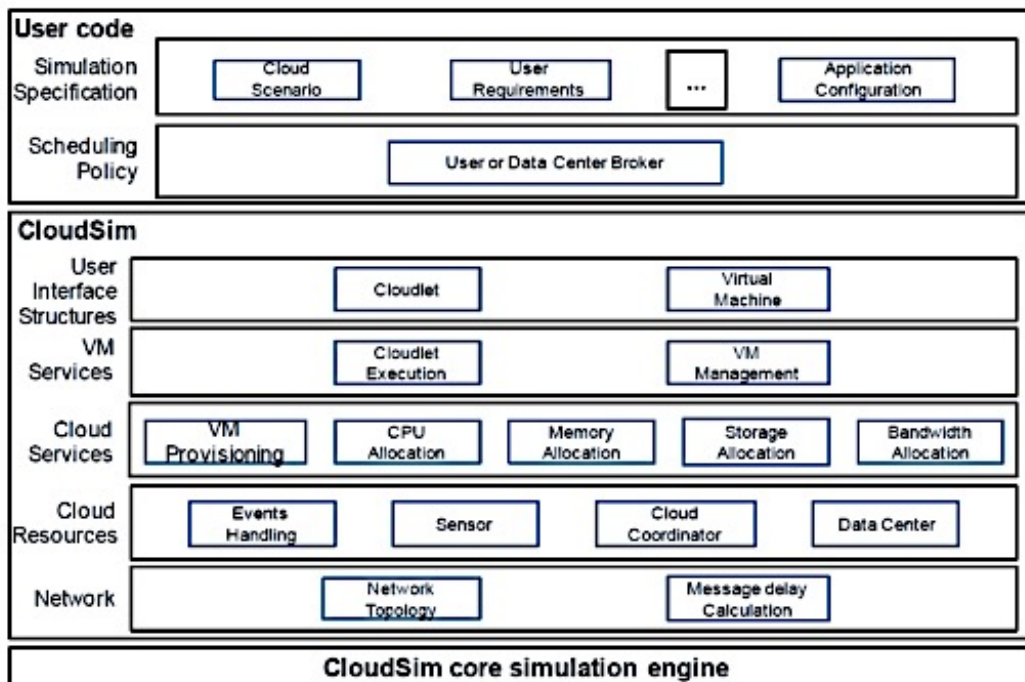


Fig. 1. Layered CloudSim Architecture.

## 2.2 Green Cloud

GreenCloud is a packet level simulator that has been created as an extension to well-known network simulator NS2. GreenCloud has been developed in the context of ECO-CLOUD and GreenIT projects. This simulator is specially made for energy-aware environment. GreenCloud permits calculation of energy consumption for any particular cloud computing component such as servers, network switches and communication links. (Boru, D. & Kliazovich, D. & Granelli, F. & Bouvry, P. & Zomaya, A.Y.,2015)

GreenCloud features:

- Permits simulation of electric energy consumption for desired model
- Defining of energy models for each type of cloud component
- Simulation of CPU, memory, storage and networking resources with special attention to networking component
- Supports virtualization
- Graphical User Interface (GUI)
- Full support for TCP/IP protocol
- Open source

GreenCloud is suitable mostly for calculating energy consumption when designing cloud computing structures. About 80 percent of GreenCloud code is implemented in C++, and the remaining 20 percent is in the form of Tool Command Language (TCL) scripts. To develop new features to GreenCloud user supposed to know both of mentioned languages. (“Greencloud - The green cloud simulator”, 2016).

The architecture of GreenCloud is represented on Fig. 2.

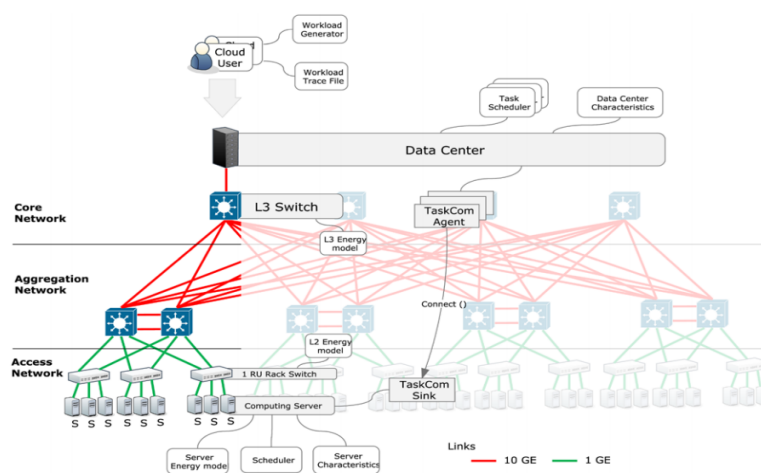


Fig. 2. Green Cloud architecture.

*Cloud Analyst* has been developed at the University of Melbourne with the purpose of evaluating the the performance of large-scale distributed cloud applications with high user workload that are geographically distributed over several data centers. *Cloud Analyst* has been built as an extension of *CloudSim*.

#### Features of CloudAnalyst:

- Intuitive Graphical User Interface (GUI)
- High degree of configurability and flexibility
- Repeat experiments with slight modifications
- Results are represented also graphically in the form of charts and tables
- Ease of extension – permits extending its capabilities to improve the simulation

The architecture of Cloud Analyst is represented on Fig. 3.

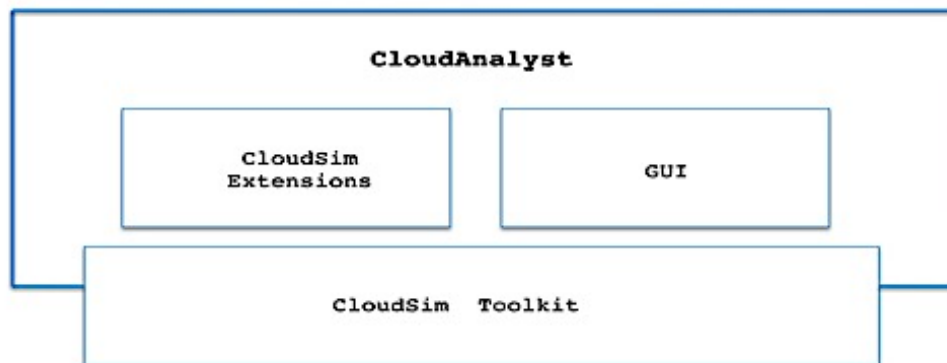


Fig. 3. Cloud Analyst architecture.

## 2.4 EMUSIM

EMUSIM has been developed at the Cloud Computing and Distributed Systems (CLOUDS) Laboratory, University of Melbourne. EMUSIM provides both capabilities of an emulator and as well of a simulator of a cloud environment. The simulator is built up on CloudSim and Automated Emulation Framework (AEF). On EMUSIM, the simulation model is generated with extracted information from application behaviour via emulation. ("EMUSIM",2016)

With EMUSIM, cloud service providers, are able now to know now how many resources are required to have a given response time considering a specific arrival time and the effects of the changes on the mentioned arrival rate. (Al-Sakib K. P.& Muhammad M. M. & Shafiullah K.,2015)

#### Features of EMUSIM:

- Includes all features of CloudSim
- Improved simulation by combining emulation and simulation of cloud computing
- EMUSIM does not include a GUI. Cluster configuration is done by editing cluster.xml file. Files aef.properties and emusim.properties are used to define information about the specific emulation to be performed

- Permits extending its capabilities to improve the simulation by working with CloudSim modules.

The architecture of EMUSIM is represented on Fig. 4.

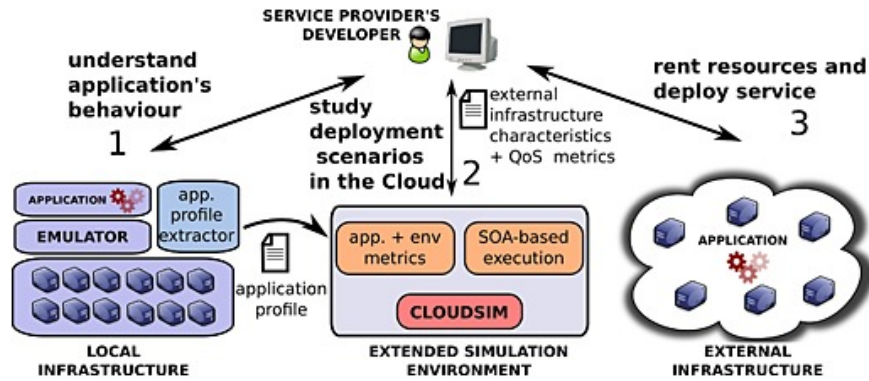


Fig. 4. EMUSIM architecture.

## 2.5 GroudSim

GroudSim (Gr-Grid and oud-Cloud Simulator) is an event simulation platform for both cloud and grid computing environments. Main programming language for GroudSim is Java. (Keckskemeti, G & Ostermann, S & Prodan, R., 2014) ("What are cloud simulators and it's applications", 2016)

GroudSim features:

- It can be extended easily by using probability distribution packages.
- GroundEntity module from GroudSim has its own definition for error behaviors. With this module user can change the configuration during each error occurrence.
- The simulation parameters are entered through configuration files in XML format. The application has no GUI interface
- Introduces background load functionality

Main components of GroudSim are as shown in following Fig. 5.

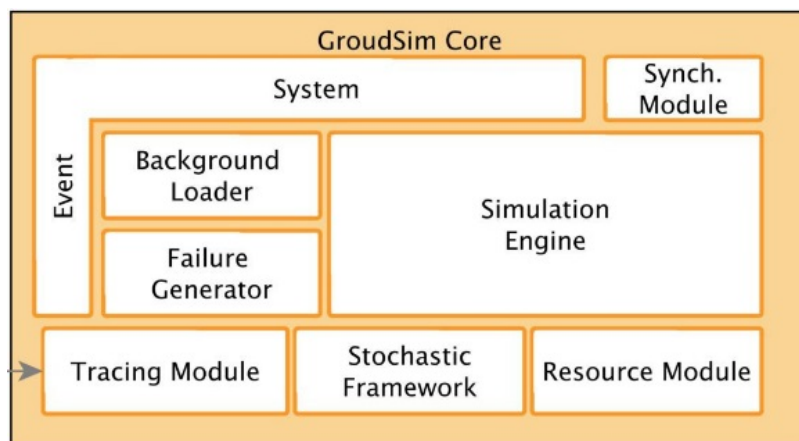


Fig. 5. GroudSim components.

## 2.6 DCSim

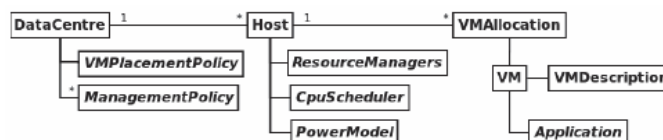
DCSim (Data Center Simulator) simulates a virtualized data center providing IaaS service for the cloud. DCSim is an event-driven simulator designed for transactional and continuous workloads such as a

web server. The simulator is developed in Java. The main component of DCSim is the DataCenter, which contains hosts, VMs, and different management components and policies. The data center is composed of interconnected hosts that are managed by a set of management policies. Each host it's composed of a set of resource managers that manage local resource allocation, a CPU scheduler to decide when to run VMs, and a power model that decides how much power is being consumed by the host at any point in time. (Al-Sakib K. P.& Muhammad M. M. & Shafiullah K.,2015) (Tighe, M. & Keller, D. & Shamy, J. & Bauer, M & Lutfiyya, H.,2013)

Figure 6 outlines the general architecture of DCSim.

DCSim features:

- VM live migration and replication
- Simulation tasks can be load balanced between multiple application instances running on different VMs
- DCSim generates a log containing the simulation results. This log can be used to generate graphs, statistics in order to understand the behavior of simulated data center. Simulator includes also a visualization tool that generates the necessary graphs using as input the generated log file.
- Sharing of workload between multiple VM
- Introduces SLA Violation parameter to monitor when a VM requires more resources than are available to it. The percentage of CPU resource required and not available is recorded.
- Calculates power consumption for each host



**Fig. 6.** DCSim general architecture.

### 3. Conclusion

Each cloud simulator presented covers a certain domain of interest. Unfortunately, on the market there is no cloud simulator to cover all possible cloud architectures. The user looking to simulate a specific feature that cannot be found on any cloud simulator can develop his own module with the help of a certain programming language.

CloudSim seems to be the most used cloud simulator to develop new features. CloudAnalyst and EMUSIM simulator took advantage of CloudSim toolkit to develop their own cloud computing features. Cloud Analyst analyses the performance of large-scale distributed cloud applications with high user workload that are geographically distributed over multiple data centers. EMUSIM combines the AEF emulator with CloudSim to optimize the simulation results obtained with CloudSim. Java is the most used programming language among cloud simulators. One benefit of using java programming is portability between operating systems or even perform mobile simulations (OpenMobster).

Analysing the synthesized results of Table 1 we can conclude that CloudSim is the most versatile cloud simulator solution.

Future work will concentrate on extending the research to other cloud simulators and to structure them by the ability of extending their features beyond their standard features. Programming language and ease of adding new features will be taken in consideration.

**Table 1.** Cloud simulators overview.

Cloud Simulator	Programing Language	Base Platform	Networking	GUI Support	Simulator Type	Energy Model	Availability
CloudSim	Java	SimJava	Limited	No	Packet level	Yes	Open Source
GreenCloud	C++, TCL	NS2	Full	Yes	Packet level	Yes	Open Source
Cloud Analyst	Java	CloudSim	Limited	Yes	Event based	Yes	Open Source
EMUSIM	Java	CloudSim, AEF	Limited	No	Event based	Yes	Open Source
GroudSim	Java	-	No	Limited	Event based	No	Open Source
DCSim	Java	-	No	No	Event based	Yes	Open Source

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