Cloud-based Simulation Tools for Cloud Testing: A Review

Ericmore Ngaramike, Gerald Ijemar, Olaitan Akinsanmi, Olaiya Folorunsho

Department of Computer Science, Federal University Oye-Ekiti, Nigeria
Department of Electrical and Electronics Engineering, Federal University Oye-Ekiti, Nigeria
ericmore.ngaramike, gerald.ijemaru, olaitan.akinsanmi@fuoye.edu.ng | ollfy0200@yahoo.com

Abstract — Cloud computing has maintained popularity and attraction in the ICT industry. Many business organizations have embraced the benefits that it offers and many more are still working towards cloud computing. One of the many concerns many organizations and individuals have about cloud computing from its inception is how to test the services and opportunities offered by cloud computing. This concern is as a result of the cost of running experiments on real cloud system and the fact that real infrastructure limits experiments within the size of the infrastructure, thereby making it really difficult to reproduce test. The alternative solution to this concern is the use of cloud simulation tools which offer a cloud environment to test cloud services in a repeated and controlled manner at no cost. Many cloud simulation tools have been developed since the inception of cloud computing. These tools have their strengths and weakness in modelling and simulating cloud system. This paper reviews some simulation tools and compares them in terms of their underlying framework, programming language, GUI, availability, cost modelling, energy modelling, simulation time, federation policy and communication model.

Keywords — Cloud computing, simulation, cloud simulation tools, cloud testing

1. INTRODUCTION

Cloud computing for the past few years has emerged as an extremely attractive and popular paradigm in ICT industry. It is a computing concept that offers individuals and business organisations full access to large amount of computing power (application, storage, network, computation) using the concept of virtualization (providing a single view of an aggregated computing resources). The key motivation of this technology is to offer computing resources as a utility: a business paradigm in which computing power is delivered on-demand; and service providers are paid on usage basis just as we pay for home utility services (Buyya, Ranjan and Calheiros, 2009). The fundamental principle driving this paradigm is providing computing as-a-service (software as a service, Platform as a service, Infrastructure as a service, Storage as a service etc). Some of the strong attractions of this concept is cost saving, speed of delivery, reliability and the ability to dynamically scale up or down to meet customer requirements. Today, many organizations that have embraced cloud computing are said to have cut down both capital and operational cost (Malhotra and Jain, 2013). Despite the benefits offered by cloud computing, business organizations and individuals like to test the performance of services before making real deployment.

For many business organizations and researchers, real infrastructure seems not to be the right platform for testing services because of the cost they will incur. Another reason is that real infrastructure reduces the performance of the experiment to the size of the cloud infrastructure, thereby making it really difficult to reproduce tests. The alternative way of testing cloud computing services is the use of simulation tools. Simulation tools provide organizations and researchers the platform to test cloud services in a repeated and controlled manner at no cost.

For cloud service providers, simulation platforms provide them the opportunity to evaluate various types of resource leasing scenarios using different load and cost distributions (Buyya, Yeo, Venugopal, Broberg and Brandic, 2009; Calheiros, Ranjan, Beloglazov, De Rose and Buyya, 2010).

2. CLOUD SIMULATION TOOLS

Since cloud computing emerged as a technology that offers reliable, fault-tolerant, secure, sustainable and scalable computational service (software, platform, and infrastructure), many IT providers and users have tried to devise ways of harnessing its benefits (Buyya et al., 2009; Buyya and Murshed, 2002). One of these is the development of cloud simulation tools that enable both providers and users to possibly evaluate hypothesis on a platform where tests can be reproduced before software development and deployment on real cloud platform. Since payment in real currency must be made before customers can be granted access to real cloud infrastructure, the use of simulation-based approach becomes a suitable alternative way to allow customers test their services at no cost in a repeated and controlled environment. Also, it provides customers the opportunity to evaluate possible bottlenecks before deploying on real cloud (Calheiros et al., 2010; Calheiros, Netto, De Rose and Buyya, 2012).

Simulation tools also enable service providers to evaluate different resource leasing scenarios with varying loads and pricing distribution. This aids the providers to optimize access to resources to maximize profit. Without these simulation tools, cloud users and providers have to depend on either a theoretical and imprecise evaluation or try-and-error approach that leads to inefficient service performance and revenue generation (Buyya et al., 2009). This review surveyed existing cloud computing simulation tools. After a careful study of their frameworks and functionalities, installation and configuration processes, eight tools were selected for this review. Different test scenarios
were set up to carry out simulation to test the performance of the tools.

### 2.1 CloudSim

CloudSim is an extensible simulation toolkit developed at the University of Melbourne, Australia. It provides an environment needed to model and simulate cloud computing systems and application provisioning environment (Calheiros et al., 2012; Calheiros et al., 2010). It provides capabilities for modelling both the system and behaviour of cloud system components (datacentres, virtual machines (VMs) and resources provisioning policies) (Shaikh and Sasikumar, 2013). CloudSim was developed by the cloudbus group to overcome the challenges of some existing distributed simulators (such as GridSim) which could not model and simulate the application workload, services, resources under varying load, data centre brokerage, resource provisioning between virtual machine, performance evaluation of cloud provisioning policies of the cloud computing environment (Pawar, 2015; Malhotra and Jain, 2013). Big companies such as HP, Universities and other leading organizations use CloudSim for cloud resource provisioning, energy-efficient management of data centres, optimization of cloud computing and research activities.

![CloudSim Architecture](image)

**Fig. 1. New Version Layered CloudSim Architecture (Calheiros et al., 2010)**

Figure 1 above describes the multi-layered design of the CloudSim framework and its architectural components. The older versions of CloudSim adopted SimJava as its discrete event simulation engine because it supports important functionalities such as queuing and processing of events, modelling of cloud system entities (host, datacentre, services, VMs, brokers), communication and interaction between cloud components, and management of simulation clock (Howell and Mcnab, 1998; Calheiros et al., 2010).

### 2.2 GreenCloud

GreenCloud is an extension of a packet-level network simulator (Ns2) (Kliazovich, Bouvry, Audzevich and Khan, 2010). Its development was motivated by the unavailability of simulation tools that could efficiently measure and evaluate cloud (data centres) performance (Pawar, 2015). The aim of GreenCloud development was to enable the simulation of energy-aware cloud environment. GreenCloud provides capability to efficiently calculate the energy consumption of computing and communication components (servers, switches, links) of the data centres as well as communication between the packet levels unlike other simulators such as CloudSim and MDCSim. Also, GreenCloud enables a comprehensive analysis of workload distribution. Data Centre Energy-Efficient Network-Aware Scheduler (DENS) is used to manage the data centre resources with attention to workload and communication (Kliazovich, Bouvry, Audzevich and Khan, 2010). GreenCloud requires large amount of time and huge memory to simulate a model and also a proficient skill in the programming languages (C++ and Otcal) which are some of its drawback.

![GreenCloud Architecture](image)

**Fig. 2. GreenCloud Architecture (Kliazovich et al., 2010)**

### 2.3 NetworkCloudSim

NetworkCloudSim is an extension of the features of the CloudSim proposed by (Garg and Buyya, 2009) to address some of the drawbacks of CloudSim to model real cloud environment. CloudSim was basically designed and developed for a single server architecture which makes it inadequate and insufficient to model a real cloud computing platform that runs various types of applications from various users. To overcome this limitation, NetworkCloudSim framework was developed to support modelling of real cloud computing data centres and other applications such High Performance Computing (HPC), workflow, Message Passing Interface (MPI) and e-commerce. It also offers support for communication and capturing of application and network elements characteristics in a data centre (Garg and Buyya, 2009). It provides a network model that allows data centres to take advantage of bandwidth sharing and latencies thereby enabling scalability and fast simulation time. With NetworkCloudSim, different network topologies can be simulated. It provides flexibility in configuring network components (router, switches, etc)
2.4 iCanCloud

iCanCloud is a simulation tool developed to achieve scalability, flexibility, usability and high performance which were major drawbacks of earlier simulators such as GreenSim, MDCSim, and CloudSim. Its design principles focused on providing capabilities that could enable users carry out large experiments which earlier simulators could not provide; to provide user with flexible and fully “customizable global hypervisor” to implement brokering policies, and to include instances provided by Amazon into the simulation framework (Nunez, Vazquez-Poletti, caminero, Castane, Carretero and Llorente, 2012). To carry out simulation, iCanCloud enables users to select the type of cloud (private, Amazon EC3, etc) on which to run the test and then allows the setup of the physical machine component, application, virtual machine, scheduling algorithm, user name and so on.

2.5 CloudAnalyst

CloudAnalyst is a cloud simulation tool built on top of the CloudSim framework. It is an enhancement of the CloudSim framework. One of these enhancements is the introduction of a graphical user interface that enables the modelling and simulation of large-scale applications that are deployed in the cloud infrastructure.

CloudAnalyst offers the capability to generate and evaluate information about the application workloads and geographic location of data centres and clients using the data centre. With this information, CloudAnalyst can analyse and determine some characteristics of a datacentre such as response time of user request, processing time of request at a particular workload. (Wickremasinghe, Calheiros and Buyya, 2010). It also offers developers the opportunity to determine the best policy for allocating resources to various available data centres, policies for selecting a data centre that suits a particular request, and cost required to carry out such operation (Wickremasinghe, Calheiros and Buyya, 2010). With its user-friendly GUI, it offers users control to configure data centre entities such as hardware components (memory, storage, network, bandwidth etc.), virtual machines (memory, bandwidth) cost per VM scheduling policy and other components that enable users achieve a cloud scenario.

2.6 MDCSim

MDCSim cloud simulation tool provides capabilities for designing and analyzing very large scale multi-tier data centres. Its main focus is analyzing performance and power consumption issues together with the underlying communication model and application level interactions of multi-tier data centres (Lim, Sharma, Nam, Kim and Das, 2009). It offers some flexibility in handling experiments with various kind of designs in the three layers and in modifying any layer without affecting other layers of the architecture. Hardware characteristics of component such as links and switches that connects the nodes can also be modelled. In order to minimize network overheads, the simulator provides capability for using infiniband Architecture (IBA) and Ethernet communication protocols instead of the popular TCP/IP in building the fundamental communication infrastructure (Lim et al., 2009).
2.7 EMUSIM
EMUSIM is a cloud simulation tool that is used to both simulate and emulate cloud applications (Calheiros et al., 2012). Its underlying framework is made up of CloudSim (used for simulation) and Automated Emulation Framework (used for emulation). It gathers information about the behaviour of applications using emulation and then uses such information to develop a simulation model that corresponds to the information. EMUSIM environment enables developers to generate more accurate models for applications and to measure their cost and performance in the cloud. EMUSIM focuses on software-as-a-service to accurate prediction of applications behaviour before actual deployment is made on cloud (Calheiros et al., 2012; Calheiros et al., 2010).

2.8 CloudSched
CloudSched is a lightweight cloud simulation tool which focuses on the evaluation of scheduling algorithms performance in the data centres. Unlike some other cloud simulation tools such as CloudAnalyst and CloudSim whose focus was on workload at application level, CloudSched focuses on providing a cloud environment that allows developers to analyze the requirements and performance of extensive cloud applications using various resource scheduling algorithms with respect to geographic distribution of cloud infrastructure and users workloads. It allows for the analysis of different resources such as CPU, network bandwidth and memory which makes it different from conventional scheduling algorithms that treats only one resource (such as CPU) which can create bottlenecks in some situations (Tian, Xua, Chen, Li, Wanga and Chena, 2015).

3. METHODOLOGY
In this section, the parameters used to compare the simulation tools are briefly discussed.

i) Underlying Framework: most cloud simulation tools are developed to work on top of some existing framework used for simulation. Since these cloud simulation tools would inherit major features of their frame, it is therefore important for users to know frameworks on which each tool is built.

ii) Programming Language: this is importation to know simulators since users would need to learn the language before they could use the tools.

iii) Graphical User Interface: this is very important since many users who are not technically proficient. This component of the simulator enables such users to adequately interact with the tools.

iv) Availability: most cloud simulation tool are open – source and are available to user at no cost, while some are commercial. MDCSim for instance is a commercial cloud simulation tool.

v) Cost Modeling: one beauty of cloud computing is its billing approach (on pay-as-you-go basis). Simulators with this component enable users to...
vi) **Energy Modeling**: this is important since huge energy is required to power data centre components.

vii) **Simulation Time**: this is the time it takes a simulator to carry out simulation. This enable a user understand how fast or slow a simulator can handle execution.

viii) **Federation Policy**: this is simply the interconnection of clouds. Cloud providers use this policy to control and coordinate resource and task sharing.

ix) **Communication Modeling**: this enables communication between data centre components to be evaluated which very important to users.

| Simulator       | Underlying Framework | Programming Language | GUI  | Availability | Cost Modeling | Energy Modeling | Simulation Time | Fed. Policy | Comm. Model |
|-----------------|----------------------|----------------------|------|---------------|---------------|-----------------|-----------------|-------------|-------------|
| CloudSim        | SimJava              | Java                 | No   | Open Source   | Yes           | Yes             | Second          | Limited     | Limited     |
| GreenCloud      | NS-2                 | C++, otel             | Limited | Open Source   | No            | Yes             | Minutes         | No          | Full        |
| NetworkCloudSim | CloudSim             | Java                 | No   | Open Source   | Yes           | Yes             | Seconds         | Yes         | Full        |
| iCanCloud       | SIMCAN               | C++                  | Yes  | Open Source   | Yes           | No              | Seconds         | No          | Limited     |
| CloudAnalyst    | CloudSim             | Java                 | Yes  | Open Source   | Yes           | Yes             | Seconds         | Yes         | Limited     |
| MDCsim          | CSIM                 | C++/Java             | No   | Commercial    | No            | Rough           | Seconds         | No          | Limited     |
| EMUSIM          | CloudSim, AEF        | Java                 | No   | Open Source   | Yes           | Yes             | Seconds         | No          | Limited     |
| CloudSched      | -                    | Java                 | Yes  | Open Source   | No            | Yes             | Seconds         | No          | Limited     |

### 4. Discussion of Results

In section 2, we presented an analysis of each of the simulation tools after a critical study and use of some of the simulation tools. This section will present a comparison of the simulation tools in a table and a brief discussion of the result. The comparison table shows that the simulators are developed in Java and C++ programming. CloudSim, NetworkCloudSim, MDCsim and EMUSIM do not have graphical user interface. A user has to manipulate the lines of code to setup a simulation scenario. iCanCloud, CloudAnalyst and CloudSched have friendly GUI. All simulation setups are done from the GUI. GreenCloud is regarded to have a limited GUI since simulation setups are done from the lines of code and the result of simulation is presented in a GUI. All the simulation tools are available for free download except MDCsim which a user has to purchase to use. All the tools can be used to model cloud computing cost except GreenCloud, MDCsim and CloudSched. Energy consumption can be modelled by all the tools except iCanCloud. MDCsim capability in modeling cost is considered rough since its result cannot provide clear understanding of the energy consumed. All the simulation tools take little time to perform simulation except GreenCloud. CloudAnalyst and NetworkCloudSim have the best capability to model federation policy. GreenCloud and NetworkCloudSim models full communication in a cloud system (server and network) while others provided limited functionality (server or network).

### 5. Conclusion

The IT industry has experienced increased growth since the evolution of cloud computing. Cloud computing has changed the way businesses are done and the way IT services are provided. This paper presented a number of cloud-based simulation tools used for testing cloud components before real deployment. These tools have their drawbacks as no one tool can completely model a real cloud system. Moreover, from our study, these tools are found to be efficient in modeling one cloud component or the other. GreenCloud is found to be most suitable in modeling energy consumption of data centre components although it has longer simulation time than other tools. CloudAnalyst is more efficient in modeling federation policy, cost, simulation time (response and processing time). and iCanCloud is suitable for modelling large data centres components and cost. NetworkCloudSim most suitable for modelling network components of the of the data centre. cloudSched is very suitable for analysing the usage of physical computer components (CPU, memory) and bandwidth by applications.

### REFERENCES

Buyya, R.B., Messina, J., Liu, F., Tong, J., and Mao, J. (2011), NIST Cloud Computing Reference Architecture, IEEE World Congress on Services.

Buyya, R., Ranjan, R., and Calheiros, R.N. (2009), Modeling and Simulation of Scalable Cloud Computing Environments and the CloudSim Toolkit: Challenges and Opportunities, Proc. of the International Conference on High Performance Computing & Simulation.

Buyya, R., Yeo, C.S., Venugopal, S., Broberg, J., and Brandic, I. (2009), Cloud Computing and Emerging IT Platforms: Vision, Hype, and Reality for Delivering Computing as the 5th Utility, Journal of Future Generation Computer Systems Vol. 25, No. 6, pp. 599–616.

Buyya, R. and Murshed, M. (2002), GridSim: A Toolkit for the Modeling and Simulation of Distributed Resource Management and Scheduling for Grid Computing, Concurrency and Computation: Practice and Experience 14 (13-15), 1173–1220.
Calheiros, R.N., Ranjan, R., Beloglazov, A., Buyya, R., and César A. F. De Rose (2010), CloudSim: A Toolkit for Modeling and Simulation of Cloud Computing Environments and Evaluation of Resource Provisioning Algorithms, Journal of Software: Practice and Experience, Vol. 41, No. 1, pp. 23–50

Calheiros, R.N., Netto, M.A.S., De Rose, C.A.F., and Buyya, R. (2012), EMUSIM: An Integrated Emulation and Simulation Environment for Modeling, Evaluation, and Validation of Performance of Cloud Computing Applications, Journal of Software: Practice and Experience, Vol. 43, No. 5, pp. 595–612.

Chu, X., Nadiminti, K., Jin, C., Venugopal, S., and Buyya, R. (2007), Aneka: Next-Generation Enterprise Grid Platform for E-Science and E-Business Applications, Third IEEE International Conference on e-Science and Grid Computing.

Conrow, E.H., Shishido, P.S. (1997), Implementing risk Management on Software Intensive Projects, IEEE Journal of Software, Vol. 14 No. 3, pp. 83-89.

Garg, S.K. and Buyya, R. (2011), NetworkCloudSim: Modelling Parallel Applications in Cloud Simulations, 2011 Fourth IEEE International Conference on Utility and Cloud Computing.

Hayes, B. (2008), Cloud Computing, Communications of the ACM, Vol. 51 No. 7.

Hoefer, C.N. and Karagiannis, G. (2010), Taxonomy of Cloud Computing Services, 2010 IEEE Globecom Workshops.

Howell, F. and Mcnab, R. (1998), SimJava: A Discrete Event Simulation Library for Java, Proceedings of the 1st International Conference on Web-Based Modeling and Simulation.

Kliazovich, D., Bouvry, P., Audzevich,Y., and Khan,S.U. (2010), GreenCloud: A Packet-Level Simulator of Energy-Aware Cloud Computing Data Centres, IEEE Global Telecommunications Conference.

Kumar, P. and Rai, A.K. (2014), An Overview and Survey of Various Cloud Simulation Tools, Journal of Global Research in Computer Science. vol. 5

Lim, S.-H., Sharma, B., Nam, G., Kim, E.K., and Das, C.R. (2009), MDCSim: A Multi-Tier Data Center Simulation, Platform, IEEE International Conference on Cluster Computing and Workshops.

Malhotra, R. and Jain, P. (2013), Study and Comparison of Various Cloud Simulators Available in the Cloud Computing, International Journal of Advanced Research in Computer Science and Software Engineering, vol. 3.

Manohar, N. (2013), A Survey on Cloud Computing- Deployment of Cloud, Building a Private Cloud and Simulators, Proceedings of International Conference on Emerging Research in Computing, Information, Communication and Applications.

Marston, S., Li, Z., Bandyopadhyay, S., Zhang, J., and Ghalsasi, A. (2011), Cloud Computing — The Business Perspective, 44th Hawaii International Conference on System Sciences.

Núñez, A., Vázquez-Poletti, J.L., Caminero, A.C., Castañé, G.G., Carretero, J., and Llorente, I.M. (2012), iCanCloud: A Flexible and Scalable Cloud Infrastructure Simulator, Journal of Grid Computing, Vol. 10, No. 1, pp. 185–209.

Pawar, C.S. (2015), A Review on Cloud Simulators, International Journal for Technological Research in Engineering, vol. 2.

Rimal, B.P., Choi, E., and Lumb, I. (2009), A Taxonomy and Survey of Cloud Computing Systems, Fifth International Joint Conference on INC, IMS and IDC.

Sadashiv, N. and Kumar, S.M.D. (2011), Cluster, Grid and Cloud Computing: A Detailed Comparison, The 6th International Conference on Computer Science & Education.

Shaikh, R. and Sasikumar, M. (2013), Cloud Simulation Tools: A Comparative Analysis, International Conference on Green Computing and Technology.

Tian, W., Xua, M., Chen, A., Li, G., Wanga, X., and Chena,Y. (2015), Open-Source Simulators for Cloud Computing: Comparative Study and Challenging Issues.

Velte, A.T., Velte, T.J., Elsenpeter, R.C., (2010), Cloud Computing: A Practical Approach, New York: McGraw-Hill.

Wickremasinghe, B., Calheiros, R.N., and Buyya, R. (2010), CloudAnalyst: A CloudSim-Based Visual Modeller for Analysing Cloud Computing Environments and Applications, 24th IEEE International Conference on Advanced Information Networking and Application.