Study and Comparison of CloudSim Simulators in the Cloud Computing

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***Abstract*—**Cloud computing is a hot topic all over the world nowadays, through which customers can access information and computer power via a web browser. As the adoption and deployment of cloud computing increase, it is critical to evaluate the performance of cloud environments. Modeling and simulation technologies are suitable for evaluating performance and security issues. Cloud simulators are required for cloud system testing to decrease the complexity and separate quality concerns. Several cloud simulators have been specifically developed for performance analysis of cloud computing environments and CloudSim is a one of them Cloud simulation application. CloudSim enables seamless modeling, simulation, and experimentation of cloud computing and application services. This paper first defines CloudSim and then explores it's all variants available in CloudSim such as CloudAnalyst, GreenCloud, Network CloudSim, EMUSIM and MDCSim. In the last, it Compares all CloudSim Variant with respect to networking, platform and language.

***Keywords*—**Cloud Computing; Cloud Simulators; CloudSim; CloudAnalyst; EMUSIM; GreenCloud; MDCSim; NetworkCloud.

***Abbreviations*—**Automatic Emulation Framework (AEF); Data Center (DC); Network Simulator 2 (NS2); Virtual Machine (VM).

I. INTRODUCTION

CLOUD computing is a model for enabling convenient and on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction [Dr. Rahul Malhotra & Prince Jain, 2013]. Cloud computing can be viewed from two different perspectives: cloud application, and cloud infrastructure as the building block for the cloud application. Now a days, most organizations focuses on adopting cloud computing model so that they can cut capital expenditure, efforts and control operating costs. These reasons trigger aggressive growth for cloud adoption in business [Calheiros et al., 2011].

Some of the traditional Cloud-based application services include social networking, web hosting, content delivery and real time instrumented data processing, which has different composition, configuration, and deployment requirements. Quantifying the performance of scheduling and allocation policies in a real Cloud computing environment for different application models is extremely challenging. The use of real infrastructures for benchmarking the application performance under variable conditions is often constrained by the rigidity of the infrastructure. Thus, it is not possible to perform benchmarking experiments in repeatable, dependable, and scalable environments using real world Cloud environments [Calheiros et al., 2011].

A more viable alternative is the use of cloud simulation tools. Cloud simulators are required for cloud system testing to decrease the complexity and separate quality concerns. They enable performance analysts to analyze system behavior by focusing on quality issues of specific component under different scenarios [Xiaoying Bai et al., 2011]. These tools open up the possibility of evaluating the hypothesis in a controlled environment where one can easily reproduce results. Simulation-based approaches offer significant benefits to IT companies by allowing them to test their services in repeatable and controllable environment and experiment with different workload mix and resource performance scenarios on simulated infrastructures for developing and testing adaptive application provisioning techniques [Calheiros et al., 2011].

None of the current distributed system simulators offer the environment that can be directly used for modeling Cloud computing environments. But CloudSim which is generalized and extensible simulation framework that allows seamless modeling, simulation, and experimentation of emerging Cloud computing infrastructures and application services. By using CloudSim, researchers and developers can test the performance of a newly developed application service in a controlled and easy to set-up environment. The vast features

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of CloudSim would speed up the development of new application provisioning algorithms for Cloud computing. This paper first gives background about various Simulators available. Section 3 define CloudSim and then explores it's all variants available in CloudSim such as CloudAnalyst, GreenCloud, NetworkCloud, EMUSIM and MDCSim. In the section 4, it Compares all CloudSim Variant with respect to networking, platform and language.

II. Related Work

In the past decade, Grids [Foster & Kesselman, 1999] have evolved as the infrastructure for delivering high-performance service for compute and data-intensive scientific applications. To support research, development and testing of new Grid components, policies and middleware, several Grid simulators such as GridSim, SimGrid, OptorSim and GangSim have been proposed. SimGrid is a generic framework for simulation of distributed applications in Grid platforms. GangSim is a Grid simulation toolkit that provides support for modeling of Grid-based virtual organizations and resources. On the other hand, GridSim is an event-driven simulation toolkit for heterogeneous Grid resources. It supports modeling of grid entities, users, machines, and network including network traffic but none of these are able to support the infrastructure and application-level requirements arising from Cloud computing paradigm. In particular, there is no support in existing Grid simulation toolkits for modeling of on-demand virtualization enabled resource and application management. Further, Cloud infrastructure modeling and simulation toolkits must provide support for economic entities such as Cloud brokers and Cloud exchange for enabling real-time trading of services. Among the currently available simulators discussed, only GridSim offers support for economic-driven resource management and application scheduling simulation.

III. CloudSim

CloudSim is a simulation application which enables seamless modeling, simulation, and experimentation of cloud computing and application services [Calheiros et al., 2009; 2011; Buyya et al., 2009] due to the problem that existing distributed system simulators were not applicable to the cloud computing environment. Evaluating the performance of cloud provisioning policies, services, application workload, models and resources performance models under varying system, user configurations and requirements is difficult to achieve. To overcome this challenge, CloudSim can be used. CloudSim is new, generalized and extensible simulation toolkit that enables seamless modeling, simulation and experimentation of emerging cloud computing system, infrastructures and application environments for single and internetworked clouds. In simple words, CloudSim [Rahul Malhotra & Prince Jain, 2013] is a development toolkit for simulation of Cloud scenarios. CloudSim is not a framework as it does not provide a ready to use environment for execution of a complete scenario with a specific input. Instead, users of CloudSim have to develop the Cloud scenario it wishes to evaluate, define the required output, and provide the input parameters [Dr. Rahul Malhotra & Prince Jain, 2013].

CloudSim is invented and developed as CloudBus Project at the University of Melbourne, Australia. The CloudSim toolkit supports system and behavior modeling of cloud system components such as data centers, virtual machines (VMs) and resource provisioning policies. It implements generic application provisioning techniques that can be extended with ease and limited efforts. CloudSim helps the researchers and developers to focus on specific system design issues without getting concerned about the low level details related to cloud-based infrastructures and services [Wickremasinghe, 2009]. CloudSim is an open source web application that launches preconfigured machines designed to run common open source robotic tools, robotics simulator Gazebo.

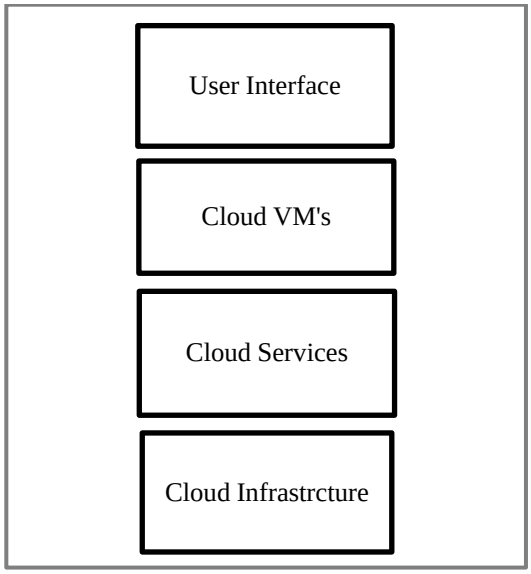

Figure 1: CloudSim Components

The users could analyze specific system problems through CloudSim, without considering the low level details related to Cloud based Infrastructures and services [Wei Zhao et al., 2012]. Several works have been done from then on to improve CloudSim as are described briefly below.

3.1. CloudAnalyst

CloudAnalyst was derived from CloudSim and extends some of its capabilities and features proposed [Wickremasinghe, 2009; Wickremasinghe & Calheiros, 2010]. CloudAnalyst separates the simulation experimentation exercise from a programming exercise. It also enables a modeler to repeatedly perform simulations and to conduct a series of simulation experiments with slight parameters variations in a quick and easy manner. CloudAnalyst can be applied to examining behavior of large scaled Internet application in a cloud environment.

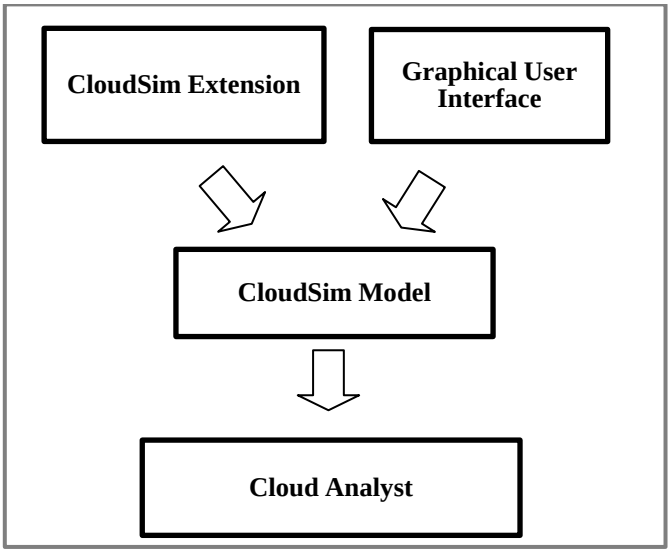

Figure 2: Pictorial View of Cloud Analyst

3.2. GreenCloud

GreenCloud is a CloudSim that have green cloud computing approach with confidently, painlessly, and successfully. In other words, GreenCloud is developed as an advanced packet level cloud network simulator with concentration on cloud communication [Kliazovich et al., 2010]. GreenCloud extracts, aggregates and makes fine grained information about the energy consumed by computing and communication elements of the data center equipment such as computing servers, network switches and communication links [Wei Zhao et al., 2012; http://www.isi.edu/nsnam/ns/] available in an unprecedented fashion. Moreover, GreenCloud offers a thorough investigation of workload distributions. In particular, a special focus is devoted to accurately capture communication patterns of currently deployed and future data center architectures. GreenCloud can act as Cloud Bridge [http://gogreencloud.com]. In simple words, GreenCloud is the practice of designing, manufacturing, using and disposing computing resources with minimal environmental damage. The Green Cloud is a supercomputing project under active development at the University of Notre Dame. Green Cloud provides a virtual computing platform by using grid heating which reduces cluster upkeep costs.

Figure 3: A User View of GreenCloud

GreenCloud Simulator is an extension of Network Simulator (NS2) simulator [Wei Zhao et al., 2012; http://www.isi.edu/nsnam/ns/]. GreenCloud simulator implements a full TCP/IP protocol reference model which allows integration of different communication protocols with the simulation. The only drawback of Green Cloud Simulator is that it confines its scalability to only small data centers due to very large simulation time and high memory requirements.

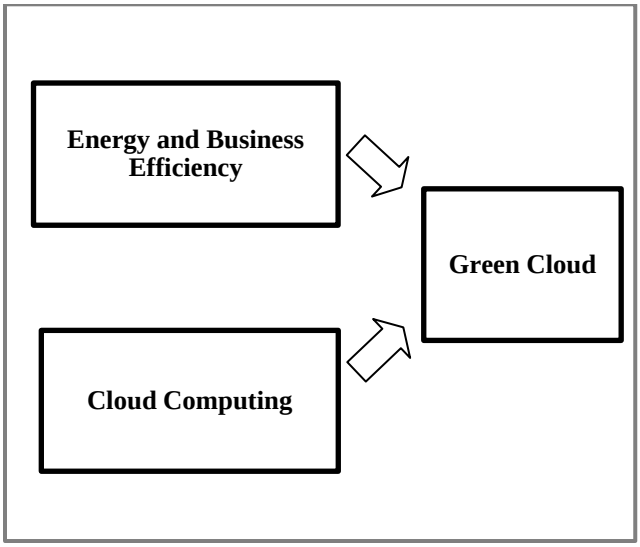

Figure 4: Pictorial View of Green Computing

GreenCloud Aim

1. To develop high-end computing systems such as Clusters, Data Centers, and Clouds that allocate resources to applications hosting Internet services to meet users' quality of service requirements
2. To minimize consumption of electric power by improving power management, dynamically managing and configuring power-aware ability of system devices [http://www.cloudbus.org/greencloud/].
3. To Provide a detailed simulators
4. To analyze energy efficiency and measure cloud performance.

GreenCloud can reduce Data Center Power Consumption by:

1. Workload consolidation via DC virtualization.
2. By statistical multiplexing Incentives leading to aggressively lowering OpEx.
3. By improving sustainability by reducing host count.

3.3. NetworkCloudSim

Network CloudSim is an extension of CloudSim as a simulation framework which supports generalized applications such as high performance computing applications, workflows and e-commerce [Buyya et al., 2009]. Network CloudSim uses Network Topology class which implements network layer in CloudSim, reads a BRITE file and generates a topological network. In network CloudSim, the topology file contains nodes, number of entities in the simulation which allows users to increase scale of simulation without changing the topology file. Each CloudSim entity must be mapped to one BRITE node to

allow proper work of the network simulation. Each BRITE node can be mapped to only one entity at a time. Network CloudSim allows for modeling of Cloud data centers utilizing bandwidth sharing and latencies to enable scalable and fast simulations. Network CloudSim structure supports designing of the real Cloud data centers and mapping different strategies. Information of network CloudSim is used to simulate latency in network traffic of CloudSim.

3.4. EMUSIM

EMUSIM is an integrated architecture [Calheiros et al., 2012] to anticipate service's behavior on cloud platforms to a higher standard [Calheiros et al., 2011; Wei Zhao et al., 2012]. 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. Such a simulation model is then used to build a simulated scenario that is closer to the actual target production environment in application computing resources and request patterns. Information that is typically not disclosed by platform owners, such as location of virtual machines and number of virtual machines per host in a given time, is not required by EMUSIM. EMUSIM is built on top of two software systems: Automated Emulation Framework (AEF) for emulation and CloudSim for simulation [Dr. Rahul Malhotra & Prince Jain, 2013].

3.5. MDCSim

MDCSim is a commercial discrete event simulator developed at the Pennsylvania State University. It helps the analyzer to model unique hardware characteristics of different components of a data center such as servers, communication links and switches which are collected from different dealers and allows estimation of power consumption. MDCSim is the most prominent tool to be used as it has low simulation overhead and moreover its network package maintains a data center topology in the form of directed graph [Dr. Pawan Kumar & Gaganjot Kaur].

IV. COMPARISON OF VARIOUS VARIANTS OF CLOUDSIM

The number of simulation environments for cloud computing data centers available for public use is limited. The CloudSim simulator is probably the most sophisticated among the simulators overviewed. The MDCSim simulator is a relatively fresh data center simulator developed at the Pennsylvania State University. It is supplied with specific hardware characteristics of data server components such as servers, communication links and switches from different vendors. Table 1 compares various CloudSim simulators via comparison of their characteristics such as platform, language, networking, Simulator type and availability [Dzmitry Kliazovich et al., 2010]. The proposed GreenCloud simulator is developed as an extension of the Ns2 network simulator which is coded in C++ with a layer of OTcl libraries implemented on top of it. It is a packet level simulator. On the contrary, CloudSim and MDCSim are event-based simulators which avoid building and processing small simulation objects individually. Such a method reduces simulation time considerably, improves scalability, but lacks in the simulation accuracy. Both GreenCloud and CloudSim simulators are released under open source GPL license. The MDCSim simulator is currently not available for public download which is a commercial product [Dzmitry Kliazovich et al., 2010].

Summarizing, short simulation times are provided by CloudSim and MDCSim even for very large data centers due to their event-based nature, while GreenCloud offers an improvement in the simulation precision keeping the simulation time at the reasonable level. None of the tools offer user-friendly graphical interface. The GreenCloud supports cloud computing workloads with deadlines, but only simple scheduling policies for single core servers are implemented. The MDCSim workloads are described with the computational requirements only and require no data to be transferred. Communication details and the level of energy models support are the key strengths of the GreenCloud which are provided via full support TCP/IP protocol reference model and packet level energy models implemented for all data center components [Dzmitry Kliazovich et al., 2010].

Table 1: Comparison of Various CloudSim

CloudSim	Platform	Programming Language	Networking	Simulator Type	Availability
CloudAnalyst	CloudSim	Java	Limited	Event Based	Open Source
GreenCloud	NS2	C++/OTCL	Full	Packet Level	Open Source
Network CloudSim	CloudSim	Java	Full	Packet Level	Open Source
EMUSIM	AEF	Java	Limited	Event Based	Open Source
MDC SIM	CSIM	C++/Java	Limited	Event Based	Commercial

V. CONCLUSION

Cloud computing has been one of the fastest growing parts in IT industry. Simulation based approaches become popular in industry and academia to evaluate cloud computing systems, application behaviors and their security. Several simulators have been specifically developed for performance analysis of cloud computing environments including CloudSim, GreenCloud, NetworkCloudSim, CloudAnalyst, EMUSIM and MDCSim but the number of simulation environments for cloud computing data centers available for public use is limited. The CloudSim simulator is probably the most sophisticated among the simulators overviewed. The MDCSim simulator is a relatively fresh data center simulator.

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