Comparison between CloudSim and GreenCloud in Measuring Energy Consumption in a Cloud Environment

Saleh Atiewi
Tenaga National University
Jalan IKRAM-UNITEN, 43000 Kajang, Selangor, Malaysia
s.atiewi@gmail.com

Salman Yussof
Tenaga National University
Jalan IKRAM-UNITEN, 43000 Kajang, Selangor, Malaysia
salman@uniten.edu.my

***Abstract*—Cloud computing is a model that relies on sharing computing resources rather than having local servers or personal devices to handle applications. Numerous studies have shown that by replacing traditional computing with cloud infrastructure, the total power consumption can be decreased because cloud computing power consumption is influenced by four key cloud factors: dynamic provisioning, multi-tenancy, server utilization, and data center efficiency. Considering the huge amount of energy consumed by computing equipment in the last several years, energy consumption and sustainability have become one of the main areas of research. Thus, obtaining high performance at a reduced cost in cloud environments has reached a turning point where computing power is no longer the most important concern. Calculate the amount of energy consumption in a real cloud computing infrastructure is difficult. Thus, simulation tools have been developed in recent years to enable cloud computing researchers to analyze a cloud computing environment. This paper will introduce and compare the two popular cloud simulators: CloudSim and GreenCloud. Both simulators provide scenarios for cloud computing based on utilization, virtualization, and load and energy consumption of the server. The comparison showed that the GreenCloud simulator is more advantageous than the CloudSim simulator based on an accurate measurement of energy consumption in a cloud computing environment.**

Keywords- CloudSim; GreenCloud; Simulator; Datacenter; Energy; Power Consumption

I. INTRODUCTION

According to the National Institute of Standards and Technology, "Cloud Computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."[1].

Cloud computing is the process of delivering computation, data access, and storage services, without end-user knowledge. Cloud computing aims to take advantage of distributed resources by combining them to achieve higher performance and solve large-scale computation problems [2].

Cloud computing has become an important aspect of our lives and has changed the way people exchange information. Many different types of cloud computing services exist. However, the three most popular infrastructure as a service (IaaS), platform as a service (PaaS) and softwareas a services (SaaS). These cloud services may be offered in a public, private, or hybrid network [3]. Regardless of the cloud service models and where they are deployed, cloud computing enables millions of users to utilize the offered services by simply using their own devices or terminals. Cloud computing aims to offer a computing environment with low cost, ease of use, and lower power consumption [4]. Fig. 1 shows how cloud computing adoption in a business environment can reduce the total energy consumed by decreasing the number of servers and by increasing server utilization. Cloud computing providers also use an advanced and highly efficient cooling system compared with the in-house and unmanaged cooling system used by most companies. Both of these characteristics can reduce the amount of power used by the business for its IT services.

The hardware layer of the cloud is usually responsible for managing the physical resources of the cloud, including physical servers, routers, switches, and power and cooling systems. In practice, the hardware layer is typically implemented in data centers [3]. According to [5], more than 500,000 data centers currently exist all over the world. Such number of data centers require a huge amount of energy. In 2010, the total electricity consumed by data centers was approximately 1.5% of the electricity of the world. Counting more than 50 million metric tons of CO_2 emissions in 2012, roughly 40% of the total energy is consumed by IT equipment [6].

Considering the increased development of cloud computing and the increase in the amount of energy consumed by cloud computing, many researchers seek to find solutions that will reduce the amount of energy consumed by cloud computing infrastructure. However, the complexity of a cloud computing environment is an obstacle faced by numerous researchers when conducting a study on a real cloud computing infrastructure. To overcome this obstacle, cloud simulation software is used. This study aims to evaluate and compare two of the most commonly used software for simulating a cloud system, namely, CloudSim and GreenCloud. Their suitability in performing a study on cloud computing energy consumption is assessed [7].

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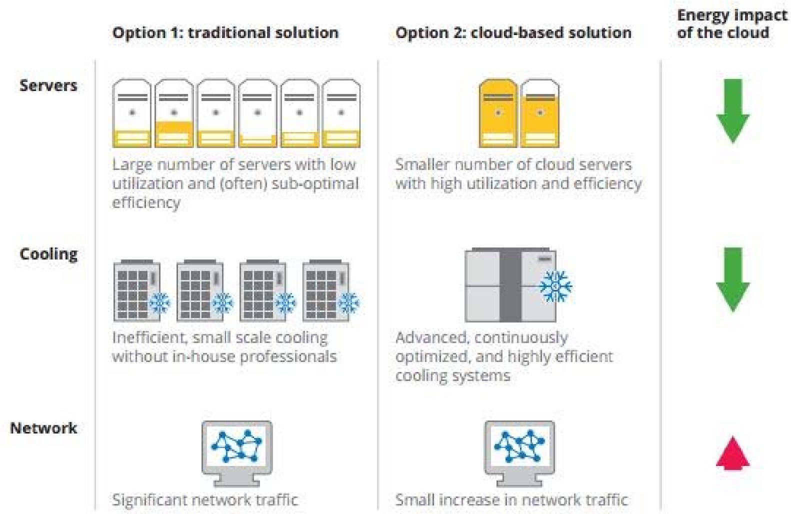

Figure 1. Adoption of cloud computing in business [8].

II. CLOUD SIMULATION SOFTWARE

Cloud simulators are required in cloud computing research to make cloud system evaluation possible. They enable researchers to analyze a cloud computing system by evaluating the performance of a specific component under different scenarios [9]. In this section, two commonly used cloud computing simulators, namely, CloudSim and GreenCloud, are evaluated. The main differences between these two simulators, especially in terms of their ability to measure power consumption, are also described. The first simulator is the CloudSim simulation framework [10][11], which is based on SimJava. SimJava is a discrete event simulation framework. CloudSim enables the modeling and creation of a huge data center with unlimited number of virtual machines, brokering policy, and other important features of the cloud computing pay-as-you-go model. One of the unique features of this simulator is its federated policy. A federated cloud is the deployment and management of multiple external and internal cloud computing services to match business needs. A federated cloud Is a multiple internal and external clouds services that are deployed to meet business needs. A federation is the combination of several smaller parts that perform a common action [12]. Fig. 2 shows the structure layers of the CloudSim simulator. The SimJava is located at the lowest layer, which deals with event handling and simulation entities. The CloudSim layer is located in the core layer, which effectively completes and extends the main functionality of the GridSim by modeling, storage, application services, resource provisioning between virtual machines, and data center brokerage. CloudSim has been modified and extended by several research groups. For example, it has been used to evaluate energy-aware algorithms in [7].

The second cloud simulator is the GreenCloud simulator, which is a packet-level simulator for an energy-aware cloud computing data center that focuses on cloud communications [13]. This simulator provides detailed steps in modeling the consumed energy in the cloud data center and network components. GreenCloud, released under the General Public License Agreement, is an extension of the well-known NS2 network simulator. Approximately 80% of the GreenCloud code is implemented in C++, whereas the remaining 20% is in the form of Tool Command Language (TCL) scripts [13].

Fig. 3 shows the structure of the GreenCloud simulator with three-tier data center architecture. The main components of this simulator are as follows [14]:

- Servers, which form the data center in the cloud, which is used to run all tasks.
- Switches and links, which form the network topology and the connection between by providing different cabling solutions.
- Workloads, which are considered as objects that model various cloud user services, such as instant messaging and social networks.

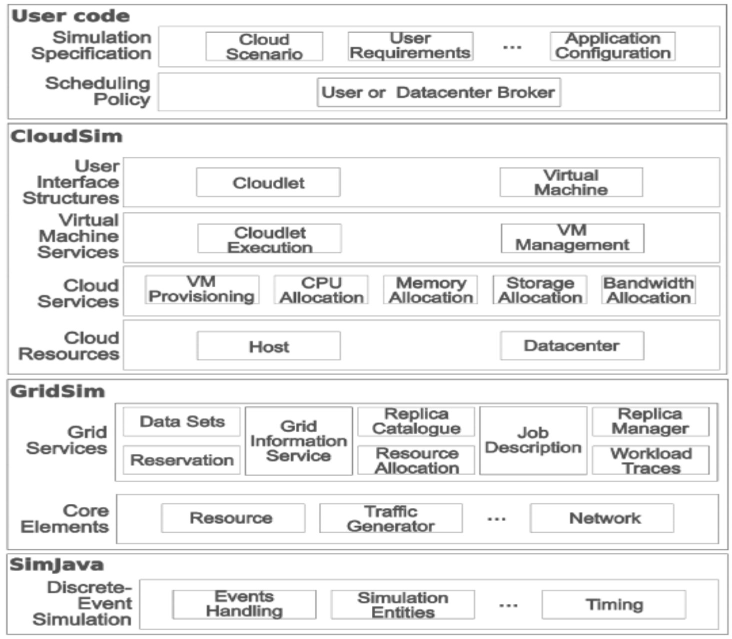

Figure 2. CloudSim architecture.

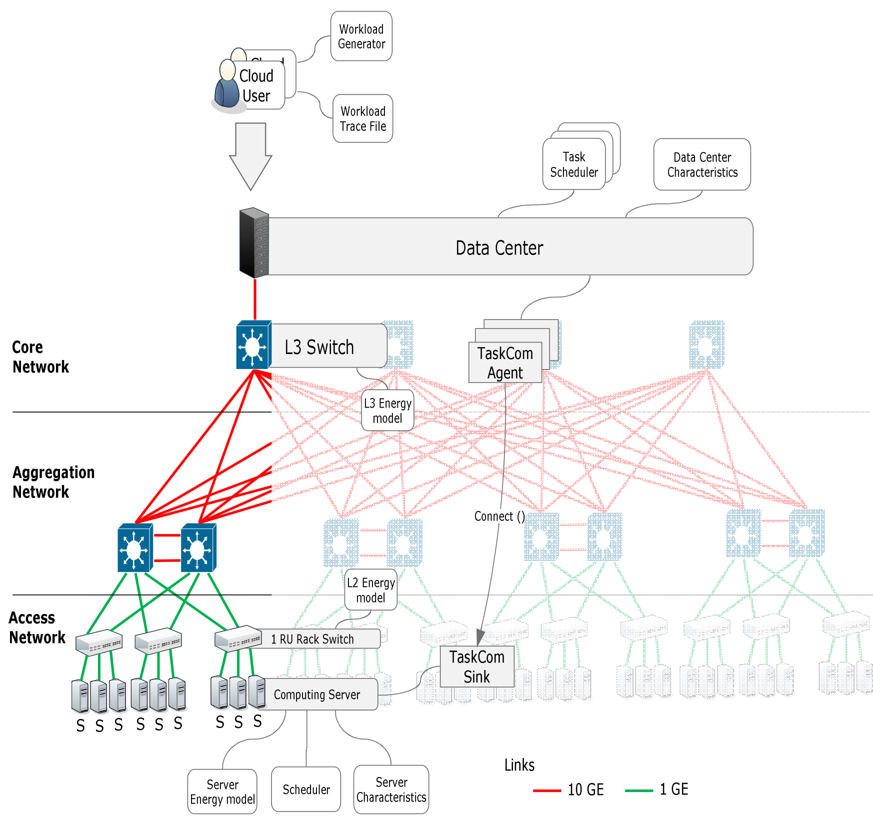

Figure 3. GreenCloud simulator architecture [14].

Table 1 shows a detailed comparison between the two simulators. Both simulators can measure performance and quality of service. However, GreenCloud provides a better process of analyzing the simulation results by providing HTML support with graphics. Both simulators can also measure energy consumption. However, this capacity is differently performed by each simulator. This difference will be discussed further in the next section.

TABLE I. DETAILED COMPARISON BETWEEN CLOUDSIM AND GREENCLOUD.

Features	**CloudSim** [11]	**GreenCloud** [14]
Description	Modular and extensible open-source simulator, can model very large-scale clouds	Simulation tools for simulating energy-aware cloud computing data center environment and capturing the detailed energy consumed in data center
GUI	Available, using CloudAnalyst simulator	Available, using NAM simulator
Performance/QOS	Support	Support
Energy efficiency	Yes	Yes
Programming language	Java	C++ and TCL
Obtaining results	Difficult, data should be analyzed using Excel	Easy, HTML report with graphics (Dashboard)
Open source	Yes	Yes
Available on the web	Yes	Yes

III. ENERGY MODEL

As a packet-level simulator, the energy consumed by the data center is calculated by summing the energy consumed by all components in the data center (servers and switches). In the case of energy consumed in servers, GreenCloud simulators offer options for power management; dynamic voltage and frequency scaling (DVFS) is a common option, which works as a trade-off between the consumed energy in the server and the computing performance [15]. Meanwhile, the power consumption of network switches mainly depends on the (a) type of switch, (b) number of ports, (c) rate transmission for each port, and (d) type of cabling. The energy consumed by a switch and all its transceivers can be defined by the following equation [5], as in (1):

$$P_{switch} = P_{chasis} + n_{linecards} \cdot P_{linecard} + \sum_{i=0}^{R} n_{ports \cdot r} \cdot P_r \quad (1)$$

Where Pswitch is the total power consumed for switch, Pchasis is the consumed power for switche's chasis (hardware) , n is the number of line cards in switch, Plinecard is the power consumed with any ative switch line card and Pr represent the power consumed by a port (transceiver) that runs at the bit rate r.

Measuring the performance of cloud activities, such as provisioning policies, application workload, and real-life resource performance, is difficult to perform. CloudSim solves this difficulty by providing a process to model and simulate cloud computing systems and application provisioning environments. Moreover, CloudSim provides custom interfaces in implementing policies and provisioning techniques for the allocation of virtual machines (VMs) under inter-networked cloud computing scenarios. Several researchers from organizations, such as HP Labs in the United States, are using CloudSim in their investigation on cloud resource provisioning and energy-efficient management of data center resources [11].

Fig. 4 shows the CloudSim class design diagram. CloudSim consists of three classes. First is the provision class, which is responsible for providing the cloud with all its main components, such as virtual machines, memory, and bandwidth. All these components are handled through a class called provisioner, which is modified and cloned for each resource, such as virtual machine and memory provisioners. Second is the allocation policy class, which manages time, space-sharing allocation policy, and VM allocation policy. Third is the scheduler class. Each host component instantiates a VM scheduler component that implements either a space-shared or a time-shared policy for allocating cores to VMs [16].

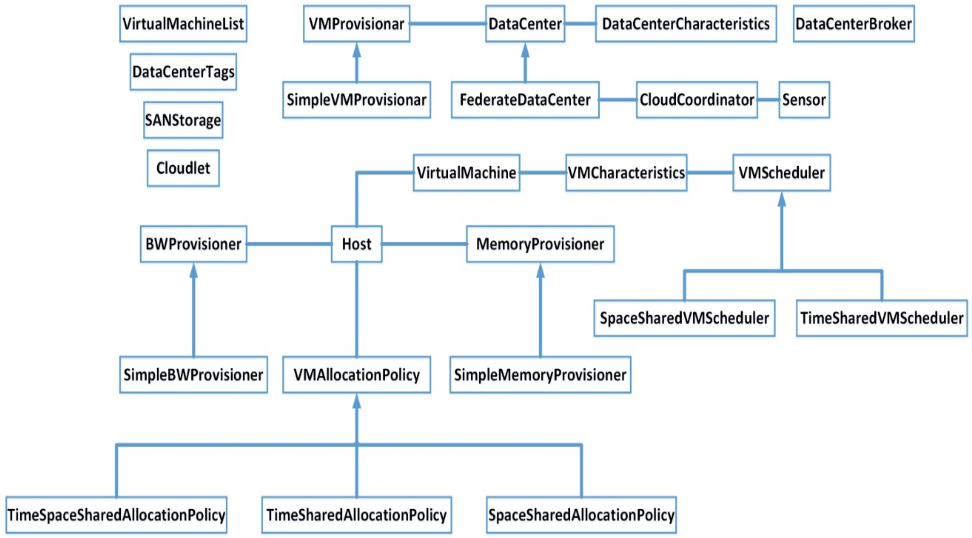

Figure 4. CloudSim class design diagram.

TABLE II. COMPARISON BETWEEN CLOUDSIM AND GREENCLOUD BASED ON ENERGY COMPUTATION [14].

Parameter	GreenCloud	CloudSim
Application models	Computation, data transfer, and execution deadline	Computation, data transfer
Communication models and TCP/IP support	Full (energy calculating affected by number of packets, link errors, switch congestion, delay, bandwidth, and routing)	Limited (data center formed as direct graph so energy calculating is limited to bandwidth and delay)
Energy models	Precise for all data center components (servers and networks)	None
Power-saving modes	DVFS, dynamic server/network shutdown (DNS) and DVFS + DNS	None

Table 2 shows that a number of differences exist between GreenCloud and CloudSim with respect to power consumption model and computation. Further details of these differences are provided below.

- **Application models:** which is implemented in both simulators as an objects that draw the necessary application requirements. both simulators also specify communicational requirements of the application based on the type and amount of transferred data. Cloudsim application model suits with high-performance computing (HPC) having no specific completion deadline, while GreenCloud have an advantage of being able to set and adding execution deadline for all tasks [14].
- **Communication models and TCP/IP:** GreenCloud simulator offers a detailed communication setup for cloud datacenter making it easy to implement TCP/IP protocol, which will allow GreenCloud simulator to capture most common protocols such TCP,IP and UDP, whenever any message sent over the network it will be fragmented to packets which can be easily monitored and captured with GreenCloud. By contrast, the communication model in CloudSim is limited only to delay of transmission and bandwidth throughput, Moreover CloudSim maintains the data center topology as a directed graph. East node is assigned with value for delay and bandwidth. However neither congestion control nor error recovery can be captured with CloudSim simulator [14].
- **Energy models:** The energy model in GreenCloud is implemented for all cloud components (servers, switches, links). Given the advantage in the simulator to calculate and update consumed energy while packets moving in all cloud components.. By contrast, CloudSim does not consider the energy spent [14].
- **Power-saving modes:** GreenCloud is the only cloud computing simulator that implement different power-saving modes (DVFS, DNS, and DVFS+ DNS) [14].

IV. CONCLUSION

Given the worldwide energy crisis, many efforts have been exerted to develop new techniques to ensure a green cloud computing environment. To test and evaluate these techniques, researchers have turned to the use of cloud computing simulators. In this study, two well-known cloud computing simulators, namely, CloudSim and GreenCloud, are introduced and compared. The comparison between these two simulators shows that GreenCloud has a number of advantages over CloudSim. GreenCloud is based on the popular NS2 network simulator, which allows it to capture packet-level details. GreenCloud also implements three power-saving algorithms (DPM, DVFS, and DPM + DVFS). This simulator accurately calculates the energy consumption, that is, energy consumption is computed on each packet arrival, task execution, and completion, whereas CloudSim provides no energy model for the packet level. Therefore, GreenCloud can provide a finer control and a more accurate result in the research on power consumption.

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