Future Generation Computer Systems ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

Energy modeling in cloud simulation frameworks

Antonios T. Makaratzis, Konstantinos M. Giannoutakis *, Dimitrios Tzovaras

Information Technologies Institute, Centre for Research and Technology Hellas, Thessaloniki 57001, Greece

HIGHLIGHTS

- A survey on modeling of open source cloud simulation frameworks is conducted.
- Energy consumption models of CPUs, memory, storage and network are examined.
- Experimentation with four cloud simulation platforms is performed.
- Comparisons of the models and the impact of the hardware components on the total energy consumption is examined.

ARTICLE INFO

Article history:
Received 28 February 2017
Received in revised form 19 May 2017
Accepted 16 June 2017
Available online xxxx

Keywords:
Cloud computing
Cloud simulators
Modeling
Energy consumption
Data center

ABSTRACT

There is a quite intensive research for Cloud simulators in the recent years, mainly due to the fact that the need for powerful computational resources has led organizations to use cloud resources instead of acquiring and maintaining private servers. In order to test and optimize the strategies that are being used on cloud resources, cloud simulators have been developed since the simulation cost is substantially smaller than experimenting on real cloud environments. Several cloud simulation frameworks have been proposed during the last years, focusing on various components of the cloud resources. In this paper, a survey on cloud simulators is conducted, in order to examine the different models that have been used for the hardware components that constitute a cloud data center. Focus is given on the energy models that have been proposed for the prediction of the energy consumption of data center components, such as CPU, memory, storage and network, while experiments are performed in order to compare the different power models used by the simulation frameworks. The following cloud simulation frameworks are considered: CloudSched, CloudSim, DCSim, GDCSim, GreenCloud and iCanCloud.

1. Introduction

Cloud computing is an emerging technology, due to the flexibility of using powerful computing resources without the need of in-house infrastructures. Organizations are shifting from traditional in-house computing towards cloud computing solutions, as they provide higher reliability, flexibility, broad network access on demand usage, security etc. As this transition is evolving, the need for evaluation of several aspects of cloud infrastructures becomes of great importance. Cloud simulation tools have been proposed during the last years, providing experimentation platforms for evaluating different strategies of the cloud resources usage. Simulation saves the expenses of experimenting on real cloud infrastructures, since a comprehensive study of the whole problem in real cloud resources is extremely difficult. Thus, cloud simulators provide simplicity, repeatability of experiments and reduces experimentation costs.

Energy consumption of cloud data centers is an important factor since the amount of the consumed energy is increasing, mainly due to non energy aware usage of cloud infrastructures. It has been reported that about 0.5% of the worldwide energy consumption concerned cloud data centers, while this is expected to quadruply in 2020, [1]. For this reason, cloud simulation frameworks have introduced energy models in order to develop strategies for the optimization of the usage of the cloud resources. This paper is focused on the energy consumption modeling of data centers, and more specifically on models for the simulation of the CPU, network, memory and storage components. The most known open source cloud simulation frameworks were considered with their corresponding models, while experimentation was performed for the impact of the models on the total energy consumption of a cloud data center.

Many cloud simulation surveys have been performed during the last years. Most of them discuss the architecture, the main concepts and functionality of each tool, while some of them provide comparisons on the high-level and technical features of each simulator, [2–6]. In [7], a survey was performed on various cloud simulators

* Corresponding author.
E-mail addresses: antomaka@iti.gr (A.T. Makaratzis), kgiannou@iti.gr (K.M. Giannoutakis), Dimitrios.Tzovaras@iti.gr (D. Tzovaras).

http://dx.doi.org/10.1016/j.future.2017.06.016
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containing some energy models, though comparisons were made only regarding the performance and the memory requirements of the cloud simulators, and not for the affect of the models on the total energy consumption of a cloud data center.

The remainder of the paper is structured as follows: In Section 2, an introduction to the cloud simulation frameworks that are considered in this survey is performed, while in Section 3 the models of the cloud simulators are presented. In Section 4, experimentation on the cloud simulation platforms is conducted, in order to compare the proposed energy consumption models. Recapitulation and conclusions are presented in Section 5.

2. Cloud simulation frameworks

In this section, a brief introduction of the well-known open source cloud simulation frameworks is given in alphabetic order, namely CloudSched, CloudSim, DCSim, GDCSim, GreenCloud and iCanCloud. In Table 1 the basic characteristics of the examined simulators are presented.

2.1. CloudSched

CloudSched, [7], is a discrete event simulator that developed in order to assist users to identify and explore appropriate solutions considering different resource scheduling algorithms. Unlike traditional scheduling algorithms, considering only one factor such as CPU, CloudSched treats multi-dimensional resources such as CPU, memory and network bandwidth, integrated for both physical and virtual machines for different scheduling objectives. CloudSched offers features such as modeling and simulation of large scale cloud computing environments, modeling of different resource scheduling policies and algorithms at IaaS layer for clouds, and both graphical and textual outputs.

2.2. CloudSim

CloudSim, [8], is the most used toolkit for modeling and simulation of Infrastructure as a Service (IaaS) cloud computing environments. It is a discrete event simulator that provides a virtualization engine with extensive features for modeling the life-cycle management of virtual machines in a data center, including policies for provisioning of virtual machines to hosts, scheduling of resources of hosts among virtual machines, scheduling of tasks in virtual machines, and modeling of costs incurring in such operations. A model for Device Voltage and Frequency Scaling (DVFS) technique has been developed and incorporated in the CloudSim simulator too, since this simulator contains abstractions for representing distributed Cloud infrastructures and power consumption, [9]. NetworkCloudSim, [10], is an extension of CloudSim which considers communication costs between VMs performing parallel computations. NetworkCloudSim has a scalable network and generalized application model, which allows more accurate evaluation of scheduling and resource provisioning policies, in order to optimize the performance of a cloud infrastructure.

2.3. DCSim

DCSim, [11,12] is a discrete event simulator that models a virtualized data center providing IaaS to multiple tenants, with a focus on interactive workloads such as web applications. It can model replicated VMs sharing incoming workload, as well as dependencies between VMs that are part of a multi-tiered application. It also provides metrics to gauge SLA violations, power consumption, and other performance metrics that serve to evaluate a data center management approach or system. Furthermore, DCSim is designed to be easily extended for implementing new features and functionality. The work in [13] extends DCSim by adding data center organization components such as racks and clusters, and proposes new built-in features, as well as new modifications to the underlying simulator to provide more flexibility for further extensions.

2.4. GDCSim

GDCSim (Green Data Center Simulator), [14], was proposed for studying the energy efficiency of data centers under various data center geometries, workload characteristics, platform power management schemes and scheduling algorithms. It aims to simulate both the management and physical design of a data center by examining their interactions and relationships. The purpose is to fine-tune the interactions between management algorithms and the physical layout of the data center, such as thermal and cooling interactions with workload placement, [11]. GDCSim is developed as a part of the BlueTool infrastructure project at Impact Lab, [14].

2.5. GreenCloud

GreenCloud, [15–17], is build on top of the NS2 network simulator and it is focused on simulating the communication between processes running in a cloud at packet level. Being build on top of NS2, it implements a full TCP/IP protocol reference model which allows integration of different communication protocols with the simulation. This limits its scalability to only small data centers due to the large simulation time and high memory requirements, [10]. It also provides a detailed modeling and analysis of the energy consumed by the elements of the network servers, routers and links between them. GreenCloud includes two methods of energy reduction: DVS (Dynamic Voltage Scaling) to decrease the voltage of switches and DNS (Dynamic Network Shutdown) that allows to shut down switches when it is possible, [9]. GreenCloud also provides plugins that allow the use of physical layer traces that make experiments more detailed.

2.6. iCanCloud

iCanCloud, [18], is a discrete event simulator that provides features such as flexibility, scalability, performance and usability. The iCanCloud simulator has been built to provide a set of advanced features: to conduct large experiments, to provide a flexible and fully customizable global hypervisor for integrating any cloud brokering policy, to reproduce the instance types provided by the given cloud infrastructure and to provide a user-friendly GUI for configuring and launching simulations. A basic characteristic of iCanCloud is that supports executions of parallel simulations, so one experiment can be executed spanning several distributed machines. Additionally, iCanCloud utilized the E-mc^2 framework, [19], for advanced analysis of energy modeling in cloud computing. Aspects like modeling the behavior of different simulated users, support of resource provisioning policies and configuration of different cloud scenarios are achieved using E-mc^2.

3. Modeling of cloud simulation frameworks

The proposed models of the cloud simulation frameworks are presented in this Section. For each simulator, CPU, Network, Memory, Storage and Energy models are briefly described. In CloudSched, the multidimensional load balancing is also included as an additional subsection.