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Green cloud computing: Efficient energy-conscious and dynamic resource management in data centers

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Abstract — The number of cloud computing users has been steadily increasing in recent years as it has become a very important technology in the computing landscape. It provides customers with decentralized services and a pay-as-you-go approach to resource usage. The growing demand for cloud services is forcing providers to deploy an increased data center infrastructure with thousands of hosts and servers to store and process data. As a result, these large servers generate a lot of heat with visible carbon emissions in the air as well as high energy consumption and higher operating costs. For this reason, research is continuing in the field of energy management, including techniques for saving energy in servers, networking, cooling, renewable energy, etc. In this paper, we address the existing energy-efficient methods in the field of green cloud computing and present our green cloud solution for dynamic resource management in data centers. Our proposed approach aims to reduce the energy consumption of the infrastructure and maintain the required performance.

Keywords—Cloud computing; green cloud; data center; energyconsumption; resource management

I. INTRODUCTION

The recent revolution in information and communication technologies has increased our dependence on energy, despite all the benefits for our way of life. More than 3 billion people use electronic devices every day, and their power consumption is strongly linked to the time spent using them, which is constantly increasing [1]. To support this revolution, huge data centers have sprung up all over the world. Service providers and data hosts are competing to invest in these data centers, which are veritable information factories where profits cannot be expected. However, the power consumption of data centers is a new puzzle that science is struggling to solve.The issue of energy has emerged in recent years as a centralconcern that humanity faces with great urgency. Population growth, the gradual exhaustion of previously explored resources, and more recently the rise of information technologies have turned this issue into a challenge that researchers and industry players are tackling [2].

In 2010, around 1.5% of the world's electricity was consumed by data centers in the information technology sector [3]. This share is steadily increasing due to the development of many areas and cloud computing in particular.In recent years, new problems have emerged in view of the environmental considerations that are increasingly present in our society. In 2014, the power consumption of Data centers exceeded 42 TWh and by 2020 the resulting CO_2 productionwill reach 670 million metric tons annually [4].

In addition, the servers in the data centers are constantly overloaded to cope with the peak demand of upcoming requests, wasting a large amount of energy [5]. One of the options for reducing power consumption consumption of data centers is to reduce the number of idle servers or to switch them into low-power sleep states as part ofthe green cloud IT vision [6].

With our work, we want to explore new ways to improve energy efficiency in cloud data centers. Specifically, we aim to dynamically optimize energy consumption in cloud computing data centers by optimizing resource usage through various policies for host and virtual machine (VM) overload detection, migration VM selection, and VM placement.

The rest of this article is organised as follows. Section II presents a literature review on the energy-aware solution for green cloud computing. Section III proposes our solution. Finally, Section IV presents the conclusions and future work.

II. RELATED WORK ON GREEN CLOUD COMPUTING

In general, green cloud data centers are associated with three main methods: dynamic voltage frequency scaling (DVFS), renewable energy scheduling and dynamic power management (DPM) [7].

To obtain an estimate of the energy consumption of the cloud client application, researchers in [8] performed an energy model under different DVFS policies. In [9], the flow pattern of the cloud tasks is studied and based on the obtained results, researchers try to adjust the incoming VM tasks with a demand-based frequency using DVFS.

In [10], the DVFS is used to minimize power consumption when scheduling tasks in the mobile cloud, but this approach does not consider server power-on and power-off control. In the study [11], the three approaches DVFS, request dispatching and dynamic service management are combined to reduce energy consumption. However, the limitation is that these researchers admitted that the servers providing different services are constantly active. In the SaaS cloud platform, an analytical framework is developed that monitors the states of the VMs (idle/busy). It characterizes and optimizes the trade-off between energy and performance [12]. In another search [13], only one type of sleep with shutdown is used in a method to reduce energy consumption, except that this solution is insufficient in the case of fast responses. In [14], a physical host in cloud computing was shut down by considering two parameters, namely time and load, to reduce energy consumption. When the working time of a VM exceeds a specified threshold, that VM is displaced. And if the utilisation of a physical host is below a specified threshold, it is shut down.

In this research [15], they relied on processor utilization, disk utilization, and performance degradation ratio as metrics of a VM to reallocate them. In [16], they used an algorithm based on CPU and memory of the VM and server as parameters to consolidate them. They select VMs that are underutilized with respect to the server. Some researchers have proven that this server consolidation approach is not suitable for large data centers. Also, several meta-heuristic optimization algorithms are used for consolidating VMs, such as those cited in [17]- [19].

According to many previous studies [20], [21], green cloud computing involves the efficient management of cloud resources and the reduction of energy consumption while ensuring the quality of service defined in the service level agreements (SLA).

A system view of green cloud computing, where energy savings are a must, is shown in Fig. 1. It illustrates that the resource manager controls resource utilization when the cloud user sends an application request and is responsible for allocating VMs on physical hosts while ensuring SLA compliance. In addition, the underutilized servers are turned off, while some others can be turned on when needed to consolidate the physical hosts (see Fig. 1).

This overview helps to recognize that there are limitations in previous research and that all important energy parameters (e.g. CPU, memory, etc.) required for ideal energy efficiency have not been taken into account.

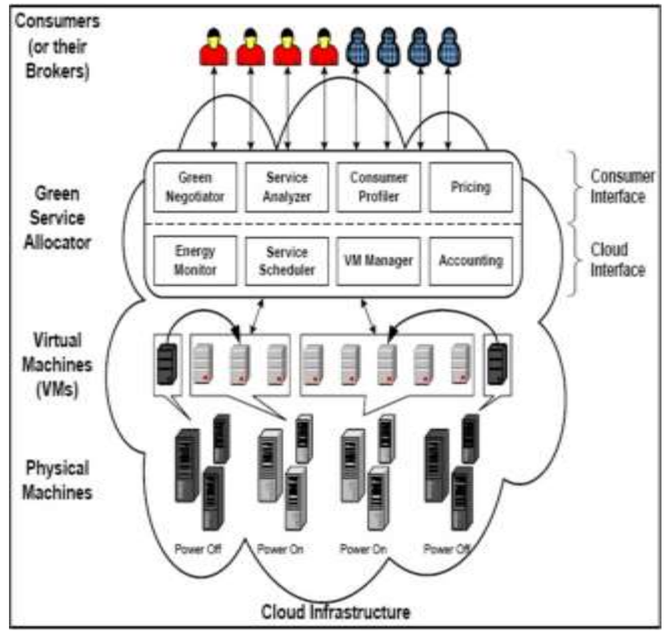

Fig. 1. Overview of green cloud computing.

DYNAMIC AND ENERGY-AWARE SOLUTIONFOR RESOURCES MANAGEMENT

Virtual machine consolidation techniques are a means to improve energy efficiency and utilization of cloud data center resources. However, aggressive VM consolidation approaches lead to overutilization of physical hosts and create massive unwanted VM migrations that result in degradation of both host and VM performance [22].

In addition, it is a major challenge to improve energy efficiency and resource utilization in the data center while providing services with guaranteed quality of service (QoS).

To solve this problem, we propose a method to improve energy-efficient and QoS dynamic resource management, which consists of four main modules. Our solution takes into account all important parameters related to the energy efficiency of the cloud data center.

Relevant energy parameters include CPUs, memory, disk space, the amount of messages transmitted over the network (bandwidth) and the available number of input/output operations per second (IOPS) on the physical host.

Besides, the VM placement depends on some precise Service Level Agreement restrictions as follows:

- The affinity constraint: between VMs aims to obtain optimal placement by taking into account the requirement that two VMs must be placed on the same physical machine (PM), for example. This constraint refers to interdependent VMs that share data within specified time limits.
- The security constraint: can be, for example, to separate two VMs on different servers (or even two data centres) to ensure their separation.
- The migration constraint: means that it is possible to perform VM placement only on a set of well-defined machines or to keep a VM on the same host (or the same data centre).

We have also defined other energy parameters, namely: the total number of VMs placed on a PM, the total number of PMs used, the number of reassignments of a VM, the time span of VM interruption in the migration period, the percentage of maximum and minimum usage of VMs/PMs, and the response time of a task at the level of a VM (SLA).

The aspect of data sustainability is also taken into account and refers to ensuring the replication of individual data in real time on multiple hosts (e.g. a primary and a backup host).

Our solution uses an infrastructure model that is informed about the state of the system at any desired point in time. The focus is on dynamic management of VM allocation and movement in the data center in terms of performance, system availability, cost and instantaneous energy consumption. This approach provides for optimized resource allocation and live migration through a decision and analysis mechanism, effectively meeting stringent SLA requirements.

Fig. 2. Overview of the proposed solution.

As Fig. 2 shows, the overview of the proposed optimized cloud model platform includes the following management steps: collecting monitoring data, evaluating this data to calculate better resource placement, creating a plan to reallocate and dynamically manage resources, and applying the proposedmeasures (see Fig. 2).

The acquisition component regularly monitors and collects data about the workload, power consumption and resource utilization of the cluster's PMs. This data includes CPU, disk space, memory usage, etc. Power consumption is also recorded with the help of tools for measuring power consumption (e.g. power meter or wattmeter).

The analysis module uses a built-in scheduler algorithm that makes decisions and evaluates the results of resource utilisation. The designed and implemented algorithm does not rely on a specific type of workload and does not require any information about the applications running on the VMs. Its execution requires accurate performance parameters and high- resolution measurements.

The input of the algorithm is the collection of the individual PMs with their assigned VMs, the different resource information collected, and the specified energy consumption parameters to determine which resource to allocate and where to relocate it. A new optimized resource placement plan with a set of nodes that are underloaded and overloaded (to be disabled, turned on later...) is the output of the algorithm execution.

The decision component aims for the migration, reallocation, and consolidation of the resources. Also, resources can be turned on/off according to the instructions of the analysis model and based on the results previouslyobtainedfrom the execution of the scheduler algorithm.

III. Conclusion and Future Works

Today's IT services use cloud computing solutions to efficiently offer their customers the services they require. However, the heavy use of the cloud leads to a strong growth of data center infrastructure. In this case, unfortunately, an enormous amount of electrical energy is consumed and a large amount of carbon dioxide is emitted into the air.

As a result, it is becoming necessary to reduce the amount of energy used in cloud data centers while maintaining optimal management of its resources, such as servers and virtual machines. This prerequisite relates to the idea of "green clouds," which allows us to protect the environment.

This paper discusses several methods that improve the allocation of green cloud resources, mostly through virtualization, migration, and consolidation. As a result, the suggested method offers efficient resource management while taking into account all significant energy metrics and significant potential restrictions on the distribution of virtual machines in PMs, which have an impact on the amount of energy used in cloud computing data centers. We also concentrated on considering the trade-off between energy and performance.

We will refine and execute the scheduling algorithm in the future, adhering to the specified SLAs and necessary service quality standards.

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