Towards an Energy Optimization Framework for Cloud Computing Data Centers

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***Abstract*— The cloud computing concept has emerged as a powerful mechanism for data storage by providing a suitable platform of data centers. Recent studies show that energy consumption of cloud computing systems is a key issue. Therefore, the energy consumption should be reduced to minimize performance losses, achieve the target battery lifetime, satisfy performance requirements, minimize power consumption, minimize the CO2 emissions, maximize the profit, and maximize resource utilization.**

In this paper, we present a taxonomy of cloud computing systems and we will discuss many energy optimization considerations. Further, our paper focuses on virtualization, migration and task scheduling algorithms to minimize energy consumption in the cloud data centers. Applying a new idea of scheduling algorithms will help to control and optimize the mapping process time between the data center servers and the incoming tasks. This will perform an optimal deployment of the data center resources to achieve good computing efficiency, network load minimization and reducing the energy consumption in the data center. To evaluate the scheduler's efficiency we use one of the different kinds of simulators that were developed specifically for cloud computing environment.

Keywords—component; cloud computing; scheduling algorithm; green computing; energy optimization, virtualization, simulation.

I. INTRODUCTION

Typically, the constant changes in computers and communications technology led to the need of on-demand network access to shared computing resources to reduce cost and time and this is known as Cloud computing, which delivers computing services to users as a pay-as-you-go manner by emerging several distributed and high-performance computing concepts. The cloud makes reaching any information or source possible from anywhere eliminating the setup and installation step, such that the user and the hardware may co-exist in different places. This comes beneficial for the users or the small companies that cannot pay for the hardware, storage or resources as the big companies. The cloud users do not need anything but the Internet connection to reach their cloud providers without the need of paying for licenses or worry about the installation and updating any resources.

II. THE CLOUD COMPUTING CONCEPT

The cloud consists of either one or multiple data centers where each data center is built using a large number of storage units, servers and communication infrastructure and these resources are provided by cloud vendors using the pay-as-use scheme [1]. Cloud computing defined as follows:

- Reference [2] defines the Cloud computing in terms of its utility to the end user: "A Cloud is a market-oriented distributed computing system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resource(s) based on service-level agreements established through negotiation between the service provider and consumers."
- National Institute of Standards and Technology (NIST) [3] defines cloud computing as follows: "Cloud computing is a model for enabling 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. This Cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models."

A. Benefits of Cloud Computing

The following main benefits are the reasons behind the growing demand of cloud computing industry [4]:

- No software is needed for the users.
- Rapid implementation.
- Ease of maintenance.
- Reliability.
- Automatic updating.
- Flexibility of picking several service providers.
- Elastic and on demand basis existence of infrastructure.

- Reduced costs of deployment of services

III. Architectural Considerations

Cloud computing designers are able to explain the main cloud practices and benefits to the end users. Therefore, moving to cloud computing infrastructure requires the following hardware and software components:

A. Cloud Elements

The cloud architecture is based on the incoming tasks, data center broker and the main data center that have all the hosts, Virtual Machines (VMs), network connection and many other components. The key cloud elements are [5]:

- Data Center:

It encapsulates the hosts (memory, cores, capacity, and storage) and the existing connection between them. Every data center has a set of policies to control its components.

- Consumers/Brokers:

The broker acts as an intermediary between the customer and the cloud where it submits service requests from anywhere in the world to the cloud.

- Service Allocator:

It is the interface between the Cloud infrastructure and user.

- VMs:

Multiple virtual machines created on one physical machine to meet the need of processing multiple tasks on a single device.

- Physical Machines:

Physical machines are the main servers used in the data center which they can be virtualized later to meet the processing demands.

- Cloudlet:

The cloudlets are the number of tasks plus the amount of storage needed to process these tasks.

- Memory Provisioner:

It has the physical memory allocation policies for the VMs.

- Cloud Coordinator:

Responsible for the communication between multiple data centers and their brokers and supervise the internal state of the data center itself for load balancing decisions.

- Cloudlet scheduler:

The scheduler defines the police of execution of the incoming tasks.

B. The service Level Agreement (SLA)

It is defined as "a contract document or a formal negotiated agreement based upon the purpose and objectives that exists between the Cloud Service Providers and the cloud users."[6]. SLAs provide the user first with a clear view to the cloud environment, security, management policies and service monitoring as shown in *Fig. 1*.

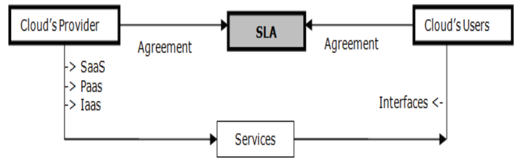

Figure 1. Service Level Agreement

C. Existing models

There are four main types of clouds. The user or company needs usually to define the cloud type that belongs to one of the following categories [3]:

- Public Cloud

The public cloud is about offering the cloud infrastructure to all the users and enabling the consumer to get the services with very little financial cost. This type cloud provides services to multiple customers.

- Private Cloud

It is a cloud created to be used by a specific organization or a precise user to have the ultimate control, security, and quality of service of the data.

- Community Cloud

It is a shared cloud infrastructure between two or more organizations to serve a common function or purpose.

- Hybrid Cloud

The hybrid cloud is simply a combination of two or more of the previously defined clouds type and bound them together as a unit.

D. Types of cloud Services

The cloud providers offer many types of services to their users [7]:

- Infrastructure-as-a-Service (IaaS)

It is the first layer of cloud computing. The provider here offers the hardware and the minimum limit of software for users to develop their work on the cloud infrastructure, and the user in this type gets the service and the ability to configure the settings and implementation of the software and programming environment (e.g., Rackspace).

- Platform-as-a-Service (PaaS)

PaaS is the second layer of cloud computing. It is the type of service where the user can build the service, and the application needed from the sources supplied from the Internet. The user who gets the PaaS service cannot have a complete control over the service. The existence of a software layer between the user and the hardware prevents him from getting a full control. This service eliminates the rule that says that the user has to be an expert to deal with such a service (e.g. Google App Engine).

- Software-as-a-Service (SaaS)

SaaS is considered as the final layer of the cloud services. It is the model in which the user can access an application that is hosted by the provider from a variety of devices through the Internet without the need of any installation, data loss or storage space (e.g. Google Docs) [8].

IV. Energy optimazation evolution

Cloud computing researchers are seeking to optimize the energy and they are facing many challenges including virtualization, migration and scheduling.

A. Virtualization

The Virtualization has been around now for more than a decade. It is the creation of a logical number of VMs on the same physical machine. It plays a decisive role in the cloud environment, and it is the heart of the cloud computing industry. Virtualization is a way to reach the ultimate and efficient use of resource's storage, and it provides data center deployment of new methods with reliable management for data to achieve green computing through the best utilization of data center resources. The motivation behind the establishment of virtual machine is to process different tasks on a single host. Each VM acts as a one physical server with its own RAM, CPU, NIC and hardware disk. The benefits of creating virtual machines in the data centers are [9]:

- Reduce infrastructure costs.
- Save energy.
- Faster server provisioning.
- Improve recovery.
- Isolate applications.
- Flexibility.
- Reliability.
- Ease of testing and developing phase.

B. VM Migration

It is an essential to manage cloud computing resources dynamically that's why the VM migration is becoming increasingly used in cloud computing. VM migration is transferring VM from a physical server to another, which grants workload balancing, hardware maintenance, high availability services and consolidated management [9].

The biggest advantages of using the live VM migration are:

1- To have a server consolidation which allows the maintenance of the virtual machine offline whenever needed or for upgrading without shutting down the whole system.

2- Maintain the load balancing in the data center.

We can turn off hosts when using VM Migration in the data center to have a better energy efficiency using server consolidation.

In any VM Migration process, two key questions will rise:

Q1. Which VM to migrate from an overloaded server?

Q2. Which server to pick as destination?

Answering these questions usually depends on the data center processing policy and the user demands.

C. Scheduling Techniques

The research community continually investigated the energy usage since the number cloud users is increasing [10]. One of the best ways to control the energy consumption within the data center is the use of a good scheduling technique. Scheduling algorithm is a way of managing and controlling the process of assigning incoming tasks to servers regarding the cloud user demands.

V. Cloud environment simulation

The fast growth of cloud research area implied the necessity of implementing tools to design an efficient data center infrastructure. A number of simulators have been precisely developed for cloud computing environments such as GreenCloud, CloudAnalyst, Cloudsim, Networkcloudsim, EMUSIM and MDCSim but only a few of them are available as an open source platform. Cloudsim simulator is the most sophisticated one among them all [11].

A. Cloudsim Simulator

Cloudsim is a novel Simulation-based approach for modeling and simulation the data center environments. It is the most popular cloud simulation tool that offers major benefits to cloud customers such as testing their services without any cost and the capability of making the needed adjustments to their data center structure before the real deploying it in the real-world [1]. The development of cloudsim simulator was in the CLOUDS laboratory at the computer since and software engineering department of the University of Melbourne.

B. Features Of Cloudsim Simulation

Cloudsim simulator is a free simulator and widely used by research scholars and practitioners. It offers many features to the users such as cloudlets creation and execution, load balancing, energy optimization, task scheduling and resource provisioning.

VI. Conclusion

Recent researches are struggling with the energy consumption rates in the cloud computing environment due to the escalating energy-hunger and CO2 emissions in the loud computing data centers.

This paper presented a survey on cloud computing and discussed the importance of minimizing the energy consumption of data centers. We introduced the main cloud architectural elements, models and services for a better understanding to reach the ultimate power optimization. Our idea is jointly based on virtualization, VM migration and scheduling under the regulations of the service level agreement. We introduced also a set of cloud computing simulators focusing on cloudsim as one of the most-used tools. Our future work consists to develop a novel framework to minimize the power consumption in cloud computing data center using cloudsim simulator.

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