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Energy-Aware Virtual Machine Allocations using Bin Packing Algorithms in Cloud Data Centers

Neha Solanki
Computer Science and Engineering Department
M.B.M Engineering College, Jai Narain Vyas University
Jodhpur, India

Rajesh Purohit
Computer Science and Engineering Department
M.B.M Engineering College, Jai Narain Vyas University
Jodhpur, India

***Abstract*—Due to the high requirement of cloud services, the data centers are kept running all the time. This eventually increases energy consumption. In addition to this, high energy consumption leads to costlier business. In this work, for reducing energy consumption, energy-aware policy is introduced which performs virtual machine allocation through various bin-packing algorithms such as best-fit-decreasing and best-fit-unordered. Migration of virtual machines among physical machines is applied as basic technique for reducing the energy consumption which minimizes the number of running physical machines to optimize the required energy.**

Keywords—Best-fit-unoreded; best-fit-decreasing; energy consumption; migration

I. INTRODUCTION

According to National Institute of Standards and Technology, USA [1] "Cloud computing is a model for enabling ubiquitous, convenient, 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". An important technology for cloud computing is virtualization, which multiplexes many Virtual Machines (VMs) on the same Physical Machines (PMs), and at the same time provide isolated environment to each Virtual Machines. VMs provide isolation among different operating systems.

In the IT world, as the use of cloud service has increased, energy consumption for these cloud services have also increased a lot. When the server is running at low utilization, then the wastage of energy occurs because total power consumption of server is more than 70% at the peak even in very low utilization [2]. From 2005 to 2010 energy consumption by data centers all over the world has increased by 56%, and in 2012 it is calculated between 1.1% and 1.5% of the total electricity used [3, 4]. One survey of six corporate data centers found that most of the servers were using only 10–30% of their available computing power, while desktop computers have less than 5% average capacity utilization [5].

To solve the problem of high energy consumption and server underutilization, it is necessary to remove the inefficiency in the way resources are utilized to serve application workloads. Efficient utilization of resources leads to the high server utilization and overall low energy consumption while offering required Quality of Service (QoS) for the customers that are negotiated in terms of Service Level Agreements (SLA), e.g. throughput, response time etc.

II. RELATED WORK

In recent years, researchers are taking interest in energy efficient mechanisms. Nathuji and Schwan *et al.* [6] have developed approach named VirtualPower, which manages online power in virtualized data centers. It has two types of policies for resource management: local and global. Local polices handles the guest operating systems' power management strategies while the global policies handle VM consolidation by migrating VM. Verma *et al.* [7] have developed an application placement controller named pMapper which meets the performance with minimizing energy and migration costs in heterogeneous servers. In this bin packing algorithms are applied with variable bin size and cost. Recently [8], Verma *et al.* have proposed a virtual machine consolidation approaches which is static and semi-static, and it has saved much more energy with compared to non energy efficient methods. Norman *et al.* [9] have developed an algorithm which allocates VMs to physical machines based on past history of demand and predicts future scenario according to the history. This algorithm uses first fit method and keeps SLA into consideration.

Gandhi *et al.* [10] introduce a queuing theory model that allows predicting the mean response time for optimal power allocation, with available power budget. The authors have found that for different scenarios the optimal power allocation varies. Cardosa *et al.* [11] have presented power efficient allocation problem of VMs, suitable for enterprise environment and private cloud. This approach does not support strict SLA and needs knowledge of application priorities. Aameek Singh *et al.* [12] have presented an algorithm which remaps the VM to physical machine by using dot product of capacity usage and resource requirement vector.

Beloglazov *et al.* [13] focused on dynamically consolidate of virtual machines. For virtual machine allocation Power Aware Best Fit Decreasing (PABFD) algorithm was used. They found out that their approach saves much energy relative to non power-aware system. Lin *et al.* [14] have focused on optimization of the resource allocation by considering it as constraint satisfaction problem. For virtual machine allocation they considered three types of resources: RAM, CPU and bandwidth. They proposed improved first-fit decreasing algorithm and improved best-fit decreasing algorithm for virtual machine allocation, and studied their performance.

III. ENERGY-AWARE VIRTUAL MACHINE ALLOCATION

The cloud services are usually run through data centers. In IaaS clouds, data centers provide Virtual Machines (VMs) as infrastructure service. Cloud users request to process their job/query from a data center by stating their resource demands (CPU, memory, and bandwidth). For this cloud provider gathers sufficient information about its available resources. To maximize utilization, VMs are formed on PMs and allocated to given job/query. On a single physical machine, multiple VMs can process job/query concurrently depending on physical machine capacity and the resource demands of the VMs (fig.1). Since the cloud services are scalable and available round the clock, the power is required to be supplied continuously which is causing high energy consumption. To energy consumption, it is necessary to allocate VMs to

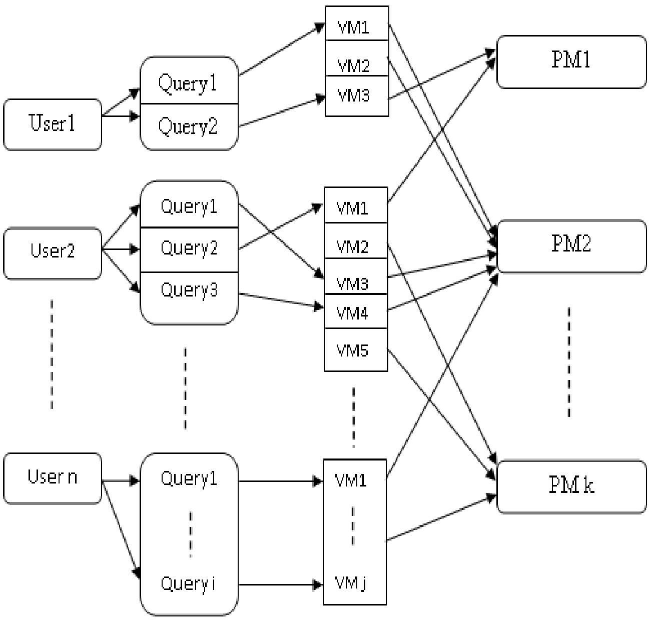

Figure 1: The Cloud Data Center.

physical machine properly and efficiently. VMs allocation on physical machines is carried out in such a way that in addition with meeting resource demand, the total energy consumption and SLA violation should be minimized.

The process of energy-aware virtual machine allocation is performed in two phases:

i. Allocation of VMs on physical machines.

ii. Migration of allocated VMs for consolidation.

A. Allocation of VMs on physical machines

VM allocation is carried out in cloud data centers with the help of bin-packing algorithms. Two types of bin-packing algorithms [45, 46] are used in this work for VM allocation, they are as follows:

a) Best-fit-decreasing allocation algorithm.

c) Best-fit-unordered allocation algorithm.

In these algorithms, VMs are allocated on the basis of CPU utilization which is measured in Million Instruction Per Second (MIPS).

- Best-fit-decreasing allocation algorithm: This algorithm sorts all the VMs in decreasing order (largest first) and then checks all the physical machines and allocates the VM to a physical machine which has the minimum remaining CPU capacity after allocation. If all the physical machines cannot allocate the VM requirement, then that VM request is dropped, which causes SLA violation.
- Best-fit-unordered allocation algorithm: This algorithm checks all the physical machines and allocates the VM to a physical machine which has the minimum remaining CPU capacity after allocation. If all the physical machines cannot allocate the VM requirement, then that VM request is dropped, which causes SLA violation. This algorithm does not sort the VMs in any order.

B. Migration of allocated VMs for consolidation

The main aim of consolidation is to reduce energy consumption and carbon emission by consolidating VMs. Consolidation of VMs is done by migrating VMs in order to

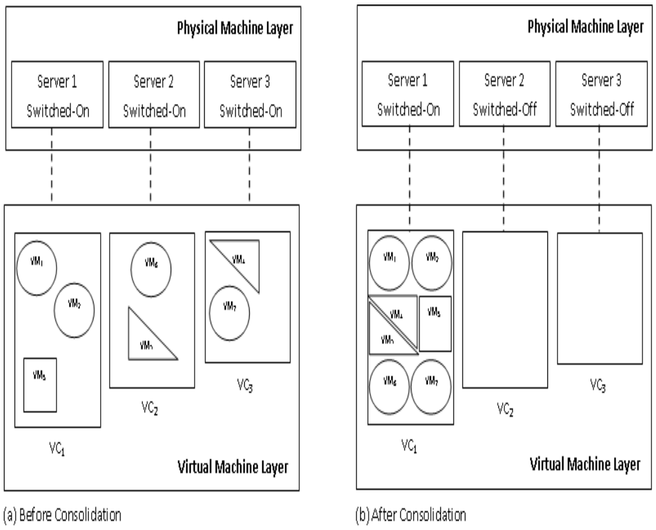

Figure 2: Consolidation of Virtual Machines in Cloud Datacenters.

decrease the number of running physical machine and switching off the idle physical machine as shown in fig.2.[15]

IV. EXPERIMENTS AND RESULTS

To measure the impact of carbon emission due to various VM allocation techniques, experiments are conducted on CloudSim-3.0.3 simulator. The performance analysis of virtual machine allocation in cloud data centers is carried out in energy-aware and non energy-aware scenarios heterogeneous resources. To analyze wide range of data, various observations were recorded by varying the number of physical machines and virtual machines.

The performance of energy-aware technique is measured by evaluating the virtual machine allocation criteria using following parameters:

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- Energy Consumption: This metric represents the total energy consumed by the data center.
- SLA Violation: This metric represents the percentage of unprocessed queries as per service level agreement.
- Number of Migrations: This metric represents the count of virtual machine migration carried out from one physical machine to another one.

Table I shows the simulated result of non energy-aware policy and energy-aware policies for heterogeneous resources. Comparisons between non energy-aware policy and energy-aware policy are carried out on the basis of energy consumption. Table I shows that energy consumption of non energy-aware policy is much higher than all the energy-aware policies.

TABLE I. COMPARISONS OF SIMULATED RESULTS FOR HETEROGENEOUS RESOURCES

Method	Energy Consumption(KWH)	SLA Violation	No. of Migrations
Non Energy-aware	23.33	-	-
Energy-aware Best-fit-unordered Allocation	4.33	0.64%	1090
Energy-aware Best-fit-decreasing Allocation	3.58	2.8%	813

In energy-aware policy using migration, best-fit-unordered allocation saves up to 81% energy relatively to non energy-aware with SLA violation of 0.64%. Best-fit-decreasing allocation saves up to 84% carbon footprints relatively to non energy-aware with SLA violation of 2.8%. Percentage of energy saving of best-fit-unordered and best-fit-decreasing are shown in fig. 3.

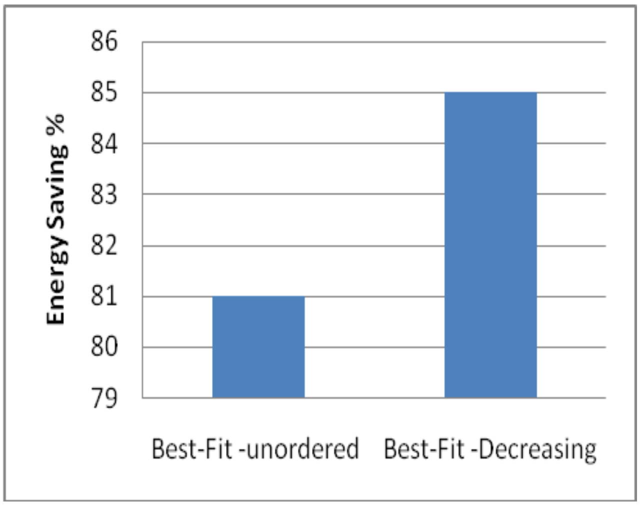

Figure 3: Energy Saving % of Best-fit-unordered and best-fit-decreasing.

V. CONCLUSION

Energy-aware virtual machine allocation is carried out according to the CPU utilization. The standard bin-packing algorithms; best-fit-unordered and best-fit-decreasing are used along with migration. Comparison between energy-aware policy and non energy-aware policy is carried out which shows that up to 84% energy can be saved by energy-aware policy relatively to non energy-aware policy.

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