Energy Efficient Resource Provisioning Through Power Stability Algorithm in Cloud Computing

Karanbir Singh and Sakshi Kaushal

Abstract Over the past few years energy consumption has become a major operational cost in data centers. Virtualization has been quite instrumental in reducing the energy consumption. Various researches have been focusing on developing energy efficient algorithms for developing power aware resource allocation and scheduling policies. Every virtual machine migration (VMM) incurs extra cost in terms of energy consumption. However, very few techniques exist which particularly focuses on reducing the total virtual machine migrations in a data center. This paper proposes an algorithm which profiles the overall energy consumed based on: max utilization of host after allocation, creation history of virtual machine (VM), and the difference in power consumed by host before and after allocation. The framework for the implementation of the proposed algorithm is conducted in CloudSim. The results show that reducing the total number of virtual machine migrations affects the overall energy consumption in the cloud.

Keywords Virtual machine · Resource provisioning, virtual machine migration · Energy consumption · Stability factor · MBFD

1 Introduction

Cloud computing is one of the biggest changes witnessed by the IT industry in recent times. Cloud computing introduces pay-as-you-go and access-anywhere model. However, modern day data centers continue to grow in complexity and scale. These data centers have become a major consumer of power and energy resources. This consumption results in high operating cost and high carbon

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dioxide emission in the environment. Carbon dioxide emission from datacenters significantly contributes to the green house effect. It contributes around 2 % of the global emission of carbon dioxide [1]. Statistics shows that average energy consumed by each data center is equivalent to energy consumption of 250,000 household appliances. According to survey of American society of heating, refrigerating, and air-conditioning engineers (ASHRAE) in 2014, the infrastructure and energy consumption cost 75 % of the total expenditure, whereas operating a data center costs only 25 % [2]. Power consumption of server is studied in [3] and results show that it cost 7.2 billion dollars in 2005 for the amount of electricity used by servers all over the world. This also includes electricity consumption for cooling purpose and of auxiliary equipments. Facts also indicate that the electricity consumption of this year is double of what it was in 2000. Managing resources in an energy efficient way is the biggest challenge that data centers are facing and it will grow rapidly and continuously unless energy efficient and advance methods of data center management are developed and applied [4–6].

Energy is mainly wasted because computing resources are used inefficiently. According to the previous year's data, even when the servers are rarely at idle mode, the utilization is never 100 % [7]. Servers normally use 10–15 % of their peak capacity but data center owner has to pay expenses of over provisioning which further results in extra Total Cost of Acquisition (TCA) and Total Cost of Ownership (TCO) [7]. Therefore, underutilized servers play a vital role in inefficient energy consumption. Another problem arising due to high energy consumption and increasing number of server components is the heat dissipation. There are efficient cooling systems in today's world but few years back, for 1 watt of power consumed, an additional 0.5–1 W was required for cooling system [8]. Beside the overwhelming cost and electricity bills, another problem arising from this issue is 2 % of global carbon dioxide that is emitted by data centers [1]. According to the estimation by the U.S. Environmental Protection Agency (EPA), the current efficiency trends led to the increase of annual CO_2 emissions from 42.8 million metric tons ($MMTCO_2$) in 2007 to 67.9 $MMTCO_2$ in 2011.

All these reasons arise the need of saving energy and power in all aspects and it becomes a first-order objective while designing modern computing systems. The rest of the paper is organized as follows: in Sect. 2, work related to different energy efficient algorithms is discussed. Section 3 describes the problem formulation and the proposed power stability algorithm (PSA). In Sect. 4, we analyzed the proposed algorithm using different parameters. Section 5 concludes the paper.

2 Related Work

Buyya et al. [9] proposed policies for selecting VMs in VM migration. These policies minimize the migration overhead as least number of VMs has been migrated. Cao et al. [10] described an extension of virtual machine consolidation (VMC) policy. In this improved policy, basic MC policy is used. Initially mean and standard deviation of CPU utilization of host are determined and then further is used to find out whether a host is overloaded or not. Second, on the basis of knowledge of statistics, range of correlation coefficient is divided into negative correlation and positive correlation. Panchal et al. [11] described virtual machine allocation as an important feature in cloud environment and provided information of allocated virtual machine in the datacenter. According to the authors, allocation policies are implemented at infrastructure layer and virtual machine allocation can be made transparent to the user. Wood et al. [12] proposed a hotspot detection algorithm that detects when the VM should be migrated. Greedy algorithm used by hotspot migration determines the destination host for migration as well as evaluates the quantity of resources that need to be allotted to VM after migration. Hai et al. [13] described compression techniques and characteristics-based compression algorithm (CBC/MECOM) for fast, stable live migration of virtual machine data. On source side, data that are to be migrated are compressed first and then migration is done. Ma et al. [14] proposed an improved pre-copy approach. Bitmap page is added to Pre-copy approach, which records or marks the frequently updated pages. Those pages are then added into the page bitmap. So, the updated pages are transferred only once at the end of iterations. This approach minimizes the quantity of data for transferring which further minimizes the total migration time. Using bitmap page also reduces number of iterations. Lie et al. [15] proposed a new approach for virtual machine migration which is known as an improved time series-based pre-copy approach. In this technique, concept of prediction is used to find out those dirty pages that are updated very frequently in the past and a precise prediction is done on those pages that are going to be updated frequently in the future also. Hines et al. [16] proposed post-copy approach for live VM migration. In this approach processor state of VM is first transferred to destination host, started the VM on the destination host and at last the memory pages are transferred. Memory pages that are not successfully transferred are known as demand pages, which are transferred at last from source and then the VM at source is suspended. The main benefit of this approach is that no duplicate transmission of memory pages is done, thus avoiding the overhead for the same as in pre-copy approach. Downtime of post-copy is higher as compared to pre-copy approach.

Stoess et al. [17] proposed a framework for energy management on virtualized servers. Generally, energy-aware OSes have the full knowledge and control over the underlying hardware and based on this, device or application-based accounting is applied in order to save energy. Cardosa et al. [18] deals with the problem of allocating virtual machines in a power efficient way in a virtualized environment. A mathematical formulation of the optimization problem is proposed by the author. Author calculated the power consumption and utility gained from the execution of a VM and named the combined results as “priori”.

From the review of literature, it has been found that there can be further improvement in the allocation policies of VMs to their destination hosts. So in this paper, we proposed a new algorithm which considers the power and stability factor while choosing a destination host. The proposed power stability algorithm (PSA) provides stability while minimizing the overall power.

3 Proposed Work

In cloud computing most of the servers in the data center are running continuously and consuming 70 % of their resources in the idle state [19]. Therefore, it is very difficult to estimate the threshold limits with accuracy as the whole utilization history of the host has to be calculated. If a host has been underutilized for a significant amount of time then it is better to shut it down so as to save energy. But shutting down a host is not easy as just turning a switch on or off. It can lead to SLA violations and maybe a single point of failure and also degrade performance. MBFD algorithm is one of the fastest algorithms available for choosing a destination host [9]. It has a linear complexity. It is used for deciding destination hosts for the purpose of allocation of VMs. It maintains a list a VM that needs to be migrated and a list of destination hosts. MBFD basically maps a VM to its destination host. The work carried out in this paper focuses on the enhancement of allocation policies for VMs such that number of VM migrations and overall energy can be reduced. The proposed algorithm, namely, power stability algorithm (PSA) can successfully reduce the number of migrations and consumption of energy.

3.1 Power Stability Algorithm (PSA)

VM placement and scheduling are studied in the aspects of resource scheduling and VM migration latency. VM allocation in cloud computing environment should be done such that the stability of the destination host is increased, i.e., the host should not be involved in any kind of migration for longer periods of time. To achieve this, we have proposed an algorithm with linear complexity, namely, PSA, which is based on MBFD algorithm. However, the PSA considers a number of factors that has not been considered in MBFD algorithm for selecting best suitable host for a particular VM from the list of all available hosts. The algorithm is based upon the following additional factors:

- Maximum Utilization of host after allocation
- Creation history of the VM
- Power of host after allocation

In general, the process of VM migration consists of the following steps: deciding the instant when to migrate a VM, choosing the most appropriate VM for migration, choosing a destination host where the particular VM shall be migrated, and finally choosing which hosts from the host list need to be switched on/off. Choosing a destination of particular VM is very important. The proposed technique is based on the fact that there is a considerable amount of energy and resources consumed while migrating a VM to a host. Moreover, during migration a particular user may witness degradation in performance. Therefore, we need to minimize the number of migrations so as to improve performance and save energy. This can only be possible if the stability of the host is increased. Stability of a host means that the total number of migrations in and out of the host is minimum. The more the stability the less the number of migrations. So, less will be the energy consumed in migration of VMs, resulting in overall reduction in energy consumption. We have calculated each host's utilization in our implementation. After calculation of each host's utilization, we made a list consisting of all hosts with their respective utilization values. From this list, while choosing the destination host, we calculated the increase in utilization for each host for that particular VM and selected the host with least increase in utilization.

3.2 PseudoCode

This section presents the detailed steps of the algorithm.

Pseudo Code

```
Begin
Step 1: Get list of all eligible hosts.
Step 2:While host list is not empty, for each host repeat the following:
    Step 2.1: Calculate the maximum utilization of each host for that particular VM.
    Step 2.2: Select host for which increase in utilization is minimum
End loop
Step 3: Check creation history of the VM.
    Step 3.1: If VM is NOT recently created and maximum utilization exceeds upper utilization
              threshold go to step 2.
    Step 3.2: Else choose that particular host for migration.
Step 4: Obtain the power of host for that particular VM.
Step 5: Calculate power difference of power after allocation and current power of host.
Step 6: Allocate the VM to that host where there is minimum power change.
END
```

4 Results and Discussions

The proposed algorithm is implemented in CloudSim. In order to analyze the work, various input sets (in terms of tasks/cloudlets) are given to the system. Each cloudlet is created randomly at runtime. Each cloudlet is then added to a central cloudlet list. Similarly, a list of VMs is also prepared at runtime consisting of all the randomly created VMs. Both the cloudlet and VM list are provided to the data center broker at runtime. Datacenters are also created containing the hosts in Cloudsim. In-bulit functions are used to calculate power of a host for a particular VM and power difference after allocations, etc. The results are analyzed with two

Table 1 Simulation parameters

Number of host machines	200
VM migration lower threshold	20 %
VM migration upper threshold	70 %
Host RAM	16,384 MB
Host bandwidth	10 Gb/s
VM size	2500 MB

performance evaluation parameters, i.e., the total energy consumed and the total number of migrations. The simulation parameters used are shown in Table 1. Five samples are captured by running simulation experiments for particular number of cloudlets.

We have compared our proposed algorithm, i.e., PSA with MBFD algorithm by considering various parameters like energy consumption and number of migrations. The following graphs show the result of the simulations. It is evident from Fig. 1 that energy consumption is increasing with the increase in number of cloudlets. Energy consumption in case of MBFD algorithm is increasing linearly. It can also be noticed that as the number of cloudlets is increasing the difference between both algorithms also increases. This happens because more VMs have to be created to manage the tasks. With increase in number of VMs, the total consumed energy also increases. Between 90 and 100 there is a sharp increase in energy consumption for MBFD algorithm because of random specifications of cloudlets that are being created at periodic intervals. Overall, our proposed algorithm consumed 23 % less energy as compared to MBFD algorithm. The main reason for this difference is that PSA has considered stability factor of a host before migrating a VM to it.

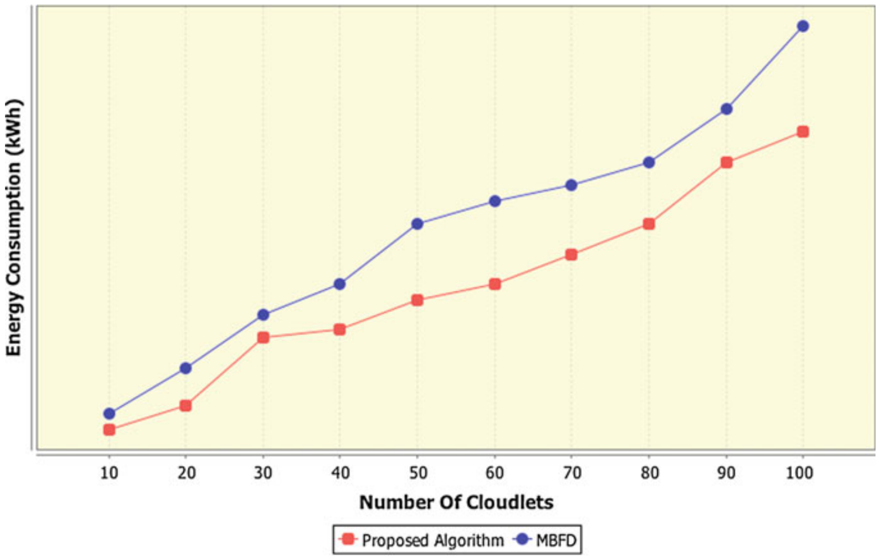

Fig. 1 Energy consumption

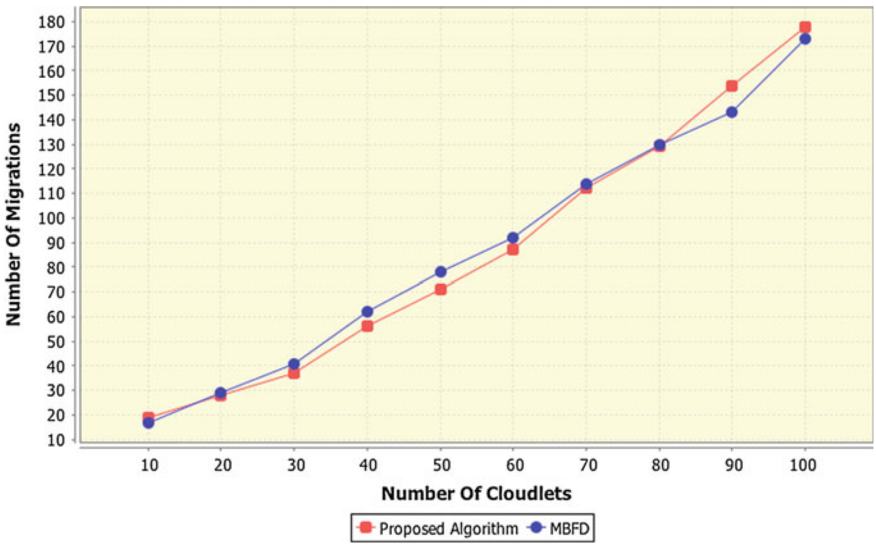

Fig. 2 Number of migrations

As it is observable from Fig. 2 the number of migrations in both the algorithms has been erratic. There is only a minor difference in the number of migrations between both algorithms for a particular number of cloudlets. With increase in number of VMs the total consumed energy also increases. This happens because the proposed algorithm takes into account the stability factor of the destination host. In this algorithm, the VMs have been migrating to hosts having the highest stability factor. This leads to the overall increase in stability of the datacenter, which decreases the total number of migrations that are taking place.

Hence, it is shown that the stability factor of a host has a direct influence on the power consumption of that host. The higher the stability factor less will be the number of migration and therefore less will be the power consumed.

5 Conclusion

This paper focuses on enhancement of VM allocation policies in such a way that energy consumption and number of VM migrations can be reduced. The performance of PSA is evaluated in CloudSim 2.0 simulator for validating the effectiveness and accuracy of results. During each simulation, maximum utilization of host is calculated after each allocation. After each migration the stability factor of host has been recalculated based upon the type of VMs it holds and increase in power after allocation. This strategy proved very efficient in reducing the number of migrations in the data center. As a result PSA consumes 23 % less energy in comparison with MBFD algorithm. To conclude, the results demonstrate that PSA has immense potential as it offers significant energy saving with comparatively less VM migrations under dynamic workload scenarios as compared to MBFD algorithm.

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