Efficient Policies of Data Management in Cloud to Reduce Energy Consumption of Data Center

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ABSTRACT: *Cloud computing has become over the last years an important paradigm in the computing landscape. Its principle is to provide decentralized services and allows client to consume resources on a pay-as you-go model. The growing demand for this type of service brings providers service clouds to increase the size of their infrastructure to the point that the energy consumption and associated costs become very important. This cloud infrastructure comprise several compoments such as servers, cooling systems, etc. In the server of data center , CPU and RAM are the compoments which consumes an important quantity of energy. In this paper, we present three policies (FDT, DDT based on CPU utilization thresholds and DRT based on CPU utilization and RAM capacity) each one with two phases. The selection phase which is based on physical resources thresholds (one or two physical resources) and the allocation phase to place the migrated VM on hosts. We simulate the proposed approaches on CloudSim simulator and compare them with existed approaches. Our proposal allows reducing energy consumption, number of migrations, the number of SLA violations and thus minimizing the CO2 emission.*

Keywords: Data Center, Cloud Computing, Energy Consumption, Virtualization, Migration, Service Level Agreement

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1. Introduction

Cloud computing has become over the last years an important paradigm in the computing landscape. It meets the needs growing demands in terms of availability and flexibility. The remarkable development of cloud computing in recent years attract more and more interest from various users of the Internet and computer looking to enjoy the best of services and applications available online through the Web user demand services and usage billing. The infrastructure of cloud computing is composed of several Data centers which are also composed of a set of servers, cooling systems, switching and network components. In cloud computing, the energy consumption is a very important subject which has become a very large problem over the years requiring effective solutions.

The power consumption of data centers worldwide was estimated in 2010 between 1.1% and 1.5% of the overall power consumption. This energy consumption is more than 200 billion kilowatt-hours (Koomey, 2008). The energy consumption is steadily rising over the years. It was estimated by 12% per year in 2007 in the United States Environmental Protection Agency to achieve a cost of electricity used by servers of data centers estimated by 7.4 billion (Brown, 2007). Power is a strategic issue for cloud data center: not enough electricity, a data center can't function. It is for this reason that data centers are built in areas where electricity infrastructures are important. The energy consumption of server rooms is increasing to meet the needs including web services.

The power consumption of data centers has doubled in 5 years and studies show that the trend is accelerating. According to a study by Stanford University, a few existing 500,000 data centers worldwide consume about 30 billion watts of electricity per year, equivalent to the output of 30 nuclear power plants (GLANZ, 2012). The consequence of energy consumption in data centers is due to several reasons. The storage servers can almost never be stopped to avoid losing the data entrusted by clients in data centers. They work 24 hour/ 24 hour, every day of the year. Furthermore, these servers are electronic devices that generate large amounts of heat. Their good functionality is ensured by energy-intensive air conditioning systems. The main part of the power consumed by a server is taken into account for the processor, followed by the RAM.That is why we have taken them into account in our approaches. Among the techniques for reducing energy consumption, we have virtualization, migration and the change of PMs (Physical Machine) states (on / off). Virtualization technology is to give access to two different clients to a complete virtual machine (VM) on the same PM. The migration technique migrate VMs from one machine to another.

The main objective of this work is to develop three efficient policies and algorithms (Fixed Double Threshold Migration (FDT), Dynamic Double Threshold Migration (DDT) and Double Resource Threshold Migration (RDT)) for virtualized data centers. We present a framework aimed at improving the performance delivered to cloud applications, while reducing the energy consumption of the involved data centers. This framework features a number of techniques, like Virtualization, Virtual Machine Migration and DVFS to switching off unused resources (Beloglazov et al., 2011b). The proposed algorithms are based on lower and upper physical resources thresholds (CPU utilization for FDT and DDT policies, CPU utilization and RAM capacity for RDT policy). The paper investigates energy savings on data centers. The main contribution is a two-phases approach. The first phase considers virtual machine migration. In the second phase, the aim is to allocate the VM using MBFD (Modified Best Fit Decreasing) algorithm.

The reminder of this paper is organized as follows: in the next section we describe the cloud and energy models; in Section 3, the related work are presented; in Section 4, we present our proposed approaches that aim to reduce energy in cloud computing; the description of the steps of simulation is presented in section 5; The experiments results are presented in section 6. We conclude the paper in Section 7.

2. Models

In this section, we describe the cloud and energy models used in our work.

2.1. Cloud Model

We assume that a data center contains many physical machines (PMs), which hold several VMs on it, and applications (cloudlets) are capsulated in VMs.

For cloudlets:

$\{T_1, T_2,\ldots,T_S\}$: S is the total number of cloudlets.

For Hosts:

$\{h_1, h_2,\ldots,h_n\}$: n is the total number of hosts.

For Vms:

$\{V_1, V_2,\ldots,V_m\}$: m is total number of VMs.

u_i: $\{u_1,u_2,\ldots,u_m\}$ is the required CPU utilization for each VM.

CPU_i: $\{CPU_1, CPU_2,\ldots, CPU_m\}$ is the required CPU utilisation for each VM.

RAM_i: $\{RAM_1, RAM_2,\ldots, RAM_m\}$ is the required RAM capacity for each VM.

2.2. Energy Model

To calculate the energy consumption, it exist several methods. In our case, we have used "power regarding utilization" method.

The studies demonstrate that the energy consumption is described like a linear relationship between the energy consumption of the processor and its utilization. Studies have shown too that a mean power consumed by an inactive server is 70% from the energy consumption compared to a server wholly used. According to (Sinha & Purohit), if the processor utilization is higher than 30%, then the lower value is constantly 0.3. The energy consumption P(u) is calculate by the following equation:

$$P(u) = P_{max} * (0.7 + 0.3u)$$

$$P_{max} = 250 \text{ watts for the modern server}$$

The constant 0.7 is the mean power consumption by an inactive server (when a server is fully used).

u is the processor utilization.

To calculate the total energy consumption of the servers, we have used the equation (1):

$$E(s) = \int_t P(u(t))\, dt \tag{1}$$

$u(t)$ is the processor utilization in the time.

The energy consumption of the data center is calculated as follow:

$$E_D = \frac{\sum_{j=1}^{m} P(u)_j}{n} \tag{2}$$

n is the number of the physical node present in the data center.

3. Related Work

(Beloglazov et al., 2011a) have introduced two phases to optimize the allocation of VMs. The first one is the selection of the VM to be migrated. In this phase three policies have been proposed: Minimization of Migration policy (MM), Highest Potential Growth policy (HPG) and Random Choice policy (RC). The second phase is the placement of the VM selected by the proposed policies. The algorithm MBFD (Modified Best Fit Decreasing) was used to allocate the VMs.

(Dad & Belalem, 2014) discuss the different technologies applied in order to reduce power and energy consumption. They also review the problem of energy consumption in cloud computing and how it is addressed in the literature.

(Sasikada, 2013) discuss in several ways found in scientific literature to optimize the consumption of energy and power. They give general methods to workload placement with the energy constraint. In (Buchbinder et al., 2011), the authors propose online algorithms for migrating applications within a cloud of multiple data centers. As results, these algorithms determine which job should be migrated and to which hosting location. The proposed approach takes into account the bandwidth costs and the current job allocation. The authors evaluate the performance of the algorithms on a real electricity pricing and job workload data and compare the results with other existed algorithms.

In this article (Mazzucco & Dyachuk, 2012), the authors propose an algorithm that aims to maximize the users experience while minimizing the amount of electricity required to run the IT infrastructure.

(Lee & Zomaya, 2010) calculate energy consumption by an objective function of the two proposed heuristics (ECTC and MaxUtil). The authors have compared the results between the algorithms applied to a set of tasks (ECTC, MaxUtil and Random) and algorithms with migration tasks (ECTC_m, MaxUtil_m and Random_m). The experimental results show that the heuristics ECTC and MaxUtil reduce energy consumption.

(Sekhar & Jeba, 2013) have proposed a method to detect over and under CPU utilization of servers. They used migration to transfer some VMs from a physical node to another. For the allocation of VMs, they used Greedy heuristics. The results are better in energy-performance than the previous heuristics used in the literature.

(Dad et al., 2014) have developed an efficient policy and algorithms for virtualized data centers. They proposed two-phases approach. The first phase considers virtual machine migration. This phase uses an algorithm to select the VMs to be migrated with the DTM algorithm. In the second phase, the aim is to allocate the VM using MBFD algorithm. The proposed approach is much better compared to the existed approaches. It consume less energy, allows the reduction of the VMs migration and the number of SLA violations with energy constraint. The energy efficient is necessary to maintain the problem of the growth of the future infrastructure and the data centers.

In (Uchechukwu et al., 2014), the authors present formulas for calculating the total energy consumption, solutions and models to resolve the problem of energy consumption and emission of carbon dioxide of data centers. They have presented their energy consumption architecture. They have also provided generic energy consumption models for server idle and server active states.

4. Description of the Proposal Approaches

4.1 Propositions

In this section, we present our propositions which use different technologies to reduce number of migrations, energy consumption and CO_2 emission. These technologies are the *virtualization*, the *live migration of VMs*.

Our model is defined as a data center that consists of a set of hosts (Physical Machines (PMs)). Each host can contain m virtual machines (heterogeneous VMs). The PMs and VMs has some physical resources like CPU utilisation, RAM capacity, storage, Thresholds, MIPS, etc.

The goal of our approach is to propose a strategy based on the migration of the virtual machines. This proposition lets us to select a minimal number of VMs. The advantage of this strategy is to increase substantially the rate of the server utilization and decrease energy demand and CO2 emission. Our problem is how to reduce the energy consumed by data centers without degrading their performance, which leads to minimize the heat production and CO2 emissions, it is means a low waste, a high utilization of servers resources and therefore can contribute to Green Computing (Green IT)

To resolve the problem of energy consumption and CO_2 emission, we proposed in this paper three policies which are: *Fixed Double Threshold (FDT), Dynamic Double Threshold (DDT)* and *Double Resource Threshold* algorithms (DRT).

The three policies are based on two phases:

Phase1: We select in this phase the VMs to migrate using *FDT, DDT or DRT.*

Phase2: The migrated VMs are placed on the physical machines using *MBFD* algorithm.

4.2. Selection Phase

4.2.1 Fixed and Dynamic Double Threshold policies

The selection of the VMs in these policies is proposed as follow: Firstly, We define two thresholds of CPU utilization (upper and lower) for each PM. If the CPU utilization of the PM is higher than the high threshold; then we must transfer some VMs to reduce the risk of SLA (Service level Agreement) violations and reduce the utilization of the host. If the CPU utilization of the PM is lower than the low threshold; then we must migrate all the VMs and set the idle host to the off state. In these policies, we take into consideration one physical resource (CPU utilization).

We present now how we obtained the fixed and the dynamic threshold.

a) Fixed Double Threshold

In this type of threshold, the selection of the upper and lower CPU utilization thresholds is fixed during the entire simulation. According to the experiments in the paper (Beloglazov et al., 2011a), the authors have obtained several results after a lot of number of simulations with several values of thresholds. They noted that it is important to leave an interval of 40% between the two thresholds. Fixed thresholds are not suitable for an environment with dynamic and unpredictable workloads.

b) Dynamic Double Threshold

A dynamic environment has different types of applications that can share the same physical resource. The system must be able to adjust automatically its behavior based on models of workload exhibited by applications.

Therefore, we use a technique to calculate automatically lower and upper CPU utilization thresholds. This technique is based on a statistical analysis of historical data collected during the lifetime of virtual machines (Sinha et al, 2011). We now present formulas to calculate the dynamics thresholds.

a) Upper Threshold

Upper threshold T_{U_i} is calculated by the formula (5) as follow:

$$U_i = \sum_{m}^{j=1} u_j \tag{3}$$

$$S_{U_i} = \sqrt{\sum_{j=0}^{m} u_j^2} \tag{4}$$

$$T_{U_i} = 1 - (\left(\left(P_{uu} * S_{U_i}\right) + U_i\right) - (\left(P_{ul} * S_{U_i}\right) + U_i \tag{5}$$

$\boldsymbol{u_j}$: CPU utilization of the *VMj*.

$\boldsymbol{m}$: Number of virtual machines.

$\boldsymbol{U_j}$: CPU utilization of the physical machines *i*.

$\boldsymbol{P_{uu}}$: equal to 95% (Sinha et al, 2011).

$\boldsymbol{P_{ul}}$: *equal to 90% (Sinha et al, 2011).*

b) Lower threshold

Lower threshold is calculated by the formula (8) as follow:

$$U_i = \frac{1}{m}\sum_{j=1}^{m} u_j \tag{6}$$

$$S_{U_i} = \sqrt{(\sum_{j=0}^{m} u_j - U_i)^2} \tag{7}$$

$$T_l = \begin{cases} U_i - \left(P_l * S_{U_i}\right), & if\ CPU\ Utilization < 0.3 \\ 0.3, & if\ CPU\ utilization > 0.3 \end{cases} \tag{8}$$

$\boldsymbol{u_j}$: CPU utilization of the virtual machine *j*.

$\boldsymbol{m}$: Number of *VMs*.

$\boldsymbol{U_i}$: CPU Utilization of the physical machine *i*.

$\boldsymbol{p_l}$: Equal to 90% (Sinha et al, 2011).

4.2.2 Double Resource Threshold Migration policy

In DRT approach, to select a number of VMs to migrate, we:

- Take into account two kinds of physical resources: CPU utilization and Memory Capacity (RAM).
- Use two thresholds (lower and upper) for each physical resource.
- Set to the off state unused machines.
- For the upper and lower thresholds of CPU utilization, we use the dynamic thresholds calculated by formulas cited above.

The Double Resource Threshold Migration (DRT) algorithm takes the list of VMs in descending order of the resource utilization (CPU and RAM). It repeats the process for each host in the data center to find the best VM to migrate. The algorithm verify for each host, if the utilization of CPU and RAM is higher than the upper threshold of CPU and RAM respectively. If it's the case, the algorithm must choose some VMs to migrate and make the utilization of the host less than the upper threshold. The upper and lower thresholds of CPU are calculated dynamically.In the treatment, the chhsed VM is the VM with the high utilization of CPU or RAM.

If the host resource utilization (CPU and RAM) is below the lower threshold, the algorithm makes a migration of all VMs to other machine and turn off the machine in question.

For the allocation of the migrated VMs which are selected by one of the three approaches described above, we use the modified MBDF algorithm.

4.3. Allocation of the VMs Using Modified MBDF Algorithm

After selecting the migrated VMs by one of the three policies using the first phase. We present now how we allocate these VMs in the PMs using the second phase. The allocation phase is done using modified MBDF algorithm.

For each VM in the migrated list of the VM in the data center, the algorithm chooses a physical machine (PM) able to allocate this VM. It verifies if the PM has sufficient resources for this VM: CPU utilization (if the policy is FDT or DDT) or CPU utilization and RAM capacity (if the policy is DRT). If it is the case, the algorithm cheeks if the physical resources of the PM after allocation is lower than the upper threshold. When this condition is true, the modified MBFD calculates the difference between the current energy consumption and the energy after allocation. If this value is the smallest comparing to all the hosts energy consumption, we allocate the VM to this PM. If the conditions are not satisfied, the algorithm chooses another PM.

5. Simulation

The simulation of the approaches is realized in the CloudSim Simulator and exactly in the power package. The Figure 1 presents the simulation steps of the FDT and DDT algorithms. As it is shown, the UpdateCloudletProcessig() method in the PowerDataCenter.java class updates the number of energy used and if the VM migration is active, it call the OptimizeAllocation() which select and allocate the migrated VMs list.

The selection phase is done with the selectionVMs() method. This method cheeks which type of approach is it, if the user selects the DDT approach, the algorithm calculates the thresholds with the formulas. Else, if the FDT approach is selected, the system takes the fixed thresholds of the CPU utilization entered by the user. This method returns a list of migrated VMs. The allocation phase is done by the AllocationVms() method and returns a host for each Vm in the migrated VM list.

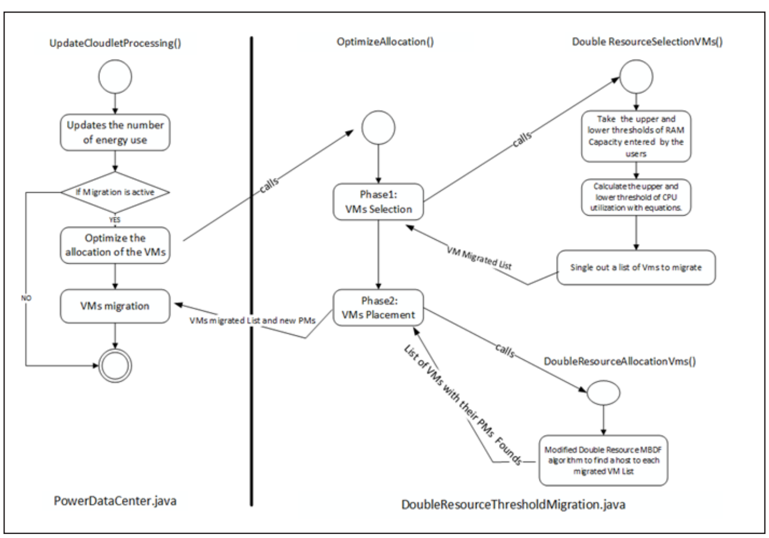

Figure 1. Fixed and dynamic Double Threshold Migration Simulation

In the Double Resource migration policy, the approach is divided also into two phases (see Figure 2). In the selection phase, the system calls DoubleResourceSelectionVms() method which chooses some VMs to migrate taking into account RAM capacity and CPU utilization. This method calculates dynamically the CPU utilization thresholds and takes a fixed RAM capacity lower and upper thresholds. After the selection of the migrated VMs, DoubleResourceAllocationV() search a host to each VM taking into account two physical resources (CPU and RAM). We find these two methods in the DoubleResourcethresholdMigration.java class.

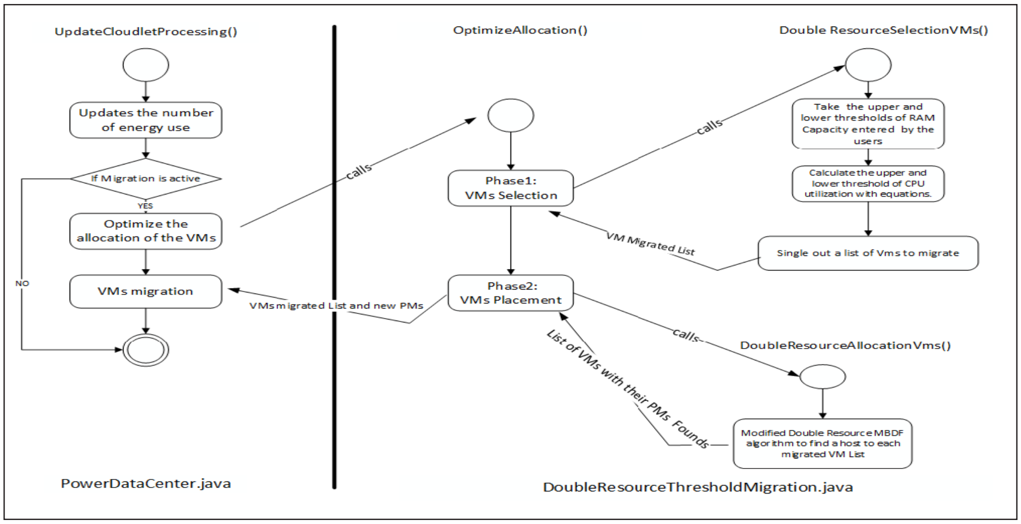

Figure 2. Double Resource Threshold Migration policy

6. Experiments Results

To evaluate the performance of our proposition, we are using CoudSim as simulation platform. CloudSIM is a new, generalized, and extensible simulation framework that allows seamless modeling, simulation, and experimentation of emerging cloud computing infrastructures and application services.

In order to compare the efficiency and evaluate the performance of our approach, we use three metrics: the energy consumption of the data center, Migrations number and SLA violations.

In order to study the behavior of our proposed approaches FDT, DDT and DRT and analyze the results obtained by the simulation, we compare our policies with two existed policies. The first one is the Non Power Aware (NPA) or Without Migration (WM) policy which does not apply any power aware optimizations and implies that all hosts run at 100% CPU utilization and consume maximum power all the time. The second policy is the Single Threshold (ST). It is based on the idea of setting the upper utilization threshold for hosts and placing VMs. At each time, all VMs are reallocated using the MBFD algorithm with additional condition of keeping the upper utilization threshold not violated.

Heterogenious Hosts Parameters		**Heterogenious VMs parameters**	
Host Number	100 hosts	VMs number From	30 to 300
CPU Core	1 core	CPU Core	1 core
MIPS	{1000, 2000, 3000}	MIPS	{250, 500, 750, 1000}
RAM	{6, 7, 8 GB}	RAM	{128, 256, 500 MB}
Storage	1 TB	Storage	1 GB

Table 1. Hosts and VMs parameters

In our simulation, several sets of simulations were undertaken according to several parameters. We have simulated a single data center comprising the Hosts and VMs parameters indicated in the Table1. Regarding the power consumption by the hosts, it is 250W with 100% CPU utilization and 175 W with 0% CPU utilization.

To evaluate the policies, We take in our experiments the threshold of the ST policy of 0.6. For the lower and upper thresholds of the Fixed Double Threshold policy (FDT), we take the values 0.3 and 0.7. For the upper and lower threshold of RAM capacity, we have taken 10% and 90% of the total utilisation of RAM.

6.1. Energy Consumption

In these results, we note that the energy consumed by our approaches FDT, DDT and DRT is below the energy consumed by other approaches (WM and ST) (see Fig. 3).We can deduce that our approaches produces less heat which is classified among the approaches of green computing. As it is shown in the Figure, DRT and DDT reduced less energy than the FDT policy because the upper and lower thresholds of CPU utilization in the two approches are calculated dynamically using formulas. By comparing the results obtained by the two approaches DRT and DDT. we note that DDT provided less energy compared to DRT when the host and VMs number is important. This is because DRT approach takes into account the two resources that consume the most energy in a server which are CPU utilization and RAM capacity.

We also note that when the number of VMs is greater than 240, the shape of the curve DRT decreases relatively to the curves of the other approaches which tend to increase. This change is justified by the made when the number of VMs in a host is high, a great need to use the CPU and RAM is required causing a large Data treatment for both physical resources, over use of PM, a large power consumption and high heat output. Consequently, DRT reduces this high workload and this energy consumption by making use of the CPU and RAM during the simulation below the upper thresholds of CPU and RAM and migrating some VMs to other PMs.

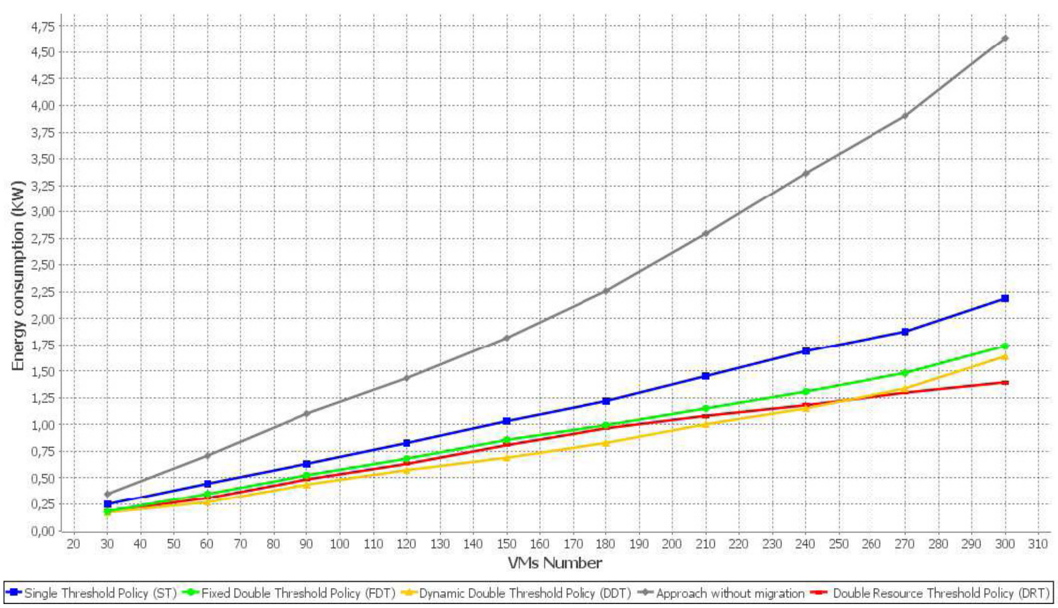

Figure 3. The energy consumption

The DDT policy reduced the energy consumption of the Data center with a gain of 63.85 % compared to WM, a gain of 29.91 %, 12.77 % and 2.89 % compared to ST, FDT and DRT policy respectively. The approach DRT reduces power consumption with a gain of 10.17% in comparaison to FDT.

6.2. Number of Migrations

In this series of simulations shown in Figure 4, we notice an increase of VMs migration in the three approaches with the increase of the VMs. We can justify this by increasing the number of VMs. We also note that with the increase of the number of VMs, the difference between the curves increases and the curves of the proposed approaches are below the curve of the ST approach. DRT, FDT and DDT are much better than the ST approach and help us to minimize the number of migrations. DRT policy creates more migration than FDT and DDT approaches. This is caused by the "over utilization" of physical resources (CPU and RAM). In order to reduce the use of these resources below upper thresholds, an aggressive migration of VMs is helpful.

The number of migrating VMs produced by DDT policy is reduced compared to the ST policy by 86%, by 81% and 50.86% compared to DRT and FDT respectively. The DRT and FDT policies reduce the number of migrating VMs by 24.72 % and 71.20 respectively compared to the ST approach.

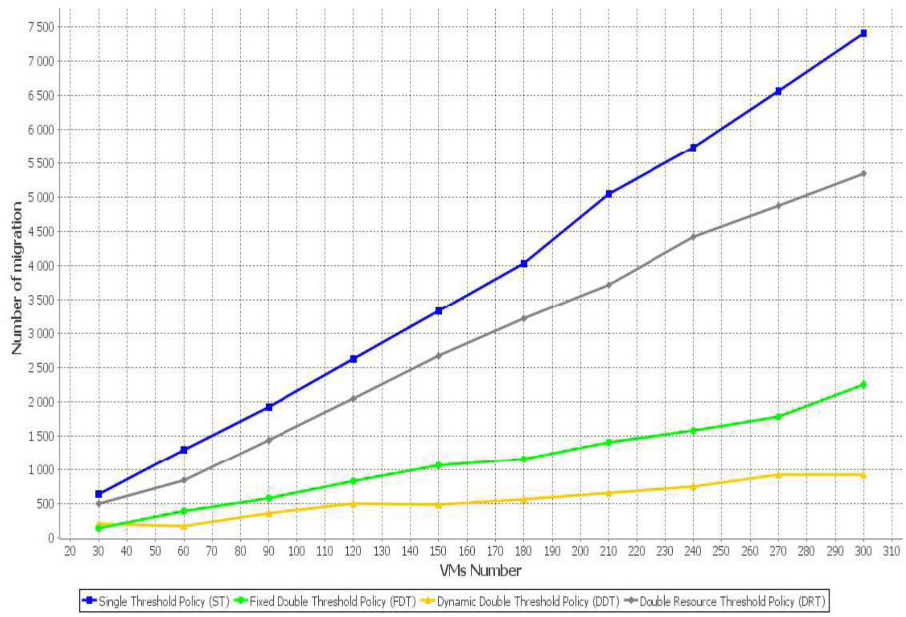

Figure 4. Number of Migrations

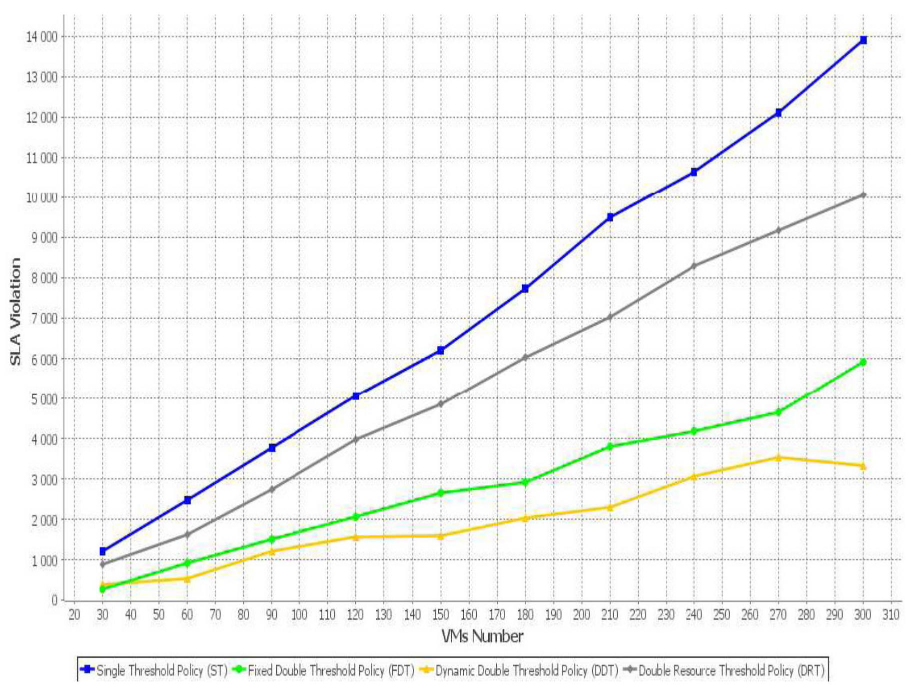

Figure 5. SLA Violations

6.3. SLA Violation

As illustrated in the figure 4, we notice that the curves of the FDT, DDT and DRT approches are below the curve of ST approach. Therefore FDT, DDT and DRT can minimize the number of SLA violations. We also note that with the increase of VMs number, the number of SLA violations produced by DDT is less than DRT and FDT.

The DRT approach generates more violations of SLAs compared to DDT and FDT. This is justified by checking two constraints (the use of the CPU and the RAM capacity) throughout all the simulation comparing to DDT and FDT which cheeks only the CPU utilization.

This is due to the fact that the violation of the different thresholds of DRT approach allow more migration and more aggressive consolidation of virtual machines to minimize the over utilisation of servers, which increases the risk of violation of SLAs.

DDT policy has reduced the percentage of violations of SLAs with a gain of 71.52 % compared to ST, a gain of 61.03%, 29.38 % compared to DRT and FDT respectively. The DRT approach reduces the percentage of violations of SLAs with a gain of 27 % compared to ST. FDT also reduced the percentage of 59.66 % compared to ST.

7. Conclusion

Efficient energy use has become a worldwide issue for designing and managing the datacenters. The data center infrastructure increase over time. This rising obviously brings various problems; including the energy consumption which is became a serious problem in our days. We must therefore develop techniques and measures to meet these new business needs.

In the literature, it exists several techniques to reduce energy consumption of data centers. Among these techniques, we have virtualization, VMs migration and Consolidation.

In this paper, we have proposed 3 approaches (FDT, DDT and DRT) based on upper and lower physical resources utilization. We simulate after these policies in CloudSim simulator.

Policies based on upper and lower resource usage thresholds (DDT, FDT and DRT) are much better than the approach based on a single threshold utilization (ST) or the approach that applies no energy optimization technique. To not produce a lot of heat from the data center IT equipment and therefore wasting too much energy for cooling systems and to optimize energy efficiency, our proposed approaches avoids the under and over utilization of servers. After the analyze of the obtained results, we can say that our policies are classified as “Green Computing Approaches”.

To continue our work, several prospects are envisaged. One of the future works is to add a temperature threshold to limit the heat and physical machines to minimize the energy consumption of servers and cooling systems. Also, we study the influence of air conditioning systems in their data center efficiencies and performance. Another direction of the future work is to implement the proposed approaches in a real environment of cloud.

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