

Comparative Analysis of Energy Efficiency in Adatacenter using DVFS with a Non-Power Aware Datacenter

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Abstract- The advancement in information technology has led to many environmental overheads like CO₂ emissions. Thus, the focus of IT is now shifting towards the green computing. Cloud Computing technology can be used to increase efficiency as well as utilization of computing resources and thus can help in providing green computing. In this paper, the datacenter energy consumption is simulated for a datacenter that is non power aware. The DVFS technique has been implemented on the same datacentre and the result of simulations are then compared. It is concluded that the energy consumption of the datacenter reduces by approximately 67% for given configuration of the datacenter.

Keywords- Cloud computing, scheduling algorithms, virtualization, simulation, Datacenters, Dynamic Voltage Frequency Scheduling.

I. INTRODUCTION

Cloud Computing technology is used to provide resources over an internet connection. These resources can be any kind of applications (like email, video conferencing applications etc.), platforms (like java platform to develop applications), or infrastructure facilities (like physical server or any number of virtual server instances). The concept of cloud computing has been explained in the following figure (Fig 1).

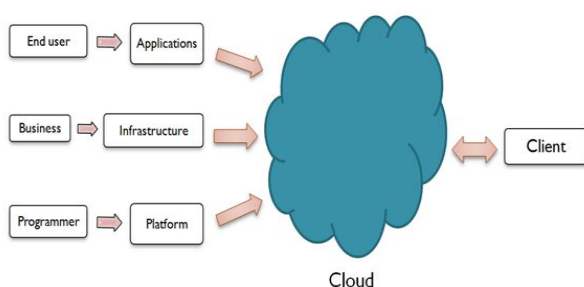


Fig 1. Concept of Cloud [26]

National Institute of Standards and Technology (which is the Unites. States' Department of Commerce) [4] defines three service models for Clouds .i.e. SaaS, PaaS and IaaS. SaaS (or Software as a Service) model provides applications to the cloud users over the internet. PaaS (or Platform as a Service model) provides platform to developers to develop their applications. IaaS (or Infrastructure as a Service), also known as Hardware as a Service provides infrastructure facilities to the customers.

NIST also defines five essential characteristics and four deployment models of Cloud Computing[4]. Characteristics of Cloud Computing- On-demand service, Infinite network access, Location independence and resource pooling, Scalable resources, Service is measured. And the three models of deployment are: public model, private model, community model, and hybrid model.

Thus establishing a Cloud requires installation of a large number of computing resources in a single datacenter. These computing resources may be thousands in number and may compute an enormous amount of power or electric energy. Based on the reports by American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), it is estimated that by 2014 the cost of energy as well as infrastructure would contribute 75% whereas Information Technology would contribute just 25% of the overall cost of operating a datacenter[22].

The main reason why such an enormous amount of energy is consumed is not just the quantity of resources used or the inefficiency on the part of the hardware, but rather it is because the resources are not utilized properly. It has been found that most of the resources are not utilized fully .i.e. their utilization rarely approaches 100%. When the data was collected from over five thousand computing servers for their utilization for six months, it was found that although the computing servers were not idle but the utilization was very rarely hundred percent [22]. Even most of the servers operated at around ten to fifty percent of their full capacity. This leads to even more expenses because when servers operate at a lower level of utilization they consumed more power than when they are utilized at hundred percent.

Also, if the servers are completely idle, they consume around seventy percent power of their highest level of power. Thus, for energy efficient computing the focus must be on utilizing the servers at their full capacity and they should also not be kept completely idle.

Along with the direct energy consumption by the resources, there is an additional expense of energy through the cooling systems that are required in each datacenter to keep all the systems cool. For every single watt of power consumed, it requires around 0.5 to 1 watt of power by the cooling systems [22]. Additionally the more the number of computing resources used, the higher is the carbon dioxide emissions. This carbon dioxide leads to greenhouse effect.

There are many ways to achieve energy efficiency in clouds, some of them are stated below:

- *Use the virtualization technology:* by using the virtualization technology, we are able to create virtual instances of a single physical node. Each of these virtual instances is capable to act as a separate host for the cloud jobs. This helps to reduce the number of physical hosts required to execute the tasks as well as it helps to increase the utilization of the physical server.
- *Switch the idle hosts to other low power consuming modes:* The hosts that are idle can be either switched off or they can be changed to some lower power consuming modes like sleep or hibernate. This helps to reduce a lot of power consumption.
- *Allowing the live migration of VMs:* The Vms can be allowed to migrate from one virtual machine to the other. This can be done to make the utilization of one host to maximum level and to make an underutilized host completely idle so that we could turn it off or change it to some low power mode.

But it must be noted that the efficient management of resources in clouds is a very tough job because the workload of clouds can never be predicted in advance. It is dynamic and changes from time to time. And if the requirement of the tasks given by the cloud users is not fulfilled, then it may lead to SLA violations. SLA is the Service Level Agreement that is signed between the Cloud providers and the Cloud users for the quality of service to be delivered. If the SLA violation occurs then it may lead to extra expenses on the part of the Cloud service provider.

In this paper we will implement DVFS technique which uses the second approach discussed above .i.e. the idle hosts are changed to lower power modes.

II. RELATED WORK

In [15], a three-phase energy-saving strategy is proposed. The proposed strategy includes algorithm for replica management, algorithm for cluster reconfiguration and algorithm for state transition. This enables flexible energy management. Simulations are performed and the results of the simulations show that the algorithm is fine for saving energy. But this method is theoretical one.

In [16], Adaptive Power-Aware Virtual Machine Provisioner (APA-VMP) is proposed. This policy schedules the workload such that the incremental sum of the power which is drawn by all the servers is minimised. This approach does not compromise with the system's performance.

[18] describes the tools which are needed to be implemented in a simulator for the energy-aware experimentation. The paper emphasises on DVFS simulation.

In [20], a new dynamic VM allocation policy is introduced. The policy takes VM's according to user requirement and allocate them in cluster form to the available datacenters. This approach helps to improve the performance of CPU and memory.

In [21], the authors present an overview of Cloud and Services offered by the Clouds. It also gives a review of various VM Migration policies.

[24], uses two host selection policies and four First-Fit mapping heuristics for the power aware allocation for VMs. Simulations performed showed that the four power aware algos help to lower the energy consumption on the hosts.

In [27], the Maximum and Minimum Frequencies DVFS (MMFDVFS) algorithm is presented. The algorithm helps to reduce the energy consumed by the processors. An optimal energy consumption formula is modelled in this paper. The linear combination of the min processor frequency and max processor frequency is used to find out the optimal consumption of energy. But, this method can be used only in homogeneous systems and not in heterogeneous systems.

III. DVFS TECHNIQUE

DVFS or Dynamic Voltage Frequency Scaling technique can be used in the cloud datacenters to reduce the power consumption of the physical hosts. DVFS enables the processors to run at different combinations of frequency as well as voltage. This is mainly done to reduce the power consumption of the processor. DVFS technique is very commonly used by the researchers to reduce the consumption of energy in the distributed systems.

DVFS is a dynamic technique that changes voltage and frequency of processor of a host dynamically. This is done according to the load on the host. The frequency has direct impact on the energy consumption by a host. A lower frequency implies that weaker voltage will be required and this results in low power consumption by the processor. But this has one shortcoming that this slows down CPU computation capacity.

DVFS can have different implementations in different operating systems. Especially in Linux operating system DVFS can have five different modes of implementing. These modes are Performance mode, PowerSaver mode, UserSpace mode, Conservative mode, and OnDemand mode [18]. With each mode there is an associated governor which is to decide whether there should be an increase or a decrease in the frequency of the processor.

Out of these five modes in Linux operating system three modes operate at the fixed frequency value while the other two modes have the dynamic operation. In the first mode that is the Performance Mode implies the processor functions at the highest frequency. In the second mode, PowerSave mode, the processor functions at the lowest frequency. In the UserSpace mode the user is allowed to choose between any one of the available CPU frequencies. The remaining two modes .i.e. Conservative mode and OnDemand mode operate dynamically using the threshold values. In these modes the governors use these threshold values to check whether the load of the processor is under or over these threshold values. Then accordingly the frequency of the hosts is adjusted [18].

The Conservative mode governor has two thresholds: 'up_threshold' and a 'low_threshold' [18]. If the load of processor is above the up_threshold the frequency is increased. And if the load of processor is below the low_threshold the frequency of the processor is then decreased [18]. The OnDemand mode on the other hand uses only a single threshold value. The governors of this

mode checks the load and if it is above this threshold then it chooses one of the fastest frequency for the CPU to work at.

IV. CLOUDSIM SIMULATOR

Since using the actual cloud infrastructure to implement any of our new proposed policies is a very tedious and costly job so we use a cloud simulator called CloudSim for this purpose. CloudSim toolkit is coded in java programming language. It is a package that is used to simulate a cloud infrastructure on a single computing node.

Various classes are used to create various clouds entities. Classes are available to create datacenter, host, processing cores, virtual machines, brokers and cloudlets. For implementing the scheduling policies for cloudlets and virtual machines, classes like CloudletSchedulerTimeShared, CloudletSchedulerSpaceShared, VmSchedulerTimeShared, and VmSchedulerSpaceShared are available. Along with all these CloudSim also includes the functionalities for provisioning of bandwidth and ram of the hosts.

CloudSim architecture involves four layers: SimJava, GridSim, CloudSim and UserCode layer [11]. CloudSim can be used to model network behaviour, model federations, model cloud market and model cloud power consumption. CloudSim includes an abstract class called PowerModel. This class is used for modelling the power consumption on the clouds. The PowerModel class includes a function `getPower()`. This function `getPower()` can be overwritten to fulfil our objective of modelling the power consumption in clouds. This helps to evaluate the power consumed and efficiency of the proposed power aware policy [26].

V. DVFS IMPLEMENTATION

The CloudSim toolkit to simulate the cloud infrastructure. The CloudSim package is deployed on the NetBeans IDE. NetBeans IDE is an Integrated Development environment which is an open source environment. It provides various tools all integrated together at the same platform to develop and run various java applications [26].

The steps in DVFS Implementation are stated below:

- ◆ *Create Datacenter:* The Datacenter class is used to create a datacenter. It is the second step in the simulation of a cloud infrastructure. The first being initiating the CloudSim package. To create datacenter we need to create hosts. The number of hosts can vary with the simulations.
- ◆ *Create hosts in datacenter:* Host class defined in the CloudSim package is used to create the hosts in the datacenter. For each host we need to define the number of processors and their MIPS rating, i.e. Millions of instructions processed per second.
- ◆ *Create virtual machines:* Virtual machines are created by using the inbuilt class Vm. Vm class accepts a list of Vms. Each Vm has specifications like, MIPS, size, ram, bandwidth, number of processing elements and the Cloudlet scheduling policy.

- ◆ *Allocate hosts to the virtual machines:* Once the virtual machines and the hosts have been created, the next step is to allocate the virtual machines to the host. The scheduling policy of virtual machines is specified while creating the host. The scheduling of virtual machines on the hosts can be either time shared or space shared depending on the policy we are implementing.
- ◆ *Allocate cloudlets to the virtual machines:* Next the cloud tasks, i.e. cloudlets are allocated to the virtual machines.
- ◆ *Start simulation:* once all the allocations have been done, we can then finally start the simulation. CloudSim provides a method `startSimulation()` for this purpose. We also provide a simulation limit (the time limit until when simulation is carried out).
- ◆ *Calculate utilization and energy consumed at the end of each time frame:* The time frames or time slots are defined before starting the simulations. After each time frame
- ◆ *Switch off the hosts with 0% utilization:* The power aware policy that we are implementing here is DVFS. This policy checks after each time frame whether any host has utilization equal to 0%. If any such host is found the power of that host is turned off to save the energy.
- ◆ At the end of simulation, calculate the net energy consumption of the datacenter and number of host shutdowns.

The simulation is carried with one datacenter. The number of hosts created in the datacenter is 25. And 25 virtual machines are created. The hosts can have either 1860 or 2660 MIPS. The MIPS for Vms can be 2500, 2000, 1000 or 500.

VI. RESULTS AND CONCLUSION

The simulation of the above defined configuration of datacenter hosts and virtual machines on the NetBeans IDE for a non-power aware cloud gives the total energy consumption as 43.45kWh. The result of simulating a non-power aware datacenter is shown in Fig 2. When the simulation was done for the same configuration of datacenter that implemented DVFS, the total energy consumption was 16.02kWh. This is shown in Fig 3.

Thus, the overall energy consumption of the datacenter is decreased by 63 % (approx.) for the given configuration of the datacenter.

Hence, DVFS is an energy saving technique. It is used to reduce the power consumption by the hosts. This is done by turning off the hosts that have utilization below a predefined value. This technique is proved as an efficient technique to reduce the power consumption of the datacenter, as it reduces the energy consumption by approximately 63%. Although this technique reduces the energy consumption but it also leads to lower performance.

```
Simulation: Reached termination time.  
CloudInformationService: Notify all CloudSim entities for shutting down.  
Broker is shutting down...  
Datacenter is shutting down...  
Simulation completed.  
Received 0 cloudlets  
Simulation completed.
```

```
Experiment name: random_npa  
Number of hosts: 25  
Number of VMs: 25  
Total simulation time: 50000.00 sec  
Energy consumption: 43.45 kWh
```

Fig 2. Simulation results of a non-power aware datacenter

```
Simulation: Reached termination time.  
CloudInformationService: Notify all CloudSim entities for shutting down.  
Broker is shutting down...  
Datacenter is shutting down...  
Simulation completed.  
Received 0 cloudlets  
Simulation completed.
```

```
Experiment name: random_dvfs  
Number of hosts: 25  
Number of VMs: 25  
Total simulation time: 50000.00 sec  
Energy consumption: 16.02 kWh
```

Fig 3. Simulation results of a datacenter with DVFS

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