Improving Energy Usage in Cloud Computing Using DVFS

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Abstract. The energy-related issues in distributed systems that may be energy conservation or energy utilization has turned out to be a critical one. Researchers worked for this energy issue and most of them used Dynamic Voltage and Frequency Scaling (DVFS) as a power management technique where less voltage supply is allowed due to a reduction of the clock frequency of processors. The cloud environment has multiple physical hosts and each host has several numbers of Virtual Machines (VMs). All online tasks or service requests are scheduled to different VMs. In this paper, an energy-optimized allocation algorithm is proposed where DVFS technique is used for virtual machines. The fundamental idea behind this is to make a compromise balance in between energy consumption and the set up time of different modes of hosts or VMs. Here, the system model that includes different sub-system models are explained formally and the implementation of algorithms in homogeneous as well as heterogeneous environment is evaluated.

Keywords: cloud computing; DVFS; task allocation; energy consumption; VM; virtualization;

1 Introduction

In the recent time, the exceptional demand for computational power by recent researchers and business applications needs a large number of data centers which consumes extensively more energy. It was estimated that the expense of consumption of energy by IT industries in the US as 4.5 billion dollars and the approximation shows double cost by 2011 [1]. Generally, there are other critical environmental issues that emerge from high power utilization like emissions of huge amount of CO_2. One of estimation is that the IT hardware equipment is responsible for around 2% of emissions of global CO_2 [2]. Therefore, proper utilization of computing resources or reduction of energy consumption becomes a critical research topic. Cloud computing is a model that can increase the resource utilization of the system and therefore, reduces numerous of IT hardware equipment. In other words, the cloud computing is a shared model in which the resources are shared among different components of the system to achieve better efficiency and performance. Moreover, data center in the cloud needs reliable internet through which a large number of physical hosts or servers are connected. There are several service providers in the cloud called Cloud Service Provider (CSP) who is capable of managing all services to the end user. The cloud computing system has several open challenges and security issues [6].

In order to reduce the electrical power for the whole system, the resource scheduling should be proper or optimized one. The scheduling of tasks to have different resources is a known NP-complete problem because of large solution space. A scheduler has schedules different resources to all the tasks. Therefore, an efficient scheduler can manage less computing resources to execute all the tasks in parallel. Most of the researcher works on static as well as dynamic energy efficient scheduling procedure for the allocation of resources [3] [5] [17]. In dynamic scheduling, processors consume approximately less than 30% of power consumption as compared to static scheduling [5]. One of the powerful technique of the cloud computing is the virtualization. This virtualization technique provides an abstraction of hardware resources. It is applied to the IaaS layer (where VM management, VM deployment,etc. are done) to virtualized the hardware resources.

Researchers give more attention towards minimizing energy consumption and corresponding cost of data centers. To balance the distribution of power management, different techniques come into picture. Dynamic Voltage and Frequency Scaling (DVFS) technique is one of such technique through which electrical power can be minimized. Broadly, there are two different methods for the reduction of power consumption and those are (a) Dynamic Component Deactivation (DCD) and (b) Dynamic Performance Scaling (DPS). Enabling and disabling of different electrical components is done by using DCD mechanism. Whereas DPS allow reduction of a certain frequency and the voltage supply moderately, and DVFS is one of the DPS technique. Here, the research is applied to develop a heuristics for the allocation of tasks to decrease the energy utilization or energy consumption by applying the DVFS approach. Before submission of tasks to the cloud by user, an agreement has to be made between the user and the CSP and the agreement is known as Service Level Agreement (SLA). If the CSP can provide services according to the negotiation or SLA, the user submit the task or service request. The primary contributions of this work are outlined as follows.

- We have clearly explained the models that include cloud system model, task allocation model, and DVFS-oriented energy model.
- We have used DVFS mechanism to the system for the reduction of energy consumption and this technique is applied to the set of VMs.
- We have proposed Energy Efficient DVFS based Task Scheduling Algorithm ($EEDTSA$) for service or task allocation in the cloud and compare with the random allocation algorithm.

We organized the rest of the paper as follows. Prerequisites for our work are in Section-2 as related work. Section-3 describes the system model for cloud infrastructure. Section-4 presents our scheduling algorithm and its description. Simulation results from experimental assessment and observations are reported in Section-5. We have concluded our work of this paper in Section-6.

2 Related Work

The resource allocations in cloud environment can differentiate in two views. First one is form user points of view where the user has two main objectives as minimizing the execution time and also minimizing the cost. Second one is from Cloud Service Provide (CSP) points of view where the CSP has objectives as resource should be utilized optimally and maintenance cost should be less. The DVFS technique is a common technique that is used to minimize the consumption of power of different electrical devices like mobiles, computers, etc. An energy-aware resource allocation heuristic algorithm is proposed for data center that also delivered Quality of Service (QoS) [7]. They also provide an autonomic mechanism for managing the cloud resources efficiently and effectively which satisfies certain level of SLAs. They mapped virtual machines to satisfactory resources, however, there is some degradation in the system performance. In [8], the authors have explain the need of a good job scheduler, which schedules all the jobs provided the running time of the jobs should be less and used fewer resources. They provide several mapping definitions with the functionalities of DVFS controller and MMS-DVFS. They have proposed an algorithm for mapping VMs with jobs and the same is simulated in CloudSim. They have experimented for multiple times and the result shows better.

There are huge applications such as social networks [11], sensor networks [14] and mobile nodes [4] always require the source of the data to be computed in the cloud. In [4], the authors have describes four steps for scheduling problem in Mobile Cloud Computing (MCC) environment and these steps are (a) finding the set of offloading tasks onto the cloud, (b) mapping of tasks to local cores, (c) frequency determination, and (d) scheduling of tasks. They have used different methodologies for minimizing the consumption of energy and lastly used DVFS technique for further reduction of energy utilized in mobile devices. Their system model constitutes a Directed Acyclic Graph (DAG), where nodes represent tasks and an edge represents the sequence of execution of tasks. They have proposed MCC task scheduling algorithm having three steps. The first step is for minimizing the execution time, the second step is for minimizing the energy consumption, and the third step is for further reduction of energy consumption using DVFS. Huang et al. [9] have also model the cloud system with the help of DAG. They have proposed parallel algorithm for reduction of energy consumption in heterogeneous environment which obeying certain SLAs.

The authors in [5] aim to schedule applications for the reduction of consumption of power for the execution of the parallel task with DVFS technology and that to maintain a relationship between task execution time and energy consumption of the system. They have also focused on two basic issues: one is Best Effort Scheduling (BES) and another is energy performance tradeoff scheduling. To use the two models: DVFS-oriented performance model and power consumption model, they have conducted multiple experiments to solve the task allocation problem efficiently and developed an algorithm named as Power-aware Threshold Unit (PTU) algorithm. Here, they have considered energy as SLA. In [16], various security issues in different layers are described. In [10], Calheiros and Buyya have proposed a methodology for the execution of a set of urgent tasks and a set of CPU-intensive tasks on the cloud frameworks that consumes minimum energy.

3 Models

In this section, the cloud system model, DVFS-oriented energy model, and the task allocation model are described in this study.

3.1 Cloud System Model

An energy-aware allocation for the execution of the task in the context of E_{SLA} (SLA for less energy consumption). Users can define the performance specifications for the computation of services as well as can specify the maximum amount of energy for executing their tasks. Requirement of energy for processing the

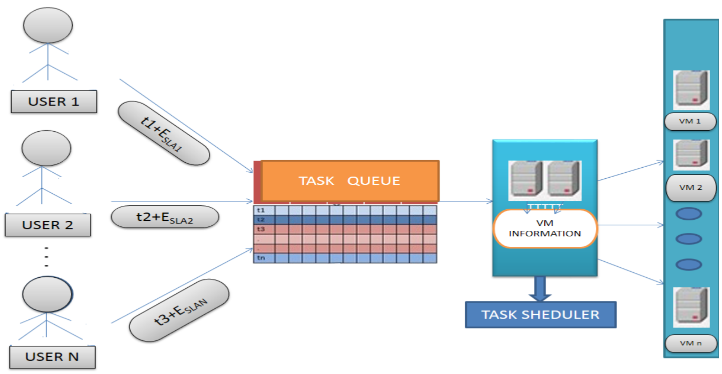

Fig. 1. Framework for task scheduling with SLA based energy consumption

tasks is an SLA between the cloud user and the CSP. The E_{SLA} has several metrics (like execution time of a task, dead-line of the task, amount of energy consumption, CO_2 emission rate, etc.). An example of E_{SLA} is: execute these tasks for x time units if the total energy consumption of the service is below w watt. When an SLA is meet, then the tasks with their E_{SLA} are submitted to the task queue. After that the scheduler (which has a complete information about all the VMs) schedule all the tasks from the task queue to different virtual machine batch-wise. Then, the tasks are executed within the specified energy by providing the computing resources or virtual machines. Each VM has a local queue to place the allocated tasks.

3.2 Task Allocation Model

A task can be modeled as four tuples (t_i, D_i, ER_i, L_i). Here, t_i is the task identification, D_i is the dead-line of task, ER_i is the energy requirement of task, and L_i is the length of the i^{th} task in million instruction (MI). Task are represented by a directed acyclic task graph $G = (V, E)$ as shown in Fig.2. Each vertex in the graph accounts for a task, and each directed edge represents the precedence of task execution. In Fig.2, it is shown that task 1 and task 2 are entry task (i.e., the task with no parent). Similarly, task 8 is the exit task (i.e., the task with no child). Independent tasks can execute in parallel (task 1 and task 2 are independent tasks).

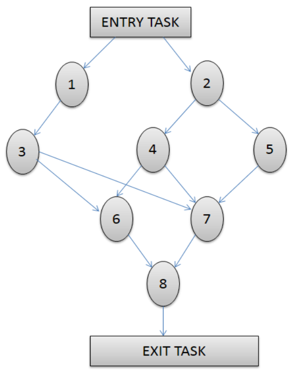

Fig. 2. An example of a task graph

3.3 DVFS-oriented Energy Model

The consumption of power by the heterogeneous nodes in the cloud is calculated from the CPU, main memory, secondary storage, and bandwidth usage. Since these resource utilization affects the power consumption of the system, we should optimize it. CPU consumes more energy as compared to other parts of a system. Therefore, we focus on optimizing the energy consumption and the CPU utilization. Present-day CPUs support Dynamic Voltage and Frequency Scaling (DVFS) methods to change its frequency dynamically to improve the energy problems. The CPU utilization is typically proportional to the overall system load. The energy consumption (E) of the cloud system is the sum of static energy consumption (E_s) and the dynamic energy consumption (E_d) as in equation 1 [15].

$$E = E_s + E_d \tag{1}$$

Here, the dynamic energy consumption is calculated as follows in equation 2.

$$E_d = \sum_{t_p} P_d.t_p = \sum_{t_p} (k.v^2.f.t_p) \tag{2}$$

Here, t_p is the time period, k is a constant related to the device, P_d is the dynamic power consumption with voltage (v) and frequency (f).
Since, static energy consumption is directly proportional to the dynamic energy consumption [12], we can have the total energy consumption as follows in equation 3.

$$E = \sum_{t_p} (k.v^2.f.t_p) \tag{3}$$

4 Algorithm

This section discusses the details of proposed scheduling algorithm, Energy Efficient DVFS based Task Scheduling Algorithm ($EEDTSA$). Here, the purpose is to minimize energy consumption overally by changing various voltage-frequency pair for each task. Inputs to the algorithm are all tasks along with their length (in million instructions), DAG task graph, Dead-line of all tasks, all VMs, and the voltage-frequency pairs of processors of all VMs as listed in Table 1. The output of the algorithm contains the allocation vector (A) and the total energy consumption (E) of all task. Here, $WinSize$ is same as the number of VMs. So, select a set of tasks T form total task and $|T| = WinSize$. Here, the Heterogeneous Earliest-Finish-Time (HEFT) list-scheduling algorithm [13] is applied to map all the tasks in the DAG to different processors. It results in a task allocation to calculate the time slots for the execution of tasks and information interchange among virtual machines. Here, a matrix is found as output noted as ET_{ij}, which is the execution time of i^{th} task on j^{th} VM.

Processor Model	Frequency	Voltage
Turion 64 ML-30	1.6 GHz	1.15 V
Turion 64 ML-34	1.8 GHz	1.20 V
Turion 64 ML-37	2.0 GHz	1.50 V
Turion 64 ML-40	2.2 GHz	1.62 V
Turion 64 ML-44	2.4 GHz	1.68 V

Table 1. Voltage-Frequency Pair

5 Experimental Result

For the experimental purpose, each VM has a single processor among the listed processors in Table-1. Here, we perform the comparative evaluation of our heuristic algorithm (EEDTSA) with the random algorithm. The processors mentioned in the Table-1 have 1 MB cache, and 35 W is the TDP (thermal design point) value that is the maximum volume of heat made by the processor. For the experiment, various combinations of processors are chosen from Table-1 for each VM.

Algorithm 1 : *EEDTSA*: Energy Efficient DVFS based Task Scheduling Algorithm

Input: $Task$: set of tasks sorted in descending order of their length; DAG task graph; D: Dead-line of all tasks; V: set of VMs; E_{SLA}, F: the voltage-frequency (vf) pairs of processors of all VMs;

Output: Energy efficient Allocation result (A and $|A| = |Task|$) and the total energy consumption (E)

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Initialize, E = 0, n = |Task|, count = 0;
Sort all VMs, V in descending order of their processing speed;
Select a set of tasks T form set Task and |T| = WinSize;
Map the DAG to V using HEFT algorithm;
for each task t_i ∈ T do
    for each VM v_j ∈ V do
        if Dead-line and E_SLA satisfies then
            Continue;
        else
            if j == 1 then
                Reject the task t_i and Break;
            end if
            Allocate t_i in v_{j−1};
            A[count × WinSize + i] = j − 1;
            count = count + 1;
            for each vf_k ∈ F do
                E_k = Calculate energy consumption of t_i using equation 3;
            end for
            E_Min = Min_{k∈F} E_k;
            E = E + E_Min; and Break;
        end if
    end for
end for
if Execution of all task not completed then
    Goto Step-3;
end if
Return A and E;
```

In scenario-1, the number of tasks is 2000 which is fixed, and the number of virtual machines increases from 40 to 200 in the gap of 20. The comparison graph for the calculation of energy using the random allocation technique and our $EEDTSA$ algorithm is shown in Fig.3. From the fig, the consumption of energy value in $EEDTSA$ algorithm is less. In scenario-2, the number of virtual machines is 100 which is fixed, and the number of tasks increases from 1000 to 10000 in the gap of 1000. The comparison graph for the calculation of energy using the random allocation technique and our $EEDTSA$ algorithm is shown in Fig.4. From the fig, the consumption of energy value in $EEDTSA$ algorithm is less.

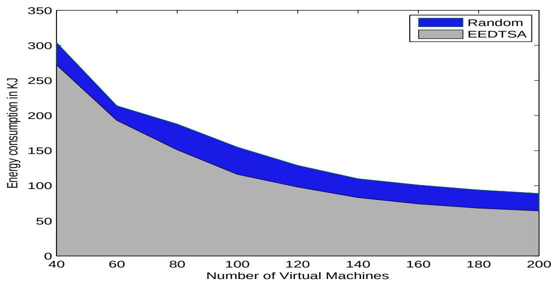

Fig. 3. Comparison of energy consumption in $EEDTSA$ and Random allocation algorithm when number of task is fixed and VM varies

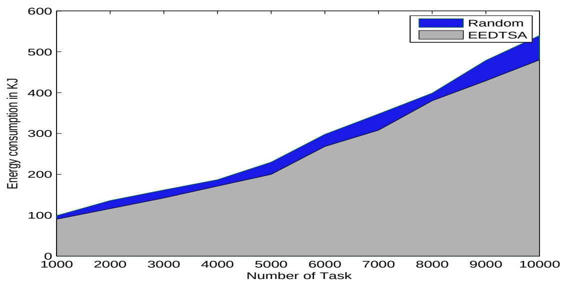

Fig. 4. Comparison of energy consumption in $EEDTSA$ and Random allocation algorithm when number of VM is fixed and task varies

6 Conclusion

In this paper, we are interested in energy-aware allocation result in the cloud and propose a novel scheduling algorithm $EEDTSA$. In $EEDTSA$, DVFS is applied to allocate tasks in the cloud resource. We have explained elaborately different heuristic algorithms where researchers used DVFS technique. We provide a cloud system model for the conservation of energy by applying E_{SLA} as a service level agreement. We have simulated the $EEDTSA$ algorithm and also made comparison graphs with random allocation algorithm. The comparison graph shows that $EEDTSA$ consumes less energy as compared to the random allocation. There is a plan to implement some recent existing algorithm to compare with $EEDTSA$ algorithm.

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