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Data Center Servers: Cost Optimization by CPU Frequency Manipulation and Renewable Energy Usage

Manjunatha S[1], Sherlin Tessy P[2], Shirisha R S[3], Swathi N[4], Meghana[5]

[1]Computer Science and Engineering, Cambridge Institute of Technology, Bengaluru
[2]Computer Science and Engineering, Cambridge Institute of Technology, Bengaluru
[3]Computer Science and Engineering, Cambridge Institute of Technology, Bengaluru
[4]Computer Science and Engineering, Cambridge Institute of Technology, Bengaluru
[5]Computer Science and Engineering, Cambridge Institute of Technology, Bengaluru

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Abstract -Data center power consumption management has been a growing issue to which various solutions are being suggested from time to time. With thousands of servers running continuously in a data center, it is clear that the cost associated with running the data center is too high. Various methods exist to reduce the electricity cost generated by data centers. This paper involves the CPU frequency manipulation based on the change in electricity price with time and use of renewable energy based on the type of workload on data center servers. First, we will consider a scenario in which we access only the predicted electricity prices. Using the electricity prices as the sole base information, we manipulate the CPU frequencies. Second, we will consider a scenario in which we access both electricity prices and workload data. Using this workload data we decide the distribution of renewable energy in the data center. Then we can see the combined effect of frequency manipulation and use of renewable energy on the total electricity cost generated.

***Key Words*:**electricity, price, frequency, workload, renewable, energy.

1.INTRODUCTION

With the emerging technology various organizations like Google, Yahoo, Amazon, Apple, Microsoft, Ibm etc. have started to introduce hyperscale data centers. Hyperscale data centers are more energy efficient and managed by organizations. They can be massively scaled. One hyperscale data center will have at least 5000 servers. It might be covering about 10,000sq.mt. Thus the amount of power consumed by one datacenter itself is quite high.

First data center was established in the USA in 1946. Today we have more than 500 hyperscale data centers according to Synergy Research. Companies are using more data centers in order to perform various tasks like security, load balancing, storage and so on. Today, the data centers are using client server model to reduce tasks. Companies are taking their time to make the working of data centers as efficient as possible. Google has achieved Power Usage Effectiveness(PUE) of 1.1. In a data center, energy is consumed by various parts. There is also power used in cooling and other overheads. In these times saving even a penny is worth a lot. Many organizations are also turning to renewable energy for their data centers[1]. In this paper we are going to reduce total electricity cost. For that we are going to consider two scenarios.

1. First, consider the electricity price change pattern. Then based on this pattern we can manipulate the frequency of the host machine. In a dynamic electricity pricing system, we can change the frequency of the CPU to reduce the power consumption when the price is high.
2. Second, we consider the workload and the electricity pricing. We keep a monitor which checks the workload. During a high pricing period, we can check the status of renewable energy and the workload to determinehow to distribute the renewable energy to the hosts and also their frequency manipulation.

2. RELATED WORKS

Most of the Researchers who have published papers to reduce electricity consumption cost in data centers have proposed green energy data centers by using renewable energy sources such as wind or solar energy[1]. Even though Google and yahoo are applying this renewable energy technology in their data centers there is a major concern of inconsistent supply of green energy. To overcome this there has been studies on Green hadoop [2] which predicts how much solar energy will be available in future and schedules map reduce jobs to maximize green energy.

On the other side electricity price is reduced by voltage scaling [3] where processing speed of cpu can be changed by changing cpu frequency. An efficient algorithm is used to reduce electricity consumption cost without knowing the future price of electricity. This can be done by applying the Markov model to predict future electricity price. A three State Markov approach[4] is to estimate the expected length of assets returns which may be raising state, falling state, and stable state of electricity prices.Another paper proposed an energy storage strategy in data centers[5] by using battery management based on the workloads guaranteeing the quality of services. Then there is a scheduling model to reduce cpu energy[6]. This can be achieved by executing a job between the arrival time and deadline by a single processor with speed.There is another study on virtual machines consolidation to save electricity power in cloud data centers[7] where virtual machines are migrated from source servers to destination servers based on the failure probability and power consumption rate of servers.

3. PROBLEM DEFINITION

Our main objective is to reduce the total electricity cost generated by a data center using CPU frequency manipulation without compromising the work to be done. Thus we take a data center and find the best way to achieve both. For this we take both electricity pricing and also the workload to manipulate the frequency and use renewable energy.

4. METHODOLOGY

We use simulation to implement the proposed system. Cloudsim DVFS[8] is an appropriate toolkit. Its library is added to Netbeans and the library is used to simulate a data center. Cloudsim layer provides an interface for virtual machines, memory, storage and bandwidth.

Many components of data center will consume large amounts of electricity due to which a large amount of electricity price is generated. We try to reduce the electricity consumption at the server level. For implementing we consider the following two scenarios.

Scenario 1

We consider a setting in which we use the varying electricity prices. The electricity prices vary according to markov chain[9] based on research. Therefore we use markov chain to generate an electricity price chain, each price given to a time slot as shown in fig. 1.

Fig -1: Input electricity price chain

Now this input is passed to the frequency regulator to manipulate the frequency accordingly. We use the following steps to change the frequency.

1. Find the average price P in the range of electricity prices. Round to the nearest existing price if needed.
2. Find the average CPU frequency F available to use.
3. Assign the maximum frequency available to time slots with prices which are less than P.
4. Assign the average frequency F to the remaining time slots that are the ones with prices equal to or greater than P.

Thus this model reduces the energy consumption from the usual value. The basic model of the system is shown in fig. 2.

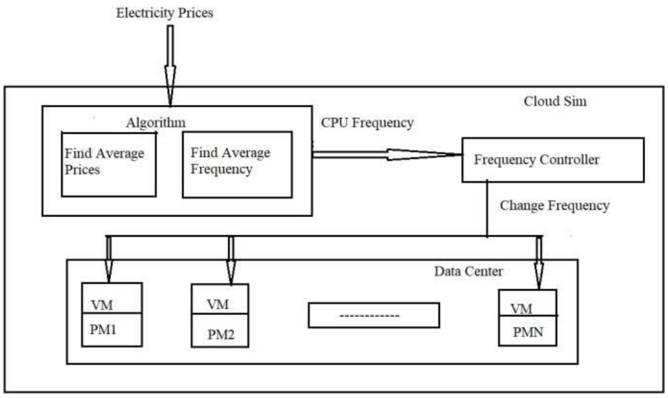

Fig -2: Basic model of the implementation

Scenario 2

In scenario 1 we proposed changing the frequency without taking into account the performance based on the deadline. In this setup we take into account the availability of renewable energy. We take the following steps to implement this. .

1. Analyze the workload and transfer requests to efficient servers.
2. During low pricing periods change the frequency of high workload hosts to maximum frequency.
3. During high pricing periods check the availability of renewable energy and do the following.
   - If there is good availability of renewable energy, then distribute this energy to high workload hosts and change frequency of remaining to F.
   - Else keep frequency of all hosts to F.
4. During low pricing periods check the availability of renewable energy and do the following.
   - If availability is good, then keep the maximum frequency for high workload hosts and distribute renewable energy to remaining.
   - Else keep maximum frequency for all hosts.

Thus we have taken these two approaches to reduce electricity consumption and overall cost generated by servers. We also did not compromise on the work to be done by the servers.

5. RESULTS

After the simulation we generated various graphs to analyze the results.The results of the simulation which show energy consumption for various price patterns, CPU frequency versus time slot, electricity price change using markov model and deadline miss in the 2 scenarios are given in fig. 3, 4, 5, 6.

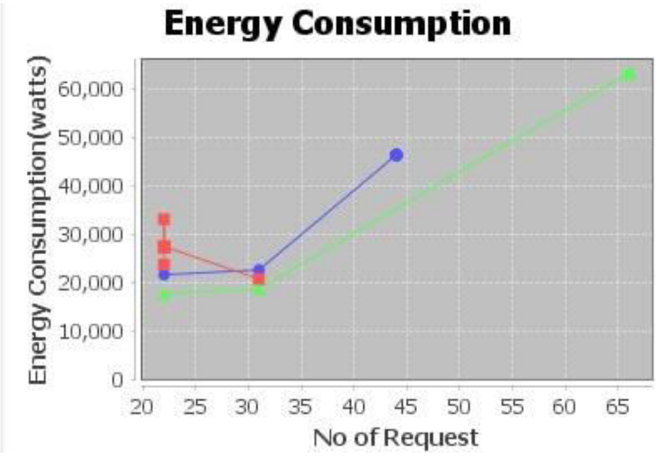

Fig -3: Energy consumption for various price patterns

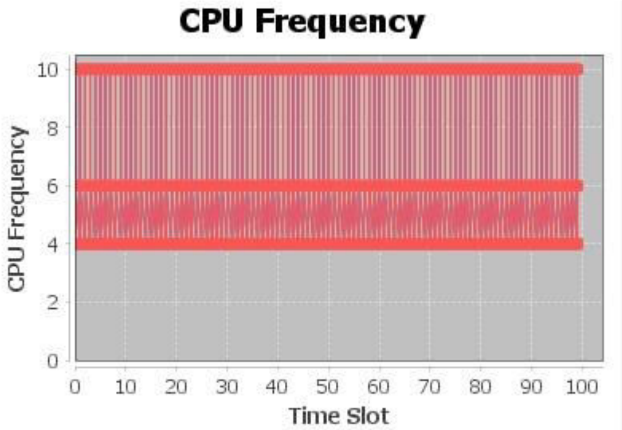

Fig -4: CPU frequency vs time slot

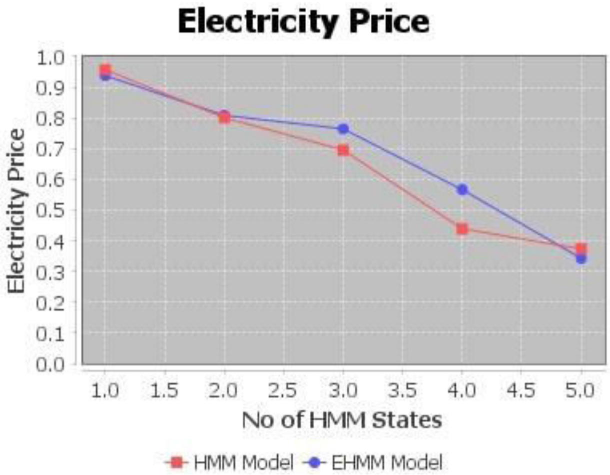

Fig -5: Electricity price change using markov model

Fig -6: Deadline miss in the 2 scenarios

6. CONCLUSION

In this paper, first we consider electricity price change,and try to minimize the electricity cost for data centers. So we have taken varying electricity prices according to the given time and then we adjust the cpu frequency of data center servers. Our main goal is to minimize the entire electricity cost generated by servers for completing each and every task within the deadline. First we have taken a setup where only an electricity price chain is considered for given time slots. The prices are assumed to change over time and there is a set of defined distinct prices. Hence the solution based on this setup is taking only the reduction in power consumption into consideration. Thus this solution helps to reduce the cost without considering workload. The performance of this solution is better than not having any sort of frequency manipulation algorithm. We also consider a setup in which we consider the workload and determine the use of renewable energy based on its availability. In this setup we consider both price change and workload and improve the performance of the first setup in which only price change is considered. This proposed system does not consider various real time data related to the data center. The real time properties might be needed to do a more detailed analysis of the performance of this solution. There is also the overhead of checking availability of renewable energy and keeping track of workload. For further advancement we would like to reduce these overheads.

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