A Study on Various Techniques for Energy Conservation in Data Centers for Green Computing

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ABSTRACT*- Cloud computing is a cost effective infrastructure that affords users to run various applications without the necessity to deploy necessary hardware to run those applications. The virtualization technology provides this opportunity. Even small organizations started to use cloud solutions for their customers. Cloud can host a variety of applications that run for seconds to several hours in pay we use manner. This led to the establishment of more data centers that resulted in high energy consumption to process those cloud services. High energy consumption causes environmental drawbacks like carbon emission which results in Global warming and also decreases the revenue. This work discusses problems of high power/energy consumption. There are several techniques to minimise the power consumed in the data centers and they are briefly discussed in this work.*

Keywords: *cloud computing, energy efficient, virtualization, green cloud.*

I. INTRODUCTION

Cloud computing is an internet based on-demand computing, pay as you use model and accessing the computing resources of third parties. The Computing resources have become cheaper, powerful and ubiquitously available than ever before due to the rapid growth in the processing and storage technologies and also the due to the success of Internet. This led to the establishment of more data centers that have significant contribution in the energy consumed worldwide and consequently environmental drawbacks like carbon emission.

Virtualization is a technique of abstracting the physical resources and making them appear as logical resources i.e., convert all hardware resources into software resources and it may be implemented at compute, storage, and network. The hardware architecture can be either X34 or X32 or X86. These architectures can run or host any one application so we go for virtualization which can host many applications despite of its architecture. Also the system designers aim at improving the system performance and high performance incorporates high energy consumption. A data center has four main components such as applications, operating system, network, and data. Modern data centers in the cloud computing environment host a variety of applications that run from few seconds to longer periods. However these data centers consume large amount of energy. According to McKinsey report on ***"Revolutionizing Data Center Energy Efficiency":***A typical data center uses as much energy as 25,000 households uses. The total energy bill for data centers in 2010 was over $11 billion and energy costs in a typical data center doublesevery five years. About 50% of power in the data center is consumed by the servers/storage and computer AC room consumes about 34% of power.High energy costs and huge carbon footprints are incurred due to the massive amount of electricity needed to power and cool the numerous servers hosted in these data centers. So, one of the main problems in a data center is power consumption since it emits more heat as a consequence of more power consumption and needs more cooling devices to reduce heat generated when the number of physical systems increase which results in more costs. Henceforth finding a way to conserve energy is important both for improved ROI/Revenue and for efficient processing of resources.

This is the stage from where the term Green computing started to evolve to find a solution for high energy consumptions. It refers to foresee not only accomplishing the efficient processing and use of computing environment, but also reducing the energy consumption. The goal of being green is reducing carbon emission that causes global warming. The most important reason of Carbon di oxide emission is energy consumption, so reducing energy consumption not only means conserving more energy sources for the future use but also means reducing CO2 emissions.Reducing the overall energy bill of a data center resides first and foremost on energy aware data center design that includes hardware and software, use of solar power, renewable energy and the next is use of energy aware scheduling and placement policies. The power consumption in a data center can be divided into two types namely Static or leakage power consumption and Dynamic power consumption. The static power consumption is caused by the leakage current in any active circuit. This can be reduced by the low level system design. The dynamic power consumption is due to the circuit activity. And this cannot be reduced without compromising the performance.

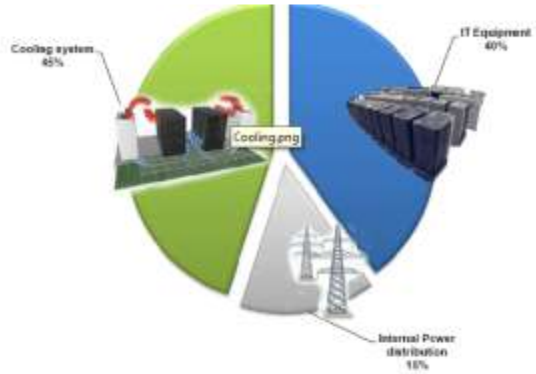


Fig. 1. Distribution of data center energy consumption

II. NEED FOR ENERGY EFFIANCY IN DATA CENTERS

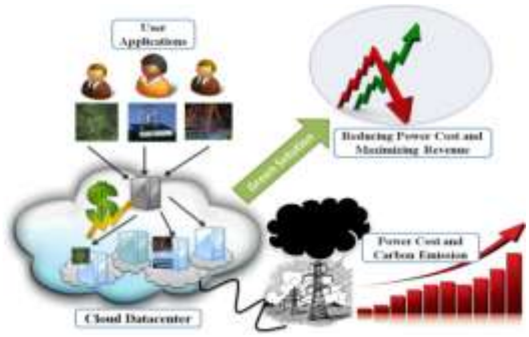
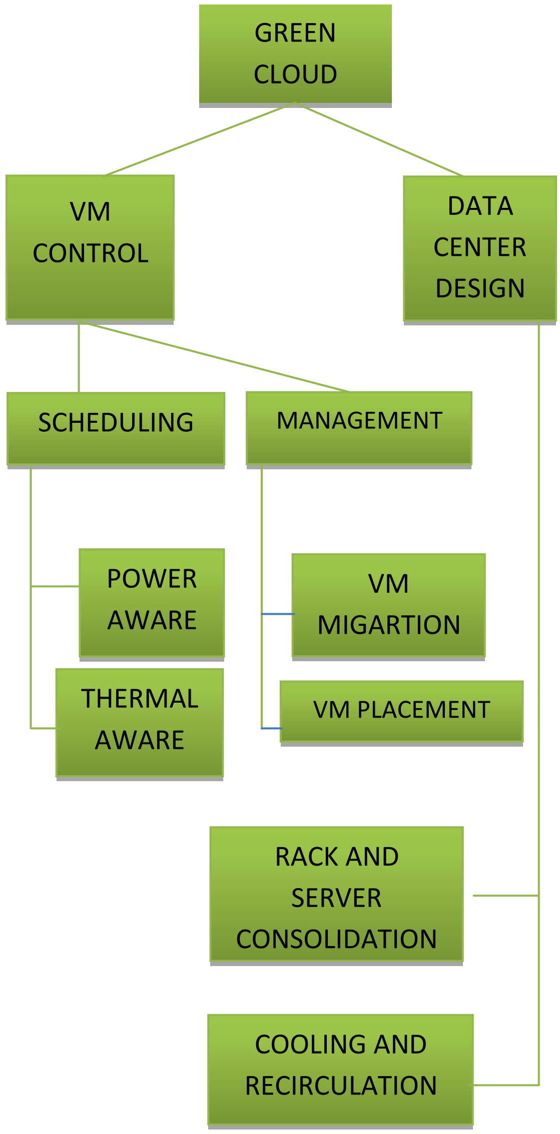


Fig. 2. Energy consumption

By 2014, energy costs contribute 75% by the data centers because of insufficient hardware usage and inefficient resource usage. Consequently, energy costs for operating and cooling the equipment of data centers have increased significantly up to a point where they are able to exceed the hardware acquisition costs. "For each watt consumed by the computing resources an additional 0.5-1 watt is required by the cooling systems and CO2 emission also contribute to significant Greenhouse effect". Fig.1 clearly shows consumption of power by data center components and the cooling systems hosted in the data centers contribute 45% of power consumption. If the number of servers increases the cooling systems that reduce the heat generated form servers also get increased. Thus when the size of data centers expands the power also increases. Hence finding a solution for processing the workload also without expanding the data center size is critical. There are several techniques available regarding energy efficacy in data centers. These techniques are briefly discussed in the next section. Also related works for those techniques are given.

III. TAXONOMY OF ENERGY EFFICIENT TECHNIQUES



IV. RELATED WORKS ON ENERGY CONSERVATION TECHNIQUES IN DATA CENTERS

Energy efficiency is much a design consideration and the primary focus is better performance and high throughput. There are several techniques which can be applied at the data center level without any overhead. Dynamic Frequency Scaling DFS also called CPU throttling is one of the techniques that were initially used. It can adjust the frequency of the process dynamically in order to save power while the energy consumption remains the same. Hence to reduce power and energy consumption, a novel technique called Dynamic Voltage Frequency Scaling DVFS is used. DVFS is a hardware technology that dynamically adjusts the voltage and frequency of a processor in execution time. Voltage and frequency can be adjusted in accordance with the specification of actual CPU into different working voltage. Vrunda et al., [15] used the combined approach of DVFS algorithm and live migration mechanism. Live migration is a technique that is often used for data centers power consumption problem. It migrates VMs from an overloaded physical server to another server. It increases the resource utilization of the servers while conserving energy. Four steps are involved in the VM machine migration process. First step is to select the physical machine which is overload or under loaded, next step is to select one or more VM, and then select the physical machine where selected VM can be placed and last step is to transfer the VM. Selecting the suitable host is one of the challenging task in the migration process, because wrong selection of host can increased the number of migration, resource wastage and energy consumption. Here [15] DVFS is applied by monitoring the CPU utilization. While CPU works in lower voltage, energy can be saved. Poojachauhan et al., [11]used scheduling algorithm for the cloud data center with DVFS technique. The proposed system can satisfy minimum requirement of resource for a job and can avoid over use of resource. Also YouwelDing et al., 2015 [16]used DVFS technique for dynamic scheduling of VMs to achieve energy efficiency and also satisfy deadline constrains with different PMs. Also for processor level energy management Benini et al., [1] proposed Network clock level gating. In network clock level gating the supplied frequency and voltage can be reduced for idle servers.

Consolidation of VMs is another technique that is always used with live migration of VMs. Consolidation is used for reducing the power consumed by the servers by migrating some of the VMs from an underutilized or over utilized physical servers to another non underutilized servers. Consolidation falls under two categories namely Static and Dynamic. Static consolidation does not involve migration where dynamic consolidation always used migration technique along with consolidation.Adnan Ashraf et al [3] used the consolidation technique for energy efficiency. Here [3] initially the VMs are placed in the servers using bin packing algorithm and utilization of CPU is predicted. If utilization is above the threshold, the VMs are migrated and consolidated using meta heuristic online algorithm namely Ant Colony System (ACS). In [9] Motta et al.,used k-nearest neighbor regression algorithm to monitor the CPU usage of each host. After predicting the over loaded host, the VMs are migrated to another non over loaded host that are determined by Power Aware Best Fit Decreasing Algorithm (PABFD) in each host. MakhloufHadji et al., [6]had used migration algorithm along with allocation algorithm. The virtual machines are initially allocated to the physical machines using energy efficient bin packing problem. The aim of the algorithm is to minimise the number of servers to process the VMs or to increase the number of idle servers. Then the VMs are migrated and consolidated using a consolidation algorithm. The migration algorithm is combined with the allocation algorithm to reduce the overall energy usage of the servers. The proposed algorithm acts as an energy aware VM scheduler. The VM migration algorithm here used is integer linear program (ILP) to achieve consolidation.GaochaoXu et al., proposed a consolidation algorithm that runs distributedly and parallelly on all physical hosts namely Distributed Parallel Ant Colony Optimization (DPACO) algorithm. The main advantage of the proposed system is that it runs distributedly and parallelly on all physical hostsand hencemigration failures can be detected in prior in each hosts.

By precise scheduling mechanisms energy can be efficiently managed in the data centers. There are two types of energy efficient scheduling techniques namely power aware and thermal aware scheduling. The right scheduling of tasks to the physical servers can greatly reduce CPU overloaded in many servers also the resource utilization can significantly increase. The goal of energy aware scheduling is to minimise the energy consumed in tasks execution in cloud environment. Daniel Guimaraes Do Lago et al., [2] used the power aware scheduling concept in order to improve the energy saving by introducing active cooling control. The algorithm tries to allocate the VMs to physical servers based on the ratio of power consumed and MIPS for each task instead of other parameters like CPU, RAM etc. In [7], KyongHoon Kim, RajkumarBuyyaproposed a scheduling algorithm for efficient operation cost and energy consumption. Dynamic Voltage Scaling (DVS) scheduling algorithm is used to reduce power consumption by proper voltage controls. Here power aware scheduling is been used for efficient power usage with deadline constraints for the tasks. The tasks must be completed within the deadline.

Next energy aware scheduling is thermal aware scheduling i.e. job scheduling that is based on predictive thermal models to select among possible job schedules to minimize its energy needs.In practice, PUE can be reduced using thermal aware scheduling. Here [5] the goal of thermal-aware scheduling is to allow the CRAC to act with higher efficiency by reducing the temperature it needs to supplyto keep all compute equipment below its red-line temperature. The scheduler does soby allocating jobs to servers so that it reaches a thermal balancecondition where allserver inlet temperatures are minimal and as equal as possible. "The more balanced the inlet temperatures are, the higher the CRAC thermostat can be set at, thus saving more energy" [5].Improper design of hardware can lead to overheated servers or overcooling servers and both can increase the operation cost. Lizhe Wang et al., [8]proposed a system for minimising the cost of the system by thermal aware scheduling that minimizes power consumption and temperature of the servers. Here the Thermal Aware Scheduling Algorithm (TASA) schedules the "hot" jobs on "cold" compute servers that are hosted on racks in the data centers and tries to minimize the temperature of the compute servers. It is calculated by the temperature sensors based on the temperatures of environment and the compute server and online job temperature.Muhammad Tayyab Chaudhry et al., 2015 [10] used thermal aware scheduling with the objective of reducing of data center thermal gradient, hotspots and cooling magnitudeby scheduling the computations.

The techniques seen until now are VM level. The proper data center design could also save energy consumed by the servers. The energy efficient data center design has two types Server & Rack placement and Air cooling & Recirculation. A typical data center has three types of switches namely Core router, Aggregation-layer, and Top-of-rack switches from top to bottom respectively. Here [13] , in addition to server consolidation as seen in many other works, the authorsSinaEsfandiarpoor et al., proposed a system that consolidates VMs into servers and further consolidates servers into minimized number of active racks. A rack has many servers that are connected via a network topology and dedicated cooling system. The minimized turned on racks employs in reduced amount of power consumption by switching off unused racks and its corresponding network and cooling systems. This server and rack consolidation resulted in 14.7% total energy conservation in the total data center. However server consolidation is adopted in VM design and data center design paradigms, the benefit is limited due to traditional air cooling system. To handle this problem hybrid air and liquid cooling technique is used in [12].The hybrid cooling system combines air and liquid cooling and uses water to cool down high-power-density components,such as processors and memory devices which dominate totalheat dissipated in servers, while it uses air to cool down otherauxiliary components which have a low power density. Thehybrid cooling system can remove heat from a data center usingless power than conventional air cooling.Here [12] sweet temperature and Available Sleeping Time Threshold(ASTT) is maintained for minimizing the total costs. Also Victor Banuelos, 2010 [14] mentioned in "Managing Data Centre Heat Issues" that employing internal air dams and filler panels in data centers can prevent Recirculation.

V. CONCLUSION AND FUTURE WORKS

This work reviewed the impacts of high energy consumption in the data centers and the techniques through which energy consumption in the data centers can be reduced. These techniques can be applied at VM design and data center design levels. They have proofed to improve the energy consumption of the servers in the data centers significantly and it is reviewed in the existing works. Various approaches using these techniques had been proposed and they are studied in this work.

The future work of thisstudy is to review many other similar techniques that can be applied in the data centers for energy conservation and to compare their performance results.

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