Minimizing CO_2 Emissions on Cloud Data Centers

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Abstract— The need of hour extended its area of conservation of energy in cloud computing. Cloud computing is the heart of research and one of the hottest topics in the field of computer science and engineering. Basically Cloud computing provides services that are referred to as Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS). As the technology advances and network access becomes faster and with lower latency, the model of delivering computing power remotely over the Internet will proliferate. Hence, Cloud data centers are expected to grow and accumulate a larger fraction of the world's computing resources. In this way, energy efficient management of data center resources is a major issue in regard to both the operating costs and CO_2 emissions to the environment. In energy conservation we try to reduce CO_2 emissions that contribute to greenhouse effect. Therefore, the reduction of power and energy consumption has become a first-order objective in the design of modern computing systems. In this paper we propose two algorithms for energy conservation on cloud based infrastructure.

Index Terms— Cloud Computing, Energy Conservation, Modified Best Fit Decreasing Algorithm, Power Aware Best Fit Decreasing Algorithm.

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1 Introduction

CLOUDS have floated as the next-generation IT platform for hosting applications in science, business, social networking, and media content delivery. Moreover it is a distributed computing paradigm which facilitates the users with a distributed access to scalable virtualized hardware or software [1]. Cloud data centers are the foundations to support many internet applications, enterprise operations, and scientific computations. Data centers are driven by large-scale computing services such as web searching, online social networking, online office and IT infrastructure outsourcing, and scientific computations [2]. A cloud consists of several elements such as clients, datacenter and distributed servers. It includes fault tolerance, high availability, scalability, flexibility, reduced overhead for users, reduced cost of ownership, on demand services etc.

The National Institute of Standards and Technology (NIST) defines cloud computing as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. The big organizations like Rackspace, Amazon, Google, Microsoft, IBM, and VMware are providing cloud computing services such as data storage, an application development platform, data access and computation. They provide the complete infrastructure to manage the IT services on-demand self-basis. Customers can dynamically choose their computing services according to their changing need at reduced costs. The providers gain benefits by reusing computing resources. Thus cloud computing is advantageous to both the service providers and the clients. Several key factors that enable cloud computing to lower energy use and carbon emissions from IT [3]:

- Dynamic Provisioning: It is the process of reducing wasted computing resources through better matching of server capacity with actual demand.
- Multi-Tenancy: Multi-tenancy in cloud service is a policy-driven enforcement, segmentation, isolation, governance, service levels, and chargeback/billing models for different consumer constituencies [4].
- Server Utilization: Operating servers at higher utilization rates.
- Data Center Efficiency: Utilizing advanced data center infrastructure designs that reduce power loss through improved cooling, power conditioning, etc.

2 Parameters of Energy Conservation

In this section we will discuss about different parameters that are essential for energy conservation.

- Number of users: It tells us the number of users in a given application.
- Number of servers: It is the number of production servers to operate a given application.

- Utility of device: Computational load that a device (server, network device or storage array) is handling relative to the specified peak load.
- How to consume power per server: Average power consumed by a server.
- Power consumption for networking and storage: Average power consumed for networking and storage equipment in addition to server power consumption.
- Effectiveness of data center power usage: Data center efficiency metric which is defined as the ratio of the total data center power consumption divided by the power consumption of the IT equipment. Power usage effectiveness accounts for the power overhead from cooling, power conditioning, lighting and other components of the data center infrastructure.
- Data center carbon intensity: It is the amount of carbon content to generate the energy consumed by a data center, depending on the mixture of primary energy sources and transmission losses. The carbon emission a key factor of carbon intensity of these energy sources.

3 RELATED WORK

Kyong Hoon Kim et al. [3] have studied the processing power management through the Virtual Machine (VM) provisioning which a vital technique in cloud based infrastructure. In this paper the authors have provided a real-time cloud service framework for requesting a virtual platform, and also investigated various power-aware VM provisioning schemes based on DVFS (Dynamic Voltage Frequency Scaling) schemes. Olivier Beaumont et al. [4] have studied approximation algorithms for minimizing both the number of used resources and the dissipated energy in the context of service allocation under reliability constraints on Clouds. For both optimization problems, authors have given lower bounds and have exhibited algorithms that achieve claimed reliability. Bo Li et al. [5] have demonstrated a novel energy efficient approach called "EnaCloud", which enables application live placement dynamically with consideration of energy efficiency in a cloud platform. Here a Virtual Machine is used to encapsulate the application, which supports applications scheduling and live migration to minimize the number of running machines; which indirectly saves energy. P. Prakash et al. [6] have given a distributed power migration and management algorithm for cloud environment that uses the resources in an effective and efficient manner ensuring minimal use of power. The proposed algorithm performs computation more efficiently in a scalable cloud computing environment that reduces up to 30% of the power consumption to execute services. Qi Zhang et al. [7] have suitably explained a control theoretic solution to the dynamic capacity provisioning problem that minimizes the total energy cost while meeting the performance objective in terms of task scheduling delay.

4 ENERGY CONSERVATION

Energy consumption is not only determined by hardware efficiency, but also by the resource management system deployed on the infrastructure and the efficiency of applications running in the system. The interdependence of different levels of computing systems in regard to energy consumption is shown in Fig.1. Energy efficiency impacts end-users in terms of resource usage costs, which are typically determined by the Total Cost of Ownership (TCO) incurred by the resource provider. Higher power consumption results not only in boosted electricity bills but also in additional requirements to the cooling system and power delivery infrastructure [8][9], i.e., Uninterruptible Power Supplies (UPS), Power Distribution Units (PDU), and so on.

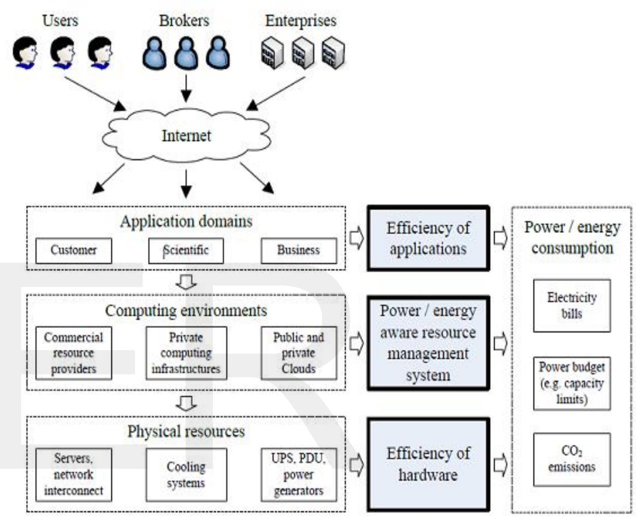

Figure 1: Energy Consumption at Different Levels in Computing Systems

5 POWER CONSUMPTION MANAGEMENT

Power consumption and energy management techniques are closely related to each other. There are two types of power consumption in cloud computing environment [11]. One is static power consumption and the other is dynamic power consumption. The static power consumption is mainly determined by the type of transistors, logic gates and process technology used on cloud based infrastucture. The reduction of static power requires improvements of the low-level system design.

Dynamic power consumption is created by circuit activity (i.e., transistor, switches, changes of values in registers, etc.) and depends mainly on a specific usage scenario, clock rates, and input-output activity. The sources of dynamic power consumption are the short circuit current and switched capacitance. Short-circuit current causes only 10-15% of the total power consumption and so far no way has been found to re-

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duce this value without compromising the performance [12][13].

Similarly power management techniques are of two types: Static Power Management (SPM) and Dynamic Power Management (DPM) as shown in Fig.2. SPM contains all the optimization methods that are applied at the design time at the circuit, logic, architectural, and system levels [13]. Whereas DPM contains all optimization at virtualization level, operating system level, and circuit level.

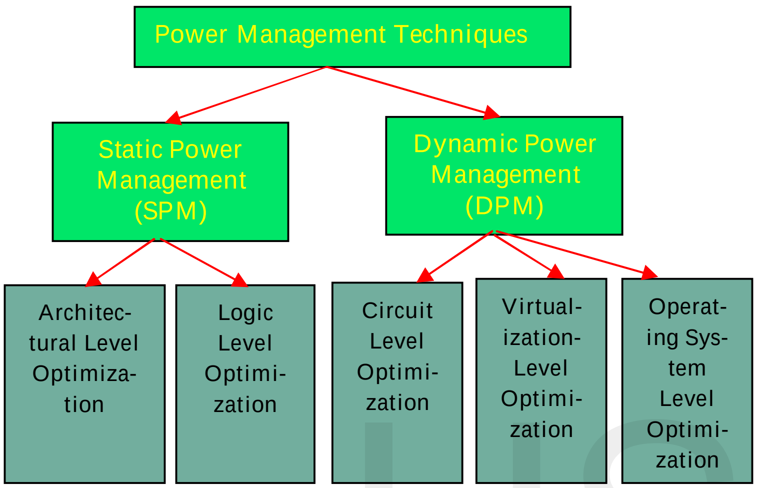

Figure 2: Energy and Power Management

6 PROPOSED ALGORITHMS FOR ENERGY CONSERVATION

In this section we propose two algorithms i.e., Modified Best Fit Decreasing (MBFD) and Power Aware Best Fit Decreasing (PABFD) for energy conservation in cloud based infrastructure.

Algorithm 1: Modified Best Fit Decreasing (MBFD)
The fundamental mechanism that we are going to implement in this algorithm is completely based on sorting the available Virtual Machines in decreasing order of their current CPU utilizations, and allocates each Virtual Machine to a host that provides the least increase of power consumption. This allows leveraging the heterogeneity of resources by choosing the most power-efficient nodes first. The pseudo-code for the algorithm is given as follow:

Input: Host list, Virtual Machine list
Output: Allocation of Virtual Machines

1. Sort the Virtual Machines in decreasing order of utilization
2. For each Virtual Machine in Virtual Machine list
3. Assign the Virtual Machine having minimum Power (which is the maximum priority) until all the allocated hosts are null
4. For each host in Host list if host has enough resource for VM then
5. Estimate the Power of VM
6. if power of the Virtual Machine is less than minimum power
7. then allocate the Host having minimum power
8. if there is no allocated Host
9. allocate Virtual Machine to a Host
10. return allocation

Algorithm 2: Power Aware Best Fit Decreasing (PABFD)
In Power Aware Best Fit Decreasing (PABFD) algorithm we sort all the Virtual Machines in the decreasing order of their current CPU utilizations and allocate each Virtual Machine to a host that provides the least increase of the power consumption caused by the allocation.

Input: Host list, Virtual Machine list
Output: Allocation of Virtual Machines

1. Sort the Virtual Machines in decreasing order of utilization
2. For each Virtual Machine in Virtual Machine list
3. Assign the Virtual Machine having minimum Power (which is the maximum priority) until all the allocated hosts are null
4. if host has enough resources for Virtual Machine then
5. for each host in Host list if host has enough resource for Virtual Machine then
6. if power of the Virtual Machine is less than minimum power
7. then allocate the Host having minimum power
8. if there is no allocated host
9. add the Virtual Machine to the allocation of VM
10. return the allocation

7 CONCLUSION AND FUTURE WORK

Data centers have become a cost-effective infrastructure for data storage and hosting large-scale service applications. However, large data centers today consume significant amounts of energy. This not only raises the operational expenses of cloud providers, but also raises environmental concerns with regard to minimizing carbon footprint. To develop a strong and competitive cloud computing environment we need to reduce the data center energy consumption costs by the virtue of which we will be able to achieve our goal.

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10 BIBLIOGRAPHY OF THE AUTHORS

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