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Survey on Energy Efficiency in Cloud Computing

Backialakshmi M[1]* and Hemavathi N[2]

[1]PG Scholar, Department of CSE, PSNA College of Engineering and Technology, India
[2]Lecturer, Department of Computer Science, Thyagarajar College, India

Abstract

The datacenters deals with huge volume of data. The datacenters that possess cloud servers are known as cloud datacenters. About 25% to 40% of the OPEX in datacenters is caused by power consumption and in it 50% of power is consumed by cooling towers. So the energy efficiency is major challenge of cloud datacenter. In current trends the users demand wide range of services within optimal resource usage and cost. So to maintain energy usage of the datacenters we use various types of algorithms both in terms of hardware and software.

Keywords: Datacenters; Energy efficiency; Cost; Resource usage; Cloud computing

Introduction

Cloud-based computing can reduce IT capital costs, reduce laborcosts, and enhance productivity. And a growing body of evidence shows thecloud is also remarkably efficient. Last year we released a paper on the energy savings from using Gmail instead of locally hosted email. It estimates, which we've supported with a case study from a Google Apps client, show that migrating basic IT applications to Google Apps significantly reducesenergy consumption and carbon emission. Based on the analysis, a typical company or organization that migrates to thecloud could to save an estimated 68-87% in energy for its office computingand reduce similar amounts of carbon emissions.

Energy consumption is not only determined by hardware efficiency, but it is also dependent on the resource management system deployed on the infrastructure and the efficiency of applications running in the system. Energy efficiency impacts end-users in terms of resource usage costs, which are typically determined by the total cost of ownership (TCO) incurred by a resource provider.

Higher power consumption results not only in boosted electricity bills but also in additional requirements to a cooling system and power delivery infrastructure, that is, uninterruptible power supplies (UPS), power distribution units (PDU), and so on. With the growth of computer components density, the cooling problem becomes crucial, as more heat has to be dissipated for a square meter (Figure 1).

The U.S. General Services Administration (GSA) migrated to Google Apps in 2012, and shared detaileddata about their IT equipment before and after the migration. GSA is an independent agency of thefederal government that helps manage and support federal agencies. This includes managing over8,300 owned and leased buildings and a 210,000 vehicle motor pool.

Typical Energy Consumption

We calculated the low and high range for estimates in this table by considering two types ofBusinesses. The low estimates are appropriate for a "data-light" business (e.g., largely clerical)that has relatively low-power computers and servers. The high estimates are appropriate for adata-intensive business (e.g., an engineering firm) with a greater number of higher poweredcomputers and servers.

For client devices (e.g., desktops, laptops, etc.), we assumed 1 laptop and 0.2 desktops per user inthe low estimate, with an annual direct energy consumption of 60 kWh for the laptop and 160 kWhfor the desktop. These energy consumption numbers are appropriate for a low-end computer ormid-range Energy Star-qualified device.16 in the high estimate; we assumed 1 laptop and 0.8 desktopsper user, with an annual direct energy consumption of 160 kWh for the laptop and 400 kWh forthe desktop.

These energy consumption figures are appropriate for a typical higher-end 60 wattlaptop and a 150 watt desktop that are on for 2,600 hours per year. We multiplied both high and lowestimates by a further factor of 1.5 to account for the additional air-conditioning needed to removethe devices' heat. For servers and server cooling, we assumed an average server power of 200 watts, one server per 50 employees, and a PUE of 2.0 in the low estimate, assuming an average server power of 500 watts, one server per 10 employees, and a PUE of 1.5 in the high estimate. We assumed 8,766 operating hours per year in both.

Current State of Energy Efficiency in it Infrastructures

IT consumes an increasing amount of energy, but is also instrumental in increasing productivity and economic prosperity and in reducing energy expenditure from other sources through e-work, e-commerce and e-learning. Traditional network design has sought to minimize infrastructure costs and maximize quality of service (QoS).

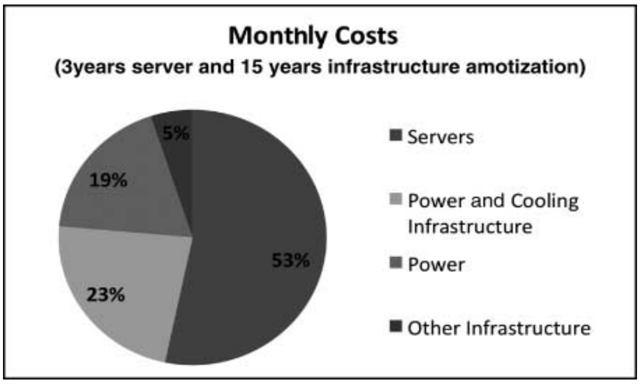

Figure 1: Monthly Cost of Datacenters.

***Corresponding author:** Backialakshmi M, PG Scholar, Department of CSE, PSNA College of Engineering and Technology, India, Tel: 0451 255 4032; E-mail: backialakshmidgl@gmail.com

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However, IT also plays a complex role in energy consumption via the ‘communicate more and travel less ‘paradigm, as well as through the use of smart devices in homes and offices to optimize energy management.

Thus, IT can reduce energy consumption and carbon emissions, but this potential reduction is partially offset by the power used by data centers and computer networks which runs into billions of dollars or euros. Thus, a fraction of energy savings in IT and networks could lead to significant financial and carbon savings. In this section, we review recent research in energy efficiency for standalone hardware, and then review work that considers energy consumption as part of the cost functions to be used for scheduling in multiprocessor and grid architectures. Finally, we briefly review energy consumption using various algorithm and techniques in cloud datacenters.

Green DCN: A general framework for achieving energy efficiency in data center networks

In this paper it determines the energy efficiency with a time-aware model. It proves the NP hardness in 2 ways. First, it solves the problem of assigning virtual machines (VM) to servers to reduce the amount of traffic and to generate favorable conditions for traffic engineering. Second, it reduces the number of active switches and balance traffic flows [1].

Speed scaling and power down are two representative techniques for energy saving strategies. Therelation between the power consumption and routing and propose a two-phase energy-efficient routing algorithm. This algorithm aims to minimize the number of switches that will be used and to balance the traffic flows among them. Experimental results shows that the about 50% of the energy is being saved.

Energy-credit scheduler: Energy-aware virtual machine scheduler for cloud systems

This model estimates the energy consumption of a virtual machine based on in-processor events generated by the virtual machine. Current billing systems use the processor time allocated or the number of VM instances as billing criteria and so the energy costs will exceed hardware purchase costs in data centers. The proposed model estimating energy consumption that calculates the amount of energy consumed by each VM without any dedicated measurement devices. This method reduces the energy consumption rate of each virtual machine to a user-defined budget [2].

The energy-credit scheduler (ECS), that schedules VMs according to their energy budgets instead of processor time credits. The evaluation of the model estimates energy consumption with errors of less than 5%. The disadvantage is that it only focuses on the processor energy consumption but not the other components.

A Multi-start local search heuristic for an energy efficient VMs assignment on top of the Open Nebula cloud manager

Energy-aware Multi start Local Search algorithm (EMLS-ONC) that optimizes the energy consumption of an Open Nebula-based Cloud. It proposes a Pareto multi-objective one named EMLS-ONCMO that deals with both the energy consumption of the hosts and the VMs performance [3].

The prior objective is to find a Pareto tradeoff between reducing the energy consumption of the cloud while preserving the performance of Virtual Machines (VMs). An Open Nebula scheduler algorithm is used which is the consolidation for energy reduction purposes. Bin packing FFD-based scheduler algorithm deals with sorting the pool of the VMs to be assigned in a decreasing order (i.e. from the most to the least requirement needs) and to assign those VMs each time to the server with the least energy consumption. Experimental results show that EMLS-ONC improves by up to 26% on average the results obtained by the OpenNebula’s default scheduler and by up to 25% the energy-aware FFD-based approach.

Distributed energy efficient clouds over core networks

This paper analyses three cloud services, namely; content delivery, Storage as a Service (StaaS) and virtual machines based applications. Optimizing the cloud content delivery reveals that replicating content into multiple clouds based on content popularity (OPR scheme). It yields 43% total saving in power consumption compared to power unaware centralized content delivery [4].

The StaaS scenario show that at lower access frequencies, the optimal clouds scheme selects to serve all users from the central cloud while at higher access frequencies content is migrated to serve users locally. It yields 48% network power savings compared to serving content from a single central location. Optimizing the placement of VMs shows that VM Slicing is the best approach compared to migration or replication schemes. It yields 25% of the total power compared to a single virtualized cloud scenario.

Energy-efficient datacenters

The objective is to analyze the resource provisioning and power or thermal management problems in datacenters, and to review strategies that maximize the datacenter energy efficiency subject to peak or total power consumption and thermal constraints meeting given SLAs [5].

A more accurate datacenter efficiency metric should focus on estimating the actual amount of power used by the IT equipment to do useful work. An energy-efficient datacenter exploits hardware heterogeneity and employs dynamic adaptation. We can develop algorithms to globally manage compute, storage, and cyber-physical resources with the objective of minimizing the total energy dissipation.

Simulation of power consumption of cloud data centers

This paper proposes a simulation-driven methodology with the accurate energy model to verify its performance, and introduces a new resource scheduling algorithm Best-Fit-Decreasing-Power (BFDP) to improve the energy efficiency without degrading the QoS of the system [6].

Simulation of energy consumption in clouds involves: building an accurate energy model, designing and implementing candidate energy-aware algorithms and evaluating simulations for running these algorithms. BFDP locates the host machine expected to use the minimum energy. BFDP has the best performance in terms of efficiency but brings more SLA violation, host shutdowns and VM migrations.

A taxonomy and survey of energy-efficient data centers and cloud computing systems

This paper proposes taxonomy of energy-efficient design of computing systems covering the hardware, operating system, virtualization and data center levels. Survey of various key works in the area and map them to our taxonomy to guide future design and development efforts. GreenCloud project aimed at development of energy-efficient provisioning of Cloud resources, while meeting QoS requirements [7].

pMapper monitors the applications’ behavior and resizes VMs according to current resource requirements and the SLA. This paper

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on the whole provides the comparative of efficient energy consumption based on power and energy models, energy management models, hardware and firm level, OS level and virtualization.

Performance evaluation of a green scheduling algorithm for energy savings in cloud computing

This paper aims at designing, implementing and evaluating a Green Scheduling Algorithm integrating a neural network predictor for optimizing server power consumption in Cloud computing [8]. The algorithm uses the prediction in making turning off/on decisions to minimize the number of running servers. It shutdowns unused servers. It also concentrates workload on a subset of servers and then turns off the others. It is used for making decision on creation and destruction of virtual machines in servers and turning servers off/on for energy savings. This mechanism saves up to 46.3% of power consumption.

A survey on architectures and energy efficiency in data center networks

It the architectural evolution of DCNs and their energy efficiency. It categorizes the existing DCN architectures into switch-centric and server-centric topologies as well as their design technologies. It analyses the conventional DC challenges and also data center evolution. The conventional data center is a switch-centric design which includes include VL2, Portland, Fat-Tree, and Monsoon. Server-centric topology includes Dcell, Bcube, and FiConn. These topologies and designs are based on packet-switched electronic networks [9].

A performance metric for Power Usage Efficiency (PUE) is used to measure how efficient a data center is in using its power and can be calculated by dividing the total facility power by the IT equipment power consumption.

Techniques for energy efficiency comprises virtualization, energy-aware routing in DCNs, dynamic voltage/frequency scaling, rate adaptation, dynamicpower management (DPM), energy-aware scheduling methodsand dynamic adjustment of active network elements in DCNs (Figure 2).

Energy-efficient application-aware online provisioning for virtualized clouds anddata centers

Energy-aware online provisioning approach for HPC applications on consolidated and virtualized computing platforms. Energy efficiency is achieved using a workload-aware, just-right dynamic provisioning mechanism and the ability to power down subsystems of a host system that are not required by the VMs mapped to it.

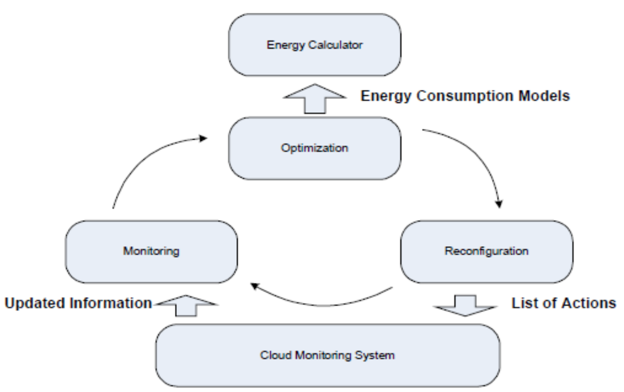

Figure 2: Energy Consumption Architecture.

Energy-aware provisioning consists of two key steps: creating VM instances to host each application request, matching the specific characteristics- VMProvisioning and mapping and scheduling these requests onto distributed physical resources- Resource provisioning [10].

It focuses on the use of clustering techniques to bridge the gap between VM provisioning and resource provisioning that negatively impacts energy efficiency. The experimental results shows the energy saving of 15% and with an acceptable penalty in QoS of 5%.

Experimental Analysis

Our aim is to characterize energy consumption and performance in Cloud environments by analyzing and measuring the impact of various task and system configurations. We contrast the energy requirements of several presumptive Cloud data centers.

Algorithm

Modified Best Fit Decreasing (MBFD)

1 Input: host List, vm List Output: allocation of VMs

2 vm List. Sort Decreasing Utilization ()

3 for each vm in vm List do

4 minPower←MAX

5 allocatedHost←NULL

6 foreach host in hostList do

7 if host has enough resource for vm then

8 power←estimate Power (host, vm)

9 if power <minPower then

10 allocatedHost←host

11 minPower←power

12 if allocatedHost/= NULL then

13 allocate vm to allocated Host

14 return allocation

Consolidation represents a data center where virtual machine consolidation increasing individual server utilization from 0.26 to 0.57 and reducing the number of active server from 81% to 44%. Improved consolidation drastically decreases aggregate energy consumption, but, cryptically, it increases power usage effectiveness (PUE; total data center energy consumption divided by IT equipment energy consumption). These results show the shortcoming of PUE as a metric for energy efficiency (Figure 3a and 3b).

The Optimal Cooling scenario posits integrated, dynamic control of cooling infrastructure. We assume an optimizer with global knowledge of data center load/environment conditions that seeks to minimize chiller energy consumption. This scenario demonstrates the potential for intelligent cooling management. Finally, Container represents a data center with containment system (e.g., servers enclosed in shipping containers), where containment index is increased to 0.99. Under this scenario, the cooling system power draw is drastically reduced and power conditioning infrastructure becomes the limiting factor on energy efficiency (Figure 4a and 4b).

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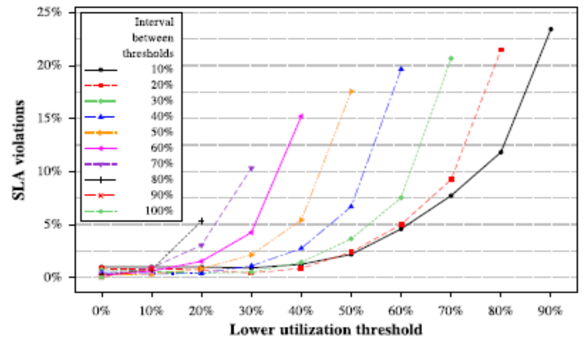
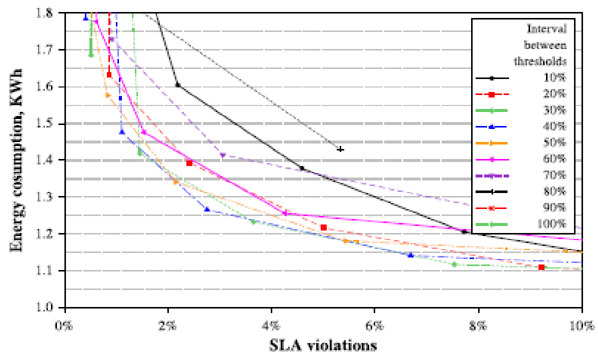


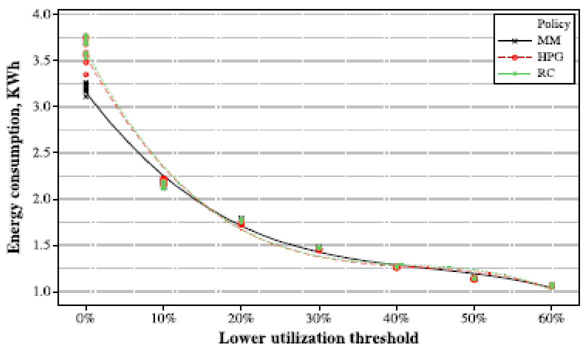
(a) The mean SLA violations bv the MM policv.

Figure 3a: The mean SLA violations bv the MM policy.



(b) The energy consumption to SLA violations by the MM policy.

Figure 3b: The energy consumption to SLA violations by the MM policy.

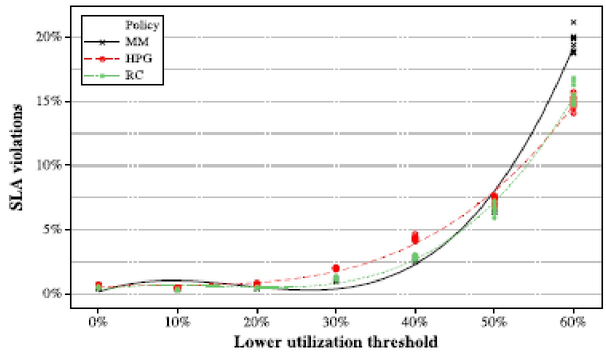


(a) The energy consumption.

Figure 4a: The energy consumption.

Conclusion

This paper has reviewed the potential impact of energy saving strategies for the management of integrated systems that include computer systems and networks. We have surveyed the contributions that are available in this area from recent research. We propose that cloud computing with virtualization as a way forward to identify the main sources of energy consumption, and the significant trade-offs between performance, QoS and energy efficiency and offer insight into the manner in which energy savings can be achieved in large-scale computer services that integrate communication needs. Based on the



(b) The SLA violations.

Figure 4b: The SLA violations.

approaches that we have identified, we think that specific plug-ins and energy-control centers for networked large-scale hardware and software can be implemented and that they can have significant impact.

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