International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 7371-7384

http://www.ripublication.com

A Survey On Research Challenges In Data Center Energy Efficiency

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ABSTRACT

In day to day life ,Information and communication technology devices and services are more important in every moment. This results in growing of power consumption associated with Information and communication technology equipment. Mainly used three Information and communication technology categories are communication networks, personal computers and data centers. Saving Power in data center networks is a challenging issue with many factors like switches, router ,traffic load ,power saving modes, PUE ,etc., In this paper analyses how power consumption efficiently utilized in data centers. Two approaches, namely distributed, centralized are studied that based on mixed integer linear programming model is followed..While managing the resources, the virtual machine migration policies are considered.

KEYWORDS Power consumption, Data center networks, Switches, Routers, Traffic Load.

1. INTRODUCTION

1.1 POWER CONSUMPTION

ICT products and services in the total worldwide power consumption has increased from about 3.9% in 2007 to 4.6% in 2012 [10].

Koomey et al., (2011) [11] provides an estimation of data center power consumption for 2005, and a lower and upper bound estimation for 2010. They use newer data to estimate a most likely value instead of an upper and lower bound for 2010, and extend these trends to 2012. The difference is including electricity use attributed to so-called ‘orphaned servers’, a typically undocumented number of servers using electricity but no longer delivering services.

1.2 OVERVIEW OF DATA CENTERS

Cloud computing offers services in a timely on demand manner , to scaling up and down of resources.Data center networks are a collection of servers arranged either geographically centralized or distributed based on SLA agreements[32]. Data centers with thousands of servers deployed by organizations like IBM,Microsoft ,Amazon and Google to provide cloud computing Services [24].

Data centers consumes huge amounts of energy, that increases the demand for resources to build large sized data centers, which requires a significant amount of power to operate :120 billion of kWh in the USA alone as stated in the report published by the USA environmental protection agency[43].

1.3 ENERGY EFFICIENT ETHERNET SWITCHES

Sivaraman V et al., (2014) [33] develops a energy consumption profiles of network switches.In order to reduce energy consumption, the IEEE Standard 802.3az:Energy Efficient Ethernet, (2010) [44] introduces the concept of Low Power Idle (LPI) which is used instead of the continuous IDLE signal when there is no data to transmit. Cloud computing offers services in a timely on demand manner , to scaling up and down of resources.Data center networks are a collection of servers arranged either geographically centralised or distributed based on SLA agreements [32] . Data centers with thousands of servers deployed by organizations like IBM,Microsoft ,Amazon and Google to provide cloud computing Services [24].

2. NEED OF ENERGY EFFICIENCY IN DATA CENTERS

The overall efficiency of data centers related to the computational efficiency, which, in its turn, depends on the workload distribution of the servers. A given load evenly distributed to a large number of servers that work at low utilization requires more energy than the same load groomed over a smaller number of servers that work at higher utilization. Virtualization is introduced to many approaches to consolidate load on few servers. The issues are used to allocate virtual machines to servers, and the methods for using highly utilized servers, become overloaded due to fluctuations of the amount of resources requested by the running virtual machines.

[Meo et al., 2014] From [26] , TREND researchers have proposed a solution, called VMPlanner [6] , which efficiently optimize the network power consumption in a cloud data center. VMPlanner performs two tasks: the virtual machines (VMs) placement inside data centers,and the traffic flow routing between the VMs. At the end of this procedure, as many network elements as possible are switched off while guaranteeing Quality of Service (QoS) constraints. The problem is formulated as an Integer Linear Problem . First the VMs are grouped into sets that exchange a minimum amount of traffic. Then the second step is the VMs are mapped to the server infrastructure in order to minimize the traffic that is exchanged between the servers. Finally, the traffic generated by the VMs is routed in such a way that as many network elements as possible can be turned off. The solution proposed in Refs. [25] ,[8] consists of delegating part of the VM placement decision processes to the servers, so that the allocation and migration strategies are implemented in a distributed fashion, with the contribution of all servers. The servers made simple probabilistic decisions about their availability to host a new virtual machine or the need to migrate them to other servers. The probability of accepting a new Virtual machine or migrating it depends on the server load. The achieved energy saving depends on the workload profile with time and, thus, on the degree of server consolidation that can be achieved. Average daily saving is typically between 30% and 40%.

3. TECHNIQUES INVOLVED IN ENERGY EFFICIENCY

Data centers use energy efficiency techniques, such as

i) resource consolidation, and

ii) Dynamic Voltage/Frequency Scaling(DVFS) [16],[35].Resource consolidation is further classified into:
   - (a) virtualization, and
   - (b) workload consolidation [32] .

Virtualization is the most adopted energy efficiency technique in data center environments [22]. Virtualization consolidates data center workload on a minimum number of physical servers using virtual machine live migration in order to provide energy efficiency. The server and memory resources are dynamically acquired according to the fluctuating QoS requirements of different applications hosted by the virtual machines (VM) [41]. Workload consolidation consolidates data center workload on minimum number of physical servers so the rest of servers can be powered off. Resource consolidation strategies require an Autonomic Power Manager (APM) to dynamically power on/off data center elements according to workload requirements.

DVFS techniques are based on the fact that data center elements can be switched to low power state by scaling either input voltage or switching frequency. The DVFS technique requires hardware support and Advanced Configuration and Power Interface (ACPI) standard implementation. DVFS techniques have been implemented in both the server [11] and switch domains [4]. Switches operate a link at lower frequency such that it provides the required bandwidth while consuming lesser energy. Junaid Shuja et al.,2014 [32] proposed DCEERS **,**a workload consolidation technique that optimizes set of active data center resources according to current workload for energy efficiency.

4. ISSUES RELATED WITH RESOURCE CONSOLIDATION

Scheduling involves task processing and resource allocation .It uses an improved differential evolution algorithm (IDEA) [34] . The proposed IDEA combines the Taguchi method and a differential evolution algorithm (DEA).

Beloglazov et al. ,(2012) [1] defined an architectural framework and principles for energy-efficient cloud computing . They use Modified Best Fit Decreasing algorithm (MBFD) to solve the dynamic allocation issue of VMs. However, the algorithm cannot achieve the dynamic consolidation of VMs with the desired maximum energy conservation.

Kessaci et al.,(2013) [15] presented an energy-aware multi-start local search algorithm (EMLS) that optimizes the energy consumption of an OpenNebula-based cloud .

Quan et al. (2012) [27] proposed a way of saving energy in traditional data centers that rearrange the resource allocation in such a way that energy is saved with suitable human effort.

Quarati et al. (2013) [28] presented a cloud brokering algorithm which offers services with different levels of non-functional requirements , to private or public resources with different scheduling criteria. To achieve the aim of maximizing user satisfaction and broker's revenues, it attains profit increases by reducing energy costs through the adoption of energy-saving mechanisms.

Kołodziej et al. (2013) [17] defined an independent batch scheduling in computational grid as a three-objective global optimization problem with Makespan, flow time, and energy consumption.The dynamic voltage scaling (DVS) methodologies used for reducing the cumulative energy. The effectiveness of these algorithms has been empirically justified in two different grid architectural scenarios in static and dynamic modes.

Luo J-P et al., (2014) [23] concentrates on dynamic resource management scheme. Consolidation of resources is achieved by VM migrations technology and low-utilized or idle hosts switched to power saving mode to achieve energy saving while ensuring that SLAs are adhered to. The intelligent method of modified shuffled frog leaping algorithm (SFLA) based on improved extremal optimization (EO) is propsed to rapidly and efficiently complete the dynamic allocation of VMs.

DVFS is a means of achieving hardware facilities energy conservation [5].

DVFS, dynamically adjusts the running frequency and voltage of the chip (for the same chip, the higher the frequency, the higher the voltage) to achieve energy saving. A low frequency can reduce power. However, energy cannot be saved by simply reducing the frequency because for a given task, energy consumption can only be reduced when the voltage and frequency are lowered simultaneously.

Circuits designed by different manufacturers differ significantly. Intel, Microsoft, Toshiba, and other companies jointly developed the advanced configuration power interface (ACPI) specification to establish a common power management interface between the operating system and the hardware facilities [37]. ACPI improves the original APM through BIOS and providesa relatively good power management mode and interface specification in configuration management. ACPI sets a maximum of six power states. Different states correspond to the different power consumptions of the processor, memory, and hard disk. Most processors at present support the states running, idling, sleeping, and closed.

Rusu, Ferreira, Scordino, and Watson (2006) [30] proposed an energy consumption management strategy based on QoS in connection with the server cluster system. The strategy is divided into backend management and local management. Local management supports DVFS. When the back-end manager detects that the system needs to close or open a server, the local manager controls power by the DVFS module and switches the server into the corresponding state. The system does not utilize live VM migrations technology; it involves the off-line calculation of the back-end server to decide whether to shut down or open the server. Such decision is limited for energy saving.

Lee and Zomaya (2010) [21] proposed an efficient energy management strategy in a distributed cloud computing system. The researchers defined the optimized objective function as a relative superiority (RS) expression according to the relation between task processing time and energy consumption. The RS value for the assigned task is calculated first. The task is then allocated to the server with maximum RS value. This algorithm assumes that all servers are active and in good running condition and ignores the heterogeneity of the system. Only the allocation of the newly added VMs was considered in this study. In the actual process, the adjustment of VMs with SLA violation should be considered as well.

Kusic et al. (2009) [20] defined the problem of energy management in virtual heterogeneous environments as a scheduling optimization problem and applied limited look-ahead control (LLC) during processing. LLC aims to maximize the profit of the resource service providers and minimize energy consumption and SLA violation. The system applies the Kalman filter to estimate the number of future client requests and predict the state of the system to achieve necessary resource integration. However, the system cannot be implemented in the IaaS cloud environment. In addition, the model is extremely complicated. Adjusting a system with 15 nodes requires 30 min. Thus, the model is difficult to apply to large-scale and real-time cloud data centers.

Verma, Ahuja, and Neogi (2008) [39] modeled the energy-aware dynamic arrangements of VMs in the virtual heterogeneous environment and turned them into a continuous optimization problem; the placement of VMs was regarded as the minimum energy consumption and the maximum performance optimization issue in each time frame. The researchers utilized a heuristic algorithm to solve the packing problem and re-allocated the VMs of each time frame by live migration strategy.

In the follow-up work from [38], the researchers applied static strategy (month and year adjustment), semi-static strategy (day and week adjustment), and dynamic strategy (minute and hour adjustment) to regular adjustment. However, these algorithms do not consider the issue of SLA violation. The system performance diminishes when the load changes, and SLAs cannot be guaranteed.

Berral et al. (2010) [2] studied the VM dynamic consolidation problem on the premise of SLAs by applying machine learning techniques to address the issue of energy consumption.

Rodero, Viswanathan, and Lee (2012) [29] employed the CPU dynamic voltage scaling technique and virtual machine dynamic integration technology to achieve the energy saving target of a data center.

Kramer, Petrucci, and Subramanian (2012) [19] adopted the column generation technique and server power-saving technology based on CPU dynamic on/off switching and developed an energy-saving scheme for heterogeneous virtual server cluster environments. The scheme provided better results in a relatively short period of time. However, the experiment did not consider the large-scale cluster network environment.

Virtualization is applied in data centers at present. The systems of these centers allow VMs to perform live migration among physical nodes to achieve improved performance or energy saving when the resources that VMs use are less than those actually assigned, the VMs can migrate to other server nodes by adjustment and combination. The idle server node would switch to energy saving mode via the ACPI interface to save energy. The current resource scheduling strategy of cloud data centers focuses on system performance improvement and ensures SLAs.

5. RELATED WORK

Jian-ping luo et al.,[2014] [23] focuses on the infrastructure as a service model ,where user defined VMs are launched in appropriate data centers. It concentrates on QOS parameters as well as maximum energy savings and green computing needs. An algorithm named shuffled frog leaping algorithm with improved extremal optimization and used for dynamic allocation problems.

Wanneng Shu et al ., [2014] [31] proposed an optimization model based on DVFS (Dynamic Voltage and Frequency Scaling] that the given resource node depends on voltage supply and resource frequency.Makespan (or overall task completion time) to be maximized.Using this parameter ,DVS,ICSA,IDEA,EMLS algorithms compared.Energy consumption achieved from scheduling cycle,lower utilization threshold and daily request arrival.ICSA is a proposed one consumed leased energy than others.

Junaid Shuja et al., [2014] [32] introduces a scheduling framework DCEERS – Data center wise energy –efficient Resource scheduling frame work that schedules the resources according to the workloads. Mixed Integer Linear Programming model is used to service workloads using Benders decomposition algorithm.

Ward Van Heddeghem et al., [2014] [10] addresses the rapid development in the Information and Communication Technology (ICT) devices and services. Then the ICT electricity consumption from 2007 to 2012 based on communication networks,PCS, and data centers, They outlined that the need for energy efficiency is required.

Gabor kecekemeti et al., [2014] [14] proposed an architecture based on resource and power usage of academic cloud users. It involves two technologies i)leader boards – behavior of academics (users) ii)direct user towards economical resource usage.

Frederic Francois et al., [2014] [7] introduces a green load balancing algorithm which jointly optimize both energy efficiency and load balancing in backbone networks. End to end traffic delay requirements increases the traffic delay. To reduce this, modifies ETE schemes required.

Indra Widjaja et al., [2014] [42] proposed a new approach how switch size chosen then how power saved.speed scaling is considered and switch –power determined with its processing rate according to traffic demand.Taking large number of small switches produces more power efficient than small number of large switches.Fat –tree topology is extendible to other types of data center network topologies.

L.Velasco et al., [2013] [36]suggests the energy consumption of data centers based on time considered with workload consolidation and virtual machine migration policies.Distributed or centralized approach followed and the problem formulated in integer linear programming and heuristics given.Based on the heuristics ,cost saving and workload placement are analyzed.

Andrea Bianco et al., [2014] [3] analyzed a distributed multistage software router (MSSR) which works well on high loads and inefficient for low loads.energy saving schemes are introduces to improve energy efficiency. It follows a mixed integer linear programming optimization model.The heuristic solution reduces the delays, minimizes service interruption.

Zohuo Guo et al., [2014] [9] proposed a joint inter and intra data center workload management schemes t cut the electricity cost of geographically distributed data centers.JET uses a short process time to determine the optimal workload distribution .other factors like prorogation delay,temperature dynamics to be considered in future.

V.Sivaraman et al., [2014] [33]analyzed the energy efficient ethernet standard IEEE 802.3az for improvement of ethernet devices more efficient.They depends on traffic characteristics.port count, traffic load,packet size ,traffic burstiness are considered for power consumption of EEE switches.

Michela Meo et al., [2014] [26] concentrates on the European commission activated under FP7 and TREND network in green networking to promote leadership in this field. They addresses the large number of opportunities and challenges.

6. COMPARITIVE STUDY

This is a comparison study about various techniques involed in datacenter energy efficiency based on various classification categories

Classification category	Reference	Technique involved	Architecture used	Mathematical model followed	Tools used
Switch	[42]	speed scaling, sleeping mode based on traffic load	Fat–tree topology	Integer Linear Programming	NS3
Router	[3]	distributed multistage software router (MSSR)	Distributed approach	Mixed Integer Linear Programming	Simulation setup-traffic traces

Resource scheduling	[32]	To service workloads using Benders decompositi on algorithm.	scheduling framework DCEERS – Data centerwise energy –efficient Resource scheduling frame work	Mixed Integer Linear Programming	GreenClou d Simulator
Resource allocation	[31]	DVFS	Compared with other existng resource allocation algorithms (IDEA,EML S, DVS)	----------------	Cloudsim
Server consolidatio n	[26]	FP7 and TREND	Discuss the issues in infrastructue and energy consumption	----------------	-------------
Virtual machine migration	[36]	workload consolidatio n and virtual machine migration policies	Distributed or centralised approach with fat tree topology	ILP model	OpenNebu la used
Load balancing	[9]	joint inter and intra data center workload management schemes	Energy aware traffic scheme invloved	Nonlinear Integer Programming Problem	-------------

7. CONCLUDING REMARKS

Energy efficiency of data center networks can be analyzed with various factors while at design stage or later stages. switch design, router ,Energy Efficient Ethernet switches insist the way of building the data centers with certain limits. Consolidation techniques are used to balance the workload with the help of virtual machine migration strategy. Energy aware traffic engineering schemes are used to avoid traffic delays. Existing approaches used either distributed or centralized.

From these analysis, we can frame a datacenter network with various traffic loads and reduces the power consumption with virtual machine migration strategies.

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Classification category	Author ,Year	Technique involved	Architecture used	Mathematical model followed	Future work	Tools used
Switch	Indra Widjaja et al., [2014]	speed scaling, sleeping mode based on traffic load	Fat–tree topology	Integer Linear Programming	Equipment cost,labour effort	[NS 3 used]
Router	Andrea Bianco et al., [2014]	distributed multistage software router	Distributed approach	MILP	Adapt distributed routers	traffic traces
Resource scheduling	Junaid Shuja et al., [2014]	To service workloads using Benders decomposition algorithm.	DCEERS – Datacenterwise energy-efficient Resource scheduling frame work	Mixed Integer Linear Programming model	FIFO,Priority ,Priority+Resource schedulers compared,	GreenCloud Simulator
Resource allocation	Wanneng Shu et al ., [2014]	DVFS	Compared with allocation algorithms like IDEA,EMLS, DVS		Considers operators,and computational complexity.	Cloudsim
Server consolidation	M.Meo et al.,[2014]	FP7 and TREND	issues in infrastructure and energy consumption			
Virtual machine migration	L.Velasco et al., [2013]	workload consolidation and virtual machine migration policies	Distributed or centralised approach with fat tree topology	ILP model		OpenNebula used
Load balancing	Zehuo Guo et al., [2014]	joint inter and intra data center workload management schemes	Energy aware traffic scheme invloved	Nonlinear Integer Programming Problem	Architecture design,propogation delay,temprature dynamics	