Energy Efficient Virtual Machine Management for Cloud Computing: A Survey

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Abstract: The adoption of Cloud computing in IT industry has led to creation of thousands of datacentres across the globe, each housing thousands of computing resources and applications. However, energy consumption of cloud's datacentres remains the major challenge facing cloud operations and its sustainability. Efficient utilization of cloud resources using various virtual infrastructure management techniques remains one of the strategic means of realising energy efficiency in cloud. Many research works on cloud energy efficiency exist, with some focusing on the infrastructure layer and some on the virtualization layer of the cloud architecture. In this paper, an attempt has been made to analyze various techniques deployed to manage virtual machine in an energy efficient manner. Although, the focus is on the virtualization layer, fundamental aspects such as the architectures, supporting technologies, methods, and overall cloud performances for each method will be considered.

KEYWORDS: Cloud Computing, Datacentres, Energy-Awareness, Energy-Efficiency, Virtualisation, Virtual Machine Placement, Virtual Machine Consolidation.

1. Introduction

Cloud computing is one of the huge technological innovations that has transformed the IT industry within the last decade. The National Institute of Standards and Technology (NIST) defines the key attributes of cloud as on-demand self service, rapid elasticity and pay-per-use utility-oriented computing model that allows easy access to a shared pool of configurable computing resources in real time without little or no human intervention [16]. Cloud offers dynamic provisioning of computing resources and utility-oriented IT services to both users and cloud providers globally [5]. Users do not have to own outright a resource but can rent from a cloud provider and thereby reduce cost of setting up from scratch and some other liabilities. This technology has widely been supported by large number of datacentre built all over the world with hundreds to thousands of physical machines (servers or host machines) residing in each datacentre. Moreover, servers in datacentres host numerous cloud applications by employing Virtual machine technologies for consolidation and environment isolation [6]. Up until recently, more emphasis has been placed on high performance cloud architecture and this has been well sorted out with lesser attention given to cloud energy consumption [5]. With the increasing number of users and more datacentre built around the world, the high operational costs on energy consumption and the hazards of Carbon dioxide emission to the environment are the major challenges that are threatening the sustainability of cloud computing.

The rest of this paper is arranged has follows; section 2 presented the overall background and related research works on energy efficiency, section 3 presented virtual machine architecture with categories of energy-aware techniques and their effectiveness. The final section presented the conclusion and the future trend of energy efficiency as related to energy-aware VM management

2. Background and Related Works

Datacentre energy consumption contributes about 45% to the entire datacentre operating cost and constitutes about 12% of the entire global economic expenditure [14]. As stated by amazon in their estimate, energy-related costs represents 42 per cent of the entire datacentre budget and this figure doubles every five-year [7]. A typical datacentre was

estimated to consume as much energy as 25,000 households [5] and with a forecast of over 15 billion cloud and Internet connected devices coming on board by 2017 [8]. This huge amount of energy consumption does not only results to high operating cost but also contributes about 2% to world CO2 emission [7] and sometimes could shorten the lifetime of cloud infrastructures. If the trend continues and the rate at which energy is been demanded keep increasing, it is forecasted to quadruple by 2020 [13]. In order to reduce the amount of energy bills and green house gas effect, datacentre energy consumption has to be reduced; this will not only aid cloud-computing sustainability but also create an environment-friendly cloud.

As the trend continues with increase in demand for energy by datacentres and users, pressure keep pilling up on institutions and cloud providers who are aiming at reducing the threat caused by carbon footprint and also reduce cost of energy consumption in cloud. However, various works has been done to combat this, with some research work focusing on the hardware aspect of cloud, leveraging the dynamic voltage and frequency scaling technique to reduce the energy consumption of the CPU [1][4][9]. This is done because CPU consumes the highest percentage of server's energy intake. Some other researchers focused on the software aspect, adopting various techniques such as Virtualisation, Virtual machine consolidation and VM placement, Virtual machine scheduling and migration [10][11] to tackle this issue. The remaining part of this section introduces the topics of Energy efficiency and Virtual machine architecture as related to this survey.

2.1 Energy Efficiency in Cloud Computing

Energy efficiency is a generic term, which simply means using less amount of energy to facilitate the quantity and quality of service, a ratio of useful output to the amount of energy Input [21]. Energy efficiency in Cloud is becoming a global issue with limited energy resources and increasing demand for computational power by cloud users [20]. Over the years, Cloud energy consumption has been on the increase, forming a larger percentage of cloud operational cost. The bulk of energy supplied in the cloud is consumed by datacentre infrastructures, which consist of the servers and cooling systems. As reported by author [19], 42 per cent of datacentre expenses go into energy provision. Also according to Greenpeace report in 2013 [20], Apple's new one billion dollar "iDatacentre" situated in Maiden North Carolina is estimated to require as much energy as two hundred and fifty thousand homes in Europe. This rise in cloud operational costs is threatening the sustainability of cloud business. It is important that cloud operators keep the energy consumption of the cloud in check with little or no effect on cloud performance. Figure 1 shows various techniques used in cloud to achieve energy efficiency. The Diagram shows techniques which a

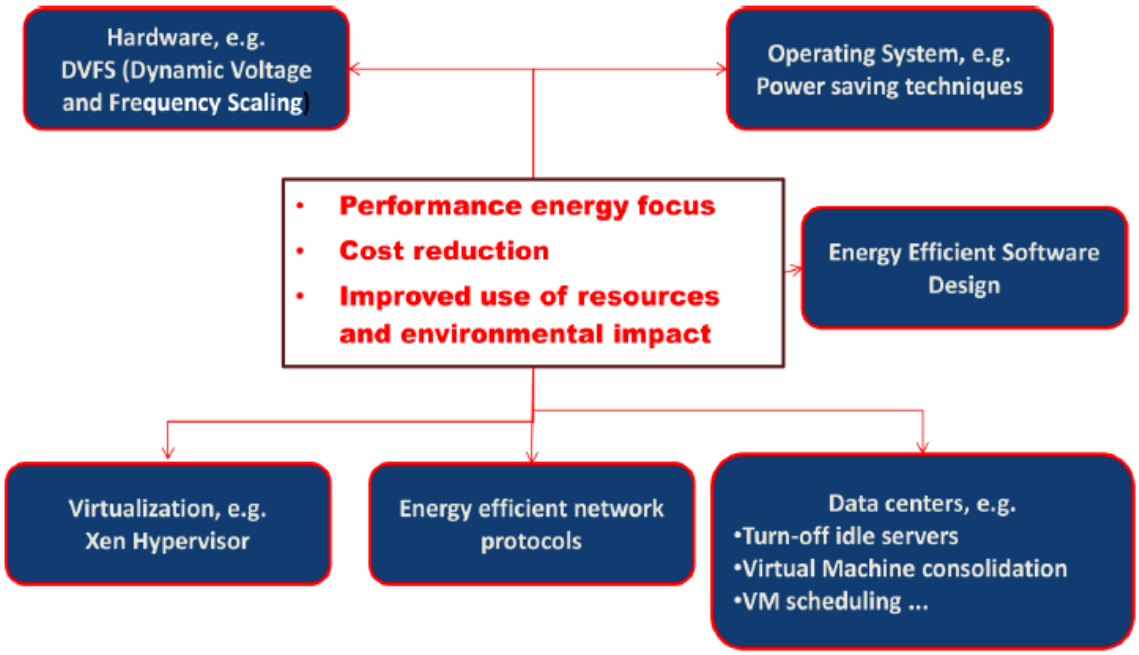

Figure 1. Major techniques used in Cloud to achieve Energy Efficiency [17].

2.2 Virtual Machine Architecture

Virtual machines are self-contained units, including operating system and hardware (virtual) drivers. Figure 2. depicted the typical architecture of Virtual Machine, showing different modes in both user space and system space. The Virtual machine manager (VMM also known as the hypervisor) is the software layer added on top of the physical resources to subdivide the physical machines into virtual resources. It coordinates and manages the physical resources made available for the running of Virtual Machines and applications deployed on them [18].

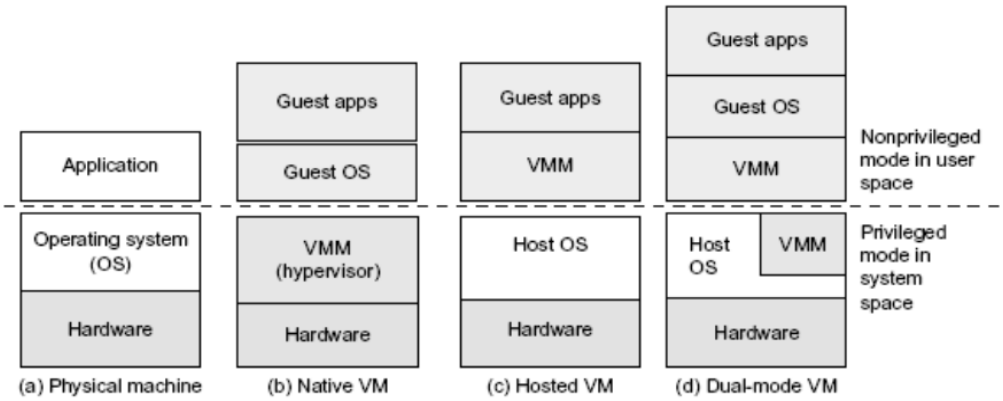

Figure 2.: Virtual Machine Architectures Compare with a Traditional Physical Machine [10]

3. Energy-Aware Virtual Machine Management Techniques

As shown in figure 3, below, power management techniques in cloud datacentres can be classified into static and dynamic power managements [13]. This classification is based on the response of the datacentres to the change in workload at runtime. While dynamic energy management configuration enables the datacentre to dynamically vary datacentre's workload at software and hardware level, the static energy management techniques neglect the runtime adaptation of datacentre response to workload changes. Furthermore, figure 4 shows how energy reduction can be achieved in the system level of typical cloud architecture. This paper focuses on the software level that deals with virtual machine management and deployment. The review of these techniques is presented in the sections below

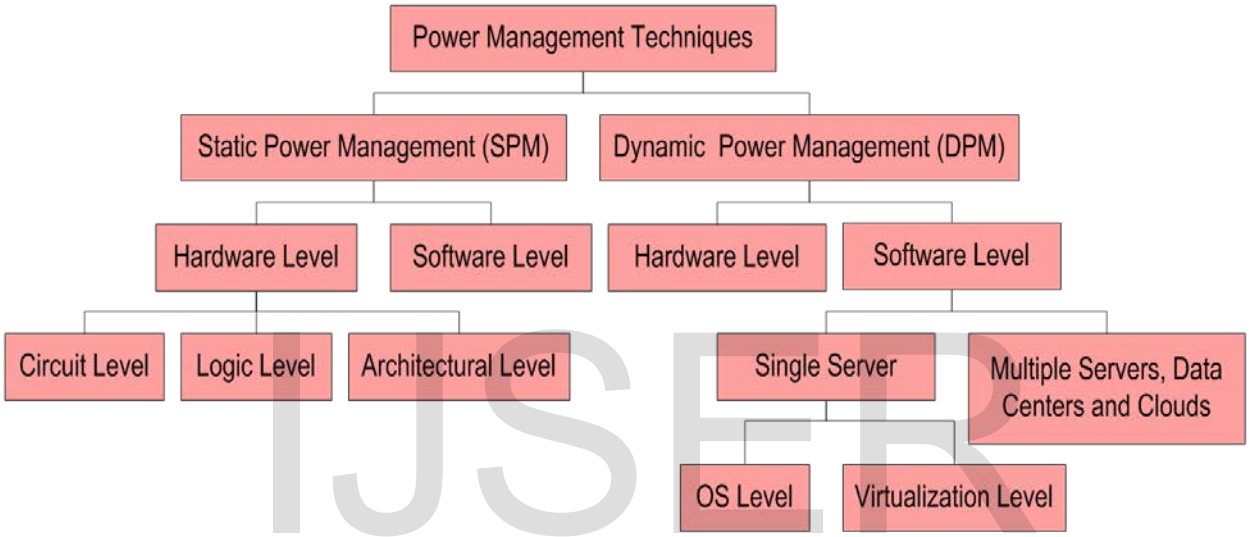

Figure 3. : Taxonomy of Power Management Technique [15]

3.1 Virtualization

Virtualisation is the underlying abstraction technology that drives cloud computing and falls within the software level of cloud computing architecture and management. Virtualisation plays a major role in reducing energy consumption in datacentres by creating multiple virtual machine instances on a single physical machine [10], thereby allowing efficient utilisation of resources and implementation of virtual machine consolidation processes. Virtualisation allows multiple virtual machines to be efficiently managed on a single host, this does not only reduce the number of physical machine in cloud but also enables the use of features such as virtual machine migration, virtual machine placement, virtual machine isolation and host load balancing in achieving energy efficiency and high performance. One of the major advantages of virtualisation is that it allows some of the fundamental assumption of physical hardware hosting to be relaxed [18]. Another important benefit of virtualization in VM management is that virtual machines can be migrated during runtime from one physical host to another. This enables a wide range of management possibilities. Since about 93% of the datacentre energy consumption depends on efficient utilization of resource [14], virtualisation plays a key role in minimizing energy consumption in the cloud

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3.2 Energy-Aware Virtual Machine Consolidation (VMC)

Virtual machine consolidation is a technique use in cloud to assign a set of virtual machines or tasks (inform of a service requests) to certain resources in cloud without violating time constraints [7]. A VMC process is enabled by

virtualisation and it is targeted at minimizing energy consumption and also maximising resources utilisation. Virtual machine consolidation as been proven to be an efficient way to realise energy efficiency through virtual machine management [5], [7], [10], [13], [14]. In order to dynamically manage variation of workloads and number virtual machines deployed on a cloud resource, VMC employ various methods such as live migration, Virtual machine placement, hibernation (i.e. switching the idle node to low power consumption mode) to bring about the efficient management of VMs and thereby minimizing idleness, overutilization and reducing the energy consumption in the cloud. Virtual machine consolidation technique consists of three major processes: (i) Migrating Selected Virtual machines from underutilized or over utilised hosts to minimize the number physical machine use. (ii) Placement: that is, determining the best place to host the migrated VMs (iii) determining the nodes to switch off or on in order to save energy.

3.3 Virtual Machine Migrations and Placement.

Virtual machine migration (especially live migration) and VM placement are backbones of virtual machine consolidation process, which are deployed in order to achieve energy efficiency and maximize resource utilization [2], [5], [7], [10], [14]. In VMs live migration; active virtual machines are migrated to a specific host during runtime or with a close to zero downtime. This allows consolidation of VMs, taking advantage of irregular fluctuation of workload and minimizing the amount of physical machine used. The key challenges during migration are:(i.) Determining where and when to migrate, (ii) selecting the appropriate VMs to be migrated, (iii) resizing and remapping the migrated VMs to another physical machines. VM placement is the method used in mapping migrated VMs to new hosts and involves two major steps [14]: (i) Virtual machine Sizing based on capacity requirements of the corresponding applications (ii) VM mapping to a new host. Although, VMC migration and placement is a viable way conserving energy in cloud, it has been seen to be much effective in small and medium scale cloud (where not) than in large-scale cloud environment.

3.4 Energy-Aware Virtual Machine Scheduling.

Energy efficiency can also be achieved by implementing a scheduling algorithm and policy based on the energy consumption of both physical resources and VMs applications. In energy aware scheduling, resources, tasks or workload are allocated according to energy consumption of each element involve. This is mostly done with the use of various cloud managers such as OpenNebula, Eucalyptus, Open stack, Nimbus [7] and so on. Various research works have been done in this area. In author [1] work, VM scheduling was done based on node ranking with respect to their application-specific energy efficiency. The scheduler designed for a cloud manager called Eucalyptus assigns application's request to nodes with highest applications-specific energy efficiency of that application and set machines with no running VM instances to sleep mode. This prevents frequent migration of VMs and reduces energy consumption. Author [16] did something similar thing in a different fashion, the scheduling algorithm implemented on same cloud manager as author [1] but energy efficiency was achieved by switching off or suspending idle nodes each time a server is unpacked. Other research works implemented energy efficient scheduling in almost a similar way focusing on various aspect of virtual cloud management. Author [7] implemented an energy aware scheduling system by integrating the algorithm with OpenNebula (a open software use as cloud Manager)

4. Conclusion and Future Work

In this paper, different approaches for realizing energy efficiency through VM management are considered, emphasizing on the energy aware virtual machine management. The paper analysed various ways in which energy reduction can be achieved in cloud system Energy efficiency plays an important role in both economical and environmental sustainability of cloud data centre. It is evident that well-managed and energy-aware cloud resources (either virtual and physical resource) will not only reduce energy consumption of cloud but also reduce operational cost of cloud datacentres. Virtualization has been considered to be the key technique and the backbone of all these approaches. Future technical works includes exploiting virtual infrastructure managers services such as the scheduling capabilities and monitoring system to provision and manage cloud virtual resources in an energy efficient way. Energy-aware scheduling algorithm could play a major part in minimizing energy in the cloud.

REFERENCES

[1] Quan Zhang, Grace Metri, Sudharsan Raghavan, Weisong Shi. "RESCUE: An energy-aware scheduler for cloud environments ." elsevier (2014): 215-224.

[2] Dupont, C., Giuliani, G., Hermenier, F., Schulze, T., & Somov, A. (2012, May). An energy aware framework for virtual machine placement in cloud federated data centres. In Future Energy Systems: Where Energy, Computing and Communication Meet (e-Energy), 2012 Third International Conference on (pp. 1-10). IEEE.

[3] Knauth, T., & Fetzer, C. (2012, December). Energy-aware scheduling for infrastructure clouds. In Cloud Computing Technology and Science (CloudCom), 2012 IEEE 4th International Conference on (pp. 58-65). IEEE.

[4] Wu, C. M., Chang, R. S., & Chan, H. Y. (2014). A green energy-efficient scheduling algorithm using the DVFS technique for cloud datacenters. Future Generation Computer Systems, 37, 141-147.

[5] Beloglazov, A., Abawajy, J., & Buyya, R. (2012). Energy-aware resource allocation heuristics for efficient management of data centers for cloud computing. Future generation computer systems, 28(5), 755-768.

[6] P. Barham, B. Dragovic, K. Fraser, S. Hand, T. Harris, A. Ho, R. Neugebauer, I. Pratt, A. Warfield, Xen and the art of virtualization, in: Proceedings of the 19th ACM Symposium on Operating Systems Principles, SOSP 2003, Bolton Landing, NY, USA, 2003, p. 177

[7] Kessaci, Y., Melab, N., & Talbi, E. G. (2014). A multi-start local search heuristic for an energy efficient VMs assignment on top of the OpenNebula cloud manager. Future Generation Computer Systems, 36, 237-256.

[8] Bolla, R., Bruschi, R., Jaramillo Ortiz, O. M., & Lago, P. (2013, January). The energy consumption of TCP. In Proceedings of the fourth international conference on Future energy systems (pp. 203-212). ACM.

[9] Zhuo, J., & Chakrabarti, C. (2008). Energy-efficient dynamic task scheduling algorithms for DVS systems. ACM Transactions on Embedded Computing Systems (TECS), 7(2),

[10] Alboaneen, D. A., Pranggono, B., & Tianfield, H. (2014, December). Energy-Aware Virtual Machine Consolidation for Cloud Data Centers. In Utility and Cloud Computing (UCC), 2014 IEEE/ACM 7th International Conference on (pp. 1010-1015). IEEE.

[11] Pawlish, M., Varde, A. S., & Robila, S. A. (2012, October). Cloud computing for environment-friendly data centers. In Proceedings of the fourth international workshop on Cloud data management (pp. 43-48). ACM.

[12] Hashimoto, H., Matsuo, K., Chikira, K., Nakamura, M., & Urata, J. (2014, November). Energy-aware resource management of virtual machines under thermal and placement constraints. In Green Computing Conference (IGCC), 2014 International (pp. 1-7). IEEE.

[13] Andrew J. Younge, Gregor von Laszewski, Lizhe Wang & Geoffery C.Fox. Providing A green Framework for Cloud Data Centres.

[14] Veni, T., Bhanu, S., & Mary, S. (2013). Dynamic energy management in cloud data centers: a survey. International Journal on Cloud Computing: Services & Architecture, 3(4).

[15] Beloglazov, A. (2013). Energy-efficient management of virtual machines in data centers for cloud computing.

[16] Mell P, Grance T (2011) The NIST definition of cloud computing. NIST Spec Publ 800:145

[17] Djemame, D.K. Energy Efficiency. [Power Point slides accessed through the VLE]. COMP5850M Cloud Computing. University Of Leeds, 2015

[18] Armstrong et al. Contextualization: dynamic configuration of virtual machines. Springers, 2015, pg 1-15

[19] Hamilton, J. Cooperative expendable micro-slice servers (CEMS): low cost, low power servers for internet-scale services. In Conference on Innovative Data Systems Research (CIDR'09) (January 2009).

[20] Greenpeace International Annual Report 2012. Available: www. Greenpeace.org/doc.

[21] Patterson, M. What is Energy Efficiency? : Concepts, indicators and methodological issues. Energy policy, 1996, 24(5), pp 377-390..