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Energy Efficiency for Data Center and Cloud Computing: A Literature Review

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Abstract*—*Energy consumption cost and environmental effect are dynamic challenge to cloud computing. Data centers are the backbone of cloud computing. They continue to be challenging problems to energy efficiency. We investigated previous research based on energy efficiency approach and obtained the conditions to facilitate green cloud computing. Reducing energy consumption and emissions of carbon dioxide (CO_2) in data centers represent open challenges and driving the future research work for green data centers. It is found that there is an urgent need for integrated energy efficiency framework fordata centers which combines a green IT architecture with specific activities and procedures that lead to minimal impact on environment and less CO_2 emissions. The required energy efficiency framework should also consider the social network applications as a vital related factor in elevating energy consumption, as well as high potential for energy efficiency.

Index Terms—**Cloud Computing; Green Cloud; Data Center; Energy Efficiency.**

I. INTRODUCTION

Cloud computing (CC) is a promising area in distributed computing. This technology can achieve communication, storage, processing, high performance, hosting and services on demand to cloud costumer. The growing of social applications and e-business need to increase the number of data centers. However, the combination of global warming and inconstant climate make the cost of energy a major challenge for the sustainability of the e-business [1]. Computer specialists expect that data centers technology is the optimal choices for next generation systems. Google managers and engineers expect that if energy consumed continues ascending, that drive to energy cost will be more than infrastructure cost. Energy consumption cost will influence to end user that pay as usage cloud resources and services. Also more power consumption requires more cooling, and that affects the environment in a negative way by producing more carbon dioxide (CO2). Cloud computing is a binding form, for example, an IBM supercomputer consumes 20 MW which is almost equal to 22,000 US building energy consumption[2], and equivalent to 0.5% of the whole world's energy. Cloud computing deals and is compatible with different type of users demand and it has three types of accessstructure throw network, public cloud, private cloud and hybrid cloud. Cloud providers can offer access to any cloud services for cloud users through web interfaces, and they can manage and monitor computing resources such as hardware, software (application, operating systems), network and storage. Cloud computing provides three types of services, software (SaaS), platform (PaaS) and infrastructure services (IaaS). Most of cloud operations, resources and physical locations cannot be seen or identified by users. Gartner’s annual report acknowledged that the information and communication technology (ICT) costs on2009 decreased by 5.2%, but the costs on 2010 have increased by 3.3% [3]. This makes cloud computing to be a new trend in world's ICT industry. The ICT manufacture will enter a renewed growth phaseIt tops Gartner’s list of 10 strategic technologies in 2010 and will become themain technology in the coming years [3].There is no consensus for unique definitions for Cloud Computing. Before cloud computing there are Grid Computing and other relevant technologies such as cluster computing and distributed systems that is mean cloud computing is not a first technology but it is related to a previous technology [4]. The National Institute of Standards and Technology (NIST) identified cloud computing approach as provide services on-demand network access to shared configurable computing resources like networks devices, computer servers, storage servers, software licenses, and services level. Cloud computer providers those have minimal level of management or interaction can increase provisioned and released the cloud computing services [5]. IDC suggests that cloud computing was reached in 2012 $42bn and revenue cloud will be in 2013 $150 bn [6]. Cloud computing is high computing model through internet-based in which data center combined of many tens of thousands of servers are connected into a computer cloud. Therefore, the benefiters access to the data centers through their heterogeneous devices (computers, laptops, mobile phones, etc). Cloud computing is elastic way to change and increase computation capacity or add ability without investing in new infrastructure, training new personnel, or buy license for new program. Cloud computing offer services that have three main features they make it distinct from conventional hosting.

1- Cloud computing sold on demand;

2- Cloud computing is elastic i.e. a user can have much demand or little of a service as they need and can change their demands according to their need at any given time; and

3- Cloud computing provider can fully managedservices (the user just needs computer device and Internet access)[7].

The structure of cloud computing is consisting of three layers which contain all the computing stack of a model. Cloud computing provide different type of services to end users as shown in Fig 1.a) Infrastructure-as-a-Service (IaaS)b) Platform as a Service (PaaS),c) Software as a

Service (SaaS) [8].

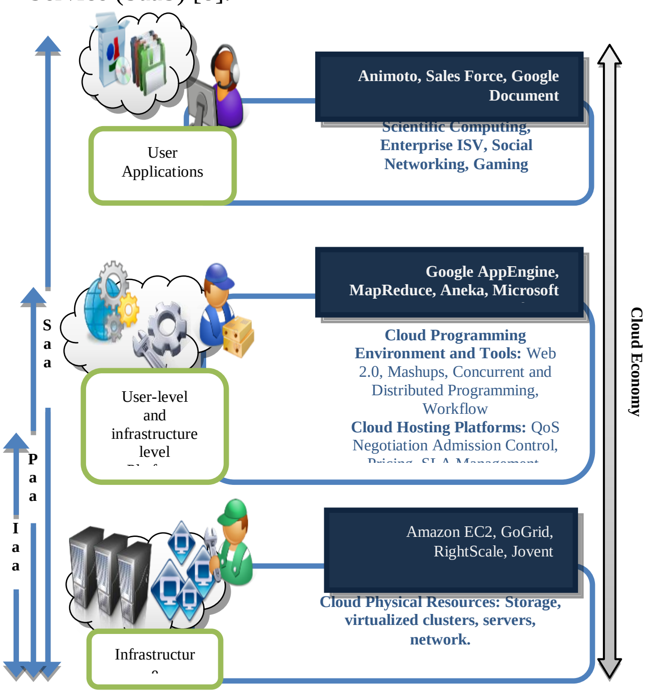

Fig1: Cloud computing layers [9].

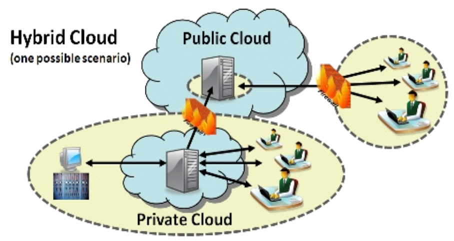

Fig2: Cloud computing infrastructure [7]

II. CLOUD COMPUTING INFRASTRUCTURE

Cloud computing provide three different type of structure fig 2 show the structure and component of each structure.

A. Private cloud

Also named company cloud, it is a marketing approach for a proprietary computing architecture that provides services like hosting, storage, servers and application. Private cloud can manage and control users because it serves a limited number of people behind a firewall. Private cloud has many features like virtualization and distributed computing power, that is has allowed company network and datacenter administrators to effectively meet the needs of their users inside the company. Private cloud is designed for an organization that needs more management and monitoring over their data than using a public cloud approach which is third-party hosted service such as Amazon's Elastic Compute Cloud (EC2). Private cloud structure is based on inside organization access. Organizations are moving to private cloud for many issues reduced energy cost, more IT performance andfriendly business environment [10].

B. Public cloud

International Data Corporation (IDC) in annual report expect that Worldwide spending on public IT cloud services will be more than $40 billion in 2013 and is expected to approach $100 billion in 2016"[6].

C. Hybrid cloud

Fig2 show the structure of hybrid cloud structure. 2013 is the year that companies need to implement a hybrid cloud strategy that puts select workloads in the public cloud and keeps others in-local network[11]. The motivation of this review paper is to find gaps in previous study that concerned on green cloud to present these gaps to researchers for more development and support energy efficiency technique.

TABLE 1: THE DISTRIBUTION OF POWER IN DATA CENTER [12].

Cost	Component	Sub-Components
45%	Servers	CPU, memory, storage systems
25%	Infrastructure	Power distribution and cooling
15%	Power draw	Electrical utility costs
15%	Network	Links, transit, equipment

III. GREEN CLOUD COMPUTING

The worldwide agitation to achieve ecological, business and environmental sustainability is starting to redraw industrial landscape, table 1: show that the consumption of cloud components. The current status of global warming, ecological deterioration and the severity of its potential consequences explain the overwhelming popularity of environmental initiatives across the world. Environmental impact of Information Technology (IT) under the bannerof "Green IT" has started being discussed by academia, media and government. Since 2007 when the Environmental Protection Agency (EPA) submitted a report to the US Congress [2] about the expected energy consumption of data centers. The main objective of Green IT is to increase energy efficiency and reduce CO_2emissions [13]. To make cloud greener there are two ways, first improve energy efficiency of cloud, second use clean energy supply. Table 2 show the energy consumption in different level in cloud computing. Power Usage Effectiveness (PUE) measures if the data center is green or not by measure the efficiency of data center [14].

PUE = Total Facility Power / IT Equipment Power (1)

*Total facility power= power + cooling
*IT equipment power= server power +storage power + communication power

Cloud computing has different techniques to solve energy-efficient problem to minimize the impact of Cloud computing on the environment. This techniques deal with energy efficiency consumption like virtualization, hardware base, operating systems base and data centers. Some new features arise like energy performance, and time wise. However, the concerns should be the swap problem between energy consumer and performance. Focusing on last 7 years, author reviewing a lot of papers, however most of this research focused on reduced energy cost rather than environment sustainability.

IV. DATA CENTER

Data center is a cornerstone of the infrastructure of cloud computing approach by which a variety of information technology (IT) services are built. They extend the ability of centralized repository for computing, hosting, storage, management, monitoring, networking and deployment of data. With the rapid increase in using data centers, there is a continuous increase in the energy consumption[14]. Data center beside consumed energy also produces carbon dioxide and that riddled with IT inefficiencies. Data center major components are thousands of servers; however these servers consumed huge energy without performing useful work. Data centers today are homes to a vast number and a variety of applications with diverse resource demands and performance objectives. There are many models to support energy efficiency in data center; the most important model is virtualization. Cloud computing supports virtualization like resources (i.e. computes, storage, and network capacity). The most basic one is at Virtual Machine (VM) level where different applications can be executed within their containers or operating systems running on the same machine hardware. Platform level enables seamless mapping of applications to one or more resources offered by different cloud infrastructure providers. Virtual machines (VMs) are a logical slit of physical resources, and it is the heart of virtualization. In data centers, the number of physical machines can be reduced using virtualization by consolidating virtual appliances onto shared servers. This can help to improve the efficiency of IT systems. The advantages are simple, it allows multiple virtual machines to be run on a single physical machine in order to provide more capability and increase the utilization level of the hardware. It always increases efficiency; it allows you to do more work with less IT equipment [2].

V. ENERGY EFFICIENCY ON CLOUD COMPUTING

In the literature review below, a previous study investigated energy efficiency on cloud computing and focused on data center technology. Table 2 shows this study in critical view showing positive and weaknesses of each technology. RajkumarBuyyaet al.[8], the author propose (a) architectural principles for energy-efficient management of Clouds; (b) energy-efficient resource allocation policies and scheduling algorithms considering quality-of-service expectations, and devices power usage characteristics; and (c) a novel software technology for energy-efficient management of Clouds. Anton Beloglazov et al.[12], he propose a novel technique for dynamic consolidation of VMs based on adaptive utilization thresholds, which ensures a high level of meeting the Service Level Agreements (SLA). He validates the high efficiency of the proposed technique across different kinds of workloads using workload traces from more than a thousand PlanetLab servers. Nguyen Quang Hung et al.[14], he propose two host selection policies, named MAP (minimum of active physical hosts) and MAP-H2L, and four algorithms solving the lease scheduling problem. Those algorithms reducing 7.24% and 7.42% energy consumption than existing greedy mapping algorithm. On their simulations show that energy consumption decreased by 34.87% and 63.12% respectively. Uddin et al.[15], he developed a tool to improve the performance and energy efficiency of data centers. He divided data center components into different resource pools depending on different parameters. The framework highlights the importance of implementing green metrics like power usage effectiveness (PUE) and data center effectiveness and carbon emission calculator to measure the efficiency of data center. The framework is based on virtualization and cloud computing. Meenakshi Sharma et al.[16], author firstly presented an analysis of different Virtual machine(VM) load balancing , a new VM load balancing algorithm has been proposed and implemented in Virtual Machine environment of cloud computing in order to achieve better response time and reduce cost. XinLia et al.[17], the author proposed a virtual machine placement algorithm EAGLE, which can balance the utilization of multidimensional resources, reduce the number of running PMs, and thus lower the energy consumption. Experimental results show, that EAGLE can reduce energy as much as 15% more energy than the first fit algorithm. Song et al.[20], he developed an adaptive and dynamic model operating system-base for efficient sharing of a server by optimizing resources (CPU and memory) between virtual machines. Bo Li, Jianxin et al.[21], he introduced an energy saving on-line placement model, based on a balance of workload by distributing it in virtual machine to achieve less number of node to execute that load. So the workloads are replaced, and resized. However, the migration and relocation of VMs for matching application demand can impact the QoS service requirements of the user. Abdelsalam H. Maly et al.[22], he investigated new model for a power efficient technique to increase the management of Cloud computing environments.

The author formulated the resource management problem in the form of an optimization model to introduce energy consumption by the Cloud. Huang, Li et al.[23], he introduced dynamic resource management hardware-base. Using dynamic setting for the frequency and voltage of the processor during running time to set the CPU in original design power. As long as CPU works in minimum voltage, the energy consumption can directly be saved. However, the complexity of management many independent voltage/ frequency islands, that make the benefits not large enough.

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Jiandun Li et al.[24], he introduced a hybrid energy-efficient scheduling model based on private clouds to minimize response time, balance workload that when data-center is executed in minimum energy mode, produce algorithm for pre-power and least load. They are concentrated on load balancing, migration on state-base of VM. If response time decreases then also energy decreases. However this technique loses significant energy in migration. Saurabh Kumar Garg et al.[25], he proposed a Green Cloud framework, which make Cloud green from both user and provider's perspective. The framework relies on two main components, Carbon Emission and Green Cloud ShaileshS.Deore et al.[26], he introduced an energy-efficient scheduling scheme technique. Workloads were distributed on a minimum physical machine, using new state pause, resume, and teleport-in state. To avoid changing the status of idle node to power on and that required an amount of energy we can use pause state, or teleport-in state, and resume state to achieve reducing amount of energy. However, This scheme did not be used effectively in Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a service (SaaS) ofcloud computing.

Table2: ENERGY EFFICIENCY TECHNIQUE

Author	Approach	Adv+	Limitation
Sourav Banerjee	Power without optimization (datacenter)	Good job performance	waiting times is high
Minsu Huang	Power-Low for idle node (datacenter)	O(n) complex, Low complexity	Much job performance take amount of time Sleep-in-Waking up-ready.
Rajkumar	resource allocation and scheduling	quality-of-service	No parameter to indicate CO_2 emission
Abdelsalam H	Resource management	forecasting the resource utilization	High complexity
Beloglazov	adaptive utilization	meeting the Service Level Agreements (SLA)	No parameter to show the energy efficiency level
Hug	minimum of active physical hosts	Reduce energy 34-63%	Reactive hosts need time and energy
Saurabh Kumar Garg	Middleware provider/user	Good in reduce energy, pricing and time	increase the internet traffic
Uddin	virtualization	increase the utilization ratio	High utilization lead to introduce CO_2
XinLia	virtual machine placement	can balance the utilization of multidimensional resources	save as much as 15%

V. CONCLUSION AND FUTURE WORK

As a result of the investigated literature review, we concluded that the previous techniques and approaches lack several features like QoS and performance against energy efficiency.Additionally, the time complexity and the reduction of the energy consumption are not highly effective. Based on our literature review we realized that the lack of and need for an integrated data center energy efficiency framework which consider the social network applications as a vital related factor in elevating energy consumption, as well as high potential for energy efficiency. The framework provides a platform on top of which the Green Cloud could be built. The framework practices from Energy Aware Computing will improve the efficiency of Cloud systems and their data centers and Clouds themselves will produce naturally efficient and focused centers of computation, advancing the pursuit of green computing. The required integrated data center energy efficiency framework should be also applicable in different types of data centers including public, private and hybrid. The existence of such framework will offer a great powerful capability to deal with service levels and resources management. The required data center Energy Efficiency framework will offer improved in scalability, elasticity, simplicity for management, delivery of cloud services and better reduction in data centers energy consumption taking into consideration the QoS for the user services.

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