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ENERGY SAVING IN GREEN CLOUD COMPUTING DATA CENTERS: A REVIEW

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ABSTRACT

The Cloud computing is a new computing standard which targets to offer reliable, adaptive and Quality of Service (QoS) based computing environments for IT users. One of the recent major concerns in cloud environment is efficient usage of energy in its data centers. This paper reviews energy saving strategies in Data Centers for cloud computing and also discusses various approaches proposed in the previous research works in this field. The paper presents an intensive study of SIXTY EIGHT (68) researches focusing on energy consumption by data center servers and networks and energy efficient approaches in cloud computing. Based on the existing studies, Servers have been introduced as the most energy consumer in Data Centers.

Keywords: *Green Cloud Computing, Data Center, Energy Saving, Energy Efficiency, Review*

1. INTRODUCTION:

The rapid growth in Information and Communications Technology (ICT) and computing systems has not ignored over the last couple of decades. Particularly these years a lot of resources have been allocated to increase efficiency. Both the operators of data center and the community of research have detected the industry to discover the important challenges quickly only if it progresses as it does today [1]. Governmental motivations and overall concerns to support development highlight the necessity of effective solutions [2]. For many years computer science has prognosticated the impractical way of utility-based computing. In recent years, by the combination of the concepts of utility computing, the standards of Web 2.0 and the requirements Cloud Computing is created [3].

The cloud computing is created in 2007 and it is still a young subject because of its quality in flexible dynamic IT infrastructures, Quality of Service (QoS) and the ability of configuring software services [4]. Cloud computing is one of the most well-known appearing technologies these days which delivers services and computing the processes as a utility [5]. Cloud computing is proposed to use the shared computing resources and to enable omnipresent, serviceable, flexible with business variations, easily in using and managing[6]. So the total number of the existing platforms of cloud computing has been increased, which includes Microsoft Live Mesh and Amazon Elastic Compute Cloud (EC2) [7].

Cloud computing includes a lot of data centers that spread across different locations around the world. Huge companies such as Yahoo, Google, Amazon and eBay are working with such large data centers to present Cloud computing services. Nonetheless, data centers use enormous amount of energy. Greenpeace Report claimed that the data center electricity demand is appraised at about 31 GW globally, that is equal to nearly 180,000 homes' issue [8]. Data centers' electricity demand is progressing very fast. J. Koomey [9] declared that the energy usage of communication, power distribution, cooling and servers was between 1.7% and 2.2% of entire power consumption of U.S. in 2010.

At the present phase, the cloud computing is developing and it does not have an accepted definition. Wang et al. [4] suggests a definition of cloud computing: a cloud computing is a series of network that enable services, provide the ability of scaling, guarantee the Quality of Service, personalize normally and having a cheap computing infrastructure on demand, which would be achieved in an easy and permeative way.

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It can be seen that the number of researches on efficient computational resources have increased in the past few years. The performance of supercomputers has been duplicated about 3000 times during 20 years ago. During the same period of time the performance per watt has raised 300 fold and performance per square has only growth 65 times [10]. Green IT or Green computing relates to environmentally sustainable IT or computing. Murugesan [11] determines the area of green computing as the study of designing, constructing, applying and arranging of computers, servers and related subsystems (like storage devices, monitors, printers, communication systems and networking) in a useful and effectual way with the lowest or no effect on the environment. Green computing serves its main purposes as decreasing the application of perilous materials, magnifying energy effectiveness during the lifetime of products, and raising the biodegradability or recyclability of departed products and the waste of factory and all these goals will be achieved by making the appliance of computers as energy efficient as feasible and designing systems and algorithms in a way to be efficiently related to technologies of computer.

The green gird is progressing metrics to evaluate the productivity of data center in addition to efficacy metrics for the total main power using subsystems at data center. Power Usage Effectiveness (PUE) and its reverse action Data Center Efficiency (DCE) metrics is suggested by the green grid in 2007. These metrics enable data center operators to swiftly appraise the efficient energy of the data center, compare the outcomes in contrast to other data centers and ascertain if the improvement in energy efficiency is needed to be made [12]. Within one year, DCE is redefined in the act of Data Center infrastructure Efficiency (DCiE) [13]. Table 1 displays some energy saving metrics for data centers.

Table 1: Energy-Saving Metrics for Data Centers

Metric Description	Metric Formulation
Power Usage Efficiency	$PUE = \frac{Total\ facility\ power}{Total\ IT\ power}$
Data Center Infrastructure Efficiency	$DCiE = \frac{Total\ IT\ power}{Total\ facility\ power}$
Carbon Usage Effectiveness	$CUE = \frac{Total\ CO2\ emissions\ from\ DC\ energy}{Total\ IT\ Equipment\ energy}$
IT Equipment Utilization	$ITEU = \frac{Total\ measured\ energy\ of\ IT}{Total\ specification\ energy\ of\ IT}$
Data Center Productivity	$DCP = \frac{Useful\ energy}{Total\ facility\ power}$
Water Usage Effectiveness	$WUE = \frac{Annual\ water\ usage}{IT\ equipment\ energy}$

Recently, main internet firms have made enormous data center to empower their online commerce. In the past, computing power mainly focused on mainframes put away in the background since there were no options except a large room-sized box that could include every important amount of computational power. The belief that this power can be spread rather than concentrated looked like such nonsense speech in 1943, Thomas Watson claimed that "I think there's a world market for maybe five computers." The time of personal computer which has been displayed since 1970 is straight against Watson's anticipation but data centers are not new either [14].

Approximately, the energy usage of data center is about 432 kWh in one hour of the execution time. The computing servers share around 70% of the entire data center power usage, while the switches and communicational links use remaining 30%. Moreover, the usage of switches is as the follow: 17% allocated for core switches, 50% for access switches and 34% for aggregation switches. Furthermore, 15% of total power usage is used by core and aggregation switches together. By the way, according to the requirements for network performance, communication strength and load balancing, the noticeable option to choose is to preserve aggregation and core switches in a distributed manner. The data center network considers for the differences among power usage levels of various data center designs. With regards to the 2-Tier network, the 3-Tier network adds about 25 kW for aggregation layer that empower the data center scale more than 10 000 nodes. The 3-Tire with high speed (3Ths) network includes less core and aggregation switches. Moreover, the accessibility of 100 G links comes at a price of the increment per-switch power usage. It is concluded that a 3Tier network consumes less than 3Ths network [15]. Figure 1 represents an average distribution of energy consumption in a 3T data center. This paper reviewed many methods for energy saving in data centers for cloud computing and it discusses various approaches proposed in previous research works in this field.

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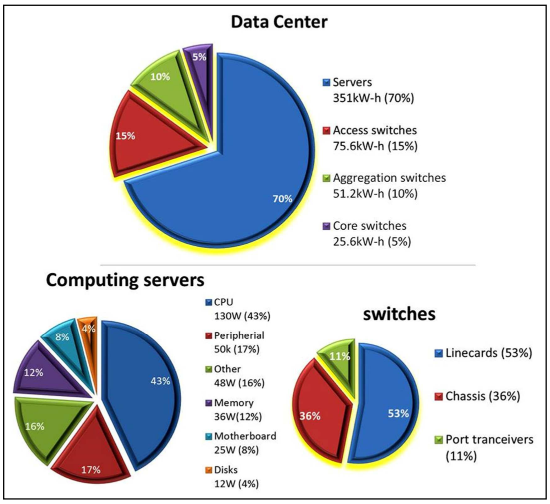

Figure 1: Distribution of Energy Consumption in a Data Center [16]

2. REVIEW METHODS

This section describes the research method used for this review paper. The aim of this work is to find out the techniques which are useful for reducing energy consumption in cloud computing data centers from previous studies and to classify them for future works. The corresponding research question in this paper is:

Q1. Which techniques could be used for saving energy consumption in Cloud Computing Data Centers?

This paper gives an overview of the current research on energy-saving in data centers. To extract techniques for energy saving suggested by previous researchers, this study conducted a vast search on electronics database as listed in Table 2.

Table 2: Search on Electronic Database

Source	URL
ACM Digital Library	http://dl.acm.org
IEEE Xplore	http://ieeexplore.ieee.org
ScienceDirect	http://www.springerlink.com
Springer	http://www.springerlink.com
Google Scholar	http://scholar.google.com

3. ENERGY SAVING TECHNIQUES AND STRATEGIES

The consumption of energy and the performance of the system were influenced by many factors like hardware, software, network etc. What follow will present energy saving strategies for cloud computing data centers in the following three aspects: energy saving solutions for Servers, energy saving solutions for Network, and energy saving solutions for mixed Servers and Network. As already mentioned in this section, energy saving using renewable energy source is considered as a new area for saving energy in this paper.

3.1. Energy Saving Techniques For Servers

Liu et al. [17] demonstrated that the average load of data center is 30% while Servers are the most energy consumers in data centers. Servers are idle most often, according to low load of data centers. Chen et al. [18] stated in a paper that an idle server for keeping memory, disks, and I/O resources in running mode may use up almost 2/3 of the peak load. It is therefore concluded that an idle server in a data center consumes a considerable amount of energy and wastes more energy comparing with other parts of data centers. The most important energy saving approaches for servers include:

- Server Virtualization
- Dynamic Power Management
- Dynamic Voltage/ Frequency scaling (DVFS)

Virtualization is a prominent technique for reducing energy consumption in servers. It refers to making more than one Virtual Machine (VM) on a server. Using this technique decreases the number of hardware in use, improves the utilization of resources and reduces hardware and operating expenditure. Server virtualization also allows consolidation of server workloads. It may achieve energy saving by decreasing the amount of active and functioning servers with regards to Quality of Service requirements.

Another important technology to decrease energy consumption is *Dynamic Power Management*. This technique is based on powering down the computing servers to save more energy. Putting inactive servers on the sleeping mode is the other way to reduce energy consumption in this technology. Moreover, joining virtualization technique with dynamic power management is another solution to save more energy for servers. This energy saving approach consolidates virtual

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machines on a subset of tangible servers and turned idle servers off or put them into sleep mode at the low utilization times. Then the servers which are powered off or putted into sleep mode are powered on when load increases and virtual machines from overloaded servers are moved to active servers that are ready to use with accessible resources.

The *Dynamic Voltage/Frequency scaling* approach sets the CPU power due to the presented load. By using this technique the power consumption will reduced, once CPU load is low. This technique relies on this fact that switching power in a chip reduce relatively to V2 * f, while V indicates voltage, and f indicates switching frequency [16]. Moreover, reducing voltage needs frequency downshift. It represents cubic relation from f in the CPU energy usage. The following formula shows the power consumption of a server:

$$P = P_{fixed} + P_f * f_3 \qquad (1)$$

In the above formula P_{fixed} indicates the energy usage that is not measured by operating frequency f and P_f indicates the energy usage of CPU that is relying on frequency.

3.2. Energy Saving Solutions For Network

Network infrastructure is the next main energy consumer in data centers. Around 30% of the entire energy usage which utilized for computation is consumed by data center network. [16].

Network in Data Centers includes switches and links. Chabarek et al. [19] expressed in a paper that the utilization of a link is not directly balanced with its power consumption. The authors stated that power consumption depends on capacity of the link instead of its utilization. Moreover, researchers illustrated that energy usage of switches relies on a marketer and it is directed with the number of line cards and ports involved. It should be considered that power usage of both links and switches are important for reducing power consumption by network. The four following solutions are existed for saving energy in data center networks:

- Adaptive Link Rate (ALR)
- Virtual Network Embedding (VNE)
- Sleep mode
- Green routing

Adaptive Link Rate technique is extensively considered on wired networks [20]. However, it has not been used on data center networks yet. This approach is based on the idea that energy usage of a link may be decreased its data rate, while traffic load of network links are low in most situations. In such cases, Adaptive Link Rate decreases link energy usage by dynamically setting link data rate to its utilization, while *sleep mode* method decreases energy usage through switching off network resources or placing them to sleep mode. Moreover, other active network resources should meet QoS requirements.

Virtual network embedding is the next approach which is useful for reducing energy consumption of network *[21]*. VNE is mostly useful while the network traffic is low. The aims of network virtualization is to use embedding algorithms to assign virtual network resources on a fewer number of physical infrastructure with an optimal approach [22]. The idle network resources could be switched off or put into sleep mode.

Recently, *Energy aware routing* or *green routing* for decreasing energy usage in data center network is studied [23]. The main idea of Energy aware routing is to deliver routing service to less number of network resources to reduce energy usage, while sustaining network performance.

3.3 Combined Energy Saving Solutions For Servers And Network

Recently, mixed approaches for saving energy in data centers are proposed extensively. Mahadevan et al. [24] stated that only 16 % of power usage may be saved by effecting network energy reducing approaches alone. It is worth mentioning that by combining server and network energy aware methods, energy could be save up 75 % of energy usage in data centers. By combining energy saving approach, network traffic consolidation and server workload consolidation are cooperatively used. Mahadevan et al. [24] suggests three techniques for saving energy in data centers:

- Link state adaptation (LSA)
- Server load consolidation (NTC)
- Network traffic consolidation (SLC)

In *LSA* the power controller adapts to the state of links according to the information about traffic on each link. *NTC* decreases energy usage considerably by removing all redundancy in the network. This approach consolidates traffic on few numbers of links and switches, and idle links and switches are deactivated. *SLC* is a way to consolidate network traffic in a fewer links and switches to allow the controller to turn off unused

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resources. To achieve this goal, SLC transfers jobs to few numbers of servers to turn off unused servers. The researchers evaluated these three techniques on a real Web 2.0 case study in a real data center. The results display that 16 % of energy could be stored by implementing only a link state adaptation approach, 75 % of energy could be stored by implementing both server load consolidation and network traffic consolidation together.

3.4 Energy Saving Using Renewable Energy Source

These days, worries about increasing energy consumption have directed to social benefits in controlling the energy usage. Achieved solutions consist of the incorporation of renewable energy as in Apple's new North Carolina data center [25], Yahoo's New York data center [26, 27], Google data centers [28], and Microsoft data centers [29].

A sorption chiller makes the cooling system work by using the thermal energy which recovered from the data center parts and supplemental solar energy [30].

It is recommended to use extra energy, if available, from alternative retrieval systems, chiefly the solar energy, while losing the remaining energy from the data centers is not adequate to switch on the cooling systems. To achieve the same purpose, the geothermal power and different alternative energy sources can be used. Essentially, the heat scattered to the environment through the data center racks is used to evaporate the cooling factors and so activate the absorption Bromine water cooling part and chill the water used to cool the data center environment. To obtain the cooling unit while the heat energy absorbed from the servers is not adequate, a two-fold system is offered to heat the water required for the absorption chiller, using solar power engineering or other existing renewing heat source [30].

4. EXISTING ENERGY EFFICIENT APPROACHES

This section discusses the existing energy efficient approaches classified into THREE (3) main categories including

a. Energy efficient approaches focusing on servers
b. Energy efficient approaches focusing on network
c. Energy efficient approaches focusing on servers and network.

These existing energy efficient approaches are discussed in the following section. Besides, APPENDIX 1 summarizes all papers reviewed in this study based on these classifications.

4.1 Existing Energy Efficient Approaches Focusing On Server

An energy-aware task consolidation (ETC) approach that decreases energy use was demonstrated by the authors of [31]. Confining the CPU use under a definite outset as well as combining functions within virtual clusters were the reasons behind the ability of ETC in doing so. Additionally, this energy-consuming framework recognizes the network delay when a function moves to another virtual cluster. Hsu et al. [31] introduce a way of maintaining the use of CPU and managing task consolidation within virtual clusters. The task consolidation technique applies the most appropriate way of using resources beneficially. Consequently, they tend to compare the outcomes with the latest attention-absorbing method, Max Util, which tries to decrease energy usage through devoting as many possible tasks as it can manage to a VM. The results prove that in a cloud system ETC can crucially minimize power loss [18]. So, a need emerges for the ETC approach to concentrate on the lower threshold of CPU use that aims at decreasing loss of energy via useless servers.

Nathuji and Schwan [32] recommended a virtual power method that integrated 'soft' and 'hard' scaling techniques and combined task consolidation and power management. The researchers found that this combination may save more energy according to the restricted number of hardware scaling cases. This method had an extensive virtualization principle to supply efficient strategies of power management. Algorithms which are presented in this paper are based on DVFS and resource consumption control that is made with physical processors and CPUs.

Raghavendra et al. [33] have studied the problem of power management for a data center environment through merging and arranging five different power management strategies based on 180 server traces from nine different real-world enterprises. The researchers investigated the problem regarding to control theory and exerted a loop to control the feedbacks for coordinating the controllers' activity. This strategy deals just with the CPU management and is independent of the workload type.

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For minimizing the energy usage, Srikantaiah et al. [34] conducted a study and examined the problem of applying the schedule of multi-tiered web applications in systems with heterogeneous virtualization. This research evaluated energy consumption, performance changes, and resource usefulness as multiple workloads with different resource usages are joined on common servers. Researchers have recommended an innovative method for the multidimentional bin packing problem like an algorithm that consolidates the workloads, to control the efficiency over numerous resources.

Using DVFS, Wang et al. [35] extend scheduling algorithm which decreases usage of energy of parallel task administration. In order to attain function administration they introduce a couple of scheduling algorithms carrying the quality of power-aware: the Power Aware List-based Scheduling as well as the Power Aware Task Clustering algorithm. Regarding the fact that the execution time of unimportant tasks can be developed, the mentioned algorithms make the reduction of the supply voltages of CPUs possible. Moreover, in order to decrease the waste of energy green service-level agreement [31] is applied. A power-performance trade off algorithm is enhanced, for decreasing the waste of energy with an optimizing function of increasing execution time, through taking the requirements of green SLA into consideration.

The problem of energy aware dynamic placement of applications in a virtualized heterogeneous system have expressed by Verma et al. [36] based on maintaining the optimization. To achieve this purpose, the placement of virtual machines is optimized at each time frame to reduce energy usage and increase performance. Researchers using variable bin size and costs to implement a heuristic method for the bin packing problem. Moreover, the authors applied live migration of virtual machines in their study while the recommended algorithms do not consider the exact requirements of SLA.

Kusic et al. [37] have presented Limited Lookahead Control (LLC) in a paper to address the problem of power management as a continuous optimization in virtualized heterogeneous environs. The main goal of this study was to maximize the benefits of the resource provider by reducing energy usage and SLA outrage. Moreover, for estimating the amount of future demands, predicting the upcoming state of the system, and performing essential re-appropriation Kalman filter is used.

Cardosa et al. [38] have offered a method for solving the problem of allocating the energy efficiency of Virtual Machines in virtualized heterogeneous environments. Research team has controlled the min, max and sharing factors of Virtual Machine Manager (VMM), which means minimum, maximum, and suitability of the CPU allotted to Virtual Machines sharing the equivalent resource.

Gandhi et al. [39] have deliberated the problem of assigning an accessible power budget between servers, while reducing the mean response time in a virtualized heterogeneous server environment. The authors introduced a queuing theoretic model for investigating the impact of various factors on mean response time. The model makes it possible to predict the mean response time as a task of the arrival rate, power-to-frequency relationship, and peak power budget. Moreover, the model is used to discover the optimum energy assignment for any configuration of the mentioned factors.

Aroca et al. [40] demonstrated the possibility of making servers regarding to low power computers by an empirical comparison of server programs executing on ARM computer architectures and x86 systems. This study [40] compare numerous ARM and x86 systems in typical server with applications and some crunching functions like database server, web server, and floating point calculation. Based on the findings of this study, ARM based systems are a good option while power productivity is required by considering the quality of performance. The results compare CPU, temperature and power consumption for each device at different workloads.

For allocating the resources in a way to keep the bandwidth warranties, Guo et al. [41] in a paper recommended and performed a virtual cluster management method. The allocation is specified through a heuristic method that reduces the whole bandwidth used. Allocating the virtual machine is adjusted when some of the virtual machines are de-allocated. Moreover, allocating the VM is not adjusted based on the present network load dynamically. However, this method does not obviously reduce energy usage by the network.

Torres et al. [42] offered a method to reduce the number of functional servers to process in heterogeneous workload environments without performance consequences as the reduction of the quality of service. The suggested method deliberated a national travel website as a real case

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study for research. The authors mixed two remarkable techniques: 1) memory compression and 2) request discrimination. The memory compression changes energy consumed by CPU into memory capacity to permit more tasks consolidation. The request discrimination barricaded unneeded requests to remove adverse resource consumption. The outcomes of this study indicate the efficiency of the proposed technique since the task was performed with 20 % less calculations.

Subrata et al. [43] presented an energy aware scheduling model for web-scale systems which consists of Nash Bargaining Solution. Moreover, this model for reducing energy consumption, sustains a marked QoS rule amongst all the service providers. The level of energy consumption controlled a specific threshold restriction to keep the appropriate QoS measure was determined through SLA.

Mazzucco et al. [44] recommended a power aware resource allocation technique to increase the benefits acquired through service providers. The resource allocation techniques introduced in his study are based on the dynamic states like switching servers on and off. The main goal of this research was to reduce the amount of energy consumption by enhancing the use of the servers.

Fujiwara et al. [45] presented a market based model to allocate various resource requests in a Cloud Computing environment. This technique makes the resources virtual and delivers them to the end-users as various set of services. The algorithm proposed in this study increased computing from the service providers as a utility. The empirical outcomes present that the recommended approach increase the possibility of allocating resources in cloud computing infrastructures.

EnaCloud is a new approach proposed by B Li et al. [46]. Regarding increasing the energy efficiency in cloud computing platforms, this method dynamically enables application live placement. EnaCloud used a VM to encapsulate the request that provides live migration and applications scheduling to reduce the number of active machines as to scale up the energy efficiency. An energy aware empirical algorithm is recommended to get a suitable solution, for bin packing problem in the application placement.

Liu et al. [47] displays the Green Cloud architecture to decrease data center power usage during guarantee of the implementation from the perspective of the users. Green Cloud architecture empowers live virtual machine migration, extensive online monitoring and virtual machine placement optimization. To corroborate the effectiveness and efficiency of obligated architecture, researchers use a real online game as a VM application called Tremulous. The results of evaluation show that it is possible to store 27% of the energy when using Green Cloud architecture.

Lee et al. [48] shows two energy aware task consolidation heuristics that intend to increase resource efficiency and definitely to take into consideration both idle and active energy usage. This study allocates each task to the resource in which the energy usage for performing the task is clearly or implicitly decreased without reducing the quality of services. According to the experimental results of this study, the investigated approach illustrates its auspicious energy saving ability.

Ghribi et al. [49] in a paper recently published, presents two precise algorithms to reduce energy consumption of VMs in cloud data centers. The researchers combined a desirable allocation algorithm with a consolidation algorithm based on migration of VMs. Moreover, the research team used a bin packing problem based on minimum power usage objective as a solution for the optimal allocation algorithm. Empirical results prove the ability of the proposed algorithms to achieve noteworthy energy savings when preserving possible convergence times.

4.2 Existing Energy Efficient Approaches Focusing On Network

The research community has been identified network infrastructure as another important energy consumer resource. Gupta et al. [50] demonstrates that putting idle links, routers and switches into sleep modes in a network can reduce energy consumption and save the energy usage in Internet infrastructures. Many researchers studied on the energy efficiency in traffic routing and performing sleep modes and performance scaling of network components [51, 52], according to the opinion stated by Gupta et al. [50].

In order to dynamically devote a group of active network nodes to serve traffic load of data center, Heller et al. [53] suggests ElasticTree , an energy-aware network optimizer. ElasticTree selects the group of network nodes which are supposed to remain active to gain the performance of the network that, later on, reduces as many unnecessary switches and nodes as it can. Authors apply greedy bin-packer method, prediction methods, and topology-aware heuristic toward specifying the

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appropriate network components subsidiary. Outcomes of simulation demonstrate that saving about 50% of energy in data center happens by ElasticTree.

Si et al. [54] presents an energy aware allocated scheme, eAware, to save energy by investigating the utilization of switch ports and inactive network components. The primary goal of this approach is relying on the queue lengths. While a queue length of a port is greater than particular threshold other ports will be enable to reduce the queue. In the other hand, if there is not any task in a port, it will be disabled. In the event that all ports of a switch are workless, switch will be switched off. The results of simulation illustrated that eAware can protect 30%-50% of energy in data center.

Botero et al. [21] in a paper shows the power aware virtual network embedding problem. The researchers allocated the group of virtual networks to the decreased group of physical network components and turning off the idle switches and links. Authors propose Mixed Integer Program [55] to solve the power aware virtual network embedding problem. The results show that the recommended approach reduces the energy usage up to 35 % when the traffic low.

In another study, Xu et al. [56] develops a throughput-guaranteed energy aware routing algorithm. The principle goal of this study is to use the minimum network energy to prepare the routing service, while considering the determined network throughput. Recommended routing algorithm estimates the routes for the traffic streams and network throughput and then eliminates links and switches since the network throughput meets the minor threshold. Eventually idle links and switches are switched to sleep mode. Simulation results suggest that the offered routing algorithm in this research can reduce energy consumption in data centers while network workload is low.

Chiaraviglio and Matta [57] in a study introduce collaboration between Internet service providers (ISPs) and component providers that enables the achievement of an effective concurrent allocation of network paths and compute resources to reduce energy usage regarding to keep the performance of network. In another study, Tomas et al. [58] considers the problem of scheduling Message Passing Interface (MPI) tasks regarding to keep the quality of service requirements while data transfers in the network.

Some other studies have been done on the thermal efficiency of resource management in data centers environment [59, 60]. The researches illustrated that extra power savings is achieved by temperature aware workload location and the software based thermal management.

4.3 Existing Energy Efficient Approaches Focusing On Server And Network

A study has been done by Shirayanagi et al. [61] to propose a power optimizer approach, namely Honeyguide, which combines Virtual Machines, bypass links and traffic consolidation methods together. This method implements traffic consolidation and VM to save energy in data center networks. But redundancy requirements prevent turning off idle nodes and virtual machine placement in network. Therefore, Honeyguide proposed as a solution to bypass links to scale up the amount of network switches. In this way switches can be turned off under the terms of redundancy. Honeyguide is implemented for fat-tree topology and employs the first-fit algorithm to locate VM. The results display that this approach in a fat tree with k=12 can store 7.8 % of energy.

Fang et al. [62] nominates an energy-aware manager to optimize traffic flow routing and VM placement and utilizes sleep mode scheduling of network components to reduce energy consumption. VMs are separated into a series of groups where overall traffic between the groups is minimized while overall traffic of inside group is maximized. Network traffic accumulated into fewer routes to put the residual network components into sleep mode for reducing energy consumption. Virtual Machine Planner (VMP) is assessed in a real data center. The result of simulation presents that VMP can save a considerable amount of energy.

An architectural framework was developed by Beloglazov et al. [63] for saving energy in Cloud Computing. Based on this study, researchers offered energy aware allocation heuristics provision for data center components to increase energy saving in data centers. This research has evaluated the energy aware resource allocation algorithms using the consolidation of Virtual Machines dynamically. The results of this paper [63] display that this method considerably reduce energy consumption in cloud data centers.

In a study, Kliazovich et al. [16] simulates energy aware for cloud computing data centers. Researchers designed this simulator to obtain the information about energy consumed through data center elements like servers, switches, and links. The results of simulation determined the efficacy of

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using power management schema like shutdown network elements dynamically, frequency scaling and voltage scaling [16].

The problem of power efficient resource management in heterogeneous environment in Internet hosting centers is studied by Chase et al. [64]. For serving request to each service, the proposed approach selects an active series of servers. In order to change the active series of servers, the network switches are reconfigured dynamically as required. By putting inactive servers into power saving mode, like sleep and hibernation, energy usage is decreased.

In another study, the problem of managing the energy efficiency of resources in a web-application environment have explored by Elnozahy et al. [65]. The authors used DVFS and changing the power of computing nodes on/off as the energy saving methods in their study. The basic idea behind this research is to specify optimal amount of physical nodes, adjust the appropriate frequency to all the nodes and to evaluate the total frequency of CPU essential to present the required response time.

According to optical burst switching technology to minimize task completion times, Koseoglu and Karasan [66] have exerted a similar method of combining allocation of network paths and computational resources in Grid environments.

Gyarmati and Trinh [67] examine the consequences of energy usage of network architectures in data centers. Network architectures optimization can be implement at design time of data center and cannot be perform dynamically. Authors stated that the energy usage of the data center architectures display different attributes correspondingly to the ability of transmission. The simulation results of their study display that there is a trade-off between energy needs and the transmission capabilities.

Gill et al. [15], showed a simulation environment for data center of energy aware cloud computing. Beside the workload dispersion, the simulator is planned to catch details of the energy that is used by data center components in addition to pocket level communication model between them. The results of simulation gained for 2-tier, 3-tier and 3-tire with high speed data center architectures that perform the simulator effectiveness in using various power administration schema, like dynamic shutdown, frequency scaling and voltage scaling.

4.4 Existing Energy Efficient Approaches Using Renewable Energy Source

Liu et al. [26] point to a unique way to model the energy progress in a data center and improve its administration. The writers believed that applying a holistic approach can decrease the environmental impact and electricity cost. This holistic approach combine renewable supply, cooling supply containing outside air cooling and chiller, dynamic pricing, and IT workload planning to develop the whole sustainability of data center administration.

Chiriac et al. [30] displayed a unique solution of retrieving the thermal energy squandered through the blades of servers in data center, consuming it to make hot water to vitalize a LiBr-HSO absorption chiller to make cold water urgent to farther cool the environment of data center. When Data Center squandered the additional energy is not only enough to cover the necessary inputs to cool process via absorption, a solar system provides additional energy or renewable energy system.

Dumitru et al. [68] presented multiple theories of productivity which are related to different technologies of improving energy efficiency for data centers, as well as various methods of energy management. The authors specified the four types of energy efficiency and the dependency between them for data centers such as facility efficiency, renewable energy efficiency, IT Usage efficiency, IT efficiency. Moreover, researchers demonstrated an overall survey about the process of energy efficiency management in a data center.

5. CONCLUSION

An effective and efficient use of computing resources in cloud can help in achieving Green Cloud Computing. The related research proposals are mostly focused on energy-saving approaches for data centers. However, due to increasing demand on bandwidth and network connectivity of data center, energy consumption of data center network and data center servers and network will rapidly grow in the future. This paper presents most of the technologies used for energy saving in data centers and discusses various approaches proposed in previous research works in this field.

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APPENDIX 1:

ENERGY EFFICIENCY APPROACHES

Existing Approaches Focus on Energy Efficiency in Servers				
Reference		Strategy	Description	Year
1	Nathuji and Schwan [32]	Combination of virtualization and DVFS	A virtual power approach that combined 'hard' and 'soft' scaling methods and integrated task consolidation into power management.	2007
2	Raghavendra et al. [33]	Virtualization and power management	Investigating the problem of power management by combining 5 varied power management strategies.	2008
3	Srikantaiah et al. [34]	Consolidation for power optimization	Presenting a heuristic algorithm for the workload consolidation for the multidimensional bin packing problem.	2008
4	Verma et al. [36]	pMapper (An application for place controller)	pMapper minimizes power and migration costs, while meeting the performance guarantees.	2008
5	Torres et al. [42]	Degradation of the QoS	Minimize the total number of active servers to process heterogeneous workload without performance penalties.	2008
6	Kusic et al. [37]	Virtualization, Limited Lookahead Control	Implemented a Limited Lookahead Control framework in a virtualized computing environment for dynamic resource provisioning.	2009
7	Cardosa et al. [38]	Virtualization	Providing a smooth mechanism for power-performance tradeoffs in data centers by virtualizations techniques.	2009
8	Gandhi et al. [39]	Power management, sleep mode	Measuring and allocating power to the server and allocating peak power among servers in a server farm to maximize performance.	2009
9	Fujiwara et al. [45]	Virtualization	Allow end-users to request an arbitrary combination of services to different providers.	2009
10	B Li et al. [46]	EnaCloud (a novel approach) Virtualization	Enable application live placement dynamically with consideration of energy efficiency in a cloud platform.	2009
11	Liu et al. [47]	Live virtual machine migration, VM placement optimization	Reduce data center power consumption, while guarantee the performance from users' perspective.	2009
12	Guo et al. [41]	Virtual cluster management	Allocates the resources in a way satisfying bandwidth guarantees	2010
13	Subrata et al. [43]	Nash Bargaining Solution	Maintains a specified QoS measure among all the service providers to reduce energy usage	2010
14	Mazzucco et al. [44]	on and off of powering servers	Improving the utilization of the server farm, i.e., by powering excess servers off.	2010
15	Lee et al. [48]	two energy-conscious task consolidation heuristic	Assigning each task to the resource on which the energy consumption for executing the task is explicitly or implicitly minimized without the performance degradation of that task.	2012
16	Aroca et al. [40]	Using ARM computer architectures	Based on low-power computers, an empirical comparison between server applications running on ARM and x86 computer architectures is presented for servers.	2012
17	Wang et al. [35]	DVFS	For reducing the voltages of CPU runtime of non-critical tasks are increased	2013

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18	Ghribi et al. [49]	VM Scheduling and migration	Combination of an optimal allocation algorithm with a consolidation algorithm relying on migration of VMs at service departures.	2013
19	Hsu et al. [31]	Virtualization	Restricting CPU use below threshold, consolidating workload among virtual clusters.	2014
Existing Approaches Focus on Energy Efficiency in Network				
Reference		**Strategy**	**Description**	**Year**
1	Gupta et al. [50]	Network sleep mode	To save more energy, putting network components into sleep mode while they are idle (like links, switches and routers).	2003
2	Heller et al. [53]	Sleep mode	Selects a set of active network components, and turn off idle links and switches	2010
3	Chiaraviglio and Matta [57]	GreenCoop: cooperative green routing	Concurrent allocation of compute resources and the paths of network to decrease energy usage under performance restriction.	2010
4	Si et al. [54]	Sleep mode	Putting idle ports and switches according to the length of queue and operation of switches and ports	2012
5	Botero et al. [21]	Virtual network embedding	Assign the virtual networks' group to decrease the number of physical network components, and useless links and switches will be turned off.	2012
6	Xu et al. [56]	Green routing	Unused network components are turn down by using a less network devices to provide routing,	2013
Existing Approaches Focus on Energy Efficiency in Server and Network				
Reference		**Strategy**	**Description**	**Year**
1	Chase et al. [64]	DVFS, sleep mode, hibernation	Reducing energy consumption by changing unused servers to power saving modes.	2001
2	Elnozahy et al. [65]	Switching power of computing nodes on/off , DVFS	Using the combinations of dynamic voltage scaling and node vary-on/vary-off- power management mechanisms to decrease the total power consumption.	2003
3	Koseoglu and Karasan [66]	optical burst switching technology	Combined allocation of network paths and computational resources.	2010
4	Gyarmati and Trinh [67]	-----	The efficiency of network architecture cannot be applied dynamically and should be done at data centers design time. There is a trade-off between energy needs and the transmission capabilities.	2010
5	Beloglazov et al. [63]	VM consolidation with switching idle nodes off	For minimizing power consumption a technique applied to focus the workload to the least of physical nodes and then turning unused nodes off.	2012
6	Kliazovich et al. [16]	Power Management like voltage scaling, frequency scaling, and dynamic shutdown	Simulating an environment for energy-aware cloud computing data centers	2012
7	Gill et al. [15]	power management methods such as voltage scaling and dynamic shutdown	The supply voltage in the active and under loaded servers reduced while the idle servers are switching to sleep mode.	2013
8	Shirayanagi et al. [61]	bypass links ,VM consolidation with network sleep mode	To face the redundancy requirements bypass links are added. Mixing network traffic consolidation and VM placement.	2013
9	Fang et al. [62]	sleep mode, green routing, VM consolidation,	By sleep scheduling network components improves efficiency of VM placement and traffic flow routing.	2013

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Existing Approaches Focus on Energy Efficient Using Renewable Energy Source				
Reference		Strategy	Description	Year
1	Dumitru et al. [68]	Renewable energy efficiency; facility efficiency; IT efficiency; IT Usage efficiency	Defining the data center energy efficiency as a function of the four types of efficiency and presenting a new and important point of view regarding the dependency between them.	2011
2	Liu et al. [26]	Renewable energy system, IT workload management	Predicting renewable energy and utilizing the prediction to produce a management plan for IT workload to schedule IT workload and to allocate IT resources in a data center.	2012
3	Chiriac et al. [30]	Renewable energy system	Recovering thermal energy to make hot water to enable a LiBr-HSO absorption chiller for producing cold water require for make the data center environment more cooler.	2012