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Energy Efficient Cloud System: Steps towards Green Computing

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Abstract— Cloud computing is a universal innovation which is spreading its root in every area of modern computing. The benefits of these services are excellent, but the data centres that run these services consume lots of energy and create a serious problem in the environment due to the increased carbon footprint. This creates the need to move to green cloud computing, that is the very important area today for researchers. Green computing provides techniques for energy management, efficient cooling, recycling, server virtualization and load balancing. We have explored potential domains to handle the issues that the development of cloud computing brings along, including underutilized resources such as conventional database management servers, processors, other servers, and cooling infrastructure. Along with the advantages, we also mentioned some of the disadvantages of the techniques. However, these impediments are not a noteworthy worry for the huge scale execution of these strategies. Once implemented, that is expected to mitigate the vitality issue and the growing carbon footprint of cloud data centres. We also discussed about a few parameters that can be utilized to calculate the energy utilization of data server and furthermore to evaluate the green energy coefficient of cloud server.

Keywords-Cloud Computing, Green Computing, Load balancing, Energy Efficient

I. INTRODUCTION

Cloud computing, a rapidly growing Internet-based technology, is defined as the "On Demand" service that allows you to share resources and manage data on the Internet instead of on local computers. As established by the NIST[1], "cloud computing is a model for providing appropriate, affordable and energy-efficient network access to the system's shared resources that can deliver quickly with the minimum management effort or interaction with the service provider. It includes mainly three types of services, software as a service (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS).

Cloud computing services offer a surplus of benefits. Some of them have little administration, less attention to infrastructure, faster and more effective. The clock is available on the Internet all day. The user can use the services in the cloud, conveniently on request. In addition, cloud services provide security and allow users to create backup copies of their data.

As a result of these advantages, several large scales, as well as small companies, have changed to a large extent to cloud computing in recent years. Forrester Research has estimated that spending on cloud computing services will increase from $ 40.7 billion in 2011 to $ 236 billion in 2020[1].

The increasing implementation of cloud computing has greatly increased the amount of energy expended in the data centres used to manage and distribute large portions of data. The vast data centre network uses a colossal amount of electricity to manage servers, processors, web peripherals and to cool the heat produced by the processor chips. According to the report on energy use of US data centres, the general use of energy by US data centres, In 2014 there were about 70 billion kilowatt-hours, which equals the amount of energy used by 6.4 million American families in 2014 and represents an increase of 4%. From 2010 to 2014 [2]. Increasing energy use in data centres is not only a threat to the environment, but also leads to inflated energy costs. Multinational companies like Google, Amazon, Microsoft and Yahoo contribute half (50%) to the total cost of three years supported by data centres for energy consumption[3].

Massive power consumption from data centres releases excessive carbon gases that are harmful to the environment. Data centre carbon emissions contributed to 60% of global greenhouse gas emissions in 2011[4]. CO_2 emissions increase the carbon footprint that affects the global climate, increases pollution, leads to global warming and has several health effects. If the carbon footprint increases without control, it will have devastating effects on the environment.

These factors make it necessary to implement Green Cloud Computing to reduce carbon dissipation and save energy. Although some companies have taken steps to resolve the problem, further steps need to be taken to make the IT industry environmentally friendly on a larger scale. The growing carbon footprint stems from an alarm that makes it necessary to prioritize green cloud computing and discover various methodologies to implement it.

The paper is structured as follows: we examine the existing work done in this field under the Section-II. Under the Section-III, we discuss about various parameters which can be used for measuring power utilization by data centres. In Section-IV, we present various prospective domains that suport green cloud computing. We discuss the future work in Section-V followed by the conclusion in Section-VI.

II. Related Work

The demand for cloud services among customers has led to an increase in energy consumption and carbon emissions from the data centre. This has made green cloud computing a trend and a popular research topic. A variety of energy-saving approaches, such as using monitors that consume less energy, recycle waste from older computers, use equipment with Energy Star labels and integrated memory controllers. , using techniques such as quad-core projects that increase performance per watt [5].

In addition, virtualization, an economic and energy-efficient feature of cloud computing, enables the processing of numerous requests and data management by creating multiple virtual environments in a single computer system. Kaur et al.[6] Discuss in their article on how virtualization reduces hardware costs and leads to less energy usage by migrating virtual machines and reduces CPU idle time.

Furthermore, numerous algorithms have been proposed to optimize activity planning and resource allocation strategies in cloud computing environments. Improved differential development algorithm (IDEA) [7] is one of these examples. It is a combination of two algorithms, namely the differential evolution algorithm (DEA) and the Taguchi method. The DEA algorithm has a robust exploration capability, while the Taguchi method provides excellent exploitability, so the IDEA algorithm is a balanced combination of exploration and exploitation capabilities. Paper [7] has shown that the IDEA algorithm can significantly improve the allocation of resources and the activity planning process, optimally exploiting the energy consumption of the server.

Zhao et al. [8] implemented another solution to reduce data centre energy consumption by improving the proportionality of energy, a relationship between the amount of energy consumed and the computer's performance, through dynamic provisioning and CPU power scale. Dynamic provisioning uses methods such as Wake-On-LAN and the migration of virtual machines that enable remote servers to be activated / deactivated. However, these approaches are less effective, since the chances of going into sleep mode are lower and when the servers are activated and the virtual machines are migrated, additional costs are generated. The CPU power balance uses the dynamic voltage / frequency dynamometer (DVFS), which reduces the CPU frequency as the workload decreases to maximize energy conservation. But this technique does not offer adequate results because even if the CPU usage is proportional to the system load, other peripherals such as the motherboard, storage devices and the disk use the same amount of power.

Load balancing is one of the key components for distributing the workload between different nodes to avoid overloading a single node. Kansal et al. [9] discussed the various current approaches to load balancing and therefore provided a comparison based on different metrics used in techniques such as resource utilization, performance, performance, etc. They also examined these methods based on the amount of energy use and carbon release. Furthermore, Jayant Baliga et al. conducted an inclusive analysis of the use of public and private energy in the cloud and the three cloud services. They analyzed the use of energy in transport, storage and processing and showed how cloud computing can use energy efficiency techniques. Furthermore, according to the document, cloud computing can sometimes use more energy than traditional computing [10].

III. POWER CONSUMPTION PARAMETER OF DATA CENTER

There are several parameters that act as metrics and can be used to quantify the energy consumption of data centers. These parameters also help us determine the sustainability and the green energy coefficient of data centres. The five most important parameters are discussed below:

A. Power Usage Effectiveness (PUE)[11]

The PUE was introduced in 2006 and advanced by Green Grid in 2007. PUE is the ratio of the total power consumed by the data center to that of the power consumed only by its computing infrastructure A PUE value approaching 1.0 indicates that approximately all the energy consumed is used for computing.

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

B. Data Center Energy Productivity (DCeP)[12]

DCeP evaluates the "valuable work" that a data centre produces in view of the energy it spends. The most intriguing thing is that DCeP allows each data centre to characterize the "valuable work" applied to its business.

$$DCeP = (\text{Useful Work Produced}) / T_{power} \quad (2)$$

C. Energy Reuse Factor (ERF)[13]

The ERF value of a data centre indicates the amount of energy which is reused for operations concentrated outside of a data centre. The main purpose of the ERF parameter is to increase energy reuse for some other operations instead of simply limiting it. The ERF value is between 0.0 and 1.0. A value close to 0 indicates that minimum energy is not reused, while a value closer to 1 indicates that most of the energy is reused for some operations outside the data centre.

$$ERF = (\text{Energy Reused}) / (\text{Total Facility Power}) \quad (3)$$

D. Green Energy Coefficient (GEC)[13]

The GEC parameter allows an organization to measure the amount of renewable energy used by its data center as part of the total energy consumed. Green energy sources can be referred to as any type of renewable energy and will naturally re-integrate over time. The GEC estimate of the energy consumed is measured in kWh. GEC has a maximum value of 1.0, which indicates that approximately all the energy used by the data center is green.

$$GEC = (\text{Green Energy Consumed}) / (\text{Total Energy Consumed}) \quad (4)$$

E. Carbon Usage Effectiveness (CUE)[13]

The CUE parameter can be utilized to evaluate the all out emanations of various ozone harming substances, for example, carbon dioxide, methane, chlorofluorocarbons, and so forth. Data centre compared to total IT energy consumption. The perfect value of CUE is 0.0, which shows that carbon usage is not related to data centre operations. The CUE unit is kg CO2 eq / kWh.

$$CUE = (\text{Total } CO_2 \text{ Emission by the Data Centre}) / (\text{Total Facility Power}) \quad (5)$$

IV. PROSPECTIVE DOMAINS SUPPORT GREEN CLOUD COMPUTING

As far as we know, data centre energy consumption is mainly divided into two categories: energy consumed by IT equipment such as the network, storage and servers, and infrastructure requirements such as COOLING. According to the study conducted by the InfoTech group shown in Fig. 1, the cooling infrastructure uses a significant amount of energy, followed by server AND storage requirements. Therefore, the methods indicated below, which we have proposed, address these two main concerns

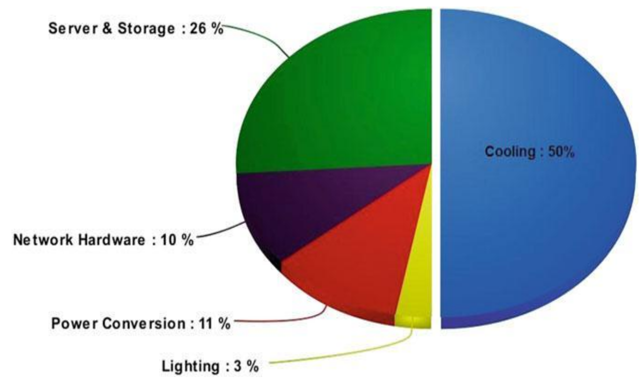

Figure 1. Power consumption breakdown of a data centre [14]

A. Datacenter Workload shifted to Microservers

Low power integrated micro servers are a more energy efficient alternative to conventional servers and can make the data centre infrastructure greener in the long term. These low-energy substitutes depend on Intel's low-power central processing units (CPU). They can be more productive than larger monolithic systems, given the correct workloads. The large groups of these micro servers that feed data centre workloads can greatly improve the work done in July, thus achieving greater energy efficiency. Micro servers are often wrongly attributed to degraded performance. However, a large swarm of these micro servers can provide almost native performance of conventional servers, especially during off-peak hours [15]. Therefore, changing data centre workloads in micro servers is a valid option, particularly for managing large amounts of archived data that is rarely accessed.

Further, there are an abundance of micro servers available in the form of defective mobile phones. This is especially true in India, which is one of the largest Smartphone markets in the world. The processors of defective mobile phones can be utilized in making large clusters of micro servers. These clusters can be used to manage the data centre workloads. This step will not only reap the aforementioned advantages of the micro servers, but will also help towards managing piles of defective smart phones, which currently, are a threat to the environment.

B. Improvement in Design of Datacenter

The continuous activity of services in the cloud makes the operation of cooling mechanisms incessant. It makes the cooling absorb most of the total data centre energy. Therefore, effective methods must be used to reduce cooling costs by using efficient cooling methods or by reducing the heat released. Data centre locations can play an important role in the amount of heat released and cooling activity. Data centres can be moved to geographic areas with abundant renewable energy sources that can be used for cooling. Alternatively, data centres can be moved to colder regions to reduce cooling costs.[16] Moreover, instead of dissipating the additional heat produced in the environment, it can be implemented to maintain the room temperature in data centres in regions with negative climates such as the Polar Regions. Furthermore, the orientation and structure of the data centre racks can also improve the cooling process adequately. Increasing the ceiling height of data centres and having an adequate data centre ventilation system can also help reduce cooling costs. All these methods can help make the cooling process profitable.

C. Combined use of Wimpy and Traditional Server

Traditional DBMS servers in data centres are largely inefficient in terms of power due to the fact that they waste a lot of energy while they are underutilized. These traditional high-end servers do not support the flexibility to reduce the scale when the workload is low. You can save a lot of energy if part of the data centre workload, preferably those that only require access to the database, moves to small (weak) groups of servers, where the number of nodes that make up the group can increase or decreased dynamically based on workload. Although these wimpy servers have their challenges, they are excellent for accessing database applications.

The use of wimpy servers in data centres also encourages the concept of micro services, which is an architecture in which different features of an application are independent flexible coupling services that communicate with each other to meet business objectives.[17] Due to a large number of advantages such as independent and accelerated production and easy updating of the application components without affecting other micro services, companies have begun to convert their monolithic applications into blocks of micro services. To improve fault tolerance of systems, replicas of these micro services should ideally be performed on different servers. Therefore, the management of a large number of micro services on traditional servers hinders energy efficiency and increases the overall cost of the infrastructure to a large extent. In essence, the use of wimpy servers, in particular for micro services, is useful both for the environment and for cloud service providers.

D. Increasing Transparency

Higher transparency regarding carbon and energy footprint among data companies will provide right statistics and help to tackle the problem of high carbon emissions and energy consumption better. After the plea was made by Greenpeace various multinational companies like Google, Face book and Apple became crystal clear about their energy and carbon footprint and also decided to go 100% renewable in coming years. However, there are other companies who remain ambiguous about their data. These data centre operators should break the silence as increasing transparency will help to take better measures to curb the impending danger. It will also increase cooperation in the IT sector. The governments of various countries should also take measures to address the increasing carbon footprint problem by setting transparency standards and enforcing environment related laws. A governing committee or a consortium can also be founded to oversee the problem of transparency and keep in check the increasing power consumption by data centres. Increasing transparency seems an insubstantial solution but any measure in this field, however small, can pave the way for an environment healthy IT sector.

The suggested methods can be used to resolve the problem and foster the implementation of green cloud computing. These practices should be executed on a large scale to get the desired results.

V. FUTURE WORK

We have discussed various methods that can be implemented to make cloud services greener. Shifting to micro servers can pose a problem when the workload is very high. Thus, the capability of micro servers to handle greater traffic is an area of future scope. Moreover, new methods can be explored so that the cost of revamping the existing infrastructure to accommodate low power embedded micro servers is minimized. Furthermore, an effective cooling method is to find proper balance between turning off the idle servers (Power Management) and minimizing the heat generation Power management techniques focus on turning off idle servers to save power which highly increase the temperature of busy servers, consequently, increasing the amount of cooling. More research can be conducted on this balancing technique which can be a significant solution to the problem of cooling. These areas of improvements are very crucial lines of future research work, which can make the proposed methods an optimal solution for green cloud computing. All these methods can be studied and tested extensively at a larger scale to eliminate the slight performance lag, keeping the power consumption in check.

VI. CONCLUSION

Evidently, cloud computing is a ground-breaking advancement in the field of computer science but it poses a great threat to the environment. This raises the concern and makes it obligatory to shift to green cloud computing. This paper demonstrates deployable techniques for sharpening the energy performance of cloud computing service providers. We explored the existing work done in the field of green cloud. We discussed various parameters for evaluating power intake of data centres. We also proposed different solutions for decreasing energy utilization and carbon emanation of these data centres. The proposed methods should be adopted on a larger scale not only by giant technical companies but also by small service providers. Measures should be taken to make IT sector more eco friendly by regulating the inflating energy utilization and CO2 emissions. It has become the need of the hour to shift to green cloud computing to modulate the expanding danger.

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