Energy Optimization in Data Centers for Cloud Computing

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Cloud is rising as an integrative research area due to its systematized handling over the varied computing resources as a service to the end users all over the web. It has emerged with adding into large scale Data centers which contain thousand number of heterogeneous servers across the globe. These Data centers require lot of energy for its functioning. Looking into the increased requirement of computing, the size of Data Centers is increasing day by day and in turn resulting in increased consumption of energy. This poses a real challenge in front of the industry to make the data Centers green and energy efficient to reduce both the cost of running and carbon foot print which is not environment sustainable. Several energy optimization approaches are suggested by various researcher in this area. Regarding this end, we identified distinct techniques which are capable of minimizing the energy intake of data centers like consolidation, cooling techniques, routing algorithms, virtualization, scheduling, load balancing and migration etc. We have also reviewed various simulation tools used by researchers for testing their energy efficient approaches. Lastly a research direction has been identified for play down the consumption of energy.

Keywords: Cloud Computing, Energy Efficiency, Data Centers, Virtual Machine Placement.

2023. In Saroj Hiranwal & Garima Mathur (eds.), *Artificial Intelligence and Communication Technologies*, 127–136. Computing & Intelligent Systems, SCRS, India. https://doi.org/10.52458/978-81-955020-5-9-12

1 Introduction

A distributed computing known as Cloud consists of variety of interrelated computers through internet which is providing diverse users to host their data on the web. This kind of computing provides good solution to the problems in processing and storage of bulk data, with on-demand, high-speed, low-cost and pay-as-you-go characteristics. The exponential growth in computing activity especially in the form of clouds has led to rising concern for energy conservation. Global warming has been a big concern with high power consumption and CO2 emission by various computing devices used in cloud computing.

The energy utilization of entities providing cloud services is steadily increasing. Enormous energy is consumed in data centers due to the overloaded or Idle servers. Idle servers may use around 69% to 97% of total energy usage. [1]

The demand for cloud infrastructure is increasing day by day which results into huge energy intake and emissions of greenhouse gases. As per an estimate of Amazon, energy consumption constitutes more than 42% of operational cost of a data center. Such high consumption of energy results in increase in overall cost of operations of a data center and poses an actual threat for cloud service providers. The main reason behind this huge energy requirement is mainly due to inefficient use of computational resources and their power consumption. [2]

The biggest challenge faced by IT organization is the energy efficiency of data center. The IT companies need to keep in check the operational cost for better growth prospect in future and better management of their financial resources.

The further part of the paper is structured as follows, Section 2 talks about the research background& motivation, Section 3 enumerates the linkages between Data Center and energy efficiency, Measures of energy efficiency and techniques are discussed in section 4 & 5, section 6 explains the cloud simulation tools and we finally conclude the paper with section 7.

2 Research Background and Motivation

Many of the cloud service provider companies such as Microsoft, Oracle, Google, Amazon, IBM, SUN etc are increasing its services with making its data centers big crosswise the world. These Data centers are utilized to store an ample amount of data in the cloud. To support this, need these Data centers need to run 24X7 which results in the need of continuous power. Moreover, one may infer that cloud services are one of the leading sources for worldwide warming due to high energy intake of these data centers. If this energy intake can be decreased by data centers it will be in good for the environmental issues. Energy reduction will lead to betterment of carbon foot print of data center along with productiveness of the system. The minimization in energy intake will cut down the cost and also is useful in protecting the geographical area [3].

For e.g., the data center named in Quincy, WA owned by Microsoft is spread over 43,600 square meters and uses chiller piping of around 4.8 km, electric wire of 965 km with 92,900 square meters of drywall, and battery backup of 1.5 metric tons. The intense power intake of in Quincy is 48 megawatts, which is sufficient to power 40,000 homes. Hence, optimization of energy become the new challenge for the researchers to evolve new technique or algorithms [4]

Based on the statistics of year 2015, It has been noted that Cloud data centers consume around 1.8% of worldwide electricity consumption and such high usage contributes almost 3% of global CO_2 emissions. It is expected that in year 2020, the power consumption of data center will rise 10 times to 18% and the

CO_2 emission to 6%[5]. Another report published in 2016 shows that Cloud data centers across the globe produce nearly 1.5 MT of CO_2 and which is further expected to triple by year 2025[6].

Based on a study [8] in the year 2030 the Data centers' energy consumption is anticipated to be around 8000 TWh as indicated in the below [Fig.1].

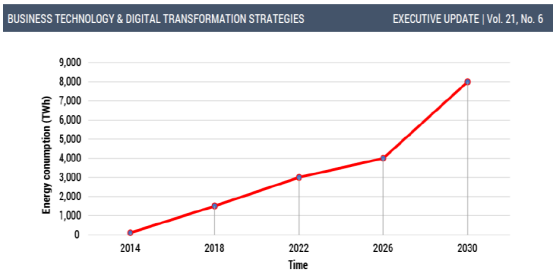

Figure1. Energy Consumption in cloud data centers (Source: Andrae and Edler.)

For both the business and academic point of view, the carbon discharge aside by cloud computing in data centers has come forth as an ascendant research topic. This is mainly on account of energy required by the data centers for its various operations like, power supply, illumination and cooling which contributes substantially towards the overall operational costs. Hence, for making cloud services sustainable and environment friendly, reduction in power consumption and loss of energy is the need of hour.[7]

3 Data Center and Energy Efficiency

In today's era of networking and computing the Data centers are the essential part of Cloud. They are mainly used for data operations like -

- Collection
- Storage
- Processing
- Distribution

Being a heart of cloud, it consists of cords, networked servers, power sources etc. that is used for hosting the functioning applications and storing the available information used for business purpose.

Energy consumption factors in data centers

A data center consists of various components having different energy cost factor. The below chart depicts the major constituents of a data center and their energy cost percentage[Fig 2]:

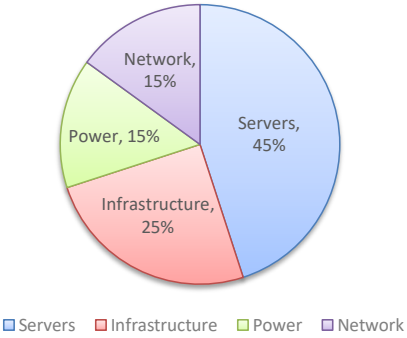

Figure 2. Energy Consumption Cost of major components of data center (Source: Anuj Kumar Yadav, 2019)

We can easily infer from the above chart that servers are the most energy consuming component of a data center and thereafter the infrastructure which helps in power distribution and cooling.

To assure the reliability and availability of the services the demand of data centers also got exaggerated over the years. To complete this demand the Data Centers components like storage devices, network devices, and servers have to run incessantly [3]

4 Measure of Energy Efficiency

Over the years people have studied various aspects to measure the energy efficiency of a data centers and many papers have been published in this area. For the measurement of the infrastructures' energy efficiency of the data centers the term Power Use Effectiveness (PUE) is developed. This term is one of the IT industry's approved metrics. The Green Grid Association evolved this term which was originally published in 2007, and globally adopted by the industry.

PUE is defined as the ratio of the total facility energy to IT equipment energy as shown in the equation below:

$$PUE = \frac{\text{Total Facility Energy}}{\text{IT Equipment Energy}}$$

The PUE can be greater than or equal to 1 and its desired value is close to 1 i.e., lesser PUE is preferred as it indicate less energy is consumed.

Uptime Institute[8], an organization is tracking the average PUE numbers of industry for last 12 years. From the figure indicated below we can say that PUE is falling at rapid rate since 2007.The cloud data centers will be treated as efficient with dropping PUE levels. However, there is not much improvement in ratings since 2013 and in-fact after 2018 it has again begun to rise. Which poses a big concern in front of the industry at large. [Fig.3]

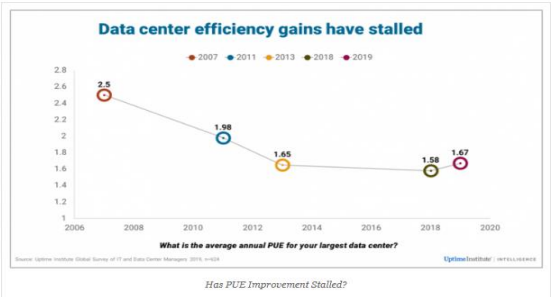

Figure3. PUE numbers of Industry in last 12 years(Source: Uptime Institute -Lawrence, 2019)

There can be many reasons behind this like -

- The high value of PUE is due to the increased temperatures in various part across the globe where data centers reside as higher temperatures are responsible for expanding cooling system.
- Data centers' workload are moving to cloud services for public domain. So, there will be many Data centers which can be worked below their desired efficiency.

In Data centers we have both under loaded as well as overloaded servers. In under loading state of the server, the power is consumed as memory, networks, processors etc. even the server is in idle state which in turn add cost to the system. For e.g. The server can absorb 50% of the peak power even if it is having the negligible load of 10% as CPU usage.

5 Energy Efficient Techniques

The below figure [Fig.4] shows various techniques which are projected in the literary study to attain energy efficiency in cloud data center.

The energy efficient techniques can be broadly divided in five categories as under:

Host Level technique mainly consist of Dynamic Power Management (DPM) which allows the server state to be in sleep mode for the prescribed time period in order to optimize energy, whereas Sleep on/Off mainly focusing switch off/on during runtime for power management based on server workload.

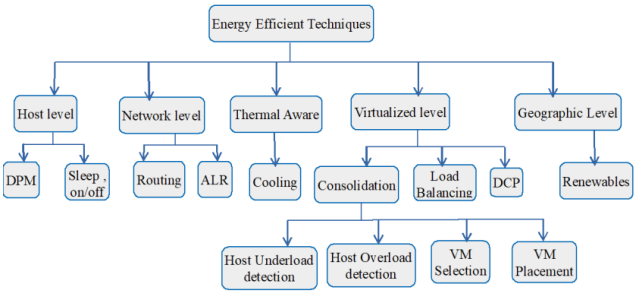

Figure4. Energy efficiency technique

Network Level technique focuses mainly on network management to share the load for data transfer through adaptive link rate (ALR) for optimum utilization of network resources

Thermal Aware technique is related to thermal state of servers and focuses on different ways tocool off the temperature

Virtualized Level technique uses consolidation technique to increase the computing resources utilization.

Geographic Level technique has concentration on renewal energy sources for sustained power resources and reducing the overall cost of energy.

On review of various research papers [9][10][11][12], virtualized level with consolidation is reasoned as the most likely approach for salvage of energy because of its resource manageability during runtime. This technique is used to increase the resources' usage of the server which in turn reduces the energy consumption.It is further sub divided into again four parts as shown in fig 5-

1. Detection of under-load Host
2. Detection of over-load Host
3. Selection of Virtual Machine for Migration
4. Place the chosen Virtual Machine on Host

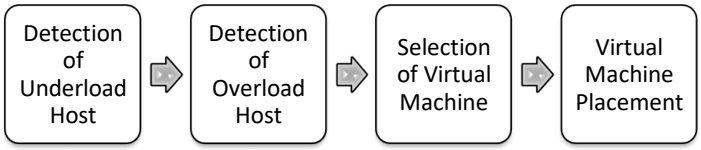

Figure 5. Consolidation technique

In this particular approach the server machine is repeatedly supervised. If the server gets in to any upper or lower threshold limit than suitable action is taken. Like if any server is found to be in under – load situation than its current accommodations (for e.g., Virtual Machines) are migrated to another selected server and it went off for the salvage of energy.

It has been shown in the empirical results that Consolidation of Virtual Machines lessen the consumption of energy around 30% with slight impact on system performance as compare to the energy consumption when no consolidation technique is used [13]

Numerous researchers are embedding efforts for reducing energy intake of cloud data centers. Few of the techniques are sighted in the table given below –

Table 1. EnergyOptimization Techniques

Author (year)	Work Carried	Ref
Hongjian Li, (2015)	They formulated anenergy-efficient multi-resource model which was based on Virtual Machine Migration and consolidation algorithm.	[14]
Zhou Zhou, (2016)	The authors worked on historical data which was used by VMs and developed an algorithm ATEA named as adaptive three threshold energy aware algorithm.	[15]
Khoshkholghi, (2017)	These authors give attention to SLA (Service Level Agreement)	[16]

	constraints for RAM, BW and CPU of the Data center. Later onthey projected VM consolidation technique which was both SLA as well as energy aware.	
Usman, (2017)	These researchers have taken care of all the resources of data centers which are under usage and proposed a Virtual Machine allocation design with the use of an algorithm titled ISA (Interior Search Algorithm).	[11]
Rajkumar Buyya, (2018)	The authors worked with the aim for reductionin the carbon footprint of Data centers. They worked in the direction to make the cloud services environment sustainable. For management of full resources of data centersthey also designed a Conceptual Model.	[17]
Alsbatin, (2020)	These authors worked for placement of Virtual machine and proposed following algorithms - • CPBFD (CPU Priority based Best-Fit Decreasing) • DCPBFD (Dynamic CPU Priority based Best-Fit Decreasing)	[18]
Sadoon Azizi, (2020)	These researchers used the ranking technique for power efficient servers and developed MinPR algorithm. The MinPR cut down active physical machine and lessens the power intake of Data centers with this approach.	[2]
Ibrahim, (2020)	These authors adopt the nature inspired way based on Swarm Intelligence and suggested PAPSO (Power Aware Particle Swarm Optimization) algorithm. This technique is used to find out the near optimal place for the Virtual machine which is migrating. PAPSO scale down the migrations by taking care of overloaded as well as underloaded hosts.	[19]
Uddin, (2021)	The authors suggested an algorithm named novel Virtualized Task Scheduling which will manage the mapping of VM to PM. It was the server consolidation technique which escalate the utilization of server machines which are already available.	[20]

We studied the above referred literature published by the respective authors with regards to the energy efficiency in cloud data centers. Basis our studies so far, we found that VM placement is one of the most relevant and appropriate technique to achieve the energy optimization. Virtual machine placement (VM Placement) is process/ method of placing virtual machines in a physical machine. There are many algorithms for VM placement such as Genetic Algorithm, Particle Swarm Optimization, Constraints, Ant Colony Optimization, Bin Packing and many others are available.

Regardless of the huge work done in the literature there are still some aspects which need to be addressed further for that purpose we propose the following workflow models under –

Identify the problem, the research work starts with identifying the problem which shall be construed as the research objective.

Study the existing work, after finding the problem area, the existing research work done shall be reviewed which will provide the necessary foundation to plan our activities to proceed further. This will

include literature surveys and online research of the available material to have a global prospect of the issue.

Analyzing the challenges, the review of existing work will help us understanding the challenges faced by the researchers while working on the research objective. Such analysis help us to have a better understanding of the key areas to focus.

Finding the solutions, after finding the problem, study of the existing work and the challenges faced by the existing researchers, we shall be dedicating our efforts towards finding the solution for the problem identified in the first course.

Suggestions / Recommendation, we shall suggest/recommend a methodology or a framework based on the findings of our research.

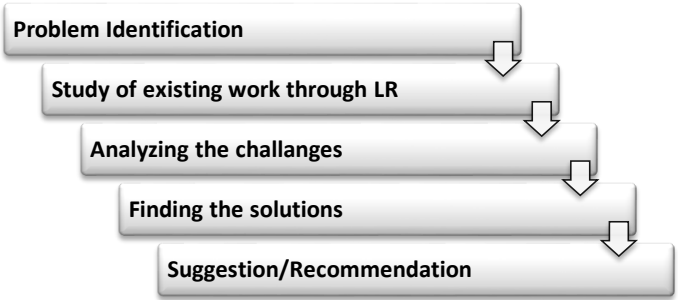

Figure 6. Proposed methodology

6 Cloud Simulation Tools

Any research in technical field is effective only when it is being tested in the real world environment but many times it is not feasible to test in real world due to various constraints. To meet this challenge a concept of Simulation was invented wherein simulation model is created having real world like environment. This helps in identifying the problems which may arise when the technology solution is implemented in actual world. Accordingly, we shall be using cloud simulation tools to test the effectiveness of our research findings.

We have reviewed the work of various authors in the field of cloud simulation tools as under:

Table 2. Cloud Simulation Tools

Author (Year)	Work Carried	Ref.
James Byrne1et. al .(2017)	In thisauthor gave an overview of around 33 cloud simulationtools with the help of reviewed literature later they came to a decision as cloud sim is the de facto standard as out of all tools reviewed there are 18 tools such asCloudAnalyst,CloudReports,CloudSimDisk,iFogSim,WorkflowSim,Cloud2 Sim and many more were the extensions of cloud sim only.	[9]
Kalpana Ettikyala, (2015)	In this work authors compared different simulation tools as CloudSim,CloudAnalyst,GreenCloud,NetworkCloudSim,EMUSim,MDCSim,C DOSim,TeachCloud,SPECI,DCSim,GroudSim,iCanCloud,FlexCloud etc.	[10]

	features such as platform and language support, limitation in network criteria ,its type and so on.	
Ilyas Bambrik, (2020)	Author classified all the cloud simulators based on the specific needs of the researchers. Later they came to the decision that none of the tool is a perfect fit for any specific need, but CloudSim is one of the most used tool due to its extensibility.	[3]
ShobhnaDogra ,(2020)	In this work authors selected the three tools as Cloud Report, Cloud Analyst and CloudSim based on their popularity. All the three tools were compared based on different criteria like cloud service related environment, could components modeling requirements and simulation related requirements. later they came to the decision that for analyzing complex simulation situation Cloud sim is the best out of all three most used tool.	[21]
Soumya Ranjan Jenaa, (2020)	Authors identified some popular cloud simulation tools as Cloudsched,Cloud Reports, Cloud Analyst,CloudSim,Green Cloud etc. and discussed their architecture as well. Later these tools were compared on different scale as language used, graphical support, energy modals, energy consumption, memory space, simulation time etc.	[22]

7 Conclusion and Future Scope

Energy consumption is a big challenge in data center which has drawn a lot of attention from researchers worldwide. With growing need of cloud computing this problem is posed to rise exponentially and we need to find a solution to make them sustainable for long term. During the course of our research, we have gone through the work of many researchers to find a direction for further work and narrowed down to VM placement as our research subject. Based on our studies we have found that swarm intelligence approach for VM placement has a good potential for optimization to scale down energy consumption to a great extent.

Following are the key findings fromour research so far as under:

- Inefficient utilization of Servers is the key to energy consumption problem of a data center
- The efficiency gains of a Data Center measured in*Power Usage Effectiveness*(PUE)has stalled over the years
- Consolidation methods with consideration of underload /overload hosts to save their idle energy lead to a promising option for optimization.
- Swarm intelligence approach for VM placement has a good potential for optimization as it scale down the consumption to a great extent
- Cloud Sim simulation tool has a good strength to handle complex situations and is a good research tool for further studies

As a forthcoming work, we shall study the various solutions catered by the researchers in this area to identify the potential of improvement which provide the optimal energy efficiency in data centers.

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