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Energy Efficiency in Green Data Centers: A Review

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Abstract – Energy consumption is increasing globally day by day. Due to this Greenhouse Gases are badly impacting our environment. Because of drastic growth and usage of the internet, energy consumption in data centers increased exponentially. There are problems related to computer systems which include the energy consumption, exhausted emissions, building resources, high maintenance costs, global warming and high-water enterprise. To avoid these problems, we have to take care of Data Centers. There are many ways through which can lower the energy wastage, electricity cost. The creation of the Green Data Center is necessary. Green data centers are sustainable. Research has been done related to energy tinctures and hike in the cost of energy. Efficiency of data centers matters the most. This paper discusses the data centers, problems faced by them, techniques to improve those problems. This paper also explains the various systems which could be used in data centers to avoid energy wastage, cost crisis.

Index Terms – Power usage effectiveness, Green metrics, Optimization, VCG mechanism, Green Grids, Resource Management, Energy Efficiency

1. INTRODUCTION

Human the principal reason for various pollution. When the earth's temperature rises above the average temperature of the surface that will lead to global warming [1]. The main reason for the increase in temperature is due to the climate change. There are various reasons for climate change they are deforestation, soil erosion, volcanic eruptions, Greenhouse gases (GHG) etc. [2,3]. The main anthropogenic reason for global warming is the emission of Greenhouse gases. The various Greenhouse gases are Water Vapor, Carbon dioxide, Ozone, Nitrous Oxide, Methane, Hydrofluorocarbons and Chlorofluorocarbons. The main causes for the emission of Greenhouse gases include the agricultural practices, livestock manure, more energy is released from the industries, data centers etc. [6]. Around 2% of Greenhouse gases are released from the IT zone that's why it is very important to minimize the energy released from the data centers [5].

Green computing is the latest trend in the market where the use and manufacture of computers and other computer related equipment are environmentally friendly [4]. To reduce the energy emitted by the data centers, the data centers are turning green by using a green computing method [8, 9]. By using the green computing, the equipment in the data centers can be designed in such a way so that they consume only minimal energy [7]. The study forecasts that in 2011 the global power consumption from the data centers is going to be 1.1%-1.5% and in 2020 it is going to be 8%. The main purpose of Green computing is to lower the emission of carbon gas which is a GHG. It's very necessary to design equipment like cooling systems, servers, power backup systems, network equipment and storage eco-friendly [10].

2. LITERATURE SURVEY

Hazril et al. [1] presented, as the demand for data centers are increasing, the energy consumption by them is also significantly rising. In order to reduce the energy consumption one can, implement Green Data Centers which uses Green computing. Green computing involves scheming a computer that contemplates both energy efficiency and processing performance. The study proves that there is an increase of 1.1% - 1.5% yearly in the energy consumption of DC if this continues then there is a chance of an increase in energy cost also. To increase the reliability of the system the DC machinist increases the capacity of their UPS system which reduces the energy efficiency of data centers. The improvement in the underutilized equipment in the data centers contributes to

improving the energy efficiency of the system. When we are maintaining the required performance at the target level it is very necessary to minimize the energy consumption. The energy consumption has issues related to maximum throughput, performance degraded and equipment damages. Power usage efficiency and Performance Watt are used to measure energy efficiency in DC.

Aryan et al. [2] discusses the various problems which are related to data centers. There are problems related to computer systems which include the energy consumption, exhausted emissions, building resources, high maintenance costs, global warming and high-water enterprise. A study says that the data centers in the USA consume nearly 2.8% of the electricity of the country. The study of green data centers can be classified into 3 important groups: cooling, computing and geographical factors. The research says the use of waste heat from IT devices and the evaporative cooling method is enough to help straight fresh air-cooling structure. Dynamic voltage frequency scaling and dynamic power management techniques are the 2 proposals for minimizing the energy utilization in servers. By using the optimized MapReduce energy efficiency technique, we can significantly reduce the energy utilization. The study proves that to minimize brown energy utilization we can use a workload-scheduling algorithm which attains the aim of 40% and that is 21% lesser than the brown energy which is consumed by other green devices.

Zhengang et al. [3] presented the study that happened in 2009 total energy consumption by the data centers is nearly 36.4 billion degrees. And it is 50 billion degrees in 2011. In 2 ways one can measure the energy efficiency index they are Power Usage Efficiency (PUE) and Data Center Infrastructure Efficiency (DCiE). When the system's energy efficiency is more, then the PUE value will get closer to 1. The standard benchmark value is 2. As the percentage value of DCiE increases, it gets even better. The most used technique around the globe is PUE. The various equipment in the data centers consume nearly 50% of energy. In that the air conditioning and ventilation system consumes around 25-30% and the lighting and other energy consumption is around 15-25%. The energy consumption by the IT equipment is nearly 57% and its PUE value is 1.6, about 25% of energy is consumed by AC system, 12% is from ventilation of AC, the UPS will consume nearly 10% and the lightning system is about 3%. When we reduce the Cooling Load Factor (CLF) then we can achieve energy consumption. That can be done in various ways by using a Chilled water air conditioning unit with natural cold source, by using Ethylene glycol air conditioning unit with natural cold source, intelligent double circular energy-saving air conditioning unit with natural cold source.

Emna et al. [4] presented the main design aims for any data center are simple installation, high scalability, small number of wires, low latency, efficient routing algorithm and high bandwidth. The data centers should include all the Quality of Service that should include La7CoDa and PTNet. The best methods for reducing energy usage. They are Renewable sources of energy, Energy efficient equipment, Energy efficient interconnections, Power-aware cooling and Power- aware routing algorithms. There are various problems that arise here; they are Underutilized networks, inefficient management of cooling infrastructure and Use of brown energy. The big companies are investing in more and more renewable energy projects like solar and wind projects. To foresee the amount of solar energy which is going to be available for future can be measured using a job scheduler. In data centers instead of using electric chillers they can implement free cooling mechanisms by using air or water. The data centers can use equipment like Optical technology, Commodity network and Wireless technology to decrease the energy used. There are 4 algorithms that can be used in the dynamic power management: Adaptive Link Rate, Power-aware routing algorithms, Virtualization and Dynamic voltage/frequency scaling. And proposed an idle data center with clean energy sources, efficient equipment and interconnection, clean cooling and heat disposal and power-aware algorithms.

Jimmy et al. [5] presented the main aim of green computing is to minimize the release of carbon dioxide from the computer systems. There are various methods that can be used in reducing power utilization, Virtualization is one of the methods. The method integrates various servers. The main parameters that are taken into consideration at that moment are input/output. Network resource and CPU. And one has to manage servers properly while doing the virtualization. A technique which is used to cluster the server according to groups is called OpenMosix Cluster Management System. On the physical hosts one can install the Virtual Machine. We can calculate the power consumed by the virtual machine that is around 16.27 watts. The power consumed is around 230.95 watt without grouping and clustering and with them is around 59.73 watts by using cluster and virtualization.

Khashif Bilal et al. [6] discussed many issues related to energy, electricity etc. There are many ways through which can lower the energy wastage, electricity cost. Green Data Centers play a major role in this. They propose various solutions for maintaining the efficiency of the energy. New Green Data Centers are providing the solutions using their new architecture. This paper tells us about the important Data center architectures, design problems, problems related to quantifiability, and non-gracefulness. It explains countless techniques which are desirable to the architectures of the DCNs.Green House Gas is one of the major problems in the world. Everyone should try to reduce it. The best way to reduce it is using efficient Data centers. Networking of Green can follow two paths. One is amalgamation of caseload. Second one is reducing the contact link information. Accordingly, a small set of baseless system association and instrumentation may be converted to a slumber or low power baseless manner.

Eugan Volk et al [7] have been done related to energy tinctures and hike in the cost of energy. Skillfulness of data centers matters the most. In this paper, the authors present two complementary energy- skillfulness improvement transformations adjoined in the compass of EU tasks – with focal points on constructing energy skillful data centers, cloud employment etc. Both the approaches make use of measures related to cost and efficiency of data centers. The important bourn of the CoolEmAll is to build forward looking models, mental imaging and conclusion backup toolkit along with the pattern of calculation developing blocks for data centers, endowing data centers makers and manipulators.

Tran Manh et al [8] explained that the Data center is a key player in maintaining the future of the data, contact applications. It is one of the trending topics. In data centers Host mental imaging and current immigration and emigration technologies alleviate skillful load equilibrium and diminution in energy ingestion. The authors of this paper build a power skillful data center by uniting host integration and baseless modal logic of the data center. They implemented a connected power administration strategy for data centers. This strategy allows us to bring off power states of both hosts and network devices. The suggested analytical VM Placement algorithm works well and it rescues the power of both hosts and switches. We could apply a testbed for this algorithm to further improve the efficiency of the data centers.

Vishtit lio et al [9] explained that the substance compartment is a hopeful energy source for green data centers because of its high-power skillfulness, low carbon emissions and high dependability. But because of the mechanical restrictions concerned with energy delivery, fuel cells are slow in altering energy output when the power bespoke, suddenly changes. This paper tells us about the issues, challenges by changing both power supply and demand through a united workload plan. Exclusively they consider various gio-distributed data centers. The authors of this paper enquired about the difficulty of reducing the time average power consumption of data centers powered by substance compartment. They found out the difficulty as a stochastic optimization problem to extenuate the power gap between workload and energy supply. To solve this problem, they constructed an online control algorithm. By using this algorithm, they were able to achieve the desired things.

Arif sari et al [10] discussed that] if we compare the total energy available in the world and power consumption, consumption has grown out of the way. We need to lower the usage of power or energy. The demand for green power is very high. This paper discusses few important techniques which could be used to increase skillfulness of data centers. It also tells us about the restrictions of security solutions of these data centers. Data centers are facing many gainsays, one of them is price problem looping in them and the techniques are not sufficient. Energy consumption in hosts also increases day by day. Second challenge is carbon dioxide footsteps. There can be many solutions to these problems in order to have a green world or peaceful world. The solutions could be mental imaging, improving the monitor systems, reducing E-waste, producing very thin devices.

Xiaoxuan Hu et al. [11] green data center management and geo distributed data centers is highly concentrated. Also, they discussed limited load following. To minimize the gap between energy supply and demand an algorithm is discussed. As renewable sources of energy are highly unstable fuel cells are emerging as energy sources for data centers. By scheduling the workloads among geo distributed data centers, we can change the energy demand. For this energy demand change workload scheduling is proposed. To mitigate the slow load following effect of fuel cells workload scheduling and fuel cell controlling among geo-distributed data centers is followed. To minimize the gap between energy demands and supply Stochastic Cost Minimization Algorithm is found. As considering the low carbon emission and high energy efficiency fuel cells are much preferred. An online control algorithm is proposed in this paper. In data centers the energy management is done by using the receding horizon control method. The potential performance will increase when energy demand is scheduled properly. Also load follow rate, charging and discharging rate, control parameter rate impacts are discussed.

Zhi Zhou et al. [12] Data Center demand response issues can be resolved using smart grids. Also load reduction is a very important factor which is done by distributed datacenters. Cloud service providers which operate on geo distributed data centers are showing inefficiency towards demand response of data centers. A proximal jacobian alternating direction method of multipliers algorithm is used for data centers to solve the issue of small-scale data center industries. Vickrey Clarke grove's payment is used for resolving the maximization of social welfare. Coincident peak pricing is the most useful program of demand response in data centers. As the data center demand response is having major priority in future the smart grid process is very useful. CSP decides the workload management of data centers to optimize the usage of smart grids. The different types of demand response strategies are discussed in this paper. The types of the demand response strategies are software based, hardware based and power source base. Also, the power load management is done by temporal and spatial load shifting. Participation of demand response auction for the geo distributed data center is discussed. And utility of smart grids and CSP is also discussed.

Baya Hadid et al. [13] Consideration of IT optimization workload DC energy efficiency is improved. Power usage effectiveness optimization is improved by cooling settings changes. The black box models are explained in these papers to predict the power usage effectiveness. By increasing the inlet temperature to the rack reduction of power consumption can be observed. DC model structure is mainly focused in this paper.

The measurements of air flows, cooling tower fans and the water flow rates as well as the temperatures of the engaged fluids in supply and return are rarely accessible. By reducing the leakage power in data centers improves energy efficiency. Dynamic models of services and cooling systems are deduced for the power gain. Dynamic simulation modelling is designed by considering the factors input output selection, order model selection is considered. The temperature setpoint increases effects on energy savings. Based on experiment data power usage effectiveness is optimized and deduced by the studies made. Thus, efficiency of energy in data centers is discussed with a data driven approach.

Ngobemi et al. [14] the trigeneration system design strategy is explained for the use of non-renewable energy. Combined cooling heat and power type of production is very useful in production of electricity. And this is the most feasible way to manage data centers' energy related issues. For better use of data centers, the tier standards should be high. a power micro grid system also gives high efficiency for data centers. Trigeneration system is economically more suitable than cogeneration for usage. Also, studies show usage of two stage coolers in gas generators is very much helpful for better efficiency. Gas specifications like boiling point, flash point mainly considered for energy efficiency and design part of data centers. By some assumptions power load factor and cooling load factor the energy modelling system is mentioned. Also, by increasing generator load efficiency will increase so that improvisation is seen. To remove more heat from the data center is considered to be generator efficiency.

Monalisa Kushwaha et al. [15] as more business is relied on data the importance is given to data centers. By this consumption of energy is increased. This paper gives us to follow better metrics and criteria to increase data centers efficiency. Efficiency of energy is a challenging factor as data centers use a lot of energy. Green grid is an important factor for the metrics categorization. The metric should be clear, simple, accurate, precise, and capable enough to act to the need of. Carbon footprint, total cost, uptime, and downtime all the factors should be given importance for the better categorization of metrics. Power of IT equipment to the total facility gives data center infrastructure efficiency. Data center power lighting density, server usage effectiveness, uninterruptible power system efficiency is considered for energy consumption metrics. Server centric method helps server to run efficiently without any interruption caused. Inter server communication latency helps when many servers are in queue because delay in processing leads to network traffic which affects performance of the data centers. Each metric plays a very important role in metrics categorization.

3. EXISTING ISSUES

The computer servers in datacenters are always on and waiting to receive data hence the data movements in the system absorb plenty of energy. There is a suitable measure to be taken to efficiently storing and processing of huge scale data. There are various problems which come in the way when the network tries to convert to green. The carbon dioxide emitted from the computer server is the same as the carbon which is emitted from a sports vehicle. The utilization of brown energy grants the release of carbon and there to climate change. Cooling systems consume more power that is around 63%. The equipment used in the existing data centers is highly costly and absorbs enormous energy which also affects the efficiency of data centers. The carbon footprint of the data centers should be minimized by adopting various methodologies and techniques. Depending on the days when data centers use the DC Networks the traffic on the systems varies according to that. To ensure that the system works when there is a high load and system failure should be minimum for that purpose over- provisioned resources like redundant servers, network and storage equipment are installed and the power to them is supplied by 2 sources. The energy efficiency of data centers will decrease when there is a power loss in UPS. Energy management is a very serious issue in the data centers.

The existing system uses switch centric DCN's which are less efficient and evolved to use the host-centric data center networks to reduce the power wastage. The DC Cell interior design also shows path diversity from source to destination. Plan of various types of data center efficiency constructing blocks indicating constellation of IT equipment and data center facilities on various coarseness grade and improvement of the SVD toolkit endowing the analysis and optimization of IT substructure. To adjust energy supply to the storage usage of limited load following is not much efficient in the existing systems.

Polymer electrolyte membrane fuel cell is used for lowering the operating temperature which increases the cost. Energy management model was struggling with the energy supply of fuel cells to data centers. Fuel cells have lower carbon footprint but in this existing system fuel cells are suffering from weakness of limited load following. The system has usage of power grids for the operational stability of data centers. But with the issues in power grids now evolving to smart grids. By this data centers have no potential towards demand response. Coincident peak pricing is not much efficient in data demand response program used in data centers priory. By considering these issues in the existing system new models and approaches to be found for better efficiency of energy consumed by data centers.

Power management is performed by temporal and spatial load shifting in the existing system. To reduce the power consumption by the data centers the inlet temperature should be high at the rack. The measurements of air flows, cooling tower fans and the water flow rates as well as the temperatures of the engaged fluids in supply and return are rarely accessible. By reducing the leakage power in data centers, they improve energy efficiency. The design of the data centers is very

important for efficiency. The combined cooling, heating and power factors are considered for the efficiency of the data centers. Trigeneration system is economically more suitable than cogeneration for usage. Gas generator and grid power interlocking mechanism is not much efficient which are used for designing the data centers. For the data centers efficiency categorization of metrics plays a very important role as the data centers have high demand in business. Each metric plays an important role in improving efficiency of data centers. By considering these challenges some design techniques, methodologies and different mechanisms are explained in proposed systems for the better energy efficiency in data centers.

4. EXISTING METHODOLOGY

The various factors which need to be considered for the energy efficiency in data centers are cooling system, power management, resource managements, and geographical features and also the design of equipment's so that it consumes less energy. The discussed works are:

- Cooling Infrastructure
- Power Management
- Resource Management
- Geographical Features
- Equipment's Design

4.1. Cooling Infrastructure

To bear the fresh air-cooling system we can use an evaporative cooling system and the waste heat which were emitted from the devices. Direct cooling and indirect cooling are the 2 procedures of a fresh air-cooling system. By using the historical sensor data, we can conserve the cooling energy. Cooling with water or air has proved efficient than cooling using electric chillers and for smart cooling we can implement intelligent sensor placements. The value of Power Usage Effectiveness (PUE) can be reduced by decreasing the value of Cooling load factor (CLF), Power load factor (PLF) or All other load factor (ALF). We can use natural cold sources for chilled water air conditioning systems, for Ethylene glycol air conditioning systems and for intelligent double circular energy-saving air conditioning.

Power usage effectiveness optimization is improved by cooling settings changes. Black box models are proposed to increase the optimization level of power usage. The study shows by using predictive models we can optimize the set point settings to increase the energy efficiency of data centers. The main importance is given to extract a DC model for high efficiency of energy consumption made by the data centers. By using computational fluid dynamic models, the delivery of cold air to servers can be optimized. The proposed idea is to use the dynamic simulation modelling method for power usage effectiveness.

4.2. Power Management

Many big companies are using renewable sources of energy. Can foresee the amount of solar energy available by using GreenSlot, a job scheduling method. Cooling with water or air has proved efficient than cooling using electric chillers and for smart cooling we can implement intelligent sensor placements. Implementing optical technology devices can reduce the energy utilization. The approaches like power- aware routing algorithm, Virtualization and Adaptive link rate can help in power management.

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4.3. Resource Management

To increase the resource utilization, can use virtualization methods for servers and a narrow supply for storage. To compute the energy productivity of a system power Usage Efficiency and Performance per watt can be used. To control load distribution and decrease the working costs of data centers there is a resource management algorithm. Dynamic voltage frequency scaling and dynamic power management are the two methods used for decreasing energy utilization in servers. When the servers go to sleep mode it will reduce the server power utilization. It is very important to manage the power mapping. By implementing and using a chilled water supply gas model, combined gas district cooling and data center control model we can reduce carbon dioxide release. Can implement Hadoop MapReduce computer cluster to estimate the energy efficiency.

To adjust energy supply to the storage usage of limited load following is not much efficient. Thus, these challenges are considered, and joint workload scheduling and management of energy is by changing the energy demand and supply to the data centers. To minimize the gap between energy demands and supply an online algorithm is proposed by managing the output from the fuel cells.

By proposing this model, the challenges faced by the existing system like cost consideration, energy storage charging, energy storage discharging, output from fuel cells can be overcome**.** Good green metrics are proposed for improving the efficiency obtained by the data centers. By categorizing the green metrics, the standard metric which should be chosen can be known for the better efficiency of data centers. For the categorization of metrics energy consumption, air flow, metrics for servers are taken into consideration.

4.4. Geographical Features

The brown energy utilization by the system can be decreased by implementing a work-scheduling algorithm. By using this algorithm, the consumption of brown energy is 21% lesser. Many big companies are using renewable sources of energy. Can foresee the amount of solar energy available by using GreenSlot, a job scheduling method. Cooling with water or air has proved efficient than cooling using electric chillers and for smart cooling we can implement intelligent sensor placements. Implementing optical technology devices can reduce the energy utilization. The approaches like power-aware routing algorithm, Virtualization and Adaptive link rate can help in power management.

4.5. Equipment's Design

By using clustering and virtualization methods we can make groups of servers which are having similar subnet masks on the networking addressing system. By implementing this method there is a decrease of 286.66% power consumption. Gas generator and grid power interlocking mechanism is not much efficient which are used for designing the data centers. Thus, the electrical interlocking system mechanism is preferred in the data centers design. To reduce the capacity of the chiller the generator load is increased which in turn efficiency is increased. For greater efficiency the generator capacity should be in between 90 to 100 percent thus more heat can be removed from the data centers. EcoClouds is one of the best ways to reduce the energy consumption. Because of that Carbon footprints will decrease drastically. Highly recommended system is the dynamic or active deployment like migration. They improve the execution of cloud applications. The current demand response is inefficient which operates on data centers. Proximal Jacobian alternating direction method of multipliers methodology helps to resolve the small-scale problems in data centers. Also, the evolution of the power grid to a smart grid is proposed. Also, similarities and differences of demand and response in data centers are found to increase the efficiency of the data centers. The payment mechanism is proposed using the VCG mechanism for the data centers.

5. CONCLUSION

This paper presented an overview of the issues, challenges faced by Data Centers. We have discussed various existing systems related to data centers. But there are few loopholes in the existing systems. To overcome these problems, we have proposed many systems, which could be implemented easily. These Proposed systems help reducing the energy consumption, greenhouse gases, carbon footprints, cost crisis. There's a need for in depth research in this field to further improve the Data Centers.

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