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Green Data Centres: A Review

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ABSTRACT

Consumption of energy is increasing exponentially daily. Non-renewable resources like oil and gas are being used to generate electricity which in turn increases the greenhouse gases in our atmosphere. These greenhouse gases are affecting our environment adversely by causing climate change and global warming. With around five billion active internet users, the number of data centres are increasing which are consuming energy at a rapid pace. Data centre equipment is required to be maintained below a certain temperature for optimum efficiency and increased lifespan. The cooling systems that are used to maintain this temperature release even more greenhouse gases. The greening of data centres becomes very important to avoid the above-mentioned problems. There are numerous ways through which can bring down the wastage of energy and electricity cost. A lot of research on energy wastage and an increase in the cost of energy has been made. This paper will analyze the different techniques used for the greening of data centres.

Index Terms – Energy, Green, Data Centre, Green Data Centre.

1. INTRODUCTION

As we know Global Warming is affecting everyone and one of the leading causes is the power consumption of computers in data centres. Green computing can increase operational efficiency, power efficiency and recycling efficiency which will help in the conservation of energy. Only in recent times have environmental issues been important news; it used to be viewed as a concern for only a select few people before. There are more warnings than ever before about the consequences of the projected rise in energy demands and greenhouse gas emissions. Governments and businesses are now giving more attention to improve energy efficiency.

Data centres are the pillars that support most internet applications and services such as email, browsing information, navigation, blogs, games, audio and video streaming, instant messaging, social media platforms, e-commerce and other financial transactions. The snowballing demand for data centres has considerably amplified the power consumption. Data centres energy consumption can originate from the IT and non-IT systems. The IT systems include routers, servers, switches, modems, storage, cables and firewalls and various others. The non-IT system includes cooling systems, power distribution systems, uninterruptible power supply and various others.

Improving the efficiency of the data centres is one of the major obstacles faced by the data centre industry. Some existing metrics are used to evaluate the efficiency of the data centres, based on the power usage calculation. The problem faced here is the absence of a standard model of metrics. A good metric must satisfy certain criteria like it must be simple, clear, accurate, precise, capable to scale, provide a data-driven decision. The Data Center Metrics are categorized into sub-metrics. These are: Metrics for Energy Consumption by the Physical Infrastructure of Data Center, metrics for data centre airflow and cooling performance, Metrics for Severs and Proposed Metrics are: Carbon Emissions, Energy Density, Total Cost Ownership and Uptime and Downtime cost metrics.

The issue faced by the data centre operators is to balance the reliability and performance of the systems to utilize resources and energy efficiently. New data centre network architectures have been proposed that are energy and resource-efficient and energy proportional, also handling other recognized design weaknesses, like E2E bandwidth, scalability, fault tolerance, and non-agility

The data centres are using the energy adversely which is causing a lot of problems. The structure of energy utilization of data centres which includes AC, ventilation, IT equipment etc are being analysed in this paper. Air conditioning accounts for a bigger extent of the total energy being consumed along with IT equipment. By further studying the energy saving of AC system this paper comes up with a new approach that makes use of the natural cold source which saves energy in terms of temperature changes of various seasons.

Combined cooling, heating and power (CCHP) system is used to meet the energy-related issues of the data centres. In the last decades, the concept of waste reduction has been launched which urges industries to recycles and minimize their waste. Data centres are distinguished by their availability classified by tiers: The higher the tier, the more robust and continuous is the data centre's operation. The uptime requirements rise from 99.671% (Tier 1) to 99.995% (Tier 4) has caused the need for the development of non-renewable energy which is less costly compared to diesel-electricity which is necessary to reduce a grid-tension and in the same time reducing the conventional cooling output while also taking care of CO2 emission Combined heat and power (CHP) or co-generation has significant potential in data Center industry.

2. LITERATURE SURVEY

Ramon M. et al. asserted that it does not depend on a single individual, organization, government or country to curb global warming [1]. Contributions can be done at all levels. Green data centres can be both environmentally friendly and economically viable by decreasing energy consumption.

40% of greenhouse gas emissions in the United States are from power plants, which makes it necessary to decrease the electricity demand. United States data centres require as much power as is produced by 5 power plants annually which makes it necessary for data centres to be energy efficient. Mechanical, electrical and computer systems in green data centres are designed in such a way as to achieve high energy efficiency and reduce the environmental impact.

Green data centres can be created by using the following 4 practices. First, regain the balance between energy usage and cooling capacity. Power schemes must prioritize the decrease in usage of energy. Second, recapture resiliency as the increase in energy costs can lead to operating resiliency, without causing issues to reliability and performance. Third, reduce energy expenses. Organizations are offered incentives from government energy funds for using methods that decrease the expenditure of energy. Fourth, recycle dying equipment as it has both economic and environmental benefits.

Anand Santhanam et al. reviews the role of data centres in increasing the scope of Green IT by surveying the different methods of transforming data centres into green data centres. [2] The paper discusses the different methods that they have found. The first find is to look into power savings of the data centre by looking into renewable energy and waste heat usage, by using more power-efficient hardware and cooling equipment and to optimize energy consumption and bring in operational excellence. The second find is to look into cost savings by looking into energy pricing methods to source electricity at the most effective rate and also the financial implications by delving deep into the cost-effectiveness of each component of the data centre. The third find is to look into sustainability and green energy by looking into different frameworks and models, monitoring by different bodies and organizations, by having the institutional motivation and also by looking into carbon footprint reduction. The fourth find is by using information technology to green data centres by optimizing cloud computing, network, and storage infrastructure, using virtual machines and virtualization effectively, using algorithms and information system and software to reduce impact and by working in tandem with IT infrastructure manufacturers and resource allocations. The final find was to align the business requirements with resource utilization by improving service level efficiency and effective business utilization.

IBM et al. brings into light how energy costs are rising, and IT equipment is increasingly requiring more power and cooling infrastructure. [3] This is making data centres consider efficiency over the normal parameters that are performance, reliability, and serviceability. While the newer server components deliver superior performance and efficiency compared to previous generations of hardware, most data centres still run-on infrastructure that is reaching the end of its usable life and is inefficient. Hence this power consumption can impact the margins and total costs associated with data centres. There is a growing demand for cheap and powerful computing resources and data centres, it is not just about procuring the best hardware but also having the capital to pay for power and cooling. The conclusion is that energy costs continue to rise as the supply is limited, infrastructure is expensive which means that the ability of data centres to meet their business demands is at stake. Thankfully, green strategies and technologies exist which can reduce costs by optimizing cooling, space and power.

There is a massive demand for data centres, but there are no proper metrics to understand the energy efficiency of a data centre. There are many metrics presented to understand the energy efficiency better one of the most widely used is the Power Usage Effectiveness (PUE) metric. The energy impact of a data centre can be expressed by the PUE value. From surveys conducted, the usual PUE value of the data centre varies between 1.8 and 1.89. The higher the value of PUE, the more efficient the data centre in energy usage. Francesco et al. propose a modified PUE metric to evaluate CCHP natural gas or biogas fuelled systems [4]. The CCHP system is used for cooling, heat and power unit. The CCHP system generates chilled water through absorption chillers, heat and electricity. The electricity produced is used for electrical loads in the data centre and to auxiliary thermal components; if the generated electricity is excess, it can be sold or exported to locations where It is required. The cooling and heating caused are used to satisfy the heating and cooling loads of the building. The paper explains the CCHP gas engine model and proposes few terms to be added to the model to make a more robust metric.

D. Irwin. et al. stated that the data centres are highly energy-driven which not only includes serving the IT equipment, they also include power transmission, cooling IT equipment, and other overhead [5]. The paper describes the design and operational analysis of the Massachusetts Green High-Performance Computing Center (MGHPCC). The data centre uses green design and geographical location to improve the data centre efficiency. The cool climate, cheap electricity, and land also help in the cause. The physical layout of the MGHPCC is a two-story building where the cooling and power infrastructure are present on the lower floor and racks are present above. The power infrastructure that is used in the data centres is similar to a small-scale distribution network in the electric grid. MGHPCC increases voltage and decreases current to maintain constant power and reduce transformer loss. The Uninterrupted Power Supply (UPS) stores the power in the kinetic energy in the flywheels which are otherwise stored chemically in the batteries. The data centre monitors the energy usage of each rack which helps in load balancing. Then a load analysis is done and the IT load is measured by aggregating the power utilization of each pod (group of the load on the data centre). The total power efficiency of data centres is defined as Total power by IT power. The trends observed during PUE analysis are, increased PUE during summer, decrease in PUE from the increase in IT load. Water usage analysis gives the water consumed by the heat exchanger to support heat loads during different months of the year, consumption also includes evaporation, windage, blowdown, filtration backwash. Carbon footprint analysis computes the CO2 emission from the data centre and reduces the carbon usage efficiency. The main cause for this is due to electricity consumption and depends on the electric utility's generation sources.

Dr Aparna S. Varde et al. discussed that it is very important to create and design energy-efficient data centres which should be moving towards a greener and sustainable environment around us [6]. The usage of power and electricity for the servers and data centres around the globe has increased to a maximum extent and it will further increase looking at the current trend. The load on the power grid is approximately 7 Gigawatts (GW) from data centres and servers and this is only from the USA. So, therefore designing and creating green energy initiatives in data centres is of utmost importance. The goal is to develop a Decision Support System (DSS) that will allow professionals of data centres to take better and correct management decisions for IT systems and servers and also look into the balance of the energy efficiency with different functionality demands. Another method that can be used in the DSS framework is Case-Based Reasoning (CBR) which is resolving new issues based on the solutions or results which are similar to past issues. CBR can be very supportive for data centre management. Virtualization and cloud computing can help the data centre managers to better manage the IT resources and servers to work towards a greener and energy-efficient data centres.

Emna et al. proposed design changes to data centres that are easy to implement and are low cost, reducing the number of wires, increasing bandwidth, using more efficient routing algorithms, etc [7]. Each data centre will have its own set of requirements and challenges. There is a lot of effort involved in building high-performance data centres that satisfy all the Quality Of Service needs. Some of the methods for reducing energy presented in the paper are using renewable energy sources, using energy-efficient equipment and interconnections, using power-aware cooling and power-aware routing algorithms. The article tells about all the problems associated with the methods mentioned earlier, such as inefficient management of cooling infrastructure, underutilized networks and use of brown energy. Most data centres invest in renewable energy sources like solar and wind, implementing and using free cooling mechanisms by using air and water instead of traditionally used electric chillers and help cut down the energy demand of a data centre. The energy efficiency can be improved further by technologies like Optical technology, Wireless technology, and Commodity network will reduce energy. The paper talks about few algorithms used in power management, routing of data, virtualization, adaptive link rate, etc. The paper proposed for a data centre to transform into a green data centre should have clean energy sources like renewable energy, efficient equipment and interconnection, efficient cooling techniques and power-aware algorithms.

Khashif Bilal et al. talked about many problems related to electricity, energy etc [8]. One of the major issues around the globe is greenhouse gases which are caused due to overutilization of energy and electricity. So, the Greening of Data Centres can play a major role in lowering energy wastage and costs due to electricity expenditure. Every 18 months, there is a doubling of bandwidth demands for new network applications.

Energy-efficient devices and methods are being developed at a rapid rate. However, a great number of legacy networking equipment are in use and will be continually in use for several years. Therefore, we need methods to increase energy efficiency in existing devices.

The paper considers various solutions, including new green data centre architectures and the performance and energy efficiency of those architectures. The network is designed in a way to shorten the routing path to the network resources so that they are used efficiently.

Designing and building efficient data centres is the best way to minimize greenhouse gases. Green networking can follow 2 methods or paths. The first one is caseload amalgamation. Minimizing the contact link information is the second path.

SP Daniel. et al. presented that the combined cooling, heat, and power i.e., converting cogeneration power which is received from the gas engine power plant is utilized for the onsite power requirement by converting heat into cooling using vapour absorption chillers [9]. It gives the importance of a trigeneration system i.e., CCHP is efficient in producing electricity from mechanical energy and uses natural gas as fuel. The efficiency of the CCHP units is about 70% out of which 30% is converted to electricity and 40 % to heat (through warm water, steam at 80 - 100 degree Celsius). This system provides a convenient way to manage energy demand, ecological concerns, cost. A detailed specification of the Natural gas that is being used is considered including its state, colour, boiling point, flash point, lower and upper explosion limit. The temperature and pressure correction formula is used in relation to the coefficient of performance that produces the ideal absorption cycle. The energy modelling for the power plant is done using a power recorder which records and analyzes output data. Assuming the power load factor and cooling load factor the Plant efficiency, plant water consumption is calculated.

Tran Manh et al. explained that the data centre is the most crucial part of the future of data services. Some of the current technologies used for efficient energy management in data centres include Dynamic Consolidation of Servers, Live Migration of Servers and Network Power-Management using Software Defined Networking (SDN). In Dynamic Consolidation of Servers, the number of servers which is on is reduced [10]. When there is a low demand for service, many servers become idle and will be consolidated into minimum physical nodes. Live Migration of Servers takes place when some of the running virtual machines are moved from one server to another server without having any impact on the users using the virtual machine service. Network-Power-Management using SDN can provide new features such as global viewing, centralized management, power monitoring and controlling, which gives greater control over managing energy. The above-mentioned techniques do increase the energy efficiency, but it is not able to satisfy the growing demand for data centres. This paper proposes Centralized Power Management (CPM) system which can manage and control both servers and network entities. The management system had a connected power administration strategy which allowed the administration to change energy states in the servers and network entities. The proposed method was able to save up to 30% more energy when compared to existing algorithms like Honeyguide.

Aryan et al. discuss the different issues that are related to data centres. There are various issues associated with computer systems; some of the problems are energy consumption, high maintenance prices, exhausted emissions, building resources, and global warming [11]. A research study into energy consumed by data centres shows that the data centres within the USA consume nearly 2.8% of the total electricity generated in the country. The study of green data centres may be classified into three groups: cooling, computing, and geographical factors. The research analysis says the utilization of waste heat generated from IT devices in data centres and the heat generated from the evaporative cooling methodology used in the data centres is enough to assist new air-cooling structure, reducing energy consumed for cooling. The approaches proposed to reduce the energy utilization in data centres are Dynamic voltage frequency scaling and dynamic power management techniques. The study proves that to attenuate brown energy utilization, a new method is proposed, which will use a workload-scheduling algorithmic program which is 21% lesser than the brown energy consumed by different green devices.

Zi Zhou et al. discusses how there have been strides made in emerging technologies and of them, data centres and smart grids are being highly regarded as having profound impacts. [12] Data centres help deploy applications across the world that serve both enterprise and end-users and the smart grid enables sustainable, cost-effective and environmental-friendly electric power generation, transmission and consumption. These two technologies have problems associated with them; the data centres manage to rack up huge electricity bills and the smart grids have operational instability due to the intermittent nature of distribution across various generation methods like solar arrays and wind turbines. These issues can be rectified by coordination between these two sides. Since data centres use up massive amounts of electricity and because of the elastic nature of the workloads which can be routed to different data centres in different locations which can take advantage of the demand response program that smart grids offer. This can allow them to curb their electricity bills up to a good extent. The work in this paper describes how to effectively balance out the needs of the data centre in a cost-effective way which ends up being a win-win for both the smart grid and the data centre.

Monalisa. et al. conveyed that the data centres which provide massive internet services are considered to be "Energy hunger infrastructures" [13]. As more businesses have relied on data, importance is given to the data centres. The major challenge to the data centres is to improve their energy efficiency. The paper gives the green matrix and the criteria along with the categorization of it which provides a standard model for the energy efficiency calculation problem. The Green grid i.e. the acceptance criteria for a good metric. The matrix must be simple, clear, scalable, and capable of analyzing and provide data-driven decisions which can help in reducing the carbon footprints of data centres. The categorization of a matrix is done based on energy consumption by the physical infrastructure, data centre airflow and cooling performance, Metrics for server, and proposed metrics. The data centre infrastructure effectiveness is the power of IT equipment by the total facility. The Power density efficiency, UPS efficiency, and data centre lighting power density are considered for energy consumption metrics. The cooling performance is measured using the return temperature index by tracking the amount of bypass air and recirculation air in the data centres, the rack cooling index measures the effective usage of equipment along with the computational fluid mechanics for the efficient cooling solution. The server usage effectiveness measures the performance capability and the future requirement for uninterrupted services. Inter-server communication latency helps in preventing network traffic and delay in process requests. Other metrics parameters like carbon emission, energy intensity, and cost help in developing better standard model metrics for the data centres.

Zhengang et al. presented that the data centres are consuming total energy of about 36.4 billion degrees in the last decade [14]. The data centres are using the energy adversely which is causing a lot of problems. Air conditioning accounts for a bigger extent of the total energy being consumed along with IT equipment. By further studying the energy saving of AC system this paper comes up with a new approach that makes use of the natural cold source which saves energy in terms of temperature changes of various seasons. There are two ways in which one can measure the efficiency index of energy and they are as follows PUE and Data Center Infrastructure Efficiency (DCiE). The PUE value will be closer to one when the energy efficiency of the system is more. The standard value is usually two. The higher the percentage value of DCiE, the better it gets. Around the globe, the most used technique is PUE. According to recent studies and statistics, the consumption of energy of IT system accounts for almost 50% of the total energy consumed which includes the energy utilized by servers, storages and network communication equipment. Air conditioning system consumes almost 37% of total energy, UPS power supply takes around 10% and lighting systems take around 3% of the total energy consumption.

There are 3 ways in which we can effectively decrease the consumption of energy by air conditioning systems. The first one is making use of chilled water AC unit with a natural cold source, secondly making use of ethylene glycol AC unit again with a natural cold source and the last one is making use of intelligent double circular energy-saving AC which uses natural cold source. The key to saving energy and making data centres green is the air conditioning system. Each data centres have their particulars, so choosing the right AC energy-saving technology which fits into the characteristics of different data centres perfectly is very significant to achieve the maximum energy-saving effect.

Jimmy H. M. et al. expressed that the primary goal of green computing is to diminish the exhaust of greenhouse gasses from computer devices [15]. Methods such as direct observation and simulation using virtualization and clustering are used to reduce power consumption. Interactions between servers are combined with virtualization methods and parameters such as input/output, network resources and CPU utilization are analysed. The process begins with the collection of power consumption data of idle servers. Then servers are given a stress test with network and local traffic and data are gathered and averaged from several runs. As a result of this, it is found that the server trade-off for server virtualization should be optimized to improve energy efficiency. OpenMosix Cluster Management System (CMS) is used to cluster the servers according to groups by their function and logical topology. Energy consumed per virtual machine is calculated by adding the energy consumed by the host machine when idle divided by the number of virtual machines and product of Percentage of CPU utilization with the extra energy consumed by the host machine when running.

Hazril I. B. et al. voiced that to accommodate the growing demand for Data Centre services, operators have been installing more and more equipment to handle the internet service requests [16]. Data centres consume large quantities of energy causing growth in emission of greenhouse gasses, so the need for implementation of Green Data Centres has increased. Issues such as the balance between performance and reliability, energy management and resource management plague Green Data Centres. Such issues are significant since the operators are required to meet the customer’s deliverables agreed upon in the Service Level Agreement.

Data Centre research until now has prioritized high-performance equipment to meet the higher processing demand. But such devices draw large amounts of energy during operation.

There is a yearly increase of 1.1% to 1.5% in Data Centre Energy consumption. To ensure reliability, high-capacity UPS systems are used which aren't energy efficient. It is necessary to balance meeting performance target level and energy efficiency. The balancing of energy consumption creates issues such as reduction in maximum throughput, degraded performance and damage of equipment.

3. EXISTING ISSUES

The usage of power and electricity for the servers and data centres around the globe has increased to a maximum extent and it will further increase looking at the current trend. The load on the power grid is approximately 7 Gigawatts (GW) from data centres and servers and this is only from the USA. The energy consumption by data centres and servers could increase to a very high level which could be more than 100 billion kWh which costs around $7.4 billion for electricity annually. Energy monitoring applications are just focused on power usage and cooling monitoring, but they do not provide any help regarding system configurations, new equipment installation and application scheduling to the IT professionals. This is a substantial problem in data centres and there is an absolute need for decision making in the energy conservation area.

The data centres consume a lot of energy and most of this energy used comes from burning fossil fuels. The energy produced in this way is known as brown energy. This form of energy is not only expensive but also pollutes the environment. It also costs billions of dollars annually in maintaining the distribution network. The servers using this brown energy are equivalent to that of a sports vehicle in terms of carbon footprint.

One of the major issues around the globe is greenhouse gases which are caused due to overutilization of energy and electricity. The power consumption of the network devices is expected to rise by almost 50% in data centres in the coming years. The demands of bandwidth for network applications are increasing rapidly. The legacy Data Center Network (DCN) architectures suffer from poor scalability, energy-inefficiency, high cost, low bandwidth, and non-agility.

The data centres are using the energy adversely which is causing a lot of problems. Air conditioning accounts for a bigger extent of the total energy being consumed along with IT equipment. According to recent studies and statistics, the consumption of energy of IT system accounts for almost 50% of the total energy consumed which includes the energy utilized by servers, storages and network communication equipment. Air conditioning system consumes almost 37% of total energy.

The main concern of the Data Centre operator is to provide the reliability and performance that was agreed upon by the clients in the Service Level Agreement (SLA). To achieve high reliability and uptime, Operators provide higher server, network, uninterrupted power supplies and storage resources than want the clients to require so that it acts as a buffer at peak load for critical operations leading to redundant equipment which also consumes extra energy even when idle. Data centres use up to 150% of the required energy to maintain redundant systems for added reliability. Data centre operators need to plan and provide resources based on the SLA to prevent over-provisioned systems.

To increase the energy efficiency of the resources, the resource utilization rate needs to be improved. But data centre operators provide redundant systems for fault tolerance, so increasing resource utilization may cause the issue of performance bottleneck causing a block in processing the requests during peak load leading to fluctuations in performance. The resource utilization rate must be monitored and if possible, dynamically managed.

The datacentre architecture and the interconnection between the servers and other network equipment like routers have to be done with a lot of considerations to ensure good performance, latency, etc. To ensure all these conditions are satisfied the data centres use enterprise-level equipment which is expensive and consume a lot of energy.

The servers are not used to their full capacity at any given time and also it varies depending on holidays, weekends, etc. Observations on servers reveal that most of the time they are used in the range of 5%-25% of their maximum output. Most of the data centres will be idle waiting to process data which consumes a lot of power and has no value in return. This idle state consumes around 70% of the peak power usage. In addition to servers, other network equipment should also be powered up and kept ready which further adds to wasteful use of energy.

Data centres consume more energy than needed for processing the traffic due to energy overheads of idle resources that consume energy, cooling systems and building powers requirements. Reducing the energy consumed leads to reduced performance, may damage equipment and reduce the maximum throughput. Energy management systems may cause additional issues such as increase the complexity of the system and may not be able to predict change in performance or damage of equipment. To reduce energy usage while maintaining performance, the workload and utilization need to be monitored and to ensure that there is no reduction in performance with energy management.

Most of the energy consumed by a data centre is used for cooling equipment. The cooling infrastructure of most data centres is very inefficient in terms of energy usage. The cooling machines are placed at locations inside the data centre with no consideration of the topology and can lead to very inefficient cooling.

Data centres and smart grids have a huge disconnect with their energy requirements and energy generation. Datacentres manage to obtain large electricity bills whereas smart grids have operational instability due to the intermittent nature of distribution across various generation methods like solar arrays and wind turbines.

Most of the energy consumers in data centres require a distinct form of energy like heat, electricity, and cooling. The higher tier data centres have continuous and more robust operations. This increases the redundancy to install components to meet the standards of higher tiers. Data Center consume a huge amount of energy to perform their operation. One of the major concerns of the data centres is energy efficiency. To deal with this problem the Data centres must specify certain green metrics which in turn reduce the carbon footprints of the data centre. Industries use several existing metrics which are used to determine the performance of the data centres but are not successful in determining the most important metrics, based on which the power usage calculation is done.

Data Center consume a huge amount of energy to perform their operation. One of the major concerns of the data centres is energy efficiency. To deal with this problem the Data centres must specify certain green metrics which intern reduce the carbon footprints of the data centre. Industries use several existing metrics which are used to determine the performance of the data centres but are not successful in determining the most important metrics, based on which the power usage calculation is done.

Most of the energy consumers in data centres require a distinct form of energy like heat, electricity, and cooling. The higher the tier data centres have continuous and more robust operations. This increases the redundancy to install components to meet the standards of higher tiers.

4. EXISTING METHODLOGY

There are various methods to make data centres green. We have explained a few of the existing methods that exist and suggested few improvements to these existing methods:

4.1. Air-Cooling Systems

PUE is used as a measurement of the data centre's energy efficiency index. By reducing the value of PUE we can reduce the energy consumption in data centres and this can be done by reducing the value of the Cooling Load Factor (CLF). To cool the data centre using a natural cold source is the most energy-efficient and the cheapest resource to protect the environment. So, using AC with a natural cold source will reduce the value of CLF and thereby increasing energy saving. There are 3 methods proposed in which we can effectively decrease the consumption of energy by air conditioning systems. The first one is making use of chilled water AC unit with a natural cold source, secondly making use of ethylene glycol AC unit with a natural cold source and the last one is making use of intelligent double circular energy-saving AC. Each data centres have their particulars, so choosing the right AC energy-saving technology which fits into the characteristics of different data centres perfectly is very significant to achieve the maximum energy-saving effect. The proposed idea is to use a sensor-based AC system where the system uses sensors to understands the outside temperature and according to that adjust the cooling effect and switch off when the temperature matches the required amount of cooling.

To reduce cooling requirements, we would try to reduce the heat generated in the Datacentre. Improvements in the datacentre layout itself will help as a first low-cost step. A few layout improvements would be to control the airflow between hot and cold aisles which would ensure that hot air does not recirculate into the cool air intakes, using low-cost supplemental cooling options like water, improving cooling rack efficiency by using a rear door heat exchanger that would dissipate heat from high-density modules.

4.2. Resource Management

DSS will allow professionals of data centres to take better and correct management decisions for IT systems and servers and also look into the balance of the energy efficiency with different functionality demands. The improved version of operational management can help save more than 20% of electricity compared to current trends. DSS gives a mechanism to assist or support the decision making of the users in a particularly given domain which is usually based on a complete analysis of the existing data of the past experiences along with the domain knowledge incorporation. So, it is a computer application that provides a solution to multifaced problems. DSS methodology makes use of an integrated framework that consists of case-based reasoning and decision trees. By using decision trees, we can reduce a large amount of uncertainty by taking into consideration many factors.

Decision trees can also help the management team of the data centre in the area of virtualisation. Another method that can be used in the DSS framework is CBR which is resolving new issues based on the solutions or results which are like the past issues. CBR can be very supportive of data centre management.

Another method would be to use network power-management using software-defined networking which requires new flexible and programmable networks and can deploy an energy-aware network that can give a lot of insights about the energy consumption in data centres such as centralized management, etc. This model will then manage the network equipment based on the traffic demand which will increase the energy efficiency of the data centre. This model can also be made to manage the servers using SDN which can further optimize the energy usage in the data centres.

4.3. Server Clustering and Virtualization

Virtualization and cloud computing can help the data centre managers to better manage the IT resources and servers to work towards a greener and energy-efficient data centres. Virtualisation provides IT professionals with a way to optimize and consolidate servers to decrease the cooling cost and power and thereby achieving energy efficiency. The proposed idea is to make use of a dynamic decision-making system that will assess the current scenario and the previous scenarios and come up with the correct and accurate decision concerning data centre management by using machine learning and artificial intelligence.

Data centres get requests from the outside world, process the request, and send a response. The physical servers have an OS that controls their hardware and is often used to run one application. Server virtualization is gaining popularity and the use of physical client-server traffic is decreasing. In server virtualization, servers have virtual machines running which can be clustered into groups by their function and logical topology. The use of virtual servers can reduce power consumption, increase productivity and are scalable. So the proposed solution is to use virtualization when the service isn't a high demand critical operation that requires a dedicated server.

Virtualization is one such technology that can be used to obtain higher energy efficiency. A server uses energy and gives off heat even if it is not running at full capacity. This is where virtualization comes into play. Virtualization can enable multiple workloads each having an independent computing environment to run on the same machine to ensure that the machine runs at full capacity and efficiency. This eliminates the need for multiple servers and can result in massive energy savings for the data centre. Virtualization can also be used in storage to combine storage capacity and can increase utilization rates.

In an experiment, 12 servers were clustered into 5 groups. The total power consumed by the virtual machines is calculated and compared to the power consumed before clustering and virtualization. It was found that the power consumed after is 59.7W while the power consumption before was 230.9W. There was a difference of 171.2W, which shows that there is 286.6% lower power consumed when using virtual machines. Through the use of virtualization and clustering, power can be conserved for the same amount of work done because multiple servers are combined into a group acting as one physical server.

4.4. DCN Architectural Design Management:

New DCN architectures are proposed to overcome the limitations of legacy DCNs and some of them are fat-tree, VL2, DCell, flattened butterfly etc. In recent years many hybrid DCN architectures have been proposed which makes use of the amalgamation of wireless and optical technologies. The DCN architecture can be classified into 3 major categories based on the network traffic routing model and they are a switch-centric model, server-centric model and hybrid model. The most commonly used DCN architecture is the three-tier architecture. With 60GHz wireless technology coming into the picture, a lot of hybrid wireless DCNs are recently proposed. The 60 GHz technology makes use of 2D and 3D beamforming, signal reflection, frequency reuse and directional antennas. The network switches used in switch-centric DCNs save energy when used along with server-centric DCNs. A lot of DCN problems can be solved by using hybrid DCNs. By using wireless connections, we can eliminate complexity, cabling cost and installation barriers associated with current DCN architectures.

Network load on the core network can be reduced by using wireless links. One of the basic design requirement of 60 GHz technology is energy efficiency and therefore provides efficient 60 GHz devices and technology. To shift the traffic from underutilized network devices to wireless links, wireless interconnects can be used so that idle devices can be kept in sleep mode to save a lot of energy. Bandwidth and high port density are provided by optical interconnect where the energy consumption is also very less and therefore reduces the overall energy consumption significantly. Almost 75% of energy savings can be achieved by making use of a complete optical DCN. Designing and building efficient data centres is the best way to minimize greenhouse gases. Green networking can follow 2 methods or paths. The first one is caseload amalgamation. Minimizing the contact link information is the second path. The proposed idea is to make use of a DCN architecture by combining all the essential components, designs and ideas of all the proposed DCN architectures and make it as energy efficient as possible.

4.5. Increasing Facilities System Efficiency and Power Management

Energy efficiency for infrastructure equipment is rapidly increasing with new technologies. Components like the UPS and chiller which have been in use for more than 15 years can be replaced with newer technologies that would provide energy savings of up to 70 per cent and 50 per cent, respectively. While it may not make sense to replace equipment before it has fully depreciated the newer models can provide way more efficient and hence can offset any lost asset value. Air delivery to the data centre can be made more efficient by using central HVAC or through CRAC units. Datacentres can also save energy and increase their cooling capacity by relaxing their relative humidity and temperature requirements for their datacentres which have been put in place because of the presence of hotspots. Removing these hotspots and relaxing these requirements will help to increase the facilities system efficiency. Data centres that can be relocated or new data centres should also consider locations that are rich in renewable energy sources.

Newer power management software now gives datacentres the flexibility to balance out idle unneeded equipment. The amount of power that is used by a single server or multiple servers in a group can be monitored and capped based on workload trends which can optimize energy use and application performance without sacrificing productivity.

4.6. Live Migration of Servers

In live migration of servers, the virtual machines are moved from one server to another server, when the virtual machine is actively being used without having any interruptions to the users.

This can be accomplished by using Network Attached Storage (NAS), the virtual machine disks are stored here and can be accessed by all servers and can share this storage for other purposes as well. The NAS makes the task of switching servers as simple as copying all the in-memory states and contents of the CPU registers from one server to another. There are various places where the performance can be improved in the data centre using this architecture.

During low service demand, many servers will be idle which can be turned off to save energy. When the service demand increases the servers, which were switched off are now turned on and the virtual machines are moved back onto them. This method is highly dependent on the efficient migration of virtual machine’s onto new servers without having any sort of disturbance to the user. The migration of virtual machines also requires certain energy, but the amount of energy saved by switching off the server is more and hence can improve the energy efficiency in the long run.

4.7. Using an Efficient Incentive Mechanism for Demand Response in Datacentres

Smart grids can be used to resolve the issues of data centre demand response. Load reduction is also a very significant factor that is achieved by distributed data centres. Cloud service providers are showing inefficiency concerning data centres demand response as they operate on geo-distributed data centres. To tackle the problems of small-scale data centres a proximal Jacobian direction alternating method of multipliers algorithm is used. For solving the issue of maximization of social welfare Vickrey Clarkegrove's payment system is used. Coincidental very high pricing is one of the most effective and useful methods of demand response in data centres. The smart grid procedure will be very helpful as the demand response in data centres is having the highest priority in the future. To optimize the utilisation of smart grids, the cloud service provider must decide the management of the workload of datacentres. Since data centres use up massive amounts of electricity and because of the elastic nature of the workloads which can be routed to different data centres in different locations which can take advantage of the demand response program that smart grids offer. This can allow them to curb their electricity bills up to a good extent.

4.8. Using a Trigeneration System

CCHP system is one of the better options for the data centres to deal with energy-related issues, like increasing energy demand, expanding energy cost, energy security and ecological concerns. CHP system produces heat and electricity which are recovered from gas engine captive power plants and these are used to meet the onsite power requirements. Absorption chillers are used to convert heat into trigeneration (CCHP) and these are deployed to cool the data centres. Trigeneration is the result of the engine which is fueled by natural gas and is used to drive a generator which in turn converts mechanical energy into electricity. This process helps in both cost reduction and the best utilization of extra heat generated. The heat produced is transferred through different mediums like steam/hot air, warm water. The current CCHP units are about 70% efficient, i.e. about 30% is converted to electricity and the rest 40% is converted to useful heat. The heat from the engine is gathered from the heat exchanger outlet which is at 90℃. Next, the exhaust gas is supplied to the heat exchanger at 98℃. Then, the water output going to the absorption chiller is maintained between 90-95℃. Finally, the water returned from the absorption chiller, shell and tube heat exchanger and plate heat exchanger is regulated at 78°C to the generator. The 3-way valve is for regulation purposes to send signals if the limits are violated so to open and close accordingly.

5. CONCLUSION

The paper says more about how green initiatives can be applied to Data Centres. The interrelatedness of reliability, performance, energy management and resource management are discussed. Data centers operators' views on meeting the service level agreement agreed upon with the customers are considered. It also suggests how data centre devices like cooling, server, storage, etc can be efficiently utilized to save energy and tells about how to use resources efficiently to lessen the effect of it to the environment by applying the green techniques to it. Existing methods which are used to convert data centers to green data centers such as virtualization and clustering are examined. Wherever applicable, necessary improvements such as weather-based dynamic cooling and service based virtualization are provided which help move to green data centres.

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