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Measuring Efficiency of Tier Level Data Centers to Implement Green Energy Efficient Data Centers

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Abstract: This paper highlights the importance of identifying and implementing Power Usage Effectiveness metrics for measuring the performance and efficiency of data center to accomplish cost and operational savings. The research highlighted in this paper emphasizes the importance of green data centers to meet business industry requirements and to reduce the effects of global warming. The results clearly indicate that there a strong need for the implementation of green metrics like power usage effectiveness as done in one of the tier level data center in Pakistan. The outcome from paper show that overall performance and efficiency of data center investigated was very poor due to the underutilization of installed equipments like servers. This measurement helps data center managers to implement green IT initiatives and techniques to improve performance of already installed components.

Key words: Energy efficiency % Energy efficient data center % Green IT % Metrics % Power Usage Effectiveness metrics

INTRODUCTION

The fast changing and dynamic global business environment requires firms to be more flexible to quickly adapt and respond to market changes. Among the forces that drive changes, requirements for corporate responsibility and sustainability are getting more urgent [1]. The worldwide agitation to achieve ecological, business and environmental sustainability is starting to redraw industrial landscape. The current status of global warming, ecological deterioration and the severity of its potential consequences explain the overwhelming popularity of environmental initiatives across the world [2]. The immense use of IT has exploded in all areas of business activities offering prodigious benefits and convenience and irreversibly transforming businesses and societies into global world. But at the same time IT has been contributing tremendously towards the environmental problems. It effects environment in several ways. Each stage of a computer's life from production, use to disposal presents environmental challenges. Globally, the total electrical energy consumption by data centers, servers and computers is steadily increasing [3]. The increase in energy consumption results in increased greenhouse gas emissions as burning coal, oil, or gas generates most of the electricity. Countless old computers and other electronic hardware, which contain toxic materials are discarded within a couple of years after purchase, end up in landfills, polluting the earth and contaminating water. The increased number of computers in use and their frequent replacements make environmental impact of IT a major concern [4]. There is a growing awareness of the necessity to reverse the process of environmental degradation and move toward sustainable business practices [5]. The current global financial and energy crisis, coupled with the growing sense of urgency by the citizens, have galvanized businesses, governments and nonprofits around the world to contemplate incorporating greener practices in all areas of the society.

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Technology has impending to create and outsource sustainable IT businesses with green economics. Unparalleled progression in the demand for IT facilities and outsourcing headed to the expansion of large, complex, resource exhaustive infrastructures called server farms to support business needs [3]. Data center industry has emerged as a significant corporate asset, playing a vital role in business management. Data centers are the building blocks and nerve cells of any information society & IT businesses [6]. They form the backbone of a wide variety of services offered via Internet including Web-hosting, e-commerce, social networking and a variety of more general services [7]. Due to rapid growth in size of data centers, there is a continuous increase in the demand for both physical infrastructure and IT equipments, resulting in continuous increase in energy consumption [8]. Ample power supply, fresh air and low humidity are the important preconditions for selecting the location for building a new data center facility [9].

The design and operation of data center infrastructure is one of the primary challenges facing IT organizations. The large number of installed components in data center including cooling, power and computer systems and diversity of these components make its design and operations complex [10]. The data center power density has increased to an average 15% annually between 2000 and 2009. Continuous accumulation of computing equipments in data center design has solicited the need to monitor, measure and manage the performance of these installed components to accomplish energy efficiency [11]. It has dramatically prioritized the importance of energy efficiency in the design and implementation of complex IT facilities and their associated infrastructures.

The measurement of power and energy usage is becoming a real demand from all stakeholders of business enterprises to meet end user expectations. There are many opportunities to reduce energy usage in data centers as wide range of efficiency practices are available, but industry is aiming for metrics, methods and instruments to provide these services more efficiently and at the same time covering all major aspects of measuring power and energy efficiently. In the face of ever increasing energy costs, researchers, practitioners and governments are now seeking effectively initiatives to regulate inefficient energy use by global business enterprises [12]. As energy climbs the list of corporate priorities, “Green IT" solutions are proliferating. Prioritizing potential fixes is not easy amidst this flood of information. It significantly requires metrics and methods to measure energy utilization as its critical for green IT solutions to succeed and flourish [13]. The major problem with data center industry is the lack of credible, appropriate and industry acceptable standard method to categorize installed hardware and software resources and workloads into measureable groups to apply available energy efficiency metrics to calculate energy utilization. The other major barricade in improving power efficiency is the privation of applicable measurement methods and tools called metrics [14]. Metrics are used to measure the performance of servers and other IT equipment’s installed in a more consistent, quantified and tacit way. Considering the large potential for energy savings, further research is indispensable to find out the awareness of energy efficiency measuring methods that could lead to improved power utilization and to establish common energy efficiency metrics and industry wide emission targets [15].

The research affirmed in this paper focuses on the context of current energy crisis in Pakistan and global warming effects affecting worldwide. To explain the importance of this research it is very much pertinent to consider current energy situation in Pakistan and the state of increasing oil prices affecting the economies of developing countries and most importantly the economy and industry of Pakistan which is going downwards rapidly due to this energy crisis. Research is going on to investigate how IT equipment energy consumption varies with computation loads and develop quantitative metrics, refine metrics and set measurement protocols for benchmarking servers [16]. In order to accomplish these requirements and to reduce the effects of global warming, there is a strong need for the awareness and implementation of green metrics to be implemented in data centers to make them energy efficient and green [13]. Purchasing data center equipments with better efficiency utilization helps to achieve energy efficiency however, the ricochet effect could potentially occur, causing increased power consumption because people overuse or misuse the equipments that are deemed energy efficient. To avoid such effects monitoring and measuring energy savings with industry accepted metrics is important. This paper seeks to identify and implement Power Usage Effectiveness (PUE) metrics to highlight the importance of green metrics and uses PUE as main measuring tool for data centers. It also discusses about the implementation of PUE metrics in one of the largest tier three level data center in Pakistan (PTCL data center), to measure overall performance in terms of energy consumption at different

levels, which in turn helps to achieve energy efficient and green data center. The results generated after applying metrics will be used as benchmarking values for all tier level data centers to embark on energy efficiency and power savings.

Problem Background: The energy use and environmental impact of data centers has recently become a significant issue for both operators and policy makers [36]. Unfortunately data centers represent a relatively easy target due to very high density of energy consumption and ease of measurement in comparison to other, possibly more significant areas of IT energy use. Policy makers have identified IT, specifically data center energy use as one of the fastest rising sectors [17]. Global warming, climate change and rising cost of energy are posing serious challenges for the sustainability of the global digital economy [18]. Public awareness of data center energy consumption and its impact on environment has influenced many companies to place a higher priority on choosing "greener" technologies in "doing their part" to protect the environment [19].

The increasing concerns about the increased rack density, quantity of servers, emission of greenhouse gases and global warming issues has raised the significance of data center energy consumption and now has become a momentous factor to managing data centers energy consumption and CO2 emissions. With rapid increase in capacity and size of data centers, there is a continuous increase in the demand for energy consumption [20]. These data centers not only consume a tremendous amount of energy but are riddled with IT inefficiencies [21]. Today's data centers are big energy consumers and they are filled with high-density, power hungry IT equipment. Gartner warns that if data center managers remain fully unaware of energy problems, they will most probably run the risk of doubling their energy costs between 2005 and 2011 [22]. A data center comprises of many thousands of servers and can consume as much energy as a small city [23]. Between the years 2000 and 2006, the number of servers installed grew from 5.5 million to 10.9 million [20]; plans are ready for over millions of servers [7]. These servers consume huge energy without performing useful work. In an average server environment, 30% of the servers are "dead" only consuming energy, without being properly utilized; their utilization ratio is only 5 to 10 %. An EPA Report to congress on server and data center energy efficiency has conservatively estimated that data centers are using 1.5% of available power in U.S [24] and this electric power consumption will jump to 3% by 2010 – 2012 [23].

Major parts of data center operating costs are in the areas of power usage by IT equipment. It's important for data center managers to understand, manage, analyze and measure the usage and consumption of power that goes into data center [25]. The other major components that contribute towards power consumption include cooling systems, power delivery and lightning [26]. In addition to cost, the scalability of data centers is affected by power consumption and heat dissipation. The power density of servers and racks has increased dramatically over time, meaning that data centers may exceed their power budgets with a small number of servers and with plenty of floor space available. When a data center reaches its maximum provisioned power, it must be replaced or augmented at great expense. Gartner (2006) estimates that half of the world's data centers will reach this point by the end of 2008 [27]. Reducing energy consumption or shifting to a more energy efficient IT model, businesses can reduce their operating expenses and enable more useful work to be done per dollar spent while improving service delivery [28]. In the context of rising energy cost, energy security concerns, environmental pressure and business demand data center operators will soon be targeted, measured, grouped or labeled by the efficiency of their facility [29].

The problem in enterprise data center power management is that, there is neither an effective approach to model power consumption, nor is there a method to implement traceability of power in the data center. Finally, there is no comprehensive architecture for managing power dynamically in the data center that could make use of power modeling and power traceability data to allow optimum tradeoffs between value to the enterprise and power consumption [30]. These reasons have driven the demand for monitoring and measuring energy savings with industry accepted metrics. The data center industry still has a long way to go in the awareness, establishment and monitoring of metrics. This demand necessitates the development of green metrics with a broad emphasis on performance and measurement of related energy consumption in almost all components of data center [31].

Research is going on to investigate how IT equipment energy consumption varies with computation loads and develop quantitative metrics, refine metrics and measurement protocols for benchmarking servers [16]. An effective generalized metric, capable of measuring the performance and efficiency of different components of data center which helps and support data center industry as whole and provides a thorough comparison of the utilization of different volume servers and other

components through the analysis and assessment of particular workload types being processed is required to fulfill the gap created in order to measure the efficiency [6]. The importance of rationale, measurable metrics becomes imperatives to measure and manage data center performance. Metrics help & facilitate energy optimizations by defining energy efficient technologies. Unlike significant on power management & optimizations, there has been relatively little focus on metrics and models [30]. These metrics would greatly improve the capability and capacity of data center to operate more efficiently and provide their services with high response time and reduced power consumption. A performance metric is a performance-measuring tool used to measure and assess the capability and performance of a particular component [32]. These metrics can be installed at individual component level or complete system or data center. When designing or developing metrics it is necessary to consider certain assumptions like, it must correlate strongly with the concerns of end users, easily understandable, universal and practical to calculate.

The problem with standard measurement techniques is that they are time consuming and costly to produce good results. Power measurements must be taken over a period of time long enough to incorporate the changes in power consumption caused by periodic workload fluctuations. When this is considered, along with the fact that data centers are constantly changing entities, measurements can be inaccurate and out of date by the time they have been gathered. So how does IT organization measure data center power consumption accurately enough to reflect efficiency improvements, yet fast enough so that the information is timely and actionable [33].

Proposed Work: Green IT solutions provide environment friendly techniques and methods towards implementing more effective and efficient organizational and national strategies and policies to attain sustainable businesses worldwide. IT plays a crucially important role in the environmental and energy issues related to Green IT, because Green IT may refer to three primary research areas: (1) energy efficiency of IT, (2) eco-compatible management of the lifecycle of IT and (3) IT as an enabler of green governance [12]. A major gap that exists in the literature today is the absence and lack of appropriate standardized metrics to measure the performance of data center in terms of energy efficiency [34]. To advance this line of research, this study attempts to bridge this gap by highlighting the importance of green metrics for measuring the performance of data center and then identifies the most common metrics adopted by the industry to measure the energy efficiency initiatives in data centers. This study is targeted to both Green IT researchers and practitioners. It focuses on the importance of implementing and applying most prevalent green metrics called as PUE to measure the performance of data center. This metric is intended to provide a roadmap for future Green IT research and development.

Energy Efficiency Metrics: Power consumption and energy efficiency are important factors in the initial design and day-to-day management of computer systems. They have direct relationship as energy efficiency decreases the rate of power consumption. Energy efficiency has become a significant metric being progressively implemented to evaluate and measure energy utilization of devices installed in data centers and as whole. Many energy efficiency metrics for networking protocols and devices have been proposed in the past, but most of them have been specialized for specific networking software or equipment and are being used in an ad-hoc way. Metrics help and facilitate energy optimizations by defining energy efficient techniques to implement green and energy efficient data centers. They must correlate strongly with the concerns of business enterprises and end users, while also being understandable, general and practical to adopt and calculate [14]. A metric must contain different proficiencies like assessment tools, analysis and benchmarking features, design, plan and implementation characteristics to help define and improve its performance and measurement capability. These metrics identify potential opportunities to reduce energy use in data centers. Unlike the significance of power management and optimizations, there has been relatively little focus on metrics and models to highlight the significance of power management and energy optimizations in data center industry [11]. There is a strong need to standardize energy efficiency metrics with a finer granularity that takes into account diverse processing functions and configurations.

Power Usage Effectiveness (PUE) Metrics: To compute the power efficiency of data centers, metrics are needed to substantially measure this power efficiency from time to time to help top management make correct decisions to implement green data centers. Extensive research from literature review and preliminary findings from interviews, questionnaires and group discussions with data center managers and top level management has strongly projected the demand for implementing appropriate

green metrics for data centers to measure their efficiency. To quantify the power efficiency of data centers, PUE has been selected according to a criterion described above and was implemented in one of the tier level data centers in Pakistan. The use of PUE to measure data center energy efficiency has received broad adoption in the industry [35]. It is defined as total power used by data center divided by total power consumed by ICT equipment. It can be used to benchmark how much energy is being usefully deployed versus how much is wasted on overheads. It provides opportunities to improved data center operational efficiency and compares efficiency with competitive data centers. The working of PUE in a data center is implemented by calculating total power drawn from utility will be the sum of total facility power for data center and total power consumed by non-data center components. IT Equipment Power would be measured after all power conversion, switching and conditioning is completed before the IT equipment itself.

RESULTS AND DISCUSSIONS

Before implementing PUE metrics following steps were performed to ensure proper implementation of PUE metrics to measure the performance in terms of energy efficiency followed by analysis to get aggregate values to benchmark and set standards. These steps are:

- Select the metric type using criteria mentioned above to fulfill all three characteristics of becoming a useful metric.
- Select data center type depending on tier levels described by ITE (Tier I, II, III & IV) to be evaluated and measured.
- Measure current individual and overall energy efficiency values (baseline values).
- Measure benchmark values for energy efficiency.
- Identify and highlight potential areas for efficiency improvement in terms of:
- Energy cost.
- Source energy.
- Carbon emissions.
- Select the elapsed time of the assessment period.
- Select the mean of source load for the assessment period.
- Select the mean of values obtained by applying the proposed metric.
- Report the highest daily values occurring during assessment period.
- Measure the lowest daily values occurring during assessment period.

Table 1: PUE Efficiency Values

PUE	DCE	Level of Efficiency
3.0	33%	Very Inefficient
2.5	40%	Inefficient
2.0	50%	Average
1.5	67%	Efficient
1.2	83%	Very Efficient

- Collect the data from different assessment periods
- Normalize the data collected from different sources
- Analyze the data
- Set benchmark values

The proposed metrics selection criteria along with above stated methodology to select appropriate metrics and generate values helps data center managers make efficiency decisions. For this case study same technique was used to generate exact values to make businesses sustainable and eco friendly. Typical tier level data centers must need to have a PUE value closer to 2 or even lower than 2. This can be achieved by properly utilizing the resources and other equipment's in data center. PUE values can range from 1.0 to infinity. A PUE value approaching 1.0 would indicate 100 percent efficiency meaning all the power is used by the IT equipment's only. Table 1 shows the range of PUE values for data centers. These values show the actual efficiency of any tier level data center.

PUE Calculations: PUE was calculated by employing above-mentioned methodology in PTCL data center in Pakistan. To calculate the exact efficiency value two values were required to measure the performance.

- Total IT Equipment Power consumed
- Total Facility Power Consumed in data center

The results obtained after applying PUE metrics are:

Total IT Equipment Power Load = 70 Kw
Total Facility Power Load in data center = 230 Kw

PUE = Total Facility Power Load/Total IT Equipment Power Load
PUE = 230/70 = 3.2
PUE = 3.2

From these results it was concluded that managing capital costs and operating expenses are vital to data centers viability. The results obtained clearly shows that

the overall performance of PTCL data center in terms of energy efficiency was very poor (very inefficient) with PUE value of 3.2, although PTCL was a new data center just established with tier level 3 specifications.

The results obtained create the realization for implementing green energy efficient data centers. Discussion were held with top level management and they agreed that, they were not implementing any proper framework or metrics to measure the efficiency of their data center.

This lack of knowledge regarding energy efficiency was due to the unawareness of top-level management regarding the concept of green data centers. There were so many reasons to justify poor performance, one the main reason was data center contains around 150 Racks, but only 15% of these racks were filled and performing their processing, while remaining 85% are underutilized only consuming power without being properly utilized, hence the overall performance and efficiency was very inefficient. This also contributes towards the emission of greenhouse gases very hazardous for environmental heath and global warming. The other reason for this inefficiency was the lack of usage of efficient technologies like virtualization, thin provisioning and physical to live migration, data de-duplication and other energy saving techniques.

CONCLUSION

In recent years, energy efficiency has emerged as one of the most important design requirements for modern computing systems, such as data centers, as they continue to consume enormous amounts of electrical power. High operating costs incurred by computing resources and their energy usage leads to significant emissions of CO2 into the environment. Unless energy efficient techniques and algorithms to manage computing resources are developed, its contribution in the world's energy consumption and CO2 emissions is expected to rise rapidly. The power management problem becomes more complicated when considered from the data center level. This is obviously unacceptable in the age of climate change and global warming. The results highlighted are taken by applying PUE metrics in one of the tier level data center in Pakistan. The results clearly show that data center needs high level of improvement to overcome energy consumption problems faced by data center. The metrics are vital tools for data center managers to use when assessing the performance of their facilities and determining which resources should be focused for improvement. As the environment continues to be affected by data center emissions, governments will start to regulate the energy use and force data centers to make improvements. By taking initiative and creating metrics, the industry can be prepared to demonstrate progress toward energy efficiency.

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