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Metrics for Computing Performance of Data Center for Instigating Energy Efficient Data Centers

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Data centers now play an important role in modern IT infrastructures. Although much research effort has been made in the field of green data center computing, performance metrics for green data centers have been left ignored. This paper is devoted to identify and implement energy efficiency and green computing performance metrics in data centers. The metrics helps data center managers to measure and implement cost and power savings in data centers. A metrics based energy efficiency model for categorizing data center into measureable units is proposed which divides data center into four measureable areas and maps metrics to measure their efficiency and performance. The results generated after applying Power Usage Effectiveness metrics clearly demonstrate poor performance of data center with PUE value of 3.5, which indicates very inefficient data center.

Keywords: Data Center Performance; Energy Efficient Data Center; Global Warming; Green Metrics; Power Usage Effectiveness Metrics.

Introduction

A data center is a home of computational power, storage, backups, networking, and processing of applications necessary to support enterprise businesses and large multinationals. The progress of information and communication technology based businesses and social practices have transformed many, economies into e-economy and businesses into e-businesses[1]. The computational demands has driven the mandate for large data centers, the massive server farms to run today's Internet, financial, commercial and business applications to aid business progression, information management and communication purposes[2]. Internet and business applications are increasingly being moved to large data centers that hold massive server and storage clusters. These data centers consume massive amount of electrical power to process large and complex applications. Electricity usage is the most expensive portion of a data center's operational costs. It leads to different issues and challenges like huge power consumption and underutilization of installed equipments[3].

Today's data centers are big energy consumers and they are filled with high-density, power hungry IT equipment. If data center managers remain fully unaware of the energy problems, they will run the risk of doubling their energy costs between 2005 and 2011[4]. Environmental Protection Agency (EPA) reported that 61 billion KWh, 1.5% of U.S electricity consumption, is used for data center computing and its equal to energy used by 5.8 million average U.S households (5% of all households[5]. Thousands of servers are densely packed in machine rooms to provide services to scamper businesses efficiently and cost effectively. The increased load is pushing the demand for installing millions of servers to match increasing business needs[6]. Koomey expects server growth and installations to expand from 6 million to almost 11 million from 2000 and 2007 and are leading consumers of IT power in any data center. Between the years 2000 and 2006, the number of servers installed in data centers grew from 5.5 million to 10.9 million[7]. The major problem with these servers is that they are underutilized and remain idle for long time durations, consuming huge energy.

Energy efficiency is the central concern comprehended by all enterprises in large computing infrastructure systems. Improving energy utilization entails metrics and models to evaluate measurement designs for these large infrastructures, and identify promising energy efficient techniques to understand

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the effects of resource utilization to implement proper power utilization decisions[8]. Research is going on to create techniques and opportunities to help data centers make better decisions in ensuring secure energy supply, protecting the environment by reducing the effects of global warming, reducing server footprints and creating sustainable businesses. The need for metrics and methods for facilitating energy consumption and efficiency is critical for implementing green energy efficient data centers. The paper highlights the importance of green metrics for measuring and improving the performance and efficiency of data centers to set benchmark values for data center industry. It enables to understand the current level of efficiency in a data center, and implement additional efficiency practices, to help gauge the effectiveness of efficiency efforts.

Problem Statement

Data centers are overwhelmed with thousands of servers performing processing for end users to facilitate and accomplish large business goals. The problem with most of the data centers is that almost 90% of the servers remain idle most of the time performing nothing but consuming huge power and simultaneously generating enormous amount of CO_2 very hazardous for environmental sustainability and global warming. The problem with data industry is the lack of standardized green metrics widely available to be implemented in data centers to measure their performance and efficiency.

Measuring Problems in Data Centers

The goal of power management is to reduce instantaneous power draws at any point in time, while energy management intends to reduce total energy consumed to perform a task. It does not necessarily improve energy efficiency. Efficient resource management is a key concern for data center operators seeking to meet application service level agreements and reducing power and operational costs[12]. Achieving better overall energy efficiency by consolidating work on fewer machines may actually lead to increased peak power in parts of the system. Energy management, on the other hand, seeks to reduce operational costs by reducing the energy use of the (over provisioned) infrastructure[9]. Despite contradicting goals, both power and energy management can be combined to gain the benefits of both strategies[10]. There are different approaches to determining energy usage. One is to take a macro view, looking at how much energy a data center consumes in total and working down to individual devices. The other approach is to take micro view of components in individual devices and then sum up the results across these devices to measure the overall energy usage[11]. The continuous increase in power and energy consumption by servers and data centers has shifted the focus of power and energy management techniques to data center industry. Energy efficiency in data centers is achieved by optimizing computing resource usage, by using the smallest computing resources to process maximum number of valuable tasks; it results in consuming low energy to process maximum number of tasks.

The key to effective data center power measurement is finding a timely and cost effective measurement technique. The complex nature of tier level data centers has lead to the inability to measure and manage power in a comprehensive way. The result is that business can neither track nor optimize Return on Investments (ROI) or Total Cost of Ownership (TCO) for investments in data center infrastructure. Data centers have no metrics to determine power costs associated with a particular infrastructure element. This gap in power measurement also means that, enterprises can’t make appropriate decisions with respect to infrastructure and management. It helps to acquire best practices, energy efficient designs and power saving technologies while satisfying green energy efficiency improvements.

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. 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[13]. 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[14].

The mounting energy costs necessitates the development of green metrics with a broad emphasis on performance and measurement of related energy consumption in almost all components of a data center. 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[15]. 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. There are many opportunities to reduce energy usage in data centers as wide range of efficiency practices are available, but industry is focusing more on instruments which provide these services more efficiently and at the same time cover all aspects of measuring efficiency. There is a strong need to standardize energy efficiency metrics with a finer granularity that takes into account diverse processing functions and configurations.

A metric should be developed in such a way that it provides a balance between power and performance in a universally appropriate and acceptable way. It must define certain rules and regulations that are impossible to avoid and provide fair comparisons across every category of computer system. This ideal is impossible to achieve in practice, so proposed metrics have specialized in different classes of workloads and systems.

Proposed Work

The metric helps to identify areas in data center that need to be improved for energy efficiency. It helps to reduce the overall cost of ownership because with measuring performance helps to identify efficiency of data center. It requires data center managers to employ and implement different energy saving techniques like virtualization, thin provisioning, live migration, data de-duplication, data shrinkages, to reduce the consumption of power[16]. Metrics demonstrate measured electric intensity to estimate overall load intensification and to predict future power needs. They are used to stipulate awareness about energy efficiency and provide enormous opportunities to build data center designs, which can easily be managed, measured and operated. The major barrier in improving energy efficiency in data center is the lack of appropriate metrics. This paper proposes the most industry acceptable metrics called Power Usage Effectiveness (PUE) to enable data center managers to quickly estimate the energy efficiency of their data centers, compare the results against other data centers, and determine if any energy efficiency improvements need to be made.

Power Usage Effectiveness (PUE) Metrics

The biggest problem any metrics faces when applied for calculating energy efficiency is the lack of standardized system of categorizing different resources of data center. To compute the power efficiency of data centers, metrics are needed to substantially measure power utilization from time to time to help top management to make correct decisions to implement green data centers. PUE was calculated as total power utilized by data center divided by total power utilized by IT equipment. It has received comprehensive acceptance and popularity in the industry[17]. It provides a complete figure on the utilization of power in IT equipment and how much is misused and ravaged on overheads. It also provides opportunities to improve data center operational and management costs by comparing the efficiency with other competitive facilities. It also provides huge prospects for repurposing power and energy for additional IT Equipments by providing a proper mechanism to illustrate the allocation of power utilization in data center components.

Implementing Power Usage Effectiveness Metrics

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:

i. Select the metric type using criteria mentioned above to fulfill all three characteristics of becoming a useful metric.
ii. Select data center type depending on tier levels described by ITE (Tier I, II, III and IV) to be evaluated and measured.
iii. Measure current individual and overall energy efficiency values (baseline values).
iv. Measure benchmark values for energy efficiency.
v. Identify and highlight potential areas for efficiency improvement in terms of:

a. Energy cost
b. Source energy
c. Carbon emissions
vi. Select the elapsed time of the assessment period
vii. Select the mean of source load for the assessment period
viii. Select the mean of values obtained by applying the proposed metric
ix. Report the highest daily values occurring during assessment period
x. Measure the lowest daily values occurring during assessment period
xi. Collect the data from different assessment periods
xii. Analyze the data
xiii. Set benchmark values

PUE was implemented by calculating the total power drawn from utility was the sum of total facility power for data center, and total power consumed by non-data center components. IT equipment power was measured after all power conversion, switching, and conditioning was completed before the IT equipment itself. The most likely measurement point was at the output of computer room power distribution units (PDUs). This measurement should represent the total power delivered to compute the equipment racks in data center.

The PUE values can range from 1.0 to infinity. A PUE value approaching 1.0 indicates 100% efficiency meaning all the power is used by the IT equipment only. Currently there is no comprehensive data that show the true spread of PUE in data centers. The preliminary research done by Green Grid and other firms indicates that many data centers have PUE values of greater than 3.0. However PUE values of 2.0 are achievable by proper design.

Results and Analysis

The research was performed through implementing (PUE) metrics in one of the tier level data center; it requires two values to measure the performance of data center.

1. Total IT Equipment Power consumed
2. Total Facility Power Consumed in data center

The results obtained after applying PUE metrics are:

Total IT Equipment Power Load = 60 Kw

Total Facility Power Load in data center = 210 Kw

PUE = Total Facility Power Load/Total IT Equipment Power Load

PUE = 210/60 = 3.5

PUE = 3.5

The results collected were normalized and it looked surprising that performance and cost were the most important attributes. 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 data center in terms of energy efficiency was very poor (very inefficient) with PUE value of 3.5. 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 are 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 this poor performance, the main reason was that; 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 and Recommendations

This paper has shown the need for the industry to develop standards and metrics for measuring energy efficiency in data centers. Such metrics will be vital tools for managers to use when assessing the performance of their facilities and determining where resources should be focused to create 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. Finally, the paper concluded with implementing PUE metrics in one of the tier level data center and shows that data center performed really poor as power consumption and underutilization ratio is very high.

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