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A PATH FOR HORIZING YOUR INNOVATIVE WORK

A HOLISTIC APPROACH TO DATA CENTRE GREENING

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Abstract- Increased digitization of modern life has lead to the increased deployement of data centre facilities. Data centers are complex ecosystem which connects elements of information, communication, electrical and mechanical fields of engineering. Falling hardware costs are stimulating growth of data centre. Nowadays big data centers consume huge amount of electricity and contribute more to carbon foot-printing and global warming. Owners, managers and policy makers of data centre are more concerned about data centre power consumption. Additionally Societal trends and interest in GREEN and SUSTAINABLE technologies have increased focus on data centre. Therefore 'green' data centers are trying to address these concerns and issues by more effectively incorporating energy efficient design together with high effeiciency power delivery and high effecency cooling facilities.

Keywords: Data centre; PUE; DCiE; cooling system; energy efficiency Metrics, Power efficiency

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INTRODUCTION

As we are moving towards digitization era the requirement for data storage has grown tremendously. This exponentially growing requirement causes increased power consumption of data centers. It has been observed that in year 2006, the data centers and servers in US consumed 1.5% of all US electricity.

In last decade millions of data servers were sold annually increasing data centre power density by 15% annually. If these trends remain continued then data center will globally consume more electricity than France, Germany, Canada and Brazil by 2020. Data centers which provide cloud services use tens of thousands of servers which use tens of Mega-Watt of power. It has been estimated that such data centers draw power approximately to $9.3 million per year. Due to huge amount of power consumption by data center, it contributes to large amount of carbon emission. A small effort to reduce energy consumption in data centers can significantly reduce environmental impact of carbon emission and increases its contribution to environmental sustainability.

Different types of techniques are proposed for managing power consumption in data centers. These power management techniques helps to maintain power efficiency and cost efficiency of data centers which are consuming huge amount of power. This paper looks at the need of power management and its solution outlines for data centers and overview of power management techniques.

The paper is organized as follows: it present basic reasons behind increased power consumption need for power management, problems of managing and optimizing data center energy and carbon footprint and overview of few power management techniques. This paper further discusses the issues faced by IT managers in addressing power management problem along with solutions needed to handle such issues.

- Data center management

  - *Causes of increased Power Consumption in Data Centers*

Tremendous growth in use of internet is also a reason behind increased number of data centers. Most of the data centers use thousands of servers which run 24 X 7 hours to satisfy huge demands placed by millions and billions of the internet users. Youtube and facebook servers are very common examples of daily life to understand the data centre usage. Every day millions of videos get uploaded on youtube whereas on facbook there are millions of active users which upload near about 2 to 3 billion photos on the facebook. Now we can think of how much energy is required to keep up these kinds of servers daily.

Increased interest in high-performance computing also increases power consumption to get high performance. Other reason behind increased power consumption can be the attitude of IT managers which focus mainly on meeting the requirement and demands from the business. They only concentrate and make sure that the IT equipment and the applications installed on the equipment are up and working good to meet the business goal. Power and energy issues are not on the priority list of these managers.

- *Need for Power Management*

Enterprises are becoming more economical in terms of costs. They are becoming cost conscious and trimming cots wherever possible with respect to wastage and in efficiency.

Environmental sustainability is also one of the major reasons for power management. Today enterprises are focusing on their carbon emission and finding out ways to reduce it at enterprise level.

These are the two most common driving forces behind greening the data centers using power management.

- *Data Center Power concerns*

To handle data center power issues a data center manager needs to find out answer to the following questions

- What is the power consumption of all the equipments of the data center with respect to the temporal and spatial granularity?
- What is the cost of cooling infrastructure whether too much money is spent on the supporting infrastructure?
- Whether best performance per watt on the IT equipment is achieved. If not how to get it?
- How energy efficient is the data center as compare to other data centers or same data center from the previous 5 to 6 months record.
- Are there any kinds of wastage of energy or inefficient energy utilization in the data center if yes then how to reduce or remove it.
- power management techniques at a glance

There are several techniques available for power management in a data center. For example DVFS (Dynamic Voltage/Frequency Scaling) based techniques, few techniques are used to transition server to low power state so that energy consumption can be reduced, and server consolidation based approach can be used to allocate required number of servers as per the workload. Thermal aware techniques can be used when thermal properties are taken into consideration. Workload or task scheduling based energy management techniques are also used nowadays.

- *DVFS (Dynamic Voltage/Frequency Scaling) based techniques*

It's a most common technique where clock frequency of a processor is dynamically changed to allow reduction in the supply voltage to achieve power savings. It is most suitable to memory bound workloads. DVFS has one limitation that if frequency is reduced, the performance of the circuit also reduces. Therefore DVFS needs to be intelligently utilized to maintain high performance. It can be used in multi-core processors, DRAM memories etc.

- *Power State Transitioning Based Techniques*

In this technique the servers are transitioned to low power state or turned off when idle or during low activity periods. Another approach called server consolidation is a technique where workload or the existing applications are consolidated onto fewer servers and rest of the unused servers are made to go in low power state. These kinds of approaches are very useful in optimizing data center energy efficiency.

- *Thermal-aware power management Techniques*

Most of the power management techniques are not thermal –aware. i. e. they do not take temperature parameter of server power consumption into consideration. Heat dissipation of processor is highly temperature dependant. Increased operating system temperature increases heat dissipation and as we know increased heat may lead to component failures. Therefore while having solutions for power management in data center we must take temperature parameter into consideration.

- Solutions to manage power consumption in data center

Before starting with solutions to power consumption in data center, we analyze the power and cooling infrastructure in a data center. A data center typically consists of IT equipment, cooling infrastructure and lighting system as major components of power consumption.

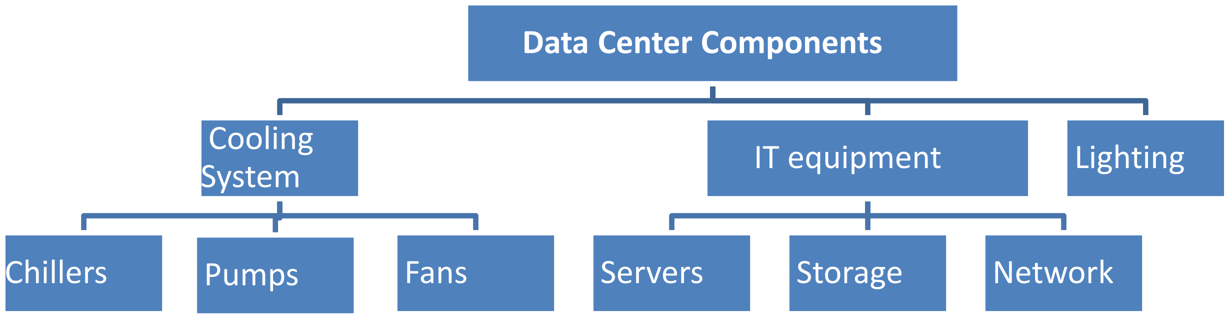

Fig. 1 Typical Power Components of Data Center

IT equipment can be servers, storage and network equipment. Cooling infrastructure is e.g. chillers pumps and fans. Cooling infrastructure and IT equipment consume 90 to 95% of power supplied to data center. Optimizing and reducing power consumption in IT equipment and cooling infrastructure reduces power consumption in a data center.

- *Power metric in data center*

Efficiency of a data center can be measured by the energy consumed to perform core IT functions in a data center. How much energy consumed by IT equipment out of the total energy supplied to a data center can be calculated and rest of electricity which is consumed by cooling infrastructure and lighting system is considered to be overhead. This overhead we need to reduce so as to increase the efficiency of data center.

Power Usage Effectiveness (PUE) and Data Center Infrastructure Efficiency (DCiE) are the two metrics used to calculate efficiency of data center. PUE calculates power consumed by computing equipment against the power consumed by cooling and other overheads.

PUE = Total power / IT equipment power

While DCiE is the reciprocal of PUE

$$\mathbf{DCiE} = \frac{\mathbf{1}}{\mathbf{PUE}}$$

Operational efficiency of a data center can also be measured by using some of the emerging data center metric such as Carbon Usage Effectiveness (CUE), Energy reuse effectiveness (ERE), Data centre energy productivity (DCeP), Data centre computer efficiency (DCeE) etc.

Carbon Usage Effectiveness (CUE):

It is used to measure data center specific carbon emission. It can be calculate as mentioned below

CUE = CO2 emitted per unit of energy × (Total energy consumed by data centre / Total energy consumed by IT equipment)

CO2 emitted in kgCO2 and unit of energy in kWh.

Energy Reuse Effectiveness (ERE):

It is the amount of waste energy recovered from data center operation and reusing it outside the data center for example cooling and heating of room etc.

It is calculated as mentioned follows

ERE = (total power – power reuse) /power consumed by IT equipment

Data Centre energy Productivity (DCeP):

It is the measure of useful work generated against the energy it needed over a period of time. It is calculated for each device or cluster of computing equipment. It is measured as follows

DCeP = Useful work produced / total data center energy consumed over time.

Data Centre Computer energy Efficiency (DCeE):

It is used mostly by data center operator to find out efficiency of compute resources. It helps to identify inefficient compute resources to replace or remove.

Following are the benefits of measuring PUE/DCiE of a data center.

- It is univerasly accepted measure for data center and is quatifiable
- It helps the data center administrator to know the effeciency of data center
- It also help to know areas of optimization to increase the efficiency of a data center.

But sometimes completely relying on these metrics does not yield fruitful result.

- *Optimizing Cooling Infrastructure Power*

Optimization of cooling infrastructure can be done if we know whether the data center is overcooled or under cooled. Usually in a data center chillers supply cool air at an inlet temperature that is much lower than the required temperature for cooling servers in a data center. If the servers are under cooled then there is a possibility of failures due to thermal emergency.

The question aroused then how to know that the data center is under cooled or overcooled? Solution to this problem is to employ Computational Fluid Dynamics (CFD) technique which is used to get thermal profile of the data center.

Computational Fluid Dynamics (CFD):

It builds thermal model of data center which is used to verify the existence of overcooling by increasing the chiller inlet temperature in the thermal model and demonstrating that the temperatures at the rack level are still within the permitted operating range. Using such solution help the data center administrator to set the highest inlet temperature which enables the IT equipment to operate in the safe zones by reducing the cooling infrastructure power.

The other benefits of using CFD modeling is that it is a very accurate and can be used to try different configurations like use of blanking panels, trying different configuration of servers and so on, in the model to identify an optimum setup that minimizes the cooling power of data center which still satisfy the computing demand of data center.

- *Optimizing IT Equipment Power*

Optimization of IT equipment power consumption can be best done by shutting it down when not in use. But this solution sounds practically difficult. Studies have shown that average utilization of servers in a data center is near about 10% and 30% of the all the servers in a data center sits idle not doing any useful work. Even if the servers are idle not doing any significant work they still consume significant amount of power. This we call as the overhead which is clearly waste of power.

Therefore we need to identify such servers which are idle and consuming power. Identifying such servers and putting them down or consolidate their workload to other servers helps in reducing the power consumed by IT equipment's in a data center.

Power consumption profile of a server is not sufficient to calculate total useful work done against the power consumed by the server over a period of time or daily. But getting such business output is practically difficult. We can use physical server utilization metric to know the business output of the server and to know usefulness of the server.

The best solution of server optimization is to get an integrated view of server power consumption and its performance. We can also get key insights of power performance of a server by comparing the utilization of server against power consumed. It helps to identify those servers which are worth spending the watts and which are not. By employing suitable algorithms we can analyze power efficiency of a data against the total watts consumed by the IT equipment.

- *Power Conditioning IT Equipments*

Before being supplied to IT equipment the power is conditioned i.e. the voltage is stepped down, converted from AC to DC. Along with optimization of power in IT equipment and cooling infrastructure, increase in efficiency of power conditioning infrastructure also benefits in data center power efficiency. The best example of power equipment can be UPS which works best when at maximum load otherwise may cause power losses.

- practical issues faced

Employing such solutions is practically bit difficult. For example in case of optimizing IT equipment power consumption by shutting down servers when not in use or migrating operations to others servers and migrating servers in a 24X7 production data center is difficult and disruptive.

Legacy data center do not have the provision to measure power utilization of the IT equipment individually.

- Future trends and direction

In near future we can see modern data centers which deploy tens to hundreds of servers having different configurations working together. This heterogeneity in computing servers will increase as size and number of data center increases. As we know most of the workload is hardware/platform dependant which makes the task sensitive to work. This heterogeneity in data center will ultimately lead in performance degradation. Therefore we need novel methods to handle heterogeneity in servers to schedule workload. Research for using renewable energy sources and other effective high performance technology are explored by researchers. Techniques like power-state transitioning and non-volatile memory can be used to reduce energy consumption of computing sources. These techniques ultimately reduces carbon foot-printing of data centers.

All the above mentioned efforts for greening of data center if deployed will definitely reduce carbon foot-printing and increase energy efficiency of data center.

- **CONCLUSION**

Enterprise must address the energy consumption and carbon foot-printing of the data center immediately to reduce costs as well as to make the data center environmentally sustainable.

The goal of making data center green can be achieved by employing power optimization techniques for IT equipment, lighting systems, cooling infrastructure. Additional optimization can be done for conditioning equipments to contribute its small share in data center power optimization.

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