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Self-Organizing Architecture In Data Centers For Power Management

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Abstract – The huge amount of data which can be stored and processed with the use of the internet has resulted in the capacity of data centers get bigger. This has resulted in the increase of the consumption of the power in data centers significantly and the management of power consumption in data centers has become essential. There are many techniques that have been proposed in that prospective. This paper highlights the need of managing the power in data centers, in order to reach the target of the efficiency of the power and observe several architectural techniques designed for its management of power. The detail of techniques is also given based on their behavior. The purpose of this paper is to provide intuition into the techniques to improve energy efficiency of data centers by using self-organizing architecture proposed and also to request the designers to continue producing solutions which can help for managing the dissipation of the power of data centers.

***Keywords* -** Self-Organizing, virtualization, server consolidation, power consumption,

I. INTRODUCTION

From a long and distinct period of history, the requirements of data storage have been changed and grown exponentially and for those reasons, the consumption of power in data centers has been also increased.

In data centers, power management is a long and a complex process that requires measurement and monitoring the power generated its management, its optimization and consumption in a data center aptitude. It is a job of the data center infrastructure management (DCIM) to process the control of all processes of a data center and also the use of electrical energy.

It has been reported that in year 2006 alone, the data centers and servers in United States, 61 billion kilowatt hours of electricity, which is 1.5 percent of all United States electricity consumption and has a monetary cost of 4.5 dollars billion [1].

Too many data centers which provide cloud services use a big number of servers which draw too much quantity of Mega-Watts of power at peak. It has been approximated that such data centers draw power worth 9.3 million of dollars per year.

The worldwide, moreover, expenditure on enterprise, power supplies and cooling has been estimated to be more than 30 billion of dollars. For that, the management of the power in data centers has become an thing of paramount importance. Researchers proposed several techniques for managing power consumption of data centers.

Because of large power consumption levels of data centers, use of these techniques has become essential to maintain both energy efficiency and cost efficiency [2]. This paper focusses on the need of reaching the energy efficiency in data centers and survey many techniques which have been proposed for ensuring good operation of data centers.

Also, in that perspective, a self-organizing architecture SelA is proposed that will help in energy efficiency. It is important to incorporate algorithm in the self-organizing architecture SelA, to fulfill tasks correctly. Since it is not possible to include detailed discussion of a large number of techniques, we take the following approach to limit the scope of this paper.

We focus on operation level and architectural level for improving the efficiency of the energy and not on circuit level techniques. This paper considers the key design of self-organizing architecture for achieving the good energy efficiency in data centers.

The contribution statement is to give a concise understanding on how the power management can be done by using the SelA architecture.
Rest of the paper is organizing as follows: Section II contain background of the power consumption, Section III contain

the some measures of power management techniques, Section IV contain the resource management in cloud, section V explain the related work, Section VI describes architectural framework, Section VII contain self-architectural for power management, Section VIII gives some recommendation, Section IX describe the challenges of this research, Section X concludes research work with future directions and Section XI is an acknowledgements.

II. BACKGROUND

A. Energy aware computing.

Due to recent growth in the use of internet, the demand placed on data centers has increased.

In nowadays, data centers contain up to tens of thousands of servers and provide services to hundreds or thousands of users.

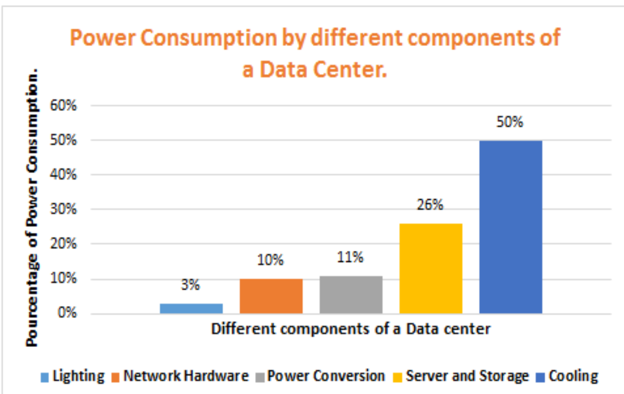

Figure 1: Percentage of the consumption of power by components in data center.

The energy utilized by the sub-elements of a data center depend on the efficiency of the equipment as well as the design of the data center.

For example, according to the statistics published by the Infotech group, the largest energy consumer in this particular data center is the cooling infrastructure which utilize around 50%, while servers and storage devices consume around 26% and is ranked to be a second consumer in the energy hierarchy.

Highlight the fact that the given values may differ from data center to data center. Other components: power conversion, Network hardware and lighting, by the same statistics, shows 11%, 10% and 3% respectively (figure 1).

The major challenge with cloud data centers is power/energy consumption. Below are reasons:

- Limits speed for high-performance computers,
- Limits battery life-time for mobile devices,
- Bad for the environment,
- Heat causes reliability issues.

B. Resource Management

The total amount of energy entering in the data center, is distributed among sub-components which has the impact to have some element consuming too much power than others and also the wastage of important quantity of the power.

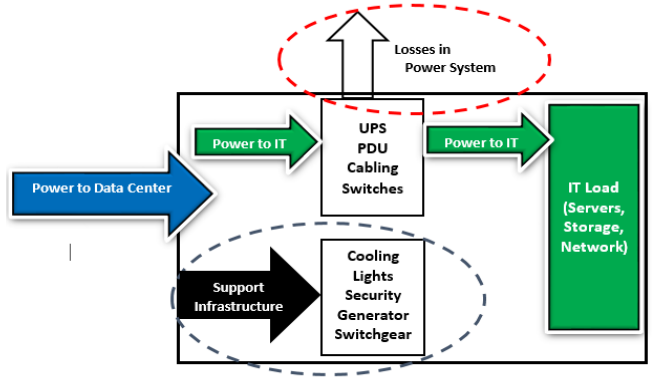

Figure 2: Distribution of the power in Data Center.

Ideally, it is assumed that all the power entering the data center is to be used to power the IT load (servers, storage and network). This will result in a PUE (Power Usage Effectiveness) value of 1. Realistically, however, some of this power must be diverted to support lighting, cooling and other support infrastructure. Another quantity of power is consumed due to losses in the power system. The remaining power then goes to service the IT load (figure 2).

To improve data center energy efficiency, there are two areas in which we can make change: reducing the power to the support infrastructure and another alternative is to reduce losses in the power system as huge quantity of the power entering the data center will make it to the IT load. This will improve our energy efficiency as well as the PUE will be reduced as well.

Some elements contribute to the power consumption:

Temperature

The denominator of paramount importance to data center power management is the temperature. A computer room air conditioner (CRAC) or a normal cooling is not sufficient for high density servers (blade servers). Related to temperature control, Data centers need a high degree of accuracy.

There are standard norms as to what the inlet and outlet temperatures set by PUE should be [3]. The temperature needs to be 21 degrees Celsius of the inlet at the front of the rack, with the maximum variation allowed being 1 degree from the norm. The outlet can be up to 31 or 32 degrees Celsius. The delta temperature (difference between inlet and outlet) should be 10 degrees.

Humidity

In data center, humidity should be around 50%, give or take 5%. On land beside sea areas humidity can go up to 70-

80%, and in the rain season it can go up to 90% [4]. When the humidity is on high level, it will cause condensation, while the dryness from low humidity creates electrostatic discharges. The high temperature causes frequent booting of systems, which is not acceptable on mission-critical sites.

Server tweaking

Earlier, data centers were built for a life span of 10-12 years. If you see the advancements in technology, earlier there were pizza boxes or 1U servers, and a rack was 42U (able to stack up to 42 servers in a single rack). These are each independent servers with fans, CD-ROMs, etc.

If you have the 7U form factor, using vertical blades with blade servers, the heat density keeps increasing. A 1U pizza box server has a consumption of power around 200 watts, while a 7U; 14-blade server will consume around 3.5 kilowatts [5]. The heat density has increased almost ten times. One solution is to do consolidation of servers to the maximum. For that, even if the heat density increase on blade servers, server optimization and space savings will lead to data center power savings.

Types of used electric power

The Consumption of the power is a function of load, and the type (Direct Current or Alternating Current) you are using affects data center power management. The kind of load and applications you have in the data center, will determine the type of power to use. Both DC and AC have their own advantages and disadvantages. The usage scenario varies from organization another. The first thing to control is to know whether your organization will upgrade the data center in the course of time. For that you need to have scalable power for successful data center power management. In the UPS, power outages should not lead to any downtime. The data center must be sure that the power supply is reliable along with being scalable. This can be reached through adaptive architecture. Data center should be sure that the UPS has inbuilt transformers. Reliability gets compromised without it.

C. Virtualization and Consolidation

Consolidating and virtualizing different applications into fewer servers has an impact which is major on energy efficiency because of reducing server energy consumption and cooling requirements. At the end, the result is energy which will be saved of 10 to 40 percent.

Virtualization will lower the usage of the energy but as we've previously seen, it may cause an increase in Power Usage Effectiveness. To optimize your power and cooling, systems has to be kept in order to get them in with the new, lighter load for keeping the Power Usage Effectiveness from rising.

D. Power Consumption Levels

The total energy consumption of data centers as a percentage of total US energy consumption has doubled between 2001 and 2015.

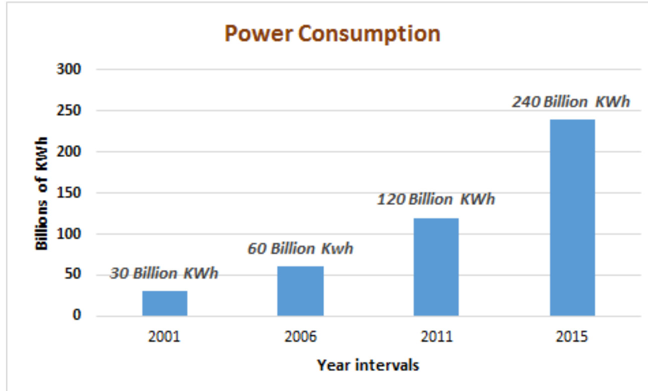

Figure 3: U.S. data center energy consumption projection.

The Expectation of energy consumption in U.S. data center is to double every 5 years. From 2001 – 2005, the consumption of energy is 30 Billion KWh, 2006 – 2010, it increase to 60 Billion KWH, 2011-2014, for 120 Billion KWh, 2015 – 2020, the consumption of the energy is expected to be 240 Billion KWh. Note that this is follows by a huge cost financially and also to the impact of environment (figure 3).

E. Need of Power Management

Researchers have shown that often, modern servers operate from 10% to 50% of maximum possible utilization. At these utilization levels, energy efficiency of the server also becomes very low. Regardless to the fact that the average utilization stays too low; there is frequent, brief bursts of activity, and to fulfill the requirements of service-level-agreements (SLAs), operators are obliged to allocate high amount of resources, which at the end, leads to poor energy efficiency.

Power management is also important from an economic consideration, because power management which is effective also improves efficiency of operation and at the same time, increases compaction.

The costs of electricity for powering servers, in data centers, forms a major cost of operation and it has been estimated that in the future, the cost of energy may contribute even more than the cost of IT [6].

A high ratio of cooling power to computing power limits the consolidation and the compaction in data centers which will result in the increased operation costs at a greater distance. For example, the high power density gives significant challenges in routing the large amounts of power needed per rack.

For example, one server can use power between **500** to **1,200 watts** per hour (Ehow.com). Suppose the average of 850 **watts** per hour is used. By day, the power of 20,400 **watts** will be consumed (20.4 kilowatts (kWh)). The consumption of the energy per year will be 7,446 kWh and per server.

The large power consumption and high assembly of nodes in data have the impact of increasing node collapse. It has been seen that a 15 degree Celsius rise increases the collapse rates in hard-disks by a factor of two [7].

To conclude, large power consumption also has an impact on environment, e.g. large emission of carbon dioxide [8].
For that, the conception of green solutions for modern data centers has been a topic of paramount importance. In this paper, we survey techniques for managing power consumption in data centers.

III. POWER MANAGEMENT TECHNIQUES

Power management in data center requires identification, implementation and monitoring processes in order to improve efficiency of power in the data center, both at the software and hardware level. This can include removing older equipment in favor of newer equipment that the consumption of power is less and also power management software installation for measurement, monitoring and control power consumption throughout the data center.
In data center, some processes in power management include:

- To Identify and to analyze the consumption of power in the data center on a modular level,
- To plan for incrementation of the capacity in line with the future requirements of the data center.
- To monitor and to upkeep backup power resources (generators, UPS, solar, etc.)
- To minimize bills of energy consumption and emission s of carbon dioxide.

Several techniques have been proposed by researchers for the purpose of managing power consumption in data centers. Because it is very difficult to draw the shape borderline of classification; for the sake of the study, we only classify the techniques in the following four types:

- Dynamic Voltage/Frequency Scaling (DVFS) based techniques.
- Transition of the server to low power or turned off the server or the use of server consolidation techniques in order to allocate required amount of server resources.
- Task scheduling or workload management based techniques.
- Thermal-management or thermal-aware techniques which take into account the thermal properties.

Some other techniques address the issues related to cooling in data centers.

IV. RESOURCE MANAGEMENT IN CLOUD

The cloud computing technology helps all its resources of the data center as a single point of access to the customer who want to access them and its implementation is designed as pay per usage.

Even though there are several advantages in using data centers, one of the major problem is to understand how the requests of the user are executed with good resources allocation to each of such request.

Unless the allocation and management of resources is organized in order for maximizing the utilization of the system and performance, managing the cloud environment for multiple customers becomes more difficult.

V. RELATED WORK

This section contains an overview of the state of the art of existing works that are related to the approaches we have used in this paper.

The authors have tried to identify workload time series to dynamically regulate CPU power and frequency to optimize power consumption. This attempt led to a reduction of consumption by to up 36% [9].

Also the work presented by Pinheiro et al. addresses the problem of consumption in server cluster. In this case the objective is turning off the highest number of servers making redistribution of the load, taking into account a maximum degradation of performance. In this case a machine is in charge to choose which server should be turned on and off per each cluster of the network, being able to measure the overall performance [2].

Another approach is introduced in [10]. In this case, an economic perspective is taken to manage shared service resources in hosting centers. In the presented ad-hoc solutions, the Muse operating system, a central unit called executive takes request as inputs and takes allocation decisions, while other three modules are in charge of monitoring and estimating the load, switching income traffic to the selected server in a transparent way for the services and managing a pool of generic and interchangeable resource.

Elnozahy et al. present five different policies to manage energy saving in a server cluster environment. This work aims at optimizing voltage scaling by dynamically adjusting the operating voltage and frequency of the CPU to match the intensity of the workload [5].

The work shown by White and Abels presents a computing model called VDC in which a centralized dynamic control system is in charge of managing resources for the applications, which are sees as isolated virtual machines. In this approach the resources are virtualized so that they can be provisioned and resized dynamically to applications as required. Moreover, application may frequently migrate from one set of resources to another. VDC implements applications as isolated virtual machines, which are built on top of their virtualized resources across the entire data center [9].

The work done by Khargharia et al. presents a theoretical framework that optimizes both power and performance for data centers at runtime. In particular the approach is based on a local management of small clusters and on a hierarchy to manage power. The hierarchy is composed of three levels: cluster, server and device, each one with a fine granularity because it is able to address consumption of processor, memory, network and disks [6].

Bennani and Menasce present a similar hierarchical approach with respect to addressing the problem of dynamically redeploying servers in a continuously varying workload scenario [4].

In this case, servers are grouped according to application environment logic, and a so called local controller that is in charge of managing a set of servers. In turn, all the local controllers report the workload prediction and the value of a local utility function to the global controller, which takes decisions on, the collective resource allocation [15].

Das et al. present a multi-agent system approach to the problem of green performance in data center. As for aforementioned papers, the framework is based on hierarchy, according to which a resource arbiter assigns resources to the application managers, which, in turn, are in charge of managing physical servers [8, 11].

Gang Sun1 et al. in his paper, he explain the efficient online live migration of multiple correlated VMs in VDC requests, for optimizing the migration performance [5, 14].

To solve this problem, he proposed an efficient VDC migration algorithm (VDC-M). He study the migration of a virtual machine from one to another physical host, the control of virtual machines which is converted to the management of services in Red Hat Cluster Suite [13].

Megha, Desai R.; Hiren, Patel B proposed how to create an availability and high load balancing cluster services, to move a virtual machine from one physical machine host to another physical machine [12].

Christopher Clark et al. is considering the design options for migrating of Operating System running services with liveness constraints, focusing on data center and cluster environments [2].

Mofijul, I. introduces and analyses the concept of writable working set and presents the implementation and design, evaluation of high performance Operating System migration built on top of the Xen VMM. Pankajdeep et al. proposed that there are various techniques and parameters available for Virtual Machine migration techniques [8, 9].

VI. ARCHITECTURAL FRAMEWORK

Self-organization is defined as an increase of order which is not influenced by an external agent and not excluding interactions of environment. This explain that, if a system starts in a non-organized form (with respect to a generic property), and ends up in an organized form without any external intervention of the environment or any other entity external to the system, then such system is a self-organizing system.

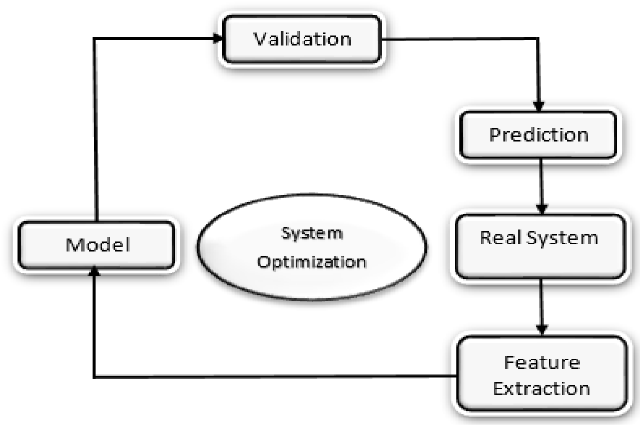

Figure 4: A view of the consumption of the energy modeling

The methodology of managing data center energy consumption is made by four main steps (Figure 4): feature extraction, model construction, model validation, and application of the model to a task such as prediction.

Feature extraction
In order to diminish the consumption of the energy in a data center, we need first to measure the consumption of the energy of its constituent components and be able to identify where most of the energy is consumed. This is the task of the feature extraction phase.

Model construction
Second, the selected input features are used to build a consumption of energy model by using analysis techniques like regression, machine learning, etc. One of the key problems in this step is that some important system parameters such as the power consumption of a particular component in a data center cannot be measured directly.

Classical analysis methods may not produce good results in such situations and machine learning techniques may work better. The outcome of this step is a power model.

Model validation
Next, the validation of the model is necessary for its fitness for its intended purposes. This is the task of model validation.

Model usage
Finally, the identified model can be used as the basis for predicting the component or system's energy consumption. Such predictions can then be used to improve the energy efficiency of the data center, for example by incorporating the model into techniques such as temperature or energy aware scheduling, dynamic voltage frequency scaling (DVFS), resource virtualization, improving the algorithms used by the applications, switching to low-power states, power capping, or even completely shutting down unused servers, etc. to make data centers more energy efficient. However, we note that having an energy model is not always necessary for energy consumption prediction.

VII. SELF-ORGANIZING ARCHITECTURE

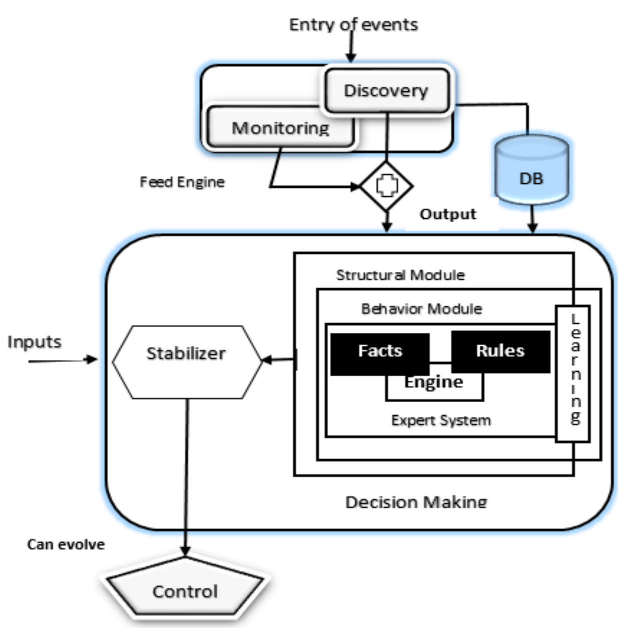

Figure 5: Self-organizing Architecture (SelA)

The proposed Architecture works like this (Figure 5):

- The communication with the other external elements takes place by Entry of events. They can be: Temperature, Humidity etc. They will be discovering by Discovery component and monitoring by Monitoring component and at the same time be saved in DB component (Data Base).
- These external elements will be sent to the Decision Making Component where they will be received by the Expert System in which their structure and their behavior will be checked by Structural Module and Behavior Module respectively. Expert System will study the facts and rules to follow for those elements. The final decision will be taken.
- The decision will be send to the Stabilizer Component, with some other external inputs, the system will be able to control the situation by Control component.

The role of different component of the figure 5 can be explained in this way:

Entry of events component
Designed for receiving the factors which has an impact to increase power consumption;

Discovery component:
Actions responsible of discovering the impact of the factors.

Monitoring component:
Actions responsible of monitoring the impact of the factors.

DB (Data Base) component:
Actions responsible of storing data which comes from Discovery and Monitoring components.

Decision Making Component:
Actions responsible of taking decisions on the events received.

Stabilizer Component:
Actions responsible of stabilizing the situation caused events received.

Control Component:
Actions responsible of controlling the situation caused events received.

VIII. RECOMMENDATION

As we have self-organizing architecture SelA which is designed, however, it is also important to design an algorithm responsible of: virtual machine migration in the data Centre, managing the power consumption, manages the necessary migration.
This algorithm should be incorporated in the self-organizing architecture, to help the self- organizing architecture to fulfil the function it must accomplish.

IX. RESEARCH CHALLENGES

In this research, multiple challenges are there for the good use of self-architecture:

- The implementation of the good architecture: Self-organizing architecture must be implemented in such way it can accomplish the role which it is designed for.
- The design of algorithm: The algorithm should be designed in such way it accomplish the role it is designed for.
- Incorporation of algorithm: The algorithm should be incorporated into a self-organizing architecture to accomplish the function it must play.

However, the design should correspond to the objectives that one want to reach. Otherwise, it will be useless.

X. CONCLUSION AND FUTURE WORK

In this work we have proposed a possible way to exploit the SelA properties provided by a self-organizing architecture SelA in the power management through their application to the use case scenario.

In particular, it is openly discussed how nowadays data centers are continuously growing up and how their dimensions represent a serious risk for their future development and for power management.

Therefore a new self-organizing architecture: SelA, has been introduced. The importance of the presented architecture are mainly related to its ability to react autonomously and to its self-management characteristics in the environment.

We have also shown how to benefit from these advantages by integrating the architecture into the system of a modern data center composed by physical nodes, which run virtualized machines on top of them with the support of the self-organizing framework.

The only primitives that the whole system relies on are the possibility to move a virtual machine from a node to another one and the possibility to hibernate idle machines and resume the operation of hibernated machines if the available ones are not able to deal with the actual workload.

The production of the above approach is pretty satisfying. Experiments have shown significant savings in power consumption through a technique based on the hibernation of the highest possible number of servers, preferably among high-consumption ones.

Some limits of the current study that will continue to be explored in a future work are the following:

- Introduction of mechanisms to restrict the number of VMs migrations, to let tasks run and to decrease the network load because it consumes power;
- Further investigation algorithm which will help the algorithm to work perfectly;
- Model refinement to introduce QoS constraints and policies to understand if the system is capable to follow rules and requirements of Service Level Agreements in a changing environment.

In conclusion, from a methodological consideration, the present paper has created a clear picture of self-organization architecture (SelA), which will contribute a lot in the management of the power in many data centers, useful to control the utilization of the energy in order to get its efficiency.

ACKNOWLEDGMENTS

My acknowledgment is addressed to anyone who contributes and gave the input and constructive explanations on the improvements of the paper.

Author Contribution

Sebagenzi Jason proposed and designed the self-organizing architecture (SelA) added to the existing techniques for power management in data center.

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