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STATE OF ART FOR ENERGY EFFICIENT RESOURCE ALLOCATION FOR GREEN CLOUD DATACENTERS

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Abstract: Cloud computing is a new paradigm of computing in which all the resources are available over the network and can easily accessible on pay per use basis. It is an emerging technology as it provides various benefits like reliability, easy to use, cost saving, availability and many more. Data centers are the fundamental component of cloud computing for providing storage, processing and management of data. Data centers are composed of electronic devices, servers, computers, communication devices, switches and therefore it requires huge amount of electricity to power and cool down these devices. Data centers are not only expensive to maintain, but also very unfriendly to the environment and consume huge amount of electrical energy, therefore the rate of carbon emission is increasing day by day. Energy consumption of data centers can be reduced by using different approaches on hardware level as well as software level. The main aim of this paper is to provide the vision and research taxonomy for energy efficient resource allocation. In this paper, the study first outlines the architecture of cloud computing then presents some research issues of infrastructure layer of cloud architecture and related survey for reduction of energy consumption in the infrastructure layer. Furthermore, state of art is summarized as research ideas for energy efficient resource allocation.

Key Words: Energy efficient resource allocation, Energy management, VM consolidation, cloud computing, Data centers.

1. INTRODUCTION

Cloud computing is gaining popularity day by day in IT as well as in academics. As with the increase in demand of cloud computing, the demand of large data centers is also growing day by day. Data centers are serving the growing demand of computation, memory, and networking therefore data centers are the main source of energy consumption in cloud environment. Energy consumption of data centers is growing with the increase of 12% every year [1]. Figure 1 provides overview that how the energy consumption in data center is increasing per every year.

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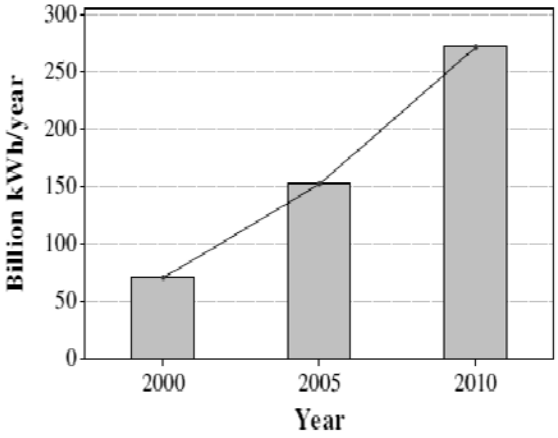

Figure 1: The worldwide data center energy consumption 2000-2010 [2]

These datacenters are very expensive and unfriendly to maintain, as they are composed of several components such as servers, switches, racks ,storage systems, air conditioning systems and many more and all these components consumes huge amount of energy. Therefore, two approaches: consolidation and virtualization that are widely used for the reduction of energy consumption of data centers. Virtualization is the technology that separate single physical machines into multiple virtual machines or multiple virtual machines are running over a single physical machine. Virtualization allows improving the machine utilization and reducing infrastructure cost and providing more computing resources to users. Virtualization means to create a virtual version of resources such as storage, servers, network and operating systems. Hypervisor, an open source software framework is used for the implementation of virtualization. Similarly consolidation is also an approach for energy saving of data centers and provides more resources to users. It is an approach for the consolidation of virtual machines to use minimum number of physical machines. Lesser the numbers of physical machines are used, lesser will be the energy consumption of data center. Energy consumption can be improved in such a way that SLA (service level agreement) should not be violated.

In this paper, we enlighten the concepts of cloud computing, emerging trends in cloud computing and research taxonomy for reduction of energy consumption in a cloud environment. This paper is organized as follows. Section 2 describes the concept of cloud computing as well as the architecture of cloud computing and emerging trends in cloud computing. In sec. 3 we provide research issues within an infrastructure layer of architecture. Section 4 presents the detail survey and research related to the reduction of energy consumption of data centers. In section 5 we proposed some ideas for energy efficient resource allocation and mentioned some research issues and challenges. Finally the paper is concluded in section 6.

2. CLOUD COMPUTING WITH EMERGING TRENDS

This new field encourages many researchers to give their ideas in this field. Here we are giving a structured review on research of cloud computing and our main aim is to provide detailed review on cloud computing environment. The field of cloud computing is not new but only thing is that all the services are available over internet on pay per use basis. Cloud computing is a technology where services and applications runs on distributed network using virtualized resources and shared by internet protocol. The Cloud is on demand network service, which we can access from anywhere with the help on any device at any time. It is a computing architecture with properties like on demand service, multitanancy, availability, pay per usage model and many more. In the Cloud computing environment, services are provided by infrastructure providers and service providers

[1]. Infrastructure providers manage cloud platforms and provide resources according to pay per usage basis, whereas service providers rent resources from many infrastructure providers. Cloud computing becomes attractive in day to day life due to its several features like Multitanenancy, Availability, Reliability, Pay per use model, Highly scalable, Easy to access. Architecture of cloud computing is divided into three different layers: infrastructure layer, platform layer and application layer. Each layer provides different services to cloud users. Figure 2 provides the detailed architecture of cloud computing.

- Infrastructure layer: provides infrastructure services such as processing, storage, network services to cloud users. This layer also virtualizes storage, network connectivity, data center's computing power. Infrastructure layer provides different virtualization services: server virtualization, network virtualization, storage virtualization, desktop virtualization, therefore this layer is also known as virtualization layer. Examples: Amazon EC2, Go Grid
- Platform layer: provides runtime environment, development tools, and databases to deploy applications using a programming language. A Cloud service provider will only manage the databases and operating systems or runtime environment. Cloud user does not need to worry for the maintenance of runtime environment. They simply create their programs which are hosted by platform services and are paying for those services. Examples of platform service providers are: Microsoft azure, Google application engine, Amazon S3. As each layer provides different services to cloud users, therefore there are various research issues in each layer of cloud computing architecture.

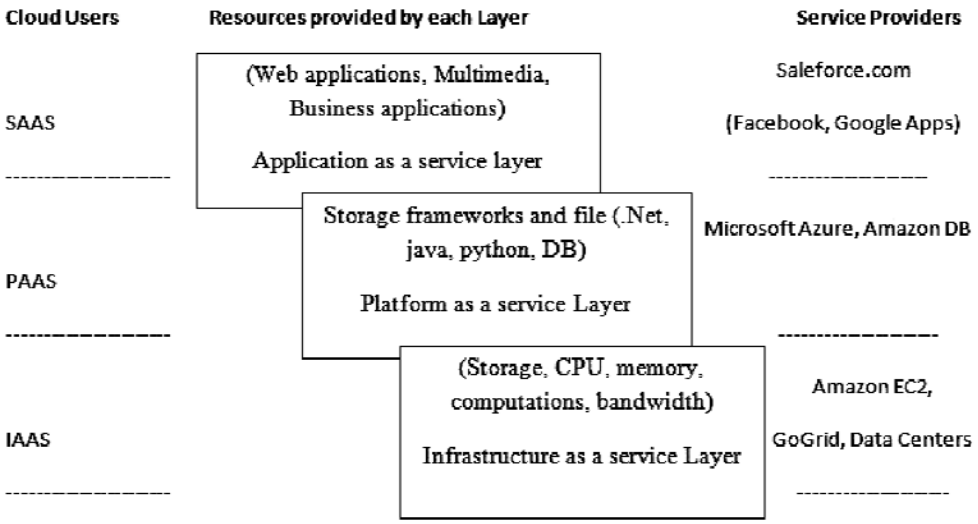

Figure 2: Architecture of cloud computing

- Application layer: Application layer: includes both applications as well as software components. This layer is also known as the software layer, as a cloud provider delivers software as services over the internet. Clients do not need to install and run applications on the customer's own computer. Examples like Google apps, Facebook. This layer is an interface layer to cloud computing services from which cloud users can access these services through web browsers, mobile devices etc.

As each layer provides different services to cloud users, therefore there are various research issues in each layer of cloud computing architecture. As our survey is an infrastructure layer centric, therefore, here we are presenting research issues of infrastructure layer and trends of research for this layer. With the emerging trends of cloud computing, several companies are providing cloud computing services such as: Amazon EC2 (Elastic Compute Cloud), Sales force,

Windows Azure platform, Google with Google application engine. All these service providers are also known as clouds. With all these services this field of cloud computing is not limited to computers only, but can be extended to mobile platform also and some examples are: Gmail, navigation, Dropbox for sharing and storing data, Google maps, Google drives etc. Along with this, cloud computing values for business, research and academy also. Eucalyptus and OpenNebula are an open source platform for experimental studies and scientific applications. OpenNebula provides virtual machines, virtual computing platforms and virtual application, whereas Eucalyptus provides resources and support for virtual machines to run on the top of Xen hypervisor. There are many research papers that focus the challenging research on cloud computing with different objectives. Here we have presented some of them.

3. RESEARCH ISSUES WITH INFRASTRUCTURE LAYER

With the several benefits and emerging trends of cloud computing, it is still a challenging field for the adoption in our day to day life. Research issues in infrastructure layer are summarized as: Security issues, Performance issues and energy management.

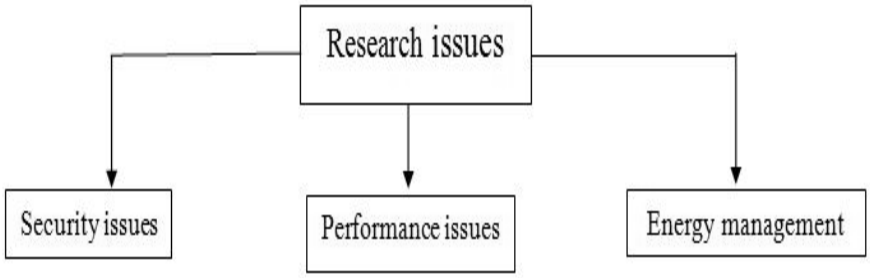

Figure 3: Research issues within infrastructure layer

(a) Security issues: security is the first main issue whenever we talk about cloud computing. Storing your data and running your application on somewhere else or someone else's CPU poses threats to our data and applications [4]. Others think that their information is confidential and protected from everyone, but they forget that they are using someone else's space and hardware, so there can be chances that your data is not fully protected. Multi-tenancy and pooled computing resources in cloud environment have introduced new security challenges. As cloud provides different services therefore, security issues should be imposed on all the services provided by cloud like in software level, in platform level or also in infrastructure level. Security issues of cloud include data security, data confidentiality, reliability, availability of data. Data security is wide research topic in the field of cloud computing. Data security is a shared responsibility between service provider and consumer. In case of infrastructure service provider they should take care of confidentiality of data and it can be achieved by using cryptographic protocols so that data that we are going to store in the data center should be in encrypted format and no one else can access it[5].

(b) Performance issues: Providing high performance of services is a very important concept in a cloud environment and there are many factors that affect the performance of this environment like: scalability, usability, processor power, workload, etc. Migration of virtual machines helps to improve performance, fault tolerance and manageability of systems [6]. Virtual machine migration improves performance by simply distribute the load from overloaded or overheated servers to servers which are available to use.

(c) Energy management issues: Main contribution of cloud computing is to provide storage, runtime environment, processing hardware and networks to cloud users. All these services are provided by the infrastructure of cloud computing, as it is composed of thousands of servers, switches, network devices. In case of servers [7] pinheiro proposed technique of load concentration (LC) for energy consumption of servers. This load concentration technique dynamically distributes the load to server. The resources of those servers which are less loaded can be put into low power mode or turned off. By this performance can be increased or decreased by depending upon server load. Similarly [8] IVS (independent voltage scaling) and CVS (coordinated voltage scaling) are two techniques used for power efficient consumption. In IVS, depending upon the current load on the server, it will decide what frequency or voltage to use where as in CVS frequency and voltage is coordinated by server to optimize energy consumption. These techniques are good for energy and power optimization. Now a day's virtualization becomes a very attractive technique for energy consumption in a cloud computing environment. It is a technology to separate single physical machine into multiple virtual machines. With the help of virtualization on one single physical machine, a lot of work can be done without turning on other physical machines, therefore virtualization is a cost effective technique. Rather than allocating virtual machines to all physical machines, it is beneficial to allocate VM to only few physical machines and turn off the other ideal ones to consume less energy This energy management in cloud computing is a challenging field in the area of research.

4. TRENDS IN INFRASTRUCTURE LAYER

Demand and usage of cloud computing are increasing day by day, that's why energy aware cloud computing environment is the main research area nowadays. In this literature our main focus is also energy aware cloud computing environment. To reduce the energy and power consumption, many authors have presented their work using different methods like: virtualization, consolidation, energy efficient resource allocation and many more.

Here in this paper, we are discussing the most important method for energy and power consumption i.e Energy efficient resource allocation for which resource allocation system is used. Resource allocation system's main objective is to fulfill application's requirement correctly by the infrastructure of cloud provider [9]. Resource allocation mechanism applies an algorithm to better allocate physical and virtual resources to an application. Resource allocation system (RAS) first has to perform following tasks before allocating resources to users. First, how to describe resources that are present in a cloud environment, known as Resource modeling and description. Resource offering and treatment will check how to represent application requirements of customers. Thirdly, RAS will check the current status of cloud resources known as resource discovery and monitoring. At last RAS will select the resources which are able to fulfill the requirements of customers known as resource selection. These four important points can be considered in two phases [9]: conception phase and operational phase. In conception phase resources are modeled and resources offered by cloud providers for that particular request, whereas in operational phase resources are discovered i.e. to determine if there are any resources available which are able to fulfill the request of the developer and if it is available then RAS may select that resource to serve the request. Both of these phases have some challenges. Resources on the cloud are of two types: physical and logical resources. Physical resources like CPU, memory, workstation, storage, network element and logical resources like operating system, energy, network throughput, bandwidth, load balancing algorithms, protocols, API. Resource allocation can be done in two ways: dynamic and static. The dynamic resource allocation scheme is better than static resource allocation scheme because in case of static resource allocation scheme resources are wasted when the application is not at its peak

load and similarly application can be slow down due to insufficient resources. Therefore, it is better to allocate resources dynamically according to the workload of the application

Virtualization is the key factor behind resource allocation. Virtualized environment helps to reduce the job response time and executes the tasks based on availability of resources [10] so that less no of physical server can be used in a cloud environment. Many researchers have proposed their policies or algorithms to allocate or provision of new VM or allocate jobs to virtual machines. [10] Saraswathi AT proposed priority based preemption policy which improves resource utilization in a virtualized environment. Weiwei Lin [11] proposed threshold based dynamic resource allocation scheme for cloud computing, in which virtual machines are allocated according to load changes and adopted the threshold method for proper resource allocation. At last Weiwei concluded that bigger the threshold value lesser the resources will reserved. In 2010 Urgaonka [12] used queuing information to implement a resource allocation and an energy management mechanism in virtualized data center. To achieve its main objective, he proposed DCA (data center control algorithm) with three steps: Admission control, routing and resource allocation. Admission control module receives new request and check whether this new request fulfills the criteria of threshold and then finally allocate resources to each virtual machine.

Beloglazov and Buyya [13] also proposed another energy resource management for virtualized data centers. They present an architecture composed of: dispatcher, global manager and local manager. Dispatcher distributes the request received by clients between virtual machines, then local manager monitors the resources of virtual machines and finally global manager selects the appropriate resource for allocation. Resource allocation provides improvement in resource utilization and resources like virtual machines is reallocated to minimize the physical machines and for minimization of energy consumption. There are certain conditions that should be satisfied for resource reallocation [13]. First, the CPU utilization of virtual machines should lie in between threshold values. Some of virtual machines have to be migrated if CPU utilization exceeds from threshold and all virtual machines have to be migrated if CPU utilization goes below threshold and then ideal nodes have to be switched off. In [14] Rajkumar Buyya again proposed energy aware resource allocation for data centers by presenting the idea that switched the idle nodes to sleep mode to reduce the power and energy consumption of data centers. He proposed MBFD (modified best fit decreasing) algorithm, in which virtual machines will be sorted in decreasing order of current CPU utilization and allocate virtual machines to host that provide less power consumption. MM (minimization of migration) policy will be used to select which and how many numbers of virtual machines, should be migrated from host to lower the CPU utilization).

Sina Esfandiarpoor [15] proposed that virtual machine consolidation and server consolidation are other approaches to reduce energy consumption of data centers. In which by performing live migration of underutilized servers keep the remaining servers in the energy saving state. The main objective of Sina Esfandiarpoor in to improve total energy consumption of data center by allocating virtual machines to those servers which are placed in same racks and turn off ideal server, switches and cooling systems. Author modified the previous algorithm by sorting the virtual machines in decreasing order of their requested MIPS, named as OBFD and this algorithm is designed for minimizing the number of ON servers for reducing power consumption of datacenter. Also for this author proposed three different policies for rack consolidation and server consolidation so that a minimum number of racks and servers should be in use and therefore the lesser number of switches and cooling systems are needed. Three different policies are: place virtual machine rack by rack (RBR), place virtual machine in non underutilized racks (NUR), hybrid server and rack consolidation (HSRC). By performing experiments the authors concluded that these policies provide energy saving up to 14.7% than previous approaches.

Energy efficient resource allocation can be modeled as a bin packing problem. The objective of the bin packing problem is to utilize a minimum number of bins to put objects into it. In resource allocation every server is treated as bin and each virtual machine is item, therefore the bin packing problem is used for packing of virtual machines inside physical machines in order to save energy by using lesser number of physical machines. [16] Weijia song proposed variable item size Bin packing algorithm (VISBP) to handle the changes in the resource demand of virtual machines. Later on Wang-Xiaoli [17] improved Bin packing algorithm and proposed a new approach by adding the concept of setting some threshold value to avoid unnecessary migration. Energy efficient allocation of virtual machines can be done in two ways [18]: first is requested for virtual machine assignment and placement of virtual machine on the host which can be considered as a Bin packing problem, the second is the optimization of current allocation by selecting the virtual machines that have to be migrated. Therefore, the authors proposed different heuristics [18] are used for the selection of virtual machines that has to be migrated like minimization of migration (MM), highest potential growth (HPG), Random choice (RC). Abbas Horri [19] presented efficient SLA aware VM consolidation algorithm by dividing the process into four different steps similar to [20]. They proposed VM placement algorithm by considering the previous concept [21] of host utilization and minimum correlation (UMC). They used LR-linear regression method to detect overloaded host machine present inside the data center and MMT - minimum migration time for selecting VM from overloaded machine. With the applicability of these algorithms they have shown the improvement in QOS and energy consumption of the data center in a cloud environment.

Ehsan Arianyan [22] presented a novel heuristic for determination of under loaded host during the consolidation of virtual machines inside the data center. They proposed TPSA policy for resource allocation, which is based upon TOPSIS a multi-criteria algorithm using different criteria as a selection procedure. Along with this, they also proposed three different policies for detecting under loaded PMS are: AC (Available capacity), MDL (Migration delay) and TACND (TOPSIS available capacity, number of VMs and migration delay). They achieved their objectives with 46%,99%,95% reduction in energy consumption, SLA violation and no of migration in comparison to previous work with the applicability of proposed policies.

Table 1
Related research and algorithms used for VM consolidation

Authors	*Objectives*	*Approach used*	*Algorithms*	*Data center structure and platform used*	*Can further improved*
[13] Rajkumar Buyya [2010]	Energy Efficient Resource Management	Consolidation of VMs according to current utilization of resources.	Bin packing algorithm	Heterogeneous data center Cloud Sim simulator	Considered only the utilization of CPU for VM migration rather than its RAM, network and bandwidth utilization. Structure of data center ,network, cooling equipments has not considered during VM consolidation
[14] Rajkumar Buyya[2011]	Energy aware resource provisioning and allocation	VM consolidation with Use of CPU utilization to sort each virtual machine	Modified best fit decreasing (MBFD)		
[11] Weiwei Lin*a* [2011]	Energy Efficient resource allocation for minimum energy consumption	Threshold based dynamic resource allocation scheme that allocate VM on the basis of changing in load.	Proposed new algorithm for VM consolidation in which threshold value is used to regulate the timing of resource reallocation to avoid unnecessary overhead.	Cloud Sim simulator and Heterogeneous data center	All virtual machines have same workload capacity during VM consolidation

Table 1 contd…

[17] Wang Xiaoli [2012]	Energy aware VM placement over physical machines	To reduce energy waste. The resource size and migration number determine the wastage of energy caused by Migration operations.	Proposed improved Bin packing algorithm	Using Matlab using C++. Homogenous data center	Only for homogenous server nodes with resource capacity of each server unit is 1. Time and energy consumption in transmission, switching network has not considered
[18] Chaima Chribi [2013]	Energy efficient VM scheduling for cloud data centers	First Resource allocation can be modeled as bin packing problem for minimum power consumption and then it is compared with best fit decreasing and exact migration results from ILP	Bin packing algorithm and ILP (integer linear programming) algorithm	Simulation using JAVA and linear solver CPLEX. For homogenous data centers	Bin packing problem can be further improved using other heuristics by comparing them using Bin ratio (BR)
[19] Abbas Horri [2014]	Proposing efficient SLA aware algorithm for finding new VMs placement	LR and MMT VM allocation and selection policies are used	Proposed utilization and minimum correlation (UMC) algorithm for under loading detection	Cloud sim simulator and for heterogeneous data centers	SLA Can be improved further by using novel method for both VM allocation and selection of VMs.
[20] Youwei Deing [2015]	Energy saving technology for hardware	Allocation of PM on the basis of optimal performance power ratio (oppr).	DVFS technology is adopted in the scheduling for reducing energy consumption of PMs. Proposed EEVS algorithm for VM scheduling using DVFS.	Heterogeneous physical machines using CloudSim simulator.	VM migration and performance of processors are ignored.

5. RESEARCH IDEAS FOR ENERGY EFFICIENT RESOURCE ALLOCATION

Energy Efficient Resource Allocation can be widely used for the reduction of energy consumption inside data center. In this manuscript our main focus is on VM consolidation process for energy efficient resource allocation. From literature we have surveyed that many authors presented their algorithms or approaches to achieve their objective of minimum energy and power consumption inside data centers. As large amount of work presented in literature and there are some approaches or algorithms which needs some improvement. Here we are presenting some more ideas for the consolidation of virtual machines for reducing the energy and power consumption.

To achieve the objective of minimizing energy consumption by using a VM consolidation process: in this process instead of considering CPU utilization, RAM, bandwidth utilization individually, better results can be obtained by considering them all together. Even results can also be improved by considering the hardware and network structure of data center. The VM consolidation process can be done in different steps [optimal paper] 1) select over utilized or underutilized host machine from datacenter. 2) Selection of particular virtual machines for migration using some criteria. 3) Placement of virtual machines over physical machine.

This VM consolidation process can be further improved from previous work by considering different workload capacity of all virtual machines. On the infrastructure level energy consumption can also minimize by considering energy in transmission and switching network. Many authors have used Bin packing algorithm for the placement of virtual machines over physical machine, this bin packing algorithm can be further improved by using the Bin ratio (BR). Bin ratio can be used for the comparison of different heuristics used for bin packing. Different VM allocation and selection policies can also be improved or new policies can be proposed for consolidation of virtual machines for better resource utilization which is directly proportional to performance of data centers.

In addition to energy efficient allocation of resources for data centers [25], QOS or SLA violation aware allocation policies also plays an important role in a cloud environment. By minimizing the level of violation of the SLA that has been negotiated between cloud users and service providers, performance of cloud environment can be improved. Therefore, some improvement should be made to provide minimum energy and performance trade-offs and also to provide energy efficiency in algorithms.

6. CONCLUSION

In this manuscript we presented the state of art for energy efficient resource allocation for green cloud data centers. As, this energy efficient resource allocation becomes one of the important research issues now a days, so there are a large number of papers in this area with different approaches from which we tried to explain some important ones. We have explained some research issues for the infrastructure layer of cloud architecture which can be improved further. Along with this we have discussed energy efficient resource allocation process with one of its main technique i.e. consolidation of virtual machines. Moreover, we have also discussed various approaches and algorithms for energy aware VM consolidation along with some improvements which can be made to them. We have mentioned some future research ideas for this allocation which can be helpful for researchers in this challenging field for further achievements.

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