Review on Energy Aware Virtual Machines Consolidation in Data Centers of Cloud

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Abstract— the numbers of datacenters are increasing with the use of cloud services. Datacenters are actually hazardous to the environment because of high energy usage and increase in carbon emission. Energy efficiency in datacenters is major issue in cloud computing, it will lead to improve physical infrastructure of modern datacenters through energy management and resource utilization. It is quint essential to reduce energy in delivery of computing resources and utilization of resources to serve application workload. Dynamic virtual machine consolidation is effective way to reduce energy consumption and better utilization of resources. The VM consolidation ensures that computing resources are efficiently utilized to serve applications workload so as to minimize energy consumption while maintaining the required QoS. VM consolidation determines in four sub problem like host overload/ under load detection, VM selection, VM placement to reduce overall energy consumption.

Keywords: cloud computing, virtual machines consolidation, cloud datacenters

I. INTRODUCTION

Cloud computing trend is growing at a rapid pace in Information and Communication Technology (ICT) industry to deliver the Infrastructure, Platform and Software as services under pay-as -you-go model. Cloud computing in itself is a practical solution for the IT requirement of the future and something that will only grow in coming years. This would mean setting up many more datacenters and other facilities to deliver the cloud services. The growing demand of cloud infrastructure services, results in more number of data centers.

Recently, datacenters are received considerable attention on designing energy efficient datacenters due to their consuming large amount of electricity and steady increasing trend. Datacenters are actually hazardous to the environment because of high energy usage and increases carbon emission. The worldwide electricity usage, in datacenters, experienced an average growth rate of 16.7 % from 2000 to 2005 [1]. For example, in 2006 the cost of energy consumption by IT infrastructures in US was estimated as 4.5 billion dollars and it is likely to double by 2011 [2].According to report by zinnov, the market for cloud computing in India is expected to grow nearly ten times to $1084 million by 2015 from the current $110 million [3].According to carbonfootprint.com, a PC running for an hour generates 40-80 grams of carbon dioxide ,while it consumes about 60-90% of normal workload power even when idle. Thus energy consumptions in datacenters point out strategies for energy efficiency.

Energy efficiency in datacenters is major issue in cloud computing, it will lead to improve physical infrastructure of modern datacenters through energy management and resource utilization. It is quint essential to reduce energy in delivery of computing resources and utilization of resources to serve application workload. One of the most important reasons for inefficiency in datacenters is the idle power wasted when servers run at a low load. Even at a very low utilization, such as 10% CPU usage, the power consumed is over 50% of the peak power [4].

Virtualization technologies multiple application can be hosted and executed on the same server in isolation, thus lead to utilization levels up to 70% [5]. Thus, it dramatically reduce active server. The goal of virtualization is improving firmness, scalability and the hardware resource utilization. Virtualization provides methods server consolidation and live migration to achieve load balancing and energy saving. VM consolidation enabled by virtualization introduces a new problem to the cloud environment. Dynamic consolidation of virtual machines is effective technique for power reduction in data center by turning off idle or underutilized servers. However, achieving the desired level of Quality of services (QoS) between user and data center is critical .Therefore dynamic consolidation can save energy while maintaining an acceptable QoS. VM consolidation is divided in to four sub problem (1) Host overload detection (2) Host under load detection (3) VM selection (4) VM placement for reduction of energy and improve utilization of resources without compromising SLA requirement.

The rest of the paper is organized as follows. We discuss the energy aware data center in Section II In this section firstly introduces sources of energy consumption, energy model and metrics for data center. Section III presents VM consolidation for data centers especially heterogeneous physical node. Finally we summarize in Section IV.

II. ENERGY AWARE DATA CENTER

A. *Energy Consumption:*

Cloud computing consist of a large number of data centers which are deployed in many location around the world. Big internet companies like Google, Amazon, eBay and yahoo are operating such huge data centers to deliver cloud computing services. However data centers consume tremendous amount of energy. According to Greenpeace Report, the data center electricity demand is estimates at around 31 GW globally. This is equivalent to nearly 180,000 homes supply [6]. Figure 1 shows that maximum numbers of energy consume by servers [6].

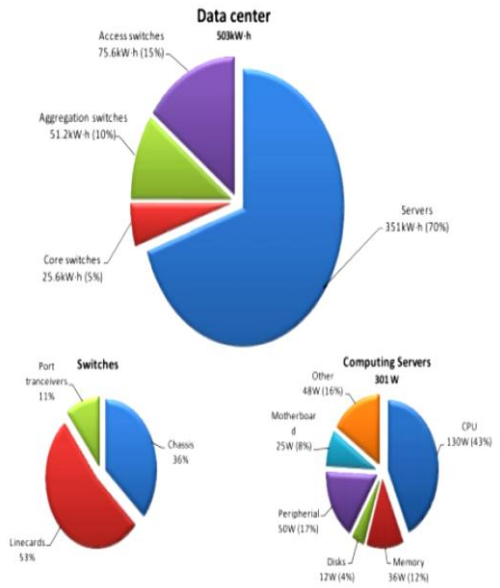

Fig. 1: Distribution of Energy consumptions in data center

B. Energy Model:

To understand power and energy management mechanisms, it is essential to clarify the terminology. Electric current is the flow of electric charge measured in amperes. Amperes define the amount of electric charge transferred by a circuit per second. Power and energy can be defined in terms of work that a system performs. Power is the rate at which the system performs the work, while energy is the total amount of work performed over a period of time. Power and energy are measured in watts (W) and watt-hour (Wh), respectively. Work is done at the rate of 1 W when 1 A is transferred through a potential difference of 1 V.It has been experimentally determined that an ideal server consumes 70% of the power utilized by a fully utilized server. The technique of switching idle server to sleep mode justify the reduction of the total power consumption. For this work power model defined in (1).

$$P(u) = P_{idle} + (P_{busy} - P_{idle})\, u, \quad (1)$$

Where, P is the estimated power consumption, P_{idle} is power consumption by an idleserver, P_{busy} is the power consumed by the server when it is fully utilized, and u is thecurrent CPU utilization.

The CPU utilization may change over time due to workload variability. So CPU utilization is the function of time and is represented as u(t). Therefore, the total energy consumption by physical node can be defined in (2).

$$E = \int_{to}^{t1} P(u(t)dt) \quad (2)$$

C. Energy Efficient Metrics:

The first step on greening the datacenters is to identify the energy efficiency metrics. Power Usage Effectiveness (PUE) is the ratio of total power used in data center to the power used for IT equipment. Data Center Infrastructure Efficiency (DCiE) is another metric to measure energy consumption and is the inverse of PUE. DCiE is the ratio of power used in IT equipment to the total power used in datacenter. Some other green metrics that are proposed for energy efficient data centers are presented in Table 1 [6].

Metric	Description	Formulation
PUE	Power Usage Effectiveness	$PUE = \frac{\text{Total data centre energy}}{\text{Total IT energy}}$
DCiE	Data Centre Infrastructure Efficiency	$DCiE = \frac{\text{Total IT energy}}{\text{Total data centre energy}}$
CUE	Carbon Usage Effctiveness	$CUE = \frac{\text{Total CO2 emmisionns from DC energy}}{\text{Total IT energy}}$
ITEU	IT Equipment Utilization	$ITEU = \frac{\text{Total measured energy of IT}}{\text{Total specification energy of IT}}$
DCP	Data Centre Productivity	$DCP = \frac{\text{Usefull energy}}{\text{Total facility power}}$
WUE	Water Usage Effectiveness	$WUE = \frac{\text{Annual water usage}}{\text{IT equipment energy}}$

Table-1: Energy –Efficiency Metrics for Data centers

III. VM CONSOLIDATION

Dynamic VM consolidation as a dynamic control procedure is an effective way to improve energy efficiency in cloud data center. The goal of this procedure is to operate in a way that optimizes resources and energy-performance trade-off inside cloud data center.

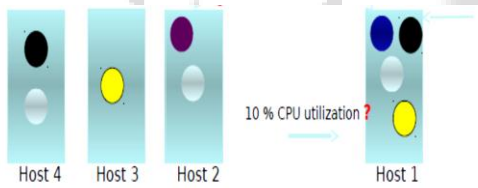

Fig. 2: VM Consolidation

In this paper, the targeted system is an IaaS environment, represented by a large-scale datacenter consisting of N heterogeneous physical nodes. Each node i is characterized by the CPU performance defined in Millions Instructions Per Second (MIPS), amount of RAM and network bandwidth. The servers do not have local disks, the storage is provided as a Network Attached Storage (NAS) to enable live migration of VMs. The type of the environment implies no knowledge of application workloads and time for which VMs are provisioned. Multiple independent users submit requests for provisioning of M heterogeneous VMs characterized by requirements to processing power defined in MIPS, amount of RAM and network bandwidth. The fact that the VMsare managed by independent users implies that the resulting workload created due to combining multiple VMs on a single physical node is mixed. The mixed workload is formed by various types of applications, such as HPC and web-applications, which utilize the resources simultaneously. The users establish SLAs with the resource provider to formalize the QoS delivered. The provider paysa penalty to the users in cases of SLA violations.

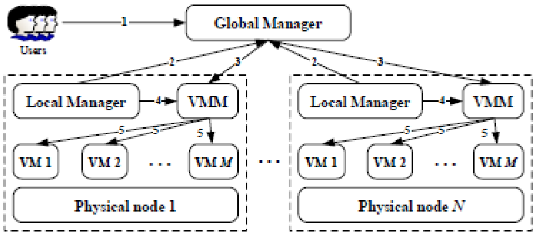

Fig. 3: System Model

The software layer of the system is tiered comprising local and global managers (Figure 3). The local managers reside on each node as a module of the VMM. Their objective is the continuous monitoring of the node's CPU utilization, resizing the VMs according to their resource needs, and deciding when and which VMs should to be migrated from the node (4). The global manager resides on the master node and collects information from the local managers to maintain the overall view of the utilization of resources (2). The global manager issues commands for the optimization of the VM placement (3). VMMs perform actual resizing and migration of VMs as well as changes in power modes of the nodes (5).VM Consolidation deals with two parts: first is with the admission of new request which can be seen as a bin packing problem with varying bin sizes and prices second is to optimize current allocation of VMs on hosts. Dynamic consolidation can save energy while maintaining an acceptable QoS. VM consolidation is divided in to four sub problem (1) Host overload detection (2) Host under load detection (3) VM selection (4) VM placement for reduction of energy and improve utilization of resources without compromising SLA requirement.

A. *Host Overload Detection Problem:*

Here, this sub problem make decision in both situation to find best time to migrate VMs to minimize energy consumption while satisfying required QoS. Each host periodically executes an overload detection algorithm to de-consolidate VMs when needed to avoid performance degradation and SLA violation. For this problem some heuristics used like Static threshold policy (THR), Local regression policy (LR), Median Absolute deviation policy (MAD), Inter Quartile range (IQR) etc.

Anton et al. [7] solved the problem of host overload detection by maximizing the mean intermigration time under the specified QoS based on Markov Chain Model. This approach is efficient handling multiple mixed heterogeneous real workloads. The Author heuristically adapts the algorithm to handle unknown non stationary workload using Multisize Sliding Window workload estimation technique.

Fahimeh et al. [8] proposed Reinforcement Learning – based dynamic consolidation method to minimize the number of active hosts according to the current resource requirement. The agent learns the optimal policy to determine host powermode. After that agent decides when a host should be switched to the sleep or active mode and improves itself as the workload changes. Experimental result compared with other heuristics policy of host overload detection and based on RL. Reinforcement Learning based dynamic consolidation minimizes energy consumption without compromising SLA requirement.

Fahimeh et al. [9] Author implemented dynamic virtual machine consolidation algorithm to minimize number of active physical server in datacenters of cloud to reduce energy consumption. The problem concern host overload under load detection using prediction method. To predict resource usage in each host K-nearest neighbor regression algorithm used for dynamic consolidation.This technique minimizes the energy consumption without compromising performance level.VM selection consider MMT (minimum migration time) policy and VM allocation consider modified power aware best fit decreasing with SLA parameter. Simulations results show that, this approach provide better result in large scale datacenter, which shows higher energy saving compare to other policies.

Pasi Lijeberg et al [10] In this paper, author implemented linear regression based CPU usage prediction method to predict over-loaded and under-loaded host. This method used in live migration process to avoid SLA violation. Linear regression method can significantly reduce the energy consumption and SLA violation rates more efficiently than THR, MAD, IQR and LR.

B. *Host Underload Detection:*

Although complex Underload detection strategies can be applied, for the purpose of simulations in this chapter a simple approach is used. First, all the overloaded hosts are found using the selected overload detection algorithm, and the VMs selected for migration are allocated to the destination hosts. Then, the system finds a compute host with the minimal utilization compared with the other hosts, and attempts to place all the VMsfrom this host on other hosts, while keeping them not overloaded. If such a placementis feasible, the VMs are set for migration to the determined target hosts. Once the migrations are completed, the source host is switched to the sleep mode to save energy. Ifall the VMs from the source host cannot be placed on other hosts, the host is kept active.

C. *Vm Selection:*

Once a host overload is detected, the next step is to select VMs to offload from the host to avoid performance degradation. This section presents three policies like Minimum Migration Time (MMT), Random Choice (RC) and Maximum Correlation (MC) for VM selection [26].

Seyed saeid Masoumzadeh et al. [11] Author have presented VM Selection task using Fuzzy Q-Learning (FQL) technique, lead to make optimal decisions to select virtual machines for migration. For better result, an adaptive and predictive mechanism can be efficient to make decisions about which criterion can achieve best result in current state. The FQL theory is so effective approach to create an adaptive and predictive VM selection during dynamic VM consolidation in cloud environment, which optimize the energy performance trade off dynamically. In FQL, first each time step to the agent observe current state stand select action from the possible action which partitioning each continuous state space variable and create fuzzy rule. Each rule in rule base has set a discrete actions according with it. For dynamic VM consolidation procedure power aware best fit decreasing algorithm for the VM placement and for host under loading detection we used a static threshold algorithm. Anton et al. [12] Author proposed the energy efficient resource allocation policies based on QOS expectation and power usage characteristics of the devices. The problem of VM selection minimization of migration policy used, which provide better than other policy based on threshold policy. VM allocation provided by modified best fit decreasing which provide fist availability of resources and then optimize current VM allocation. Some open challenges for resource utilization provided network, CPU usage and based on thermal states. Simulation result provides minimize migration policy is better than any other policy.in this paper author discuss open challenges.

Rajkumar Buyya et al. [13] authorstudied optimal online deterministic algorithms and adaptive heuristics for energy and performance efficient dynamic consolidation of virtual machine in datacenters. First system model is represented for energy efficient data center.VM consolidation problem discussed for offline and online algorithm for single host and multiple hosts. Here, discussed system model for heterogeneous physical node which include power model, cost of live migration, and SLA violation metrics. Host overload detection include Median Absolute deviation, Local Regression, Static Threshold policy.VM selection include Minimization Co relation, Minimize migration Time and Random Choice Policy. VM placement is known as bin packing problem where bins represents physical machine. Best fit decreasing and power aware best fit deceasing use for resource allocation.The results of the experiments has shown that local regression based algorithm combined with minimum migration time policy as VM selection provide better results than the other policy.

D. *Vm Placement:*

VM placement can be seen as a bin packing problem with variable bin sizes and prices, where bins represent the physical nodes; items are the VMs that have to be allocated; bin sizes are the available CPU capacities of the nodes; and prices correspond to the power consumption by the nodes. As the bin packing problem is NP-hard, it is reasonable to apply a heuristic, such as the Best Fit Decreasing (BFD) algorithm, which has been shown to use no more than 11/9 OPT + 1 bins (where OPT is the number of bins provided by the optimal solution)[26].

Negin Kord et al. [14] Author presented energy efficient approach based on minimum correlation coefficient (MCC) for virtual machine placement in virtualizeddatacenters. This approach is related to service level agreement (SLA) and lower energy consumption using power aware best fit decreasing algorithm and minimum coefficient concept for VM assignment. Minimum correlation coefficient provides higher the correlation between the resource usages by application running on a host. Here VM selection performance based on fuzzy Analysis Hierarchy Process (AHP), which provide a good decision about selecting better host for VM placement. Power aware best fit decreasing algorithm used for the VM placement problem. Simulation results were compared with LR and MMT policy. This approach provides less energy consumption and SLA violation than the LR and MMT method.

Yongqiang Wu et al. [15] Author solved the VM placement problem to optimize the power consumption. Here, Author represents simulation annealing virtual machine placement algorithm based on simulation annealing theory. The proposed algorithm is potential to replace First Fit Decreasing or combine with FFD to generate a better VM placement. SAVPM algorithm works on temperature based parameter, which used random search method to choose PM solution until it finds suitable one for feasible solution. This algorithm provides better solution when capacity index is larger and search space is smaller. SAVMP can generate better VM assignment then FFD, with 0-25 % more energy saving FFD. This algorithm used to improve energy efficient in datacenters.

Xiao-Dong et al. [16] have proposed heuristics algorithm for virtual machine consolidation .Author used 0-1 knapsack problem as a variable size bin packing problem for virtual machine consolidation heuristics. This approach can reduce energy consumption of the entire system effectively.

Xin Li et al. [17] have proposedEnergy efficient Virtual machine placement based on EAGLE algorithm which is balance utilization of multidimensional resources and lowering down the number of running PMs. Author proposed a multi-dimensional space partition model, To characterize the multi-dimensional resource usage states of PMs, then set three domain (acceptance domain, forbidden domain, safety domain) of multidimensional partition model.EAGLE algorithm can save as much as 15% more energy than the first fit algorithm.

Eugen Feller et al. [18] author presented energy management algorithms and novel holistic energy aware VM management framework for private clouds. Virtual machine placement and dynamic scheduling algorithms proposed to reduce energy consumption by idle servers. This VM management mechanism is achievable energy saving highly depend on workload and datacentre size.

Tapio Pahikkala et al. [19] author proposed dynamically optimize the VM placement based on local agent's decisions. Author used reinforcement learning approach to optimize the VM placement based on local agents' decisions. The proposed dynamic consolidation method is able to reduce energy cost and SLA violation rate efficiently.

IV. CONCLUSION

After the comprehensive study of VM Consolidation for the datacenter we survey many techniques for overload/Underload detection, VM selection and VM placement. In this we found Machine learning techniques for overload detection, better decision making for VM selection and power aware best fit decreasing for VM placement as the maximum user satisfaction without increasing power consumption. Automatic virtual machine placement can be design to improve VM placement. Machine learning approach can explore the trade-off in power performance design space and conversing to a better power management policy. There are very a few research have done in multidimensional resource placement.

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