Power Efficient VM Placement and Consolidation for a Green Cloud Computing

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Abstract- *Power consumption has become an important research area as the use of cloud computing technology became more due to the ease of internet usage, processing and storage on cloud. Even small organisations started to use cloud solutions for their customers. This led to the growth of cloud computing techniques, also, to the growth of the data centers in cloud which resulted in significant amounts of drawbacks in the environment like carbon emissions. Virtualization technologies provide the ability to transfer virtual machines between the physical machines using live VM migration in cloud computing. Here Virtual machines are placed into the physical machines using Power Aware Best Fit Decreasing algorithm (PABFD) to minimise the power usage and also the VMs are further consolidated using dynamic VM consolidation technique that uses Metaheuristic Ant Colony System to minimize the number of active Physical machines. Thus minimising the power consumed by the physical machines in the data centers. The simulation results show that the proposed system results in better power conservation.*

Keywords- cloud computing, green cloud, virtualization, VM consolidation

I. INTRODUCTION

Cloud computing is an internet based on- demand computing, pay as you use model and accessing the computing resources of third parties. The Computing resources have become cheaper, powerful and ubiquitously available than ever before because of the rapid development in the processing and storage technologies and also the success of Internet. This led to the establishment of more data centers that have significant contribution in the energy consumed worldwide and consequently the environmental drawbacks like high carbon emissions.

The National Institute of Standards and Technology (NIST)[15] define Cloud Computingas follows:

"Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction". The cloud model has five essential characteristics**,** three service models, and four deployment models.

Cloud computing also has many challenges and some of them are mentioned below:

Challenges in cloud

- Automated service provisioning
- Virtual machine migration
- Server consolidation
- Traffic management and analysis
- Data security
- Storage technologies.

The term Green computing refers to foresee not only accomplishing the efficient processing and use of computing environment, but also reducing the energy consumption. The goal of being green is reducing carbon emission that causes global warming. The most important reason of Carbon di oxide emission is energy consumption, so reducing energy consumption not only means conserving more energy sources for the future use but also means reducing CO2 emissions which have significant environmental drawbacks.

Virtualization is a technique for converting the hardware resources into software resources. The virtual machine monitor (VMM)[5] has the ability to migrate a virtual machine from one host to another and performs the actual migration.

In this paper we have proposed one of the novel bin packing algorithms for efficient placement of VMs onto the Physical hosts. Power Aware Best Fit Decreasing algorithm (PABFD) is based on the best fit decreasing algorithm. Here the virtual machines are placed in the physical machines such that the power used by each physical machine to run the VMs is minimal. After the initial, power efficient placement of the virtual machines, the VM consolidation technique is applied to further improve the power conservation in the data centers i.e., minimise the number of active physical hosts and also to increase the resource utilization. Ant colony Optimization is used for the VM consolidation.

The remainder of the paper is organised as follows: section 2 discusses the literature survey of VM Placement and VM consolidation. Section 3 presents the proposed system model. Section 4 presents the results and section 5 discusses the conclusion and future works and section 6 is the references.

II. RELATED WORK

This section shows some of the existing work for energy conservation using live VM migration and consolidation techniques.

Makhlouf Hadji et al had proposed a novel and online linear programming algorithm based on b-matching theory[14] to solve the consolidation problem with negligible SLA violations. This paper focused on optimal and online repacking algorithm to reduce overall cost and to improve resource sharing and utilization and, also aims to find the optimal amount of resource pool to be used to handle the SLA violations which is described as the percentage of over-used servers. This problem can also be considered as a classical NP-Hard Virtual Machines placement problem in which, to meet the user's request we look for the number of servers to be used.

Live migration of VMs plays an imminent role in power conservation and this technique is one of the popular and widely used techniques. Li Y et al [12] focused on the VM placement selection of live migration for power saving. They presented a novel heuristic approach called PS-ABC[12].

Most of the workload consolidation approaches in practical until now are limited to a single resource (e.g., CPU) and rely on relatively simple greedy algorithms[13] such as First-Fit Decreasing (FFD), which perform resource-dissipative workload placement. Eugen Feller et al proposed a model in which the workload placement problem is considered as an instance of the multi-dimensional bin-packing (MDBP) problem and design a different, nature inspired algorithm based on the Ant Colony Optimization (ACO) meta-heuristic to figure the placements dynamically, according to the current load. This is the first work to apply Ant Colony Optimization on the MDBP problem in the context of dynamic workload placement and apply ACO in order to conserve energy.

Fthiagoko et al, focused on the problem[8] of an energy efficient initial VM placement, and described three new algorithms for the effective and efficient placement problem. An energy efficient VM placement aims at reducing the number of active servers, by increasing the workload among the current active machines. The approach used to place the Virtual Machines to the Physical machines must be careful not to overload a host, since it is imperative not to violate any Service-Level Agreements (SLAs) between the cloud provider and the client.

Xiao-Fang et al proposed an approach based on Ant Colony Optimization for efficient VM Placement namely ACO-VMC to efficiently use the physical resource and reduce the number of active physical servers. Initially the number of physical machines and virtual machines are same in number then the proposed algorithm ACO-VMC tries to reduce the physical servers one by one. The proposed VMP approach is formulated as a combinatorial optimization problem and is solved using Ant Colony Optimization. The main difference between other works from the proposed approach is that normally the pheromone is deposited between PMs and VMs but here the pheromone is deposited in between the VMs to find the possibility of placing them in a same server. But the heuristic value is considered between the VMs and physical servers. The heuristic value improves the algorithm further to place the VMs onto suitable physical servers.

Ant Colony Optimization (ACO) is one of the solutions for VM placement problem but may stop before getting an optimal solution when the number of VMs and PMs are more. GaochaoXu et alhad proposed distributed and parallel ACO algorithm[9] that is executed on several physical servers to get a better solution by increasing the iterative times for the large scale VMs live migration problem. A Distributed Parallel Ant Colony Optimization (DPACO) Algorithm of placement strategy for virtual machines Live Migration on cloud platform executes in two stages. It executes the ant colony optimization algorithm distributedly and parallellyon several selected physical hosts in the first stage. Then it continues to execute the second stage of ant colony optimization algorithm with solutions calculated by the first stage.

Not only the migration technique is applied for reducing the active physical servers by migrating VMs, the migration and consolidation techniques are also applied for scheduling and loadbalancing paradigms. Ghribi et al had proposed two exact allocation algorithm for energy efficient scheduling[10] of VMs. The authors combined the energy efficient VM allocation to the hosts with a consolidation algorithm and thus it is seen as a combined algorithm for saving energy. The migration algorithm is combined with the allocation algorithm to reduce the overall energy usage of the servers. The proposed algorithm acts as an energy aware VM scheduler. The VM migration algorithm here used is integer linear program (ILP) to achieve consolidation. The objective of the proposed migration algorithm is to migrate a VM from source node to the destination node to minimise the number of active nodes and increase the number of VMs handled by the active nodes. The algorithm not only reduces the power consumed by the data center but also reduces the power during migration. The main advantage of the proposed system is that is also gains energy at high load.

There are a number of ant algorithms like AS, MinMax AS, ACS, Continuous orthogonal ant colony (COAC), that has many applications including Traveling Salesman Problem, Quadratic Assignment Problem, Network Model Problem, Vehicle routing. Here the proposed system uses ACS (Ant Colony System) that has better performance in power saving and some other existing techniques for power conservation in data centers include [6], [7], [11], [18].

Also the initial VM placement to the physical machines is usually done using heuristic algorithms [8], [12], [16].

III. PROPOSED SYSTEM

The proposed system initially places the virtual machines using Power aware Best Fit Decreasing algorithm (PABFD) which is a variant of First Fit Decreasing algorithm. It is one of the novel bin packing algorithms. The algorithm is also known as Modified Best Fit decreasing algorithm and morerecently as power aware best fit decreasing algorithm.

The bin packing problem is a combinatorial NP-hard problem. In bin packing problems, the objects of different volumes must be packed into a finite number of bins of capacity M in such a way that minimizes the number of bins used. Most of the reliable bin packing algorithms use heuristics to accomplish results. This provides a solution, which, though very good in most cases, may not be the optimal solution. For example, the first fit algorithm provides a fast but often non-optimal solution, involving placing each item into the first bin in which it will fit. It requires (n log n) time, where n is the number of elements to be packed. Hence the proposed system uses a modified bin packing algorithm whose time complexity is (n*m) where n is the number of objects and m is the number of bins used.

Here the VM placement problem can be designed as a bin packing problem by considering Physical machines as bins and the VM's to be placed can be considered as objects to be filled in the bins.

While the algorithm itself is similar to FFD, the main difference is that PABFD calculates the increase in power consumption after the allocation of the current VM in each host in data center, storing the lowest increase in power consumption. The VM is then allocated to the host that had the lowest increase in power consumption.

There are many other heuristic algorithms in practice that are used for VM placements but the reason for using Power Aware BFD in the proposed system is that it allocates the VMs based on the power need for them to be processed by each PMs. In this way it is one step ahead of the other heuristic algorithms. This way is an advantage of the proposed system since the initial VM placement itself is energy effective.

The pseudocode of Power aware best fit search is as follows:

```
Input :  hostList, VMs
Output: VM Placement
vmList.sortDecreasingUtilization()
foreach vm in vmList do
minPower   MAX
allocatedHost   NULL
foreach host in hostList do
if host has enough resources for vm  then
power   estimatePower(host, vm)
if power < minPower then
allocatedHost   host
minPower   power
if allocatedHost = NULL then
allocation.add(vm, allocatedHost)
return allocation
```

Algorithm1: Power Aware Best Fit Decreasing For VM Placement

Due to varying workloads the initial efficient placement must be augmented with VM Consolidation technique since the resource utilization of a VM keeps on changing. Hence after the power efficient initial placement of VMs onto the Physical Machines, the Dynamic consolidation technique is applied periodically to further improve the decrease the power consumed by the physical servers. The dynamic consolidation of VMs is used to consolidate the virtual machines onto reduced number of active Physical Machines and thus minimising the amount of power consumed by the data center through switching off the unused servers. Here to consolidate the VMs, an optimal metaheuristic online algorithm namely Ant Colony System is used. The ant colony system is an NP hard problem and tries to get a near optimal solution for the VM placement. It is a reinforcement learning technique that modifies the problem representation at each iteration by iteratively adding solution components like Heuristic information also called heuristic value that gives a priori information about each instance or run time information provided by a source different from other ants. Most of the times it is the cost factor according to which the problem is designed and Trace/Pheromone trails are the long term memory about the entire ants traversal process and is updated by the ants themselves. The Ant Colony System is a well-known solution that is being used for more hard combinatorial problems. The proposed ACS-based VM Consolidation[5] (ACS-VMC) approach uses artificial ants for consolidating the VMs into a reduced number of active PMs according to the current resource needs so that power consumed by the idle machines can be reduced.

The ACO is a metaheuristic approach since it is inspired by the behavior of real ants. ACO is inspired from the social insects like ant colonies that work together in foraging behavior for solving hard combinatorial optimization problems. The ACO is a unique algorithm for many reasonslike the optimum solution is built not by a single entity but various entities, which traverse the length and breadth in all dimensions of the network and then these individually build upon a solution.

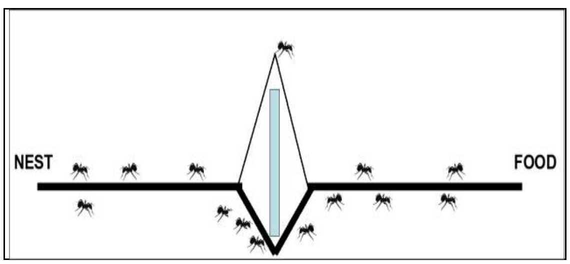

Fig. 1 Ant Colony System

While searching for food, the ants move in groups simultaneously searching the food in many different paths. Each ant deposits pheromone in its path so that the other ants follow it sensing that pheromone trails. The path which has high pheromone trail is the path which is used by other ants for communication and the ants always uses the path which has the shortest distance between its nest and the food source. The shortest path has more pheromone trails.

After the VMs placed into the PMs, the Virtual Machine Monitor (VMM) should select the physical machines that are to be migrated from one PM to another. There are three ways for finding the physical host that must be subjected to migration. They are periodic adaptation, threshold based, and decision making based on the historical data. The proposed system uses the second way i.e., the threshold based.

The VMs are migrated after their initial placements from a physical machine to another if they fall under any one of the following threshold levels.

Hot spots- the power consumed in a physical machine exceeds the upper threshold level so that some of its VMs can be migrated from it.

Cold spots- the physical machine utilization is below the lower threshold and hence its VMs can be migrated from it so, that physical machine can be put into sleep mode and thus providing a way for power conservation.

ACS based VM consolidation[5] doesn't only decrease the power consumed by the physical machines in the data centers, it also results in minimum number of VM migrations and reduced SLA violations.

The general pseudocode of Ant Colony System is as follows:

Input: a set of PMs and VMs
Output: reduced set of active PMs.
1. initialize pheromone trails
2. declare threshold values for nodes
3. ants move through nodes
4. if load<threshold
5. traverse to node with nearest maximum trailing pheromone
6. else
7. traverse to node with minimum foraging pheromone
8. reassign resources if node is needed.

Algorithm 2: Ant Colony System

ANT COLONY SYSTEM BASED VIRTUAL MACHINE CONSOLIDATION[5]

1. The PM where the VM resides is the source PM $p_{so}$and a VM can be migrated to any other PM.
2. Any other PM is a potential destination PM p_{de} to which a VM has been migrated.
3. The algorithm creates tuples consisting of the source PM pso, the VM to be migrated v, and the destination PM p_{de} t= (p_{so},v, p_{de}) (3.1)
4. There are two constraints while making a tuple
   1. Only a predicted overloaded, or an overloaded, or an under-loaded PM is used as a source PM p_{so} .
   2. None of the overloaded P_{over} and predicted overloaded $^{\wedge}P_{over}$ PMs become a destination PM p_{de} .
5. The objective function of the proposed algorithm is
   $f(M) = |ps|^{\gamma} + \frac{1}{|M|}$(3.2)
   where, M is the migration plan,
   P_s is set of PMs that will be switched to sleep mode
   γ determines implementation of $|p_s|$ with respect to |M|

6. When all VMs are migrated from a PM then that PM can be put into sleep mode.
7. When the migration plan is enforced it restricts reduced number of active PMs, it results in reduced underutilization of PMs.
8. A PM can only be switched to the sleep mode when all of its VMs migrate from it, that is, when the PM no longer hosts any VMs.

   $P_s = \{\square_p \in P \mid V_p = 0\}$ (3.3)

9. There will be no virtual machines being processing in a physical machine and it will be put into low power mode.
10. Each of the nA ants uses a stochastic state transition rule to choose the next tuple to traverse.

$$\Delta\tau_{ij}^{k} = \begin{cases} Q / LK, & if\ (i,j) \in path\ in\ list \\ 0 & , otherwise \end{cases} \quad (3.4)$$

11. The probability p_s of an ant k to choose tuple s to traverse next is defined as

$$p_{ij}^{k}(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha}\,[\eta_{ij}]^{\beta}}{\Sigma[\tau_{ik}(t)^{\alpha}\,[\eta_{ik}]^{\beta}} \end{cases} \quad (3.5)$$

12. The pheromone of each node is calculated as follows

$$\Delta\tau_{ij} := \Delta\tau_{ij} + \Delta\tau_{ij}^{k} \quad (3.6)$$

13. The heuristic value of a tuple s is defined as given below:

$$\eta_s = \begin{cases} (|C\,p_{de} - (U\,p_{de} + U_v)|_1)^{-1} & if\ (U\,p_{de}\,U_v) <= C\,p_{de} \\ 0, & else. \end{cases}$$

   It favours VM migrations that result in a reduced under-utilization of PMs. Furthermore, the constraint $(U\,p_{de} + U_v) <= Cp_{de}$ prevents migrations that would result in the overloading of the destination PM p_{de}. . U_{pde} denotes the utilization capacity of p_{de} and Uv denotes the utilized capacity in destination PM by a virtual machine v.

14. Local and Global migration evaporation rule are also applied at the end of each iteration.
15. Evaporation avoids unrestricted increase of the pheromone trails and enables the algorithm to forget bad decisions previously taken.
16. After evaporation, all ants deposit their pheromone trails on the arcs they have crossed in their tour.
17. Ants chooses shortest path because that path will have more pheromone traces.

IV. RESULTS

This paper clearly points out some of the shortcomings about the existing literature work for efficient VM Consolidation. The proposed approach when tested produces more optimal results. The proposed system is compared with the literature instances and it proves to be more efficient in VM Placements and thus reducing the power consumed by the VMs and also it further reduces the power consumed by the physical servers by consolidating the VMs and thus results in minimum number of active physical machines.

V. CONCLUSION AND FUTURE WORK

The proposed system places the virtual machines initially into the physical machines using PABFD that results in minimal power needed for each physical machine to process those assigned virtual machines. Further the physical machines that are active are reduced by migrating the virtual machines from one physical machine to other and consolidating them into reduced number of physical machines using Ant colony System thus, reducing the number of active machines. The idle machines are put into sleep mode and providing a way for power conservation.

Our future work is to compare and evaluate the proposed approach with many other heuristics algorithms both online and offline and also to use other techniques like Operating system migration, DVFS etc. for consolidation of Virtual Machines.

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