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Constraint Programming approach based Virtual Machine Placement Algorithm for Server Consolidation in Cloud data center

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Abstract **-**Server consolidation has recently become a major issue in cloud data centers. Energy efficiency is a key aspect in solving server consolidation issues. Virtual machine placement algorithms play an important role in maximizing the resource utilization may lead to energy efficiency. Constraint programming is an approach used to find the available servers and migrate these servers to the virtual machines by treating them as constraints to find optimal solution. The objective function of this work is to increase resource utilization by minimizing the number of active physical machines and decrease the search time of constraint solver for better energy efficiency. In this paper a Best Fit Resource Utilization (BFRU) algorithm is proposed for virtual machine placement, it use best fit algorithm technique. However, virtual machine placement problem is formulated as a variant of multidimensional bin packing problem and then a constraint solver is used to solve the problem using the dataset collected from Amazon EC2.The proposed BFRU algorithm implemented through NetBeans IDE to evaluate the data collected. The simulation result shows that constraint programming based virtual machine placement algorithm BFRU can effectively reduce the energy consumption with respect to memory.

Keywords- BFRU algorithm, Amazon EC2, Best Fit Resource Utilization (BFRU) algorithm

I. INTRODUCTION

Cloud computing is an on demand network access provisioned by the service provider and shared pool of configurable computing resources [1]. The main goal of cloud computing is to share the resources among cloud service customers, cloud partners and cloud vendors in cloud computing chain. The resources can be shared in various levels such as 1. IaaS (Infrastructure as a Service) for example hardware, IT infrastructure management, 2. SaaS (Software as a Service) for example traditional CRM as service, 3. Application cloud for example XML modeling as a service, social network as service, 4. Business cloud for example business process as a service.

By utilization of virtualization technology, cloud data center able to consolidate all kinds of computing resources [2]. In cloud data center the consolidated computing resources may became overloaded while other resources remain under utilized. To balance the use of resources may result in maximize use of physical servers, regarding this problem, choosing an appropriate virtual machine may lead to optimize resource utilization and energy consumption for cloud users[3-5]. The energy consumption of data centers increased by 56% worldwide from 2005-2010 which is accounts for 1.3% of total electricity use [6]. Moreover the energy consumption of datacenters is mainly due to low utilization of the physical machines [7]. For example the utilization of servers of Google's cluster is less than 50% on average [8]. Therefore it is important to utilize resources for energy efficiency. The major problem is to allocate resources like CPU capacity, RAM, storage to virtual machine, for this allocation a virtual machine placement algorithms are used. In virtual machine placement algorithm, for an efficient server consolidation of server depends on two ways of approaches, static and dynamic as follows. Static approach algorithms mainly do offline calculation, whereas dynamic approach algorithms implemented on time scales and do online virtual machine placement [9]. However, the virtual machine placement algorithm, Best Fit Resource Utilization is proposed based on constraint programming approach. In this algorithm virtual machine placement problem is defined as constraint satisfaction model. Finally the proposed algorithm is implemented using NetBeans IDE. This paper is organized as follows, section 2 discusses the related work, while section 3 defines the considered problem. Section 4 explains the system model and section 5 presents the details of proposed algorithm and section 6 presents the simulation setup and results obtained. Section 7 concludes this paper.

II. RELATED WORK

Recently, several methods have been proposed to solve problems of virtual machine placement by making resource utilization, energy consumption and migration costs.
Verma et al.[10] have proposed pMapper algorithm with a power-aware application placement controller for server

clusters in heterogeneous. pMapper explained heuristic method to address virtual machine placement problem. Moreover, the sizes of working set are considered while placing applications on physical machines.Wood et al.[11] presented Sandpiper, which automates the tasks of monitoring the cloud datacenters and capable of detecting overloaded virtual machines. The new mapping relations are determined by virtual machines and physical machines. Sandpiper implements a black-box approach. The Black-box approach is fully OS- and application dependent. Moreover the gray-box approach that can help to collect information from OS and application. The work has taken by platform management and virtualization management in datacenters.Kumar et al.[12] explained the solution that loosely couple platform and virtualization management in datacenters. In particularly, their algorithm with solution is designed as a stabilizer component. To prevent unnecessary virtual machine migrations, the migration decision is based on probability. In [13], Dhiman et al. present vGreen, a multitier software system for energy efficiency of virtual machines in virtualized clusters environment. The most important feature of vGreen is that it has scheduling policies and power management. The power management of virtual machine using novel hierarchical is capable for capturing energy consumption and performance characteristics of both virtual machines and physical machines. Used to handle local optimization problem of virtual machine placement in cloud datacenters. Rossi et al.[14] investigated global optimization technique and proposed Entropy resource manager for homogeneous clusters, This work depends on entropy, which utilizes constraint programming to perform dynamic virtual machine consolidation. However the focus on virtual machine placement problem occurred in initial plan stage, and implementation of virtual machine placement algorithm based on constraint programming in CloudSim.Campegiani et al.[15] presented a genetic algorithm to search the optimal allocation strategy of virtual machines and find unfeasible solutions. Therefore the placement of virtual machines is calculated by search time of the servers.Jing XU et al.[16] presented a two level control system with workloads. To find the mapping of workloads to virtual machines using genetic algorithm is proposed and virtual machines to physical resources mapping is done by using an improved genetic algorithm with fuzzy multi-objective evaluation.

III. PROBLEM FORMULATION

(i) Resource Utilization Problem

Consider a cloud data centers which provides the limited amount of physical resources such as CPU capacity, RAM and storage, since there are more number of request for resources ,the cloud service provider has to decide on how many number physical resources can be allocated based on cloud user request. By virtualization technology, the cloud data centers has its unlimited number of virtual resources, such resources are used to deploy newly created virtual machines for maximizing resource utilization. To formulate resource utilization in virtual machine problem, a set of virtual machines VM = {vm1,vm2….vm_i} and set of physical machines PM = { pm1,pm2….pm_j},Where each virtual machine vm_i represented by (CPU_i,RAM_i,$storage_i$),$1\leq i \leq n$ and physical machines are represented by (CPU_j,RAM_j,$storage_j$), $1 \leq j \leq n$, are used.

(ii) Constraint Programming Problem

Constraint programming is an efficient method for solving complex optimization problems, heuristic approach is used, and where it is dependent technique, not guarantee for finding optimal solution and try to find out the solution in short time period, these problems are represented by variables. Variables take the values from domains and constraints. Constraints need to identify the problem and solved by means of constraint solving techniques (CST). CST is defined by triplet [X,D,C],where X={x1,x2...xn} represents a set of variables, D={d1,d2….dn} represents a set of domains, C={c1,c2,…cn} represents a set of constraints.CST can be divided into two steps, first step is the virtual machine placement problem can be seen as a multidimensional bin packing problem with variable bin sizes, where bins represents the physical machines and the resources that are packed in virtual machines. The packed resources are of definite size and no change in space requirement, once the resources are placed therefore the unused space is waste. By using the virtual machine placement algorithm, the virtual machines may change their resource requirement depending upon the workload [17]. Therefore the wasted space can be utilized by the resources in virtual machine placement algorithm. The set of variables and constraints are used to represent the problem. Second step is to use the constraint to solve the problem.

IV. SYSTEM MODEL

(i) Energy Consumption Model

In a cloud datacenter, the main energy consumption derived from the computing nodes only [18] which usually determined by hardware efficiency. When Dynamic Voltage and Frequency Scaling (DVFS) is applied; the power consumption by servers can be accurately described by a linear relationship between the power consumption and CPU utilization [19-20]. In general, given a CPU utilization $u \in [0,1]$, let utilization of CPU $u(t)$ be the function of time t, the power consumed by the server can be denoted as:

$$E(u(t)) = E_s + E_d \cdot u(t)$$

where u is the percentage of CPU utilization, Es refers to static power consumption which is independent of workload. Ed refers to the dynamic power consumption [21]. For each $VM \in PM$,we define the CPU utilization of PMs as the ratio of the CPU resources allocated to the VMs to the total CPU capacity during the time slot *t* period as follow:

$$u_i(t) = \sum_{vm \in pm} VM^{cpu}(t) / Res^{cpu}$$

Given a Cluster with **N** PMs, the total energy consumed ***EC***can be expressed as:

$$EC = \sum_{i=1} \int_t E(u(t))\, dt$$

(ii) Resource Utility Model

Power consumption in heterogeneous systems depends greatly on the type of processors used in resources. Power efficiency reflects on how much useful work produced by the resources for a given power consumption, the higher CPU utilization of PM, the better power efficiency. The utility of resources is defined as below:

$$Res(x) = 2 / \; e - {}^{\alpha x} \; -1$$

where α is the parameter will affect the function sharpness and *x* is the normalized value which belongs to [0, 1].

V. PROPOSED ALGORITHM BEST FIT RESOURCE UTILIZATION (BFRU)

The proposed algorithm is best fit resource utilization (BFRU), this algorithm sort the incoming virtual machine list based on CPU capacity usage in descending order. Then initialize the placed physical machine as null. The physical machine checks for the availability of resources, in case of non availability of resources then the physical machine is placed on virtual machine, it is similar to best fit algorithm, the main difference is that BFRU calculates the increase in power consumption after the placement of the current virtual machine. The virtual machine is then placed to the physical machine that had the lowest increase in power consumption. Finally, the idle physical machine is suspended.The BFRU algorithm is modified from lines (12-17), consider that every physical machine placed are subject to new constraint solver that, calculates the power consumption after placement is used to solve the problem. This change has made the placement of a virtual machine in terms of energy consumption. The energy efficiency of virtual machine placement is divided into two sub problems. The fist one is to place the requested virtual machine on physical machine and the second one is to optimize the current placement. Whereas in this BFRU algorithm the both problems are rectified by placing the virtual machine and constraint programming techniques used to optimize the current placement.

Input: *hostList, vmList*
Output: CP based VMP

1 for each *host in host List* do
2 Assume *host* is suspended;
3 Sort *vmList(cpu)* in the order of decreasing utilization;
4 for each *vm in vmList* do
5 *min Power*←∞;
6 *placed Host* ← *Null*;
7 for each hosts *in host List* do
8 if *host has enough resources for vm* then
9 if *host is suspended* then
10 hosts *was Suspended* ← *True*;
11 Assume Wake-on-Lan on *host*;
12 *power* ← *estimate Increase In Power*(*host, vm(cpu)*);
13 if *host Was Suspended* = *True* then
14 Assume *host* is suspended;
15 if *power* < *minPower* then
16 *place the Host* ← *host*;
17 *minPower* ← *power*;
18 if *placed Host* = *Null* then
19 Place *vm* in *host*;
20 for each *host in hostList* do
21 if *host has not placed in vm* then
22 Suspend *host*

Algorithm: Best Fit Resource Utilization

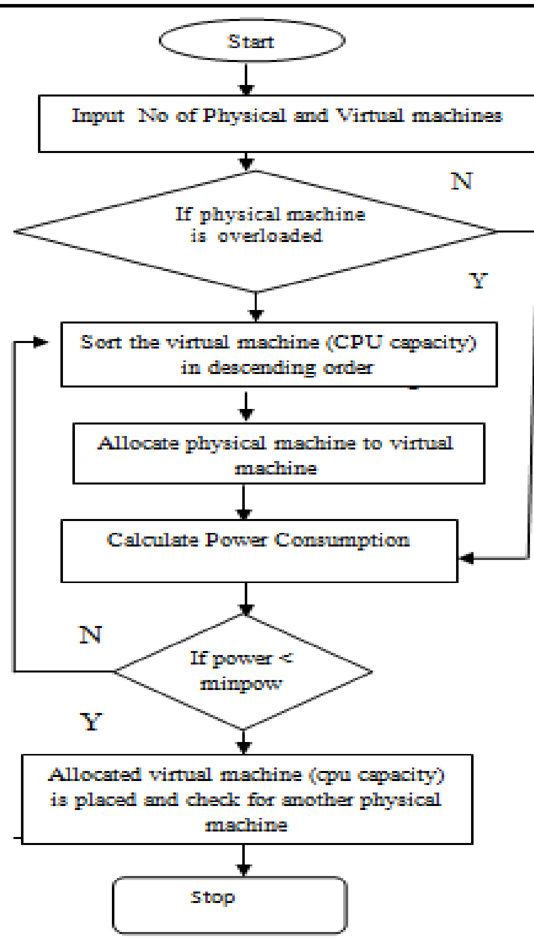

Fig 1: Flowchart of proposed algorithm BFRU

The Fig 1: shows the process of research framework. In this framework, the BFRU algorithm is used to identify whether the physical machine is overloaded, if it is false then, it calculates the power consumption with a constraint defines the power is less than minimum power then allocated the virtual machine resource(CPU capacity) is placed otherwise virtual machine resource is sorted in descending order. The top most physical machine is allocated to the virtual machine. Then it calculates the power consumption, if power is less the virtual machine is placed. Therefore the number of physical machine and virtual machine is used as input and allocated physical machine is placed with virtual machine is an output.

VI. SIMULATION SETUP AND RESULT

In order to illustrate and validate the proposed algorithm BFRU, some simulation experiments which shows how the virtual machines and physical machines are placed with the resources and the power consumption is calculated by the servers and resource utilization. For the simulation experiment the open source integrated development environment NetBeans IDE is used to evaluate the increase in resource utilization by minimizing the number of active physical machines and decreasing the search time using constraints for power consumption. The dataset considered for the resource requirement of virtual machine request is equal to one of virtual machine instance type provided by the Amazon EC2[22]. The dataset used to know the exact resource placement of the virtual machines across different type of resources and six virtual machine instance type is in the form of deployment request for resource (cpu capacity). Consider the size of physical machine as nine, which has nine items and the above mentioned virtual machine instance type of six machines with resources mentioned in Table I is taken to verify the constraint programming virtual machine BRFU algorithm that can be effectively reduce the number of physical machines used.

Table I : Resource Dataset from AmazonEC2

Virtual machine instance type	CPU Capacity	RAM	Storage
VM-1:Small	1	1.7	160
VM-2 :Medium	2	3.75	410
VM-3 :Large	4	7.5	840
VM-4 :Xlarge	8	15.0	1680
VM-5 :High-CPU	20	7.0	1680
VM-6 :High Memory	13	34.2	850

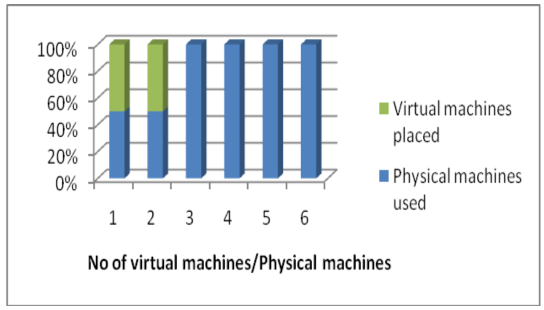

Fig 2: Number of virtual machines/physical machines placed using algorithm BFRU

Throughout experiments a machine with Intel(R) Core™ 2 Duo CPU E4500 @ 2.20 and 3 GB memory is installed with NetBeans IDE. Consider the datacenter consist of six numbers of physical machines with CPU capacity and six numbers of virtual machines with CPU capacity are shown in Fig 2. The BFRU algorithm takes the input as the number of virtual machines as six, the CPU capacity of the virtual machine taken from the Amazon EC2 dataset. As per algorithm the data is arranged in descending order and topmost CPU capacity is placed, then the power consumption is calculated by search time of constraint solver as 22ms. Therefore the maximum resource utilization virtual machines from physical machines may lead to energy efficiency.

VII. CONCLUSION

This study has focused the problem of virtual machine placement in datacenters .The implementation of virtual machine placement algorithm with constraint programming approach in NetBeans IDE is an challenging aspect. The virtual machine placement algorithm BFRU is proposed and constraint solver is used solve the problem to minimize number of active physical machines. Experimental results shows that, constraint programming-based virtual machine placement algorithm increase resource utilization and decrease the search time of constraint solver for better energy efficiency.

As a future work, we are planning to study how to apply virtual machine placement algorithms for virtual machine live migration technologies with dynamic peak workloads.

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