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Solve the Packing Problem of Virtual Machine Placement based on PSO algorithm

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ABSTRACT: *Cloud computing offers utility-oriented IT services to users worldwide, and has recently emerged as a highly successful alternative IT paradigm. Using virtualization technology is a key to share resource in data center. As virtual machine (VM) is hosted on physical Machine, great energy is consumed by maintaining the Physical machine in data center. More physical Machines mean more energy consumption and cost. Therefore, the primary problem being virtual machine placement (VMP), which is to choose a proper physical machine (PM) to deploy virtual machines (VMs) in runtime, in this way, several studies have been presented in order to propose some methods to solve this problem. In this paper, we present an approach to solve VMP for that a 2-dimensional mathematical model for bin packing problems is formulated, this refers to renting the Virtual machine to the smallest number the physical machine, to minimize the bins used and to balance the load of each bin. Then propose a modification of practical swarm optimization algorithm to find the best solution, and generate result with Workspace Eclipse SDK and Microsoft Excel.*

Keywords:*Bin packing, Cloud computing, Virtualization, Virtual machine placement, Particle swarm optimization.*

1. INTRODUCTION

Energy consumption is one of the most important practical and timely problem associated with data centers for cloud computing. Rapidly growing with the goal of providing virtually infinite amount of computing, storage, and communication resources where customers are provisioned these resources according to their demands as a pay-per-use business model [1]. There are different cloud systems available like sharing the infrastructure [Iaas], sharing the Software [Saas] and sharing the Hardware/platform [Paas] resources. These services are available through virtualization techniques. Virtual machines are connected with physical machines that are operated by cloud provider.To meet the rapid growth of customer demands for computing power, cloud providers such as Amazon and Google are deploying large number of planet-scale power-hungry data centers across the world, even comprising more than 1 million servers [2]. A report show that energy is one of the critical TCO (Total Cost of Ownership) variables in managing a data center, and servers and data equipment account for 55% of energy used by data centers [3].

Inefficient use of energy is one of the key factors for the extremely high energy consumption: in traditional data centers, on average servers operate only at 10-15% of their full capacity most of the time, leading to expenses on over-provisioning of resources [4]. As we know virtualization allows provide multiple virtual machines (VMs) to share resources on a physical machine (PM) trough VM monitor or hypervisor, each of which acts like a real computer with an operating system, are created on underlying physical machines (PMs). In addition, the basic key issue in server virtualization is virtual machine placement (VMP), which is to select some suitable PM to deploy each newly-created VM in runtime. Virtual machine placement (VMP) is a primary problem, one important concern during the virtual machine placement process is reducing energy consumption caused by the running PMs.

Based on data collected from Google's data centers, Barroso et al argued in [5] that the energy cost of a physical server increases nearly linearly with its increased CPU load. Furthermore, the CPU utilization level for thousands of servers was found to be between 10 and 50 percent of their maximum utilization most of the time. Obviously, a very simple scheduling strategy to solve the VMP problem is a random placement strategy. However, such a strategy may not obtain promising solutions. In the literatures, many works have been conducted to solve the VMP problem. In this paper, the VM placement problem is taking as a NP-hard problem; and presented in our approach as a bin packing problem, we present a suitable physical server as bins with capacity constraint CPUs and Memory; and the Virtual machine (items) the objects must be packed to bins without exceeding the capacity, defined vector with the same constraint (CPU and memory) demand. Despite the fact that the bin packing problem has an NP-hard, optimal solution of the problem is not guarantee. Many heuristics have been developed: for example, the first fit algorithm provides a fast but often non-optimal solution; the first-fit decreasing algorithm can be made much more effective by first sorting the list of elements into decreasing order, although this still does not guarantee an optimal solution. Concern this paper we are going to modifier an algorithm Particle swarm optimization (PSO) to solve our optimization problem.

The remainder of this paper is organized as follows: Section 2 presents review of other related work, proposes algorithm and methods. Section 3 the problem formulation. Section 4 our approach modeling and Algorithm propose; and section 5 the simulation result. Finally, in section 6 conclusion and future work are presented.

2. RELATED WORK

In this section, present a briefly review previous works related to this work, namely Virtual machine placement problem to minimize power consumption by physical machine in data center. In recent years, there have been major significant researches in data center energy efficiency.

One of the first works, in which power management has been applied at the data center level, has been done by Pinheiro et al. [6]. In this work the authors have proposed a technique for minimization of power consumption in a heterogeneous cluster of computing nodes serving multiple web-applications. The main technique applied to minimize power consumption is concentrating the workload to the minimum of physical nodes and switching idle nodes off. The proposed algorithm periodically monitors the load of resources (CPU, disk storage and network interface), compare to our case we only considering (CPU and memory). As virtualization is an important technology in cloud computing, the VM placement (VMP) problem has become a significant research topic in cloud computing. VMP is to find an optimal map to place the VMs to physical servers so as to make the cloud resources used efficiently [7].

Therefore, the most of those literatures focus on the CPU as the most critical resource and characterize PMs in terms of their CPU capacity and VMs in terms of their CPU load [8, 9, 10, 11, 12, and 13]. On the other hand, some study makes the problem multi-dimensional by also considering some other resource types like memory and I/O [14, 15, 16, and 17].

In [8], the authors have applied a heuristic for the bin packing problem with variable bin sizes and costs, on the contrary to our approach; the bins have capacity constraints such as CPU and memory. Optimal bin packing one of the classic NP-complete problems (Garey & Johnson 1979). The vast majority of the literature on this problem concerns polynomial-time approximation algorithms, such as first-fit and best-fit decreasing, and the quality of the solutions they compute, rather than optimal solutions. As the objective the paper concentrate in power consumption, minimizing energy consumption is a central objective in most literature, however, there are differences in the level of detail that energy consumption is modeled with. Several works consider the number of active PMs as an indication of energy consumption [18, 11, 19, and 13].Beyond energy consumption, a further objective in some works is to minimize the number of overloaded PMs because of the performance degradation that results from overloads [20, 10, 11, and 13]. Some works also considered the cost of migration of VMs [10, 21, and 20].

In this context, for solving the problem some algorithmic techniques has proposed, some works suggested exact methods but the majority applied heuristics. The proposed exact methods rely almost always on some form of mathematic programming (e.g., integer linear programming) and appropriate solvers [22-48]. Unfortunately, these approaches are not able to solve the practical problem sizes. Many different heuristics have been proposed from simple greedy algorithms to evolutionary methods. As already mentioned in section-3, the VM placement optimization problem is closely related to bin packing as it presented in this paper.Accordingly, several researchers have suggested adapting such packing heuristics to the more complex VM placement optimization problem [23, 20, 11, 17, and 13].

3. PROBLEM FORMULATION

The proposal aims to reduce power utilization in data centers. As there is a mathematical model available in pervious literature for bin packing problems; in this section; we introduce problem formulation and present an architecture design for VM placement in Section 3-1.

3-1. Problem formulation

In a cloud environment, a large number of physical servers are connected through a communication network. The physical machines are virtualized and all applications are running on the VMs. The VMP problem is to maps VMs to server nodes, which is similar to the bin packing problems. The physical server represents the bins and VMs represent the items to be packed. Each machine (bin) has capacity constraints of different resources it can supply, such as CPU and memory. A Virtual Machine (item) is defined as a vector with CPU and memory resources demand.

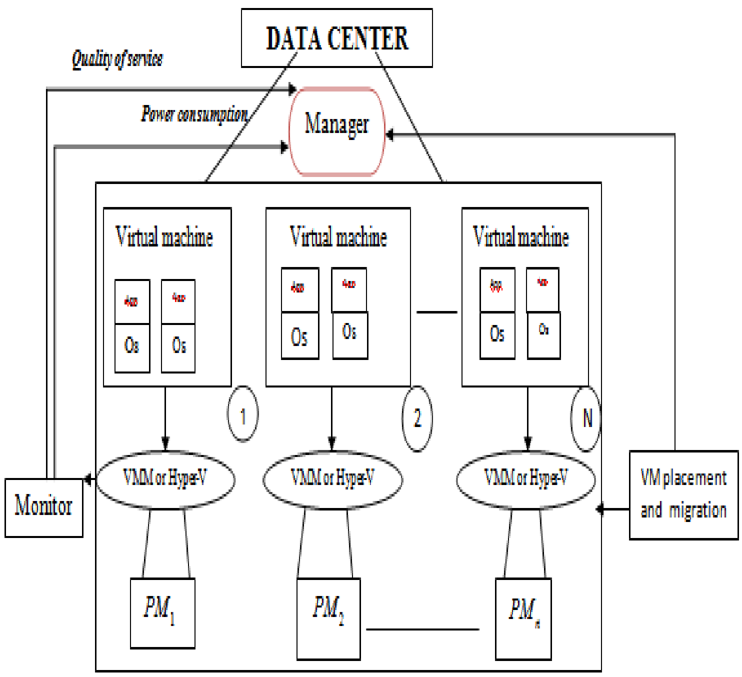

Figure 1;an architecture design for Virtual machine placement in cloud data centerscenario to optimize energy

Suppose that we are given a set of M physical machine denoted as I , and a set of N VMs denoted as J . Both physical server and VM are defined as 2-dimensional vector. Each dimension represents a kind of resource. For simplicity, we consider only CPU resource and memory resource in this paper. Each physical machine $i\left(1 \le i \le S\right)$ has CPU capacity PC_i and memory capacity PM_i . Each VM $j\left(1 \le j \le N\right)$ has its CPU demand VC_j and memory demand VM_j . We assume that the resources demand of each VM is less than the resources that a physical server can supply. The formulation of the VMP problem is as [22].

$$Minimize(z) = \sum_{i=0}^{M} y_i \tag{3.1}$$

Subject to:

$$y_i = \sum\nolimits_{j=1}^{N} x_{ij}, \forall i \in I \tag{3.2}$$

$$\sum\nolimits_{i=0}^{M} x_{ij}, \forall i \in I \tag{3.3}$$

$$\sum\nolimits_{j=1}^{N} VC_j x_{ij} \le PC_i, \forall i \in I \tag{3.4}$$

$$\sum\nolimits_{J=1}^{N} VM_j x_{ij} \le PM_i, \forall i \in I \tag{3.5}$$

$$x_{ij} \in \{0,1\}, \forall i \in I \text{ And } j \in J \tag{3.6}$$

Eq. (3.2) shows that whether a physical machine is used $y_i = 0$ or not $\left(y_i = 0\right)$.Constraint (3.3) shows that a VM is assigned to only one of the physical machine. The capacity constraint of the physical machine is described in constraint (3.4) and (3.5) for the CPU and memory respectively. Constraint (3.6) defines the placement information of physical machine i and VM j , $x_{ij} = 1$ means VM j is placed on physical machine i while $x_{ij} = 0$ means not.

4. VIRTUAL MACHINE PLACEMENT APPROACH & SYSTEM MODELS

In this section, we introduce Particle Swarm Optimization (PSO) approach for minimizing the Energy consumption for VMs placement. We present the construction of solution and the pseudo code will be presented.

PSO is a random search algorithm that is based on swarm intelligence and was first introduced by Kennedy and Eberhart in 1995 [25]. PSO shares many similarities with evolutionary computation techniques such as genetic algorithms (GA) (it is an adaptive heuristic search algorithm premised on the evolutionary ideas of natural selection and genetics) [26]. Compared to GAs, the advantages of PSO are that it is easy to implement and there are few parameters to adjust. Moreover, in terms of the computational efficiency, the superiority of the PSO over the GA has been statistically proven with a 99% confidence level [27]. Compared with other similar optimization algorithms, PSOs have such advantages as a faster execution and higher efficiency of problem-solving. In most cases, PSO outperforms the Branch and Bound algorithm, which is a general algorithm for finding optimal solutions of various optimization problems, especially in discrete and combinatorial optimization [28]. Thus, the PSO has been successfully applied in many areas, such as function optimization, artificial neural network training and fuzzy systems control.

From the previous section, we show that the PSO is a good algorithm for solving optimization problems in many areas. Thus, we will also attempt to use it for solving the Energy reducing virtual machine placement optimization problem.

To apply a PSO to our study, the PSO must have several advancements. The apprehension are as follows:

- ✓ PSO algorithm is proper only for solving a continuous optimization problem and is not adopted to solve a discrete optimization problem, which means that the parameters and operators of the PSO must be redefined.

And

- ✓ Applying the PSO to solve the virtual machine placement problem, the position update strategy and the coding scheme must be adjusted. Thus, in this paper, we adopt the improved PSO as the key to our approach to solve the energy-aware virtual machine placement optimization problem.

How can we improve the PSO and use to reduce the energy?

4-1: Particle Swarm Optimization

PSO emerged as a powerful family of optimization techniques. Every individual of the swarm is called a particle and represents a feasible solution of the problem. Every particle has two parameters, i.e., the velocity and position. Every particle position is associated with a fitness value, which is used to evaluate the quality of the solution. The PSO begins by initializing randomly each particle, and then, it finds the optimal solution by performing iterations. It imitates the interactive behavior of birds flocking around food sources. Every particle flies in the multi-dimension search space at a specified velocity while referring to the local best position $Pbest$ and the global best position $Gbest$, and then, it updates its velocity and position by the following equation:

$$v_{i+1} = \omega V_i + c_1 r_1 (pbest_i - X_i) + c_2 r_2 (gbest - X_i) \quad (4.1)$$

$$X_{i+1} = X_i + v_{i+1} \quad (4.2)$$

Where V_i and V_{i+1} are the velocity before the update and theupdated velocity, respectively; and X_i and X_{i+1} are the position before the update and the updated position, respectively. Here, w is called the inertia weight coefficient, which represents the inheritance of the current velocity of the particle and can balance the local and global search capability of the particles; c_1 and c_2 are called learning factors, which enable the individual to have the ability to learn; and r_1 and r_2 are random numbers that are between 0 and 1.

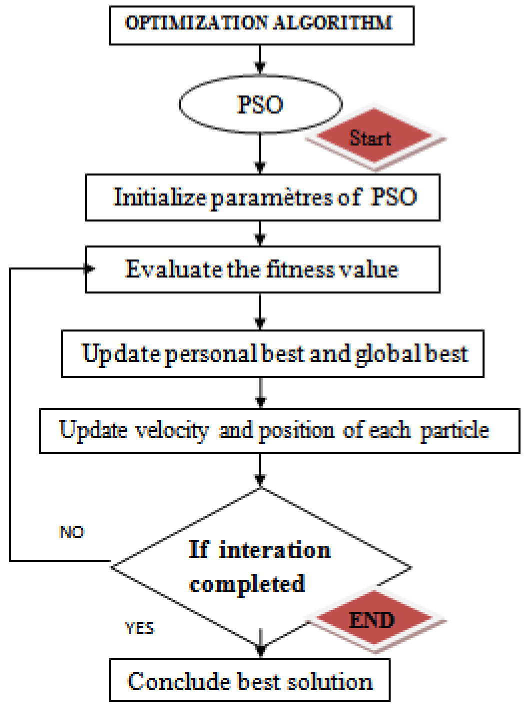

Fig. 3: General principle of PSO.

4-2. POWER CONSUMPTION MODELS

The energy consumption of servers depends on the comprehensive utilization of a CPU, memory, disk and network card. It is well known that, among the above factors, the CPU is the most important energy consumption component. Therefore, the resource utilization of a server is usually represented by its CPU utilization [29, 30]. As we mentioned in the previews section, the following formula to describe the consumption of a physical machine in the data center: The power function is show in eq (4.1) and previous proposed in work [24].

$$Power_i = P_{idle} + (P_{busy} - P_{idle}) * U_i \qquad (4.3)$$

Where, $Power_i$ refers to the energy consumption of a physical host or server, and P_{idle} refers to the physical machine not used but in run mode and the P_{busy} can be set as busy physical machine. U_i Represent the CPU capacity. This formula obtains the energy consumption of the physical host, and calculates the energy consumption of data center.

Minimizing energy consumption is one of the objectives of multi-objective optimization problem in this paper. we can look at a two-dimensional bin packing problem (BPP), a cloud computing center, whose physical hosts include $PM = \{pm_1, pm_2, ..., pm_m\}$, $i = 1, 2, ..., m$ can be considered as M a different large box, each big box contains the CPU, memory two-attribute vector; user-requested virtual machines, including $VM = \{vm_1, vm_2, ..., vm_n\}$, $j = 1, 2, ..., n$; considered N a different item, each item contains two properties : CPU, a vector of memory two properties.

According to the problem, we get the fitness function as follows:

$$F_i = (k_1 \sum_{j=0}^{m_{host}} f_{power} + k_2 \sum_{j=0}^{m_{host}} f_{resource}) / m_{host} \quad (4.4)$$

Where, m_{host} represents the number of target host in the i^{th} VM collection, k_1 isthe weight of CPU influential factor in the formula and $k_1 \gg k_2$, because the average electricity power consumption in CPU is bigger than the memory k_2, we can consider that k_2 can be ignored.

In this paper, we are modeling a heterogeneous virtualized data center that is composed of m servers that host a set of n virtual machines. A cloud provider is often implemented as a virtual machine that is deployed to a server while satisfying its specified resource (i.e., in our case CPU and memory). The optimization objective of the virtual machine placement is to minimize the total power consumption in an optimization period while satisfying the resource requirements. In other study, if the requested maximum resources of the virtual machine are allocated, then the cloud service can run on this virtual machine with good performance [31].

4-2. MODIFICATION PSO FOR VIRTUAL MACHINE PLACEMENT OPTIMIZATION

Based on the modification, we can obtain the best virtual machine placement by following the nine steps.

The algorithm is described as follows:

Step 1: Repeatedly collecting the continuously arrived virtual machine requests and set of physical machines as the input of our proposed approach.

Step 2**:** Initialization particle populations.

- ✓ The particle population size is set to be N, and the maximum iteration number is set to be $V_{\max}$.
- ✓ Set up the initial population. The current virtual machine collection is recorded as $(Vm_j^J, ..., Vm_j^J)_j$ it means that the j^{th} virtual machine request set, $J_j - \dim ensional$ virtual machine request, the initial particle population size denoted as **N**. Each particle is a $J_i - \dim ensional$ vector with the value of each dimension ranging from 1 to n as $X_i = (x_1, x_2, ..., x_i)$. The particle's initial position is determined by the initial population, and then, the particle's initial velocity is determined by the status information of the particle's first dimension. Iterative operation of particle swarm optimization is started.

Step 3 : By calculating the fitness of all of the particles in the initial population, we obtain the local best position of every particle and further obtain the global best position of the population, and the fitness value is calculated by the formula (4.2).

Step 4: Until the current iteration, the j^{th} particle finds its local optimal position $pbest_i$ and get its current position X_i, and at the same time, it can get the current global optimal position, select the global optimal value $gbest$ from the local optimal position.

Step 5: In this step, we are going to update the velocity of each particle in eq (4.3), and the current position show up in eq (4.4).

Step 6: Updating the local best and global best particle position information based on the updated new population.

Step 7: Go to Step 3 when the current iteration number is less than the specified maximum iteration number $V_{\max}$, or go to Step 8.

Step 8: Output the global best position and its fitness, and then, obtain the optimal solution for the energy-aware virtual machine placement problem.

Step 9: All of the virtual machine requests are placed on the current physical machine, and the approach ends.

Virtual Machine Placement Algorithm:

Our algorithm named Virtual Machine Placement Algorithm which has goal to reduce the energy.

PSEUDO: VMP Algorithm
1.**INPUT**: PMList m, VMList n 2.**OUTPUT**: HostVMs-to-PMs 3.**Initialization** *Step 1*: v Particle velocity *Step 2*:n Size of VMList and m Find out PMList count *Step 3*: InitialVMstoPMs *Step 4*: PM's cpu utilization (initial)and PM's energy consumption (initial) *Step 5*: Initial $pbest[\ ]$ and $gbest$ *Step 6*:FitnessFunction () 4.**PSO algorithm to calculate** *Step 1*:Update speed and location *Step 2*:Cross-border judge *Step 3*:Recalculate the cpu utilization, energy consumption as well the fitness Function *Step 4*:Update $pbest$ and $gbest$ *Step 5*:Record the current position and speed *Step 6*: Iteration repeat Step 1 to Step 5 5. end

Fig. 2: Pseudo-code for hosting the VM to PM in Virtual Machine Placement scenario

Table 1. Parameter settings used by modification-PSO in the simulation

The number of PM (m)	10
The number of VM (n)	50
Default Intertie coefficient (w)	1
Personal and Social acceleration coefficient (c_1)	2
Prevent falling into a local minimum (c_2)	0
Individual extreme	$Pbest$
Global maximum	$Gbest$
Maximum speed ($V_{\max}$)	9
The maximum number of iterations ($G_{\max}$)	100
The current positions of the particle	X
The objective function	Z
Physical machine's energy consumption function	$P[\ ]$
Idle energy consumption ($Pidle$)	56
Full load of energy consumption ($Pbusy$)	80
CPU utilization	$U[\ ]$

5. EXPERIMENTS AND COMPARISONS

To evaluate the performance of our proposed approach in this paper, we compare it with other approaches in terms of the energy consumption. Moreover, we also evaluate the scalability of our proposed approach.

5-1. Experiment process

In the process of simulation, we simulate a heterogeneous virtualized data center that contains 50 virtual machines (VMs) and 10 physical machines (PMs). As shown in Table II, the parameters of resource requests for each virtual machine and physical machines to runs a cloud service/application.

Moreover, Program source code of particle swarm optimization (PSO) is written by JAVA code, and compilation and simulation are completed under Workspace Eclipse SDK [32]. The paper adopts the task graph needed for the experiment and is generated randomly from self-compiled program. The performance of solution is examined on various instances, the BPP-2D problem describe in **Section 3-A-1**; the detail of parameter setting of the PSO is show in **Table 1.**

All of the experiments are conducted on the same computer, with an Intel Core i5-4210U 1.7 GHz with Turbo Boost up to 2.7 GHz processor, 6 GB of RAM, Windows 10 Pro. We compare this approach with the approach (called First-fit) in [33] is very straightforward greedy approximation algorithms and other PSO approach [34].

Table 2. PM and VM Configuration

	CPU	Memory
Physical machine	**12 Core**	**64Mb**
Virtual machine	**1 Core or 2 Core**	**4MB**

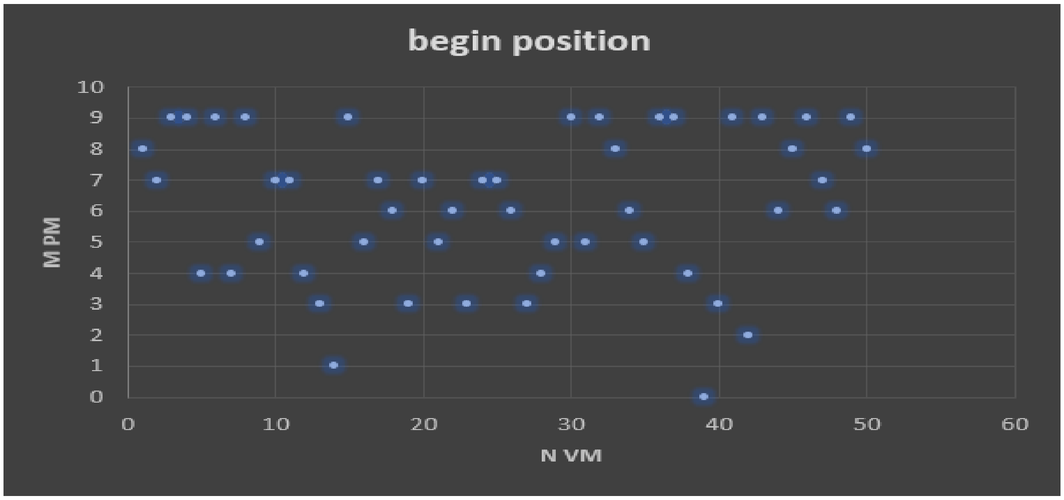

Figure 4: The beginning positions of each particle are randomly position

After the PSO run, each particle is moving to find the best solution in search space according their current position, ***figure 4*** the virtual machines are randomly allocated in to physical and show the beginning position of each particle.

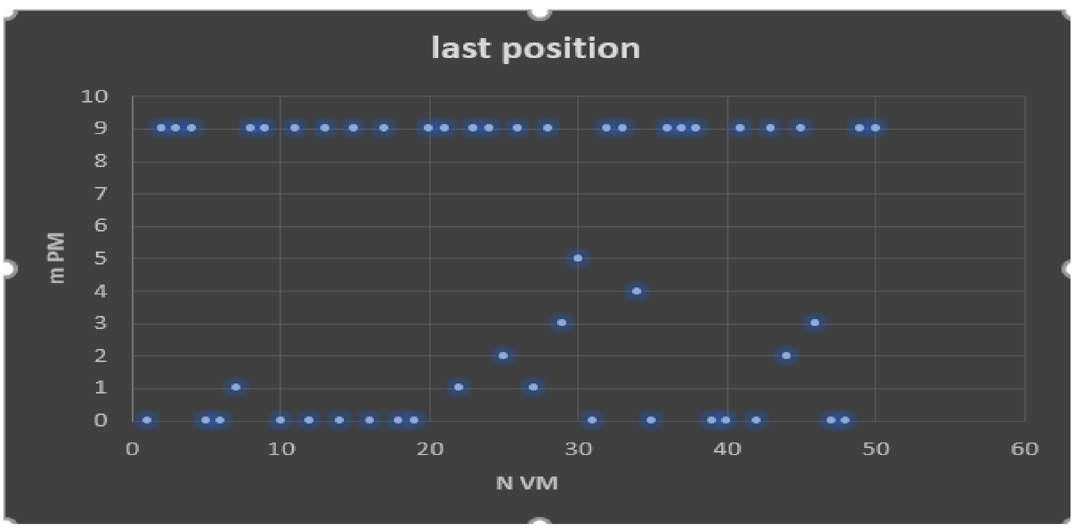

Figure 5. The last position for each particle after the PSO run

As can be seen from the ***figure 5***; after 100 iterations. VM distribution more concentrated; below we give the line chart of the objective function and the *Gbest* during PSO operation.

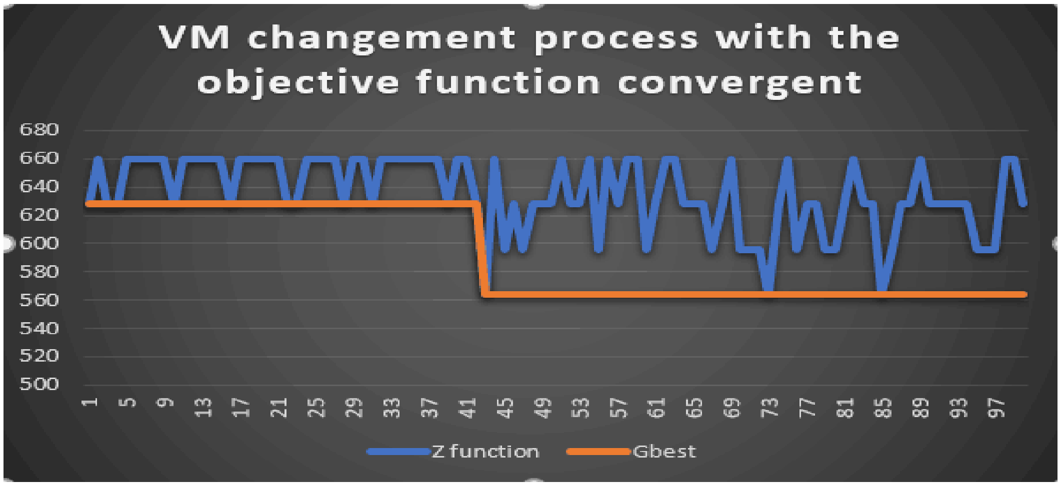

Figure 6. VM process with the objective function convergent

From the figure 6 above, we can see that the function converges after 41 iterations, at which point the objective function reaches the minimum, and the position information of the virtual machine at this moment is obtained.

5.2. Advantages and Disadvantages

In our model as all other model construction have advantage and disadvantage, the fellow point seen the details:

Advantage:

- ✓ Easy to implement, high precision, fast convergence
- ✓ Let C2 = 0 avoid falling into the local optimal solution

Disadvantage:

- ✓ Discrete optimization problems are poorly handled, easy to fall into the local optimum
- ✓ Some parameters of the objective function are given qualitatively

5-2. Comparison Results on Energy Consumption

In this paper, the energy consumption is the total power consumption of all of the active machine, we consider in our case all the physical machines are active. Because the power consumption is demonstrated in function **Eq. (4.1),** the energy consumption must be calculated using the definite integral. In our approach function is linearly related and used to calculate the definite integral to obtain the total energy consumption value. As shown in **Fig. 3**, we give the comparison results.

Our ***figure 6*** indicates that our proposed approach enables the data center operators to save more energy than other approaches. Compared with the other two approaches, our approach can save approximately 14% to 33% on the energy bill.

Why is our approach better than other approaches? Because the FF lack global information (i.e., the energy consumption characteristics of the heterogeneous servers in the virtualized data center), they only account for the multi-dimensional resource constraints and do not consider the energy difference of the different servers in the problem-solving process; and other PSO approach [33]algorithm although convergence speed but easy to fall into the local minimum, in other words may lead to training failure. But our PSO algorithm solves this problem. We consider that there is no exchange of information between the virtual machines, so the entire population is equivalent to blind random search of multiple particles, although the convergence speed may be slower. However, we avoid falling into local minimum, so we can find the minimum energy consumption. So, our PSO algorithm activates as few servers as possible and reduces the overall energy consumption of virtualized data centers.

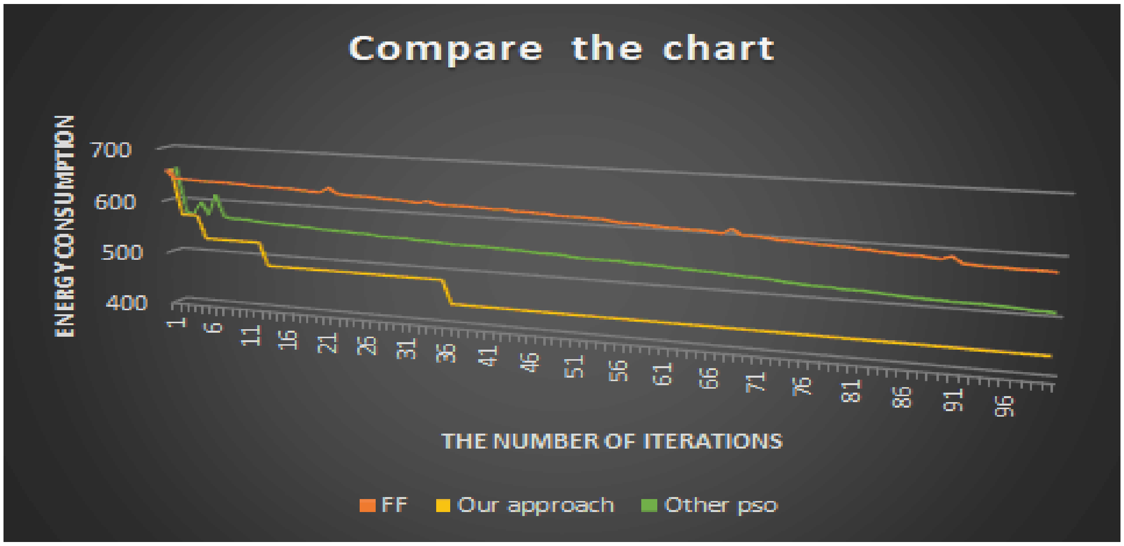

Figure 7. Total of energy consumption

6. CONCLUSION & FUTUR WORK

The paper we studied energy optimization in data centers, and a brief introduction into basic and relevant knowledge about Virtual machine placement has been presented, the high cost of energy consumption cost for running server, it's essential to efficiently assign VM to physical servers and improve the resource utilization. we propose a modification an algorithm based on Particle swarm optimization for minimizing the Energy consume by servers used cause of the server idle or uncharged consume 70% of energy, so the after a good virtual machine placement the server consume less Energy than before about 14% to 33% decrease.

Apart from saving the cost by good mapping the VM to the Physical machines, the resources of Physical machines are properly used. Future this article wasn't the first to solution for this problem, other research has been done previously, and most of the them are focus on Energy consume buy the Physical machine in run time, but negligent the process of the case PM idle.

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