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Resource Optimization in Cloud Data Centers Using Particle Swarm Optimization

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ABSTRACT

To meet the ever-growing demand for computational resources, it is mandatory to have the best resource allocation algorithm. In this paper, particle swarm optimization (PSO) algorithm is used to address the resource optimization problem. Particle swarm optimization is suitable for continuous data optimization. To use in discrete data as in the case of virtual machine placement, we need to fine-tune some of the parameters in particle swarm optimization. The virtual machine placement problem is addressed by the authors' proposed model called improved particle swarm optimization (IM-PSO), where the main aim is to maximize the utilization of resources in the cloud datacenter. The obtained results show that the proposed algorithm provides an optimized solution when compared to the existing algorithms.

KEYWORDS

Cloud Computing, Datacenter, Nature-Inspired Algorithms, Particle Swarm Optimization, Resource Utilization, Swarm Intelligence, Virtual Machine Optimization

INTRODUCTION

Cloud computing is a paradigm where the IT requirements are fulfilled on a subscription-based model, cloud computing enables users to use a portion of the computing resources, storage, RAM from a datacentre that will host all the above-mentioned resources. Virtualization is a technique where a fraction of cloud datacentre resources is reserved for a given user for a limited period. Cloud computing deals with several aspects such as storing and retrieving the data from web applications to more complex scientific modeling problems where cloud customers no need to worry much about the cost associated with it.Number of dynamic scheduling techniques has been reassessed based on meta-heuristics and deterministic to map out with the challenges of resource provisioning (Malaisamy and Murali, 2020). To reduce the time complexity and to increase the efficiency heuristic and meta-heuristic algorithms are used.

The number of people using cloud resources is increasing at an exponential rate this necessitates efficient algorithms for resource sharing and allocation, many researchers worked in this area to bring out optimization in Cloud resource sharing and allocation.

Figure 1. Shows the basic architecture of Virtualization over the cloud datacenters. IaaS is the platform where it provides infrastructure as a service to the end-users based on their need. Cloud

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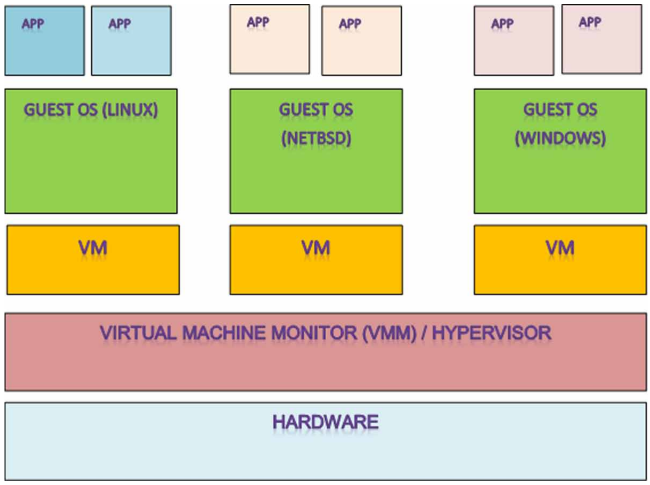
Figure 1. Virtual Machine Architecture



virtualization allows user-customized applications. Cloud Computing serves both software and hardware applications based on user demands.

Our objective is to study all the existing algorithms and implement a new algorithm that will do the multidimensional optimization, less time consuming to reduce the number of running physical systems thereby increasing the power efficiency of the whole data center. Particle Swarm Optimization (PSO) (Kennedy & R Eberhart, 1995) is a population-based optimization method based on Swarm Intelligence (SI) technique. The basic idea is to find the particle's potential position according to its own experience and that of neighbors. PSO is one of the powerful optimization technique where only a few parameters to adjust when compared to other heuristic algorithms. PSO has been applied to a wide range of applications where finding an optimal solution is abundant. It has a considerable amount of interest from nature-inspired community computing that has been seen to many offers which influence solving the optimization problems in multidimensional search spaces. The common goal of the swarm is to find the source of food (Loganathan M.K & Gandhi 2016), individual particle position is represented as P_{best} and one of the particles in the swarm reaches best possible position $g_{best,}$ is the global search position. The PSO algorithm searches in parallel as well as in a group of individuals. Individuals or particles over a problem space, approach the optimal value through their current velocity, with their previous experience, and with the experience of their neighbors. The total number of particles and the swarm size always affect the performance of the algorithm (Y. Shen et al 2018). The author proposed modified Particle swarm optimization (C. Wen and W. Jiang 2019) using the crossover to maximize the resource utilization by introducing two major models for load balancing as well as to know the resource wastage. CPSO model presents the scenario by adjusting the crossover parameters in each iteration.

The main objective is to place the requested Virtual Machines in such a way to reduce the number of active physical machines and the total power consumption of the datacenter. Being an approximation algorithm Particle Swarm Optimization (PSO) performs better when there are a lot of Virtual Machines (VMs) instances to be allocated on an active PM while satisfying the given objective.

In the current paper, section 2 emphasizes the related work already done their models and methodologies and discussed the optimization results. In section 3 we explain the big picture of our problem statement using a block diagram that clearly explains the inputs to the system process followed and the expected output. In the 4th section, we elaborate on the block diagram and define the model and the process followed. We have explained the lower-level implementation details of our algorithm. In section 5 section we have resulted in a discussion wherein we compare our results with the existing algorithms and provide nice visual charts for easy comparison. In the last section, we conclude our paper by mentioning the learning outcome of the selected problem and how it is better than earlier algorithms, and the scope of the future of work.

RELATED WORK

Optimizing resource sharing and allocation is an NP-hard problem as it has multidimensional properties if it was single dimensional problem Bin Packing algorithm would have solved the problem efficiently. In our problem statement, we consider computational elements, RAM, Bandwidth are the three major dimensions, the physical machine to be optimized. Modified Best-Fit Decreasing (MBFD) (A. Beloglazov& R. Buyya 2010) for Virtual Machine (VM) placement problem by choosing the active node with minimum CPU capacity that map to the current VM and while mapping checks for the availability and selects the smallest RAM from the cloud data center. Only the active nodes will be turned on and turn off the remaining nodes. MBFD increases the utilization of resources and reduces the power consumption, but the algorithm fails to check the overloaded probabilities of VM before mapping with the active nodes, in turn, it there is an increase in VM migrations and also it increases the Service Level Agreement (SLA) violations. One robust algorithm is needed to improve resource utilization by reducing energy consumption and also needs improvement in SLA violations. The energy consumed and resources utilized mainly focuses on the CPU cycles and storage. Virtual Machine scheduling algorithms use different procedures to distribute precedence to subtasks which produce different makespan in a heterogeneous computing system (Azad, Poupak and Navimipour, Nima. 2017).

(Priyanka C.P & S. Subbiah 2017) proposed Random Resource Allocation (RRA) algorithm where the Virtual Machine placement problem is solved by placing the VM to the PM randomly. (Srikantaiah et al. 2010).introduced the Modified Best Fit Heuristic (MBFH) algorithm to minimize energy consumption in data centers by optimizing the cloud resources. Energy efficiency is calculated using the current selection and optimal selection within the data center. The energy consumed and resources utilized mainly focuses on the CPU cycles and storage. (S. Wang et al. 2013) investigated A reliable virtual machine placement for a single dimension of resource request failure over the cloud data center by considering the physical resource utilization and the loss rate of the optimization. (D. Kumar & Z. Raza 2015)the proposed two-dimensional encoding scheme for VM placement consists of a number of the physical machine and the subset of compromising VMs in the VM placement problem. Meta-heuristics have been developed to tackle computationally difficult problems (Brezinski, Kenneth &Guevarra, Michael &Ferens, Ken. 2020).

(A. Tripathi et al. 2017), in this paper, Binary Particle Swarm Optimization (BPSO) is used to optimize the VM allocation by modifying the particle position and updating the particle velocity. CPU and Memory utilization dimensions are considered for the Virtual Machine-Physical Machine (VM-PM) placement problem. (S. Pandey et al. 2010) in this paper, the author presents the PSO algorithm for VM placement by considering both communication costs and data transmission cost to eliminate the overall cost estimation of the scheduling process thereby improving the resource utilization over the cloud datacenter.

(M. K. Gupta & T. Amgoth 2019) introduced Scheduled Virtual Machine Placement by using Modified Particle Swarm Optimization (MPSO) with semi scheduled mechanism where initial selection is based on the demands of VMs. In chaotic optimization algorithm replacement of chaotic variables enables the algorithm to escape from local optima (Saidala, Ravi Kumar & Devarakonda, Nagaraju. 2018). (S. G. Domanal et al. 2020) Cat Swarm Optimization(CSO) technique represents two phases Seeking mode and Tracing mode whereas Modified Cat Swarm Optimization(MCSO) operated in seeking mode instead of tracing mode to increase the efficiency of the method, author considered CSO seeking mode. MCSO improves the dynamic allocation of resources over the cloud datacenter. (An-ping Xiong and Chun-xiangXu 2014) proposed Multi-Resource Energy Efficiency

Table 1. PSO-Based Virtual Machine Placement schemes

Authors	Methodology	Remarks
(Abdessamia et al. 2017)	An improved particle swarm optimization for energy-efficiency virtual machine placement	Resource consumption is linearly related to CPU Utilization.
(Dashti, S.E, 2016)	Dynamic Virtual Machines placement for energy efficiency by Particle Swarm Optimization (PSO) in cloud computing.	Improved Dynamic resource allocation in data centers by using PSO parameters
(D. Pal et al., 2016)	Improved Optimization Technique using Hybrid Ant Colony Optimization (ACO) - Particle Swarm Optimization (PSO)	PSO used to enhance the ACO attributes, indicates that the parameter selection depends on the particles in the PSO and thus reduces the number of available paths in ACO.
(Sreelakshmi& S. Sindhu 2016)	Multi-Objective Particle Swarm Optimization (PSO) Based Task Scheduling - A Load Balancing Approach in Cloud	The multi-objective method produces better makespan in terms of cost and execution time
(Fu. X et al. 2018)	Energy-aware Virtual Machines initial placement strategy based on Binary Particle Swarm Optimization (BPSO) in cloud computing.	Particles indicate the binary code and update the optimal VM placement in each iteration
(Yan, J et al. 2018)	Discrete PSO-based workload optimization in virtual machine placement.	Increases the optimization speed with decreasing intensity of resource allocation
(L. Chou et al. 2018)	DPRA: Dynamic Power-Saving Resource Allocation for Cloud Data Center Using Particle Swarm Optimization	least squares regression technique is used to represent the resource allocation
(D. Wu 2018)	Cloud Computing Task Scheduling Policy Based on Improved Particle Swarm Optimization	PSO parameters were selected iteratively to avoid premature convergence.
(V. A. Metre et al. 2019)	An Efficient Clustering Approach utilizing an Advanced Particle Swarm Optimization Variant	Cluster image classification using K-PSO proposed new methods for selecting inertia weight
(S. Xu et al. 2020)	An Improved Multi-objective Particle Swarm Optimization	Different weight vectors are assigned in the analysis
(Madhumala et al. 2021)	Virtual Machine Placement Using Energy Efficient Particle Swarm Optimization in Cloud Datacenter	PSO parameters are redefined to improve resource optimization in data centers by using energy efficient PSO algorithm.

Particle Swarm Optimization (MREE-PSO) for improving energy efficiency in cloud data center based on PSO, the fitness function for the given problem space is measured to determine the optimal allocation of resources by minimizing the energy consumption.

PROBLEM FORMULATION

Proposed Algorithm

The basic Particle Swarm Optimization (PSO) algorithm simulates bird flocking behavior. The flight of bird flocks is simulated with good accuracy by maintaining the distance between the different birds. The distance depends on the size. The bird is treated as a particle and each particle is assigned a parameter called fitness value that is evaluated by a function that is optimized and has a speed corresponding to the flying of the particle. The performance of the system improves if the value of gbest improves in the problem search space (C. Wen & W. Jiang 2019).

In the Modified PSO, each particle is represented by its position and velocity. The global method of PSO is to update the particle's position and velocity at each iteration. p_{best} and g_{best} are the particle's personal best and global best positions in the given problem space (Madhumala R.B &Tiwari H. 2020). The fitness function is used to determine the local/personal best (p_{best}) and global best (g_{best}) values. In our proposed approach each particle refers to VMs, p_{best} refers to under-loaded, and g_{best}indicates the global minimum value out of all p_{best} values. The algorithm in each step tries to find the new personal best (p_{best}) and global best (g_{best}) values. In Modified PSO velocity and positions are updated using the following equations:

Updated Velocity in problem space:

$$V_{id} = V_{id} + C_1 * Rnd_1 (0, 1) * (VMpb_{id} – PM_{id}) + C_2 * Rnd_2 (0, 1) * (VMgb – PM_{id}) \tag{1}$$

Updated Position in problem space:

$$PM_{id} = PM_{id} + V_{id} \tag{2}$$

where,

i,d – i^{th} number of particles in d dimension
V_{id} –Particle's velocity at iteration d
PM_{id}– Particle's position at iteration d
C_1C_2 – Social components
Rnd_1, Rnd_2 – uniformly distributed random numbers
$VMpb_{id}$ –Particle's personal best position
VMgb – global best position of the particle

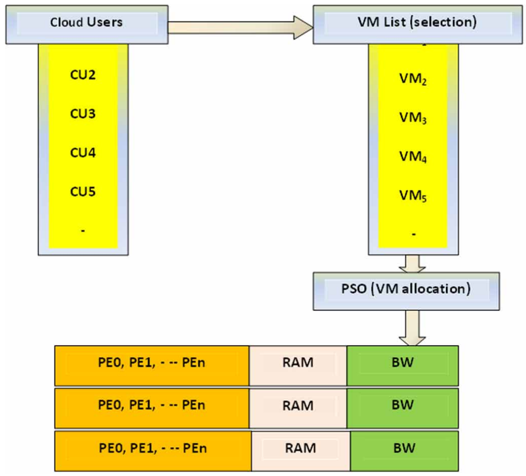
PSO is suitable for continuous data optimization (Madhumala R.B et al. 2021), to use in discrete data as in the case of VM placement we need to tune some of the parameters in PSO. The Virtual Machine problem is addressed by our proposed model called IM-PSO (Improved Particle Swarm Optimization), where the main aim is to maximize the utilization of resources. The following algorithm describes the steps used in the method, wherein it shows how and when the particle's position and velocity need to be updated. The particle's velocity in each dimension d in D is calculated in the given problem space.

Steps in Improved Particle Swarm Optimization

This section presents the data preparation, data initialization, and the fitness function used for optimization. We first construct the utilization matrices for each VM and PM for the utilization of MIPS, Ram, and BW. The proposed system rearranges Physical Machines (PMs) according to their threshold value and 80% threshold value for each machine serving as the maximum utilization range for VMs allocation. The proposed system then spreads load across all PMs until each machine attains 80% of its threshold value. If this level is attained and there are still VMs at the global queue, the 20% un-utilized threshold value can then be used. The system also monitors PM efficiency and stops allocation to any PM that does not perform to its optimum level. The utilization of thresholds will limit the CPU utilization, RAM utilization, and the processor temperature (Dad, Djouhra ,Belalem and Ghalem, 2020).

The main goal of resource optimization is to reduce the total amount of energy consumed during the VM placement, according to the procedure followed Figure 2 represents the Virtual Machine placement process in the cloud datacenter. We can observe set of cloud users and set of VMs. Cloud users are represented using CU1, CU2,….CUm and set of VMs are represented as VM1,VM2,…

Figure 2. Virtual Machine Placement Process



VMn. Cloud users requests for the service based on the resource availability service will be honored and for allocating the demanded resources we use Particle Swarm Optimization (PSO) Algorithm. We have made some changes to the original PSO As follows:

We used C1 value of 0.5 and C2 value of 1.5.The number of iterations is set to be 100 and Vmax is set to be 9. We have used the Jswarm package for implementing the PSO algorithm and the Jswarm package gives the liberty to researchers to provide their fitness function and values for C1 and C2(social components).

The Fitness function used for our PSO is as follows:

$$\text{MipsUtilization} = \frac{\text{MIPS utilized}}{\text{MIPS available}} \tag{3}$$

$$\text{RAMUtilization} = \frac{\text{RAM utilized}}{\text{RAM available}} \tag{4}$$

$$\text{BWUtilization} = \frac{\text{BW utilized}}{\text{BW available}} \tag{5}$$

$$\text{PSOFitnessFunction} = \left\{ \frac{MipsUtilization\left(0.6\right) + RAMUtilization\left(0.3\right) + BWUtilization\left(0.4\right)}{3} \right\} \tag{6}$$

At each time the number of active PMs will be reduced which indicates that decreasing the power consumption of VM-PM mapping and also increases the maximum utilization of resources

(Li, Hongjian, et al. 2018). The main intention of the selection and allocation of VM is to solve the energy by switching off the underutilized servers.

EXPERIMENT SET-UP

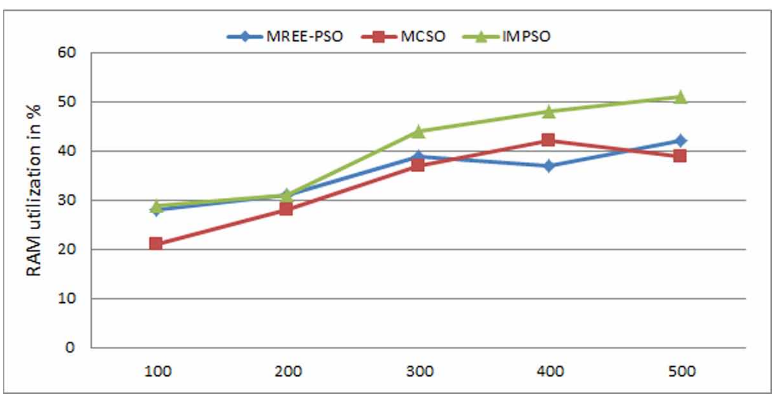
We have used the Cloudsim toolkit for simulation. Planet Lab real-time data is used for evaluation purposes. VMs are classified based on the MIPS, RAM, and BW requirements. We have used PowerVC Standard Version 1.4.1 values for the energy utilization of the hosts. All the experiments are conducted on Intel i5, Seventh generation processor with 1.7 GHz quad-core CPU with 8GB of memory. The operating system used for the experiment setup is Windows 10 Pro and Eclipse IDE is used for JAVA code editing.

RESULTS AND DISCUSSIONS

Finding an optimal resource allocation for a search space is always an NP-hard problem (Z. Xiaoqing 2017) Balanced usage of physical resources is a great solution to improve resource utilization. The development of a Resource allocation algorithm with very high energy efficiency can greatly reduce energy consumption over the cloud data center (S. G. Domanal et al. 2020).

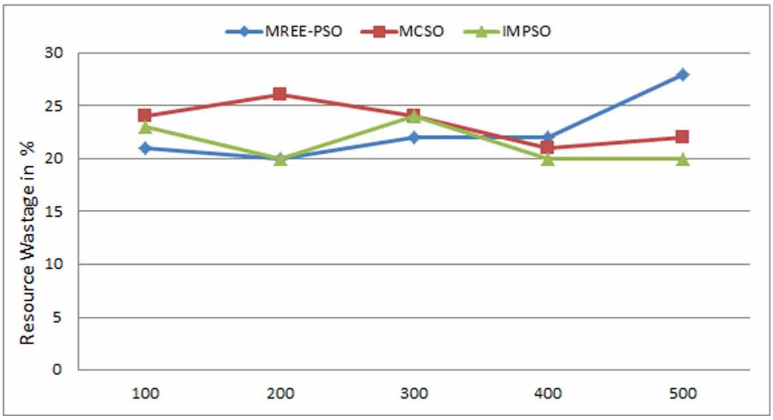
From the figure 3 we can notice that our algorithm performs in line with MREE-PSO till the VM size is around 200. As we increase the number of VMs our algorithm performs much better than MREE-PSO (An-ping Xiong and Chun-xiangXu 2014) and MCSO (S. G. Domanal et al. 2020). For example when VM size is 300 RAM utilization in MREE-PSO was about 39% and MCSO is 37% whereas RAM utilization for IMPSO is 44%. Similarly for VM size=500 MREE-PSO is MCSO are roughly around 40% where as our proposed algorithm has RAM utilization of 51%. A whopping 11% increase in the RAM utilization. This proves the necessity and applicability of the algorithm.

Figure 3. RAM utilization



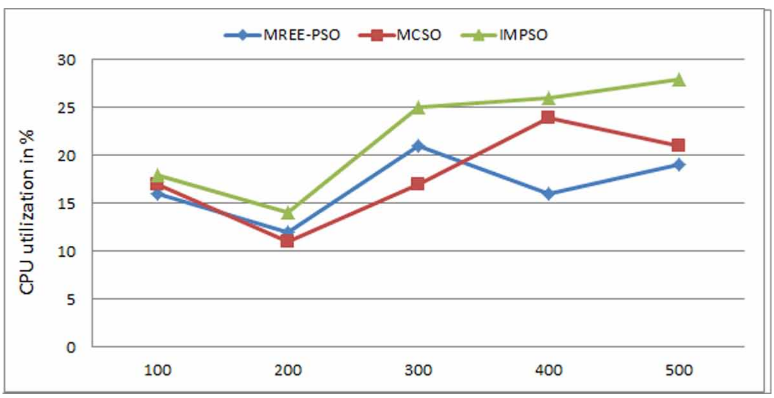
As illustrated in the figure 4 MREE-PSO has lesser resource wastage compared to MCSO and and proposed algorithm for VM size less than 200. As the VM size is increased the performance of MREE-PSO degrades and our algorithm surpasses the results of both MREE-PSO and MCSO. For VM size of 500 MREE-PSO has a resource wastage of 28%, MCSO has 23% but our proposed IMPSO 20%. Thus we can state that the proposed algorithm is well suited in the situations where VM size is considerably high.

Figure 4. Resource Wastage



The time complexity of PSO is given as O (N log(n)) And the time complexity for finding the initial position of candidate solutions is n2 (1 For loop to find the candidate solution to apply to PSO). The time complexity of the proposed algorithm is n2 X O (N log (n)).

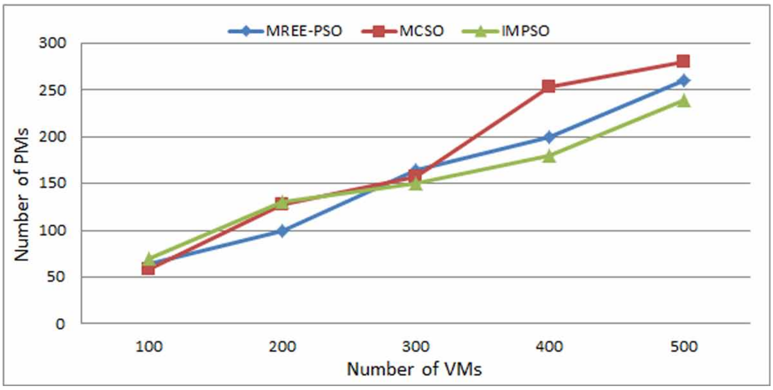
Figure 5. CPU utilization



We can observe from the figure 5 that our proposed algorithm performs better than the other two algorithms MREE-PSO (An-ping Xiong and Chun-xiangXu 2014) and MCSO (S. G. Domanal et al. 2020), in terms of RAM utilization. Figure 3.c shows the CPU Utilization of the proposed algorithm with the other two algorithms and the results are plotted. The results look promising as we increase the number of VMs.

In our last experiment figure 6 we compared the number of running physical machines as the number of VMs increased in steps of 100. From the results, we observe our algorithm performs better, as we increase the number of VMs and the other two are good when the Number of VMs is less and finally, there is an improvement in maximizing the resource utilization. Thus, our proposed algorithm maximizes resource utilization by reducing the number of host Machines.

Figure 6. VM-PM comparisons



CONCLUSION

An efficient Virtual Machine placement problem results in optimized Virtual Machine resource utilization. In this work, we have proposed an Improved Particle Swarm Optimization (IM-PSO) by redefining the parameters of the Particle Swarm Optimization technique for maximizing resource utilization in a cloud datacenter. Our proposed algorithms perform better. The obtained results indicate that our proposed method performs better in terms of resource wastage, the number of Physical machines used, and in utilizing the CPU cycles when compared with the existing algorithms. This work can be extended in the future to reduce the number of running physical machines by combining other methods.

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