ITC 4/48
Information Technology and Control
Vol. 48 / No. 4 / 2019
pp. 545-556
DOI 10.5755/j01.itc.48.4.23062

The Placement of Virtual Machines Under Optimal Conditions in Cloud Datacenter

Received 2019/03/31 | Accepted after revision 2019/11/13

http://dx.doi.org/10.5755/j01.itc.48.4.23062

The Placement of Virtual Machines Under Optimal Conditions in Cloud Datacenter

Sasan Gharehpasha, Mohammad Masdari

Department of Computer Engineering, Urmia Branch, Islamic Azad University, Urmia, Iran,
e-mails: S.gharehpasha@Iaurmia.ac.ir, M.masdari, A.jafarian@Iaurmia.ac.ir

Ahmad Jafarian

Department of Mathematics, Urmia Branch, Islamic Azad University, Urmia, Iran,
e-mail: A.jafarian@Iaurmia.ac.ir

Corresponding author: M.masdari@Iaurmia.ac.ir

Nowadays cloud computing is progressing very fast and has resulted in advances in other technologies too. Cloud computing provides quite a convenient platform for millions of users to use computing resources through the internet. Cloud computing provides the possibility of only concentrating on business goals instead of expanding hardware resources for users. Using virtualization technology in computing resources results in the efficient use of resources. A challenging work in virtualization technology is the placement of virtual machines under optimal conditions on physical machines in cloud data centers. Optimal placement of virtual machines on physical machines in cloud data centers can lead to the management of resources and prevention of the resources waste. In this paper, a new method is proffered based on the combination of hybrid discrete multi-object sine cosine algorithm and multi-verse optimizer for optimal placement. The first goal of the proposed approach is to decrease the power consumption which is consumed in cloud data centers by reducing active physical machines. The second goal is to cut in resource wastage and managing resources using the optimal placement of virtual machines on physical machines in cloud data centers. With this approach, the increasing rate of virtual migration to physical machines is prevented. Finally, the results gained from our proposed algorithm are compared to some algorithms like the first fit (FF), virtual machine placement ant colony system (VMPACS), modified best fit decreasing (MBFD).

KEYWORDS: Cloud Computing, Virtualization, Sine Cosine Algorithm, Source Management, Power Consumption, Multi-Verse Optimizer.

1. Introduction

Nowadays cloud computing is progressing very fast and has resulted in advances in other technologies too. Cloud computing yields quite a convenient platform for millions of users to employ computing resources via the internet. It renders the possibility of only concentrating on business goals instead of expanding hardware resources for users [2]. Moreover, it has become a public service for its users. In cloud computing fashion, resources like physical machines, storage resources, networks, software, etc. stand as cloud services for users. Computational resources are placed in the cloud data center and an organization named cloud service provider manages this place [15]. With this organization, three types of services are introduced, which are called infrastructure, software, and platform as a service for cloud users [22]. Typically, there are four types of cloud in cloud computing, namely, public clouds, communication clouds, private clouds, and combined clouds [11]. There are some cloud platforms like Amazon, Google computing engine, etc. [6]. Cloud computing provides flexibility, hardware dependence and trust for users in a cost-efficient manner [18, 23].

The computation of cloud has opened the opportunity of employing existing resources used for computation as a proper service instead of expansions in resources. To this end, cloud computing employs the virtualization technology in cloud data centers. In virtualization technology, the resources belonging to the hardware of one or more computers are divided into some environments which are mainly used for execution so-called virtual machines. Each virtual machine is completely separated from the other existing virtual machines in the cloud data center which can operate demanded services from users independently. The existing Server in the cloud data center ought to provide hardware resources for virtual machines built upon that. CPU, memory, storage and network bandwidth are included in these resources [4]. The virtual machines placed on a physical machine are controlled and managed by a particular layer of software, namely, a virtual machine monitor. This layer has to build, migrate and execute the duties related to virtual machines [3].

The migration of virtual machines between physical machines in cloud data centers is an interesting aspect of cloud computing that is used to meet the dynamic response to users' requests. Thus, when a virtual machine requests a resource from the host physical machine and the host physical machine cannot provide the resource, the requesting virtual machine migrates to an appropriate physical machine that is responsible for the provision of the resource. In order to better manage cloud data centers, such migration of virtual machines is feasible.

How to place virtual machines on physical machines in an optimal way in the cloud data center is really crucial in cloud computing. When the placement in cloud data centers is performed optimally, the amount of utilization of hardware resources is controlled and hence the amount of power consumption and resource wastage can be reduced [14].

One of the approaches to reach the mentioned goals is using appropriate placement algorithms for optimal placement in the cloud data center. The main goal of these algorithms is to perform a placement in a way that usage of computing resources is convenient and the waste of them can be decreased. Additionally, the total number of active physical machines in cloud data centers is minimized. There have been several algorithms presented in recent years. These algorithms cannot create a proper balance while using computing resources so the waste of resources can be prevented and power consumption at the same time can be minimized.

In this manuscript, a new algorithm is introduced by which the virtual machines are placed in optimal conditions on physical machines for better management of computing resources besides power consumption. Initially, the objective of the proposed algorithm is to reduce power consumption by using a decrease in active physical machines in cloud data centers. The second goal is to decrease the wastage of resources and manage the resources by optimal placement. Furthermore, some other factors like CPU, memory, and bandwidth consumption are also considered. Using the proposed algorithm can offer lower migrations in cloud data centers. The proposed algorithm is compared with some other work done in this regard, such as FF, VMPACS, and MBFD.

The paper is organized as follows: some related works are studied in the second section. In the third and fourth sections, the placement of the virtual machine concept and the basic concepts are addressed, respectively. In the Section 5, the proffered algorithm is discussed, thoroughly and finally, in the Section 6, experiments and results are shown. At the end of the paper in Section 7, the conclusion of this research is presented.

2. Related Works

There are some algorithms proposed to minimize energy consumption and energy waste as well as the management of computing resources.

Xu and et al. in [21] have proposed a multi-object genetic algorithm for the placement of virtual machines. The goal of this algorithm is to reduce the resource wastage and energy consumption in cloud data centers using the search in problem space. This algorithm also attempts to reduce the number of migrations by the virtual machine in cloud data centers. However, this algorithm does not provide the proper balance for the management of computing resources and active physical machines. The authors in [8] have proposed a different algorithm for placement problem which was more effective in comparison to the algorithm proposed in [21].

This algorithm used a meta-heuristic ant colony for the placement of virtual machines. This algorithm tried to minimize the energy consumption and better management of resources in cloud data centers. This algorithm did not provide the proper balance for the management of computing resources and active servers either. In addition, the cost of the migration of virtual machines to physical machines was very high.

Li and et al. in [12] have proposed another approach for the placement problem but the algorithm did not observe the base concept of resource management and preventing energy wastage properly. In [13], the authors have proffered another algorithm based on multi-dimensional space. This algorithm somehow provided a balance for the management of computing resources and active servers in cloud data centers. In [9], an approach has been discussed on how to place virtual machines on a homogenous cloud environment for minimizing the energy consumption and resource wastage. All discussed algorithms might not be appropriate for heterogeneous cloud data centers. However, the algorithm proposed here is suitable for both homogeneous and heterogeneous data centers.

Dai and et al. in [5] proposed a new algorithm for energy consumption optimization. In this approach, a greedy algorithm is used for the optimization of energy consumption. The authors have tried to reduce the cost in the network by placing the requested virtual machines of users in one server otherwise in the servers positioned in one rack. In [20], the authors proposed an algorithm to minimize the energy consumed in cloud data centers. The enhanced PSO algorithm was used to place the virtual machines in cloud data centers. The main purposes of the proposed algorithms can be summarized as follows:

1 Minimizing energy consumption and management of computing resources.
2 Minimizing the number of active servers in cloud data centers.
3 Minimizing the number of virtual machine migrations in cloud data centers.

3. Preliminaries

This section mainly focuses on the sine cosine algorithm, multi-verse optimizer and chaotic functions that are used in our approach.

3.1. Sine Cosine Algorithm

The sine cosine algorithm [16], is a new population-based optimization approach. In this algorithm, updating of the solutions is carried out based upon the sine and cosine mathematical functions. In SCA, the process starts with some random solutions that are positioned fortuitously in the search space of an optimization problem. Each solution is guided to the optimal point in the search spaces. In each iteration, the fitness function of each solution is evaluated and the movement of solutions toward optimal point done through the fitness function.

In SCA, the procedure of optimization is divided into two phases: exploration versus exploitation. In order to update the position of the solution for two phases in this work, the following equations are used, respectively.

$$X_i^{t+1} = x_i^t + r_1 \times sin(r_2) \times | r_3 p_i^t - x_i^t | \quad (1)$$

$$X_i^{t+1} = x_i^t + r_1 \times cos(r_2) \times | r_3 p_i^t - x_i^t | . \quad (2)$$

Eqs. (1) and (2) are combined into one function that is presented in Equation (3).

$$X_i^{t+1} = \begin{cases} x_i^t + r_1 \times sin(r_2) \times | r_3 p_i^t - x_i^t |, r_4 < 0.5 \\ x_i^t + r_1 \times cos(r_2) \times | r_3 p_i^t - x_i^t |, r_4 \geq 0.5 \end{cases} \quad (3)$$

In Equation (3), *r1*, *r2*, *r3*, and *r4* are random parameters. *X* presents the position of the current solution, *P* is a destination solution and | | denotes the absolute value.

3.2. Multi-Verse Optimizer

The multi-verse theory is a famous theory in the field of physics [7]. It connotes the existence of universes beyond the one where we live in. MVO algorithm is inspired by the concept of the multi-verse theory which consists of the following three verses: white holes, black holes and wormholes [19].

In this algorithm [17], a population-based approach divides the search process into two phases, namely, exploration and exploitation. The two concepts of a white hole and black hole are employed to find the search spaces by MVO. The search spaces are exploited by MVO with the help of Wormholes. In MVO, each part corresponds to a particular item, a solution to a universe, a variable in the solution to an object in the universe, the inflation rate of a solution to the fitness of the solution, and the term time to the iteration.

A universe can have higher or lower inflation rates. In the case of having a higher inflation rate, it can probably have white holes and thus the objects can be sent through white holes. Otherwise, the lower rate of inflation is prone to black holes and hence the objects are received through black holes. The objects are exchanged between different universes via the white/black hole tunnels. In spite of having high or low inflation rates, the objects belonging to all universes can more likely be shifted to the best universe via wormholes.

There are rules that have been applied in MVO to the Universe:

1. The higher the inflation rate, the higher the probability of having a white hole.
2. The higher the inflation rate, the lower the probability of having a black holes.
3. Universes with higher inflation rate tend to send objects through white holes.
4. Universes with lower inflation rate tend to receive more objects through black holes.
5. The objects in all universes may face random movement towards the best universe via wormholes regardless of the inflation rate.

4. The Placement of Virtual Machines

The placement of virtual machines on physical machines in an optimal way in cloud data centers is considered as one of the main issues in cloud computing. The goal of optimal placement of virtual machines on physical machines in cloud data centers in cloud computing infrastructure is minimizing some factors like energy consumption, minimizing resource wastage and maximizing efficiency.

An important technology in cloud computing is virtualization. Virtual machines are built, managed and run by a software layer called Virtual Machine Monitor. Figure 1 shows the virtualization structure in the cloud data center.

One of the complexities in cloud computing is how to place virtual machines. The issue of virtual machine placement in the cloud data center follows no consistent pattern and it is unpredictable. As an example, if we have *n* virtual machines and *m* physical machines in a cloud data center, then the maximum mapping of virtual machines on physical machines equals m^n, which shows the complexity of the placement problem. Figure 2 shows the placement problem.

Figure 1
Virtualization mechanism

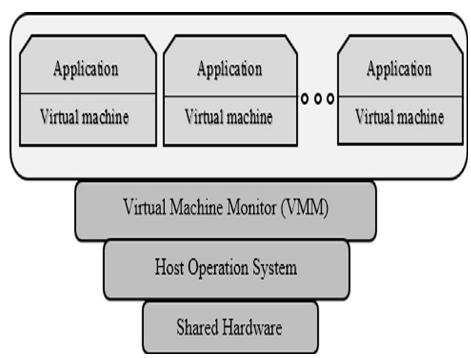
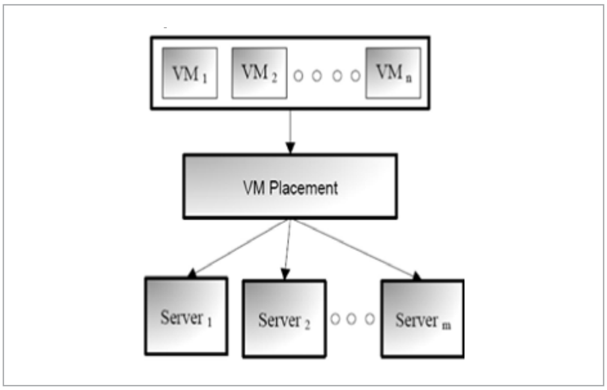


Figure 2

The placement of virtual machines



The first addressed object is how much energy is consumed by physical machines in cloud data centers. Recent studies show that energy consumption by servers in the data centers can be exactly calculated using a linear equation between energy consumption and CPU usage. The equation below shows the energy consumption in the cloud computing data center [5].

$$P_p^{power} = (P_p^{busy} - P_p^{idle}) \times U_p^{CPU} + P_P^{idle}. \tag{4}$$

In Equation (4), P_P^{power} shows the energy consumption of physical machine P in the cloud data center. P_p^{busy} shows the energy consumption of physical machine P, when it is. P_P^{idle} shows the amount of energy used when the physical machine p is idle and U_p^{cpu} shows the amount of CPU that the physical machine P used in MIPS. According to Equation (4), energy consumption has a linear relationship with CPU consumption, hence as the CPU consumption of physical machines goes higher, the same amount of energy consumption in data centers increases.

Hence the overall energy consumption in cloud data centers calculated will be as follows:

$$\sum_{p=1}^{m} P_p^{power} = \sum_{p=1}^{m} b_p \times ((P_p^{busy} - P_p^{idle}) \times \sum_{v=1}^{n} (a_{vp}.C_v) + P_p^{idle}). \tag{5}$$

In Equation (5), *a* and *b* are binary variables that indicate whether the physical machines in cloud data centers are active or not. C_v shows the CPU consumption of physical machines using virtual machines.

One of the other important objects in the placement of virtual machines is preventing the waste of resources in cloud data centers. Each server in the data center has a hardware resource and can host different virtual machines. The unused resources on servers should be managed appropriately. Equation (6) shows the waste of resources [12]:

$$R_p^{wastage} = \frac{| NR_p^{cpu} - NR_p^{mem} | + \in}{U_p^{cpu} + U_p^{mem}}. \tag{6}$$

In Equation (6), $P_p^{wastage}$ presents the resource waste of physical machines in a cloud data center. NR_p^{cpu} is a variable showing the remained power of CPU of physical machines P based on MIPS. NR_p^{mem}, this variable represents the remaining memory in the physical machine P. U_p^{cpu} shows the amount of CPU that the physical machine P used in MIPS. The amount of memory used by virtual machines on the physical machine P is shown by the U_p^{mem}. The total amount of resources consumed in the cloud data center is shown in Equation (7).

$$\sum_{p=1}^{m} R_p^{wastage} = \sum_{p=1}^{m} [b_p \times \frac{| (T_p^{cpu} - \sum_{v=1}^{n} (a_{vp}.C_v)) - (T_p^{mem} - \sum_{v=1}^{n} (a_{vp}.B_v)) | + \hat{I}}{\sum_{v=1}^{n} (a_{vp}.C_v) + \sum_{v=1}^{n} (a_{vp}.M_v)}]. \tag{7}$$

In Equation (7), T_p^{cpu} and T_p^{mem} represent the total CPU and memory used by all virtual machines on physical machines in the cloud data center. M_v is the amount of memory that one physical machine should assign to a virtual machine that was built on it. The rest of the parameters were mentioned earlier.

Notice that when the values of b_p and a_{vp} are equal to one, the physical machine P is active and the virtual machine V is located on it. Thus, according to the above equations, the goals of the placement of virtual machines on physical machines in the cloud data center are:

$$Minimize \sum_{p=1}^{m} P_p^{power} \tag{8}$$

$$Minimize \sum_{p=1}^{m} R_p^{wastage}. \tag{9}$$

In the optimal placement of virtual machines on physical machines in the cloud data center there are some restrictions like the following:

$$\sum_{p=1}^{m} a_{vp} = 1 \quad (8)$$

$$\sum_{v=1}^{n} a_{vp}.C_v \leq T_p^{cpu}.b_p\, TU^B \quad (9)$$

$$\sum_{v=1}^{n} a_{vp}.M_v \leq T_p^{mem}.b_p \quad (10)$$

$$\sum_{v=1}^{n} a_{vp}.H_v \leq T_p^{hdd}.b_p \quad (11)$$

$$\sum_{v=1}^{n} a_{vp}.B_v \leq T_p^{bandwidth}.b_p. \quad (12)$$

Equation (10) shows that each virtual machine can be mapped on only one physical machine. Equations (11)- (14) point out that the total required CPU, memory, storage space, and bandwidth for virtual machines on physical machines should not be higher than the amount of CPU, memory, storage space, and bandwidth of that physical machine.

5. The Proposed Work

There is a cloud data center with several types of physical machines with different hardware. In addition, there are several types of virtual machines with different requirements. Virtual machines available in the cloud data center to get started are located on physical machines as a host. There is a set of resources for every physical machine in the cloud data center, so if the virtual machines are placed in such a way that all physical machine resources are fully utilized, then the physical machine uses all its processing power and does not waste any resources. If the placement of virtual machines is not optimized, then the resources of physical machines in the cloud data center are wasted. With the optimal placement of virtual machines, the processing capabilities of physical machines in the cloud data center can be fully utilized and this work prevents the waste of resources in the cloud data center. In order to have a smart cloud data center, it is necessary that the use of resources in physical machines are minimized. In this paper, the combination of a sine cosine algorithm and a multi-verse optimizer with chaotic functions is applied for the placement of virtual machines on physical machines in cloud data centers. The main purpose followed by this solution is to minimize the amount of consumed energy and resource wastage in the cloud data center.

The problem of how to place virtual machines on physical machines seems to be discrete. The way that meta-heuristic algorithms work is continuous. Thus for the placement of virtual machines on physical machines in cloud data centers, new operators are used to solving the discrete placement problem with the help of the proposed algorithm.

Here, as proposed, the new operators include multiply, minus, and plus. In the proposed algorithm, we use a new minus operator, crossover operator instead of sum and mutation operator instead of multiply. Figure 3 shows the placement of virtual machines on physical machines.

Figure 3
Virtual Machines Mapping on Physical Machines

Virtual Machines	VM5	VM4	VM3	VM2	VM1
Physical Machines	PM2	PM1	PM1	PM2	PM1

In the proposed algorithm, the new minus algorithm is used; two particles A and B are considered as follows:

Figure 4
Sample of Particles in Virtual Machines Placement

A	1	2	3	1	2
B	2	2	1	2	3

In the new minus operator, if the fitness function of particle A is higher than the fitness function of B, particle A is chosen as an answer. Otherwise, the particle B is chosen.

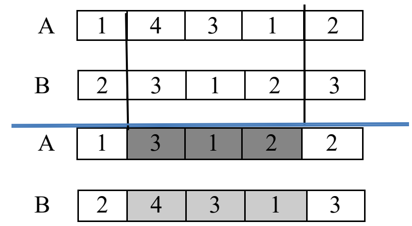
In the proposed algorithm, we used the crossover operator instead of the plus operator. In this operator, two particles are chosen randomly and the crossover is made through those points and the containment between these two pints are exchanged in particles. The final answer is chosen accidentally from one of these particles.

Figure 5 shows the operation of the crossover operator. In this figure, one of the particles A and B are chosen randomly as the answer.

In the proposed algorithm, we used the mutation operator instead of multiply. In this operator, one digit is chosen randomly and according to that digit, homes are chosen randomly from particles and the containment of these homes are exchanged.

Figure 5

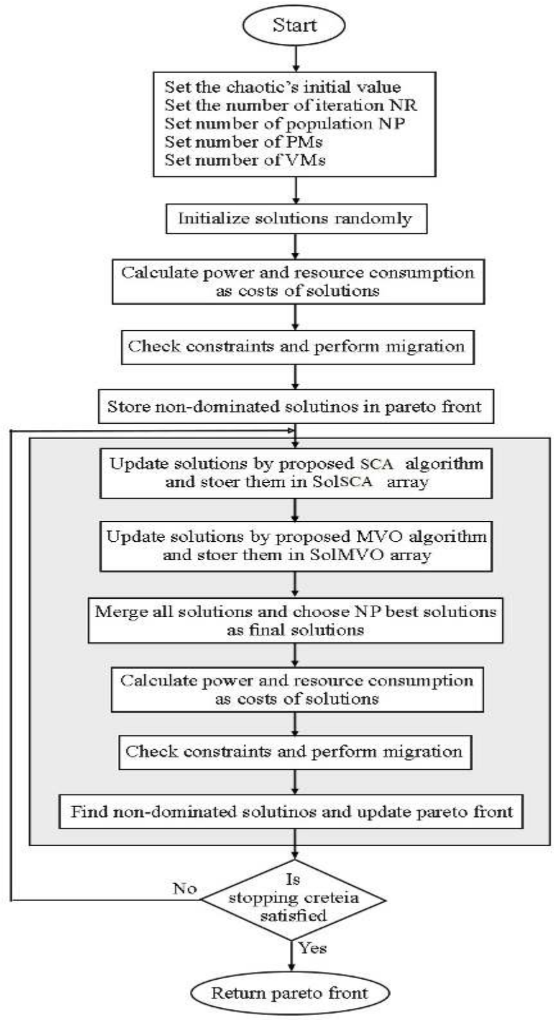
The Crossover Operator



The proposed algorithm starts its work by analyzing the existing population using the hybrid discrete multi-object sine cosine algorithm and multi-verse optimizer. Each particle is evaluated and its fitness function is calculated according to Equations (4) and (6). Given the hardware requirement of any virtual machine, it is placed on a physical machine. If the physical machine does not have the ability to allocate the necessary resources for the virtual machine, then the virtual machines migrate from one host to another. The proposed algorithm is repeated several times to achieve the desirable outcome. The proposed algorithm process is shown in Figure 6.

Figure 6

The Flowchart of the Implementation Proposed Algorithm



6. Evaluation

6.1. Simulation Result Using Cloud User-Customized

Virtual Machines In this section, performance metrics and experimental setup are presented, and the simulation result of the proposed approach are compared and evaluated with the existing virtual machine placement algorithms such as VMPACS [12], MBFD [1] and First Fit (FF). The main goal of placing virtual machines on physical machines in an optimal way in cloud data centers is to minimize some of the issues, such as energy consumption, prevention of resources wastage and reduction of the cost as well as to maximize some of the factors like the total performance. In this paper, several performance metrics, such as resource wastage, power consumption, memory utilization, overall CPU utilization, overall storage space, overall bandwidth and a number of active physical machines are used.

6.2. Performance Metrics

Performance metrics: the following formulae are used to calculate the overall memory utilization, CPU utilization, storage space utilization and bandwidth utilization for the k number of active physical machines, as (15), (16), (17) and (18), respectively.

$$TU^{cpu} = \frac{1}{k}\sum_{p=1}^{k}\left[\frac{\sum_{v=1}^{n} a_{vp}.C_v}{T_p^p}\right] \tag{15}$$

$$TU^{mem} = \frac{1}{k}\sum_{p=1}^{k}\left[\frac{\sum_{v=1}^{n} a_{vp}.M_v}{T_p^m}\right] \tag{16}$$

$$TU^{hdd} = \frac{1}{k}\sum_{p=1}^{k}\left[\frac{\sum_{v=1}^{n} a_{vp}.H_v}{T_p^h}\right] \tag{17}$$

$$TU^{B} = \frac{1}{k}\sum_{p=1}^{k}\left[\frac{\sum_{v=1}^{n} a_{vp}.B_v}{T_p^b}\right]. \tag{18}$$

Experimental setup: The experimentation of the proposed algorithm is performed on a personal computer having features like Intel Core i7 CPU, 3.33GHz, 6GB of RAM, and Windows 10. In this paper, the simulations are written in MATLAB environment. In the simulation environment, 600 servers for placement in a cloud data center have been used. In addition, 100, 300, 500, 700, 900, 1.100, 1.300 and 1.500 virtual machines are used to be placed into the cloud data center. For experimentation, we used four types of virtual machines as cloud user-customized virtual machines [10].

Virtual machines with different resource requirements are placed on physical machines in the cloud data center. The resources required for virtual machines at the cloud data center are provided by physical machines and if the resources of the virtual machines are not provided by the physical machines or require more resources during processing and if these requirements are not be provided by a physical machine, the virtual machine migrates from the physical machine that is located on it to another host in cloud data center.

The number of active physical machines will decrease based on how much less virtual machine migration in the cloud data center happens and as a result, the efficiency of data centers increases.

In this simulation, as mentioned earlier, 600 physical machines were used for placement. Each physical machine has the resources shown in Table 2.

Table 2

Resources of Physical Machines

CPU (MIPS)	Memory (GB)	Storage Space (GB)	Bandwidth (MB)
1000	2	1024	512
2000	4	2048	1024
3000	6	4096	2048
4000	8	8192	4096

Each virtual machine requires a series of resources. Virtual machines are located on physical machines in cloud data centers. This placement should meet the requirements of Equations (7)-(11). The required resources of virtual machines are shown in Table 3.

Table 3

Resources of Virtual Machines

CPU (MIPS)	Memory (MB)	Storage Space (GB)	Bandwidth (MB)
250	512	40	256
500	512	80	512
750	1024	120	768
1000	2048	160	1024

The Simulation results using cloud user-customized placement of virtual machine are as follows:

Table 4

Power consumption

Number of Virtual Machines								Algorithms
1500	1300	1100	900	700	500	300	100	
$1.3455*10^6$	$1.2805*10^6$	$1.1804*10^6$	$1.0373*10^6$	$1.0875*10^6$	$1.0906*10^6$	$1.1483*10^6$	$1.0785*10^6$	DMOSCA-MVO
$1.5781*10^6$	$1.3998*10^6$	$1.2064*10^6$	$1.1515*10^6$	$1.1074*10^6$	$1.1501*10^6$	$1.2031*10^6$	$1.4287*10^6$	VMPACS
$1.6777*10^6$	$1.6089*10^6$	$1.3995*10^6$	$1.2593*10^6$	$1.2349*10^6$	$1.1784*10^6$	$1.2297*10^6$	$1.3144*10^6$	MBFD
$1.4817*10^6$	$1.3327*10^6$	$1.2713*10^6$	$1.1715*10^6$	$1.1149*10^6$	$1.1537*10^6$	$1.3018*10^6$	$1.2895*10^6$	FF

Table 5
Resource wastage

Number of Virtual Machines								Algorithms
1500	1300	1100	900	700	500	300	100	
443.713	443.9828	445.8883	445.7859	449.5105	449.442	450.576348	452.3247	DMOSCA-MVO
443.1255	443.967	447.1867	447.2766	448.419	451.3283	452.277428	452.962	VMPACS
444.712	446.4918	446.6922	447.3643	449.1595	449.6858	452.186164	452.9074	MBFD
443.7514	445.3643	447.3342	448.4351	449.8736	450.2575	452.236948	452.631	FF

Table 6
Number of Active Physical Machines (%)

Number of Virtual Machines								Algorithms
1500	1300	1100	900	700	500	300	100	
82.94	80.8	76.04	71.76	63.78	50.6	35.56	13.48	DMOSCA-MVO
83.72	80.96	76.96	71.6	63.48	51.36	35.88	14.10	VMPACS
84.48	82.34	78.8	72.22	63.49	53.66	38.32	15.18	MBFD
84.18	81.26	78.66	72.68	63.78	53.36	38.64	14.56	FF

Table 7
CPU Utilization (%)

Number of Virtual Machines								Algorithms
1500	1300	1100	900	700	500	300	100	
56.50	49.93	42.28	34.12	27.22	19.04	11.58	3.69	DMOSCA-MVO
59.96	53.54	43.81	36.11	27.33	19.62	12.05	3,66	VMPACS
57.15	50.33	41.33	34.8	25.87	19.09	11.23	3.79	MBFD
58.38	49.75	42.43	35.72	26.79	19.43	11.71	4.35	FF

Table 8
Memory Utilization (%)

Number of Virtual Machines								Algorithms
1500	1300	1100	900	700	500	300	100	
63.96	56.23	47.71	38.42	29.67	21.52	10.65	4.25	DMOSCA-MVO
67.56	60.31	49.81	40.73	31.56	22.3	13.48	4.52	VMPACS
67.35	56.46	50.21	40.07	32.85	23.07	13.74	4.69	MBFD
66.03	57.38	49.19	40.36	31.24	21.87	13.07	4.48	FF

Table 9

Bandwidth Utilization (%)

Number of Virtual Machines								Algorithms
1500	1300	1100	900	700	500	300	100	
75.03	66.25	56.14	45.31	36.14	25.28	18.23	5.06	DMOSCA-MVO
82.50	72.98	59.70	49.15	38.2	26.7	16.38	5.49	VMPACS
81.90	72	58.26	49.48	39	25.89	15.75	5.39	MBFD
79.51	70.52	58.24	48.87	38.43	26.56	15.7	5.26	FF

Table 10

Storage Space Utilization (%)

Number of Virtual Machines								Algorithms
1500	1300	1100	900	700	500	300	100	
63.16	55.81	47.27	35.08	27.99	19.57	11.78	3.91	DMOSCA-MVO
68.55	61.21	50.09	37.97	28.75	21.56	12.61	4.22	VMPACS
67.31	58.46	48.31	38.37	27.71	20.66	12.59	4.13	MBFD
66.73	59.79	49.25	40.77	27.68	21.31	12.02	4.19	FF

From these simulation results, we understand that the proposed algorithm improved the performance of our system. The results in Table 4 show the total power consumption of the active physical machines in the cloud data center. From the results in this table, it can be clearly seen that the total power consumption of the data center using the proposed algorithm is reduced when compared to the existing algorithms. According to the results of Table 6, we can observe that the proposed algorithm placed the virtual machines in such a way that the resources of the active physical machines are properly utilized and balanced. As a result, the number of virtual machines can be placed in a less number of physical machines in the cloud data center. According to the results of Table 5, it is clear that the proposed algorithm minimizes the total resource wastage if compared to the existing algorithms. This is mainly due to better and balanced utilization of CPU and memory resources of the active physical machines, as presented in Tables 7-8. Moreover, the results in Tables 9-10 show that the storage space and bandwidth consumption by the virtual machine are reduced and improved by using the proposed algorithm.

The superior performance of the proposed algorithm is justified and summarized as follows:

1 The proposed algorithm has minimized the number of active physical machines in the cloud data center.

2 The proposed algorithm has balanced the resource utilization in each active physical machine in the cloud data center.

3 Minimization of the number of active physical machines results in less power consumption of the cloud data center.

4 It is clear that the proposed algorithm minimizes the total resource in the cloud data center.

5 The CPU, memory, storage space and bandwidth utilization have minimized by using the proposed algorithm.

6 In VMPACS, resource balance among the physical machines is completely ignored, and migration cost is very high. In our proposed algorithm, migration cost is comparatively very low.

7 First Fit (FF) algorithm places a virtual machine on any arbitrary physical machines without considering balance resource utilization among the physical machines.

8 In MBFD, the resource balance among the physical machines is completely ignored and considered resource such as CPU only.

7. Conclusion

In this work, we have proposed a new virtual machine placement algorithm. The proposed algorithm is based on hybrid discrete multi-object sine cosine algorithm and multi-verse optimizer. The first objective of the proposed algorithm is to minimize the power consumption of the data center by minimizing the number of active physical machines. According to the new technique, with placing the virtual machine on a suitable physical machine, the resources of the physical machine can be utilized appropriately. The second objective is to minimize the unbalanced resource utilization of the active physical machines in the cloud data center. We have proposed a new resource usage model that makes optimal use of physical machine resources. By using the proposed algorithm, the migration of virtual machines has been reduced and minimized the unbalanced resource utilization. Finally, the proposed algorithm is compared with the existing algorithms in terms of various performance metrics. The simulation results present the performance of the proposed algorithm. In the future, we will try to minimize the SLA in the cloud data center.

References

1. Beloglazov, A., Abawajy, J., Buyya, R. Energy-Aware Resource Allocation Heuristics for Efficient Management of Data Centers for Cloud Computing. Future Generation Computer Systems, 2012, 28(5), 755-768. https://doi.org/10.1016/j.future.2011.04.017
2. Buyya, R., Yeo, S., Venugopal, S., Broberg, J., Brandic, F. Cloud Computing and Emerging IT Platforms Vision, Hype and Reality for Delivering Computing as the 5th Utility. Future Generation Computer Systems, 2009, 25(6), 59-16. https://doi.org/10.1016/j.future.2008.12.001
3. Chen, K., Xu, Y., Xi, K., Chia, H. Intelligent Virtual Machine Placement for the Cost Efficiency in Geo-Distributed Cloud Systems. In IEEE International Conference on Communication (ICC), 2013, 3498-3503. https://doi.org/10.1109/ICC.2013.6655092
4. Chen, W., Qiao, X., Wei, J., Hunang, T. A Profit Aware Virtual Machine Deployment Optimization Framework for the Cloud Providers. In: IEEE 5th International Conference on Cloud Computing (Cloud), 2012, 978-986. https://doi.org/10.1109/CLOUD.2012.60
5. Dai, X., Wang, J., Bensaou, B. Energy-Efficient Virtual Machine Placement in Data Centers with Heterogeneous Requirements. In: Proceedings of 3rd International Conference on Cloud Networking (CloudNet), 2014, 161-166. https://doi.org/10.1109/CloudNet.2014.6968986
6. Davidovic, V., Iiijevic, D., Luk, V., Pogarcic, I. Private Cloud Computing and Delegation of Control. Procedia Engineering. 2015, 196-205. https://doi.org/10.1016/j.proeng.2015.01.358
7. Eardley, D. Death of White Holes in the Early Universe. Physical Review Letters. 1974, 33-442. https://doi.org/10.1103/PhysRevLett.33.442. https://doi.org/10.1103/PhysRevLett.33.442
8. Gao, Y., Guan, H., Qi, Z., Hou, Y., Lu, L. A Multi-Objective Ant Colony System Algorithm for Virtual Machine Placement in Cloud Computing. Journal of Computer and System Sciences, 2013, 79(8), 1230-1242. https://doi.org/10.1016/j.jcss.2013.02.004
9. Gupta, M., Amgoth, T. Resource-Aware Algorithm for Virtual Placement in Cloud Environment. In: Proceedings of 9th IEEE International Conference on Contemporary Computing (IC3), India, 2016, 16-22. https://doi.org/10.1109/IC3.2016.7880251
10. Gupta, M., Amgoth, T. Resource-Aware Virtual Machine Placement Algorithm for IaaS Cloud. The Journal of Supercomputing, 2018, 74(1), 122-140. https://doi.org/10.1007/s11227-017-2112-9
11. Komu, M., Sethi, M., Mallavarapu, R., Oriola, H., Khan, R., Tarkoma, S. Secure Networking for Virtualmachines in the Cloud. In: Proceedings of IEEE International Conference on Cluster Computing Workshops, 2012, 88-96. https://doi.org/10.1109/ClusterW.2012.29
12. Li, X., Qian, Z., Chi, R., Zhang, B., Lu, S. Balancing Resource Utilization for Continuous Virtual Machine Requests in Clouds. In: Proceedings of 6th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, 2012, 266-273. https://doi.org/10.1109/IMIS.2012.72
13. Li, X., Qian, Z., Lu, S., Wu, J. Energy Efficient Virtual Machine Placement Algorithm with Balanced and Improved Resource Utilization in a Data Center. Journal of Mathematical Computer Modeling, 2013, 58(5), 1222-1235. https://doi.org/10.1016/j.mcm.2013.02.003

14. Liu, C., Shen, C., Li, S., Wang, S. A New Evolutionary Multi-Object Algorithm to Virtual Machine Placement in Virtualized Data center. In: 5th IEEE International Conference on Software Engineering and Service Science, 2014, 272-275. https://doi.org/10.1109/ICSESS.2014.6933561

15. Lombardi, F., Pietro, R. Secure Virtualization for Cloud Computing. Journal of Network and Computer Applications, 2011, 34(4), 1113-1122. https://doi.org/10.1016/j.jnca.2010.06.008

16. Mirjalili, S. A Sine Cosine Algorithm for Solving Optimization Problems. Knowledge-Based Systems, 2016, 96(15), 120-133. https://doi.org/10.1016/j.knosys.2015.12.022

17. Mirjalili, S., Mirjalili, M., Hatamlou, A. Multi-Verse Optimizer: A Nature-Inspired Algorithm for Global Optimization. The Natural Computing Applications Forum, 2016, 27(2), 495-513. https://doi.org/10.1007/s00521-015-1870-7

18. Srinivasan, A., Quadir, M., Vijayakumar, V. Era of Cloud Computing: A New Insight to Hybrid Cloud. Procedia Computer Science, 2015, 42-51. https://doi.org/10.1016/j.procs.2015.04.059

19. Steinhardt, P., Turok, N. A Cyclic Model of the Universe. Physical Science, 2001, 1436-1439. https://doi.org/10.1126/science.1070462

20. Wang, S., Liu, Z., Zheng, Z. Particle Swarm Optimization for Energy-Aware Virtual Machine Placement Optimization in Virtualized Data Centers. In: Proceedings of International Conference on Parallel and Distributed Systems (ICPADS), 2013, 102-109. https://doi.org/10.1109/ICPADS.2013.26

21. Xu, J., Fortes, J. Multi-Objective Virtual Machine Placement in Virtualized Data Center Environments. In: Proceedings of IEEE/ACM International Conference on Cyber, Physical and Social Computing, Green Computing and Communications, 2010, 179-188. https://doi.org/10.1109/GreenCom-CPSCom.2010.137

22. Zhang, Q., Cheng, L., Boutaba, R. Cloud Computing: State of the Art and Research Challenges. Journal of Internet Services and Applications, 2010, 1(1), 7-18. https://doi.org/10.1007/s13174-010-0007-6

23. Zhang, Q., Li, M., Hu, X. Network Traffic-Aware Virtual Machine Placement with Availability Guarantees Based on Shadows. In: Proceedings of 14th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (CCGrid), 2014, 542-543. https://doi.org/10.1109/CCGrid.2014.40