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Efficient Firefly Algorithm based Energy Saving Technique in Cloud Data Center

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Abstract

The increasing demand for energy by cloud data centers has led to the generation of large amounts of energy, which results in high operating costs and emission ofCO_2 . In addition, it becomes necessary for the cloud computing providers to provide high-quality services to their users and hence need to manage power shortage. Reducing energy consumption by large data center becomes a great challenge for researchers as well as scientists. To solve this problem, VM migration methods are adopted for server consolidation to minimize energy consumption. In this research, the work is carried out into three phases: In the first phase, the energy utilization of each PM is analyzed and then arranged them in decreasing order according to their energy consumption using Modified Best Fit Decreasing (MBFD) approach. In second phase, Firefly (FF) algorithm is applied to deal with the new user requests. In the last phase, the formerly deployed and assigned VM's are ratified in terms of normal loaded, overloaded or under-loaded by adopting artificial neural network (ANN) approach. Using the proposed technique, the host /machine that has minimum possibility of over-utilization and needs least migration is selected as the best host for migrating VM. The performance of the proposed work has been exhibited in MATLAB simulator and validated the results in terms of number of hosts, number of migrations and energy consumptions. The results show that energy up to 43.9 % is saved, thereby, making the cloud data Centre more energy aware.

Keywords: *Cloud Computing, Virtual Machine, Phisical Machine, Firefly algorithm, Artificial Neural Network, Modified Best Fit Decreasing.*

I. Introduction

All With the rapid development of cloud computing and the explosive growth of cloud data centers, energy consumption is also significantly increasing. Numerous reports have shown that approximately 8% of total energy has been absorbed by computer systems, which poses a serious threat to the environment [1]. In this case, high-energy efficiency in the cloud data Centre is being widely studied by researchers throughout the world to reduce energy consumption [2]. The cloud data center has two reasons for its high energy consumption: one is the vast increase in the number of computers along with the cloud users, which causes large amounts of energy absorptions due to the large data centers; another reason of energy consumption is the inadequate allocation of resources in cloud computing. Distribution of resources (such as CPU, disk, memory [3], and bandwidth) becomes a major problem that needs to be solved as undesired resource allocation can lead to extra energy exhaustion in the cloud data center. Algorithm of resource allocation with high energy efficiency has been extensively studied in the field of cloud

July-August 2020
ISSN: 0193-4120 Page No. 4570 - 4579

computing as it can significantly reduce energy consumption [4]. There are three broad objectives in the problem of energy efficiency research: (1) to optimize service quality and to play down energy consumption; (2) increased performance; (3) simultaneously meet performance and energy goals. For practical purposes, allocation of resources in the cloud data center is not only a reduction in energy consumption but also a response to Service Quality or Service Agreements [5-7]. Virtualization technology plays an important role in meeting energy as well as service quality requirements, in the cloud data centre. It is allowed to integrate multiple servers into one physical machine (PM) using the concept of virtualization [8]. This technology can greatly improve the use of resources in applications. Therefore, the allocation of VM in cloud data center is similar to a multidimensional problem of different cost and sizes. Hence, to find an optimal VM allocation becomes a complete NP-hard problem and the best possible solution for the allocation of VMs is often computed when there are many customers and hosts in the cloud environment [9].

Green cloud is a necessary for cloud service providers (CSP) as it reduces the benefits of CSPs since it requires the large investment in data centres to provide cooling infrastructure for large power dissipation [10]. Gartner [11] has estimated that 2% of global CO_2 emissions appear due to the utilization of computers, servers, telephony, local network and printers. Table 1 shows the energy consumption values of different parameter.

Table 1. Power Consumption in Data Centers of US [12]

Year	Energy Utilization	Electricity Bills (the US, $B)	Power Plants (500 MW)	CO_2 US (Million MT)
2013	91	$9	34	97
2020	139	$13.70	51.0	147
Percentage Increase	53	52	50	52

Due to the rapid advancement in cloud services, the cloud data centres have used large amounts of energy. For example, in the year 2013, the cloud data centres situated in US has used electricity of about 34 power plants. By 2020, it is estimated that the nation will use 17 power plants with similar configuration; See in Table 1. This additional energy consumption, in turn, leads to an increase in emission of CO_2. The Natural Resources Defense Council (NRDC), an environmental association, submitted a report on energy efficiency in data centres. According to the reported data, all data centres in the US consumed 91 billion kilowatt-hours of electricity in 2013, with an increase of 139 billion kilowatt-hours in 2020 and an increase of 53% has been calculated [13].

Virtualization is one of the best ways to minimize energy consumption in data cloud centres that plays an important role in effective management of distinct resources in cloud data centres. Virtualization technique allows the resources of an individual physical host to be distributed by a large number of distinct machines known as virtual machines (VMs) [14]. One of the appropriate ways to minimize power consumption in cloud data centres is virtualization technology which plays a significant role in the efficient management of resources at data centres. Virtualization allows resources of a single physical host to be shared by many individually distinct machines called virtual machines (VMs). During virtualization process, the VM's are migrated from one host to another host. These results in extinguish ideal/ empty hosts and hence achieve optimized energy consumption. VM migration is performed on the basis of the host CPU usage, such as overutilization and underutilization [15]. The problem of efficient use of energy in cloud computing is an NP-hard problem because there is no algorithm that can produce the best results in the long run. Much of previous research has focused on different nature-inspired methods [16]. Artificial Colony (ACO)

[17], Particle Swarm Optimization (PSO) [18], Firefly and Genetic Algorithm (GA) [19] are popular optimization schemes used in this area. Firefly is a nature-inspired algorithm, which is used to find solution for above defined NP-hard problem. In this research, the main goal is to minimize energy consumption by less migration. The purpose of the proposed work is to reduce energy consumption with less migration. To do this, the VM allocation algorithm based on the Firefly as a nature-inspired technique is presented by considering the CPU utilization as threshold value of the host.

II. RELATED WORK

The objThe research to save energy in cloud data centres has drawn attention over the past few years since it is one of the reasons to increase CO_2 as well as its operational cost. This section reviews various solutions presented to minimize energy consumption. Chaisiri et al. [20] have presented a "linear programming based" approach to obtained best VM allocation on PM. The main aim was to utilized minimum number of nodes and the presented approach has also been considered for multiple consolidation problems. In [21] Goiri et al; have employed a dynamic approach to allocating resources with minimum energy in a virtualized datacenter. The aim of this approach is to accommodate data from distinct machines and then forwarded that data to smaller number of nodes by maintaining service parameters of every job. The energy has been saved by switching off the ideal server and hence save the energy consumption of cloud at centre. The authors have achieved up to 15 % of energy consumption. Beloglazov et al. [22] have presented a well-known heuristic algorithm, Modified Best-Fit Decreasing (MBFD) for VM allocation. This is a power-aware algorithm and utilized flexible threshold migration. Despite the fact the need for energy and time constraints were ignored. This problem has been overcome by Quang-Hung et al. [23]. The researchers have integrated genetic Algorithm with power-aware scheme and hence resolve the issues of static VM allocation. The results show that the computation time has been reduced to a great extent. Also, it is suggested that the migration policy should also be taken into account. Mi et al. [24] have presented a real-time self-configuration scheme using the concept of nature-inspired GA for the reallocation of VM in cloud data centre. Brown's quadratic exponential smoothing approach has been used to for the prior prediction of workload condition and using GA the best reconfiguration plan has been determined. From experiments, the results have confirmed that the designed approach can effectively extinguish PMs that operate more unnecessarily than current approaches without compromising system performance. Kansal et al. [25] have presented a Firefly algorithm based energy-aware VM migration scheme. The objective of this research is to migrate the heavily loaded VM to the least loaded node by keeping the performance of the system unaffected.

Based on the case studies, it is to be concluded that most of the methods are focused on energy saving through VM consolidation and VM deployment. In the same way, the proposed technique aims at improving the performance and energy consumption through VM migration. In addition, we have presented a bio-inspired FFO technique with artificial intelligence ANN algorithm. With the increasing complexity of large-scale distributed computer services, there is a need to create heterogeneous and robust computing techniques that can be addressed equally with other issues such as heterogeneity and growing energy crises. Thus, it is important to explore and plan new paradigms in addition to basic infrastructure support (which is possible through cloud computing in this case).

For our research, we have selected the biologically inspired Firefly algorithm for migrating VMs. The decisive factor to choose this algorithm is due to its faster convergence and

July-August 2020
ISSN: 0193-4120 Page No. 4570 - 4579

global optimization properties. As with most VM migration techniques, the FF-based method has saved storage space using Network Add-on Storage (NAS) capabilities, except for all the above techniques. The energy has been saved due to the attraction capabilities of fireflies.

III. METHOLOGY/ TECHNIQUE USED

This section described the techniques and the procedure used to allocation appropriate VM to PM with minimum energy.The proposed energy-aware model for VM migration is shown in Figure 1 and the detail description is provided in the following section. The three working steps of the proposed work are described along with their algorithm used.

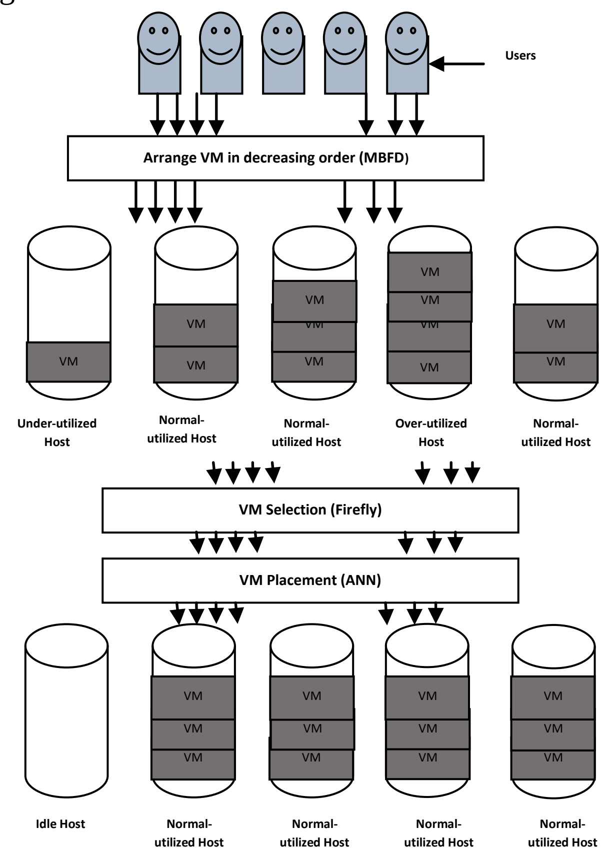

Fig. 1: Proposed Work

VM Sorting

VMs refer to at least one operating system where an application is running in a separate compartment within the computers. Multiple VMs may be available on the solitary physical server. If a machine is overloaded or fails, the VMs in that machine must be transferred to another PM so that less interruption can be made to the users [26]. VM migration is known as the process of transferring a virtual document from one PM to another PM as an image file. In this research, process of VM allocation is segregated into three phases, in the first phase, the system has to check the energy utilization of each PM and arrange them in decreasing order as per their energy. In second phase, deal with the new request and provide a VM using firefly algorithm with a novel fitness condition. Finally, the previously deployed and assigned VM's are validated in terms of normal loaded, overloaded or under-loaded using the concept of artificial neural network as shown in Figure 2.

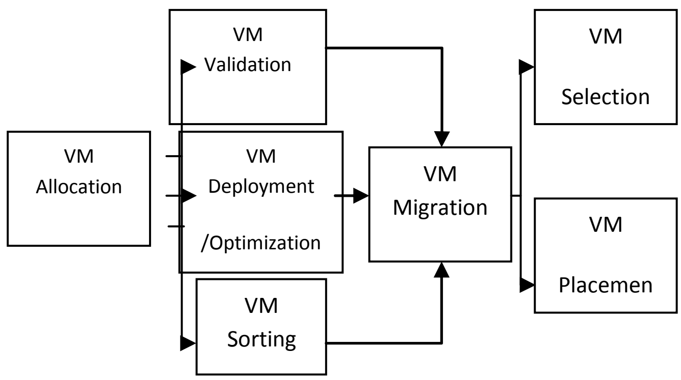

Fig. 2: Proposed VM allocation Process

Product Development and Production Process

Most of the energy consumption in cloud data centers is provided by VMs and physical servers. Among the diverse hardware components, the CPU is the major power-consuming element on the server. Consequently, CPU usage is the foremost parameter for computing the energy consumption of the complete system. Therefore, one can say that the energy consumption parameter has direct relationship with CPU utilization. It has been studied that, the ideal state of server consumes approximately 70 % of its maximum energy. The power consumption during

July-August 2020
ISSN: 0193-4120 Page No. 4570 - 4579

the ideal sate of server and when the server is in its operating mode is known as "static power consumption" and "dynamic power consumption respectively [27].

$$P_{Total} = P_{is} + CPU_l \times (P_{max} - P_{is})$$

= Static power + Dynamic Power × CPU utilization.

Where;

P_{is} → Power consumed when server is not performing any task (Static Power)

P_{max} → Power consumption in the cloud center 100 % maximum

$CPU_l \times (P_{max} - P_{is})$ → Dynamic power

CPU_l → CPU utilization irrespective of workload on the cloud server

P_{Total} → Total Power consumption by the entire cloud data center.

As we know that, the workload on data center is not static, therefore the CPU utilization varies continuously according to the load. The energy parameter can be calculated as an integration of power consumption with respect to time and is defined as:

$$E = \int P_{Total}(t)dt$$

Using MBFD approach, VMs are assigned to hosts as per their power consumption as well as on the basis of CPU utilization. During this research process, the VMs are assigned to the hosts in such a way so that they consume minimum energy also the CPU utilization maintains in the desired level. The algorithm for MBFD used during the experiment is written below:

Pseudo Code of MBFD

```
Start
For each users
    {Calcuate, Minpower←max
    Allocated VM←[null]
    For each VMs
        {Power, P ←Estimated Power (VMs, Users)
        If P<mean(P) then
            {Allocate VM←VM
            Min(P)←P}
            if Allocated server ≠ null then
              {Allocate VM
                Sort VMs according to P}
Return: Sorted VMs based on power utilization
End
```

VM optimization usinf Firefly Algorithm

It is the nature-inspired optimization algorithm proposed by Xin-She Yang in late 2007. It intensifies the attractive features of fireflies and the following three idealized procedures are being taken place: Initially, one firefly draws attention of other fireflies regardless of their sex since the entire fireflies are of abiogenetic. Secondly, the attractiveness of the fireflies is directly related to the brightness, therefore, with the increase in the distance both attractiveness as well as the brightness reduces [28]. Therefore, the firefly, which accommodates less brightness move towards the brighter one. If the brightness is equal, then the flies move randomly. Thirdly, the objective function is used to regulate the brightness of firefly in an optimized manner [29]. In this way, the deviation of the attractiveness φ with distance d can be stated as

$$\varphi = \varphi_0 e^{-\alpha d^2}$$

φ_0 is known as the attractiveness of fireflies at d=0. The motion of firefly (i) towards another brighter firefly (j) can be computed as:

$$y_i^{t+1} = y_i^t + \varphi_0 e^{-\alpha d_{ij}^2}\left(y_j^t - y_i^t\right) + \beta_t \varepsilon_i^t$$

Here β_t is termed as randomization parameter utilized for the maintenance of randomness, ε_i^t is the vector, which is derived from Gaussian distribution at a particular instant of time t. If φ_0=0, the fireflies walks randomly. The algorithm for Firefly approach is written below:

Pseudo Code of Firefly

1 Start
2 Initialize FFA parameter – Iterations (T)
– Population Size (S)
– Lower Bound (LB)
– Upper Bound (UB)
– Number of selection (N)
3 Calculate Size of VMs, SZ ← Size (VMs)
4 Fitness function, $f\ (fit)$

$$\boldsymbol{f\ (fit)} = \begin{cases} \boldsymbol{True}; & \boldsymbol{if\ Alloacted\ VM\ Power\ by\ MBFD} < Mean(VMs\ Power) \\ \boldsymbol{False}; & \boldsymbol{otherwise} \end{cases}$$

5 For each T & SZ
6 $\{ fs = \sum_{i=1}^{P} Power(VM)$
7 $ft = \frac{\sum_{i=1}^{P} Power\ (VMs)}{S_Z}$
8 $f(fit)$ = fitness function which define above
9 $VM_{Allocation} = FFA(P, T, LB, UB, N, f(fit))\}$
10 Return: Allocated VMs
11 End

VM Validation using ANN

In this phase, ANN is used to validate the selected VM by Firefly algorithm and find out their exact condition like overloaded, under-loaded and normal loaded. Firstly, on the basis of ideal properties of VM, the proposed model is trained, which helps in final selection and placement of VM. The training structure is shown in Figure 3, followed by ANN algorithm [30]

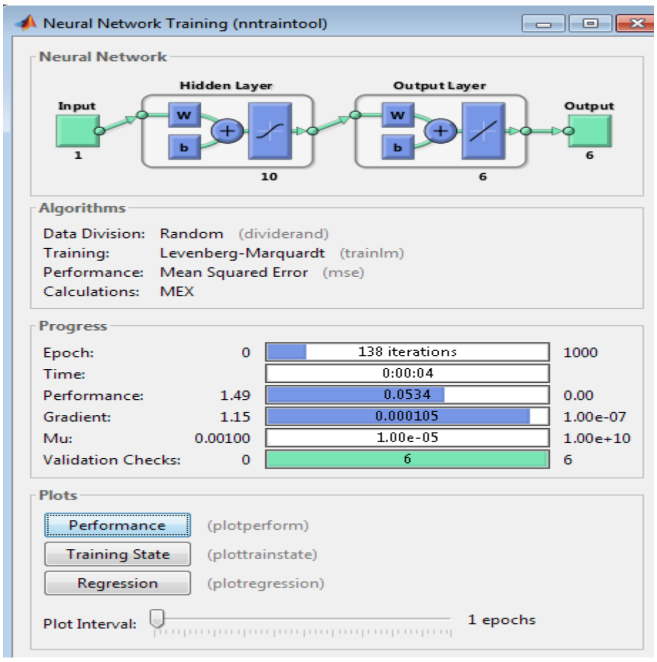

Fig. 3: ANN Structure

Pseudo Code of ANN

1 Start
2 Call and set the ANN using VM properties as training data (T-Data), No. of VMs as a Target (TR) and Neurons (N)
3 Set, Cloud-Net = Newff (T-Data, TR, N)
4 Cloud-Net.TrainParam.Epoch = 1000
5 Cloud-Net.Ratio.Training = 70%
6 Cloud-Net.Ratio.Testing = 15%
7 Cloud-Net.Ratio.Validation = 15%
8 Cloud-Net = Train (Cloud-Net, T-Data, TR)
9 Current VM = Properties of current VM in Cloud-Net
10 VM Characteristics = simulate (Cloud-Net, Current VM)
11 If VM Characteristics is valid and have power then
12 VM = Validated
13 Else
14 VM = Need correction because may be under or over loaded VM
15 End
16 Return: VM as a valid allocation
17 End

July-August 2020
ISSN: 0193-4120 Page No. 4570 - 4579

IV. RESULT AND DISCUSSION

To validate the proposed energy efficient model, the proposed algorithm is compared with the existing techniques such as MBFD and Firefly Algorithm.

Table 2. Simulation Parameter

Parameter	Value
Number of VMs	20-200
Number of Hosts	10-200
Bandwidth	25 Gbps
Host Ram	4 GB
Host Storage	1TB
VM RAM	05 GB to 4 GB
VM Size	2.5 GB

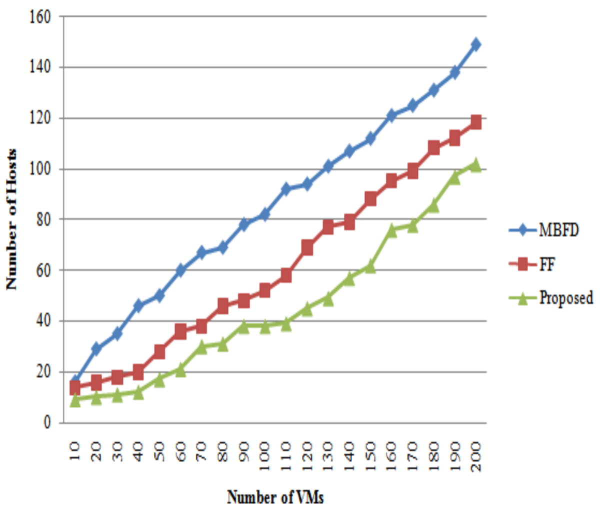

Fig. 4: ANN Structure

Figure. 4 shows the comparative analysis of the three algorithms such as MBFD, FF and proposed an approach, which is the combination of MBFD and FF with ANN technique. The graph represents the evaluated values of required number of host with respect to the number of VMs towards y-axis and x-axis respectively. The continuous monitoring of number of hosts is essential so that the probability of unnecessary consumption of energy by the idle hosts can be minimized. In case, if a host is identified as idle, it is kept on sleep mode. Or if the hosts are underutilized or over-utilized then the VM's are migrated in such a way so that the hosts are normally utilized. From the graph it is clear that the proposed technique operates minimum number of alive hosts in contrast to individual techniques and hence contributed to minimize wastage of energy. The average value analyzed using MBFD, FF and proposed approach is 85.1, 60.65 and 45.4 respectively. Thus, there is reduction of 46.65 %, and 25.14 % has been obtained in contrast to traditional MBFD and FF algorithm.

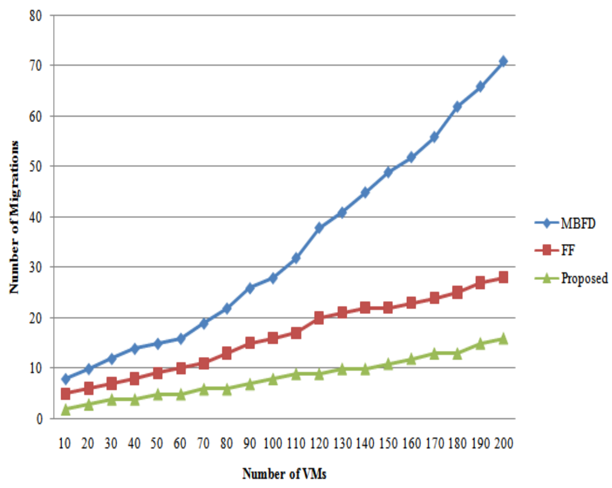

Fig. 5: VMS with respect to Number of Migrations

The number of migrations performed by three techniques in composition with a number of VMs is illustrated in Fig, 5. From the figure it is very much clear that the number of migrations performed by the proposed technique is much less than that of the MBFD and FF techniques. This is due to the capability of the proposed technique to find out the best host for VM migration without negotiating the energy consumption parameter. From the above graph, the average of number of VMs migrated for MBFD, FF and proposed approach are 34.1, 16.45 and 8.4 respectively. Therefore, it is clearly observed that the percentage reduction in the migration of VM's using proposed approach compared to existing MBFD and FF approach are 75.3 %, and 51.76 % respectably.

July-August 2020
ISSN: 0193-4120 Page No. 4570 - 4579

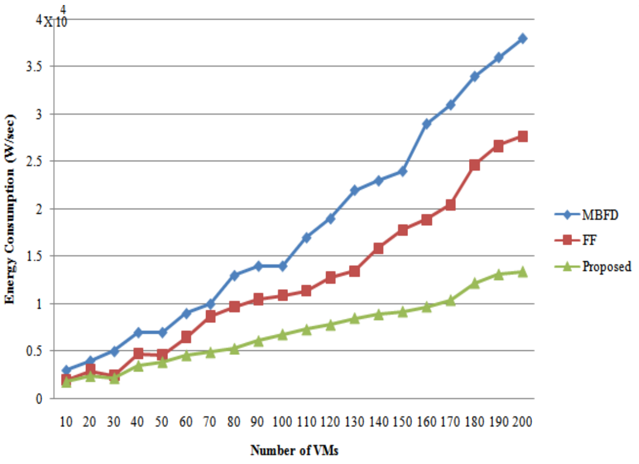

Fig. 6: VM vs Energy Consumption

V. CONCLUSION

In recent years, energy efficiency has emerged as the most important condition for the current cloud computing systems. It extends from solitary servers to the large computer system (cloud) as these consume massive energy. Therefore, effective energy management policies are essential for energy management. Many researchers are currently focusing on and to apply nature-inspired computing algorithms to manage heterogeneity along With the growing energy crisis. Likewise, in our research, we have chosen the nature-inspired behavior of firefly and developed a new hybrid approach, which is the combination of MBFD, FF and ANN techniques for migration purpose in cloud data center. The reason to select FF as an optimization technique is because of its faster convergence rate to select from and large-scale optimization accomplishment. The proposed algorithm can be utilized as an efficient solution for migrating VMs in cloud data centre by equally distributing the load on each host and hence resolve the problem of energy consumption to a great extent. The results show that the proposed approach is highly efficient by lowering the usages of number of hosts, completing its operation by migrating less VM with less consumption of energy compared to individual MBFD and FF approach. The proposed technique show improvement in terms of reducing migration by 51.76 %, saving an average of hosts and energy by 25.14 % and 43.9 % respectively compared to individual FF approach and hence contributing to the green cloud environment.

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