Energy-Efficient VM Allocation and Migration Approach Using Swarm Intelligence Algorithm in Cloud Computing Environment

Rachhpal Singh
Computer Science
Shri Guru Granth Sahib World University, Fatehgarh Sahib
Fatehgarh Sahib,India
rachhpal@pbi.ac

Sarpreet Singh
Computer Science
Shri Guru Granth Sahib World University, Fatehgarh Sahib
Fatehgarh Sahib,India
ersarpreetvirk@gmail.com

Balwinder Kaur
Computer Science
Punjabi University Centre for Emerging and Innovative Technology, Mohali,India
balwinder_03@pbi.ac.in

2023 14th International Conference on Computing Communication and Networking Technologies (ICCCNT) | 979-8-3503-3509-5/23/$31.00 ©2023 IEEE | DOI: 10.1109/ICCCNT56998.2023.10306680

***Abstract*— The cloud computing environment is a demanding platform to perform large-scale business operations for different clients. Several studies have been carried out in order to minimize the power consumption in data centres. Intelligent VM allocation and migration is an effective approach to minimize unwanted CPU utilization without violating the SLA. The modified best fit decreasing (MBFD) has been employed to allocate the VM to the best available host in an efficient manner. In this paper, a novel swarm intelligence-based Grasshopper optimization technique has been proposed in order to improve the VM selection. The proposed framework provides a significant solution in the cloud data centre for minimizing overall energy consumption. The obtained results using the proposed model are highly efficient in terms of power consumption and SLA violations.**

Keywords— Cloud computing, VM allocation, VM migration, MBFD, Service level agreement, Grasshopper optimization.

I. INTRODUCTION

Cloud computing (CC) is an increasing need for modern IT companies. Data sharing through online platforms are used extensively. The web-based applications produced a considerable quantity of data that needs to be preserved and regularly transferred via the Internet. According to research conducted by the University of California [1] on CC as a utility that has the potential to manage a substantial segment of the IT industry. The CC also allows IT companies to focus on developing innovative products and providing services that offer real value to their client's businesses by managing the huge amount of data on a cloud platform with the help of various cloud service providers such as Amazon, IBM, Google, etc. has been used [2]. According to [3] the average resource usage of a cloud data centre is estimated at thirty percent. However, idle energy usage may account up to 70% of the overall power consumption in a data centre. As a consequence, a significant amount of energy is wasted [4]. In order to conserve energy, several methods inspired by the concept of virtualization have been developed in the past decade [5]. The virtualization concept is applied in various research studies which allows overutilized servers to distribute their workload over numerous virtual machines (VMs) with the help of intelligent VM allocation and migration without affecting service performance and the issue of unwanted power consumption is also addressed [6]. As a consequence, efficient VM consumption has played a crucial role in offering cost-friendly services to customers by managing massive volumes of data in the modern cloud computing environment.

The VM offers virtual application resources to multiple users simultaneously with high adaptability and economical operations [7]. Virtualization strategy aids in managing server load by allocating and migrating programmes to less or moderately loaded machines. This approach comprises offsetting numerous virtual computers to reduce the burden on the over-utilized machine by considering the violations in "Service level agreements" (SLA), energy usage, and the total migrations are the primary factors that must be managed in a balanced manner [8]. Any disparity between the specified metrics might affect the data centres performance and QoS. This implies that hardware that is underused and equipment that is overutilized should be differentiated [9]. Hence, the designed framework has been used to manage critical service quality parameters. In this work, a framework is developed to minimize unnecessary energy consumption by using an intelligent VM allocation and migration strategy. The proposed strategy consists of an integrated MBFD and swarm intelligence-based grasshopper optimization approach to identify the optimum VM for the best available host by considering the essential energy requirements and SLA constraints.

The remaining sections are categorized as follows. section 2 discusses related work, while Section 3 presents the VM allocation and migration using MBFD for an energy-efficient Cloud computing environment. Section 4 discusses the VM selection using the proposed technique. Section 5 presents a performance evaluation of the proposed algorithm. In Section 6, the work is summarized and directed for further research.

II. RELATED WORK

It has been shown that a considerable amount of energy is used in cloud data centres for server shifting and computation. While there is an energy cost associated with VM migration, it ultimately results in a more efficient data centre. Virtualization's most important feature is machine allocation, followed by migration. Researchers have utilized a variety of approaches to choose the best VM to allow minimum migration and minimize energy consumption during the entire virtualization operation. VM migration is influenced by a wide range of programmes and external elements. Economic VM migration, the diverse nature of cloud services, system burden, and memory are only some of the VM migration issues that have been addressed. Security is another major issue during VM migration [10]. Yakhchi improved resource management by using the Cuckoo Search (CS) optimization method to identify overutilized hosts and

Authorized licensed use limited to: Nirma University Institute of Technology. Downloaded on March 09,2024 at 16:03:49 UTC from IEEE Xplore. Restrictions apply.

minimum migration duration strategy has been employed to shift units from overutilized to normal use. Low migration rates resulted in an average energy consumption of 19.95 kWh, as shown by a simulation investigation [11].

To achieve power-efficient VM migration, Dhanoa et. al. suggested a hybrid GA-based technique that includes SLA violations, energy consumption, and VM migrations to enhance response times. The major goal of the research was to find the most efficient way to do live migrations in order to save energy under different conditions. As compared to the standard approach, the hybrid VM allocation reduced energy consumption by 72% while maintaining service quality in simulated studies [12]. For making globally optimized selections on VM consolidation, Jiang et. al. proposed an energy model. The GPU and CPU utilization rates are crucial to this model. The research investigated two different VM allocation and selection procedures for operational VMs. The (Ant colony optimization) ACO paradigm reduced energy consumption by 25%–35% in comparison with other techniques [13]. Perumal proposed a fuzzy hybrid nature-inspired meta-heuristic approach to the VM placement issue. Energy consumption, resource degradation, and cloud-based VM deployment were the primary research objectives. The experimental results showed that compared to the ACO, Firefly, MMAS, and FFD algorithms, the hybrid approach achieved better results [14].

The issue of energy usage in cloud data centres was addressed by the VM placement method using "Enhanced Cuckoo Search" (ECS), which was proposed by Barlaskar et al., which was inspired by the CS algorithm. The ECS algorithm's workload was monitored using Planet Lab. Low energy consumption was seen for ECS in comparison to the "Optimized Firefly Search" (OFS) algorithm, the "Ant Colony Optimization" (ACO) approach, and the "Genetic Algorithm" (GA) [14-15]. In [15], Ruan developed a method for allocating and migrating VMs based on their performance-to-energy ratio. Sampled rates of machine use were used to determine this ratio. This information was used to verify that the machines were using as minimal energy as possible without compromising performance. Using the VM selection and allocation paradigm [15], energy usage was shown to be reduced by a significant 69.31 percent when compared to conventional methods. Kumar et al. introduced the "Cuckoo Search with Firefly" (CS-FA) technique, which employed cloud computing for load Migrating VMs in the cloud in an energy-efficient manner is shown in Fig. 1. With the goal of efficiently utilizing the PM-2 resources, VM-3 has been migrated from PM 2 to PM-1. The PM-1 has the capacity to host three VMs. Inactive servers use less power than active ones. The suggested MBFD strategy helps to migrate the VMs from an underutilized PM to a normally utilized PM and also minimizes false migrations. Each VM has been sorted in descending order of their resource utilization and assign each VM to the host with the lowest increment in energy consumption as a result of this allocation. This enables a wide range of resources to be used by selecting the most energy-efficient host first balancing. The CS-FA algorithm was designed to perform two objectives:(1) find the best VMs to allocate the workload, and migrate workloads from overutilized VMs to underutilized [16-17].

Karthikeyan [18] overcame the energy constraints through hybrid optimization. Bat and "Artificial Bee Colony" (ABC) methods were integrated by these researchers, and the ML classifier was utilized to determine which VM would best satisfy the energy needs. Jangra used an ANN with the CS algorithm to maximize efficiency with minimal power usage. The researchers ranked the VM by their CPU utilization, which was determined using the MBFD approach. It was found that the proposed CS-based method used 13.15 percent less energy than the previous SI-technique-based approach [19]. In order to allocate the workload fairly among numerous VMs, Talwani and Singla [20] suggested using an Extended Artificial Bee Colony (E-ABC) method. Results from simulations show that the E-ABC approach has high scalability, with fewer VM migrations occurring as a consequence. The E-ABC strategy saved 15–17% more energy and resulted in 10% fewer migrations than the current concept [21-24].

The detailed literature review shows that the reduced energy usage and optimal resource utilization during VM allocation and migration are two benefits of current technologies documented in the literature. It is also observed that the swarm intelligence techniques combined with MBFD strategy can further enhance these aspects. However, there are also some drawbacks to consider like overloading of physical systems is not confirmed in some of the current investigations. It has been observed that most of the studies lack proper investigation and challenge of where and how to optimally allocate, migrate, and select the VM remained an open research area. Thus, to resolve this the paper presents an energy efficient VM allocation strategy inspired by swarm intelligence.

III. Proposed Methodology

The proposed approach having an edge over prior methods in terms of VM allocation and migration using MBFD and SI-based grasshopper technique is used for VM selection improvement by considering the SLA constraints on priority.

A. VM allocation and migration using MBFD

In a cloud computing platform, each physical machine (PM) acts as a host for many VMs. The intelligent VM allocation and migration provide solutions to issues that arise while using an overutilized PM as mentioned in Fig 1. The goal of the VM migration technique is to minimize energy consumption. The VMs are migrated to the best available host using the MBFD strategy.

The procedure for VM allocation to PM using the MBFD strategy is as followed:

1. $Input - hostlist., VMlist;$
   $output - VM\ allocation\ to\ PM$
2. $VMlist.sorting_{decresing\ resource\ utilization}$
3. $every\ VM\ in\ VMList\ do$
4. $Min_{power} \leftarrow MAX$
5. $Allocate_{host} \leftarrow NULL$
6. $every\ Host \rightarrow Host_{list}\ do$
7. $For\ overutilized\ host\ then,$
8. $Energy \leftarrow Approx_{energy}(Host, VM)$
9. $If, Energy < Min_{power}$
10. $Allocate_{host} \leftarrow Host$
11. $Min_{power} \leftarrow energy$

Authorized licensed use limited to: Nirma University Institute of Technology. Downloaded on March 09,2024 at 16:03:49 UTC from IEEE Xplore. Restrictions apply.

12. $If\ Allocate_{host} \neq NULL$
13. $VM_{allocte} \rightarrow Allocate_{host}$
14. $Return\ Allocate_{list}$

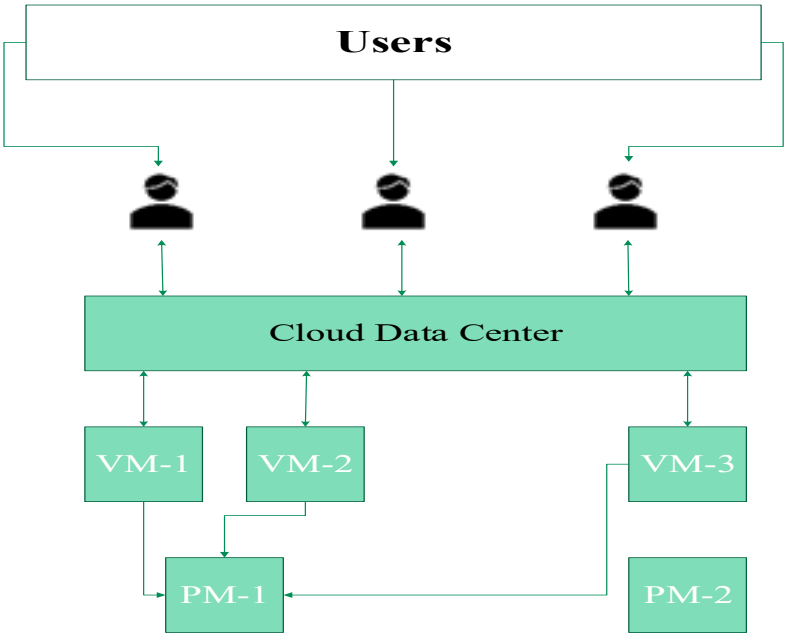

Fig. 1. The concept of VM Allocation and migration strategy

When a certain PM is considered unfit for hosting VM, a migration to a best-fit PM is initiated. The migration process consumes a substantial amount of energy. Therefore, reducing migrations is extremely important for lowering energy consumption by considering the SLA constraints. False allocation is the main cause of migration. The migration minimization (MM) approach is a powerful mechanism for halting the migration process discussed as follows:

1. $Every\ host\ \rightarrow Host_{list}$
2. $compute\ Energy_{utilized}$
3. $Min_{energy} \& Max_{energy}\ \rightarrow Threshold_{value}$
4. $when, Energy_{utilized} < Min_{threshold}$
5. $if, VM_{underutilized} \rightarrow VM_{migrate} \& Host_{poweroff}$
6. $when, Min_{threshold} < Energy_{utilized} < Max_{threshold}, then$
7. $Host_{normalutilized}$
8. $When, Energy_{utilized} > Max_{threshold}$
9. $Host_{overutilized}$
10. $Required, VM_{migrate} \rightarrow PM_{New}$

IV. VM SELECTION USING GRASSHOPPER OPTIMIZATION ALGORITHM (GOA)

The grasshopper is an insect. They are classified as a pest due to their crop harming nature. The grasshopper life cycle is depicted in Fig 2. While grasshoppers are often seen alone in the outdoors, they form the greatest swarm of all vertebrates [25]. Unique to the grasshopper swarm is the presence of swarming behaviour in both nymphs and adults. Grasshopper swarming is also characterised by the key characteristic of searching for food sources. It consists of two behaviours: exploration and exploitation. During exploration, search agents are urged to travel quickly, but during exploitation, they prefer to move locally.

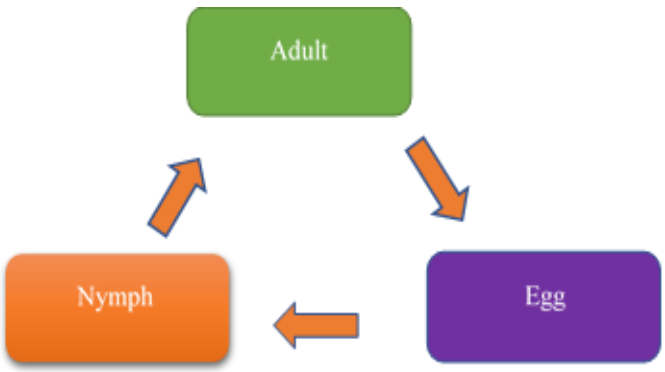

Fig. 2. Grasshopper life cycle

Fig. 2 depicts the grasshopper life cycle, in which the insect may survive in two stages. In the first phase, the nymphs do not interact with one another; this phase is known as the solitary phase. In the second phase, the adults communicate with one another and create the swarm. The movement of a swarm is determined by environmental elements such as wind speed, sunlight, and air temperature. This behaviour is represented in mathematical form as follows [25]:

$$X_i = a_1\alpha_p + a_2\beta_p + a_3\gamma_p \quad (1)$$

where, $\boldsymbol{X_i}$ represents the position of the grasshopper. $\boldsymbol{\alpha_p}$ represents the social interaction among the insects. $\boldsymbol{\beta_p}$ represents the gravity force. $\boldsymbol{\gamma_p}$ represents the wind

Authorized licensed use limited to: Nirma University Institute of Technology. Downloaded on March 09,2024 at 16:03:49 UTC from IEEE Xplore. Restrictions apply.

advection and $\boldsymbol{a_1}, \boldsymbol{a_2}$ *and* $\boldsymbol{a_3}$ are the random values lies between [0, 1].
The interaction force among the grasshopper is represented as:

$$\alpha_p = \sum_{\substack{p=1 \\ p\neq k}}^{n} s(D_{pk}) \left(\frac{X_p - X_k}{D_{pk}}\right) \tag{2}$$

Where,

$$D_{pk} = \left|X_p - X_k\right| \tag{3}$$

The 'S' represents the parameter of interaction forces presented in eqn(4)

$$s(D_{pk}) = Ae^{\left(\frac{D_{pk}}{L}\right)} - e^{(D_{pk})} \tag{4}$$

Where, 'A' represents the "intensity of attraction force" and 'L' depicts the "scale length" of the attractive force. The swarm nature also depends on the gravity force which is presented as follow:

$$\beta_p = -g\overrightarrow{e_g} \tag{5}$$

Where, g shows the "gravitational constant" and $\overrightarrow{e_g}$ represented as unity vector. The "wind advection" is presented as follows:

$$\gamma_p = u\overrightarrow{e_w} \tag{6}$$

By putting values of α_p, β_p *and* γ_p in eqn(1)

$$X_i = \sum_{\substack{p=1 \\ p\neq k}}^{n} s(D_{pk}) \left(\frac{X_p - X_k}{D_{pk}}\right) - g\overrightarrow{e_g} + u\overrightarrow{e_w} \tag{7}$$

In order to selection the best fit host for VM migration using GOA Eqn (8) helps to find the optimal VM allocation.

$$X_i = B\left(\sum_{\substack{p=1 \\ p\neq k}}^{n} B\left(\frac{U_l - L_l}{2}\right) s(D_{pk}) \left(\frac{X_p - X_k}{D_{pk}}\right)\right) + X_p^{best} \tag{8}$$

Where, U_l *and* L_l represents the upper and lower limit respectively of the variable. X_p^{best} represents the best position/placement of the grasshopper. The 'B' represents the operator for improving the searching abilities of the approach depicted as follows:

$$B = B_{max} - t\left(\frac{B_{max} - B_{min}}{t_{max}}\right) \tag{9}$$

Where, B_{max} *and* B_{min} represents the limits of B. The t_{max} shows the max. migration count. The steps involving for the GOA for resolving the VM allocation problem while considering the SLA-violations is stated as follow:

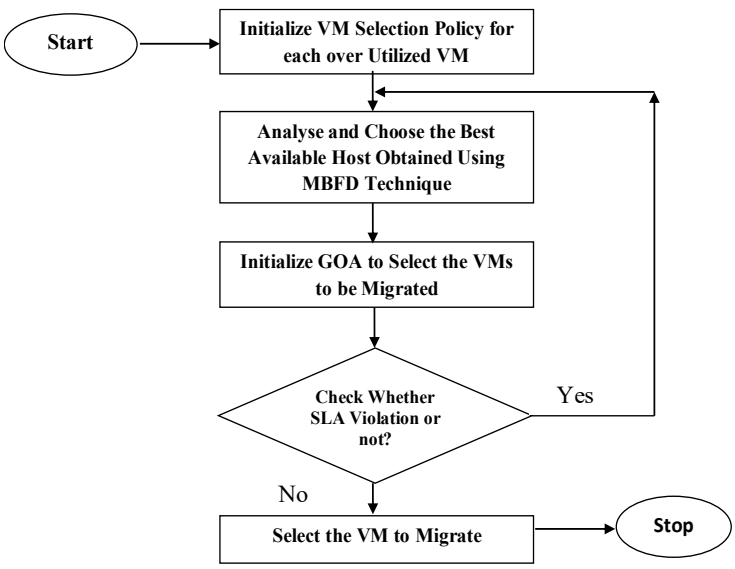

Fig. 3: process flowchart of proposed technique

Steps for selection of VMs for Migration from Over-Utilized to best fit Host Using integrated MBFD and Grasshopper optimization technique is as follows:

1. $Input - hostlist., VMlist;$
   $output: VM\ allocation\ to\ PM$
2. $init. GOA\ parameters \rightarrow Search_{agent}, A, L, U_l, L_l,$
   $t_{max}, B_{max}\ and\ B_{min}$
3. $generate, Init._{population} \rightarrow X_i = L_l + a \times (U_l - L_l)$
4. $if, VM_{underutilized} \rightarrow VM_{migrate} \& Host_{poweroff}$
5. $Identify, Best_{fithost} \rightarrow MBFD\ \&$
   $VM_{select} \rightarrow PM_{noramlutilized}\ using\ GOA$
6. $when, Min_{threshold} < Energy_{utilized} < Max_{threshold}$
   $then$
7. $Host_{normalutilized}$
8. $When, Energy_{utilized} > Max_{threshold}$
9. $Host_{overutilized}$
10. $Required, VM_{migrate} \rightarrow PM_{New}$

Authorized licensed use limited to: Nirma University Institute of Technology. Downloaded on March 09,2024 at 16:03:49 UTC from IEEE Xplore. Restrictions apply.

V. Results

The proposed strategy is compared with ABC[18], E-ABC[20] and CS[11] algorithms in terms of energy consumption, SLA-Violations and the number of VM migrations

TABLE I. COMPARISON OF TECHNIQUES ON THE BASIS OF ENERGY CONSUMPTION(WATT)

No. of. Host count	No. of. VM count	Host to VM ratio	Energy consumption (Watt)			
			ABC	E-ABC	CS	Proposed
1	10	0.1	23.5421	17.8754	14.7649	9.2183
2	21	0.095238	18.9547	16.9875	11.8759	9.8591
3	34	0.088235	23.6654	19.5463	14.8769	10.7375
4	42	0.095238	21.7653	18.9104	13.7647	8.6725
5	56	0.089285	19.8953	16.9054	13.3568	11.4473
6	64	0.09375	18.8753	15.9897	14.2638	12.9274
7	73	0.09589	20.8796	19.6543	15.9835	9.3285
8	82	0.09756	23.8943	20.8765	13.3628	11.8547
9	91	0.0989	22.3491	21.8654	12.8896	10.4375
10	103	0.097087	23.6739	20.7653	16.8364	11.4599

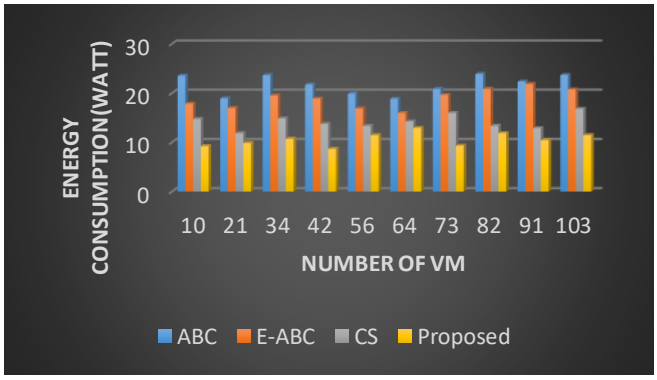

Fig.4. Comparison of proposed technique with other in terms of energy consumption.

The Fig 4 represented the overall consumption of the energy during the VM migration is least in case of proposed technique as compare to other traditional techniques. The average values of the different techniques such as ABC[18], E-ABC[20], CS[11] and proposed are 21.7495 watt, 18.93762 watt, 14.19753 watt and 10.59427 watt respectively. The proposed technique has the minimum energy consumption(watt) during the VM migration i.e., 10.59427 watt in comparison with other techniques.

TABLE II. COMPARISON OF TECHNIQUES ON THE BASIS OF SLA VIOLATIONS

No. of. Host count	No. of. VM count	Host to VM ratio	SLA violations			
			ABC	E-ABC	CS	Proposed
1	10	0.1	0.4678	0.3452	0.2342	0.1018
2	21	0.095238	0.4269	0.3877	0.2653	0.1273
3	34	0.088235	0.4982	0.3754	0.2256	0.1039
4	42	0.095238	0.4538	0.3280	0.2672	0.1458
5	56	0.089285	0.4238	0.3321	0.2942	0.1367
6	64	0.09375	0.4685	0.3569	0.2085	0.1643
7	73	0.09589	0.4383	0.3091	0.2549	0.1193
8	82	0.09756	0.4092	0.3683	0.2719	0.1543
9	91	0.0989	0.4739	0.3468	0.2639	0.1467
10	103	0.097087	0.4429	0.3924	0.2178	0.1672

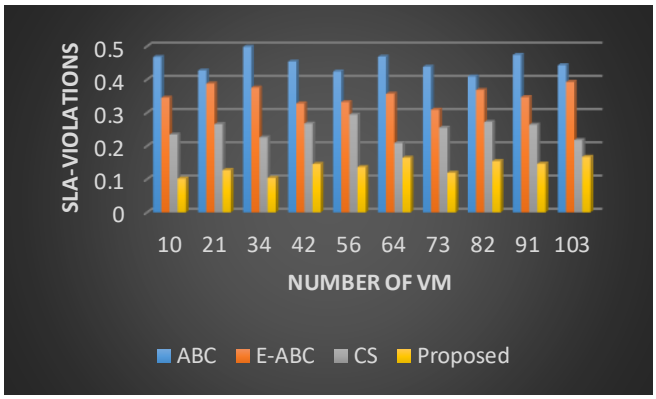

Fig. 5 Comparison of proposed technique with other in terms of SLA-Violations

The Fig 5 depicted that the overall SLA-violations during the VM allocation and migration is minimum in case of proposed technique as compare to other traditional techniques. The average values of the different techniques such as ABC[18], E-ABC[20], CS[11] and proposed are 0.45033, 0.35419, 0.25035 and 0.13673 respectively. The proposed technique has the minimum SLA-violations i.e., 0.13673 in comparison with other techniques.

TABLE III. COMPARISON OF TECHNIQUES ON THE BASIS OF VM MIGRATIONS

No. of. Host count	No. of. VM count	Host to VM ratio	Number of Migrations			
			ABC	E-ABC	CS	Proposed
1	10	0.1	5	3	2	1
2	21	0.095238	7	4	3	2
3	34	0.088235	10	8	6	5
4	42	0.095238	13	10	9	7
5	56	0.089285	11	7	5	3
6	64	0.09375	14	10	7	4
7	73	0.09589	18	16	12	11
8	82	0.09756	15	13	10	8
9	91	0.0989	17	14	11	9
10	103	0.097087	12	9	7	6

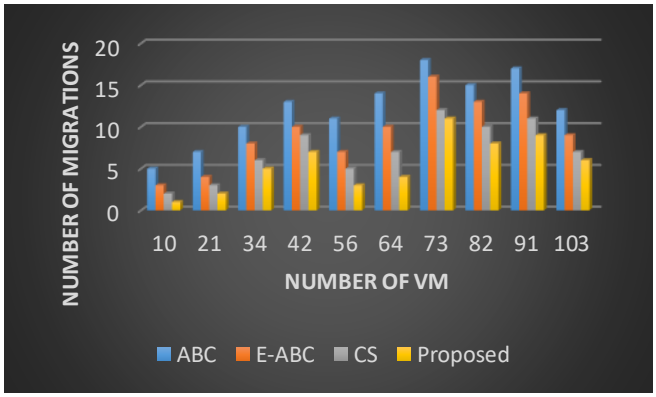

Fig.6. Comparison of proposed technique with other in terms of total migrations.

Authorized licensed use limited to: Nirma University Institute of Technology. Downloaded on March 09,2024 at 16:03:49 UTC from IEEE Xplore. Restrictions apply.

The Fig 6. represented that the proposed technique has minimize the total migrations in order to avoid the unnecessary energy waste during the migrations and proposed framework also perform better in comparison with other techniques. The average values of the different techniques such as ABC [18], E-ABC [20], CS [11] and proposed are 12.2, 9.4, 7.2 and 5.6 respectively. The proposed technique has the lowest rate of migration i.e., 5.6 in comparison with other techniques.

VI. Conclusion

In real-world applications, the suggested method improves resource utilisation in VMs and also minimising the energy consumption, number of migrations. The proposed GOA helps to minimise the problem related to SLA-violation and false migrations and ensure optimum VM selection. The VM Migration is a procedure in which the VM are first allocated on an appropriate PM and then migrated demanding upon the requirement. The allocation strategy is dependent on both the resource utilisation of VM and hosts. The minimization of energy consumption during the migration process, the suggested MBFD algorithm continuously updates the minimum power necessary for the allocation or migration of a VM across a Host. The proposed work is outperformed as compare to other traditional techniques ABC [18], E-ABC [20] and CS [11] in terms of energy consumption, SLA-violations and number of migrations using MBFD algorithm and GOA. The paper has achieved distinguishing performance on limited hosts (10 hosts deploying 103 VMs) that will be further investigated while involving more number of hosts and VMs in near future.

References

[1] X. Zhang et al., "Energy-aware virtual machine allocation for cloud with resource reservation," Journal of Systems and Software, vol. 147, pp. 147–161, Jan. 2019, doi: 10.1016/j.jss.2018.09.084.

[2] R. Buyya, C. S. Yeo, S. Venugopal, J. Broberg, and I. Brandic, "Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility," Future Generation Computer Systems, vol. 25, no. 6, pp. 599–616, Jun. 2009, doi: 10.1016/j.future.2008.12.001.

[3] Y. Moon, H. Yu, J.-M. Gil, and J. Lim, "A slave ants based ant colony optimization algorithm for task scheduling in cloud computing environments," Human-centric Computing and Information Sciences, vol. 7, no. 1, Oct. 2017, doi: 10.1186/s13673-017-0109-2.

[4] R. Keller, L. Häfner, T. Sachs, and G. Fridgen, "Scheduling Flexible Demand in Cloud Computing Spot Markets," Business & Information Systems Engineering, vol. 62, no. 1, pp. 25–39, Mar. 2019, doi: 10.1007/s12599-019-00592-5.

[5] M. Ghobaei-Arani, A. A. Rahmanian, M. Shamsi, and A. Rasouli-Kenari, "A learning-based approach for virtual machine placement in cloud data centers," International Journal of Communication Systems, vol. 31, no. 8, p. e3537, Feb. 2018, doi: 10.1002/dac.3537.

[6] C. Ghribi, M. Hadji, and D. Zeghlache, "Energy Efficient VM Scheduling for Cloud Data Centers: Exact Allocation and Migration Algorithms," 2013 13th IEEE/ACM International Symposium on Cluster, Cloud, and Grid Computing, May 2013, doi: 10.1109/ccgrid.2013.89.

[7] D. Dad, D. E. Yagoubi, and G. Belalem, "Energy Efficient VM Live Migration and Allocation at Cloud Data Centers," International Journal of Cloud Applications and Computing, vol. 4, no. 4, pp. 55–63, Oct. 2014, doi: 10.4018/ijcac.2014100105.

[8] N. N. Devi and S. V. Kumar, "SLAV Mitigation and Energy-Efficient VM Allocation Technique Using Improvised Grey Wolf Optimization Algorithm for Cloud Computing," 2022 8th International Conference on Advanced Computing and Communication Systems (ICACCS), Mar. 2022, doi: 10.1109/icaccs54159.2022.9785078.

[9] P. Pranav, N. Rizvi, and R. Jha, "QoS aware VM allocation policy in cloud using a credit based scheduling algorithm," Communication and Computing Systems, Nov. 2016, doi: 10.1201/9781315364094-81.

[10] R. W. Ahmad, A. Gani, S. H. Ab. Hamid, M. Shiraz, F. Xia, and S. A. Madani, "Virtual machine migration in cloud data centers: a review, taxonomy, and open research issues," The Journal of Supercomputing, vol. 71, no. 7, pp. 2473–2515, Mar. 2015, doi: 10.1007/s11227-015-1400-5.

[11] M. Yakhchi, S. M. Ghafari, S. Yakhchi, M. Fazeli, and A. Patooghi, "Proposing a load balancing method based on Cuckoo Optimization Algorithm for energy management in cloud computing infrastructures," 2015 6th International Conference on Modeling, Simulation, and Applied Optimization (ICMSAO), May 2015, doi: 10.1109/icmsao.2015.7152209.

[12] I. S. Dhanoa and S. Singh, "Power Efficient Hybrid VM Allocation Algorithm," International Journal of Computer Applications, vol. 127, no. 17, pp. 39–43, Oct. 2015, doi: 10.5120/ijca2015906722.

[13] J. Jiang, Y. Feng, J. Zhao, and K. Li, "DataABC: A fast ABC based energy-efficient live VM consolidation policy with data-intensive energy evaluation model," Future Generation Computer Systems, vol. 74, pp. 132–141, Sep. 2017, doi: 10.1016/j.future.2016.05.013.

[14] B. Perumal, M. Aramudhan, and R. K. Saravanaguru, "Fuzzy Bio-Inspired Hybrid Techniques for Server Consolidation and Virtual Machine Placement in Cloud Environment," Cybernetics and Information Technologies, vol. 17, no. 4, pp. 52–68, Nov. 2017, doi: 10.1515/cait-2017-0041.

[15] X. Ruan, H. Chen, Y. Tian, and S. Yin, "Virtual machine allocation and migration based on performance-to-power ratio in energy-efficient clouds," Future Generation Computer Systems, vol. 100, pp. 380–394, Nov. 2019, doi: 10.1016/j.future.2019.05.036.

[16] S. More, J. Singla, O.-Y. Song, U. Tariq, and S. Malebary, "Denoising Medical Images Using Deep Learning in IoT Environment," Computers, Materials & Continua, vol. 69, no. 3, pp. 3127–3143, 2021, doi: 10.32604/cmc.2021.018230.

[17] K. Kumar et al., "An Efficient Load Balancing Technique based on Cuckoo Search and Firefly Algorithm in Cloud," International Journal of Intelligent Engineering and Systems, vol. 13, no. 3, pp. 422–432, Jun. 2020, doi: 10.22266/ijies2020.0630.38.

[18] K. Karthikeyan et al., "RETRACTED ARTICLE: Energy consumption analysis of Virtual Machine migration in cloud using hybrid swarm optimization (ABC–BA)," The Journal of Supercomputing, vol. 76, no. 5, pp. 3374–3390, Sep. 2018, doi: 10.1007/s11227-018-2583-3.

[19] V. B. Kaur, and S. Jangra, "Cuckoo-Neural Approach for Secure Execution and Energy Management in Mobile Cloud Computing," International Journal of Advanced Computer Science and Applications, vol. 12, no. 1, 2021, doi: 10.14569/ijacsa.2021.0120175.

[20] S. Talwani and J. Singla, "Enhanced Bee Colony Approach for reducing the energy consumption during VM migration in cloud computing environment," IOP Conference Series: Materials Science and Engineering, vol. 1022, no. 1, p. 012069, Jan. 2021, doi: 10.1088/1757-899x/1022/1/012069.

[21] S. Kumar Pande et al., "A Resource Management Algorithm for Virtual Machine Migration in Vehicular Cloud Computing," Computers, Materials & Continua, vol. 67, no. 2, pp. 2647–2663, 2021, doi: 10.32604/cmc.2021.015026.

[22] D. A. Shafiq, N. Z. Jhanjhi, and A. Abdullah, "Load balancing techniques in cloud computing environment: A review," Journal of King Saud University - Computer and Information Sciences, vol. 34, no. 7, pp. 3910–3933, Jul. 2022, doi: 10.1016/j.jksuci.2021.02.007.

[23] D. A. Shafiq, N. Jhanjhi, and A. Abdullah, "Machine Learning Approaches for Load Balancing in Cloud Computing Services," 2021 National Computing Colleges Conference (NCCC), Mar. 2021, doi: 10.1109/nccc49330.2021.9428825.

[24] D. A. Shafiq, N. Z. Jhanjhi, A. Abdullah, and M. A. Alzain, "A Load Balancing Algorithm for the Data Centres to Optimize Cloud Computing Applications," IEEE Access, vol. 9, pp. 41731–41744, 2021, doi: 10.1109/access.2021.3065308.

[25] S. Saremi, S. Mirjalili, and A. Lewis, "Grasshopper optimisation algorithm: Theory and application", Advances in Engineering Software, vol. 105, pp. 30-47, 2017.

Authorized licensed use limited to: Nirma University Institute of Technology. Downloaded on March 09,2024 at 16:03:49 UTC from IEEE Xplore. Restrictions apply.