Machine Learning and Bio-inspired Integrated Approach for Virtual Machine Placement

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ABSTRACT

Optimal allocation of resources is crucial for achieving the considerably elevated quality of service parameters. In the context for employing a machine learning and bio-inspired integrated way for virtual machine placement arises from the cloud's increasing complexity and dynamic nature. Traditional methods often rely on heuristic rules or optimization techniques, which may not adapt well to changing conditions. The task is to develop a multi-objective optimization method that minimizes power consumption without breaching the SLA. The central focus is to accomplish the most efficient VMP strategy with a focus on energy efficiency. Several SOTA algorithms have been studied, and a hybrid integration of machine learning with meta-heuristic has been experimented with that performs the optimal allocation of VM taking into account the energy used, migration count, and the breaching of SLA In terms of comparison with the latest advancements, the proposed approach has been assessed against dual advanced methodologies. It has demonstrated an enhancement in power consumption, with a maximum increase of around 15.83%. Additionally, it has also shown a 15.32% improvement in mitigating SLA violations. The suggested optimization approach demonstrates outstanding performance in power consumption, SLA-V, and multiple migrations in comparison with dual competent and contemporary meta-heuristic techniques.

1. INTRODUCTION

With the intent of both time and technology, computing in the cloud environment has become paramount [1]. There is a surge in the need for computing resources, which must be handled efficiently at the data centers. Thus, resource provisioning becomes an eminent task in the cloud center environment. Virtualization has complimented the entire data center scenario and cloud hosting services; thus, there is rampant growth in its adoption. Coincidently, the dynamic and proficient allocation of available resources for virtual machines (VMs) becomes more pivotal [2, 3].

Optimized allocation of resources can induce better solutions for cloud service providers and end users for getting efficient VM sizing, thereby reducing multiple costs. On the contrary, it may lead to energy inefficiency at the data center. Virtualization has been proven to be the pivotal technique in aiding the reduction of power consumption at the data center. It's been recognized that a fully ideal sever consuming 70% of its peak power [4]. Thus resource allocation and management become a major concern for virtual machine placement problems[5, 6]. Virtual machine placement is an optimization problem and is considered bin-packing related problem in this context. Therefore, it is NP-hard. Refer to [7] Consolidating certain numbers of virtual machines on fewer nodes and switching off ideal server can provide various advantages pre-eminently. It helps in minimizing the overall energy consumption at the data cloud center. Although server consolidation results in a reduction of power consumption this solution have a trade-off with increased resource consumption and may degrade the performance [8].

This paper considers the VMP dilemma as a multi-dimensional bin-packing issue associated along multiple objectives with subject to certain constraints. Resources of physical machines, such as memory and CPU utilization consumption by virtual instances, are considered the constraints. To reduce power consumption and SLA violation, a new algorithm cr_Cuckoo is introduced to determine the scheduling of available virtual machines. cr_Cuckoo combines the meta-heuristic algorithm with the with the self-guided machine learning K means grouping. The integration of both algorithms' strategies an optimal solution to deployment issue with virtual machines. To demonstrate the efficacy of this method, it is being compared to the currently known virtual machine placement algorithms. The experimental findings demonstrate that this

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strategy effectively and promptly deactivates superfluous hosts by prioritizing energy efficiency, hence enhancing the data center's load distribution.

The primary contributions of the work are outlined as follows:

- Applying the meta-heuristic method with the VM placement problem.
- A hybrid integration of machine learning with a meta-heuristic that performs the optimal allocation of VM taking into account the energy used, the quantity of migrations, and the breaches of SLA.
- An empirical evaluation of the proposed solution with the existing techniques.

The subsequent parts of the paper are organized as given. Section 1 discusses an introductory description of work. Section 2 undertakes the necessary details of extensive literature and related work. The literature has explored twin parameters, virtual machine placement techniques, and the optimization objective of energy efficiency. The problem statement and model formulation tasks have been described in Section 3, and the cr_Cuckoo algorithm is elaborated in Section 4. Following Sections 5 and sixth state the parameters and experimental outcomes respectively moreover compare them with other methods. In Section 7, the paper is concluded.

2. EXISTING WORK

Virtual machine allocation is one of the core aspect in virtualization techniques. The phase is subsequently followed by the relocation of virtual machines.

Also, it has been observed that the migration of virtual machines consumes significant energy at the data center thus the researchers have incorporated numerous methodologies to determine the better virtual machines for the allocation to have reduction in the number of migrations also thereby save energy requirement.

Varied optimization techniques traversing from heuristic to stochastic integer programming, constraint programming and meta-heuristic have been employed for the placement of virtual machines. Table 1 gives a snapshot of the related work in the respective optimization technique.

Table 1. Related Work of Various Optimization Techniques

Author	Objective	Summary /gap
Approach: Heuristics Based		
Xiaoli et al.[9]	Energy Efficiency & resource utilization	Employed component event invoker and concentrate manager. Approach lack in resource size demand
Babu et al.[10]	Allocation of maximum VMs to the server	Employed bin packing approach considered worst fit algorithm for VM placement
Noumankhan et al.[11]	Load balancing-based placement	Proposed FFDl algorithm for performing disk I/o-based VM placement. The algorithm does nothing if the host does not have enough resources
Wang et al.[12]	To avoid congestion and network degradation	Proposed EQVMP an algorithm for VM placement with incorporated Best fit Decreasing Ignores resource utilization
Approach: Stochastic integer programming		
Chaisiri et al. [13]	Energy efficiency focuses on resource and application-aware	Proposed OVMP for the provisioning of the resources
Li et al. [14]	Load balancing	Proposed Min –Max method of optimization and worked on optimization based on upper bound
Zamanifar et al. [15]	VM placement and minimizing delays in the transfer of data	Proposed Rate Optimal VM placement algorithm(ROVMP)
Approach: Constraint Programming		
Hermenier et al. [16]	To handle VM migration and allocation	The authors proposed an entropy manager for resources to handle using constraint programming
Van et al. [17]	To handle the VMP problem as constraint satisfaction	The authors proposed a combined framework with the entities' configuration and placement for VMP
Approach: Meta-Heuristic		
Luo et al. [18]	Reduction in energy requirements and resource wastage	The presenter proposed multi-objective PSO for optimizing the ratio of link loss. However, the authors have not stated the consideration of static or dynamic environments.
Guo et al. [19]	To optimize time and cost	The authors proposed PSO and a graph of processor interaction for optimizing cost and time.
Li et al. [20]	To improve the usage of PMs for energy efficiency	The authors proposed a scheme known as EEVMC
Ding et al.	To address security	The authors proposed a

[21]	and optimize performance	framework incorporating the firefly algorithm.
Riahi & Krichen[22]	To work on reduction in resource consumption and consumed power	The authors employed a genetic algorithm and also statistical Bernoulli distribution.
Qian et al. [23]	To enhance network efficiency and reduce operating expenses.	The authors integrated generated and simulated annealing algorithms.
Ariyan et al. [24]	To enhance energy efficiency and minimize footprints of carbon	Proposed fuzzy with multiple objective DVFS aware approach

Varied approaches to achieving the optimization objective of attaining energy efficiency techniques traversing from server consolidation, Dynamic Voltage, and frequency scaling (DVFS), thermal management, and bio-inspired methods have been employed. Table 2 gives a snapshot of the related research in the optimization objective of energy conservation.

Table 2. Related work to attain optimization objective of energy efficiency

Author	**Objective**	**Summary /gap**
Approach: Server Consolidation		
Dang et al.[25]	To work on energy efficiency	The technology works on energy-conserving and an algorithm for globally optimization in cloud also for the consolidation of servers. The author did not consider cost optimization.
Usman et al.[26]	Reduction in energy consumption and resource underutilizat ion	The authors proposed Energy Efficient based on Interior Search (EEIS). The proposed approach saved approx. 30% of energy
Wang et al.[27]	Reduction in SLA, energy worked on load balance and scalability	The authors used 2D heuristic based greedy algorithm
Approach: DVFS		
Garg et al.[28]	To meet the deadline for application	Employed DVFS to predict the CPU operating frequency
Kim et al.[29]	Selection of least expensive VMs	Based on the DVFS scheme provisioning is applied
Ding et al.[30]	Energy Efficiency	Hosts are prioritized based on the ratio to compute the peak power of each host
Approach: Thermal Management		
Chen et al.[31]	To avoid hotspots	The approach based on scheduling is used and uses imperative factors for the placement of VMs
Xiao et al.[32]	To measure the degree of overload of resources	The authors worked on skewness metric for quantification of utilization of resources
Approach: Bio-inspired		
Kansal et al.[33]	To reduce energy and VM migration	The authors proposed a firefly algorithm for attaining a better solution
Jiang et al.[34]	To have energy efficiency at the data center.	The authors proposed the Ant Colony Optimization ACO algorithm to attain energy efficiency globally
Moon et al.[35	To attain energy efficiency	The authors proposed ACO which can work on heterogeneous type
Perumal et al.[36]	To attain energy efficiency	The authors proposed a fuzzy ant colony cuckoo search and fuzzy firefly
Barlaskar et al.[37]	To attain energy efficiency	The authors proposed Enhanced Cuckoo Search ECS which works in a heterogeneous environment.
Kaaouache et al.[38]	To attain optimal energy performance .	The authors proposed a framework for working on optimization techniques.
Karda et al.[39]	To attain optimal energy performance .	The authors proposed ACO which works in a heterogeneous environment
Chaudhrani et al.[40]	To attain optimal energy performance .	The authors proposed PSO which works in heterogeneous
Jena et al.[41]	To distribute and maintain load and save energy	Authors proposed Modified Particle Swarm Optimization MPSO for dynamically balancing the load.
Jangra et al.[42]	To attain energy efficiency	The authors proposed Cuckoo Search with ANN

Talwani et al.[43]	To attain energy efficiency and reduce migrations	The authors proposed the Enhanced Artificial Bee Colony (EABC) algorithm in virtue of saving energy.

2.1 Survey Outcome

Despite the wide range of VMP approaches published annually for various objectives, a comprehensive survey has found that meta-heuristic algorithms are the most popular optimization algorithms. Furthermore, the survey suggests that enhancing and incorporating these algorithms with machine learning schemes can yield more resilient solutions.

3. PROBLEM STATEMENT

To leverage the complete benefit from virtualization technology numerous virtual instances are created called virtual machines. These machines are kept abstracted from the actual hardware and these machines are then placed onto the physical machine. Allocation of these instances can help in attaining various benefits. This placement of a virtual machine to the nodes/physical machines is designated virtual machine placement.

3.1. Preliminaries

3.1.1. Constraints

The proper placement of the resources at the data center is required and must align with certain constraints such as:

- Required resources: Virtual machines tend to require a certain set of resources from the host.
- Context awareness: this states that the given virtual machines are deployed to nodes or physical servers or machines then the node must have ample resources to perform its required base task
- Migration policy: although efficient allocation follows a context awareness policy sometimes simulating in the real-time environment virtual machines may consume more resources leading to overloaded hosts, so few virtual machines need to be migrated.

3.1.2. Virtual Machine Placement

Let collection of VM’s by VM = {VM1, VM2, VM3. VMn}

Consider set of PM’s by PM = {PM1, PM2, PM3 …. PMm}

The objective is:

a) To find certain physical machines from the given physical machines PMn for mapping the virtual machines from the set VMn to the PM efficiently according to certain optimization objectives such as reduction in power consumption and SLA breaching.

b) To fulfill the requirement of the resources by the VMs.

c) To increase the amount of idle physical hosts to reduce power consumption.

Fig. 1 illustrates the virtual machine placement scenario.

3.1.3. Overview of Power Consumption Scenario

One significant metric given in data cloud center is to determine the overall power consumption. Generally, it’s computed by considering the fraction by the total amount of power incoming in data center with consumed power of the installed equipment.

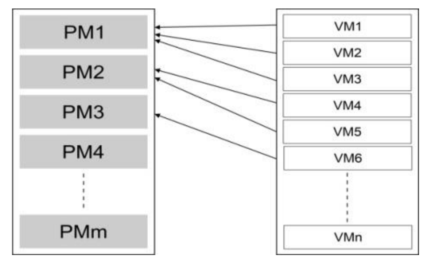

Fig. 1. Virtual Machine Placement (VMP).

Power consumption is calculated in 2 cases as depicted in Fig. 2 First when the VM is placed on PM, power consumption draws equals the maximum required by physical machine, and when the VM is not allocated on host. The utilization of CPU is the factor that is given by the CPU usage employed by each VMs on the PM divided with overall usage of PM.

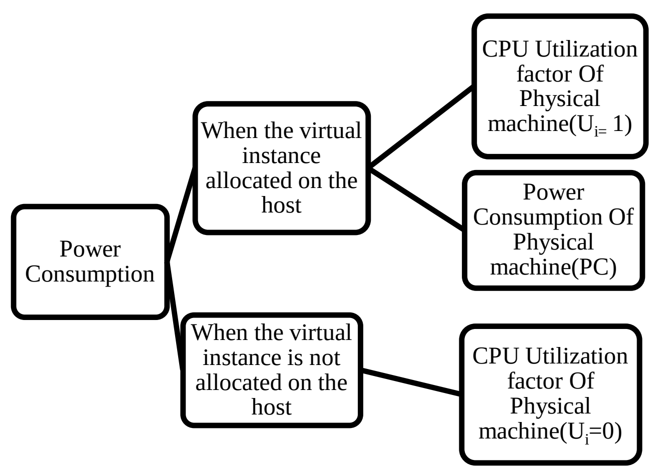

Fig. 2. Power Consumption Model.

The above analysis can help in resolving the deploying problem of available virtual machines with help of mathematical formulation. The placement of VMs onto physical servers is classified in dual cases formerly if the VM is hosted onto PM given by one and in later cases if not hosted by the PM given by zero.

3.2 Problem Definition

The above analysis can help in resolving the deploying problem of available virtual machines with help of mathematical formulation. The placement of VMs onto physical servers is classified in dual cases formerly if the VM is hosted onto PM given by one and in later cases if not hosted by the PM given by zero.

Table 3. Abbreviation and terms

Abbreviation	Term
PM	Physical machine
VM	Virtual machine
K	Marks each hosts/or PM
Totalpc	Consumed Power
CPUi	Compute Capacity
CPUutil	Total Compute utilization of all VMs
Allocated_PM	Allocated Host
Idle_PM	Idle Host

To address the VMPP, it is necessary to take into account several assumptions, objectives, and constraints. Additionally, few specific notations utilized are given in Table 3.

3.2.1 Assumptions

A few assumptions for the VM provisioning are given as:

- The work considers the case of a single cloud infrastructure hub.
- Multiple VMs can be assigned to the host.
- CPU is the major consumer of energy at the data center besides all resources.
- CPU utilization and power consumption have a linear relationship [27].

3.2.2 Power Consumption Model

Power consumption can be evaluated by considering all the different states a host can have in the compute data center. A host's state may operate in: allocated, idle, or powered off state. The power consumption by a host or the physical machine is calculated as given in equation (1)

$$PMpc = (Allocated\_PM - Idle\_PM) * CPUutil + Idle\_PM \quad (1)$$

The overall total power consumption (Totalpc) computation at the data center is done after the allotment of virtual instances is specified as a function of F at a particular time and shown in equation (2)

$$Totalpc = \sum_{i=1}^{n} PMpc(F,t) \quad (2)$$

- *Objective Criterion*

The centered objective criterion of presented technique is centered around minimizing power usage. The objective function or criterion F is given as in equation 3:

$$F = \sum_{k=1}^{n} Totalpc \quad (3)$$

where, k = for the range of physical machines; Totalpc = Total power consumed.

- *Constraints*

Constraint 1: VMs must be initially allocated to PMs

Constraint 2: VMs must not exceed the resource usage allocated to them.

4. PROPOSED ALGORITHM

The section proposes the hybrid algorithm to resolve the stated problem in section 3. The work incorporates a bio-inspired cuckoo search algorithm.

The algorithm workflow broadly is presented in Fig. 3 given below:

The virtual machine placement scenario is an optimization challenge so fascinated by the analogous behavior of cuckoos as they look for nests to lay their eggs. Moreover, it employs the concept of correlation factor in finding the near-optimal solution. Thus the proposed algorithm named cr_cuckoo is given as follows:

In the first phase, the unassigned virtual machines are formerly assigned to the server's physical machines. The VMP problem may further solved by finding the overloaded physical hosts termed hotspots, selecting the suitable virtual machine selection policy VM to be reallocated, and finally using the Cuckoo search optimization algorithm VMs allocated to the target physical machine

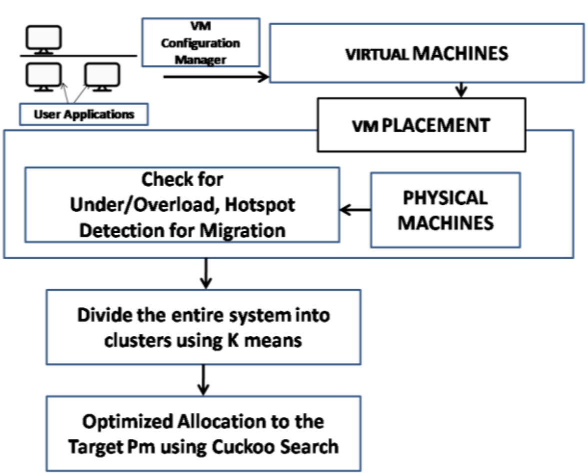

Fig. 3. Flow of the Proposed Approach.

The pseudo-code of the presented algorithm:

Algorithm: Proposed cr-Cuckoo algorithm for VM Placement

1. Input: VM allocation Table
2. Output:VM Migration list for migration(VMlist)
3. **Step 1:** Extract the overloaded PMs from the allocation table
4. PMl=Allocationtable.OverloadedPMs

5. **Step 2:** For (p in PMl)
6. QoS=Allocation Table.p.QoS //Extract the QoS parameters
7. **Step 3**: Initalize of number of nests or hives by applying k-means for cuckoo eggs set levy flight lf=5;
8. **Step 4:** Calculate the fitness function for the initial population
9. **Step5:** [Cindex,Ccentroid]=kmeans(QoS,2) //Divide the entire population in two nests or hives
10. **Step 6:** Identify the best optimal nest position as
11. OGb((o))VMl = AllocationTable.Find(p)as host
12. **Step 7:** For (VM as the egg in VMlist do) //for each VM in overloaded list
13. **Step 8:** Reward = []; //Generate a reward matrix based on co-relation defined
14. **Step 9:** For (k=1: lf)
15. **Step 10:** Update the positioning of the hive nest considering the weight function
16. **Step 11**: Increment theVM load for all VM
17. **Step 12**: Compute the fitness function for the newly updated position based on co-relation
18. **Step 13**: Repeat and obtain the optimal solution //select the best VM and then migrate
19. **Step 14: I**f VM (satisfies population)
20. **Step 15:** Reward.Append(1) //Add reward point
21. **Step 16:** EndIf
22. **Step 17:** EndFork

4.1 Algorithm Phases

The algorithm given in the above section traverses from certain phases as described in subsequent sections

4.1.1 Phase 1: VM Initial Allocation

The initial phase begins with the demand for the virtual instances to execute the task by the user application as illustrated in Fig. 4. The demand for the VMs is taken by the entity designated as the VM configuration manager. Configuration VM manager handles the provisioning of VMs to the hosts or the physical machine. After provisioning the resources onto the host the applications are allocated to the physical machines which are handled by another entity known as the VM placement manager. This phase also deals with certain prerequisites such as whether a VM can fulfill the demand of required resources by the VMs.

Thus a Modified Best Fit Decreasing algorithm was employed to rank the given hosts according to their respective requirements of power consumption and finally the VMs are initially allocated.

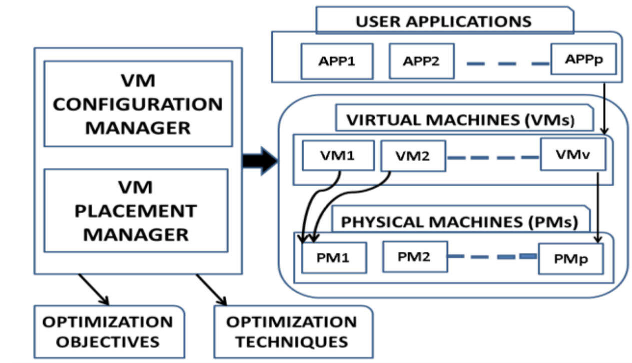

Fig. 4. VM Initial Allocation (Phase 1).

Similarly, the instances (VMs) are deployed to the hosts or nodes(PMs), as illustrated in Fig. 5.

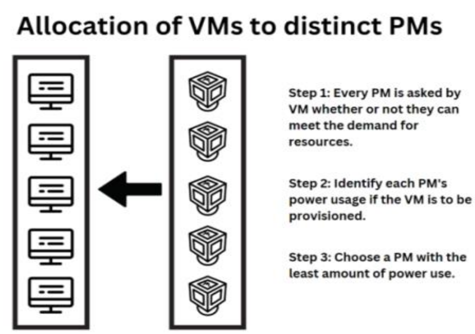

Fig. 5. VMs Allocation to the PMs.

4.1.2. Phase 2: Detection of the hotspot node and selection of VMs for migration

Following the initial allocation of the virtual machines in the first phase, it may be probable that certain hosts may get overutilized and some may get underutilized. The nodes which are under or overutilized are identified and termed as the hotspot nodes. Subsequently, there arises a need for the movement of instances virtual machines. Fig. 6 illustrates detection of hotspot node.

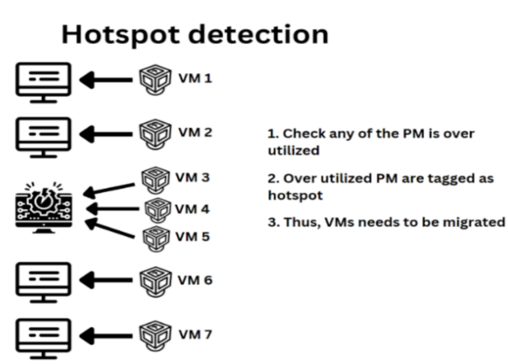

Fig. 6. Hotspot detection (Phase 2).

After the identification of hotspot nodes, the migration of VMs is done based on the minimum migration policy, Fig. 7 depicts the stated scenario.

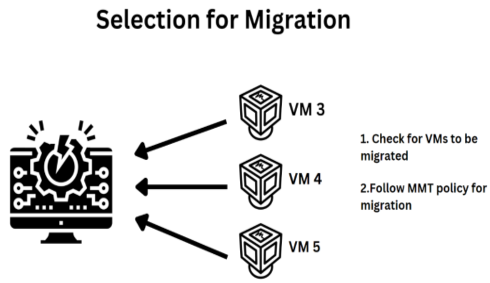

Fig. 7. Selection for Migration (Phase 2).

4.1.3. Phase 3: PM Division and grouping

This incorporates the clustering process to classify the entire population in two hives.

The segregation of the physical hosts based on the load assignment will aid in the next phase.

VMs are reallocated based on this classification. The two hives separate the underutilized nodes from the overutilized nodes.

The Fig. 8 illustrates the complete division process for VM redistribution.

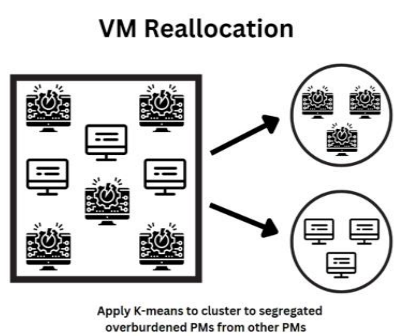

Fig. 8. VM Reallocation based on clustering (Phase 3).

4.1.4 Phase 4: Deployment based on Cuckoo Search

In this phase finally, the migrated VMs are reallocated. Reallocation of VMs is done using the meta-heuristic-based cuckoo search algorithm. Finally, the entire process resulted in attaining a near-optimal solution. Allocation and reallocation of instances or virtual machines in the cloud data center here are inspired by the cuckoo's peculiar behavior of laying eggs. Fig. 9 presents the reallocation based on the Cuckoo Search

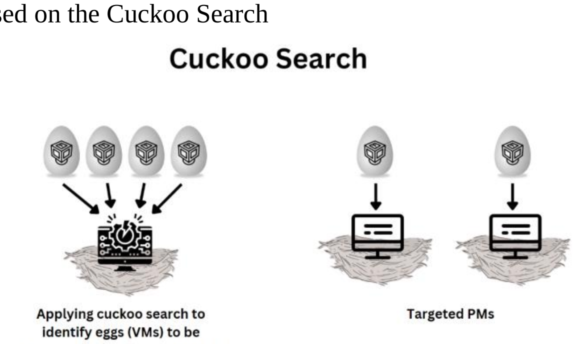

Fig 9. Allocation based on Cuckoo Search (Phase 4).

4.2. Mathematical Model

The section outlines the mathematical model for the above given phases of the given approach for resolving the virtual machine scheduling or deployment problem. The model transit from a few phases given in the subsequent sections as follows:

4.2.1. Initialization

Let

- N = the number of virtual machines (VMs).
- i = index for VMs.
- ui = the CPU requirement of VMi
- M = the number of physical machines (PMs).
- j = index for PMs.
- vj = the total CPU capacity of PM_j
- x_{ij} = binary decision variable

It is the decision variable indicating whether VM_i is placed on PM_j as given in equation 4.

$$Xij = \begin{cases} 1, if\ VMi\ is\ placed\ on\ PMj \\ 0, otherwise \end{cases} \tag{4}$$

4.2.2. Objective Criterion

The aim or objective is to reduce overall resource wastage, such as the CPU requirement of VMi which can be represented as given in equation 5.

Minimize:

$$\sum_{i=1}^{N}\sum_{j=1}^{M} uiC(1 - xij) \tag{5}$$

4.2.3. Constraints

i. For every VM must be assigned to individual PM as given in equation 6.

$$\sum_{j=1}^{M} xij = 1\ \forall I \tag{6}$$

ii. The total resource demand for virtual machines allocated to a physical host cannot exceed its capacity as given in equation 7.

$$\sum_{i=1}^{N} ri.xij < Cj \tag{7}$$

4.2.4. Cuckoo search

i. Initialization:

Randomly initialize the nest locations, i.e., the placement of VMs on PMs equation 8:

$$xij \sim Uniform(0,1) \tag{8}$$

for i = 1, 2,..., N and for j = 1, 2,..., M; xij here is a binary decision field indicating whether VM_i is placed on PM_j

ii. Evaluation of Fitness Function

In this phase global centroid is computed with the help of taking the mean utilization of CPU and RAM utilization across all the VMs

Let N be overall allocated VMs, and M be the total overall physical machines (PMs). Let CPU_{ij} represent the

CPU utilization of VM_i on PM_j and RAMij represent the RAM utilization of VMi on PM_j.

The aggregated CPU and RAM utilization for each VMs across PMs equation 9 and 10 respectively:

$$Sum\_CPU = \sum_{i=1}^{N} CPUij \quad (9)$$

$$Sum\_RAM = \sum_{i=1}^{N} RAMij \quad (10)$$

The total number of allocations (total number of VMs across PMs) equation 11:

$$Total\_Allocations = n * m \quad (11)$$

The mean of CPU and RAM utilization is given in equations 12 and 13 respectively:

$$Mean\_CPU = Sum\_CPU/Total\_Allocations \quad (12)$$

$$Mean\_RAM = Sum\_RAM/Total\_Allocations \quad (13)$$

The global centroid coordinates represent the mean CPU and RAM utilization across all allocated VMs:

Global_Centroid is the Mean_CPU, Mean_RAM.Calculate the deviation with the help of Euclidean distance from global centroid.VMs with a lower deviation are closer to the global centroid and less likely to imbalance when migrated. The fitness criterion of every nest (solution) is computed by the objective criterion function as given:

$$f(x) = 1.0 \text{ if } vj>ui$$
$$= 0.0 \text{ otherwise} \quad (14)$$

This equation 14 evaluates to 1.0 if the total CPU capacity of the PM is more(vj) than or equating the total CPU demand of the VMs allocated(ui) to it, indicating that the PM satisfies the CPU requirement. Otherwise, it evaluates to 0.0, indicating that the PM does not satisfy the CPU requirement.

The nest population starts with random initialization, denoted as $m^{(o)}$ given in equation 15 comprising a vector of initial positions

$$m(o) = [o1(o), o2(o), o3(o), o4(o), \ldots, on(o))]t \quad (15)$$

After evaluating the criterion/fitness of the function for this given initial population, the optimal nest point or position is determined as
$o_{Gb}{}^{(o)}$.

Subsequent step involves updating the nest position using a weight coefficient, defined as follows in equation 16:

$$wc = wc\_max - ((wc\_max - wc\_min) \times Sim\_current / Sim\_max) \quad (16)$$

The weight maximum and weight minimum coefficients are denoted like wc_max and wc_min, individually. Sim_current represents the current simulation round, while Sim_max denotes the maximum simulation rounds for the optimization technique.

iii. Generate New Solutions:

New solutions are generated by randomly selecting a nest and replacing it with a new solution as given in equation 17:

$$x'ij = x\,ij + \alpha * Levy\ Flight\ (0, \lambda) \quad (17)$$

for i = 1, 2, ..., N & for j = 1, 2, ..., M
where, λ is the step size and scaling factor assumed as 5

Therefore, it is represented as given in equation 18

$$x'ij = x\,ij + 5 \otimes P(\phi) \quad (18)$$

$$P(\phi) \sim v = \boldsymbol{t}^{-\boldsymbol{\phi}} \quad (19)$$

where in equation 19; P(ϕ) is the levy flight distribution; ϕ is the parameter influencing how flight lengths are distributed; v is the distance traveled during each step of the flight; and t is the step size.

iv. Evaluate New Solutions:

The performance of the taken solutions is computed in the form of: Fitness(x') = f(x') for x′in the population of new solutions.

By evaluating both current and historical fitness metrics relative to the population region, the best nest is selected. Equation 20 defines the updated positions as follows:

$$k(j+1)=[o1(j+1),o2(j+1),o3\ (j+1),\ldots\ldots\ldots,on(j+1)]t \quad (20)$$

v. Selection

The nests are replaced with better solutions based on their fitness values. A replacement strategy is used to retain the best solutions. The procedure filters out randomized data and computes a probability parameter (*F_probability*) to assess the nest. Upon egg detection by a host, the nest undergoes a state shift, expressed mathematically as a v-dimensional vector problem as $Q_v = [q_1 q_2, q_3 \ldots, q_k]$. For each q_i in Q_v, every vector adheres to a uniform distribution [0,1], and if q_i exceeds the F_probability threshold, the positions of the nests are randomly altered.

The best nest for migration is formulated as follows:

$$Best_{j+1} = [o_1(j+1), o_2(j+1), o_3(j+1), \ldots \ldots . o_n(j+1)]^T \quad (21)$$

By applying equation 21, the optimal position of the nest is revised, and this process continues until the termination conditions are satisfied. A reward matrix is created if it finds the best solution.

vi. Termination

The algorithm is terminated if the stopping criterion of rewards is met. And if the present solution meets termination criterion, the process halts; else it recommences the equation 16.

vii. Iteration

Repeat Steps 3 to 6 until the termination condition is satisfied. Employing the equation mentioned above, the optimal point of t hive or nest is adjusted, and this procedure is iterated till the eliminating or termination conditions are fulfilled

5. PARAMETERS FOR ALGORITHM EVALUATION

The presented algorithm is contrasted with the leading contemporary algorithms [3][8]. The evaluation of the given algorithm is quantified using three independent variables. The quality-of-service parameters that are considered are SLA violation, number of migrations, and power consumption. The stated parameters have their significance and crucially in the performance aspect of the problem. The parameters under consideration are:

5.1. Power consumption

With the intent of time the technology is moving towards sustainable methods. Therefore, to have efficiency at the data center, one of the crucial aspects is the computation of the aggregated consumption of the power at the compute data center. The reduction in the metric of power consumption is a vital and challenging task at the data center. Moreover, this aspect leads to a greener cloud and in turn sustainability. Also, it is computed while considering the fraction of the power incoming in the data center and the one factor that is power utilized made by the installed equipment there.

5.2. Service level agreement (SLA-V)

It’s a formal contract among the provider of cloud services and the user. The contract helps in getting the terms and conditions for the performance of the offered services. Violation in the scenario of service level agreement known as SLA-V refers to the breach of services stated in the agreement. SLA-V may occur due to various reasons such as due to a hike in the count of migrations or an increase in the metric power consumption and an increase in number of VM migrations.

5.3. Number of migrations

Reallocation or the Migration of VMs plays a significant part in handling the data center's overall state. But on the flip side rise in the number of VM migrations may lead to a rise in power consumption as well as the SLA violations. As a result, number of migrations needs to decrease so that they won’t hinder with pros manifested with thoughtful migration.

Hence, the given work has been assessed for respective performance analysis with respect to the three chosen parameters.

6. RESULT AND DISCUSSION

The performance of the proposed algorithm is contrasted with that of existing algorithms. The varied count in virtual machines has been taken to evaluate the performance. The VMs are considered five times the number of PMs. In the experiment conducted for a maximum of 2500 VMs.

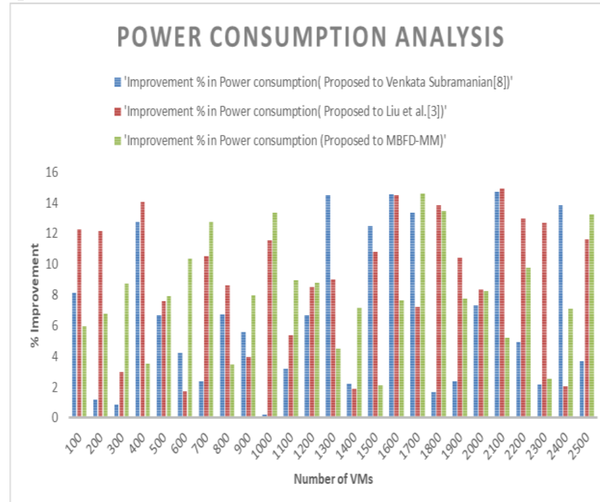

Fig. 10. Power Consumption.

Table 4. Power Consumption Analysis

PMs Count	VMs Count	kw Proposed	Venkata Subramanian et al. [8]	kw Liu et al. [3]
20	100	8.4478	9.197421	9.6286
40	200	8.8397	8.947707	10.064
60	300	9.3422	9.42366	9.6289
80	400	9.6889	11.10521	11.277
100	500	10.224	10.95737	11.066
120	600	10.457	10.91876	10.64
140	700	11.11	11.38404	12.419
160	800	11.251	12.06355	12.31
180	900	11.879	12.58056	12.369
200	1000	12.455	12.48184	14.081
220	1100	12.756	13.17476	13.477
240	1200	12.996	13.92544	14.205
260	1300	13.586	15.88802	14.931
280	1400	13.968	14.28481	14.241
300	1500	14.568	16.64731	16.331
320	1600	14.644	17.13238	17.125
340	1700	14.949	17.25207	16.112
360	1800	15.205	15.46074	17.652
380	1900	15.852	16.24155	17.701
400	2000	16.189	17.46967	17.667
420	2100	16.576	19.43661	19.491
440	2200	16.884	17.76198	19.403
460	2300	17.727	18.11664	20.301
480	2400	18.691	21.69129	19.083
500	2500	18.389	19.09112	20.81

6.1. Power Consumption Analysis

Table 4 presents the comparative analysis of the proposed algorithm with other existing algorithms. The proposed algorithm consumes 18.39 units of power, and the other techniques are approximately beyond 2 kW.

Fig. 10 illustrates the enhancement in the consumption of usage of power.

Fig. 10 depicts the improvement of a maximum of 13.33% of the proposed work to the Liu, a maximum of 8 % work to the Subramanian, and 15.83% concerning the traditional MBFD algorithm.

6.2. SLA-V Analysis

Table 5 presents the comparative analysis of given proposed algorithm with existing algorithms in terms of SLA-V analysis.

Table 5. SLA-V Analysis

Number of PMs	Number of VMs	SLA-V Venkata Subramanian et al. [8]	SLA-V Liu et al. [3]	SLA-V MBFD-MM.
20	100	0.09408778	0.09332424	0.09559801
40	200	0.09107927	0.09484226	0.08676893
60	300	0.08808653	0.09771751	0.09512323
80	400	0.09984496	0.08937885	0.09060758
100	500	0.09791387	0.09021476	0.09181373
120	600	0.09747992	0.09547406	0.09617521
140	700	0.09232334	0.09022594	0.09634488
160	800	0.09758512	0.09222196	0.09875113
180	900	0.0984218	0.09051424	0.09117096
200	1000	0.09585505	0.09434619	0.08756511
220	1100	0.08735006	0.09750268	0.09901093
240	1200	0.10587141	0.10284053	0.09364148
260	1300	0.09687204	0.10033815	0.09906627
280	1400	0.10040121	0.10136834	0.09725679
300	1500	0.09536787	0.09305409	0.10181426
320	1600	0.09733652	0.09908423	0.1009659
340	1700	0.09929936	0.103028	0.10394464
360	1800	0.09275544	0.09132323	0.09140966
380	1900	0.10102023	0.09368512	0.09329804
400	2000	0.10529643	0.09039102	0.10622235
420	2100	0.09353589	0.09802261	0.09992057
440	2200	0.08951739	0.0931745	0.09331479
460	2300	0.09768612	0.09880585	0.09739336
480	2400	0.09751561	0.09540592	0.10399083
500	2500	0.10110989	0.09722213	0.0938995

Fig.11 illustrates the improvement in the SLAV values by the proposed work.

It has been observed that while increasing the load on the system Liu showed violations of 12% and 11% by Subramanian, and 15.32% of violations by MBFD-MM.

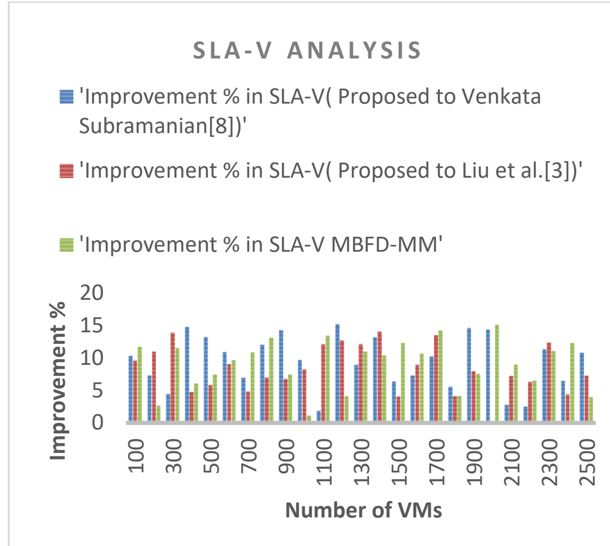

Fig. 11 SLA-V Improvement Analysis.

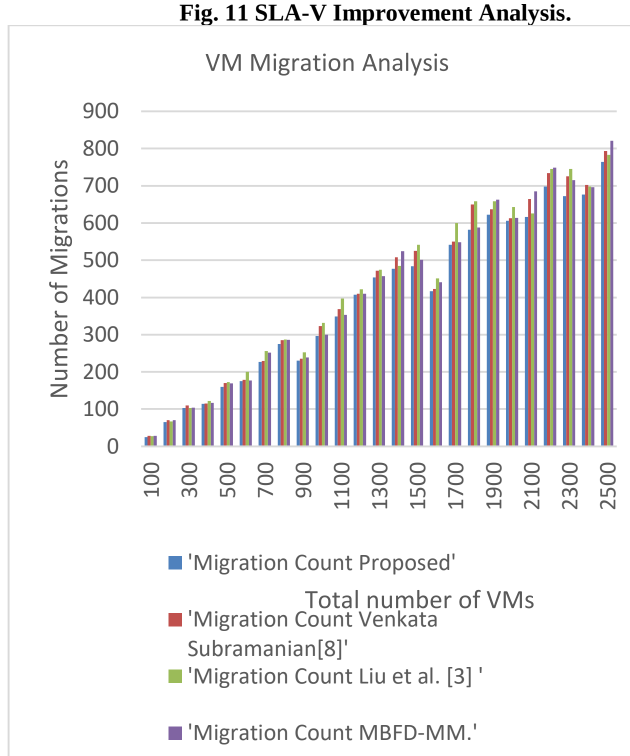

Fig. 12 VM Migration Analysis.

6.3. VM Migration Analysis

Furthermore, the suggested work additionally performs the calculation of VM migration analysis. The quantity of virtual machines (VMs) that require migration reflects the stability of the allocation policy's structure. The correlation among the overall count of migrations and total number of virtual machines (VMs) is evident: as the latter increases, so does the former. Additional migrations indicate an imbalance in the network's burden. Fig. 12 exhibits the migration analysis of the proposed algorithm in contrast to leading-edge techniques.

By virtue of the suitable virtual machine selection policy, the suggested work achieves higher power efficiency compared to other strategies mentioned in the reference, with fewer migrations. To achieve a maximum number of 2500 virtual machines (VMs), the suggested work migrates 764 VMs to balance the load. In comparison, Venkat et al. migrate 793 VMs, Liu et al. migrate 783 VMs, and MBFD-MM migrates 821 VMs. The mean number of migrations in the identical sequence is 401,421,430 and 420 virtual machines (VMs).

7. CONCLUSIONS

The introduction of virtualization, which involves deploying virtual instances on servers, has greatly improved the efficiency of cloud data environments. Therefore, VMP has been identified as a prominent study field for attaining efficiency objectives. The VMP problem is reformulated as a multi-objective bin-packing optimization in this study which is subjected with many constraints and optimization objectives. The optimization target is to minimize power consumption, the migrations count, and breach of SLA while maximizing load balancing at the data center. The proposed approach exhibits percentage improvements in power consumption by comparatively to other approaches by 11.6% and 3.68% respectively. Also, while increasing the load on the system Liu et al. showed violations of 12% and 11% by Venkat et al, and 15.32% of violations by MBFD-MM. Analogously there is an improvement in tthe mean number of migrations 401,421,430 and 420 of virtual machines (VMs) by the proposed and in comparison, with Venkat et al., Liu et al., MBFD-MM. The experimental results demonstrate that the cr_Cuckoo algorithm attained higher energy efficiency and reduction in SLA violations and migration count. One of the primary limitations on the virtual machine deployment and allocation process is upholding data integrity, privacy, and secure communication. The present condition exhibits numerous potentialities and capabilities for the future. To reduce risks and safeguard the integrity and confidentiality of user data, strong security measures and privacy-preserving strategies must be incorporated into VM allocation algorithms. Moreover, the inclusion of a learning mechanism may also enhance subsequent outcomes.

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