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Enhanced Cloud Resource Optimization Using Secretary Bird Optimization Algorithm and Dynamic Workload Balancing

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Abstract-In this paper, a framework for optimizing cloud resource allocation using the Secretary Bird Optimization Algorithm and dynamic workload balancing has been presented. The presented method tackles inefficiency in cloud computing systems, such as inefficiency in task scheduling and resource overload, through dynamic task distribution among resources. With the introduction of SBOA, prompted by the innate behavior of secretary birds, and workload balancing, the approach achieves maximum resource utilization, minimum makespan, and lower computational expense. Global attention mechanisms are further incorporated into the framework to direct computational effort at the most salient features, which improves efficiency. Simulation results show improved cloud resource optimization by a significant extent over conventional approaches, rendering the method feasible for dynamic, large-scale cloud environments.

Keywords*:* Cloud Resource Optimization, Secretary Bird Optimization Algorithm, Dynamic Workload Balancing, Task Scheduling, Metaheuristic Algorithms.

1. Introduction

Cloud resource optimization is required in order to enhance the performance and efficiency of cloud computing systems, in which cloud resources like computing power, storage, and network bandwidth are dynamically assigned in response to different applications[1],[2]. In this regard, the Secretary Bird Optimization Algorithm, a population-based metaheuristic optimization technique, offers a new approach to solving optimization problems[3]. SBOA replicates natural secretary bird dynamics to search for optimal solutions step by step and optimize them through searching the search space[4],[5]. Through the use of dynamic workload balancing, the technique makes sure that the workload is assigned appropriately to resources in use without overload and maximum use of resources[6]. The improved technique minimizes makes pan, balancing workload, and cost of computation in cloud computing[7], [8].

There are many problems associated with the optimization of cloud resources like task overload, resource imbalance for allocation, and suboptimal task scheduling. If the resource balancing is improper, certain resources get overloaded and, hence, degrade performance or waste other resources[9],[10]. Dynamic workloads, variable resource needs, and processor-intensive processes make these challenges more prominent. In addition, conventional optimisation techniques are not able to cope with changing needs of cloud computing systems and therefore provide non-optimal results[11],[12]. Proper workload distribution and resource allocation are important to overcome such problems and provide optimal resource usage with system reliability[13], [14].

Genetic algorithms, particle swarm optimization, and ant colony optimization are optimization methods applied in cloud resources today that try to find optimal solutions to scheduling, allocation, and resource management issues[15], [16]. Such methods do find it challenging, however, to cope with real-time and dynamic shifts in resource requirements[17], [18]. In more contemporary times, metaheuristic algorithms such as Artificial Bee Colony and Differential Evolution have been put forward for optimizing resource allocation in accordance with natural processes[19], [20]These, however, do not have the tendency to balance exploration and exploitation and thus are plagued by premature convergence or wastage of resources. Moreover, the current methods also do not take into consideration the significance of workload balancing and thus result in inefficient performance of large systems[21], [22].

To overcome the limitations of current optimization methods, Secretary Bird Optimization Algorithm with dynamic workload balancing is a good method[23]. SBOA is able to deal with dynamic cloud environments through ensuring more exploration and exploitation of the solution space[24], [25]. By workload balancing, the algorithm guarantees uniform distribution of tasks on resources so that no task overloads the resources and resources are used efficiently[26], [27]. This combination of SBOA and CMA-ES accomplishes a balance of local enhancement and global search with maximum convergence and computational efficiency. Also, SBOA's ability to simulate natural tendencies renders it capable of effectively exploring dense problem spaces, making it an excellent candidate for real-time cloud resource optimization[28].

- Introduction of SBOA to Cloud Resource Optimization: This current article introduces the Secretary Bird Optimization Algorithm as a novel cloud resource optimization algorithm. The secretary bird-based algorithm introduces an effective method of resource distribution and balance in cloud environments to realize optimum performance.
- Integration of Dynamic Workload Balancing: The main contribution of this paper is the integration of dynamic workload balancing into the SBOA framework. This enables the algorithm to distribute tasks in an optimal manner to available resources such that no resource gets overloaded and computational resources are utilized to the maximum extent.
- Improved Resource Utilization and Cost Savings: The paper demonstrates how the suggested technique can minimize makespan and computation cost in cloud computing systems. Through dynamic real-time resource provisioning, the technique maximizes resource utilization and system efficiency.

This paper is organized as follows: Section 2 introduces cloud resource optimization issues and the function of workload balancing in enhancing system efficiency. Section 3 describes the proposed system, combining the Secretary Bird Optimization Algorithm with dynamic workload balancing for managing

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cloud resources. Section 4 compares the performance of the proposed method with the conventional optimization methods. Lastly, Section 5 concludes the paper and hints at directions for further research in cloud resource optimization with the aid of sophisticated algorithms and balancing methods.

2. Literature review

Comparative study with other blockchain-based schemes consistently shows better performance, particularly in terms of lower time costs with more CSPs, reflecting the method's scalability in large-scale applications [29]. Pre-processing of data was done with cloud computing for large-scale analysis, and optimization were performed to enhance sensitivity and specificity measures for different medical applications [30]. The operations of the banking sector and customer interaction can significantly be boosted by implementing these technologies into an integrated system [31]. Accuracy, customer satisfaction, response time, and cost savings were some of the most important performance indicators [32]. Through the integration of these methods, complete client profile, accurate engagement level forecast, and tailored CRM solutions are enabled [33]. The effectiveness of the proposed paradigm in increasing collaboration completion rates and ensuring security is demonstrated through extensive theoretical study and simulations [34]. Deployed on a scalable cloud infrastructure, the system integrates IoT-capable sensors for data acquisition, ABC for feature engineering, BBO for fuzzy rule tuning, and ANFIS for disease classification [35]. The system is more robust to noisy IoT data when data preprocessing is applied, i.e., feature extraction and normalization [36]. The hash function operates on the input message in blocks through a compression mechanism that may be bespoke or derived from block cipher modes [37]. Cryptographic libraries such as OpenSSL and Bouncy Castle are applied in cloud environments, and cloud service platforms such as AWS KMS and Azure Key Vault are used for key management securely [38]. An efficient cloud environment demands automation, network optimization, real-time monitoring, and compliance and governance rules [39]. Furthermore, recent advances in blockchain consensus algorithms have improved throughput and latency [40]. Integration of machine learning with blockchain enhances predictive analytics and anomaly detection in healthcare data [41]. Privacy-preserving techniques like homomorphic encryption have been adopted to secure sensitive data in distributed systems [42]. Finally, multi-cloud deployment strategies offer better fault tolerance and load balancing for critical applications [43].

2.1 Problem statement

Even with developments in the convergence of blockchain, cloud computing, and IoT technologies across industries such as banking and healthcare, there are still challenges in maximizing resource utilization, providing security to data, and scaling systems efficiently [44]. In banking, effective customer interaction and precise predictions must be done in order to make timely decisions [45]. In healthcare applications, data pre-processing and noisy IoT data handling concerns affect performance, particularly in accuracy and classification [46]. Although cryptographic libraries and secure key management offer some solutions, an even stronger, scalable, and secure framework is needed that integrates these technologies to enhance system efficiency and optimize large-scale implementations [47]. Furthermore, interoperability among diverse IoT devices and cloud platforms remains a significant hurdle that limits seamless data exchange

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and processing [48]. Scalability issues also arise due to the growing volume of IoT-generated data, which demands efficient resource management strategies [49], [50]. Therefore, developing an integrated, robust, and adaptive system is critical to overcoming these limitations and enabling practical deployment across various sectors [51].

3. Proposed methodology

The method to be adopted for optimizing cloud resources incorporates Secretary Bird Optimization Algorithm with workload balancing dynamically in order to deploy tasks effectively on cloud resources. The tasks are pre-processed through missing value handling, data normalization, and workload balancing. Candidate solutions are assessed by SBOA using makespan, workload, and cost as metrics, employing differential evolution to explore and Levy flight to refine. A Global Attention Mechanism gives higher importance to important tasks, optimizing effectively. The system converges to an optimal task-VM allocation, enhancing cloud resource utilization, scalability, and cost-effectiveness. Figure1 illustrates the Architecture of the proposed load balancing model.

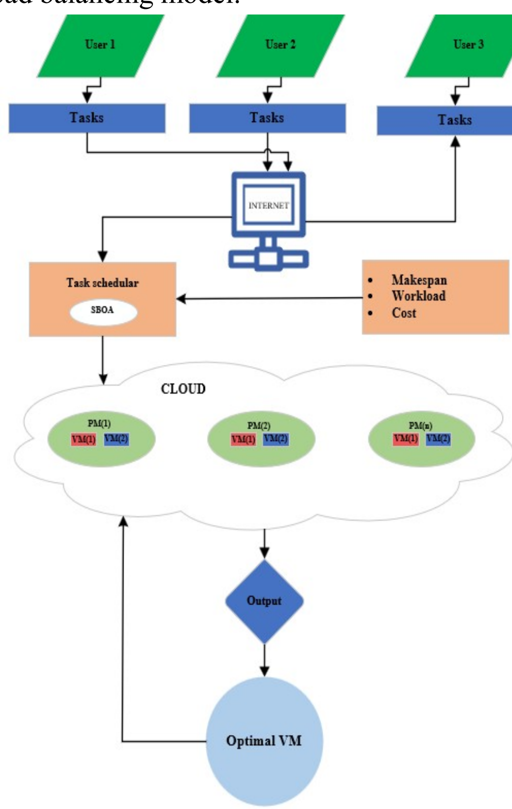

Figure 1: Architecture of the proposed load balancing model

The figure 1 shows a cloud-based task scheduling system using the Secretary Bird Optimization Algorithm to allocate tasks to virtual machines in an efficient manner. Three users create tasks that are forwarded to the Task Scheduler, which uses SBOA to optimize task allocation based on goals such as makespan, workload, and cost. The cloud infrastructure has several physical machines (PM1, PM2, PM3) with virtual machines (VM1, VM2, VM3). SBOA analyses the optimal assignment of tasks to these VMs so as to

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optimize execution time, distribute the load, and incur lower costs. The output is the Optimal VM that results in the maximum efficient processing of tasks.

3.1. System model

The system model presented in this paper makes use of the Secretary Bird Optimization Algorithm to optimize cloud resources. The model targets dynamic workload balancing to effectively distribute tasks over cloud resources to avoid overloading and underloading. It is presented as a multi-objective optimization problem that minimizes makespan, workload balance, and computational costs. SBOA utilizes Levy flight and differential evolution to facilitate efficient exploration and exploitation of the solution space. In addition, global attention mechanisms are employed to direct computational resources to the most important features, enhancing task performance and resource allocation in the cloud.

3.2. Multi-Objective-Based Problem Formation for SBOA

Here, Multi-objective Optimization is used to the Secretary Bird Optimization Algorithm with an objective to solve credit risk assessment issues through the optimization of makespan, resource utilization, and cost-effectiveness at the same time. The goal here is to reduce the time it takes to accomplish tasks, increase the utilization of resources, and reduce the computing resource cost. All these goals are conflicting and have to be optimized at the same time.

i) Makespan Minimization:

Makespan is the time taken to complete all tasks. It is given by the maximum load on any resource:

$$M = \max_{j \in R} \left(\sum_{i \in T} C_i \cdot X_{ij} \right) \tag{1}$$

Where, M is the makespan, C_i is the computational cost of task T_i, X_{ij} is a binary assignment that tells us whether task T_i is assigned to resource R_j.

ii) Workload Balance:

The workload balance guarantees that the workload is shared evenly between resources. The difference in workload between resources should not be more than a specific threshold:

$$\left| \sum_{i \in T} C_i \cdot X_{ij} - \sum_{i \in T} C_i \cdot X_{ik} \right| \leq \delta \; \forall j, k \in R \tag{2}$$

Where, δ is the maximum deviation in workload between resources.

iii) Cost Minimization:

The overall computational cost is minimized, taking into account the cost per unit of computation for every resource:

$$C = \sum_{j \in R} \sum_{i \in T} C_i \cdot X_{ij} \cdot \text{Cost}_j \tag{3}$$

Where, C is the overall cost, Cost_j is the cost of utilizing resource R_j to perform task T_i.

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In this case, Multi-objective Optimization is implemented to the Secretary Bird Optimization Algorithm where we are to solve credit risk assessment issues through optimizing makespan, utilization of resources, and cost efficiency together. The aim is to minimize the time it takes to accomplish tasks, maximize the usage of resources, and minimize the expenditure of computing resources. All of these goals are conflicting in nature and have to be optimized simultaneously.

3.3. Overall Objective Function for SBOA

The total goal function for minimizing three conflicting objectives of optimizing Credit Risk Assessment through the Secretary Bird Optimization Algorithm is to minimize simultaneously Makespan, Workload Balance, and Cost. The objective is to identify the best task distribution to resources available in such a way that the tasks take the shortest possible time, the resources are properly utilized (workload balance), and the cost of computation is minimized.

The combined multi-objective optimization problem can be written as:

$$\min f(X) = \lambda_1 M(X) + \lambda_2 \cdot (-W(X)) + \lambda_3 C(X) \tag{4}$$

Where, $f(X)$ is the total objective function that should be minimized, $M(X)$ is the Makespan, or the time it takes to finish all the tasks, $W(X)$ is the Workload Balance, to make sure tasks are evenly distributed over resources, $C(X)$ is the Total Computational Cost of executing the tasks over the resources, $\lambda_1, \lambda_2, \lambda_3$ are weights assigned to every objective, to indicate their relative significance in the optimization process.

3.4. Work load balancing using SBOA algorithm

In Secretary Bird Optimization Algorithm with workload balancing, the algorithm starts with initial setup when Secretary Birds are initialized at random and workload is balanced among resources. During exploration, differential evolution is employed to update the worker bird locations, distributing tasks evenly, while Levy flight supports exploration. In exploitation, solutions are refined by birds employing evasion strategies and workloads are redistributed dynamically. A global attention mechanism concentrates computational resources on the appropriate features for enhanced efficiency. Lastly, in the convergence and evaluation step, the optimal solution is chosen, taking into account both solution quality and workload, with the final solution balancing task loads and optimizing results for tasks such as credit risk assessment.

Step 1: Initial Setup

Random Initialization: Secretary Birds' locations are initialized randomly within the specified boundaries, and their initial workload is distributed equally among resources to prevent overloading.

$$X_{i,j} = lb_j + r \times (ub_j - lb_j) \tag{5}$$

Step 2: Exploration Phase (Hunting Strategy)

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Differential Evolution Strategy: During this phase, Secretary Birds' locations are updated by differential evolution to balance task allocation.

$$v_i = \frac{\sum_j c_{ij} u_j}{\left\|\sum_j c_{ij} u_j\right\|} \tag{6}$$

Workload Balancing: Dynamically, tasks are assigned to prevent overloading one bird, and Levy flight is added to enhance exploration.

Step 3: Exploitation Phase (Escape Strategy)

- Evasion Strategies: The birds fine-tune their solutions and manage threats through quick movements or flight.
- Balanced Workload: When a bird is overloaded, the tasks are reallocated to maintain efficient optimization without bottlenecks.

$$v_i^{\text{masked}} = v_i \cdot m_i \tag{7}$$

Step 4: Global Attention Mechanism

Computational resources are allocated to most useful features of the task in order to enhance efficiency in learning.

$$a_i = \frac{\exp(q \cdot k_i)}{\sum_j \exp(q \cdot k_j)} \tag{8}$$

Step 5: Update Secretary Bird Position

Update positions based on optimum solution at every stage considering quality of the solution as well as workload.

Step 6: Evaluation and Convergence

Assesses the quality of solution for each bird, considering workload.

$$F = [F(X_1), F(X_2), \ldots, F(X_N)] \tag{9}$$

Step 7: Final Solution

The last solution is chosen, which optimizes task loads and maximizes outcomes for credit risk evaluation or any other optimization problem.

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Termination of the optimization process is reached when the algorithm converges on an optimal solution or when it reaches a maximum number of iterations. The best solution is determined by the objective function evaluation of workload, makespan, and computational cost. Upon termination, the positions of the Secretary Birds are updated according to the last task distribution so that there is an efficient and balanced resource utilization. The algorithm terminates when convergence conditions are achieved, and the best solution is chosen for additional implementation or online deployment in credit risk evaluation or other optimization problem.

4. Result and discussion

The method from the proposed Secretary Bird Optimization Algorithm with dynamic workload scheduling maximizes cloud resource allocation through optimal task allocation and prevention of overloading. SBOA's natural behaviors, including hunting and fleeing tactics, improve scalability and minimize computational cost. The addition of the global attention mechanism further enhances performance by concentrating on relevant features to optimize resource use. In comparison to traditional approaches, this method is superior in reducing makespan, achieving workload balance, and improving cloud resource management under dynamic scenarios.

4.1 Simulation Parameters

Simulation parameters are the parameters determining cloud resource optimization experiment conditions. They are task size, quantity of virtual machines, VM run rates, and power usage that affect resource distribution and system efficiency. SBOA configuration parameters like iteration, population, and velocity range are the parameters influencing the optimization procedure to achieve workload balancing and optimal solution search.

i) Cloud Environment Parameters

Table 1: Simulation parameters for Cloud

Parameter	Value Range
Number of Tasks (Nt)	100 – 1000 tasks
Size of Tasks (MI)	1000 – 4000 million Instructions (MI)
Number of Virtual Machines (Nv)	1 – 5 VMs
Execution Rate of VMs (MIPS)	1000 – 5000 MIPS
Power Consumption of VMs (Watt)	200 – 1000 watts
Power Consumption (Idle/Active State)	60 – 70%

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ii) SBOA Configuration

Table 2: Simulation parameters for SBOA Algorithm

Parameter	Value
Iteration Count	50 iterations
Population Size	70 particles
Velocity Range	[-1, 1]
Inertia Factor	0.9 to 0.2
Acceleration Constants (c1, c2)	2

4.2 Comparison by Varying VM Count

Table 3: Performance Metrics for Different Virtual Machines

Number of VMs	VM Load	Energy Consumption (kWh)	CPU Utilization (%)	Memory Usage (GB)	Makespan (s)	Cost ($)
1	25	1.25	50	19	179	155.53
2	18	0.9	36	12	209	165.63
3	26	1.3	52	12	210	192.7
4	24	1.2	48	18	126	130.82
5	21	1.05	42	14	240	177

These bar charts compare performance measurements across different numbers of Virtual Machines (VMs). "VM Load" is quite stable, while "Energy Consumption (kWh)" has very little variation across all VM settings. "CPU Utilization (%)" is slightly higher for 3 and 5 VMs, reflecting greater workload distribution. The "Makespan (s)" is minimized using 4 VMs, and the "Cost ($)" is higher as the number of VMs increases, with the maximum cost at 5 VMs. Performance overall increases with increasing VMs, but at a cost. Figure 2 Performance Metric Comparison Based on Different VM Counts is asfollows.

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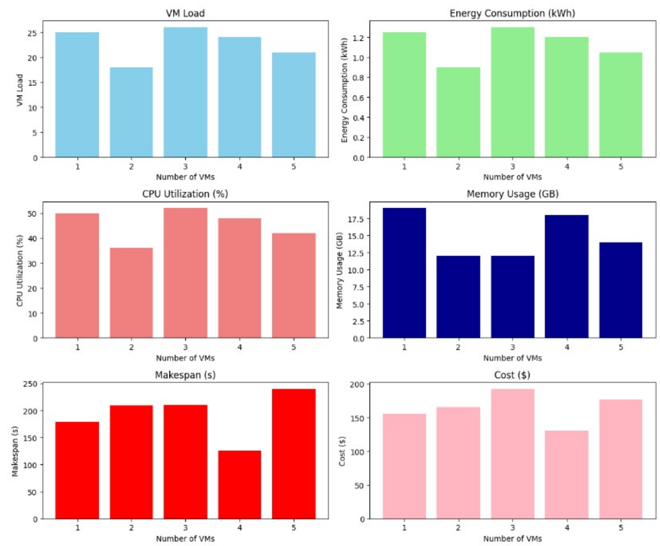

Figure 2: Performance Metric Comparison Based on Different VM Counts

4.3 Conclusion

The envisaged method employing the Secretary Bird Optimization Algorithm (SBOA) and dynamic workload balancing efficiently enhances cloud resource optimization and scalability. Optimized distribution of tasks and reduced computational cost are achieved, ensuring improved utilization of resources. The incorporation of global attention mechanisms also improves execution of tasks by concentrating on pertinent features. This work offers a solid solution for managing cloud resources, and it may find applications in credit risk rating and other applications. Further work can be undertaken to integrate this model with other sophisticated algorithms for better efficiency.

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