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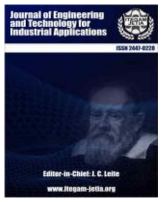

RESEARCH ARTICLE | OPEN ACCESS

RESOURCE ALLOCATION METAHEURISTIC TECHNIQUES IN CLOUD COMPUTING

Sonia Sharma*[1] and Dr. Nipun Chhabra[2]

[1]Research Scholar, School of Engineering Design and Automation, GNAUniversity, Phagwara, Punjab, India
[2]Associate Professor,School of Engineering Design and Automation, GNAUniversity, Phagwara, Punjab, India

[1]https://orcid.org/0009-0002-7157-0361, [2]https://orcid.org/0000-0001-5318-5043

Email: *salwan.sonia299@gmail.com, nipun.chhabra@gnauniversity.edu.in

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ABSTRACT

Cloud computing is a computer paradigm that delivers IT resources as services, such as platforms, apps, and infrastructure, via the Internet. The cloud Computing offers the infrastructure needed to process and compute any kind of data resource, and it is used to handle massive volumes of data. Large, well-known businesses have moved their processing and storage to cloud computing in recent years. Businesses and organizations may lower their infrastructure costs by utilizing cloud computing. Businesses can test their apps faster, more effectively, and with less maintenance. Cloud computing enables the IT team to adjust resources to fluctuating and changing requirements. Allocating resources in cloud computing is intrinsically difficult since more and more people are using various cloud apps in some infrastructure. The majority of resource allocation solutions now in use focus on performance, which is impacted by the volume of applications from scientific and business domains. This article presents an analysis of meta-heuristic approaches for resource allocation in cloud computing systems. When allocating resources in the cloud, the examined meta-heuristic algorithms can achieve much better performance, lower costs, shorter turnaround times, better resource usage, and increased energy efficiency.This study compares several scheduling algorithms for cloud and grid systems using three well-known metaheuristic approaches: Particle Swarm Optimization (PSO), Genetic Algorithm (GA), and Ant Colony Optimization (ACO).

I. INTRODUCTION

A group of advanced on-demand computing services that were first made available by for-profit companies like Amazon, Google, and Microsoft are collectively referred to as cloud computing. It refers to a paradigm wherein a computing infrastructure is perceived as a cloud from which people and companies may readily access applications from any location in the world [1].To lower energy expenses and provide end-user assistance through negotiated quality of service (QoS), which is created in the form of Service Level Agreements (SLA), the resource pool must be professionally controlled.Three primary cloud models are available: Platform as a Service (PaaS), Software as a Service (SaaS), and Infrastructure as a Service (IaaS). These are the three main ways that services are frequently supplied [2]. A single physical computer may run many programs thanks to the resources' high heterogeneity and virtualization.

When necessary, an appropriate physical system is used to instantiate the user programs, but they are confined to a virtual machine. It is debatable if the apps' requirements for CPU, memory, processing speed, network bandwidth, and reaction time are reasonable. Based on client demand, resources are combined and made accessible.Cloud companies like Flexiant, Microsoft, Amazon, Google, Gogidi, and Others constructed several data centers to accommodate the resource requirements of a huge number of users [3]. Cloud data centers have numerous advantages, but they can have drawbacks, such as high-power usage [4]. Each of the many resources in these data centers has a corresponding power usage. The ability to execute HPC applications on cloud infrastructures has increased the popularity of cloud computing [5]. The resource allocation strategy is utilized to ensure that all application requirements are fulfilled. For all of these reasons, one of the maingoal in a cloud computing system is resource allocation.

In addition, industry and researchers are concerned about lowering energy usage and carbon footprints, as well as providing user applications with adequate resources to meet quality of service (QoS). Energy usage and resource use are strongly linked.Furthermore, for green manufacturing, energy usage during machine operations and idle time should be considered [6]. In the construction industry, the severity of falls from height is even more alarming: 65% of accidents involve this type of occurrence, and more than half result in death [5].

In Rio Grande do Sul, the scenario is equally concerning. In 2023, 384 work-related deaths were recorded, representing a 35% increase compared to 2022. Among these cases, 320 were typical accidents, 63 were commuting accidents, and 1 was due to occupational illness. It is noteworthy that workers with precarious employment relationships—such as self-employed and unregistered workers—accounted for 50.01% of fatal typical accidents, with self-employed individuals representing 38.13% of occurrences [6].

I.1 FOUR TYPES OF CLOUD

1. **Public Cloud** - Public users can access and utilize the public cloud. The third-party organization that owns and operates it offers internet-based services to customers who only pay for the services they utilize. Nonetheless, public cloud settings are frequently more vulnerable to security flaws and intrusions [7].
2. **Private Cloud** - A private cloud is used only by one company. Because the business manages the infrastructure and data directly, it offers better control and increased security whether it is hosted on-site or by an outside supplier.
3. **Hybrid Cloud**: A hybrid cloud uses standardized technologies to combine private and public cloud infrastructures. Businesses may reroute excess traffic to the public cloud using this integrated approach's flexibility and scalability to preserve service availability and avoid disruptions.
4. **Community cloud**: A particular community with common issues is supported by shared cloud infrastructure, which is shared by certain organizations (e.g., governance, education and compliance). It may be managed by the groups or by a third party, and it may be located on or off campus.

I.2 SCHEDULING ALGORITHMS ANALYSIS

There are two kinds of algorithms for work scheduling:

1. **Heuristic**:This problem-solving method uses specific guidelines and suggestions (strategies) to do a focused search. The aim is to identify feasible, realistic solutions that take into account the limitations of the problem [8]. Round robin, min-min, priority-based, and first-come, first-served scheduling are examples of heuristic scheduling methods.
2. **Metaheuristic**:Metaheuristic algorithms draw inspiration from physical processes, evolutionary biology, and natural phenomena such as swarm intelligence. They use techniques including problem space exploration, local search, randomization, and searching for possible answers. Complex optimization issues are solved using metaheuristic algorithms [9]. It finds the best option out of a plethora of alternatives. Unlike classical algorithms that may provide exact answers, metaheuristics provide approximate solutions that are deemed appropriate for practical reasons [10]. Examples are PSO, GWO, and Jaya.The ultimate goal of cloud computing resource computation is to minimize cloud customers' financial expenses while optimizing revenues for cloud providers [11].

However, compared to alternative methods like analytical processes and identical numerical programming, conventional procedures are simpler to comprehend and utilize. Approaches do not ensure that the result will be created correctly [12]. Programming for cloud computers is associated with a set of issues called NP-hard drives because there are so many potential solutions, and it takes time to choose the optimal one. To solve these problems, none of the methods can get the right answer in a multinomial amount of time. Finding a more effective solution in the near term is preferable when it comes to cloud computing. For such problems, meta-heuristic-based approaches have demonstrated the ability to obtain optimal solutions in a sensitive time frame [13].Heuristic approaches have been applied without guaranteeing accuracy or viability for a workable answer at a minimal computing cost. Examining different strategies to enhance the efficiency of metaheuristics in algorithms increases the efficacy of heuristic processes that employ metaheuristics approaches.

Larger integration rates, less coverage of optima, longer computation durations, more complex operators, and the development of a binary or real search environment are other characteristics of contemporary algorithms.Strong scheduling techniques must be used in cloud computing in order to optimize resource consumption and system efficiency[14]. Teaching Learning Based Optimization (TLBO) The TLBO methodology is a metaheuristic optimization method that draws inspiration from educational environments. Because of its bias, troubleshooting optimization may be simpler [15]. Thus, gravity serves as a means of transmitting information among separate entities [16]. Despite being suggested, the path frequently develops into a comprehensive response to multiple iterations, unlike GA, and does GSA techniques avoid being locked in the local optimum [17].

II. ALGORITHMS USING META-HEURISTICS FROM 1975 TO 1997

Ant colony efficiency solves optimization problems using the same method [18]. Scatter search can be used in cloud computing by developing a "Scatter Search" metaheuristic algorithm on a cloud platform to tackle complicated optimization issues or by using a "Scatter/Gather" pattern for dispersed activities. Particle Swarm Optimization (PSO) the Particle Swarm Optimization technique is a suitable meta-heuristic algorithm for optimizing continuous nonlinear functions. The idea of identifying the optimal solution was motivated by the notion of bird cruelty, which is frequently seen in animal groups such as flocks and the sea [19]. Each candidate (birds, fish, insects) is treated as a particle in particle swarm optimization, which uses a community known as a swarm and develops them using random circumstances and velocities. Assuming a cross between the evolution of the Pareto method of optimization and the evolutionary approach, The Improve PSO (IPSO) algorithm has been used in this work to establish a resource scheduling approach for quality-of-service constrained resources.

According to the study's findings, the model can boost productivity and enhance search speed while indicating a specific height [20]. The PSO process suggests a more methodical virtual machine allocation strategy and a more effective resource allocation energy model to maximize energy usage in the cloud data center. The PSO stiffness function in this method differs from the remaining finishing point between resource utility and energy consumption. This approach can escape down to local optima, common to traditional approaches [21]. The Metaplan Complex scheduling and optimization problems, especially those requiring resource allocation, are resolved in cloud computing by using meta-heuristic algorithms. In situations when workloads are constantly changing, they successfully provide almost ideal results. Complex optimization issues like load balancing, virtual machine (VM) migration, and resource allocation are handled in cloud computing through the use of simulated annealing.

By mimicking the real annealing process, which entails progressively cooling a material to its lowest energy state, this technique helps identify the best way to allocate cloud resources. Tabu Search is a metaheuristic optimization method used in cloud computing to solve challenging issues such as work scheduling, load balancing, and resource allocation. A "tabu list" of previously explored movements or solutions is kept up to date when investigating solutions in order to prevent becoming trapped in local optima. Unaffected algorithms Use cloud computing's biological immune system ideas to solve security, load balancing, and optimization problems. Reactive search optimization in cloud computing involves using self-tuning, adaptive algorithms to optimize cloud resource allocation and scheduling in response to changing conditions.

Differential Evolution is used in cloud computing as a powerful optimization algorithm for complex problems like task scheduling, data center selection, and resource allocation. ACO learns from the destructive nature of some ant species. These ants use a pheromone to mark a specific track in the ground, which the other ants in the colony may follow. We learned how to properly allocate cloud resources in this paper in order to optimize cost, service quality, time, and resource load balance. The response has been the modified ACO algorithm. More planning is being done for this effort, though, including the resources' qualities and how well they match the job criteria, as well as the primary sources of qualified applicant resources.

III. METHODS OF META-HEURISTICS FROM 2001 TO 2009

Harmony Search Algorithm (HS) The Harmony Search algorithm has received a lot of attention lately. It is a metaheuristic technique that seeks to achieve the perfect harmony by simulating the singer's development. The HS method is easy to apply, rapidly yields the correct answer, and gives a sufficient solution for the required length of time. Because of these benefits, the HS algorithm has been used to solve issues requiring the application of different technical contexts [22]. Making effective use of cloud resources requires a systematic approach to resource planning. This method uses makespan to analyze the correctness of the answer and relies on HS, a novel meta-heuristic tool. The CloudSim 3.0.3 program has been utilized as a cloud simulator to assess the Harmony Search algorithm's performance. According to this study, the number of cloudlets has been increasing with variable makespan (in seconds) when employing a cloud scheduling method based on Harmony Search.[23].

Optimization in Renewable Energy Systems: Recent Perspectives addresses every significant area in which optimization methods have been used to lower uncertainty or enhance outcomes in renewable energy systems [24]. Less waiting time is achieved by the hybrid TLBO and grey wolves optimization algorithm (GW) algorithm, which precisely balances priorities and takes performance into account based on time, cost, and avoiding local optimum traps.In terms of makespan and load variation, the Grey Wolf Optimization Algorithm with Simulated Annealing (GWO-SA) outperforms all other methods [25]. Artificial Bee Colony Algorithm (ABC) This approach to continuous optimization issues was initially introduced in 2005. The employed and unemployed bees in this strategy just update the 1D food position. One solution update rule is used by the artificial agents for the whole search. It has two kinds of bees: those that work and those that don't. Whereas other bees locate food sources using the information that employed bees supply, employed bees gather fluid from food sources and advise other unemployed bees of food locations. It is an energy resource consumption process model that has been studied to optimize cloud resources and improve their use.

The method of powering resources of the same size as the model is what the ABC uses when assigning functions to cloud computing resources. Additionally, through server interfaces, visualization makes it possible to reduce cloud power utilization since it reduces user-desired procedures. In accordance with the ABC-based energy-conscious resource consumption approach, the architecture allocates functions and resources to the cloud. A comparison between the efficacy of the proposed technique and existing approaches is made using the CloudSim tool. According to the test findings, the recommended process works better than existing methods by reducing the energy and running time of cloud-based programs. A genetic algorithm (GA) is a kind of evolutionary algorithm that finds excellent answers to challenging optimization and search problems. It was inspired by natural selection. It functions by generating a population of potential solutions that change through crossover, mutation, and selection over the course of several generations. This method is designed to maximize resource usage while minimizing job completion time and cost [26].

Table 1: Algorithms Using Meta-Heuristics From 1975 to 1997.

Sr. No	Algorithm	Proposed	Year	Description / Key Idea
1.	Genetic Algorithm	Holland [27]	1975	Laid the foundation for evolutionary computation.
2.	Scatter Search	Glover[28]	1977	Introduced a structured combination of solution vectors.
3.	Metaplan	Mercer and Sampson[29]	1978	Early conceptual model for metaheuristic planning.
4.	Simulated Annealing	Kirkpatrick et al.[30]	1983	Motivated by the process of metallurgical annealing.
5.	Tabu Search	Glover[31]	1986	Used adaptive memory to escape local optima.
6.	Ant Colony Optimization	Dorigo[32]	1992	Ant foraging behavior was modeled to determine the best routes.
7.	Immune algorithm	Mori et al.[33]	1993	Based on the principles of biological immune systems.
8.	Reactive Search Optimization	Battiti and Brunato[34]	1994	Combined machine learning with metaheuristic optimization.
9.	Particle Swarm Optimization	Kennedy and Eberhart[35]	1995	Influenced by the social behavior of fish schools and flocks of birds.
10.	Differential Evolution	Storn and Price[36]	1997	Developed for continuous optimization with differential mutation.

Source: Authors, (2026).

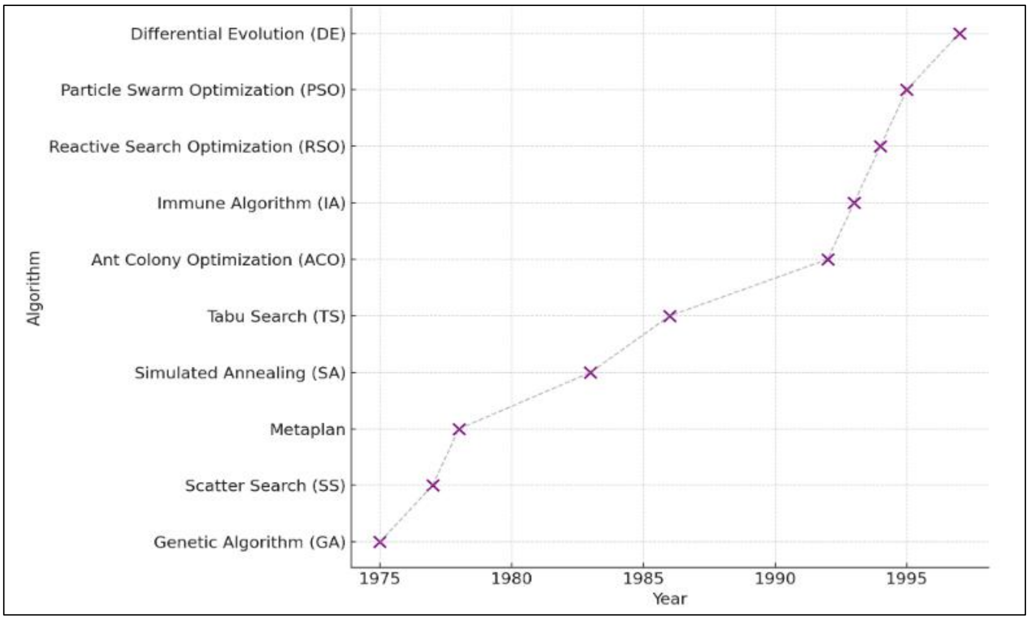

Figure 1: Graphical representation of meta-heuristic methods from 1975 to 1997.
Source: Authors, (2026).

Table 2: Methods of Meta-Heuristics from 2001 to 2009.

Sr. No	Algorithm	Proposed	Year	Description / Inspiration
1.	Harmony Search	Geem et al. [37]	2001	Mimics the improvisation process of musicians searching for harmony.
2.	Artificial Bee Colony Algorithm	Karaboga[38]	2005	Inspired by the foraging behavior of honey bees.
3.	Glowworm Swarm Optimization	Krishnanand and Ghose [39]	2005	Simulates glowworms' luminescent communication to locate optimal solutions.
4.	Honey bee Mating Optimization	Haddad et al.[40]	2006	Based on the mating behavior of honey bees.
5.	Shuffled frog leaping algorithm	Eusuff et al. [41]	2006	Models the memetic evolution of frogs in search of food.
6.	Imperialist Competitive Algorithm	Atashpaz-Gargari[42]	2007	Inspired by socio-political imperialistic competition.
7.	Intelligent Water Drops	Shah-Hosseini[43]	2007	Simulates the natural flow of rivers and water drops.
8.	River formation dynamics	Rabanal et al. [44]	2007	Models how rivers carve paths toward the sea through erosion and sedimentation.
9.	Firefly Algorithm	Yang[45]	2008	Inspired by the flashing behavior and attraction patterns of fireflies.
10.	Cuckoo Search	Yang and De[46]	2009	Based on the cuckoo species' brood parasitism behavior.

Source: Authors, (2026).

Glowworm Swarm Optimizationis a swarm intelligence technique used in cloud computing for work scheduling and resource allocation. is mostly used in cloud computing for scheduling tasks and allocating resources. Honey bee Mating Optimization: It optimizes the way jobs are distributed among virtual machines (VMs) and data centers using ideas derived from honey bee mating behavior in order to accomplish objectives such as lowering makespan, increasing resource usage, and improving load balancing.Shuffled frog leaping algorithm is used in cloud computing for complex optimization tasks like resource allocation, task scheduling, and energy management. Imperialist Competitive Algorithm is a meta-heuristic optimization technique used in cloud computing to address challenging issues like resource allocation and service composition.

It was motivated by historical imperialism and competition.Intelligent Water Drops A meta-heuristic optimization method inspired by the natural flow of water droplets is used to solve cloud computing problems such as workflow scheduling and virtual machine (VM) allocation. River formation dynamics is a metaheuristic for work scheduling and resource optimization that draws inspiration from nature. In order to determine the most effective routes for distributing cloud resources, including virtual machines (VMs), to user workloads (referred to as "cloudlets"), it analyzes how water creates riverbeds. Firefly Algorithm (FA) The Firefly Algorithm falls within the categories of meta-heuristic, swarm intelligence, and nature-inspired. It turns out that certain fireflies employ brilliant light activity to communicate, find partners, and warn predators of danger.

The firefly algorithm's objective function is linked to the flashing light characteristics of the firefly population. This aim may determine the proper distance function between any two fireflies since the optical principle of light intensity specifies that the distance between any two fireflies is about equal in the square of the area. Cuckoo Searchutilized in cloud computing to solve optimization issues such as intrusion detection, virtual machine (VM) consolidation, and resource scheduling. By seeing eggs as solutions and nests as possible solutions to a problem, it uses the natural behavior of cuckoos to identify the best answers. In dynamic, complicated contexts, cloud applications use computer science (CS) to increase security, lower power consumption, and improve quality of service (QoS).

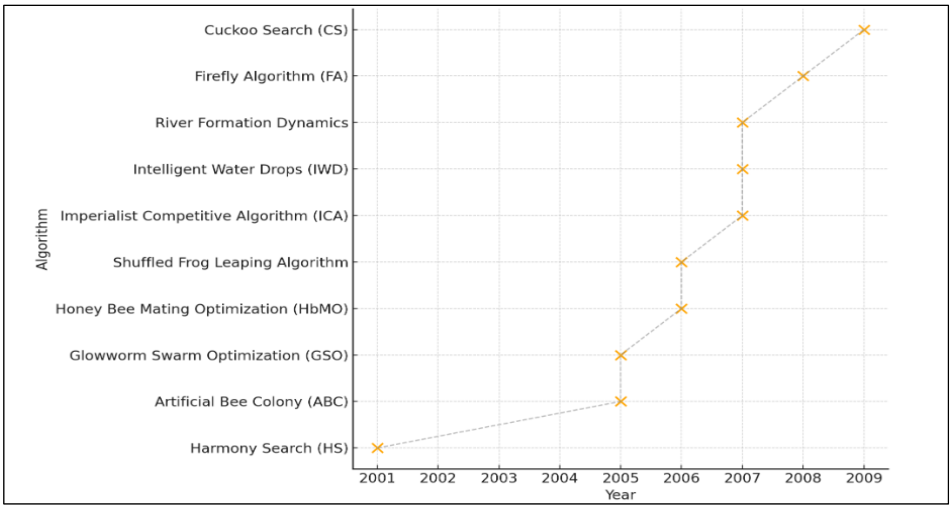

Figure 2: Graphical representation of meta-heuristic methods from 2001 to 2009.
Source: Authors, (2026).

IV. METHODS OF META-HEURISTICS FROM 2009 TO 2024

Gravitational Search Algorithm (GSA) fundamentally operates on the principles of gravity and the interaction of mass. The approach adopted by GSA is grounded in Newtonian physics, and its researchers comprise a diverse assembly of masses. Within GSA, an exclusive system for these masses is implemented. By leveraging gravity, each mass within the network can observe the conditions of other masses. GSA is very good at tackling nonlinear problems, and it has been used to allocate resources in cloud computing environments. In addition to providing resources for jobs with the lowest mean flow and span of time with load balancing other ways, the suggested method demonstrates that it receives about the same application reaction for resource allocation when compared to the GA and GSA without fuzzy improvements. Bat Algorithm is a metaheuristic optimization method that may be used to address complicated issues in cloud computing, particularly those related to work scheduling. In order to decrease processing time and maximize resource usage, the algorithm employs "virtual bats" to determine the most effective way to assign jobs to available resources. Spiral Optimization is a meta-heuristic algorithm that finds the optimal method to divide up scarce cloud resources among different jobs in order to improve performance or decrease cost.

Table 3: Methods of Meta-Heuristics from 2009 T0 2024.

Sr. No	Algorithm	Proposed	Year	Description / Inspiration
1.	Gravitational Search Algorithm	Rashedi et al. [47]	2009	Based on mass interactions between agents and the law of gravity.
2.	Bat Algorithm	Yang [48]	2010	Inspired by the echolocation behavior of bats.
3.	Spiral Optimization	Tamura and Yasuda [49]	2011	Models spiral movements for global and local search efficiency.
4.	Teaching Learning Based Optimization	Rao et al. [50]	2011	Simulates the effect of teaching and learning in a classroom.
5.	Krill Herd	Gandomi and Alavi [51]	2012	Influenced by the way krill individuals in seas crowd one another.
6.	Swallow Swarm Optimization	Neshat et al. [52]	2013	Based on the collective and dynamic flight behavior of swallows.
7.	Interior Search Algorithm	Gandom [53]	2014	Inspired by interior design and object placement strategies.
8.	Gradient Evolution Algorithm	Kuo and Zulvia [54]	2015	Combines gradient-based methods with evolutionary search.
9.	Water Wave Optimization	Zheng [55]	2015	Mimics the propagation, refraction, and breaking of water waves.
10.	Killer Whale Algorithm	Biyanto [56]	2016	Inspired by the social hunting behavior of killer whales.
11.	Rain Water Algorithm	Biyanto [57]	2017	Based on the collection and flow of rainwater in nature.
12.	Hydrological Cycle Algorithm	Zheng [58]	2018	Models the complete natural water cycle process.
13.	Emperor Penguins colony	Wedyan et al. [59]	2019	Simulates huddling and cooperation among emperor penguins.
14.	Aquila Optimizer	Harifi et al. [60]	2020	Inspired by the hunting and attacking strategies of eagles.
15.	Colony Predation Algorithm	Jiaze Tu et al. [61]	2021	Models group predation and cooperative hunting in animal colonies.
16.	Dwarf Mongoose Optimization	Agushaka et al. [62]	2022	Based on the cooperative hunting and social behavior of mongooses.
17.	Improved Chicken Swarm Optimization with Differential Evolution	Faramarz et al. [63]	2023	Hybrid strategy that combines Differential Evolution with Chicken Swarm Optimization for improved performance.
18.	Hybrid GWO-Salp Swarm	Krish Rustagi et al. [64]	2024	Merges Grey Wolf Optimizer with Salp Swarm Algorithm for better convergence and exploration.

Source: Authors, (2026)

Krill Herdis an optimization method with biological inspiration that is applied in cloud computing to issues including resource allocation, workload scheduling, and virtual machine (VM) deployment. In order to obtain the best answers, it mimics the herding behavior of krill, frequently seeking to enhance aspects like cost reduction, load balance, and energy efficiency. Swallow Swarm Optimization:can be used in cloud computing for tasks like scheduling, load balancing, and resource allocation, where its clever swarm behavior aids in the discovery of effective solutions.

Its special characteristicsexplorer, aimless, and leader particlesallow it to perform better than conventional techniques by accelerating convergence, avoiding local optima, and skillfully striking a balance between exploration and exploitation. Interior Search Algorithmis not a particular cloud computing technique, but rather a metaheuristic optimization algorithm influenced by interior design concepts. By improving the cloud environment, it is utilized in cloud computing research for tasks like resource assignment and energy-efficient virtual machine allocation. By identifying the best answers in expansive search spaces, which are typical in cloud computing, this method may resolve complicated, large-scale issues like load balancing and resource scheduling.

Gradient Evolution Algorithm (GEA)is a metaheuristic optimization technique that applies a gradient-based methodology to challenges such as neural architecture searches and difficult optimization issues. It is used in cloud computing to optimize multi-objective, complicated issues such as resource allocation and work scheduling. Water Wave Optimizationis a metaheuristic inspired by nature that is used in cloud computing to address difficult optimization problems like resource management and task scheduling. WWO finds the best answers in the search space by simulating the behavior of shallow water waves utilizing operators including propagation, refraction, and breaking. Killer Whale Algorithm is a cloud computing optimization method that uses natural inspiration to solve difficult problems including work scheduling, resource allocation, and load balancing.

In order to identify the optimum use of cloud resources, it mimics the cooperative hunting behavior of a killer whale pod, with a leader looking for the best answers and the members carrying out the "chase" or exploitation.Hydrological Cycle Algorithm is an optimization technique inspired by nature that applies the water cycle's concepts to cloud computing issues including load balancing and work scheduling. Solutions are represented by the algorithm as "water drops" that flow, evaporate, and condense according to their "fitness" or quality.Emperor Penguins colony refers to a series of bio-inspired metaheuristic optimization algorithms that use emperor penguin huddling behavior to address challenging cloud computing issues including resource scheduling and Quality of Service (QoS) management. Aquila Optimizer is a metaheuristic method that is used in cloud computing to handle complicated optimization issues, especially those involving task offloading and resource allocation.

It is a nature-inspired algorithm that effectively finds the best answers by imitating the Aquila bird's hunting style. Although the algorithm's use in cloud computing is still in its infancy, it has the potential to lower metrics like response time, execution time, and energy usage. Colony Predation The meta-heuristic optimization technique known as an algorithm is modeled after the cooperative hunting approach of social animals like wolves and lions. Complex optimization issues like load balancing, resource allocation, and job scheduling are resolved by cloud computing. Dwarf Mongoose Optimization (DMO)is use in this particular field is still in its infancy, it can be hosted on-premises or by a metaheuristic algorithm inspired by the foraging behavior of dwarf mongooses that can be applied to cloud computing challenges outside vendor It is used to optimize cloud resource allocation, task scheduling, and other complex problems by imitating the cooperative strategies of the animal.

Hybrid GWO-Salp Swarm is a metaheuristic method used in cloud computing to solve difficult optimization issues like resource allocation and job scheduling.By combining the advantages of both algorithms, GWO-SSA enhances performance and gets around the drawbacks of each one when applied separately. It is a nature-inspired algorithm that solves optimization issues by simulating wolves' hunting behavior. Its success in solving problems has led to its rise in popularity. Alpha, beta, delta, and omega are the four tiers of dominance that the wolves fall into. The omega wolf has the lowest place in the hierarchy, whereas the alfa wolf represents the leader. The search for the best answer is guided by the dominance level.GWO Steps: 1) The wolves move to encircle the prey by changing postures. By getting closer to the best answer, the wolf adjusts their locations. 2) The top three solutionsalfa, beta, and deltaact as leaders in prey hunting. When it comes to possible roles, they are the most knowledgeable.

Wolves enhance the general hunt for the answer by taking positions that are more advantageous to their leaders. 3) Prey attacking: In this phase, they focus their search on potential answers.There are several noteworthy and significant meta-heuristic algorithms in the field of resource management in cloud computing systems. Examples include Honey Bee Mating Optimization (HBMO), Ant Colony Optimization (ACO), Firefly Algorithm (FA), Artificial Bee Colony Algorithm (ABC), Glowworm Swarm Optimization (GSO), Cuckoo Search (CS), Genetic Algorithm (GA), Simulated Annealing (SA), and many more. Some of the most important metaheuristic techniques are included in the table. Cloud computing resource allocation uses meta-heuristic techniques like Teaching Learning Based Optimization (TLBO), Artificial Bee Colony (ABC), Harmony Search (HS), Ant Colony Optimization (ACO), Gravitational Search Algorithm (GSA), Cuckoo Search (CS) Algorithm, Firefly Algorithm (FA), Genetic Algorithm (GA), Shuffled Frog Leaping Algorithm (SFLA), and Particle Swarm Optimization (PSO). The section that follows discusses them.

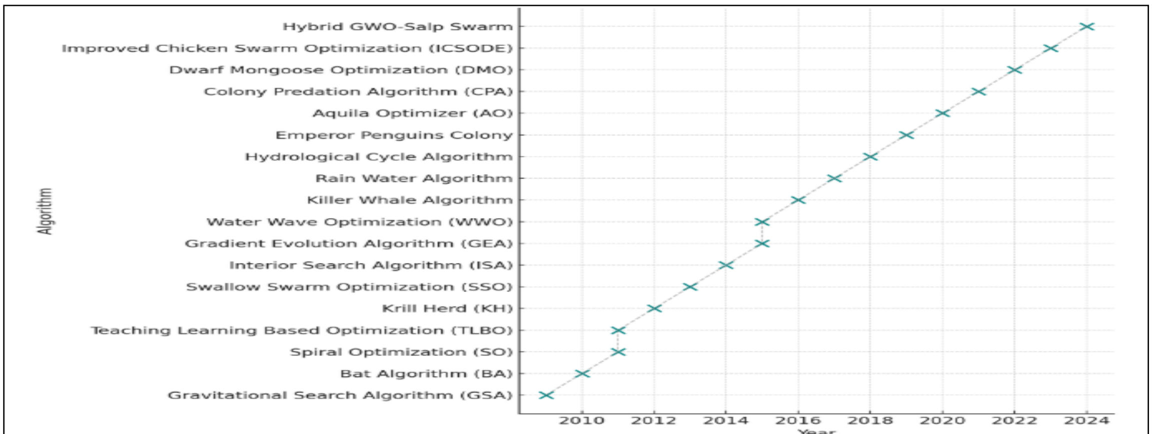

Figure 3: Graphical representation of meta-heuristic methods from 2009 to 2024.
Source: Authors, (2026).

V.CONCLUSION

These days, cloud computing is the most popular topic among IT firms worldwide. Businesses that employ cloud computing for the implementation and scalability of IT for business processes stand to gain a great deal from it. Cloud computing services are being adopted by an increasing number of businesses, including zoological organizations and accounting firms. This paper examined a few meta-heuristic algorithms for cloud resource allocation. These evaluations look at a variety of methods to make meta-heuristics more successful. Nonetheless, the meta-heuristic algorithms under consideration are adept at attaining much better performance, lower costs, shorter turnaround times, better resource utilization, and increased energy efficiency when allocating resources on the cloud. Future resource allocation in the cloud may make use of other meta-heuristic techniques not included in this study.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Sonia Sharma, Nipun Chhabra.
Methodology: Sonia Sharma, Nipun Chhabra.
Investigation: Sonia Sharma, Nipun Chhabra.
Discussion of results: Sonia Sharma, Nipun Chhabra.
Writing – Original Draft: Sonia Sharma.
Writing – Review and Editing: Sonia Sharma and Nipun Chhabra.
Resources: Sonia Sharma.
Supervision: Nipun Chhabra.
Approval of the final text: Sonia Sharma and Nipun Chhabra.

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