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A Review on Meta-Heuristic Task Scheduling Algorithms in Cloud Technology

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Abstract*— Cloud computing has gained significant popularity due to its ability to provide shared computing resources over the internet. As the demand for cloud services increases, task scheduling plays a crucial role in resource utilization. This paper examines heuristic and meta-heuristic methods for task scheduling in cloud environments such as First come First Serve (FCFS), Grey Wolf Optimizer (GWO), Jaya, Min-Min, Particle Swarm Optimization (PSO), Priority-Based Task Scheduling Algorithm, and Round-Robin (RR). These algorithms aim to improve resource utilization, reduce response time, efficient makespan, etc. The scientists conduct an examination of the goals, benefits, and drawbacks of each algorithm under specific environments.

Keywords* — Cloud Computing, GWO, Jaya, PSO, Task Scheduling, Virtual Machines.

I. INTRODUCTION

Cloud computing has gathered more significant attention within the scientific community due to its numerous advantages. Cloud computing offers a more flexible environment compared to traditional computing methods and plays a crucial role in meeting these needs by providing a cost-effective environment. With this, users can access their data from anywhere at any time through the cloud [1]. Accessibility and easy availability of resources has motivated organizations to shift their operations to cloud computing. They can freely utilize their resources to meet their needs. It offers a wide range of on-demand services, including dynamic access and rapid scalability [2]. The popularity gained by cloud computing relies on performance, efficiency, and resource management [3]. Cloud computing services can be categorized into three main service models: SaaS, PaaS, and IaaS as provided in Fig. 1.

1) SaaS: SaaS provides ready-to-use software applications to cloud users so that they can have access to them, which is provided by the cloud, such as google docs, Gmail, etc. where users can utilize these applications without the need of local installation or maintenance.
2) PaaS: PaaS provides the platform to the users for developing and deploying applications without the hassle of managing its infrastructure. For example Microsoft Azure, Google App Engine, etc.
3) IaaS: IaaS provides virtualized infrastructure resources for running various software stacks. Users can run and deploy any software, including OS services, and applications. For example, amazon web services EC2 and S3 [4], [5].

Task scheduling poses a substantial challenge in the domain of cloud computing. The primary aim is to assign incoming tasks from users to available VMs, while also taking into account various parameters like load balancing, execution time, quality of service, response time, and other relevant factors. To improve task scheduling, combining multiple scheduling metrics into a single algorithm is beneficial [6], [7]. This approach can have more potential to generate better outcomes.

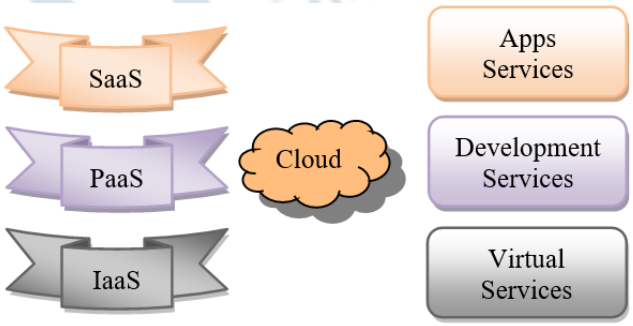

Fig. 1 Cloud Computing service model and Characteristics

A. Types of Cloud

The cloud categorization includes four types of clouds:

1) *Public Cloud* - The public cloud is accessible to the general public. It is owned and managed by the organization itself. Users can use cloud services on the internet, and they have to pay for the services they utilize. However public clouds may have security issues and are more vulnerable to attacks [8].
2) *Private Cloud* - The private cloud is dedicated to a specific organization and is typically hosted within the organization's premises or managed by an external provider. It offers more control and security as the data and infrastructure are managed within the organization [8].
3) *Hybrid Cloud:* The hybrid cloud integrates both public and private cloud infrastructures. Organizations use a mix of both clouds. They are connected through standardized technology. This allows flexibility and scalability with overflow traffic being redirected to a public cloud to

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prevent service interruption [8].

4) *Community Cloud:* A community cloud shares the computing environment with a specific group of organizations that have common interests or requirements and allows them to access and exchange information [9].

B. Task Scheduling Importance

Task scheduling involves assigning user tasks to VMs for execution. Load balancing is crucial in task scheduling as it ensures efficient distribution of workloads among servers, resource usage, and achieving the best throughput. As user expects their tasks to be completed quickly, whereas providers aim to maximize resource utilization and user satisfaction [6], [10].

C. Research Objective

The aim of this research is to highlight several existing algorithms which are related to task scheduling in a cloud computing. This paper includes a comparison between the existing techniques and outlines their type of issue related to task scheduling in the cloud and emphasizes the significance and advantages of the heuristic and meta-heuristic algorithm in cloud computing.

II. SCHEDULING ALGORITHMS ANALYSIS

Task-scheduling algorithms can be categorized into two types:

1) Heuristic: It is a problem-solving approach that employs specific methods and strategies to search for feasible solutions. It uses rules and guidelines to guide the search process and find solutions that are reasonable within the given problem context [10]. Examples of heuristic approaches are Round Robin, min-min, First Come First Serve, Priority-based Scheduling, etc.
2) Metaheuristic: Metaheuristic algorithms are inspired by natural processes, such as evolutionary biology, swarm intelligence, or physical phenomena. They use techniques like randomization, local search, exploring the problem space, and searching for promising solution. Metaheuristic algorithms are used to solve complex optimization problems [11]. This entails the discovery of finding the optimal solution among a vast number of possibilities. Metaheuristics gives approximate solutions that are considered good for practical purposes, unlike traditional algorithms which may give exact solutions [12]. Some of the examples are PSO, GWO, Jaya.

Table 1. Difference between Heuristic and Meta-Heuristic Algorithms

Parameters	Heuristic Algorithms	Meta-Heuristic Algorithms
Adaptability	Limited adaptability.	More adaptable than heuristic approaches.
Scalability	May struggle in large scale and complex problems.	Easily scale up to larger problems.
Memory Usage	Low memory is required.	Required More memory due to the approach can be based on population size.
Robustness	Tends to be less robust.	It is often more robust.
Hybridization	Can be a hybrid with another heuristic or optimization approach.	Easily combined with both heuristic and meta-heuristic approaches.
Nature of solutions	Provide more discrete solutions.	Provide more continuous values.
Sensitivity to Parameters	Less sensitive to changed parameters	May affect the outcomes sometimes
Execution Speed	It is faster.	Bit slow then heuristic but accurate results.

III. LITERATURE REVIEW

A. Round Robin

RR is a straightforward load-balancing technique commonly used in task scheduling. Its primary objective is to ensure equal load distribution across resources. It follows a cyclic approach where the schedular selects a task, assign it to the controller, and moves on to the next task after a fixed time interval. The process continues and ensures that each task should be assigned to the controller at least once before it returns back to the first task. It provides an improvement in load balancing and response time. Each task has an equal chance of being selected, ensuring fairness in resource allocation [10], [13].

B. First Come First Serve

FCFS is a simple technique used in task scheduling in cloud computing. Without considering any other parameter FCFS prioritizes tasks based on their arrival time. The task which arrived first will get assigned to a virtual machine for executions. Let five tasks arrive for execution and there are only four VMs then the first four will get the VMs and the remaining one has to wait for VMs to get free. After that, it may get executed. And if it has a child function to execute it has to wait till the parent task executes completely. This may result in idle VMs and underutilization of resources when task dependencies are involved [14].

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C. Priority-Based Scheduling

In PBS set of tasks that should be executed are prioritized by incorporating multiplicative standards to determine the decision-making model for tasks that have three levels of priorities: programming level, resource level, and work level. Which will be responsible for obtaining the highest-ranked task by being selected and allocated a resource? The list of tasks will further update over time and scheduling will continue till all tasks are appropriately assigned to resources [15], [16].

D. Min-Min

Min-Min is the popular task-scheduling heuristic algorithm. It is a simple and quick approach as it selects the task with minimum execution time. In each iteration, a Set of unassigned tasks are selected which have minimal execution time. Once the task is allocated to a resource its completion time is computed based on the expected execution time and then the task will be removed, it continues till all tasks have been assigned to resources [17].

E. Particle swarm optimization

PSO is inspired by the collective behavior of bird swarms searching for food. Each particle initializes a random position and velocity. The aim of this algorithm is to find the best possible solution within a multidimensional search space. PSO involves the exploration and exploitation phases where in exploration particles explore different regions of the search space to find out the potential best solution and in the exploitation phase particle are focused on intensifying the search around promising regions to refine and improve the solutions [18].

F. The Grey Wolf Optimizer

GWO is a nature-inspired algorithm that mimics the hunting behavior of wolves in order to solve optimization problems. It has gained popularity due to its effectiveness in finding solutions. The wolves are categorized into four levels of dominance alpha, beta, delta, and omega. The alfa wolf symbolizes as the leader, whereas the omega wolf occupies the lowest position in the hierarchy. The level of dominance is to guide the search for the optimal solution [19].

GWO Steps:

1) Prey encircling: the wolves adjust their positions to encircle the prey. The wolf updates their positions by moving closer to the optimal solution.
2) Prey hunting: the top three solutions alfa, beta, and delta act as a leader. They have the best knowledge about potential positions. By adjusting their positions relative to their leaders, wolves improve the overall search for the solution.
3) Prey attacking: This step involves refining their search around promising solutions. The extent of adjustment gradually decreases over time to fine-tune the search process.

G. Jaya

The Jaya algorithm is named after the Sanskrit word victory. It is a population-based metaheuristic approach. It draws inspiration from social behavior and the concept of generations. Jaya algorithm leverages ideas from both evolutionary and swarm intelligent algorithms. Jaya doesn't rely on complex details of specific problems. Instead, it focuses on the idea of cooperation among solutions to find better solutions. Its if flexibility and adaptability have led to its widespread use [20], [21].

Table 2 presents an analysis of the Methodology, Parameters, Merit, and Demerits of various heuristic and meta-heuristic algorithms.

Table 2. Analysis of Different Algorithms

Algorithms	Methodology	Parameter(s)	Merit	Demerit
Priority-Based Job Scheduling Algorithm	It ensures that tasks are scheduled on the basics of their relative priorities.	Priority to each queue	Easy to utilize, user friendly	Tasks having low priority can be lost when the system crashes. Starvation for resources.
Round Robin	The algorithm employs cyclic methodology with an equally small-time unit of distribution so each task gets an equal chance to execute.	Time of Arrival and Time Slicing	Response time is good. less complexity	Once the time slice expires, pre-emption forces the process to leave the execution.
Min-Min Algorithm	Min-Min selects the task which has the minimum execution time from all the tasks.	Makespan	Quick response time, simplicity, Better makespan	load unbalancing and QoS is not so good.

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Algorithms	Methodology	Parameter(s)	Merit	Demerit
First Come First Serve	FIFO queues are used to manage the tasks where the task that comes first will get executed on VM.	Time of Arrival	Simple and fast execution	Task scheduling relies on arrival time, and neglects any other criteria, which leads to underutilization of VMs.
Particle Swarm Optimization	PSO is a population-based approach that identifies the optimal minimum value which assists in establishing an accurate task order and scheduling tasks to appropriate resources.	The objective function, search space bounds, population size, max number of iterations, inertia weight.	It exhibits exceptional resource utilization, aims to discover the optimal solution, and minimizes processing time.	The performance of the algorithm depends on the problem .in the case of a large search space can cause slow convergence speed.
Grey Wolve Optimizer (GWO)	GWO utilizes the behavioural characteristic of grey wolves to explore dynamically and search for the optimal solution.	Search space bounds, population size, and max number of iterations, initial population, and coefficient parameters.	GWO Algorithm has faster convergence because it incorporates less randomness and assigns varying no. of individuals to global and local search procedures.	Premature convergence, sensitivity to initialization.
Jaya	Jaya encourages collaboration among candidate solutions to improve the overall population fitness and allow it to explore the search space while moving toward better solutions.	The objective function, search space bounds, population size, and a maximum number of iterations.	Jaya has the potential to find global optima. Does not require algorithmic parameters.	Jaya doesn't have a diversity preservation mechanism within its population.

IV. CONCLUSION

Task scheduling is a critical concern in cloud computing and various techniques have been developed to address this issue and enhance resource utilization, cost, response time, and also user satisfaction. This paper provides a concise overview of task scheduling algorithm in the cloud, including GWO, PSO, Jaya, Min-Min, FCFS, PRS, and Round Robin. Each algorithm possesses its unique methodology, parameters, merits and demerits which are critically determining their suitability and performance real-world scenarios. As in Priority-Based Job Scheduling Algorithm is a user-friendly approach and easy to use but it faces challenges such as potential task loss during system crashes or starvation. In Round Robin, it fairly distribute the execution time among tasks, and demonstrates good response time and simplicity but it faces problem like pre-emption i.e. after time slice expiry may lead to inefficiencies. In Min-Min, it works excellent in response time and it holds simplicity by selecting tasks with the minimum execution time. However, it faces issues in load balancing and doesn't prioritize QoS. Whereas FCFS is simple and fast, suffers from underutilization of VMs as it solely relies on task arrival time for scheduling decisions. In PSO, it impresses with its exceptional resource utilization and ability to minimize processing time. But, it's performance is influenced by the problem at hand and it may experience slow convergence in local search space. Here, GWO exhibits faster convergence by leveraging the behavioral characteristics of grey wolfs. Yet, it is susceptible to premature convergence, and initialization sensitivity due to local optima struck. In case of Jaya, it promotes collaboration among candidate solutions and has the potential to find optimal solution without requiring algorithmic parameters. But, it lacks in mechanism to preserve population diversity.

Selecting the most suitable task scheduling algorithm for specific cloud environment involves a carful consideration of desired objectives and trade-offs. This study is valuable for researchers seeking to address research challenges related to task scheduling, enhance QoS parameters, reduce time complexity, improve response time, ensure solution quality, and mitigate server failures.

V. FUTURE SCOPE

Future research in this field should be focus on addressing the identified limitations and develop hybrid approaches. The motivation behind hybridization is to enhance the capability of metaheuristic algorithms. As in earlier stages, of metaheuristic algorithms different communities worked on these techniques independently without much interaction. As a result, the standard form of meta-heuristic algorithms reached their limits. Then, researchers started combing different algorithms to create hybrids. These hybrids combine various algorithms components or parameters which can be used in different areas of optimization and achieve better results.

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