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Multi-Objective Task Scheduling for Mobile Cloud Computing

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Abstract: *This study compares the effectiveness of three optimization algorithms—Grey Wolf Optimizer (GWO), Flower Pollination Algorithm (FPA), and Particle Swarm Optimization (PSO)—for task scheduling in a cloud computing environment. The simulation results reveal that GWO consistently outperforms both FPA and PSO in terms of execution time and cost efficiency. Specifically, GWO delivers the fastest execution times, starting from 122.2 milliseconds for 200 tasks and increasing to 162.6 milliseconds for 1000 tasks. It also demonstrates superior cost efficiency, with costs beginning at Rs 123.2 for 200 tasks and rising to Rs 152.6 for 1000 tasks. In comparison, FPA and PSO show higher execution times and costs, particularly for larger task sizes. These results highlight GWO's effectiveness in managing task scheduling efficiently and economically, making it a preferable choice for large-scale and cost-sensitive cloud computing applications.*

Keywords: *Task Scheduling, Grey Wolf Optimizer (GWO), Flower Pollination Algorithm (FPA), Particle Swarm Optimization (PSO), Cloud Computing.*

1. Introduction

Cloud computing has transformed the delivery of internet-based services by providing scalable, cost-effective, and on-demand access to resources like memory, storage, and network bandwidth. Users benefit from a pay-as-you-go model, accessing services from any device with internet connectivity without the need to manage the underlying infrastructure. As the use of cloud computing expands, efficient resource management and scheduling become crucial, particularly as the number of users grows and demands fluctuate. Virtual machines are central to resource allocation, requiring careful isolation to ensure optimal performance within their host constraints. Scheduling involves assigning resources based on predefined criteria, aiming to maximize performance and resource utilization while meeting user-defined constraints such as deadlines, security, and costs. Effective scheduling in cloud environments is complex, requiring solutions that address Quality of Service (QoS) issues to optimize task execution. In mobile cloud computing, multi-objective scheduling strategies are essential for balancing these various demands. Scheduling algorithms in cloud computing must address specific requirements, dividing computation-intensive jobs into smaller tasks, which are executed using designated resources. A job is treated as an indivisible entity, and non-preemptible instructions allow it to run on specific nodes with various execution methods. Optimization criteria in scheduling focus on completing tasks efficiently and securely, even without set deadlines or budgets. Cloud service providers dynamically manage physical resources, enabling flexible task submission and scheduling based on availability. Effective task scheduling is crucial for optimizing resource management and cloud performance, supporting key objectives like high performance, utilization, scalability, and efficiency.

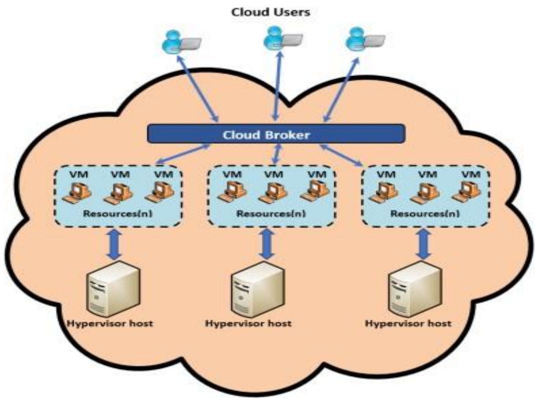

Figure 1 Task Scheduling in Cloud Computing

Effective job scheduling in cloud computing requires careful management and capacity planning to select the best virtual machine (VM) resources, addressing multiple Quality of Service (QoS) considerations. VMs provide virtualized environments for task execution, and the task scheduler must match tasks with suitable VMs to avoid increased wait times, prolonged makespan, and reduced performance. The main challenge is balancing task assignments between high- and low-capacity VMs to optimize system performance. Poor scheduling can lead to lower throughput for providers and unmet QoS standards, higher costs, and dissatisfaction for clients. Optimized scheduling algorithms are crucial for aligning workloads with appropriate VMs, reducing time and costs while meeting QoS needs like makespan and resource utilization, ultimately benefiting both providers and users.

2. Literature Review

Task scheduling in cloud and grid computing is a critical area of research aimed at optimizing resource utilization, reducing costs, and improving system performance. With the rapid growth of cloud services and the increasing complexity of computing environments, various optimization algorithms have been proposed to enhance task scheduling. This literature survey examines key contributions in this field, focusing on algorithms such as Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Genetic Algorithms (GA), and their hybrids. Early research explored foundational algorithms, highlighting their strengths and limitations in task scheduling scenarios. For instance, ACO has been shown to be effective in developing scalable solutions for green cloud environments (Damakoa et al., 2017), while PSO and GA have demonstrated significant improvements in scheduling efficiency and resource utilization (Chen & Long, 2017; Jang et al., 2012). Modified PSO algorithms have also been applied to enhance scheduling in cloud environments (Abdi et al., 2014).

Table 1 Summary of Literature survey

Author	Work Done	Findings
Jasti et al. (2022)	Developed a machine learning and image processing technique for breast cancer diagnosis.	The technique improves medical image analysis for breast cancer diagnosis.
Damakoa et al. (2017)	Proposed an ACO-based task scheduling method for green cloud computing.	Achieved efficient and scalable task scheduling in a green cloud computing environment.
Chen and Long (2017)	Integrated particle swarm algorithm with ant colony algorithm for task scheduling.	Enhanced task scheduling in cloud computing with improved performance.
Joundy et al. (2015)	Conducted a comparative study of various task scheduling algorithms in cloud computing.	Provided insights into the effectiveness of different scheduling algorithms in cloud environments.
Kansal and Chana (2015)	Introduced an artificial bee colony-based energy-aware resource utilization technique.	Improved energy efficiency and resource utilization in cloud computing.
Abdi et al. (2014)	Applied a modified PSO algorithm for task scheduling in cloud computing.	Enhanced task scheduling efficiency using a modified version of the PSO algorithm.
Balasubramani and Marcus (2014)	Studied an unspecified issue related to cloud computing.	Specific findings not detailed; focused on cloud computing issues.
Chitra et al. (2014)	Proposed a local minima jump PSO algorithm for workflow scheduling.	Improved workflow scheduling by addressing local minima issues in PSO.
Kim et al. (2013)	Used binary artificial bee colony optimization for job scheduling in grid computing.	Achieved optimal job scheduling in grid computing with binary artificial bee colony optimization.
Mondal et al. (2012)	Explored load balancing in cloud computing using stochastic hill climbing.	Enhanced load balancing through stochastic hill climbing in cloud environments.
Jang et al. (2012)	Investigated genetic algorithm-based task scheduling for cloud computing.	Showed effectiveness of genetic algorithms in improving task scheduling performance.
Alireza (2011)	Applied PSO with adaptive mutation and inertia weight for dynamic systems parameter estimation.	Improved parameter estimation in dynamic systems using adaptive PSO techniques.

3. Research Gap

Current research in task scheduling often emphasizes individual algorithms like ACO, PSO, and genetic algorithms, with limited exploration of hybrid approaches. There is also a gap in addressing the scalability of these algorithms under dynamic conditions and integrating real-time data for adaptive scheduling. Future studies should focus on hybrid algorithms, scalability improvements, and real-time adaptive mechanisms for diverse cloud environments.

4. Methodology

Cloud computing offers a range of services, including data storage, application development, and on-demand access. Managing these resources efficiently for multiple users is challenging. Effective task scheduling is crucial to optimizing resource use, reducing costs, minimizing execution time, and improving server utilization. To address these challenges, a framework combining Particle Swarm Optimization (PSO), Grey Wolf Optimization (GWO), and Flower Pollination Algorithm (FPA) is proposed. This framework aims to enhance scheduling efficiency and achieve goals such as reduced execution time, cost, and server utilization. The FPA imitates natural pollination processes, using principles from plant behavior and various natural mechanisms. It incorporates both self-pollination and cross-pollination techniques to explore a wider search space during optimization. The GWO algorithm mimics the social behavior of wolves in hunting. Additionally, the PSO algorithm utilizes the swarming behavior of animals, where each particle has a unique position and velocity, allowing flexible movement in the search space.

5. Result & Discussion

The setup includes a simulation environment with a configuration of 20 cloudlets, each containing four virtual machines, within a data center. This setup allows for the application of optimization algorithms like GWO, PSO, and FPA to improve scheduling strategies. The objective is to optimize task scheduling to reduce costs, minimize execution time, and enhance server utilization. The results of execution time are displayed in relevant tables and figures, along with the corresponding cost analysis.

Table 2 Execution time of GWO, FPA and PSO in milliseconds

No of Tasks	GWO	FPA	PSO
200	122.2	144.1	146.4
400	127.3	155.6	159.6
600	132.1	159.8	164.7
800	142.5	170.9	176.2
1000	162.6	179.7	188.3

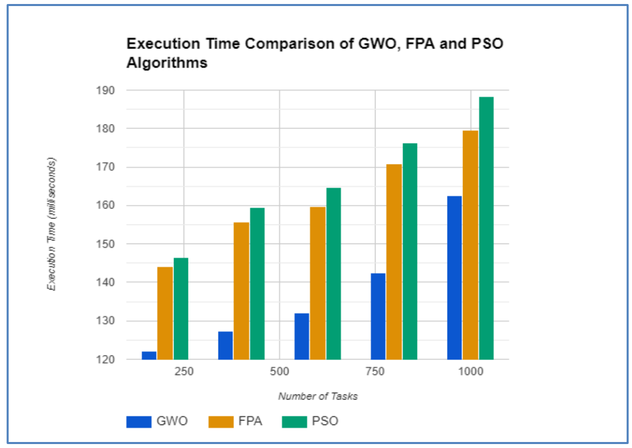

Fig. 2 Execution Time Comparison of GWO, FPA, and PSO Algorithms

Table 2 & graph 2 presents the execution times in milliseconds for three optimization algorithms—GWO (Grey Wolf Optimizer), FPA (Flower Pollination Algorithm), and PSO (Particle Swarm Optimization)—across varying numbers of tasks. For 200 tasks, GWO achieves the fastest execution time at 122.2 ms, followed by FPA at 144.1 ms, and PSO at 146.4 ms. As the number of tasks increases, the execution times for all algorithms rise. GWO maintains the shortest execution time, reaching 162.6 ms for 1000 tasks. FPA and PSO show higher execution times, with FPA reaching 179.7 ms and PSO 188.3 ms for the same task count. This trend indicates that GWO consistently outperforms FPA and PSO in terms of efficiency as the problem size scales.

Table 3 Cost of GWO, FPA and PSO in Rs

No of Tasks	GWO	FPA	PSO
200	123.2	136.5	156.2
400	128.3	140.3	160.3
600	133.6	144.6	166.3
800	142.2	149.6	222.4
1000	152.6	164.5	237.4

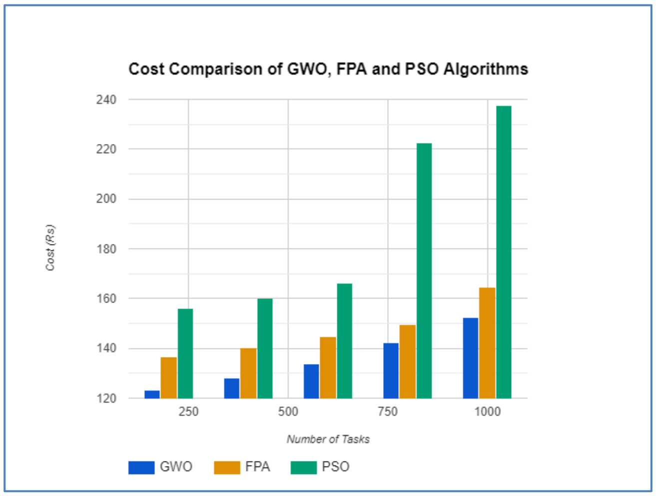

Fig. 3 Cost Comparison of GWO, FPA, and PSO Algorithms in Rupees

Table 3 & Fig. 3 displays the cost in Indian Rupees (Rs) associated with three optimization algorithms—GWO (Grey Wolf Optimizer), FPA (Flower Pollination Algorithm), and PSO (Particle Swarm Optimization)—across different task sizes. For 200 tasks, GWO incurs the lowest cost at Rs 123.2, compared to FPA at Rs 136.5 and PSO at Rs 156.2. As the number of tasks increases, the costs for all algorithms rise. GWO's cost increases to Rs 152.6 for 1000 tasks, while FPA's cost grows to Rs 164.5, and PSO's cost reaches Rs 237.4. The data indicates that GWO remains the most cost-effective algorithm, with FPA and PSO showing progressively higher costs, particularly for larger task sizes. This suggests that GWO is more economical across different scales of the problem compared to FPA and PSO.

6. Conclusion

The simulation study evaluating GWO (Grey Wolf Optimizer), FPA (Flower Pollination Algorithm), and PSO (Particle Swarm Optimization) in a cloud computing environment demonstrates that GWO outperforms the other two algorithms in both execution time and cost efficiency. As shown in Table 2 and Figure 2, GWO consistently provides the fastest execution times across varying numbers of tasks, starting from 122.2 milliseconds for 200 tasks and increasing to 162.6 milliseconds for 1000 tasks. This indicates its superior efficiency in handling larger workloads. Similarly, Table 3 and Figure 3 reveal that GWO is the most cost-effective, with costs starting at Rs 123.2 for 200 tasks and rising to Rs 152.6 for 1000 tasks. In comparison, both FPA and PSO show progressively higher execution times and costs, particularly for larger task sizes. GWO's ability to deliver faster performance and lower costs makes it a more advantageous choice for optimizing task scheduling in cloud computing environments. This study underscores GWO's efficiency and economic benefits, positioning it as a preferable option for large-scale and cost-sensitive applications.

Scope for Future Research:

1. **Algorithm Comparison**: Extend evaluations to include additional optimization algorithms to validate the observed trends and identify potentially better solutions.
2. **Dynamic Environments**: Test the algorithms in more dynamic and real-world environments with varying workloads and task characteristics.
3. **Scalability Studies**: Investigate the scalability of these algorithms with even larger task sizes and more complex cloud configurations.
4. **Energy Efficiency**: Explore the impact of these algorithms on energy consumption and sustainability in cloud computing.
5. **Hybrid Approaches**: Develop and assess hybrid algorithms that combine strengths of GWO, FPA, and PSO for improved performance and cost-effectiveness.

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