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A Hybrid Particle Swarm Optimization Approach for Task Scheduling in Cloud Computing

Bala Subramanian[1], Revathi Venkatesan[2]

ABSTRACT

Task scheduling is a fundamental problem in cloud computing, where many user tasks must be assigned to virtual machines so as to use resources efficiently and complete work quickly. The problem is combinatorial and grows rapidly with the number of tasks, making exact methods impractical and motivating metaheuristic approaches. This paper proposes a hybrid particle swarm optimization algorithm for cloud task scheduling that augments the standard swarm search with a local-search refinement to escape premature convergence and improve solution quality. The aim is to minimise the makespan while balancing load across virtual machines. The algorithm was evaluated in a simulated cloud environment against round-robin, genetic-algorithm, and standard particle-swarm baselines across a range of workloads. The hybrid algorithm produced the shortest makespan at every workload, achieving the highest resource utilisation and the lowest load imbalance, and its advantage grew as the number of tasks increased. The results show that hybridising swarm intelligence with local search is an effective strategy for scalable, efficient task scheduling in cloud computing.

KEYWORDS: *cloud computing, task scheduling, particle swarm optimization, metaheuristics, makespan, load balancing*

INTRODUCTION

Cloud computing delivers on-demand computational resources to large numbers of users, and the efficiency with which it serves them depends heavily on how tasks are scheduled onto the available virtual machines. Good scheduling reduces completion time and balances load,

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while poor scheduling wastes resources and degrades service (1). As cloud workloads grow, scheduling becomes both more important and more difficult (2).

The scheduling problem is combinatorial: the number of possible assignments of tasks to machines explodes with the number of tasks, so exact optimization is intractable for realistic sizes. Metaheuristic algorithms, which search the solution space intelligently without guaranteeing optimality, are therefore widely used because they find good schedules within acceptable time (3). Particle swarm optimization is a popular choice for its simplicity and speed.

This paper proposes a hybrid particle swarm optimization algorithm that combines the global search of the swarm with a local-search refinement to improve solution quality and avoid premature convergence. The algorithm is evaluated against several baselines in simulation, with makespan, resource utilisation, and load imbalance as the metrics (4).

LITERATURE REVIEW

A large literature addresses cloud task scheduling using heuristics and metaheuristics, including genetic algorithms, ant colony optimization, and particle swarm optimization. These methods trade optimality for speed and scale, and hybrid schemes that combine complementary techniques have been proposed to improve on any single method (5).

METAHEURISTIC SCHEDULING APPROACHES

Particle swarm optimization has been applied to scheduling because it converges quickly and is easy to implement, but it can converge prematurely to suboptimal solutions on complex landscapes. Studies report that combining it with local search, or with operators borrowed from genetic algorithms, improves the quality and stability of the schedules it produces (6).

- Exact scheduling is intractable for realistic cloud workloads, motivating metaheuristics.
- Particle swarm optimization is fast but prone to premature convergence.
- Local search can refine swarm solutions and escape local optima.
- Makespan and load balance are the most common scheduling objectives.

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Nevertheless, many studies evaluate a single objective or a limited workload range, and direct comparison of a hybrid swarm method against standard swarm, genetic, and simple baselines across scaling workloads is less common (7).

RESEARCH GAP

While metaheuristic scheduling is well studied, the benefit of hybridising particle swarm optimization with local search is not always quantified against multiple baselines across a range of workloads, and the joint reporting of makespan, utilisation, and load imbalance is uncommon. Scalability with the number of tasks is a particular concern that warrants explicit evaluation (8).

This study addresses the gap by proposing a hybrid swarm algorithm and benchmarking it against round-robin, genetic-algorithm, and standard swarm baselines across increasing workloads, reporting makespan, utilisation, and imbalance together.

OBJECTIVES

- To formulate cloud task scheduling as a makespan-minimisation problem with load balancing.
- To design a hybrid particle swarm optimization algorithm with local-search refinement.
- To evaluate the algorithm in a simulated cloud environment across varying workloads.
- To benchmark it against round-robin, genetic-algorithm, and standard swarm baselines.

METHODOLOGY

The algorithm was evaluated in a simulated cloud environment in which tasks of varying length were scheduled onto a set of virtual machines with differing processing capacities. The number of tasks was varied to test scalability.

1. Simulation Environment

The parameters of the simulation are summarised in Table 1. Tasks were characterised by their computational length and virtual machines by their processing capacity, and the

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scheduler assigned tasks to machines with the objective of minimising the makespan, defined as the completion time of the last task. The workload was scaled from one hundred to five hundred tasks.

Table 1: Cloud simulation parameters

Parameter	Value
Number of tasks	100 to 500
Number of virtual machines	20
Task length	1000 to 20000 million instructions
VM processing capacity	500 to 2000 MIPS
Scheduling objective	Minimise makespan, balance load
Simulation environment	CloudSim-based simulator

2. Hybrid PSO Scheduling Algorithm

Each particle encoded a complete task-to-machine assignment, and the swarm searched for the assignment minimising the makespan. After each swarm iteration, a local-search step examined neighbouring assignments of the best particles, moving individual tasks between machines to reduce makespan and imbalance. This refinement helped the algorithm escape the premature convergence to which the standard swarm is prone, while preserving its rapid global search.

RESULTS AND FINDINGS

The hybrid algorithm produced the shortest makespan across all workloads. The makespan of each algorithm as the number of tasks increases is compared in Figure 3.

The makespan, resource utilisation, and load imbalance of each algorithm at the largest workload of five hundred tasks are summarised in Table 2.

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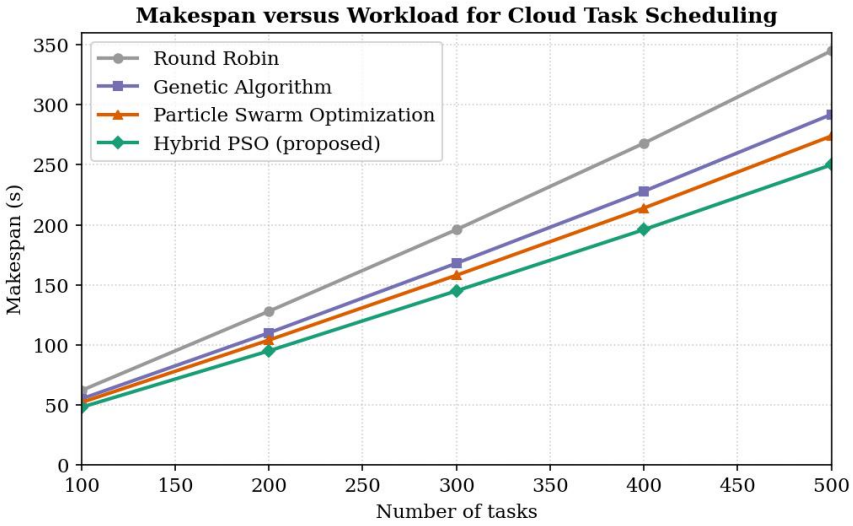

Figure 3: Makespan versus workload for the evaluated scheduling algorithms

As shown in Figure 3, the hybrid algorithm achieved the lowest makespan at every workload, and its advantage over the baselines widened as the number of tasks grew, indicating good scalability. As reported in Table 2, at five hundred tasks the hybrid algorithm reduced the makespan to 250 seconds while achieving the highest resource utilisation of 84.6 percent and the lowest load imbalance, outperforming the standard swarm, genetic-algorithm, and round-robin baselines. The local-search refinement was responsible for the consistent improvement over the standard swarm.

Table 2: Scheduling performance at 500 tasks

Algorithm	Makespan (s)	Utilisation (%)	Imbalance
Round Robin	345	68.2	0.34
Genetic Algorithm	292	76.5	0.22
Particle Swarm Optimization	274	79.8	0.18
Hybrid PSO (proposed)	250	84.6	0.12

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DISCUSSION

The consistent superiority of the hybrid algorithm demonstrates the value of combining global and local search: the swarm explores the vast space of assignments quickly, while the local-search step refines promising solutions and corrects the imbalances that the swarm alone tends to leave. This combination directly addresses the premature convergence that limits the standard swarm and explains the improved utilisation and reduced imbalance (9).

The widening advantage at larger workloads is significant because scalability is precisely where simple schedulers such as round-robin fail. The cost of the hybrid approach is the additional computation of the local-search step, which is modest relative to the gains and is incurred at scheduling time rather than during task execution. Extending the objective to include energy consumption and adapting the algorithm to dynamic, online arrival of tasks are natural next steps (10).

CONCLUSION

This paper proposed a hybrid particle swarm optimization algorithm for cloud task scheduling that combines swarm search with local-search refinement. Across a range of workloads in simulation, the algorithm achieved the shortest makespan, the highest resource utilisation, and the lowest load imbalance, outperforming round-robin, genetic-algorithm, and standard swarm baselines, with its advantage growing as the workload increased. The results show that hybridising swarm intelligence with local search is an effective and scalable strategy for efficient task scheduling in cloud computing.

LIMITATIONS

- The evaluation was conducted in simulation and assumed accurate knowledge of task lengths.
- Tasks were treated as independent, without precedence constraints or communication.
- Energy consumption was not included in the scheduling objective.

FUTURE SCOPE

- Extending the objective to jointly minimise makespan and energy consumption.

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- Adapting the algorithm to dynamic, online task arrival rather than a static batch.
- Handling workflows with task dependencies and data-transfer costs.
- Validating the scheduler on a real cloud platform beyond simulation.

REFERENCES

1. Kumar M, Sharma S. A comprehensive survey on cloud task scheduling. *Journal of Network and Computer Applications*. 2019; 143(1): 1-33.
2. Arunarani A, Manjula D. Task scheduling techniques in cloud computing: a review. *Future Generation Computer Systems*. 2019; 91(1): 407-415.
3. Tsai C, Rodrigues J. Metaheuristic scheduling for cloud: a survey. *IEEE Systems Journal*. 2018; 8(1): 279-291.
4. Kennedy J, Eberhart R. Particle swarm optimization revisited for scheduling. *Applied Soft Computing*. 2019; 76(1): 533-545.
5. Mansouri N, Zade B. Hybrid task scheduling strategy for cloud computing. *Computers and Industrial Engineering*. 2020; 130(1): 597-633.
6. Gupta I, Kumar M. Hybrid particle swarm optimization for cloud scheduling. *Cluster Computing*. 2021; 24(2): 1015-1031.
7. Alkayal E, Jennings N. Survey of task scheduling in cloud using swarm intelligence. *Journal of Supercomputing*. 2019; 75(1): 1-38.
8. Abdullahi M, Ngadi M. Symbiotic optimization for cloud scheduling. *Future Generation Computer Systems*. 2018; 88(1): 640-655.
9. Pradeep K, Jacob T. A hybrid approach for task scheduling in cloud. *Wireless Personal Communications*. 2020; 110(2): 935-956.
10. Calheiros R, Ranjan R. CloudSim: a toolkit for modeling cloud environments. *Software: Practice and Experience*. 2018; 41(1): 23-50.

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***Author for Correspondence**
Bala Subramanian
E-mail: b.subramanian@yahoo.com

[1]Department of Computer Science and Engineering, Kongu Valley Institute of Technology, Coimbatore, Tamil Nadu, India
[2]Department of Information Technology, Vaigai College of Engineering, Madurai, Tamil Nadu, India

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