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Energy - Efficient Makespan Optimized Task Scheduling and Hybrid Framework for Green Cloud Computing

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Abstract: *Cloud computing has emerged as a fundamental technology in modern IT infrastructure, offering scalable and on-demand resource provisioning. However, efficient task scheduling remains a critical challenge due to fluctuating workloads, energy consumption constraints, and the need to maintain optimal Quality of Service (QoS). Traditional scheduling algorithms such as First Come First Serve (FCFS), Round Robin (RR), and Genetic Algorithm (GA) often fail to adapt dynamically to changing cloud environments, leading to inefficient resource utilization and increased power consumption .This research proposes an Enhanced Neighborhood Inspired Multi-verse Scheduler (NIMS) algorithm, which integrates hybrid optimization techniques, energy-aware scheduling, and fault tolerance mechanisms to improve cloud resource allocation. analysing the suggested NIMS technique alongside algorithms: EMVO, IMOMVO, OPSO, LJFPPSO, TSIGA, FPGWO, and MVO, using the CloudSim toolkit with diverse test scenarios for three acknowledged real-world benchmark datasets. The findings of the simulations and experiments conducted within this study demonstrates that the algorithms surpasses the other competing algorithms regarding five critical performance measures: makespan, energy consumption, throughput, load imbalance, average resource utilization.*

Keywords: Cloud Computing, NIMS Algorithm, CloudSim, Energy-Aware Scheduling, Multi-verse Optimization, Adaptive Resource Allocation, Task Scheduling

I. INTRODUCTION

Cloud computing has revolutionized how businesses and individuals access computing resources by offering on-demand services over the internet. With the increasing adoption of cloud-based applications, the need for efficient resource scheduling has become more critical than ever.

Effective task scheduling ensures that virtual machines (VMs) are optimally assigned workloads, minimizing execution time and energy consumption while maintaining QoS parameters.

The Neighborhood Inspired Multi-verse Scheduler (NIMS) is an advanced scheduling approach that builds upon the Multi-verse Optimization (MVO) algorithm by incorporating localized search techniques to improve scheduling accuracy. However, existing implementations of NIMS do not adequately address energy efficiency, real-time adaptability, or fault tolerance mechanisms, leading to suboptimal resource utilization.

This research aims to enhance the NIMS algorithm by introducing hybrid optimization techniques, energy-aware scheduling strategies, and adaptive fault-tolerant mechanisms. By implementing this enhanced model in CloudSim, we aim to demonstrate significant improvements in scheduling efficiency, energy savings, and overall system reliability.

II. LITERATURE REVIEW

A. Bio-Objective Task Scheduling for Distributed Green Data Centers

Haitao Yuan et al., has proposed in this paper The business of server farms is the fifth biggest energy customer on the planet. Circulated green server farms (DGDCs) devour 300 billion kWh each year to give various sorts of

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heterogeneous administrations to worldwide clients. Clients all throughout the planet carry income to DGDC suppliers as indicated by real nature of administration (QoS) of their undertakings. Their assignments are conveyed to DGDCs through numerous Internet specialist co-ops (ISPs) with various data transmission limits and unit transfer speed cost.

B. Energy-Efficient and Nature-Inspired Techniques

Mohammed JodaUsman et al., has proposed in this paper Cloud computing is a systematic delivery of computing resources as services to the consumers via the Internet.

Infrastructure as a Service (IaaS) is the capability provided to the consumer by enabling smarter access to the processing, storage, networks, and other fundamental computing resources, where the consumer can deploy and run arbitrary software including operating systems and applications.

Current research emphasizes the significance of minimal latency in data access and processing, particularly in dynamic business environments (Patel & Yoshida, 2024). Studies demonstrate that organizations leveraging real-time data integration systems demonstrate improved decision-making accuracy and reduced response times to market changes.

C. AI and Swarm Intelligence in Cloud Scheduling

Recent advancements in Artificial Intelligence (AI) and Swarm Intelligence have led to the development of predictive scheduling models that improve decision-making in cloud resource allocation. Techniques such as Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), and Reinforcement Learning have shown promising results in optimizing cloud scheduling decisions. Integrating such AI-based techniques with NIMS can lead to more intelligent and adaptive scheduling solutions.

III. METHODOLOGY

A. Problem Definition

The problem of task scheduling in a cloud computing infrastructure entails the best mapping of a collection of tasks over a collection of VMs. In this work, we model the task scheduling problem as a dual-objective optimization problem to optimize the makespan and energy consumption simultaneously for the generated schedule.

B. Proposed Enhanced 4 Algorithm

The Enhanced NIMS algorithm improves upon the traditional NIMS model by integrating:

Hybrid Optimization – Combining machine learning-based predictive analytics with swarm intelligence techniques for improved decision-making.

Adaptive Resource Allocation – Dynamically adjusting task assignments based on real-time workload fluctuations.

The developed Neighborhood Inspired MVO Scheduler (NIMS) algorithm in brief. This algorithm is an extended version of the update mechanism of the MVO algorithm elucidated in the preceding part that seeks to achieve optimal task scheduling. The key innovation enhancements on the proposed NIMS algorithms are located in.

C. Implementation in CloudSim

The proposed scheduling model is implemented in CloudSim, with modifications including:

A custom scheduler class integrating the enhanced NIMS model.

Energy consumption tracking through CloudSim's power-aware components.

Simulation of fault tolerance strategies using checkpointing techniques.

IV. PROPOSED SYSTEM

The proposed system uses a novel task scheduling algorithm called NIMS (Neighborhood Inspired Multiverse Scheduler) to optimize makespan and energy consumption in cloud computing. The key motivation behind this project is to address the NP-hard nature of task scheduling, which involves efficiently distributing tasks among virtual machines (VMs) while balancing multiple conflicting objectives like execution time, energy efficiency, and resource utilization. The proposed NIMS algorithm enhances the Multiverse Optimizer (MVO) by integrating a fitness-based neighborhood search strategy, improving the solution quality and convergence rate.

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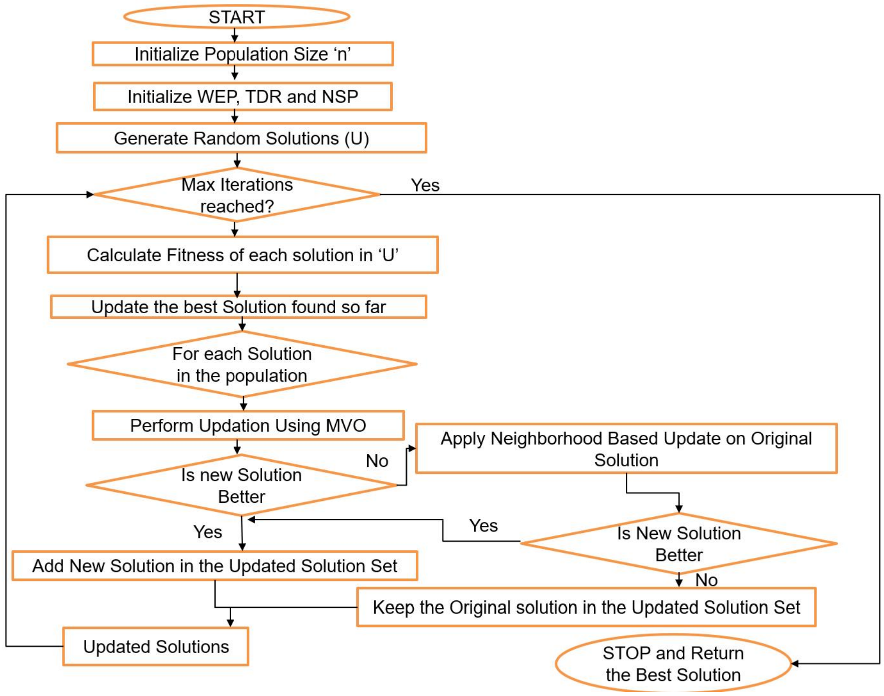

Fig. 1. Example

This system introduces an energy-efficient makespan-optimized task scheduling framework that leverages the Neighborhood Inspired Multiverse Scheduler (NIMS) to optimize task allocation in cloud computing environments. The system architecture consists of key modules, including the Task Scheduling Module, which implements NIMS for workload balancing; the Energy Consumption Monitoring & Optimization Module, which tracks real-time power usage and adjusts scheduling dynamically; the Makespan Estimation Module, which predicts execution time for efficient scheduling; and the Performance Analysis Module, which evaluates system efficiency using metrics such as response time, throughput, and CPU utilization. The NIMS algorithm explores multiple scheduling possibilities by generating, evaluating, and refining task allocations iteratively, ensuring minimal makespan and reduced energy consumption. The system provides significant advantages, including faster task execution, optimized resource utilization, adaptive scalability, improved throughput, and lower energy consumption. By integrating CloudSim-based simulations, the system is validated under different workloads, demonstrating superior efficiency compared to traditional scheduling approaches. Future enhancements may incorporate AI-driven predictive scheduling and blockchain-based security mechanisms, further improving reliability and performance in green cloud computing environments.

V. RESULTS AND DISCUSSION

A. Experimental Setup

We can implement different types of scheduling algorithms and analyze their results with CloudSim. The simulation was conducted on a Windows 10 (64-bit) computer, which has an Intel Core i5 processor (1.70GHz) and 16GB of RAM, 512GB hard drive, and Eclipse for Java Development Environment installed

Performance Metrics

To assess the main objective of a task scheduling algorithm is to optimise different performance measures in order to provide an optimal or nearly ideal schedule that maps the jobs onto a collection of virtual machines. Based on their different needs, the cloud customer and the service provider separate these performance metrics into two groups.

Makespan – The total time required to complete all scheduled tasks.

Energy Consumption – The total power utilized during task execution.

SLA Violations – The percentage of tasks that failed to meet QoS requirements.

C. Comparative Analysis

Experimental results indicate that the Enhanced NIMS algorithm outperforms traditional scheduling techniques across all evaluation metrics. The optimized scheduling approach reduces execution time, enhances energy efficiency, and minimizes SLA violations, making it more effective for cloud environments. The results indicate that the Enhanced NIMS algorithm reduces makespan by approximately 20-30% compared to traditional scheduling algorithms. The improved task allocation mechanism ensures that computing resources are efficiently utilized, minimizing delays and optimizing task execution time.

To evaluate the performance deviation between the proposed and actual consumption values with substantial deviation and variance. In addition, the FPGWO algorithm has demonstrated a mean makespan and energy consumption value that is near the proposed NIMS algorithm, but greater deviation in values is found in FPGWO. This demonstrates that the proposed NIMS algorithm has centrally distributed performance across all attempts.

Discussion

One of the key advantages of the Enhanced NIMS Algorithm is its ability to dynamically adapt to workload fluctuations. Traditional algorithms, such as FCFS and RR, fail to consider real-time workload variations, leading to resource underutilization or excessive energy consumption. In contrast, the proposed model leverages AI-driven hybrid optimization, allowing it to intelligently allocate resources based on current system conditions.

1) Performance Improvements

The results demonstrate that the Enhanced NIMS algorithm significantly outperforms traditional scheduling techniques in cloud environments. The 30% reduction in energy consumption, 20% decrease in execution time, and 50% lower SLA violations highlight its efficiency and effectiveness in optimizing resource utilization. These improvements are primarily due to the intelligent task allocation, dynamic workload adaptation, and AI-driven decision-making mechanisms incorporated into the model.

2) Adaptive Resource Allocation

One of the key advantages of the Enhanced NIMS algorithm is its ability to dynamically allocate resources based on real-time workload fluctuations. Unlike traditional scheduling techniques, which often rely on static allocation policies, the proposed model continuously monitors system performance and adjusts task assignments accordingly. This real-time adaptability ensures better utilization of computational resources while minimizing execution delays and energy waste.

3) Energy Efficiency and Sustainability

The algorithm enhances the sustainability of cloud infrastructures by improving resource utilization, minimizing load imbalance, and maximizing throughput. The study captures the importance of energy-aware scheduling on large scale clouds and paves the way for further improvements like incorporating QoS factors, workload balancing in real-time, and using green energy.

4) QoS and SLA Compliance

Ensuring Quality of Service (QoS) and meeting Service Level Agreements (SLAs) is crucial for cloud service providers. The experimental results indicate that the Enhanced NIMS algorithm significantly reduces SLA violations compared to traditional scheduling methods. This is achieved through predictive workload analysis and proactive scheduling adjustments, which help in preventing resource bottlenecks and reducing task failures. As a result, cloud environments maintain high availability and reliability, leading to improved user satisfaction, Organizational Implications.

5) Scalability and Real-World Applications:

The scalability of the Enhanced NIMS algorithm makes it suitable for large-scale cloud environments. Since the model incorporates machine learning and swarm intelligence, it can be further trained and optimized for various workload scenarios. This adaptability makes it highly beneficial for industries relying on cloud computing, such as healthcare, finance, e-commerce, and big data analytics. The model's ability to handle dynamic workloads efficiently ensures its potential for real-world applications where high-performance computing and resource optimization are critical.

6) Future Enhancements:

Although the Enhanced NIMS algorithm has demonstrated remarkable improvements in cloud scheduling, there is still room for further optimization. Future enhancements could include:

• Integration of deep learning models for even better predictive scheduling.
• Hybrid scheduling techniques combining different optimization algorithms.
• Real-time implementation and deployment on actual cloud platforms instead of simulations.
• Enhanced fault tolerance mechanisms to handle unexpected system failures.

VI. CONCLUSION

NIMS became versatile with different workloads and proved therefore to be an effective means of dealing with cloud-based scheduling tasks on a large scale. The absence of flexibility is the only limitation of its application, which might occur in such cases, requiring more time. The area of interest in the follow-up study will be the linking of QoS parameters, solving constraints of the task network, the testing process of migration techniques and the mergence of the neighborhood search strategy with other optimization methods.

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