SSRG International Journal of Electronics and Communication Engineering
ISSN: 2348-8549/ https://doi.org/10.14445/23488549/IJECE-V11I7P120

Volume 11 Issue 7, 200-207, July 2024
© 2024 Seventh Sense Research Group®

Original Article

Cloud Brain Fog Scheduler Machine Learning-Enhanced Task Allocation

Hardik Mahendrabhai Patel[1], Kirit J. Modi[2], Chirag I. Patel[3]

[1,2]*Computer Engineering, Sankalchand Patel University, Visnagar, Gujarat, India.*
[3]*Information Technology Department, Charotar University, Changa, Gujarat, India.*

[1]*Corresponding Author : profhmp9@gmail.com*

Received: 14 May 2024 Revised: 12 June 2024 Accepted: 12 July 2024 Published: 27 July 2024

Abstract *- Fog computing bridges the advantages of cloud computing with edge computing, enhancing service delivery, reducing latency, and supporting mobility. Despite facing challenges in security, service management, operation, and data handling, fog computing holds promise in sectors like agriculture, urban planning, and healthcare. This paper introduces an innovative machine learning algorithm designed to aid cloud platforms in selecting optimal scheduling strategies through multi-criteria decision-making, thereby improving performance optimization. Our primary objective is to minimize the makespan for a given set of tasks. To assess the effectiveness of our approach, we perform simulations using the CloudSim toolkit, examining the algorithm's performance across various configurations, including different numbers of Virtual Machines (VMs).*

Keywords *- Machine learning, Cloud computing, Fog computing, Real time task scheduling, Energy efficient, Distributed system.*

1. Introduction

The integration of cloud and fog computing systems has become essential in the rapidly evolving landscape of modern computing paradigms. These systems offer efficient resource utilization, reduced latency, and enhanced performance, promising to revolutionize our use of computing resources. This is particularly crucial as data continuously streams in from an increasing array of Internet of Things (IoT) devices. The Cloud-Fog architecture, characterized by distributed Fog nodes strategically placed at the network edge and centralized Cloud nodes, has emerged as a powerful solution to the challenges posed by this data influx. To fully leverage this hybrid architecture, it is critical to understand the intricacies of real-time job scheduling within this complex ecosystem.

This research study delves into the intricacies of real-time task scheduling in Cloud-Fog systems by focusing on adaptive load balancing and resource allocation. By integrating a novel machine learning approach, we aim to optimize the allocation of computing resources, ensuring timely job completion, reducing latency, and enhancing the quality of service. Our machine learning algorithm is designed to dynamically adapt to varying workloads and network conditions, making intelligent decisions to improve overall system efficiency. (QoS) provided to end users. The understanding of the varied and dynamic nature of workloads in Cloud-Fog systems sits at the core of our investigation. Intelligent, adaptable procedures are required due to the erratic application requirements and the wide range of capabilities of fog nodes and cloud data centres. Our study aims to achieve a harmonic balance between flexibility and efficiency to tackle these problems. In this study, we provide a set of novel approaches ready to take on these complex problems. As mentioned in Figure 1, The core principles of flexibility, foresight, and resources of the main Optimization is the focal point of our suggested methodologies, which are all contextualized within the context of real- time task scheduling.

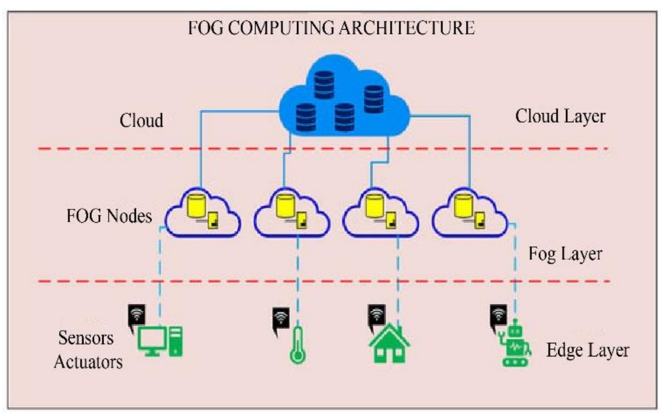

Fig. 1 Architecture of fog computing system

We delve into the intricate relationships between Cloud and Fog nodes, exploring how their dynamic interplay can be managed for optimal outcomes across various scenarios. Our contributions are centered on adaptive load-balancing algorithms that intelligently allocate computing tasks between

Cloud and Fog nodes. These algorithms utilize real-time workload estimations to optimize job distribution and maintain balanced resource utilization. Simultaneously, we introduce resource allocation techniques designed to maximize the use of available resources. These techniques consider factors such as task urgency, network conditions, and Fog node capabilities to minimize resource consumption while efficiently executing tasks. Incorporating a machine learning approach, our algorithms adapt to changing workloads and network environments, making data-driven decisions that enhance overall system efficiency. We aim to demonstrate the effectiveness of our proposed techniques in improving the performance, reliability, and flexibility of Cloud-Fog systems through extensive simulations, empirical analysis, and practical implementations. Our research addresses the evolving needs of various sectors, including healthcare, logistics, and smart cities, where rapid data processing, timely decision-making, and seamless service delivery are critical.

In the subsequent sections of this research, we explore the theoretical foundations of our adaptive load-balancing and resource-allocation approaches. We present the results of our comprehensive evaluations, uncover the complexities of their real-world implementations, and provide insights into the broader implications of our work. Through this detailed investigation, we aspire to make significant advancements in the development of Cloud-Fog systems and their crucial role in enabling real-time, data-driven applications across multiple industries.

2. Related Work

In the paper [1], a comprehensive review of fog computing is presented, covering its foundational principles, key issues, and challenges. The authors delve into the unique characteristics of fog computing, such as its proximity to edge devices and its role in enhancing the efficiency of data processing. Moreover, the authors discuss the challenges that fog computing faces, including resource management, security, and scalability. A significant contribution of this work lies in its exploration of the potential applications of fog computing across various domains, including healthcare, transportation, and smart cities.

This paper serves as a foundational resource for researchers and professionals interested in fog computing. It closely aligns with works like “Genetic-based Optimization in Fog Computing” and “Green Fog Planning for Optimal Internet-of-Thing Task Scheduling,” which also delve into the technical aspects and optimization techniques in fog computing.

Author Proposed [2], a scalable simulator designed explicitly for cloud, fog, and edge computing platforms, with a specific focus on mobility support, is presented. The simulator addresses the pressing need for performance evaluation and resource allocation in dynamic computing environments. It provides a valuable tool for researchers and practitioners to simulate and analyze the behaviour of cloud, fog, and edge systems under various conditions. Mobility support, a key aspect of this work, is crucial for applications that require real-time data processing and decision-making as devices move. This paper is particularly relevant to works that discuss fog computing at a foundational level and those that address resource management in the Industrial Internet of Things (IIoT). In [3], the critical domain of security within the context of the Industrial Internet of Things (IIoT) is explored. The focus is on resource management in the context of smart manufacturing, where resource allocation and data transmission require robust security measures. The authors propose an IoT framework that emphasizes secure communication and efficient resource utilization. This work contributes significantly to the growing body of research aimed at safeguarding IIoT ecosystems. It shares thematic overlaps with papers discussing big data optimization frameworks and task scheduling algorithms, as these aspects are intertwined in the pursuit of efficient resource management.

The paper [4] provides a comprehensive examination of the current landscape of integrating Artificial Intelligence (AI) into edge and fog computing environments. The paper discusses emerging trends and challenges in harnessing AI to enhance the capabilities of edge and fog computing. It emphasizes the potential of AI to optimize decision-making, enhance data analytics, and improve resource management in these decentralized computing paradigms. Additionally, the paper outlines key research directions, providing valuable insights for researchers and practitioners interested in the convergence of AI and edge/fog computing. This work is especially relevant to those researching genetic-based optimization methods in fog computing and foundational reviews on fog computing, as it offers a forward-looking perspective on the field.

In the paper [5], a significant focus is placed on characterizing the task response time in fog-enabled Internet of Things (IoT) networks. The study emphasizes how fog computing can enhance the timeliness and efficiency of task execution in IoT networks. This focus is particularly relevant given the growing importance of real-time data processing and decision-making in IoT applications.In our research, we explore how the dynamic interplay of Cloud and Fog nodes can be controlled to achieve optimal outcomes in various scenarios. Our contributions are fundamentally based on adaptive load-balancing algorithms enhanced with machine learning, allowing for the dynamic allocation of computing jobs between Cloud and Fog nodes. These algorithms use real-time workload estimations to optimize job distribution and maintain balanced resource utilization. At the same time, we present resource allocation techniques that aim to maximize the use of existing resources. These techniques consider factors such as task urgency, network conditions, and Fog node capabilities to minimize resource consumption. By incorporating machine learning approaches, our algorithms adapt to changing workloads and network environments, making intelligent, data-driven decisions to improve system efficiency. Our primary objective is to allocate computing resources as efficiently as possible while ensuring timely job completion, reducing latency, and enhancing the quality of service. We aim to demonstrate the effectiveness of our proposed techniques in improving the performance, reliability, and flexibility of Cloud-Fog systems through extensive simulations, empirical analysis, and practical implementations. This research aligns with the evolving demands of various sectors, including healthcare, logistics, smart cities, and more, where quick data processing, prompt decision-making, and seamless service delivery are absolute necessities. In the subsequent sections of our paper, we explore the theoretical underpinnings of our adaptive load-balancing and resource allocation approaches. We present the findings of our comprehensive assessments, uncover the complexities of their real-world implementations, and provide insights into the broader implications of our work. Through this thorough investigation, we aim to significantly advance the development of Cloud-Fog systems and their essential role in enabling real-time, data-driven applications across a variety of sectors.

Paper [6] introduces a novel task scheduling algorithm inspired by the Density-Based Spatial Clustering of Applications with Noise (DBSCAN) method. Motivated by the need to optimize resource allocation in cloud infrastructure environments, the authors propose an algorithm that leverages DBSCAN principles to enhance task scheduling. This approach improves resource utilization and performance, making it a valuable addition to cloud computing and resource management literature. This work is particularly relevant to secure frameworks in the Industrial Internet of Things (IIoT) and genetic-based optimization techniques, as these areas intersect inefficient resource allocation within distributed computing environments. In article [7], the author offers a detailed taxonomy of challenges and future research directions in distributed application execution in fog computing. This paper provides a comprehensive guide for researchers interested in this specialized area. It delves into the complexities of distributing applications across fog computing nodes, highlighting challenges related to load balancing, resource management, and communication protocols. Addressing these challenges is essential to unlock the full potential of fog computing in various applications. This paper is closely related to works focusing on task response time in fog-enabled IoT networks, as both explore performance aspects of fog computing in distributed environments. The paper [8] focuses on utilizing genetic algorithms for optimization in fog computing. The authors review current trends and identify gaps where further research is needed. Genetic-based optimization techniques are noted for their ability to adapt to complex and dynamic fog computing environments. This paper serves as an extension to foundational reviews on fog computing, offering a specialized perspective on optimization methods. It is particularly relevant to AI-augmented solutions in fog and edge computing, complementing these efforts by providing a detailed exploration of genetic-based optimization strategies. Paper [9] introduces a green computing perspective to fog computing, focusing on green fog planning for optimal task scheduling in IoT environments. The authors advocate for energy-efficient fog computing, emphasizing the need to reduce energy consumption while maintaining optimal performance. Green computing is a critical aspect of sustainability, and this work contributes to the discourse by addressing the energy implications of fog computing. This paper is closely aligned with comprehensive reviews on fog computing and research focusing on genetic-based optimization techniques, as energy-efficient task scheduling is integral to optimizing fog computing resources.

In the paper [10], the authors tackle the challenges associated with task offloading in fog computing environments. With the ubiquitous adoption of wireless communication technology and advancements in IoT, fog computing architecture, comprising edge, fog, and cloud layers, has emerged as a prominent paradigm. The authors propose a robust multi-objective optimization framework rooted in network calculus principles. This framework aims to enhance the decision-making process for task offloading by considering critical factors such as latency, resource utilization, and energy consumption. By doing so, the research significantly contributes to improving the performance and scalability of fog computing systems. The paper [11] introduces the Grey Wolf Optimizer (GWO) algorithm, a nature-inspired optimization technique designed to address the complex challenges of multi-objective optimization in task scheduling within cloud-fog computing environments. The GWO algorithm proves to be a valuable tool, offering a novel approach to task scheduling that considers factors such as execution time and energy consumption. By leveraging the GWO algorithm, the authors aim to foster more efficient and intelligent task scheduling in cloud-fog setups' paper [12], the authors present a pioneering multi-swarm Particle Swarm Optimization (PSO) algorithm explicitly designed for static workflow scheduling in cloud-fog environments. The core focus is on optimizing task allocation and load balancing, two critical aspects of task execution orchestration. By introducing this innovative PSO algorithm, the paper aims to streamline task scheduling processes and improve resource allocation within cloud-fog computing systems.

Research [13] explores the realm of edge computing, emphasizing priority-based task scheduling and resource allocation. The paper recognizes the pivotal role of task priorities and resource availability in shaping efficient task execution. By carefully considering these factors within edge computing environments, the authors aim to enhance system efficiency, ultimately leading to improved task execution and resource management. Paper [11] introduces a novel scheduler named RACE that prioritizes resource-aware task allocation within cloud-fog environments. The authors emphasize the importance of cost-efficiency and resource utilization in cloud-fog computing. By introducing the RACE scheduler, they seek to pave the way for more intelligent and efficient resource management, thereby optimizing task execution and resource allocation. Paper [14] explores a ground-breaking approach to fog node allocation within cloud-based IoT applications by leveraging reinforcement learning. The primary objective is to enhance the efficiency and performance of IoT applications hosted in the cloud-fog computing paradigm. By optimizing the selection of fog nodes and the execution of tasks, the research promises to elevate the overall performance of IoT applications, leading to improved user experiences and resource utilization. In the paper [15], the authors introduce an enhanced firewall algorithm tailored to address task scheduling challenges within fog computing environments. The central focus is on optimizing task allocation and resource utilization. By leveraging this improved algorithm, the research aims to define more efficient and effective strategies for task execution within fog computing setups.

Paper [10] serves as a comprehensive systematic survey of diverse task scheduling mechanisms utilized in the fog computing domain. It offers valuable insights into the state-of-the-art approaches and the intricate challenges associated with task scheduling within fog computing. As a resource, this survey provides researchers and practitioners with a deeper understanding of the evolving landscape of task scheduling in fog computing. Research [16] explores workload allocation towards an energy consumption-delay trade-off in cloud-fog computing using a multi-objective Non-Dominated Particle Swarm Optimization (NPSO) algorithm. The authors aim to strike a balance between energy consumption and task completion delay, offering a flexible approach for optimizing cloud-fog computing environments. The paper [17] delves into the increasingly critical role of virtual machine retask scheduling within cloud computing environments. The authors emphasize the growing demand for efficient resource utilization and load balancing in cloud infrastructures to maintain consistent performance. The paper explores various scheduling strategies and mechanisms, aiming to optimize the allocation of virtual machines to tasks. Furthermore, it discusses the challenges posed by dynamic workloads and fluctuating resource demands, offering insights into potential solutions to ensure robust and efficient cloud operations.

In the paper [18], the authors address the unique challenges encountered in the healthcare domain when adopting cloud-based solutions. They introduce a novel task-scheduling algorithm tailored specifically for healthcare applications hosted in the cloud. The authors emphasize optimizing both performance and resource utilization while ensuring the security and privacy of patient data. This paper delves into the intricacies of healthcare system requirements and presents a comprehensive approach to meet these demands through innovative scheduling algorithms. Paper [19] provides an extensive survey of scheduling strategies in fog computing. With the rapid integration of the Internet of Things (IoT) into various aspects of daily life, the paper underscores the need for efficient scheduling mechanisms within fog environments. These fog environments serve as intermediaries between IoT devices and cloud infrastructure, necessitating adaptive and responsive scheduling strategies. The paper reviews existing algorithms and identifies emerging trends and challenges in fog scheduling, shedding light on the evolving landscape of computing paradigms.

Work [20] introduces an innovative method to enhance the security of scheduling algorithms within fog environments, particularly in smart home applications. It recognizes the growing prevalence of IoT-based smart home systems and the complex scheduling requirements they entail. The paper dives into the intricacies of securing scheduling processes within fog environments and offers a comprehensive framework to address these challenges. It emphasizes the need to balance efficiency and security, a crucial consideration in the ever-expanding domain of smart homes. In the paper [21], the authors present the EEOA algorithm, designed to optimize both cost and energy consumption in a hybrid cloud-fog setup. This paper underlines the significance of dual optimization, given the increasing demand for performance efficiency and energy conservation in modern computing environments. It explores the challenges posed by IoT-driven applications and the trade-offs involved in cost-effective and energy-efficient task scheduling. The EEOA algorithm offers a unique approach to address these challenges, aiming to strike a balance between cost-effectiveness and energy conservation [22], and offers a comprehensive review of resource scheduling strategies within fog computing environments. It distinguishes between the cloud and fog computing models, highlighting the unique characteristics and challenges presented by fog computing. The author proposed [26] delves into the nuances of resource allocation and scheduling in fog environments, emphasizing the need for adaptive and responsive strategies. It surveys existing scheduling algorithms.

3. Proposed Work

3.1. Task Scheduling Algorithm Using ML Technique

This algorithm is designed to schedule tasks on available resources considering various constraints such as dependencies, deadlines, levels, priorities, and states. It does so by first identifying eligible resources based on these constraints and then employing Particle Swarm Optimization (PSO) to generate an optimized schedule for the task set. Here is a concise breakdown:

Step 1: Initialization: Set up tasks and their attributes (deadlines, levels, priorities, states) and obtain available resources.
Step 2: Eligible Resource Identification: Determine which resources meet specified conditions regarding dependencies, deadlines, levels, priorities, and states.
Step 3: Task Scheduling: Determine which tasks can be scheduled based on the eligible resources identified.
Step 4: Optimization: Use PSO, a metaheuristic algorithm, to optimize the scheduling of tasks based on certain objectives or constraints.

Algorithm 1 Task-Scheduling Algorithm

```
Initialize Task Set: T, D, L, P, S = initialize task sets()
R = get resources()
RT = []
for each ri in R do
    di, li, pi, si = get dependencies(ri, D, L, P, S)
    if di = 1 and li = 1 and pi = 1 and si = 1 then
        RT.append(ri)
    end if
end for
nTS = get schedulable task set(RT)
optimized_schedule = particle swarm optimization(TS)
```

In essence, the algorithm aims to efficiently allocate tasks to available resources while satisfying various constraints, ultimately optimizing the overall scheduling process.

3.2. Priority Queue Algorithm

This algorithm appears to be a prioritization and queue management process for job requests. Let us break it down into steps.

Step 1: Initialization: Initialize variables such as the total number of job request types (Job Type), the total number of emergency jobs set by the service provider (Emergency Type), and set priorities accordingly.
Step 2: Separate Jobs into Priority and Non-Priority Queues: Iterate through each job in the initial queue and determine whether it should be placed in the priority queue or the non-priority queue based on certain conditions such as priority number and job length compared to the average length.
Step 3: Divide the Priority Queue: Divide the priority queue into smaller queues to manage the priority jobs more efficiently.
Step 4: Adjust the Non-Priority Queue: Depending on the number of jobs in the priority queue compared to the non-priority queue, adjust the size of the non-priority queue accordingly to balance the workload.
Step 5: Merge the Two Queues: Merge the adjusted priority and non-priority queues into a final queue while alternating between priority and non-priority jobs, ensuring a balanced distribution.

```
# Initialize variables
JobType = "Total number of job request types"
EmergencyType = "Total number of emergency jobs set by service provider"
# Set priorities
for I in range(JobType):
for j in range(EmergencyType):
    if EmergencyType == JobType:
        priority_number = 1
    else:
        priority_number = 0
JobNumber = "Total number of jobs in the initial queue"
priority_queue = []
non_priority_queue = []
Separate jobs into priority and non-priority queues
for i in range(JobNumber):
if priority_number == 1 and JobLength < AverageLength:
    priority_queue.append(job)
else:
    non_priority_queue.append(job)
PriorityCount = 0
NewPriorityQueue = []
# Divide the priority queue
for i in range(len(priority_queue) // n):
    NewPriorityQueue.append(priority_queue[i])
    PriorityCount = len(priority_queue) // n
NonPriorityCount = 1
# Adjust the non-priority queue based on the number of jobs in  the priority queue
if len(non_priority_queue) > 2 * len(priority_queue):
non_priority_queue =  non_priority_queue[:len(non_priority_queue) // (2 * n)]
NewNonPriorityQueue = []
for i in range(len(non_priority_queue)):
    NewNonPriorityQueue.append(non_priority_queue[i])
    NonPriorityCount = len(non_priority_queue) // (2 * n)
    for i in range(len(non_priority_queue)):
    NewNonPriorityQueue.append(non_priority_queue[i])
    NonPriorityCount = len(non_priority_queue) // (2 * n)
```

4. Fog Computing and Machine Learning: Characteristics and Synergies

The existing literature consistently underscores the defining attributes of fog computing, stressing its close proximity to edge devices and its pivotal role in augmenting data processing efficiency. Positioned near IoT devices, fog nodes diminish latency and furnish real-time responsiveness, a critical facet in situations necessitating swift data processing and decision-making, such as in smart cities and industrial contexts. The diverse array of potential applications spanning healthcare, transportation, and smart cities further accentuates the relevance of fog computing in meeting the evolving demands of these sectors. Concerns regarding energy efficiency in fog computing are gaining traction, as evidenced by the study [16], which introduces a green computing dimension to the field. By focusing on energy-efficient fog planning for IoT task scheduling, the research addresses the imperative to curtail energy consumption while upholding performance standards. Green computing principles align with sustainability objectives and constitute an indispensable component of the enduring viability of fog computing systems. In summary, the literature review illuminates fog computing as a burgeoning paradigm with vast potential for tackling the exigencies of real-time data processing and decision-making. Key focal points in the field encompass adaptive load balancing, resource allocation, mobility support, optimization methodologies, and green computing. The infusion of AI and the exploration of diverse use cases across industries underscore the versatility of fog computing. Future research endeavors in this sphere should persist in advancing these concepts, catering to the evolving requisites of IoT applications and industries reliant on real-time data processing and analysis.

5. Simulation Results

In this section, we have compared the results between early and proposed algorithm graphs.

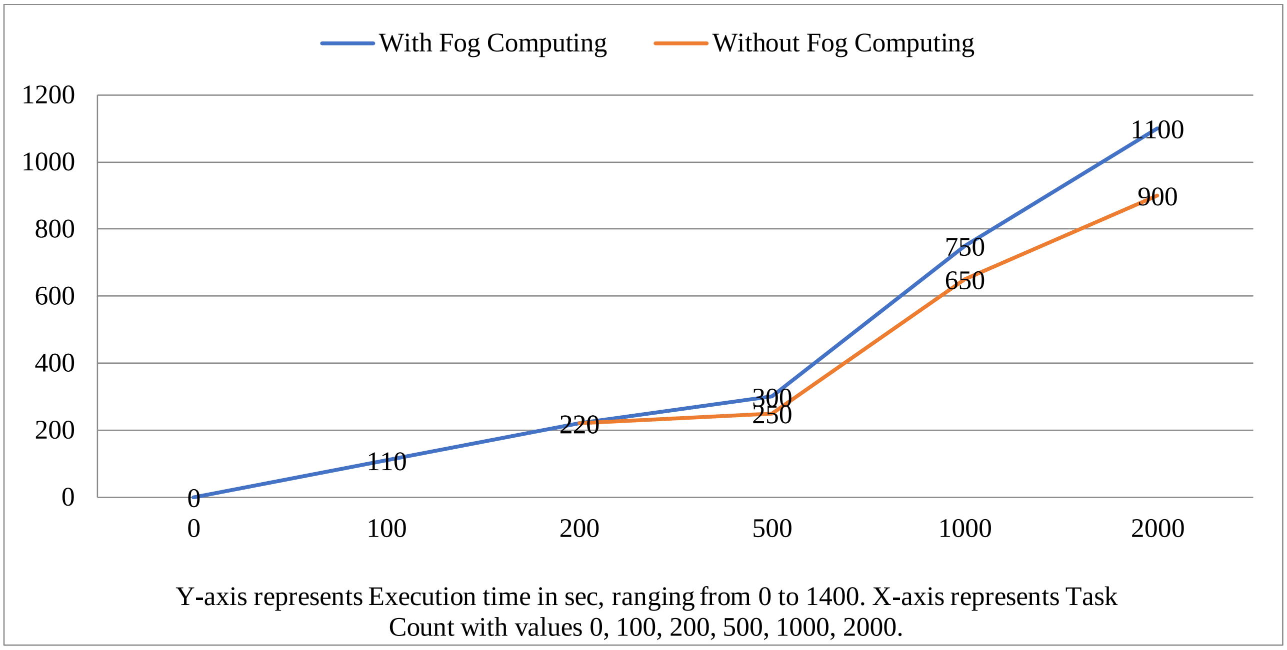

Fig. 2 Compression for execution time with fog and without fog node

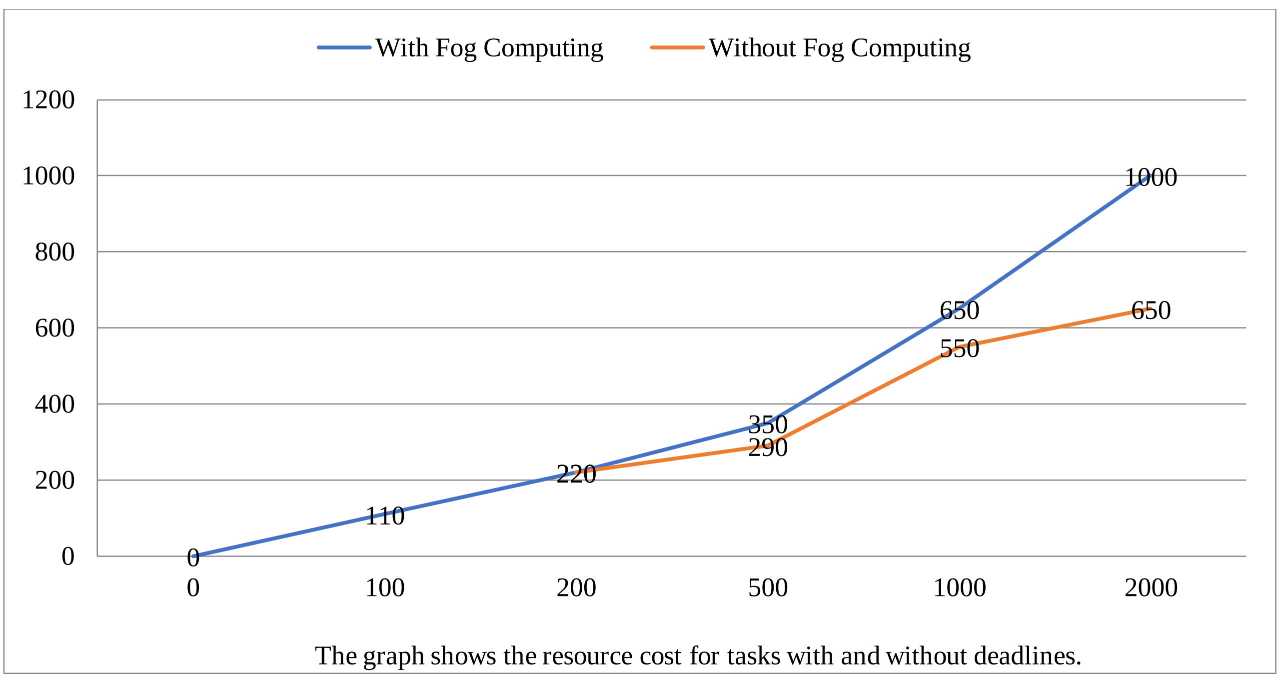

Fig. 3 Resource cost for tasks with and without deadline

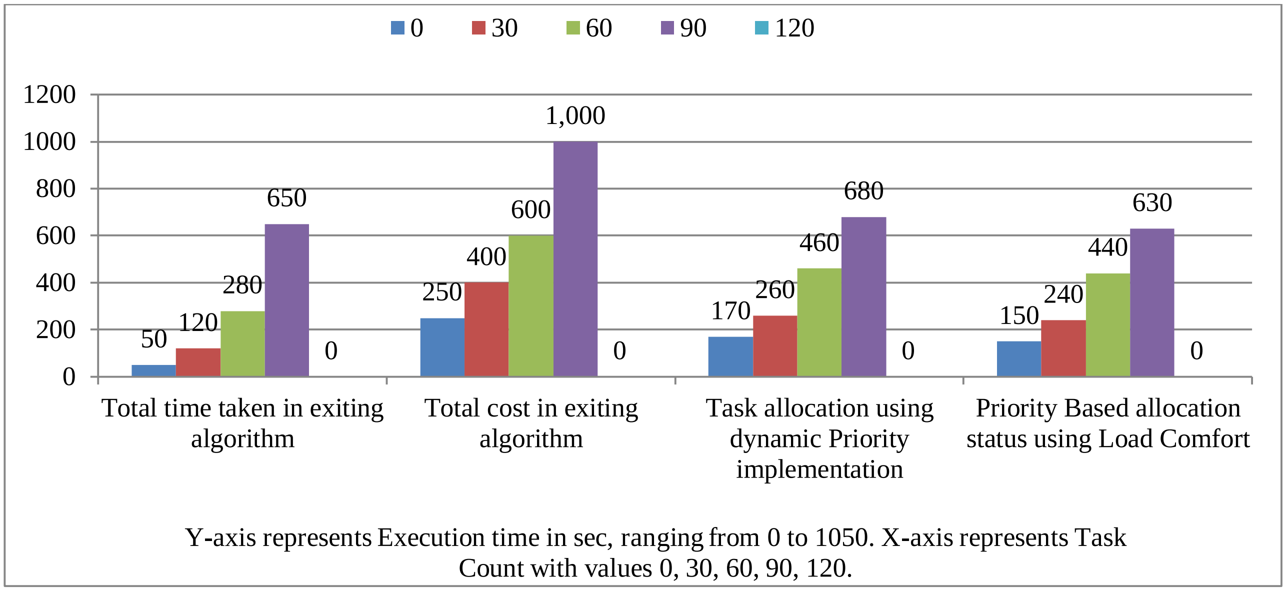

Fig. 4 Compression between execution time, cost, load comfort

6. Conclusion

In this analysis, we delve into how fog computing tackles contemporary hurdles in data processing, latency mitigation, and application distribution. Positioned closely to edge devices, fog computing offers advantages in sectors such as healthcare, logistics, and smart cities. Effective resource allocation is vital, particularly within the Industrial Internet of Things (IIoT), where managing resources while prioritizing security is critical. Dynamic load balancing algorithms optimize interactions between the cloud and fog layers, decreasing latency and boosting Quality of Service (QoS). The support for mobility is indispensable for IoT and edge devices in motion, necessitating instantaneous data processing. Optimization methodologies, including genetic-based approaches and AI, enhance decision-making, data analysis, and resource management. Embracing green computing principles through energy-efficient fog planning aligns with sustainability objectives. In essence, fog computing is revolutionizing computing paradigms, empowering real-time, data-driven applications across sectors via dynamic load balancing, resource allocation, mobility support, optimization, and green computing.

References

[1] Resul Das, and Muhammad Muhammad Inuwa, “A Review on Fog Computing: Issues, Characteristics, Challenges, and Potential Applications,” *Telematics and Informatics Reports*, vol. 10, pp. 1-20, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[2] Shashank Swarup, Elhadi M. Shakshuki, and Ansar Yasar, “Energy Efficient Task Scheduling in Fog Environment Using Deep Reinforcement Learning Approach,” *Procedia Computer Science*, vol. 191, pp. 65-75, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[3] Biji Nair, and S. Mary Saira Bhanu, “Task Scheduling in Fog Node within the Tactical Cloud,” *Defence Science Journal*, vol. 72, no. 1, pp. 49-55, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[4] Sundas Iftikhar et al., “HunterPlus: AI Based Energy-Efficient Task Scheduling for Cloud–Fog Computing Environments,” *Internet of Things*, vol. 21, pp. 1-17, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[5] S. Benila, and N. Usha Bhanu, “Fog Managed Data Model for IoT Based Healthcare Systems,” *Journal of Internet Technology*, vol. 23, no. 2, pp. 217-226, 2022. [Google Scholar] [Publisher Link]

[6] A.S. Abohamama, Amir El-Ghamry, and Eslam Hamouda, “Real-Time Task Scheduling Algorithm for IoT-Based Applications in the Cloud–Fog Environment,” *Journal of Network and Systems Management*, vol. 30, pp. 1-35, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[7] Dk. Siti Nur Khadhijah Pg. Ali Kumar et al., “Green Demand Aware Fog Computing: A Prediction-Based Dynamic Resource Provisioning Approach,” *Electronics*, vol. 11, no. 4, pp. 1-23, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[8] Husam Suleiman, “A Cost-Aware Framework for QoS-Based and Energy-Efficient Scheduling in Cloud–Fog Computing,” *Future Internet*, vol. 14, no. 11, pp. 1-21, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[9] Mohamed Abdel-Basset et al., “Task Scheduling Approach in Cloud Computing Environment Using Hybrid Differential Evolution,” *Mathematics*, vol. 10, no. 21, pp. 1-26, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[10] David Perez Abreu et al., "A Comparative Analysis of Simulators for the Cloud to Fog Continuum," *Simulation Modelling Practice and Theory*, vol. 101, pp. 1-27, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[11] V. Sindhu, M. Prakash, and P. Mohan Kumar, "Energy-Efficient Task Scheduling and Resource Allocation for Improving the Performance of a Cloud–Fog Environment," *Symmetry*, vol. 14, no. 11, pp. 1-16, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[12] Kholoud Alatoun et al., "A Novel Low-Latency and Energy-Efficient Task Scheduling Framework for Internet of Medical Things in an Edge Fog Cloud System," *Sensors*, vol. 22, no. 14, pp. 1-36, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[13] Sanna Mehraj Kak, Parul Agarwal, and M. Afshar Alam, "Task Scheduling Techniques for Energy Efficiency in the Cloud," *EAI Endorsed Transactions on Energy Web*, vol. 9, no. 39, pp. 1-6, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[14] Ranumayee Sing et al., "EMCS: An Energy-Efficient Makespan Cost-Aware Scheduling Algorithm Using Evolutionary Learning Approach for Cloud-Fog-Based IoT Applications," *Sustainability*, vol. 14, no. 22, pp. 1-25, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[15] Zhong Zong, "An Improvement of Task Scheduling Algorithms for Green Cloud Computing," *The 15th International Conference on Computer Science & Education (ICCSE)*, Delft, Netherlands, pp. 654-657, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[16] Gaurav Agarwal et al., "Multiprocessor Task Scheduling Using Multi-Objective Hybrid Genetic Algorithm in Fog-Cloud Computing," *Knowledge-Based Systems*, vol. 272, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[17] Mekala Ratna Raju, and Sai Krishna Mothku, "Delay and Energy Aware Task Scheduling Mechanism for Fog-Enabled IoT Applications: A Reinforcement Learning Approach," *Computer Networks*, vol. 224, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[18] Shinu M. Rajagopal, M. Supriya, and Rajkumar Buyya, "FedSDM: Federated Learning Based Smart Decision Making Module for ECG Data in IoT Integrated Edge–Fog–Cloud Computing Environments," *Internet of Things*, vol. 22, pp. 1-20, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[19] Elías Del-Pozo-Puñal, Félix García-Carballeira, and Diego Camarmas-Alonso, "A Scalable Simulator for Cloud, Fog and Edge Computing Platforms with Mobility Support," *Future Generation Computer Systems*, vol. 144, pp. 117-130, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[20] Fulong Xu et al., "Adaptive Scheduling Strategy of Fog Computing Tasks with Different Priority for Intelligent Production Lines," *Procedia Computer Science*, vol. 183, pp. 311-317, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[21] Hamza Baniata, Ahmad Anaqreh, and Attila Kertesz, "PF-BTS: A Privacy-Aware Fog-Enhanced Blockchain-assisted Task Scheduling," *Information Processing & Management*, vol. 58, no. 1, pp. 1-18, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[22] Muhammad Ali Jamshed et al., "Reinforcement Learning-based Allocation of Fog Nodes for Cloud-based Smart Grid," *E-Prime - Advances in Electrical Engineering, Electronics and Energy*, vol. 4, pp. 1-11, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[23] Thomas Dreibholz, and Somnath Mazumdar, "Towards a Lightweight Task Scheduling Framework for Cloud and Edge Platform," *Internet of Things*, vol. 21, pp. 1-16, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[24] Malvinder Singh Bali et al., "An Effective Technique to Schedule Priority Aware Tasks to Offload Data on Edge and Cloud Servers," *Measurement: Sensors*, vol. 26, pp. 1-9, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[25] Gaith Rjoub, and Jamal Bentahar, "Cloud Task Scheduling Based on Swarm Intelligence and Machine Learning," *2017 IEEE 5th International Conference on Future Internet of Things and Cloud (FiCloud)*, Prague, Czech Republic, pp. 272-279, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[26] Bruno Cunha et al., "Intelligent Scheduling with Reinforcement Learning," *Applied Sciences*, vol. 11, no. 8, pp. 1-22, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[27] Gomatheeshwari Balasekaran, Selvakumar Jayakumar, and Rocio Perez de Prado, "An Intelligent Task Scheduling Mechanism for Autonomous Vehicles via Deep Learning," *Energies*, vol. 14, no. 6, pp. 1-22, 2021. [CrossRef] [Google Scholar] [Publisher Link]