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An Efficient Proposed Methodology for Efficient Task Management in Fog Computing for Healthcare System Using Hybrid Meta-Heuristic Function

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Abstract: The paper introduces a new paradigm for fog computing system task management to minimize latency and enhance the overall system efficiency. The proposed methodology is for global and local task optimization and for resolving the issue of latency in communication networks employed in fog computing. The methodology utilizes the Whale Optimization Algorithm (WOA), a bio-inspired optimization algorithm based on the social behavior and hunting pattern of humpback whales. Two meta-heuristic task offloading algorithms, Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO), are also introduced inspired by this paradigm. The algorithms reduce the IoT application response time considerably and distribute tasks uniformly among fog nodes and outperform the conventional approaches such as Round Robin (RR) and throttled algorithms and other bio-inspired approaches such as Modified PSO (MPSO) and Bat Algorithm (BLA). Experimental results validate the significant reduction of latency for IoT-sensor applications when the proposed methodology is used compared to conventional algorithms. This confirms the effectiveness of the proposed method in task management optimization and enhancing the performance of fog computing systems.
Keywords: Healthcare, IoT, Cloud Computing, Fog Computing, Task Management, Swarm Intelligence.

I.INTRODUCTION

The diffusion of mobile devices has significantly enhanced the services provided by healthcare systems, particularly for patients battling critical diseases [1,2,3,4]. These mobile devices rely on various technologies and digital components, such as sensors, actuators, and cloud data storage, to function effectively. However, the integration of these components, especially with technologies like cloud computing and the Internet of Things (IoT), introduces challenges such as latency and bandwidth limitations in communication systems. Addressing these challenges necessitates the adoption of distributed computing environments, commonly referred to as fog computing, which an evolution of cloud is computing. Mobile devices in healthcare systems leverage a multitude of digital components, including sensors, actuators, and cloud data storage, to provide essential services to patients, particularly those facing critical illnesses. The integration of diverse digital components, along with technologies like cloud computing and IoT, exacerbates issues related to latency and bandwidth in communication systems [5]. These challenges can hinder the efficient transmission and processing of healthcare data, impacting the performance of healthcare systems. Fog computing emerges as a distributed computing paradigm, stemming from cloud computing, to address the latency and bandwidth constraints encountered in communication systems. By bringing computational resources closer to the data source, fog computing aims to enhance the efficiency and responsiveness of healthcare systems [6]. Fog computing leverages edge devices and edge computing nodes to collect and process vast amounts of healthcare data generated by mobile devices and sensors. This localized processing reduces latency and bandwidth consumption, thereby improving the overall performance of healthcare systems. Despite its benefits, the influx of large volumes of healthcare data collected through fog computing introduces new challenges, such as task misbalancing. Uneven distribution of computational tasks can negatively affect the performance and responsiveness of healthcare systems, necessitating innovative solutions for workload optimization [6,7,8]. The integration of digital components and technologies in healthcare systems has led to significant advancements in patient care, facilitated by mobile devices. However, challenges such as latency, bandwidth limitations, and task misbalancing persist. Fog computing emerges as a promising solution to address these challenges by enabling distributed computing environments that optimize the processing of healthcare data. Through its localized approach to data processing, fog computing enhances the efficiency and performance of healthcare systems, ultimately benefiting patients and healthcare providers alike. While fog computing offers numerous benefits for processing large datasets, one of its most significant challenges lies in efficiently scheduling operations within the network. This entails assigning tasks to appropriate fog nodes while considering various objectives, with minimizing execution time being paramount. Real-time applications demand rapid responses to prevent potential adverse effects of delays, emphasizing the importance of efficiency in task scheduling.

Customers expect prompt interactions with applications, underscoring the need for time optimization, particularly in interactive scenarios where minimizing reaction time ensures a satisfactory user experience [9,10,11]. The overall efficacy and efficiency of the system hinge on minimizing the sum of all job completion times. Reducing completion time is crucial to avoid network bottlenecks and ensure effective task processing. Processing data near its origin reduces data transportation over unsecured networks, mitigating network congestion and enhancing data privacy. However, achieving these objectives simultaneously can be challenging, as prioritizing execution time may lead to increased response times if tasks are assigned to heavily loaded fog nodes. Optimizing task scheduling within the Big Data framework necessitates a multi-objective strategy. Balancing these objectives requires careful consideration of all goals simultaneously to identify the optimal middle ground. By implementing this approach, fog computing systems can achieve efficient task scheduling while meeting diverse performance criteria and ensuring a satisfactory user experience. The development of swarm intelligence-based algorithms for task management in fog computing, including Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), and various heuristic methods, has seen significant advancements. This paper proposes a hybrid algorithm tailored for task management in fog computing environments. The algorithm focuses on effectively selecting edge devices and fog nodes for task processing, a challenge that grows more complex as the number of IoT sensor nodes and fog nodes increases exponentially. Managing this exponential growth is a critical challenge in fog computing, particularly as it falls under the category of NP-hard problems. Addressing the scalability of fog nodes and IoT sensor nodes is a central focus in this context. This paper's key contributions are outlined below:

1. This chapter introduces a novel method for fog computing task management, proposing a hybrid algorithm that can handle the impact of communication network latency utilized in fog computing.
2. Results and discussions of Enhanced integration strategies between IoT and cloud computing to improve overall system efficiency.

The following sections detail the structure of this paper. Section II provides an overview of related work in the field. Section III introduces the proposed methodology for task management. Section IV presents the experimental results and evaluates the effectiveness of the proposed approach. Section V delves into the discussion of these results. Finally, Section VI concludes the paper and outlines potential directions for future research.

II.RELATED WORK

The integration of multiple technology platforms in healthcare systems marks a significant leap forward in the medical community's ability to deliver efficient and effective services. This integration often involves combining platforms like the Internet of Things (IoT) and cloud computing, which generate vast amounts of data. However, the sheer volume and complexity of this data pose challenges in task management and load balancing within healthcare systems. Traditional methods often struggle to handle the scale and intricacies of tasks such as data collection, storage, analysis, and dissemination, leading to inefficiencies and bottlenecks. To address these challenges, researchers have proposed swarm intelligence-based algorithms, inspired by the collective behavior of natural systems like ant colonies or bird flocks. These algorithms leverage decentralized decision-making and collaboration to dynamically allocate tasks, optimize resource utilization, and adapt to changing system conditions in real-time. By enhancing task allocation and workflow management, these algorithms aim to streamline processes, reduce operational costs, and improve patient outcomes. The exploration of such innovative solutions highlights the importance of addressing the evolving needs of the medical community through advanced data management techniques. Further research and implementation of these algorithms hold promise for shaping the future of healthcare delivery and advancing the capabilities of medical systems. In recent studies, various aspects of healthcare technology have been explored. For instance, [1] discusses remote patient monitoring (RPM) systems, focusing on chronic disease monitoring and the role of artificial intelligence (AI) in enhancing these systems. Challenges such as transmission protocols, data privacy, and interoperability are also addressed. [2] Delves into fog computing's role in distributed computation for healthcare IoT applications, presenting an Intelligent Multimedia Data Segregation (IMDS) scheme that uses machine-learning to improve response times and e-healthcare services. [3] Addresses optimization problems in fog computing for the Internet of Medical Things (IoMT), proposing a low-complexity scheme for computation-offloading and resource management. [4] Introduces a fog computing architecture for healthcare, focusing on load balancing and outlining future research directions. [5] Highlights security concerns in fog computing, proposing blockchain-based solutions to address issues like fake fog nodes and rogue access points. [6] Emphasizes fog computing's role in real-time data processing for IoT applications, particularly in monitoring Corona patients, and proposes a priority-based scheduling method. [7] explores the use of X-rays in dental treatment and proposes an IoT-based architecture for improved interaction between doctors and X-ray images, utilizing fog and cloud technologies. [8] focuses on accurate and most efficient emergency decision-making in healthcare to minimize loss of life and property. [9] discusses data collection for disease diagnosis and early prediction using fog computing, addressing challenges like rising costs and data privacy. [10] suggests a multi-layer fog computing architecture for analyzing IoT device data, showing better performance in terms of delay time, network usage, and energy consumption. [11] integrates

analysis tools, monitoring devices, and imaging tools in fog computing for healthcare applications, emphasizing improved diagnosis and remote patient monitoring. [12] introduces a fog computing architecture for load balancing and scheduling, addressing total make span, energy, cost, and time models. [13] discusses the use of fog nodes for recording patient data, integrating blockchain for reliable access and control. [14] proposes a modified decoy technique to enhance the security of medical big data (MBD) in the cloud. [15] presents the Trust Enforced Computational Offloading (TEFLON) Framework for healthcare applications in fog computing, focusing on trust enforcement and safe offloading. [16] highlights the performance of fog-cloud-enabled networks in healthcare applications, focusing on reducing latency and network usage. [17] proposes a Fault-Tolerant Data Management (FTDM) scheme for healthcare IoT in fog computing, providing fault tolerance at tasks and device/node levels. [18] addresses smart healthcare design and development, integrating conventional healthcare with biosensors. [19] discusses remote monitoring for all patients 24/7, studying smart healthcare system architecture for remote patient monitoring. [20] introduces a new approach to e-health, integrating IoT, cloud computing, and fog computing, while highlighting challenges in data heterogeneity, processing, and security. [21] proposes a lightweight and safe model for monitoring health and tactical analysis in sports using fog computing and IoT-based architecture. [22] focuses on improving health through an efficient remote monitoring system using the TCVC algorithm and fog computing technology. [23] proposes an FT-architecture for fog servers in healthcare data processing, utilizing primary backup replication and dynamic load balancing techniques. [24] integrates cloud computing with IoT, exploring technical aspects of edge, fog, and cloud computing in healthcare. [25] uses an analytic network-process approach to select and rank fog computing-based IoT for health monitoring. [26] discusses the positive impact of edge computing on IoT, smart cities, and healthcare. [27] focuses on real-time monitoring and analysis of ICU patient health parameters using IoT devices and fog computing. [28] proposes a deep-learning ensemble technique for fog computing, enhancing heart-patient diagnosis. [29] introduces a semantic sensor network for enhancing sensor interoperability in e-health systems. [30] introduces fog computing in healthcare monitoring to improve quality-of-service (QoS), emphasizing reduced latency compared to cloud computing. These studies collectively provide a comprehensive overview of the application of fog computing in healthcare, spanning various aspects such as patient monitoring, data security, and system efficiency.

III. PROPOSED METHODOLOGY

This Paper introduces a novel method for fog computing task management, proposing a hybrid algorithm that can handle the impact of communication network latency utilized in fog computing The algorithm introduced in this paper is a blend of two of the most well-known meta-heuristic algorithms, the Whale Optimization Algorithm (WOA) and the Firefly Algorithm. The hybrid approach in this paper is created to leverage the strength of both the algorithms to address different tasks of the optimization problem. In the combined approach, the Firefly Algorithm is used to collect data from local devices for personal clients. Because of its ability to simulate the attraction of fireflies to each other and move towards brighter solutions, the Firefly Algorithm is more appropriate for efficient data collection from local devices in a decentralized system. In contrast, the Whale Optimization Algorithm is used to find the global optimum of tasks for cloud storage processing. With the ability to explore and exploit the search space effectively, WOA can efficiently carry out task optimization at a global level to ensure overall processing is optimized for cloud storage. Using the Firefly Algorithm to collect data locally and the Whale Optimization Algorithm to optimize tasks globally, the introduced algorithm aims to achieve a balanced solution to task management in fog computing. With optimal task selection, the combined approaches enable the elimination of latency problems in the communication network. The algorithmic process is described below.

The processing of hybrid algorithm processes the different tasks as t1,t2,…….,tn. The W is the weight factor of all task assign for the fog environments. M is the value of mates of firefly, k1 and k2 is mean of whale agents, c is constants value of agent The allocation process of task describe here.

Begin 1 define the value of task set T={ t1,t2,…….,tn} in WOA population

Set the parameters k1=0 and k2=0 and W=0

Virtual machine (VM) coupling according to given condition.

$$F(T) = \frac{(FLt - FGt)}{VmtX\ vmt}, Wi\epsilon T(t1, t2 \ldots . tn) \quad (1)$$

Here Vm is local individual VM and Gt is couple virtual machine of set of define task matrix of fog

The chosen tasks allocate as FF algorithm fireflies TF= {ft1, ft2,…….,ftn} the local optimal estimation function as

$$Gbest = \{\frac{(M_i)^{\alpha}\left(LI_i^{S_j}\right)^{\beta}}{\sum_{g \notin S_j}\ (M_g)^{\alpha}\left(LI_g^{S_j}\right)^{\beta}}\ \ if\ \ i \notin S_j \quad (2)$$

$$0 \qquad otherwise$$

Here, M is mates value of ants and LI is value of least interface of ants.

Begin 2. Exchange the local best to global best allocation
Put the local best task matrix for the processing of resource allocation.

1. Estimate task difference as relative task difference

$RT = \frac{TSI}{Wd}$ Here Tsi is interference value of ants and Wd is sum value of PSO space.

2. WOA space generates the states of allocation of resources

$$Allocation = \{ \frac{\frac{(RF)}{} - F(s)}{\frac{max}{h=1:}(WS)} \quad 0 \quad otherwise \quad if \quad T_i \in RT_j \qquad (3)$$

3. Estimate relative job distance as

$$Rd = \sum_{fd=1}^{n} \sum_{pf=1}^{m} (Ti - Tr) \qquad (4)$$

4. The value of Rd is zero resource is allocated to dedicated tasks.
5. Otherwise, the allocation process moves on to step 2

The process of algorithm described in figure2.

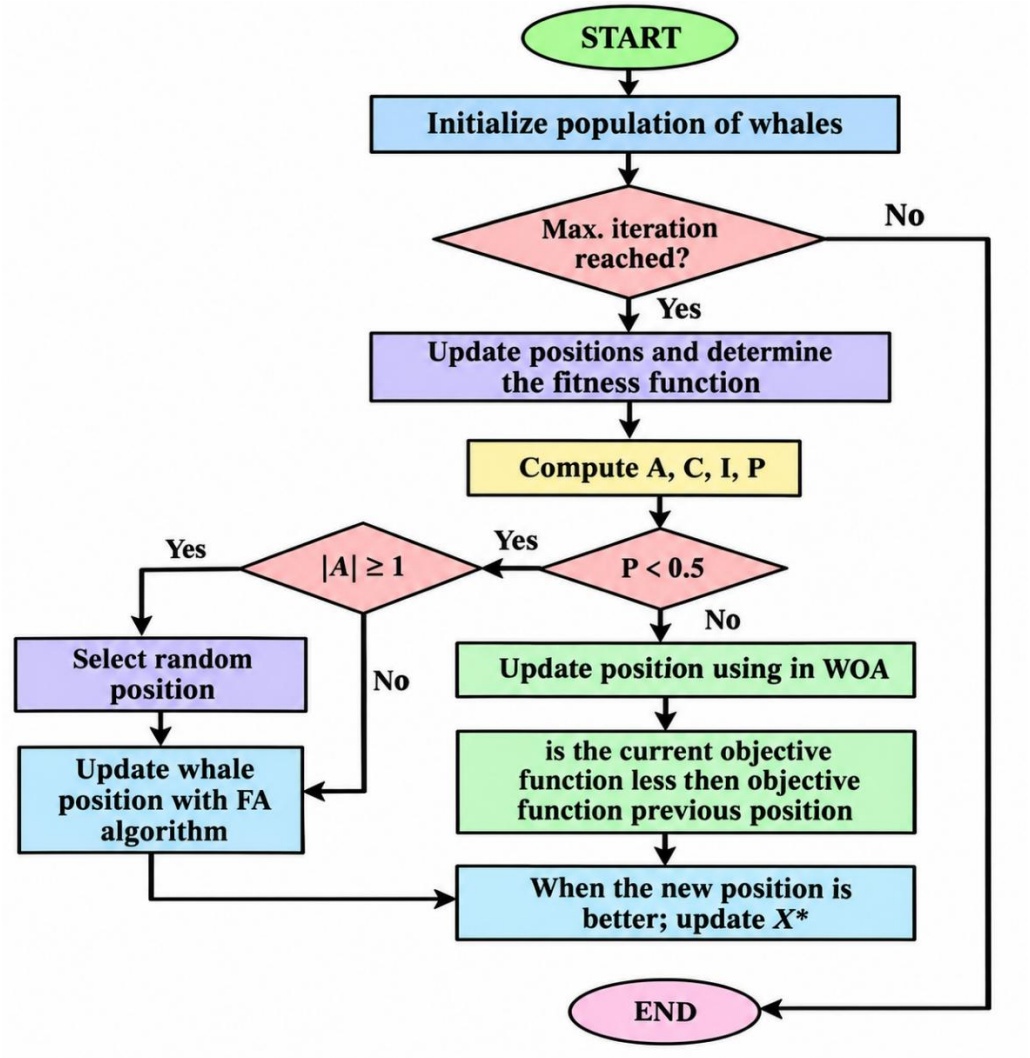


Figure 1 Flow diagram of proposed methodology of hybrid algorithm

IV.EXPERIMENTAL ANALYSIS

The proposed task management algorithm for fog computing is simulated using the Fog-simulator, an open-source fog and cloud-based IoT network simulator. Simulation of the proposed algorithm is conducted in four case scenarios. The primary goal of the proposed algorithm is to reduce latency time compared to other task management algorithms. For performance evaluation of the proposed algorithm, an IoT test-case scenario is used. The scenario has three layers: the first layer consists of a large number of sensors, e.g., various IoT sensors used

to gather data like traffic status, temperature, and surveillance video. The number of IoT sensors is between 200 and 2000, distributed randomly in 100 to 300 meters distance from fog nodes. Each sensor generates data from 250 to 1024KB depending on its own task, with a tolerance delay of 100 milliseconds. The second layer consists of 8 to 20 fog nodes used to aggregate data and process the workload generated by the sensors in the first layer. It is assumed that each fog node consists of different virtual machines used to carry out task offloading, with each virtual machine dedicated to a specific class of IoT applications. Lastly, the cloud layer consists of one data center connected with the fog layer through the Internet, used as the end destination for data processing and storage. Through this multi-layer model, the proposed algorithm attempts to maximize task management in fog computing environments, particularly reduce latency and maximize overall system efficiency[25,36,27,33]. Simulation parameter configuration describes in table 1.

Table 1. Simulation Parameters of Fog-Simulator Configurations [32,33]

Parameters	Value
Sensor nodes	250–2500
Fog Nodes	10–25
X_p	250-1024 KB
λ_i	5–50
λ_f	10–50
λ_c	25–75
μ_f	50–300
μ_c	100–400
Nants	40
Maxiter	125
P	0.1
A	0.5
Υ	5.0
Bf	50 MB/S
Bc	100 MB/S

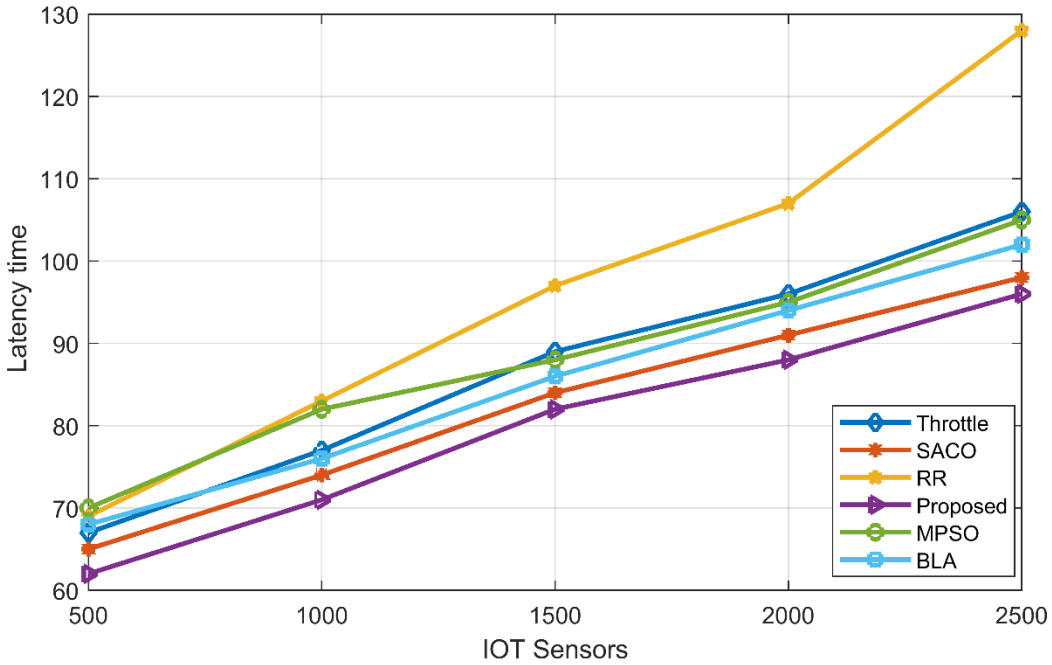


Figure 2 Performance analysis of latency time of scenario-1

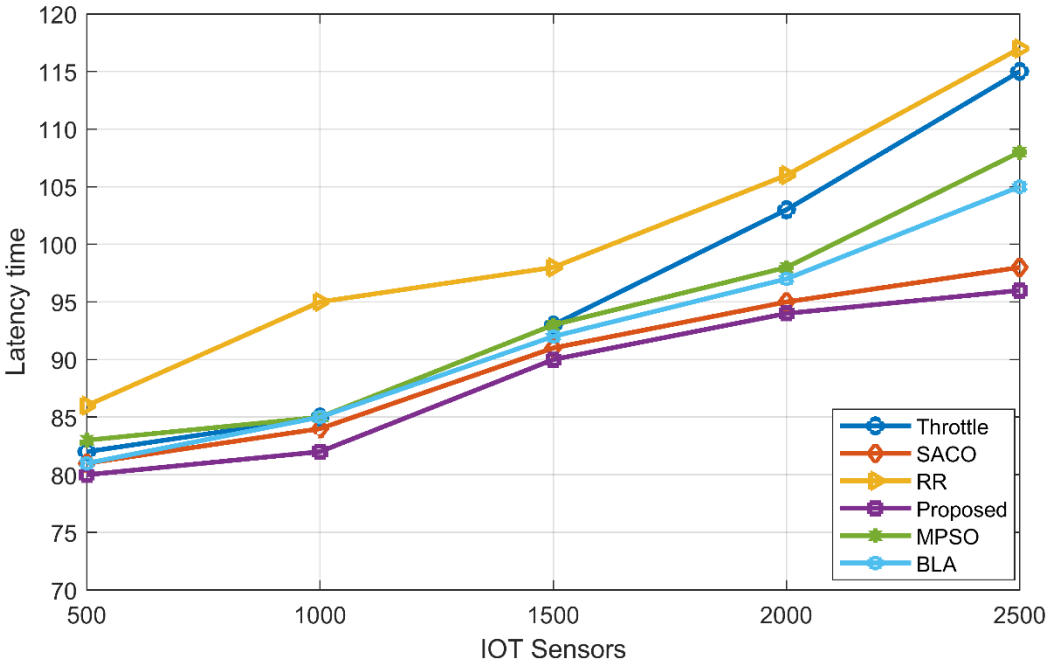


Figure 3 Performance analysis of latency time of scenario-2

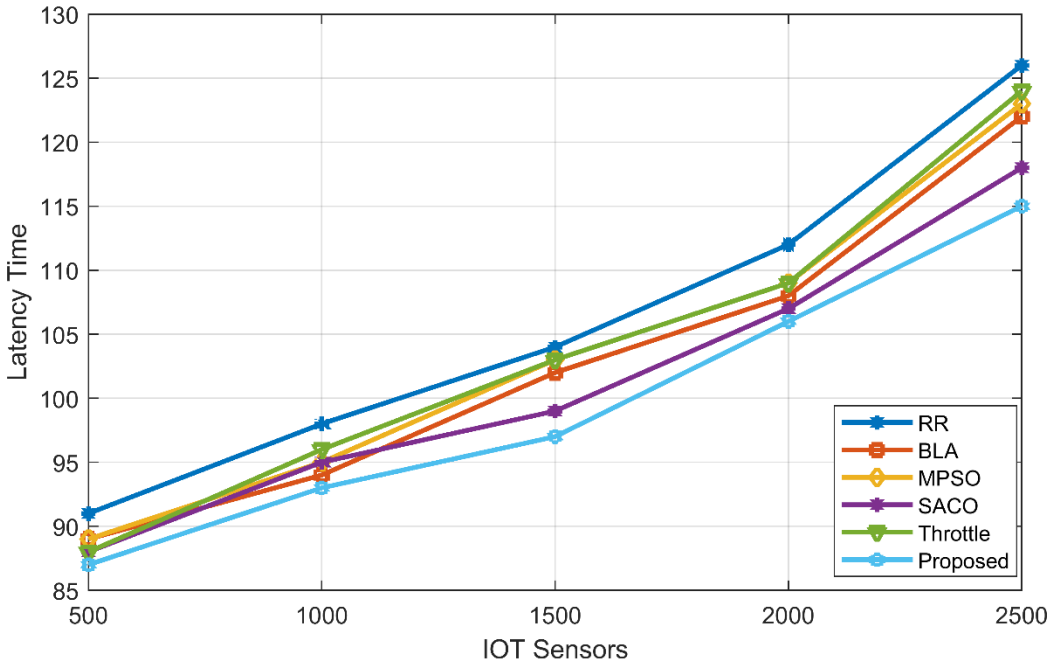


Figure 4 Performance analysis of latency time of scenario-3

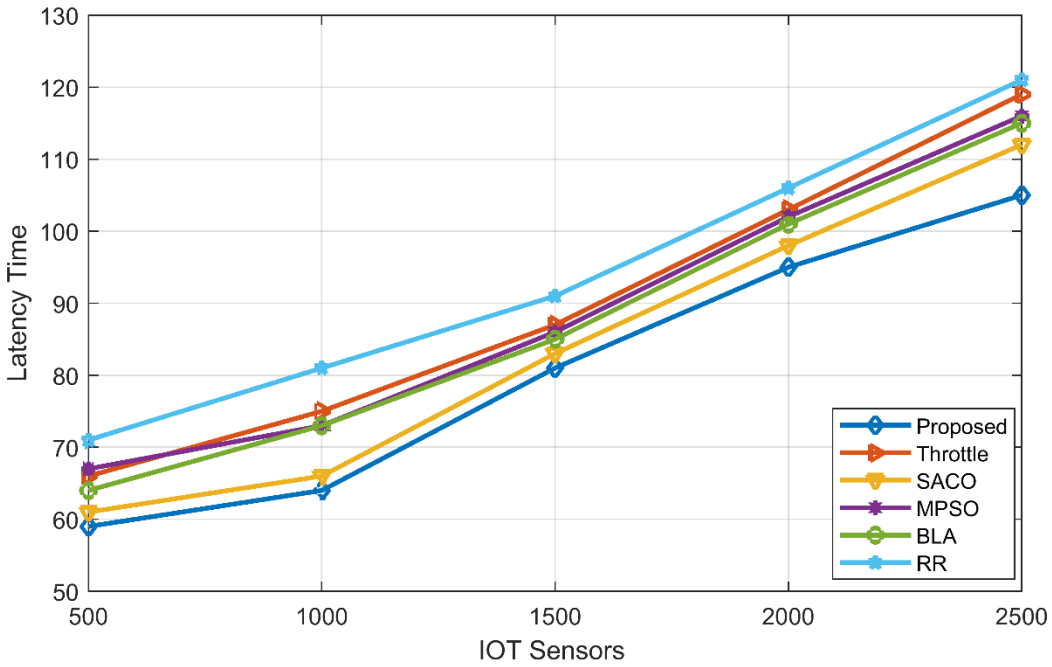


Figure 5 Performance analysis of latency time of scenario-4

V.RESULTS & DISCUSSION

The proposed algorithm is simulated under different scenarios to evaluate its performance in fog computing systems. Under scenario one, for the small number of fog nodes (FGnodes = 10), task arrival rates (ʎi), and service rates (µij) are varied. The latency time during offloading the task is compared with the RR, throttle, MPSO, and BLA algorithms. The results, as presented in Figure 3, indicate the reduction in latency time by the proposed algorithm compared to the other algorithms with an increase in the number of tasks and IoT sensors. Under scenario two, the reduction is seen in the same parameters as in scenario one but with an increase in data rates (ʎi) and the same number of fog nodes (FGnodes = 10). The reduction in latency time by the proposed algorithm is seen even with increased data rates, as presented in Figure 4. Scenario three considers the maximum

number of fog nodes (FGnodes = 25) with variable values of parameters for data rate and service rate. The reduction in latency time by the proposed algorithm is presented as the number of IoT sensors increases, as presented in Figure 5. In the next scenario, variations in the number of sensor nodes are considered, with specific classes (CL = 1, 2, 3) having varying data rates (λi) and service rates (μij). Figure 6 presents that the proposed algorithm always presents the reduction in latency time irrespective of the increase in the number of IoT sensors compared to throttle, RR algorithms, MPSO, and BLA.

VI.CONCLUSION & FUTURE WORK

This paper introduces the healthcare system scenario, in which multiple distributed IoT sensors produce enormous amounts of data for decision-making and coordinated action. Fog computing is promoted as the keystone of this scenario, providing enhanced response times for IoT applications by using its low latencies rather than depending solely on cloud processing. A formal model of IoT task offloading onto fog nodes is proposed, taking into account network latency and fog node service rates. Two nature-inspired meta-heuristic task offloading algorithms, ACO and PSO, are also developed based on this model. Experimental results confirm that the ACO task offloading algorithm decreases IoT application response times drastically and successfully offloads tasks to fog nodes. The proposed model accounts for computation and communication latencies in the fog environment. A meta-heuristic scheduler inspired by nature is also proposed to facilitate the IoT-sensor application-based task offloading model, with a processing time of 106.5 ms. Numerical results show a significant decrease in task offloading latency for IoT-sensor applications compared to traditional algorithms such as RR and throttled algorithms, as well as two bio-inspired algorithms (MPSO and BLA). Future research directions include investigating multi-objective optimization including power consumption, communication cost, and computation cost. In addition, there is a future plan to explore IoT applications including cooperation among multiple sensors, which may create dependencies among IoT tasks from different sensors.

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