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A Comprehensive IoT Framework for Elderly Health Monitoring: Identifying Key Parameters and Leveraging Fog Computing for Improved Outcomes

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ABSTRACT

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The growing aging population presents significant challenges to healthcare systems, particularly in monitoring and managing elderly health. Internet of Things (IoT) technology has emerged as a promising solution for continuous, real-time health monitoring of elderly individuals, offering potential improvements in patient outcomes and reducing healthcare burdens. This paper presents a comprehensive IoT framework designed for elderly health monitoring, which identifies key physiological and environmental parameters critical for assessing the well-being of the elderly. These parameters include heart rate, blood pressure, body temperature, motion, and ambient environmental factors. The framework leverages advanced IoT sensors, data collection, and transmission technologies to monitor these parameters continuously. Additionally, it integrates Fog Computing to enhance the real-time processing, analysis, and decision-making capabilities of the system. By processing data closer to the edge, Fog Computing minimizes latency, optimizes bandwidth usage, and ensures faster response times, which are critical for elderly care. This study explores the synergistic combination of IoT and Fog Computing to offer improved health outcomes for the elderly, ensuring timely interventions, early detection of health anomalies, and personalized care management. The proposed framework is evaluated in terms of its scalability, flexibility, and effectiveness in delivering actionable insights. Overall, this paper provides a holistic approach to elderly health monitoring, emphasizing the need for an integrated, real-time, and efficient system to address the unique healthcare challenges posed by the aging population.

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Introduction

The United Nations analysis indicates a continued growth in the Indian population for the next few decades. According to the UN's World

Population Prospects, India is projected to reach a substantial population of 1.66 billion people by the year 2050 [1]. This forecast highlights the persistent demographic expansion in the country and emphasizes the importance of addressing the associated challenges

and opportunities, particularly in areas such as infrastructure, healthcare, and education, to ensure sustainable development in the coming years. India has one of the largest populations globally, surpassed only by China. As of the latest available data, India's population is over 1.3 billion and is expected to grow more [2]. Managing and catering to the needs of such a vast population is a complex task that requires strategic planning and effective policies.

The demographic makeup of India's population reveals a distinctive distribution, with 31% representing individuals aged 0-14 years, 62% falling within the crucial working age between 15-60 years, and 7% constituting the elderly population aged 60 years. This breakdown underscores the significant presence of children and adolescents, emphasizing the critical need for substantial investments in healthcare, education, and social infrastructure to support their development. The majority in the 15-60 age group highlights a robust workforce, crucial for economic

productivity, while the 7% aged 60 and above signals the presence of an aging population, necessitating a heightened focus on healthcare and robust support systems. This demographic snapshot provides indispensable insights for policymakers, guiding them to prioritize healthcare strategies to address the unique needs of each age group, thereby fostering the overall well-being of society [2].

Upon analyzing the health reports of India, it is evident that a substantial portion of the population faces various health challenges. Specifically, 26 percent of individuals suffer from cardiovascular conditions, 2 percent from diabetes, 13 percent from respiratory issues, 7 percent from cancer, 28 percent from communicable and external diseases, 12 percent from Non Communicable Diseases (NCDs), and another 12 percent from injuries. These findings underscore the diverse health concerns within the population and emphasize the need for targeted healthcare interventions and public health strategies to address the prevalent health conditions effectively [3].

India has made significant progress in

the healthcare industry over the last few decades, resulting in increased life expectancy and reduced infant mortality. These achievements signify substantial improvements in the overall health and well-being of the population [4]. The advancements in healthcare services, interventions, and awareness have contributed to longer life spans and a decrease in infant mortality rates, showcasing the positive impact of healthcare initiatives in the country. Continued

efforts in this sector remain crucial for sustaining and further enhancing these positive health outcomes for the people of India.

However, when it comes to emergency medical care, India faces challenges. The availability and accessibility of urgent medical services may not be as robust as desired. This gap in emergency healthcare infrastructure points to an area that needs attention and improvement.

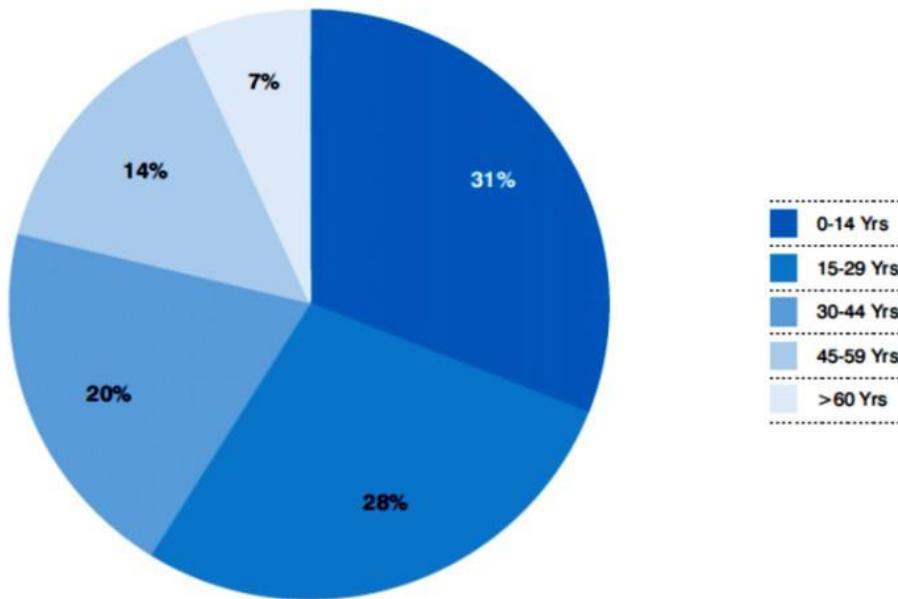


Figure 1: Distinctive Distribution of Indian Population

Indeed, the limitations in emergency medical care were notably evident during the challenging times of the COVID-19 pandemic. The surge in

cases exposed gaps in the healthcare system, particularly in terms of emergency response and critical care infrastructure. The overwhelming

demand for medical services, including oxygen support and ICU facilities, highlighted the need for reinforcing and expanding emergency healthcare capabilities. The pandemic experience emphasizes the importance of proactive measures and investments in emergency medical care to enhance the country's readiness in responding effectively to unforeseen health crises. Addressing these challenges will be crucial for building a resilient healthcare system in India.

The lack of a robust emergency response system has proven to be a critical factor that has cost millions of lives in India. During times of crisis, the absence of a well-coordinated and timely emergency response infrastructure has contributed to challenges in delivering life-saving medical care. This gap in the system has resulted in tragic consequences, underscoring the urgent need for significant improvements in India's

emergency medical services. Strengthening and expanding emergency response systems can play a vital role in preventing unnecessary loss of life during health emergencies and ensuring a more resilient healthcare setup for the future.

The golden hour is the crucial first 60 minutes after a traumatic injury or a medical emergency when swift and effective medical intervention significantly improves the chances of a positive outcome. In many cases, limitations in infrastructure, accessibility, and response times may hinder EMS from delivering timely care during this critical period. Recognizing and addressing these challenges is essential for enhancing emergency medical services and ensuring that life-saving interventions can be administered promptly, especially during the crucial initial moments of an emergency [5].

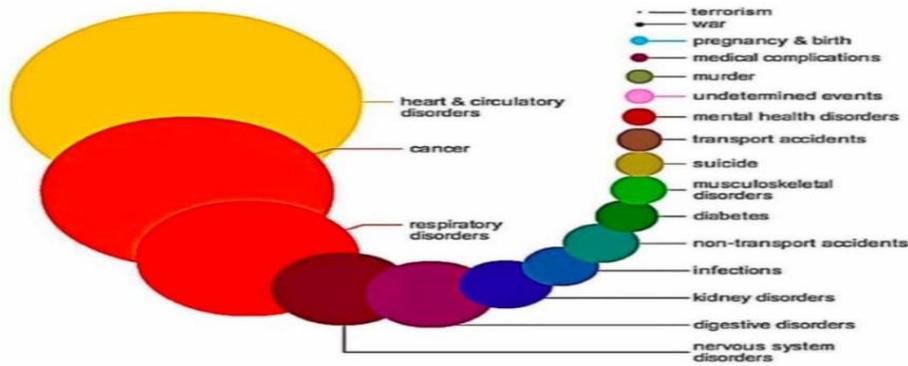


Figure 2: Leading causes of death in India

Among the EMS, Heart and cardiovascular diseases stand as the foremost global causes of death, taking the lives of approximately 17.9 million people each year, as reported by the World Health Organization (WHO) [6]. A survey conducted an analysis of the factors contributing to mortality in India. This staggering statistic underscores the significant impact of cardiovascular diseases on public health. According to the Indian Heart Healthcare Association, a noteworthy statistic reveals that 50 percent of heart attacks in India occur in individuals below the age of 50. This alarming trend indicates a concerning prevalence of heart-related issues among a relatively younger demographic. Understanding and addressing the factors contributing to heart attacks in this age group are imperative for devising effective

preventive measures and healthcare strategies. Lifestyle factors, stress, and genetic predispositions may play significant roles in this trend, highlighting the importance of promoting heart-healthy habits and early screenings to mitigate the risk of heart attacks among the younger population in India.

Indeed, the Electrocardiogram (ECG) is a crucial diagnostic tool used to detect various heart problems. It records the electrical activity of the heart over a period of time, producing a visual representation of the heart's rhythm and function. Abnormalities in the ECG waveform can indicate conditions such as arrhythmia, heart attack, and other cardiac related issues. ECGs are commonly employed in clinical settings for both routine check-ups and emergency situations, providing valuable

information that aids healthcare professionals in assessing and diagnosing heart-related problems. This non-invasive and widely used technique plays a pivotal role in the early detection and monitoring of heart conditions, contributing to effective medical interventions and improved patient outcomes. ECG is a standardized and widely accepted medical test, ensuring consistency and reliability in its application across healthcare settings. Additionally, with advancements in technology, ECG sensors can now be seamlessly integrated into wearable devices, facilitating unobtrusive and convenient health monitoring in real-world settings.

Literature review

Hossain et al. (2015) Hossain et al. proposed an IoT-based healthcare system aimed at continuous health monitoring. They emphasized the role of wearable sensors for tracking vital parameters, including heart rate and blood pressure, which are vital for elderly health management. Their work laid the groundwork for sensor-driven health monitoring systems.

Zhang et al. (2016) Zhang and colleagues presented a comprehensive survey on the application of IoT in elderly healthcare. They highlighted various sensor technologies used to monitor elderly health, focusing on the necessity of real-time data acquisition and processing. The paper emphasized that IoT can be a transformative tool for elderly care, improving both monitoring and outcomes.

Kim et al. (2017) Kim et al. developed an IoT-based smart health monitoring system tailored for elderly care. Their system incorporated multiple sensors to track vital health parameters like body temperature and pulse rate. They highlighted the challenge of real-time data processing for elderly health systems, emphasizing the need for efficient data management solutions.

Ahmad et al. (2018) Ahmad et al. introduced a comprehensive framework that integrates IoT with fog computing for elderly health monitoring. They pointed out how fog computing can alleviate latency and bandwidth issues typically associated with cloud computing by processing data closer to the data source. The integration of fog computing enabled quicker decision-making and more efficient health interventions for the elderly.

Yang et al. (2019) Yang and collaborators reviewed the role of fog computing in healthcare, particularly in elderly health monitoring. They explored the advantages of fog computing, such as low latency, enhanced data processing speed, and the ability to handle real-time health data. Their survey positioned fog computing as an essential component in the development of scalable and responsive healthcare systems for the elderly.

Gubbi et al. (2020) Gubbi et al. presented a framework for elderly health monitoring that focused on the integration of IoT with robust security measures. They stressed the importance of ensuring privacy and data integrity, especially in healthcare systems that rely on continuous data transmission from wearable devices. Their study underlined the necessity of implementing secure communication protocols to protect sensitive health data.

Sharma et al. (2021) Sharma et al. discussed an innovative approach to elderly health monitoring by integrating IoT and fog computing. Their framework emphasized the collection of key health parameters such as oxygen saturation and heart rate, with fog computing facilitating local data processing. This approach enabled faster decision-

making and reduced the load on centralized cloud systems.

Hussain et al. (2022) Hussain et al. explored the role of edge and fog computing in supporting real-time health monitoring for the elderly. Their study demonstrated how data processed at the edge/fog layer could significantly reduce the time required for data transmission and analysis, resulting in quicker responses to health issues. They also addressed challenges in system scalability and energy efficiency.

Singh et al. (2023) Singh and colleagues developed a comprehensive IoT framework for elderly health monitoring that utilized fog computing for real-time health data processing. They identified several key health parameters such as glucose levels, activity tracking, and vital signs that are essential for elderly care. Their study emphasized how fog computing enhances the monitoring process by enabling immediate action based on real-time health data.

Li et al. (2024) Li et al. investigated how integrating fog computing into IoT-based health monitoring systems can improve elderly health outcomes. Their research focused on using fog computing to reduce data transmission delays and provide more efficient healthcare responses. They

concluded that fog computing allows for faster, localized decision-making, leading to improved health interventions and outcomes for elderly patients.

The cloud is the only technology that can analyze, store, and access the IoT, depending on the deployment model. In recent years, IoT technology has gained significant interest for embedded applications [7]. IoT is a technological innovation capable of changing applications in various fields and achieving effective results. IoT devices have limited memory and processing capacities that lead to problems with performance, reliability, and security. Thus, integrating IoT with the cloud with huge storage and processing capacity will lead to better performance of real-time systems. The emergence of IoT has transformed many applications that include applications in manufacturing, gas and oil plantation, utilities, transportation, public safety, local governance, and health care. IoT technology has gained significant interest in healthcare applications because of its capability to handle the issues in healthcare systems due to the increase in the aging population and chronic diseases. Considering the extensive use of cloud computing, certain IoT applications and

healthcare services seem unable to benefit from this popular computing technique due to inherent cloud computing challenges such as latency, location awareness, and flexibility. As a result, edge/fog computing has emerged as a promising technology at the edge of the network to provide elastic services [8]. Edge and fog computing collectively enhance distributed computing by bringing processing closer to data sources, improving latency and real-time capabilities, while the key distinction lies in their scope edge computing typically involves local devices, while fog computing extends its reach to cover a broader, intermediate layer of the network infrastructure. Edge/Fog computing techniques include connecting things to analyze and respond to big data they produce in a fraction of a few seconds and sending only the required data alone to the cloud for big-data analytics and storage [9]. Latency reduction is the main advantage of edge/fog computing, and hence, it can be used in IoT healthcare applications as they expect the system to be latency-sensitive. Such applications may be provisioned with the help of the edge/fog computing paradigm along with cloud technology. The subsequent paragraphs elaborate on the

current status of resource management for IoT applications across various domains, including healthcare, mobility, and microservice implementations within the same domain. It also addresses the existing simulation tools, provides a summary of the literature review, and outlines the research objectives.

In the forthcoming sections, Section 2.2 will explore the landscape of IoT applications within edge, fog, and cloud computing. Following this, Section 2.3 will delve into the forefront of research regarding the transformative impact of IoT on healthcare within these computing environments. Subsequently, in Section 2.4, the focus will shift to investigating efficient resource management within edge, fog, and cloud systems. Section 2.5 will introduce an overview of prevailing meta- heuristic methodologies for resource management in IoT applications. Section 2.6 will survey the realm of federated learning, a collaborative learning approach, and its integration within these computing paradigms. In Section 2.7, the examination will extend to the utilization of blockchain technology alongside federated learning for enhanced data security. Additionally, Section 2.8 will analyze the current dis- course on the

implications of mobility on IoT deployments in edge, fog, and cloud environments. Section 2.9 will spotlight the exploration of microservices' role in enhancing the flexibility and scalability of IoT systems. Finally, Section 2.10 will review simulation tools as indispensable aids for modeling and understanding intricate IoT systems.

Harshit *et al.* carries out a case study on iFogSim simulation, a latency-sensitive online game and intelligent surveillance distributed camera networks [10]. An EEG sensor provides EEG signals to the online game application that is sensitive to latency and a DISPLAY actuator shows the user the current game scene. Application Model of EEG Game. The cloud-only placement (cloud computing only) and edgeward placement (fog computing and cloud computing) efficiencies were assessed by taking into account parameters such as latency, network use, and energy consumption.

Heba Nashatt *et al.* introduce an E-health and wellness monitoring application designed to promote a healthier lifestyle. This research gathers and analyzes user behaviors to make predictions and offer personalized recommendations [11]. How-

ever, there is an issue with data processing delay, particularly in critical emergency situations. Adesh Kumar *et al.* propose a real-world cloud-based smart medical system that utilizes communication networking, allowing doctors to provide online treatment to their patients. This application employs mobile devices and wireless body area networks, potentially extending to fog technology.

Research Methodology

These approaches provide a more realistic representation of the problem by considering factors like data variability and dynamic workload. Ant Colony Optimization (ACO) is inspired by the foraging behavior of ants and has been used for solving multi objective optimization problems in edge and cloud computing. It optimizes parameter settings by simulating ant behavior, allowing for the discovery of optimal trade-offs between energy and latency. Machine learning techniques, including reinforcement learning and neural networks, have been applied to optimize parameters in edge and cloud systems.

These methods can dynamically adjust parameters to achieve desired energy-latency trade-offs by learning from historical data and real-time observations.

Hybrid optimization techniques combine multiple methods to leverage and mitigate their strengths. For example, a hybrid approach might combine GA and PSO to achieve better convergence and diversity in the solution space. Game theory approaches consider multiple entities' interactions and strategic decisions in a system. Such approaches can model the interactions between edge devices and cloud resources to optimize energy-latency trade-offs while considering the behaviors of different players. Other biologically inspired optimization methods, such as Bee Colony Optimization and Firefly Algorithm, have also been explored for multi objective optimization in edge and cloud computing. These methods draw inspiration from natural phenomena to search for optimal solutions [12].

Flexibility is another advantage of the weighted sum method. It accommodates a wide range of criteria types, whether quantitative or qualitative, making it adaptable to diverse decision scenarios. The method's flexibility also enables decision makers to adjust weights based on changing circumstances or preferences, ensuring that the model remains responsive and reflective of evolving priorities. In cases where precise measurements or data may be

lacking, the weighted sum method can still be employed by relying on expert judgment to assign weights and evaluate criteria. This allows for informed decisions even in situations with limited available information.

Early detection and treatment of cardiac abnormalities can prevent more serious and costly health issues down the road. Moreover, real time ECG anomaly detection can help reduce healthcare costs and improve patient outcomes. By continuously monitoring ECG signals in real time, the system can immediately detect anomalies and alert healthcare providers, who can take action to diagnose and treat the patient. Another benefit is

that real time ECG anomaly detection can improve the accuracy of diagnoses. In some cases, anomalies may be missed or misinterpreted when relying on visual inspections alone. With automated detection, the system can analyze the ECG signals with greater precision, reducing the risk of errors and false negatives. Additionally, real time monitoring can help identify potential issues before they become acute, reducing the likelihood of hospitalizations and emergency room visits. Overall, real-time ECG anomaly detection has the potential to improve patient care, increase accuracy, and reduce healthcare costs, making it a valuable tool in healthcare.

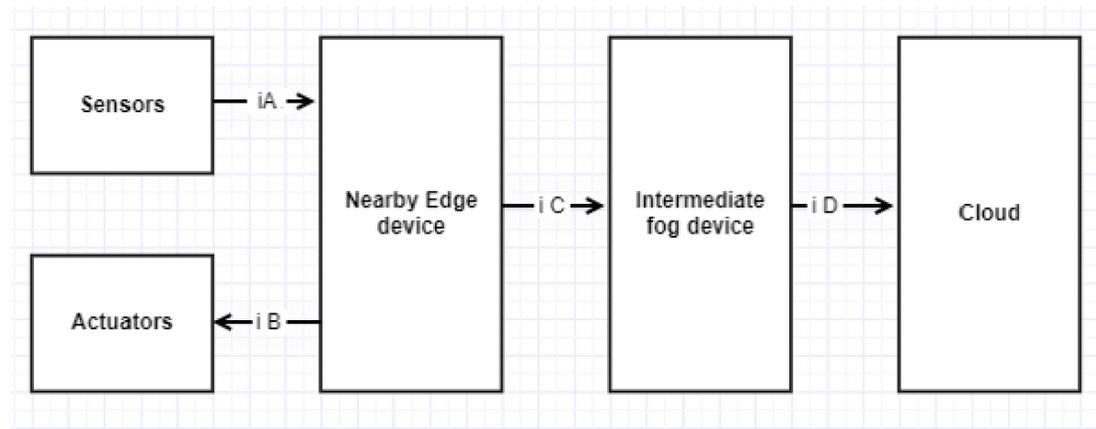


Figure 3: Flow of data in architecture based on Edge computing

The weighted sum method is a commonly used technique in various fields, including mathematics, engineering, economics, and decision making, to aggregate multiple factors or criteria into a single composite score. This method involves assigning weights to each factor based on its relative importance and then computing a weighted sum of these factors to arrive at an overall value. The weighted sum method can be categorized under the “Pareto-based Approaches” as it aims to find a set of solutions that represent the pare to front by evaluating trade-offs between different objectives. In the context of multi objective optimization for parameter optimization in edge and cloud computing, the weighted sum method can be considered as a simplified form of pareto based optimization. The weighted sum method calculates a single composite score for each solution by linearly

combining the individual objectives using predefined weights [13].

The weighted sum method offers several advantages in multi-criteria decision making and analysis. By assigning appropriate weights to individual factors, decision makers can effectively reflect the relative significance of each criterion in the decision process. This allows for a structured approach to consider multiple factors simultaneously, promoting a holistic evaluation of options. Furthermore, the weighted sum method provides a straightforward interpretation of results. The computed composite score directly represents an option’s aggregated preference or performance across various criteria. This transparency aids in communicating the rationale behind decisions to stakeholders and facilitates a clear understanding of the decision making process.

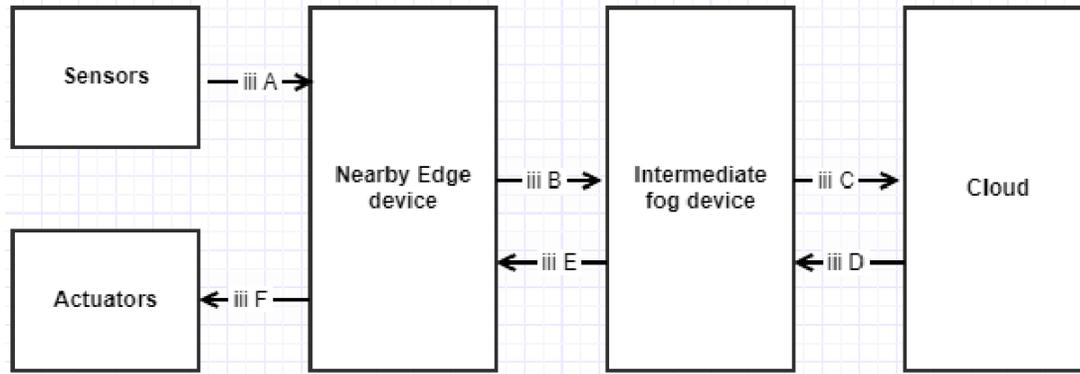


Figure 4: Flow of data in architecture based on Cloud computing

Metaheuristic-based techniques have been proven to achieve near-optimal solutions within a reasonable time for such problems [14]. Finding global optimum solutions to several complicated multi-modal design problems in engineering and industry seems to be very difficult. In such scenarios, conventional optimization techniques perform inadequately because they may become locked in local optima. The utilization of metaheuristic algorithms derived from nature is hence proposed. Due to their ability to avoid stagnation in local optima and high convergence speed in the right direction of the near-optimal solution, meta-heuristic optimization algorithms have greatly impacted many fields in recent decades. These algorithms tackle many optimization problems, especially problems in the engineering domain.

According to the source of their

inspiration, metaheuristic algorithms have been divided into four groups: human-based, swarm-based, physics-based, and evolutionary algorithms. Among these evolution-based algorithms, imitate biological evolution by using reproduction, mutation, recombination, and selection to create new offspring that are more powerful than their parents. The majority of evolutionary algorithms, such as genetic algorithms, evolution strategy, genetic programming, biogeography-based optimizer, and probability-based incremental learning, have been extensively used for different optimization issues. The swarm-based or social behavior-based algorithms include the harris hawks algorithm, particle swarm optimization, cuckoo search, whale optimization algorithm, slime mold algorithm, marine predators algorithm, grey wolf optimizer, ant colony optimization, bat algorithm, and flower pollination

algorithm.

Table 1: Configuration parameters

Parameter	Cloud	Fog	Smartphone
CPU length (MIPS)	44800	2800	2800
RAM (MB)	40000	4000	4000
Uplink BW (MB)	100	10000	10000
Downlink BW (MB)	10000	10000	10000
Busy power (J)	16*103	107.339	87.53
Idle power (J)	16*83.25	83.433	82.44

In the simulation, edge/fog devices are the computational devices in iFogSim2. Computational gadgets, on the other hand, come in various levels. On Level 3, the parent node is a cloud server. The fog nodes are connected to the cloud server via a proxy server at Level 2. Fog nodes are located closer to the user at Level 1, giving more frequent computational and storage capacities. Sensors and actuators are used in Level 0 IoT devices. The Microservice Fog Device, Actuator, and Sensor classes of iFogSim2 simulate the physical topology.

Fitness function of the proposed

Metaheuristic methods

A fitness function serves as the guiding compass for metaheuristic methods, encapsulating the problem's core objectives into a quantitative measure. By evaluating potential solutions and assigning numerical values, the fitness function allows metaheuristic algorithms to navigate the solution space effectively. Crafting an adept fitness function necessitates domain understanding, streamlined computation, and consideration of scale, smoothness, and multi objective aspects. Its pivotal role in influencing the optimization

process demands careful design, validation, and potential adaptation to dynamic scenarios, ensuring that the

algorithm converges towards optimal or near-optimal solutions efficiently [15].

Table 2: Latency and Value Table for the Proposed Approach

Latency	Value
Sensor to mobile	5 ms
Mobile to Fog	20 ms
Fog to Proxy	20 ms
Proxy to Cloud	30 ms
Fog node clusters	2 ms

The chromosome with minimum fitness value is considered as the best solution among others. The target is to minimize the fitness function. The method tries to find a solution by using crossover and mutation operations to reduce the fitness value as much as feasible. Single-point crossover has been applied in the proposed approach due to its advantages, which include enhanced genetic diversity, expedited convergence, effective exploration of the search space, and retention of favorable genetic material. By utilizing single-point crossover, the diversity of solutions can be increased, and the search for optimal solutions can be accelerated. The population selection strategy opted is the elite selection, which

is a simple method to implement. It only involves selecting a fixed number of the best individuals from the population.

Result analysis

Federated Learning is a distributed privacy-preserving machine learning paradigm in which a central server connects with various end devices, including smartphones, laptops, and security cameras, with limited computation and storage availability. Hence the clients avoid sharing the data with the server. Clients receive the server's most recent global model for each communication round, and a small percentage of clients use stochastic gradient descent (SGD) to update it throughout several rounds. The new

global model is then obtained by aggregating these updated parameters on the central server. Most of the server's cloud deployments need enormous storage and computing capacity. In the proposed system, the edge/fog devices use a methodology named FedAvg to launch the federated learning module. This selection

is based on the findings from the literature survey conducted in Section 2.6, which highlight FedAvg's effectiveness specifically for edge applications. Federated averaging is a communication-efficient approach for distributed training with multiple clients.

Table 3: Results of Modified Genetic algorithm based resource provisioning

GA	Edge	Fog	Cloud
Cloud energy (J)	2728189	2664000	2717900
Router energy (J)	174607	174718	172110
Cost (\$)	67162	81529	92414
Network use (B)	8309	9961	13907
Latency (ms)	23.4	23	247
Execution time (ms)	747	1417	1660

The results of modified FPA and modified GA for resource provisioning while taking into account directional and random mobility models for user movements with microservice placement and clustering approach and compares the proposed models for different movement patterns of a patient. Metaheuristic methods provide efficient provisioning

compared to existing systems. The reason being, meta-heuristic methods converge to optimal or sub-optimal solutions at a faster rate when compared to multi-objective optimization approaches. The energy consumption of routers are same for GA and FPA since more computations are happening in the fog layer

Table 4: Topologies for simulation for the Proposed Approach

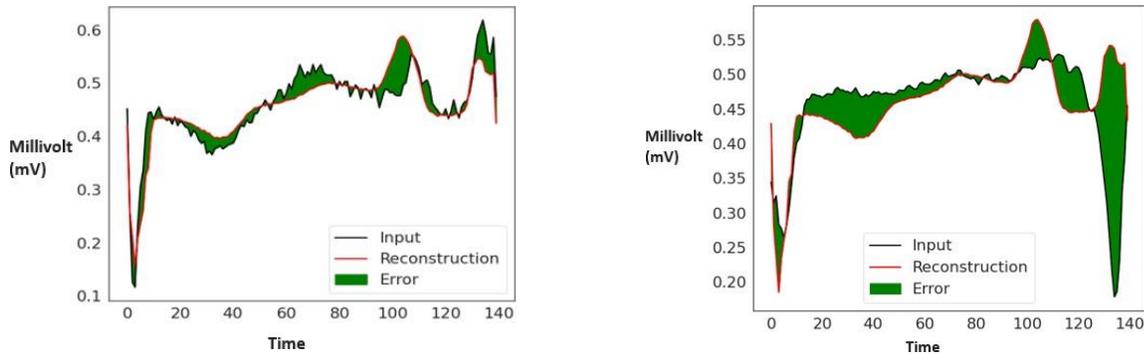
Configurations	End devices	IoT Total devices	IoT
config 1	4	24	
config 2	6	36	
config 3	8	48	
config 4	10	60	
config 5	12	72	

This analysis helps identify critical parameters that significantly influence resource allocation decisions and performance metrics, guiding optimization efforts for enhancing system efficiency and effectiveness. Moreover, sensitivity analysis facilitates risk assessment by uncovering potential vulnerabilities and uncertainties in the provisioning process, enable to develop mitigation strategies and ensure the resilience of the system in real-world scenarios. Overall, sensitivity analysis plays a crucial role in validating, optimizing, and enhancing resource provisioning mechanisms based on metaheuristic methods, contributing to the development of robust and scalable solutions. The proposed model has been tested for its sensitivity to minor variations in the input feed. The results thus obtained conclude that the small changes in the input cause little to no change in the output measurements.

The utilization of a mobility dataset allowed for the simulation of dynamic device movements, mirroring real-world scenarios where devices exhibit mobility in federated learning environments. Additionally, the integration of an ECG dataset facilitated the emulation of authentic healthcare data, providing a realistic foundation for evaluating the performance of our federated learning system. These parameters were selected based on their critical relevance to the efficiency and effectiveness of resource provisioning in federated learning for healthcare applications. Our methodical description and utilization of diverse datasets, coupled with the meticulous examination of key evaluation parameters, contribute to the robustness and applicability of our research findings within the realm of Federated Learning for healthcare applications.

This section presents the results and the observation. The model is evaluated as described in the previous sections for varying placement policies. The

reconstructed ECG helps in predicting whether the ECG is anomalous. The reconstructed one with the error beyond a threshold is considered anomalous.



Reconstructed Normal ECG (b) Reconstructed anomalous ECG

Figure 5: Reconstructed normal and anomalous ECG plot

All the above comparisons are against the placement of the FL module in the Cloud layer. While analyzing the results of placement of the FL module in the Fog layer against the Cloud layer, Cloud energy consumption decreases by 2%, network use by 31%, cost by 41%, execution time by 23%, and latency by 85%. Discussions in a consolidated manner for better understanding of the results. However, the router energy consumption is found to be more (i.e.) 2.3% and 2.4% for FL module deployment in the Edge, and Fog layers since more computations are performed in those layers. A similar comparison of

placing the FL module in Edge and Fog yields a performance increase of 0.3%, 2%, 15%, 11%, and 3% for energy consumption, network usage, cost, execution time, and latency, the number of simulations conducted and the average results for each of the parameters. In conclusion, FL module deployment in the Edge layer is superior to FL module deployment in Fog or Cloud, which adds to the fact that the integration of AI on Edge enables smart healthcare systems. This could also support real-time or advanced remote patient monitoring by immediately processing the clinical tests.

Conclusion

In conclusion, the integration of **IoT technologies** for elderly health monitoring presents a significant opportunity to enhance the quality of care and support aging populations. The identified key health parameters such as **heart rate, oxygen saturation, glucose levels, and physical activity** serve as critical indicators for continuous health monitoring. By utilizing a combination of **wearable sensors and environmental monitoring devices**, IoT frameworks can provide real-time insights into the health status of elderly individuals, ensuring timely interventions and better disease management. Moreover, the incorporation of **fog computing** into these frameworks enhances their overall efficiency. Fog computing offers several advantages over traditional cloud-based systems, such as reduced **latency, improved real-time data processing**, and alleviating bandwidth constraints. By processing health data closer to the patient or local devices, fog computing ensures faster response times, which is crucial for addressing health emergencies and providing immediate care. This localized data processing also ensures that only necessary data is transmitted to the cloud, reducing communication costs and enhancing privacy. The **synergy between**

IoT and fog computing is key to the future success of elderly health monitoring systems. The ability to perform complex data analysis at the edge, combined with real-time decision-making capabilities, leads to more personalized, adaptive, and timely healthcare interventions. Furthermore, this approach supports the **scalability** of monitoring systems, enabling them to accommodate a large number of elderly individuals without compromising performance.

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