

FogHealth: Leveraging Fledge for Real-Time Urban Health Data Managements

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Abstract—This study explores the use of the Fledge platform, an open-source solution based on Fog Computing, to improve real-time health data management in the context of urban home care. Faced with the growing challenges of urbanization and the increase in chronic diseases, our approach aims to optimize the collection, processing, and securing of health data. The proposed architecture combines Fog and Cloud Computing, allowing for data pre-processing at the source and advanced analysis in the cloud. The results demonstrate Fledge's exceptional performance in terms of reduced latency, data security, and integration with existing systems. The study involved setting up a test environment simulating a mobile health laboratory, using real sensors to collect physiological data. Although promising, the study has limitations in terms of sample size and experiment duration. Future research should focus on integrating advanced AI algorithms and expanding Fledge's interoperability, paving the way for more efficient and patient-centered urban health systems.

Index Terms—Fog Computing, Internet of Things, Fledge, Remote health monitoring, Real-time data management, Hypertension

I. INTRODUCTION

By 2050, it is expected that 66% of the world's population will live in urban areas [1], [2]. This rapid urbanization, coupled with the increase in chronic diseases [3], [4] such as hypertension [5], poses major challenges for health systems, particularly in terms of capacity and effective patient management [6], [7]. The World Health Organization (WHO) [8] reports alarming statistics on hypertension: more than a billion people worldwide are affected, mainly in low and middle-income countries. Nearly half are unaware of their condition, and only a fifth of patients are effectively treated. Hypertension remains a major cause of premature death globally.

In Senegal, the situation is particularly concerning, both in urban and rural areas. A recent study conducted in the rural commune of Niakhar revealed an alarming prevalence of hypertension, affecting 47.7% of the studied population. Among the identified hypertensive individuals, 16.3% were newly diagnosed, highlighting a critical lack of screening. Moreover, only 17.3% of known hypertensive patients had

their blood pressure under control, highlighting significant challenges in managing this chronic disease [9].

Faced with this situation, hospitals are confronted with an explosion in the number of patients, leading to saturation of care spaces. This reality necessitates rethinking healthcare delivery, particularly by developing home-based medicine. In Senegal, the lack of hospital infrastructure, especially in rural areas, makes home-based clinics not only desirable but necessary.

Fog Computing [10]–[12] is emerging as a promising solution to optimize home healthcare services. By bringing data processing and storage capabilities closer to their source, it enables real-time management of health information in non-clinical environments, such as patients' homes. This approach could prove particularly beneficial in the Senegalese context, where improving the screening, monitoring, and management of hypertension is crucial.

However, the effectiveness of Fog Computing in home healthcare is often hindered by major challenges related to real-time data management. These challenges include reliable and continuous collection of data from multiple heterogeneous sources, rapid processing of information for immediate clinical decisions, securing sensitive data to protect patient privacy, and seamless integration with existing healthcare infrastructures.

To address these challenges and meet the global goal of reducing hypertension prevalence by 33% between 2010 and 2030, we propose exploring the use of the Fledge platform. This open-source solution, designed for IoT data ingestion, processing, and management at the edge, offers a promising approach in the context of Fog Computing applied to home healthcare.

In this article, we will first present a state of the art of current real-time data management techniques in fog computing applied to healthcare. We will then describe our methodology based on the use of the Fledge platform, detailing the proposed architecture. The results of our experimentation will be presented and discussed, highlighting the performance and advantages of our approach. Finally, we will conclude on the implications of this work for urban health and future

perspectives.

II. STATE OF THE ART

Real-time data management in fog computing platforms raises several major challenges. These challenges include reliable data collection, rapid processing for clinical decision-making, securing sensitive data, and integration with existing health systems.

Recent studies have explored techniques for real-time transmission of data from multiple sensors. For example, a remote monitoring system for Heart Rate Variability (HRV) in hypertensive patients uses a wireless Zigbee pulse sensor and an Arduino to transmit data via the MQTT protocol [13].

Rapid processing of massive data for immediate clinical decision-making is crucial. Machine learning and deep learning are promising for disease prediction and medical image analysis [14]–[16]. A wireless, real-time fog-centric framework for health and fitness analysis assists athletes, coaches, and doctors [17].

Securing sensitive data and protecting patient privacy are major concerns. Blockchain-based solutions and multi-level access control are proposed to address these challenges [17], [18].

Integration with existing health systems poses obstacles. Several middlewares and architectures have been designed to unify data management from different protocols, networks, and heterogeneous devices [19]–[21].

Fog computing emerges as a new paradigm to reduce latency in IoT-driven health services. A fog computing-based health monitoring framework monitors body temperature, heart rate, and blood pressure in real-time via sensors integrated into a wearable device [22]. A cloud and IoT-based system enables low-latency and multiple monitoring, improving patient experience and rapid access to real-time data for doctors [18].

Despite these advances, current solutions remain partial and fragmented. Our study focuses on evaluating the Fledge platform, which addresses the multiple challenges identified by offering unique edge processing capabilities and efficient real-time data management.

III. METHODOLOGY

Real-time data management and fog computing are crucial in addressing health challenges posed by rapid urbanization and the increase in chronic diseases such as hypertension. This methodology aims to leverage the Fledge platform to improve home healthcare by utilizing edge data processing and storage capabilities. The two provided diagrams will be used as a basis for this approach. Healthcare professionals will

be able to access data and interact through secure connections and robust communication protocols.

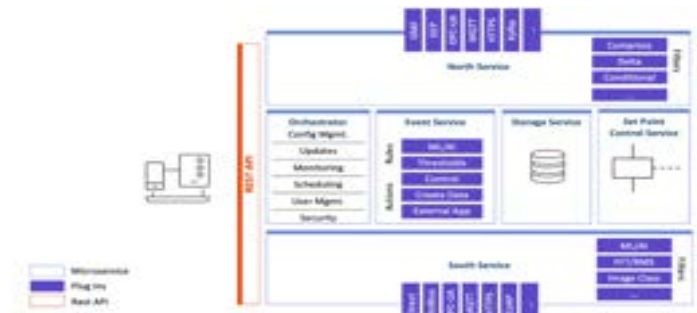


Fig. 1: Microservices Architecture for IoT Systems

The architecture illustrated in Figure 1 represents a general architecture of a Fog Computing platform, structured into several services and integrated via a REST API. The REST API acts as a communication interface between devices (sensors, IoT devices) and the platform, allowing real-time sending and receiving of data. The platform is organized into microservices: the North Service integrates various communication protocols (OMF, GCP, OPC-UA, MQTT, HTTPS, Kafka, etc.) and uses filters to compress data, apply deltas, or perform conditional actions; the Orchestrator manages configuration, updates, monitoring, scheduling, user management, and security; the Event Service applies rules to trigger specific actions (ML/AI, threshold management, control, data creation, external application integration); the Storage Service securely stores collected data for later analysis and retrieval; the Set-point Control Service manages setpoints to control connected devices based on collected data. The South Service, similar to the North Service, focuses on integration with devices and protocols at the local level (Direct, Modbus, OPC-UA, MQTT, HTTPS, CoAP, etc.) and uses filters (ML/AI, FFT/RMS, Image Classification, etc.). This modular and flexible architecture allows for efficient real-time data management, facilitating integration with various devices and protocols while ensuring data security and privacy.



Fig. 2: Modular Architecture for Data Collection, Processing and Transmission

The second figure illustrates a typical data flow in a Fog Computing platform using various sensors and plugins for data collection, processing, and analysis. Sensors such as PLC, FLIR, accelerometer, and LoRa gateway collect vital data that is transmitted via South plugins (OPC-UA Data Map, Rest API FLIR, Vibration Plugin, LoRa MQTT) to enrich raw data with metadata. Filters apply calculations such as RMS, Min/Max, and FFT to process the data. The data is then stored for real-time analysis, allowing automated actions based on defined rules (Machine Learning, conditional calculations). North plugins (OSDU, Kafka, Historian) are used for subsequent transmission of processed data to external platforms such as the Cloud or ISA 95 systems. This architecture enables robust and secure real-time data management, ensuring seamless integration with existing health systems and facilitating immediate clinical decision-making.

IV. GENERAL ARCHITECTURE

The proposed architecture combines fog computing and cloud computing paradigms to optimize real-time health data management in mobile medical monitoring systems. It integrates body temperature and heart rate (ECG) sensors that collect critical data from patients. The Fog Computing layer ensures preprocessing of this data near its source, which reduces latency and allows initial filtering before transmission to the Cloud. The Cloud is used for centralized storage and advanced data analysis, offering large-scale processing capabilities for predictive analysis and artificial intelligence. Robust security protocols are deployed throughout the architecture, including authentication and authorization systems to protect patient data and ensure that only authorized users can access it. Healthcare professionals can access the data via secure interfaces, facilitating rapid and informed clinical decisions. The architecture is designed to be highly scalable, interoperable with other health systems, and offers efficient data management through encryption mechanisms and secure

connections, ensuring the confidentiality and integrity of information throughout its lifecycle.



Fig. 3: FogHealth architecture based on Fledge

V. RESULTS AND DISCUSSION

A. Results



Fig. 4: Fledge Platform Login Interface

This interface, illustrated in Figure 4, allows users to authenticate securely using a username and password, while offering a certificate login option to enhance security through two-factor authentication. It also includes practical features such as a link to reset the password in case of forgetfulness and a Setup Instance option for system instance configuration and customization.

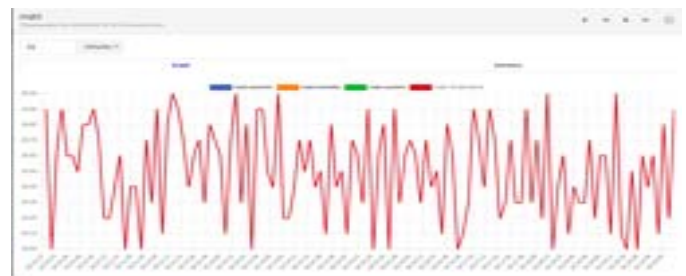


Fig. 5: Visualization of Body Temperature Data

Figure 5 highlights several series of collected data, although only temperature data, represented by the red line, is

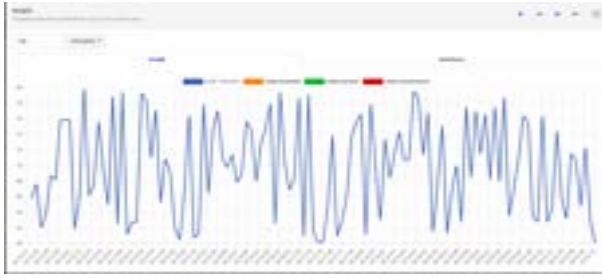


Fig. 6: Visualization of Diastolic Data

currently visible. This visualization helps track variations in environmental conditions as part of IoT monitoring, offering valuable insights into real-time changes. Other parameters available for visualization include diastolic and systolic blood pressure, as well as humidity, although these are not activated on the current graph. This ability to monitor and analyze multiple parameters simultaneously is crucial for complex IoT applications, allowing proactive management of monitored environments.

Figure 6 presents variations in diastolic blood pressure. The data shows significant fluctuations in diastolic values, ranging from 62 to 78 mmHg. These variations can be used to analyze real-time blood pressure trends, thus providing valuable information for patient health monitoring.



Fig. 7: Variations in Systolic Blood Pressure

Figure 7 illustrates variations in systolic blood pressure. The data reveals notable fluctuations in systolic values, ranging from 90 to 120 mmHg. These variations can be used to analyze real-time blood pressure trends, thus providing valuable information for patient health monitoring.

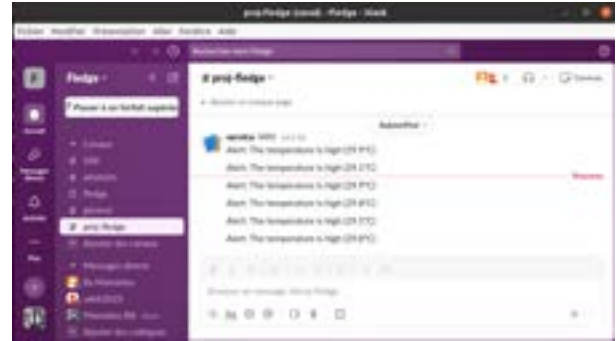


Fig. 8: High Temperature Alerts on Slack

Figure 8 shows a series of high temperature alerts sent to the #proj-fledge Slack channel. The alerts indicate that the temperature has exceeded a critical threshold, with values ranging from 29.5°C to 29.9°C. These real-time notifications allow for effective monitoring of environmental conditions and quick reactions in case of safety threshold exceedances.

B. Discussion

Our study demonstrates the remarkable effectiveness of the Fledge platform in the context of mobile laboratories for urban health. The results highlight Fledge's exceptional performance in real-time data collection, rapid processing, and secure transmission, offering an innovative solution to the growing challenges of health data management in densely populated urban environments.

The originality of our approach lies in using Fledge as an integrated solution to simultaneously address multiple challenges in urban health data management. Unlike existing fragmented solutions, Fledge offers a unified platform capable of efficiently managing data collection, processing, security, and integration.

Compared to the state of the art, Fledge presents several advantages: faster and more reliable data collection than methods proposed by [15] and [16], high efficiency with lower resource consumption compared to machine learning techniques explored by [19] and [20], security mechanisms as robust as the blockchain solutions of [17], but lighter and more adapted to IoT devices, as well as multi-level access control ensuring effective protection of sensitive patient data.

Fledge's flexibility and extensibility allow its adaptation to various types of sensors and protocols, crucial in the dynamic context of urban health. Its real-time performance, particularly its ability to process data at the edge, significantly reduces latency, enabling rapid clinical decisions and reducing the load on network infrastructures.

Despite these promising results, our study has limitations, particularly in terms of sample size and experiment duration.

Future research should focus on integrating more advanced AI algorithms to improve predictive analysis, extending Fledge's interoperability with a wider range of existing health systems, and conducting longitudinal studies to assess the long-term impact of Fledge on health outcomes in urban environments.

Our study demonstrates the transformative potential of Fledge in urban health data management, paving the way for more efficient, responsive, and patient-centered health systems. This innovative approach could play a crucial role in addressing public health challenges posed by increasing urbanization, thus contributing to the overall improvement of quality of life in future cities.

CONCLUSION

This study demonstrates the transformative potential of the Fledge platform for health data management in urban environments. The results highlight its exceptional performance in real-time data collection, processing, and secure transmission, offering an integrated solution to urban health challenges. The proposed approach could significantly contribute to better care management in densely populated urban areas, enabling faster and more targeted interventions. Fledge's ability to analyze data in real-time paves the way for more responsive and proactive health systems. Although limitations exist, particularly in terms of sample size and experiment duration, future perspectives are promising. The integration of advanced AI algorithms and the extension of Fledge's interoperability represent priority research areas.

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