Secured Public Health data Management Framework using the Internet of Things in a Smart City Environment

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ABSTRACT

The Internet of Things (IoT) is being embraced and impacts various aspects of lives. Integrating IoT technology in the healthcare sector paves the way for continuous remote monitoring of individuals' health status. The healthcare (HC) sector has traditionally produced substantial data. Due to the implementation of the IoT, this quantity has significantly increased. Ensuring proper HC storage is imperative to derive meaningful insights from the data. This study presents a public health (PH) framework that utilizes cloudlets and IoT technology. The primary objective of this PH architecture is to facilitate the retrieval of real-time data by using cloudlets. The research provides and executes an HC data management system to store vast HC data and handle consumer queries to retrieve HC information. The efficacy of the proposed model has been evaluated in terms of data transmission time, energy usage, query response time, and data packet loss. The proposed model outperforms existing PH systems by comparing the assessment findings of the proposed approach with the performance of typical PH systems.

1. Introduction

Around 75% of the population of the European Union resides in metropolitan areas. Metropolitan areas are the primary sources of energy consumption and carbon emissions. The urban setting has prioritized concerns such as pollution, noise, disease, and the dense concentration of people. An increasing amount of research indicates the beneficial and detrimental effects of the physical urban environment on healthcare (HC) and well-being [1]. Smart Cities (SC) is a novel idea encompassing various viewpoints to promote a sustainable model for urban economics, mobility, environment, living conditions, and government [2]. Due to the global population explosion and the growing number of elderly individuals, HC has become a highly prioritized sector in SC development [14]. The existing resources and staff need to align with the necessary medical facilities. The process is time-consuming and necessitates a substantial expenditure to address this gap in demand. Given the current situation, using an Internet of Things (IoT) enabled remote HC surveillance system is more efficient in terms of time, cost, and adaptability [4]. The portable device is responsible for detecting and measuring different HC indicators. It sends this data wirelessly to a remote location for additional analysis and storage [3]. The information is examined to assist clinical decision-making and provide expedited, improved patient care.

Medical data possesses three key characteristics: size, speed, and variety. The majority of this data is in an unorganized format. It is imperative to optimize public health (PH) utilization to prevent the squandering of communication and energy resources [5]. To comprehend data, it is essential to structure the data appropriately [12]. It is crucial to deliver services promptly in the PH sector. The goal is to present a PH platform that can effectively tackle the challenges above. The main objective is to create an IoT-enabled PH architecture to provide an efficient PH system for the SC scenario. This paper presents the proposal for this framework and explores the methods for managing the large amount of HC data involved. The primary contributions of this study include creating a structure and handling data inside the suggested framework to store sensed data[4]. The utilization of data aggregation approaches for PH is examined. The cloudlet layer integrates intelligence to enhance the effectiveness of remote monitoring [19].

2. Literature Review

The IoT technology's ubiquity and extensive reach have garnered significant attention from researchers over the past decade. Theodoropoulos et al. examined the essential security measures in state-of-the-art HC ecosystems and developed a secure architecture [18]. The authors comprehensively analyzed the various ways the IoT is used in HC. A highly effective HC monitoring method designed to regulate HC indicators such as blood pressure, hemoglobin, blood glucose, and abnormal cellular development for individuals who lack financial resources [15]. The survey examines RFID technology and its uses for collecting data on consumers' living surroundings [7]. The study assesses the concept based on feasibility, speed, and efficiency. The authors emphasized the significance and practical uses of the IoT in the HC industry. Cremaschi et al. introduced a semantic data architecture to store and interpret data [8]. The authors proposed a novel conceptual framework called Home HC for tracking the physiological characteristics of elderly individuals [6]. Kineber et al. examined IoT-based solutions and delved into their implementation's technological and managerial obstacles [16]. It emphasizes the three IoT classifications employed to augment consumer value for business applications [9].

The authors introduced an approach demonstrating how edge computing can verify search outcomes. The suggested technique generates verification objects for verifying the requests. Rafique et al. introduced an HC system that utilizes blockchain technology to ensure secure and privacy-preserving communication among all entities involved in a medical ecosystem [10]. SC provides a favorable setting for implementing technology to address several issues. The authors discuss applying big data and analytical techniques for processing data in a SC. They introduced a prototype that was utilized to identify a range of approaches for analyzing medical information [20]. The authors explore how HC data can enhance the efficiency of medical facilities and lower the expenses associated with these services for individuals [17]. The authors analyze the specific technological aspects of HC in SC [11]. They examine the critical applications in this domain, the level of advancement achieved, and the significant obstacles hindering its widespread adoption [13]. The article discusses the primary advantages of smart HC in this field.

Proposed IoT-based innovative PH monitoring system in SC

A SC typically features several HC facilities in various parts of the municipality, such as pathological centers and hospitals. A substantial volume of HC information is generated from these medical centers. Effectively storing all HC data is essential, as it enables clinicians to analyze ailments and facilitates the research of patients' HC case history for future reference in SC. This section examines the PH structure, considering all possible concerns, as seen in Figure 1.

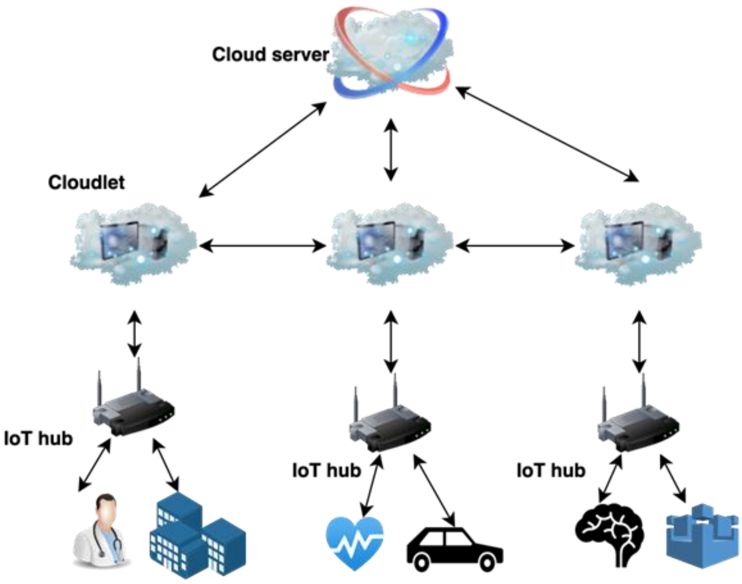


Figure 1. Architecture of the proposed system

HC centers are dispersed across different locations. Several IoT devices are employed or utilized to monitor HC in real time. A large amount of data is produced. To enhance the HC experience, sharing data between multiple centers is necessary. Handling and distributing this large amount of data in real-time poses challenges for IoT devices with limited resources. Despite the cloud's ability to facilitate advanced data processing, the restricted bandwidth and distance between the cloud and IoT resources make it challenging to promptly transmit the large amount of HC data recorded from all IoT gadgets. Processing the acquired data and making decisions is delayed. In the PH area, real-time service is crucial. To address this issue, the research proposes a framework that utilizes cloudlets. While cloudlets do not possess the same level of computational strength as clouds, they do facilitate data processing near IoT gadgets in SC. Cloudlet alleviates the communication load of transmitting information to the cloud. The suggested PH architecture consists of three layers, as described below.

1) IoT Layer: This layer comprises diverse IoT devices that monitor real-time medical conditions. The IoT devices encompass traditional medical equipment such as blood pressure monitors, thermometers, blood oxygen monitors, and monitoring, as well as intelligent gadgets like smartwatches, smart monitors, and smart scales. These IoT devices connect exclusively with a selected IoT Hub. It is the primary interface or gateway for IoT gadgets to connect with the external world. It can communicate with IoT gadgets using various access methods such as WiFi, Bluetooth, and Zigbee. IoT gadgets and Hubs must be improved in processing energy and storage resources.

2) Cloudlet Layer: This layer is added to the architecture to enhance the limitations of the IoT tier. Cloudlets are small-scale replicas of cloud infrastructure strategically positioned near IoT hubs. Cloudlets perform critical functions in local settings, such as HC centers or similar establishments. The majority of HC information is handled within this layer. Cloudlets located in various geographical places interact with each other. The HC care information is distributed across many stakeholders or consumers. This tier handles queries for diverse health-related information.

3) Cloud Layer: The central HC information database serves as a foundation for running multiple applications for analytics and processing queries. Multiple end-users, such as caregivers and HC suppliers (hospitals, ambulances), require data retrieval to deliver fast services. The cloudlets handle the queries on a local level. The cloud layer is utilized when a comprehensive examination of HC data is required to perform the query. This research aggregates and analyzes HC information across several layers of SC architecture. The proposed methodology has been partitioned into three distinct stages to enhance comprehension of the procedure.

3. Methodology

Data collection

This is the first step of the planned SMS architecture. The patients' real-time information is obtained using sensor-based gadgets such as wearables and other medical supplies during this stage. These gadgets are used to gather the physiological characteristics of the patients and additional HC information.

Data Encryption and Standardization

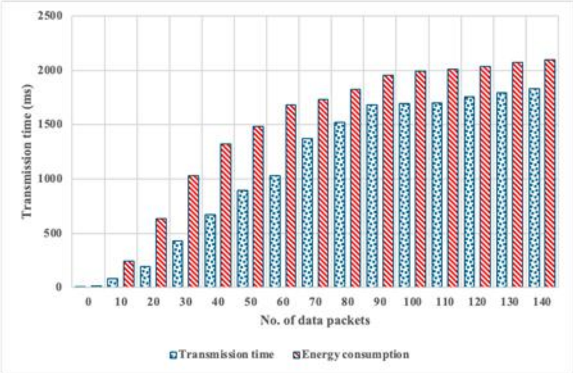
During the second phase, the information collected is encrypted and transformed into a predetermined standard structure to ensure the data's consistency, secrecy, and security. Standardizing information is essential due to the variation in data capture and storage formats across various gadgets. Information needs to be translated into a preset uniform format to ensure consistency.

Data Storage

After encrypting and standardizing the patient's records, they are transferred to the individual's pre-authenticated cloud account for preservation. This encompasses time-based, level-based, or unrestricted access. Once the expiration of the threshold value occurs, access disappears. This approach is beneficial for ensuring the coherence of the data, as well as for providing authorization and identification. Clinicians, scholars, and academics can access the secret data stored in the cloud for HC assistance and case studies upon collaborative agreements with clinics and patients in SC. During the last stage, hospitals and physicians retrieve the records in real time by connecting them to the central tracking system and asking admission to the individuals' data and knowledge.

4. Results and discussion

All IoT gadgets transmit the data to the regional IoT Hub upon capturing the HC information. Within the PH structure, most IoT Hubs are gadgets with limited resources. The research utilizing the Raspberry Pi is used to construct the IoT Hub. Each device is equipped with 8 GB of internal storage space.



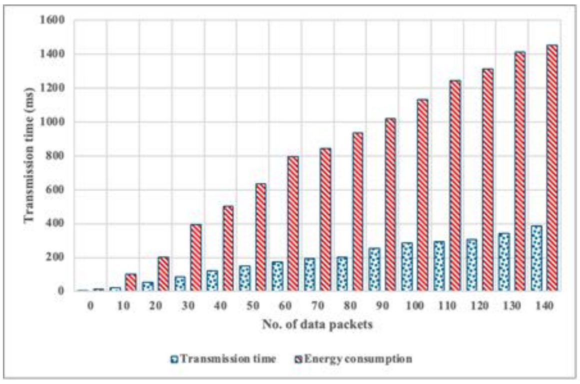
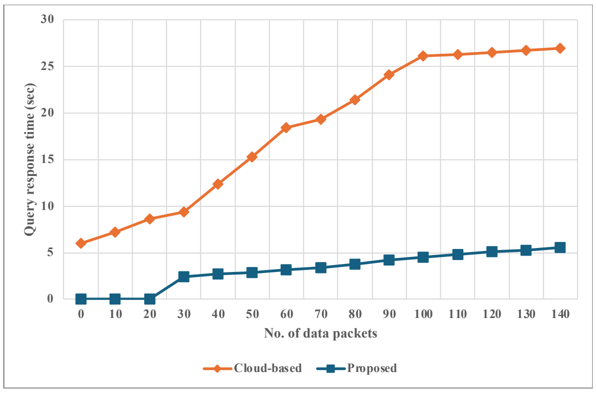


Figure 2. Transmission power analysis (a). Direct transmission (b). Indirect transmission

Figure 2(a) displays the efficiency assessment of the PH system. Research demonstrates that bandwidth usage increases when the number of unique data packets (without duplication) increases. This can result in higher latency when transmitting data packets from an IoT Hub to the higher levels of a PH system. Despite the inherent unreliability of network connections for obtaining cloud services at the edge, the delay interval for data transmission increased.

By examining Figure 2(b), increasing the number of distinct data packets leads to a progressive rise in data transmission time. This time remains lower compared to a standard cloud-based approach. The research discovered that the proximity of the cloudlet nodes to the IoT Hub nodes results in a substantial reduction in communication delay between them. The energy-consuming rate of IoT Hub nodes has been decreased, extending their longevity.



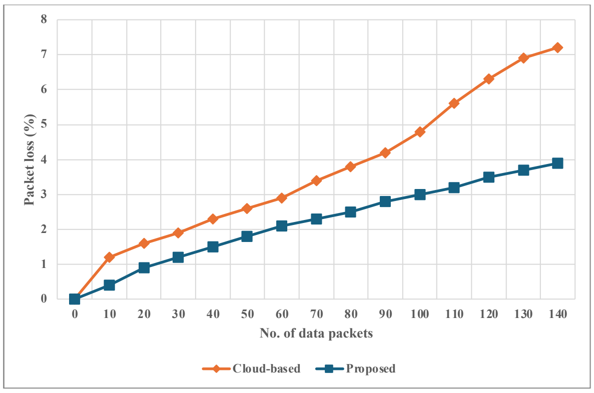


Figure 3(a). Query response analysis (b). Packet loss analysis

The response time for running the query processing approach in the typical cloud-based PH system is represented by the blue line in Figure 3(a). The research conducted a verification test on ten thousand separate data packets and received a response in 5.12 seconds. Incorporating a cloudlet among the cloud and end-users will significantly enhance the efficiency of the PH architecture. Based on the information in Figure 3(b), the conventional cloud-based PH architecture experiences a greater data packet loss rate due to the cloud service's unreliability at the system's edge. The research's cloudlet layer fills the gap and ensures the security of cloud services at the network edges. This is the fundamental reason the PH architecture has a low rate of information packet loss.

5. Conclusion and future scope

This study presents an approach for PH that utilizes cloudlet technology and is compatible with the IoT in SC. Utilizing cloudlet nodes allows for real-time data access, opening up possibilities for new HC surveillance systems. The research assessed the efficacy of the suggested methods for data management in the PH field by conducting several experiments. The study conducted a comparative analysis between the proposed PH system and the current PH system to validate the efficacy and efficiency of the proposed framework. First, the research stores and analyzes the HC information collected on the IoT Hubs to minimize needless data transmission across the network. Once the data has been gathered from several sources, such as sensors, IoT Hubs transmit it to the closest cloudlet node. This decreases the time it takes to transmit data and lowers the energy used for communication in small IoT devices. It ensures the longevity of compact battery-operated IoT gadgets. Delivering the data over the network edge enhances query response time. The suggested PH architecture benefits the current cloud-based PH structure. The research has observed a substantial enhancement in data transmission and query response time, resulting in reduced energy usage and a significant decrease in data packet loss

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