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International Journal for Modern Trends in Science and Technology
Volume 12, Issue 06, pages 73-81.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol12issue06.html
DOI: https://doi.org/10.5281/zenodo.20739493

A Privacy Preserving IoT Health Data Collection System with Encrypted Cloud Sync and Patient Consent Control

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To Cite this Article
Ch. Rama Krishna Raju, Palagummi Sai Siri Vennela, Bonam Ramya & Penumalla Naveen Kumar (2026). A Privacy Preserving IoT Health Data Collection System with Encrypted Cloud Sync and Patient Consent Control. International Journal for Modern Trends in Science and Technology, 12(06), 73-81. https://doi.org/10.5281/zenodo.20739493

Article Info
Received: 16 May 2026; Revised: 07 May 2026; Accepted: 12 June 2026.

KEYWORDS

Internet of Things (IoT), Healthcare Monitoring, Cloud Computing, Data Security, Encryption, Patient Consent, Access Control, Privacy Preservation

ABSTRACT

The rapid advancement of Internet of Things (IoT) technologies has significantly transformed the healthcare sector by enabling continuous monitoring of patient health through wearable sensors and smart medical devices. These devices collect large volumes of sensitive health data, which are typically transmitted and stored in cloud platforms for remote monitoring and analysis. However, the transmission and storage of medical data in cloud environments raise serious concerns related to privacy, security, and unauthorized access. Protecting patient data while ensuring accessibility to authorized healthcare providers has become a major challenge. This project proposes a privacy-preserving IoT health data collection system integrated with encrypted cloud synchronization and patient consent control mechanisms. In the proposed system, health data collected from IoT devices is encrypted before transmission and securely stored in the cloud. A consent management module allows patients to control who can access their medical information, ensuring that only authorized doctors or healthcare providers can retrieve the data. The system enhances confidentiality, integrity, and controlled accessibility of patient health records. By combining IoT monitoring, encryption techniques, and consent-based access control, the proposed solution improves patient trust, strengthens healthcare data security, and supports efficient remote healthcare services.

1. INTRODUCTION

In recent years, the integration of technology into healthcare has significantly improved the way patient monitoring and diagnosis are performed. Traditional healthcare systems rely heavily on manual monitoring, where patients are required to visit hospitals frequently for regular check-ups. This approach is time-consuming, less efficient, and may not provide continuous monitoring of a patient's health condition. To overcome these limitations, the concept of a Health Monitoring System using the Internet of Things (IoT) has emerged as an effective solution.

The Health Monitoring System using IoT is designed to continuously monitor vital health parameters such as heart rate, body temperature, and electrocardiogram (ECG) signals in real-time. In this system, various sensors are used to collect physiological data from the patient's body. These sensors are connected to a microcontroller, such as ESP32, which processes the collected data and transmits it to cloud platforms through wireless communication. This enables doctors and caregivers to monitor patient health remotely from anywhere at any time. One of the major advantages of this system is real-time monitoring and instant alert generation. Whenever abnormal conditions are detected, such as high heart rate or unusual ECG patterns, the system triggers alerts using buzzer or LED indicators. This helps in early detection of potential health issues and ensures timely medical intervention. Additionally, the system provides a user-friendly interface through an LCD display and cloud dashboard, making it easy to visualize the health parameters .The use of IoT in healthcare not only improves patient safety but also reduces the workload on medical professionals. It enables continuous data collection, better analysis, and efficient decision-making. Moreover, the integration of cloud platforms like ThingSpeak allows for secure data storage and remote access, making the system more reliable and scalable.

Overall, the Health Monitoring System using IoT represents a significant advancement in modern healthcare technology. It provides an efficient, cost-effective, and reliable solution for continuous health monitoring, which can be particularly beneficial for elderly patients and individuals with chronic diseases. This project aims to develop such a system that ensures accurate monitoring, real-time alerts, and remote accessibility, thereby improving the quality of healthcare services.The proposed IoT-Based Health Monitoring System is designed to monitor vital health parameters such as heart rate and body temperature using sensors. These sensors are connected to a microcontroller (ESP32), which collects and processes the data.

1.1 Introduction to Health Monitoring System

The rapid advancement of technology has significantly transformed the healthcare sector, enabling more efficient and reliable patient monitoring systems. Traditional healthcare methods primarily rely on manual observation and periodic check-ups, which are often time-consuming and may not provide continuous monitoring of a patient's condition. To address these limitations, the concept of a Health Monitoring System using the Internet of Things (IoT) has been introduced.

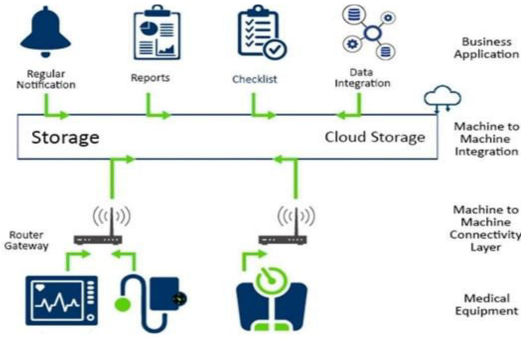

Fig:1.1 IoT-Based Health Monitoring System Architecture

The Health Monitoring System using IoT is designed to continuously monitor vital health parameters such as heart rate, body temperature, and electrocardiogram (ECG) signals in real-time. This system utilizes various sensors to collect physiological data from the patient. These sensors are interfaced with a microcontroller, such as ESP32, which processes the collected data and converts it into a meaningful format.

Internet of Things (IoT) enables continuous health monitoring using wearable sensors . Health data is highly sensitive and requires strong privacy protection. Traditional systems send raw data to cloud servers, causing security risks. Our system ensures secure encrypted data collection and privacy-preserving processing.

Once the data is processed, it is transmitted to cloud platforms using wireless communication technologies such as Wi-Fi. This allows healthcare professionals to access patient data remotely and monitor their condition from any location. The system also includes a local display unit, such as an LCD, to show real-time values, making it easier for users to view their health status instantly. One of the key features of this system is its ability to detect abnormal health conditions. If any parameter exceeds the normal threshold, the system generates alerts using indicators like buzzers or LEDs. This helps in early diagnosis and timely medical intervention, which can be critical in emergency situations.

In addition, the integration of IoT technology improves the overall efficiency and reliability of healthcare services. It reduces the dependency on manual monitoring, minimizes human errors, and provides accurate and continuous data. The system is also cost-effective and can be implemented in both urban and rural areas.

The Health Monitoring System using IoT represents a significant step towards smart healthcare. It enhances patient care by providing continuous monitoring, real-time alerts, and remote accessibility, making healthcare services more efficient and accessible.

In this system, various sensors continuously collect physiological data from the patient's body. The ESP32 microcontroller acts as the central processing unit, which processes and transmits the data to cloud platforms such as ThingSpeak. This enables real-time monitoring and storage of patient data for future analysis.

One of the key features of this system is its ability to detect abnormal health conditions using predefined threshold values. When any parameter exceeds the normal range, the system generates alerts through buzzers or LEDs. This ensures immediate attention and helps in preventing serious health complications.

Additionally, the system provides both local and remote monitoring capabilities. The LCD display shows real-time values for immediate reference, while cloud integration allows access from anywhere. This improves convenience for both patients and healthcare providers.

verall, the Health Monitoring System using IoT is a smart, efficient, and cost-effective solution that enhances patient care by providing continuous monitoring, real-time alerts, and remote accessibility.

1.2 Need for the Project

Traditional healthcare systems depend on manual monitoring and frequent hospital visits. Continuous monitoring is difficult in such systems, which may delay the detection of serious health issues. Patients often need to visit hospitals regularly, which can be inconvenient and time-consuming.

Manual monitoring also increases the workload on healthcare professionals and may lead to human errors. In emergency situations, delays in identifying abnormal conditions can result in severe consequences. Therefore, there is a need for a system that can provide continuous and real-time monitoring of patient health.

The proposed Health Monitoring System using IoT addresses these challenges by providing an automated and efficient solution. It continuously monitors vital health parameters and sends the data to cloud platforms, allowing remote access by healthcare providers.

This system reduces the need for frequent hospital visits and enables patients to stay at home while being monitored. It also ensures timely alerts in case of abnormal conditions, which helps in early diagnosis and treatment.

Furthermore, the system helps in reducing healthcare costs and improves the efficiency of medical services. It is especially beneficial for elderly patients and individuals with chronic diseases who require constant monitoring.

The system is also designed to be user-friendly and easy to operate, making it suitable for people of all age groups. Patients or caregivers can easily view the health parameters through the display unit or cloud interface. This improves awareness about health conditions and encourages proactive health management.

Moreover, the system is highly scalable and can be upgraded with additional features in the future. New sensors can be integrated to monitor more health parameters, and advanced technologies such as artificial intelligence can be used to predict diseases based on collected data. This makes the system adaptable to future healthcare needs.

In rural and remote areas where access to healthcare facilities is limited, this system can play a crucial role. It enables remote monitoring and reduces the need for patients to travel long distances for medical consultations. This improves healthcare accessibility and ensures better medical support for underserved populations.

2 LITERATURE SURVEY

The literature review provides an overview of existing health monitoring systems and the technologies used in modern healthcare applications. Traditionally, patient monitoring systems were limited to hospitals and relied on manual observation and basic medical devices. These systems required continuous supervision by healthcare professionals and were not suitable for real-time or remote monitoring. These systems use various sensors to measure physiological parameters such as heart rate, temperature, blood pressure, and ECG signals. Although these systems improved the accuracy of measurements, many of them lacked connectivity and real-time data sharing capabilities.

2.1 Existing Health Monitoring Systems

Health monitoring systems have been widely used in the medical field for observing and analyzing patient conditions. In earlier times, patient monitoring was primarily carried out using manual methods, where healthcare professionals directly measured and recorded vital parameters such as temperature, pulse rate, and blood pressure. These traditional systems required continuous human involvement and were mostly limited to hospital environments.

With the advancement of medical devices, electronic monitoring systems were introduced. These systems use instruments such as ECG machines, digital thermometers, and heart rate monitors to measure physiological parameters. Although these devices improved accuracy compared to manual methods, they still operate as standalone systems and do not provide continuous monitoring or remote accessibility. The collected data is often displayed locally and requires manual interpretation by medical staff.

In recent years, wearable health monitoring devices have also been developed. These devices are capable of measuring parameters such as heart rate, physical activity, and sleep patterns. They are compact and convenient for users; however, many of these systems lack integration with centralized data platforms. As a result, data sharing and long-term monitoring become difficult.

Another important limitation of existing systems is that they are mostly reactive rather than proactive. They provide information only when measurements are taken and do not continuously track patient health. This makes it difficult to detect sudden changes in health conditions. In critical situations, the absence of real-time monitoring may delay medical intervention.

2.2 IoT Applications in Healthcare

The Internet of Things (IoT) has emerged as a transformative technology in the healthcare sector. IoT refers to a network of interconnected devices that communicate with each other and exchange data over the internet. In healthcare, IoT enables the integration of sensors, medical devices, and communication technologies to create smart and efficient monitoring systems. IoT-based healthcare applications include remote patient monitoring, wearable devices, smart hospital systems, and telemedicine services. These applications use sensors to collect real-time data from patients and transmit it to cloud platforms for storage and analysis. Healthcare professionals can access this data remotely, allowing them to monitor patient conditions without physical presence.

One of the major advantages of IoT in healthcare is real-time monitoring. IoT systems continuously collect and update data, ensuring that any changes in a patient's condition are detected immediately. This helps in early diagnosis and timely treatment, reducing the risk of serious health complications.

IoT also improves the accessibility of healthcare services. Patients living in remote areas can receive medical attention without traveling to hospitals. Telemedicine applications allow patients to consult doctors through digital platforms, saving time and resources. This is especially beneficial for elderly patients and individuals with mobility issues.

Another important feature of IoT in healthcare is data integration and analysis. The collected data can be stored on cloud platforms and analyzed to identify patterns and trends. This helps in predicting potential health issues and supports preventive healthcare. IoT systems can also be integrated with mobile applications, providing users with easy access to their health data.

2.3 Sensor-Based Monitoring Technologies

Sensor-based monitoring technologies form the backbone of modern healthcare systems. These technologies use various sensors to measure physiological parameters and provide accurate data for analysis. Sensors play a crucial role in detecting changes in patient health and enabling continuous monitoring.

Different types of sensors are used in health monitoring systems. Temperature sensors are used to measure body temperature, heart rate sensors monitor pulse rate, and ECG sensors record the electrical activity of the heart. Other sensors such as blood pressure sensors and oxygen level sensors are also commonly used in advanced systems.

These sensors are connected to microcontrollers, which process the collected data and convert it into a readable format. The processed data can be displayed on local devices such as LCD screens or transmitted to external systems for further analysis. Sensor-based systems provide continuous and accurate data, making them more reliable than manual methods. One of the key advantages of sensor-based technologies is their ability to provide real-time monitoring. Sensors continuously collect data and update it at regular intervals. This helps in detecting abnormalities at an early stage and allows timely medical intervention.

However, standalone sensor systems have certain limitations. They often lack connectivity and cannot transmit data over long distances. This restricts their usage to local environments and limits remote monitoring capabilities. Integrating sensors with IoT technology overcomes these limitations by enabling data transmission to cloud platforms. Another important aspect of sensor-based systems is their efficiency and ease of use. Modern sensors are compact, low-cost, and energy-efficient, making them suitable for wearable and portable devices. This allows patients to monitor their health conveniently without the need for complex equipment.

2.4 Limitations of Existing Systems

Emerging Despite the availability of various health monitoring technologies, several limitations still exist in current systems. One of the major drawbacks is the lack of continuous monitoring. Many traditional systems provide data only at specific intervals, making it difficult to track sudden changes in a patient's condition.

Another limitation is the absence of remote monitoring capabilities. Most existing systems are confined to hospitals or specific locations, and patients cannot be monitored from a distance. This creates challenges for individuals who require constant supervision, especially in home or rural environments.

Data security and privacy are also significant concerns. Patient health data is sensitive and must be protected from unauthorized access. Some systems do not implement adequate security measures, which can lead to data breaches and misuse of information.

In addition, many existing systems are not scalable and cannot be easily upgraded with new features. They may lack compatibility with modern technologies such as cloud computing and mobile applications. This limits their functionality and reduces their effectiveness in modern healthcare environments. Another important limitation is the lack of automated alert mechanisms. In many systems, healthcare professionals must manually analyze data to identify abnormalities. This increases workload and may lead to delays in responding to critical situations.

2.5 Summary of Literature Review

The literature review highlights the evolution of health monitoring systems from traditional manual methods to modern IoT-based solutions. Traditional systems provide basic monitoring capabilities but lack features such as continuous data collection, remote accessibility, and automation.

The introduction of IoT has significantly improved healthcare systems by enabling real-time monitoring and data sharing. IoT-based systems integrate sensors, microcontrollers, and cloud platforms to provide efficient and reliable monitoring solutions. Sensor-based technologies play a crucial role in collecting accurate data, while cloud platforms enable storage and remote access.

However, existing systems still face challenges such as lack of scalability, data security issues, and limited functionality. These challenges emphasize the need for advanced systems that can overcome these limitations and provide better healthcare services. The proposed Health Monitoring System aims to address these issues by combining sensor technology, IoT, and cloud computing. It provides continuous monitoring, real-time alerts, and remote accessibility, making it a more efficient and reliable solution for patient care.

3 PROPOSED METHODOLOGY

The proposed system is an IoT-based Health Monitoring System designed to overcome the limitations of traditional healthcare systems. It integrates sensors, a microcontroller, and cloud technology to provide continuous and real-time monitoring of patient health parameters. In this system, sensors are used to measure vital parameters such as heart rate, body temperature, and ECG signals. These sensors are connected to an ESP32 microcontroller, which acts as the central processing unit. The microcontroller collects data from the sensors, processes it, and converts it into a meaningful format.

The processed data is transmitted to a cloud platform using wireless communication technologies such as Wi-Fi. This allows healthcare professionals to access patient data remotely and monitor their condition from any location. The use of cloud platforms also enables data storage and analysis, which can be useful for long-term healthcare management. The system also includes a local display unit, such as an LCD, which shows real-time health parameters. This provides immediate feedback to the patient and allows them to monitor their own health condition easily.

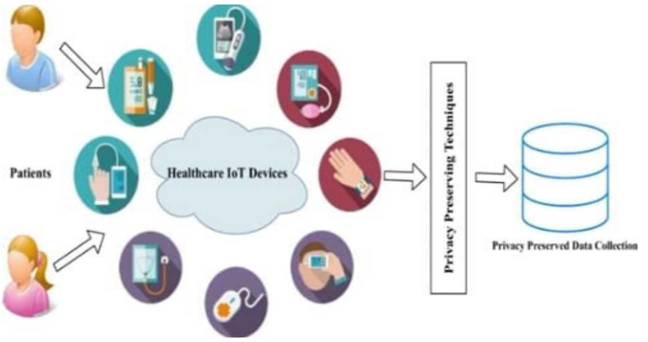

Fig:3.1 Proposed IoT-Based Health Monitoring System

An important feature of the proposed system is its automated alert mechanism. The system is programmed with predefined threshold values for each parameter.

When any parameter exceeds the normal range, the system generates alerts using buzzers or LEDs. This ensures that abnormal conditions are detected immediately and appropriate action can be taken.

The system is designed to be user-friendly and easy to operate. It does not require specialized knowledge to use, making it suitable for a wide range of users. It is also cost-effective, as it uses readily available components such as sensors and microcontrollers.

The proposed system can be implemented in various environments, including hospitals, homes, and remote areas. It provides a flexible and scalable solution that can be expanded with additional features such as mobile applications and advanced data analysis tools.

The proposed system improves efficiency, enhances patient safety, and provides a reliable solution for modern healthcare monitoring.

3.1 SYSTEM ARCHITECTURE

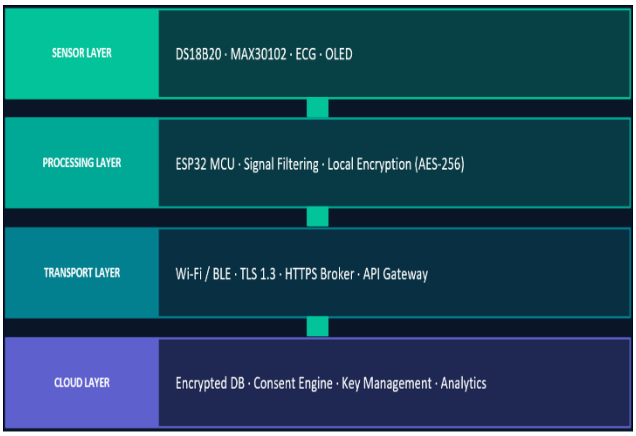

Fig 3.1 Proposed System Architecture

The sensing layer forms the foundation of the system architecture and is responsible for collecting physiological data from the patient. This layer includes various sensors that are used to measure vital health parameters such as heart rate, body temperature, and ECG signals.

Each sensor is designed to detect specific biological signals from the human body. For example, the heart rate sensor measures pulse rate by detecting blood flow variations, the temperature sensor measures body temperature, and the ECG sensor records the electrical activity of the heart. These sensors continuously collect data at regular intervals to ensure real-time monitoring.

The accuracy of the entire system depends on the performance of this layer. Therefore, reliable and precise sensors are used to ensure correct data collection. The collected data is in raw form and needs to be processed before it can be used for analysis. This data is transmitted to the processing layer for further operations..

3.2 BLOCK DIAGRAM DESCRIPTION

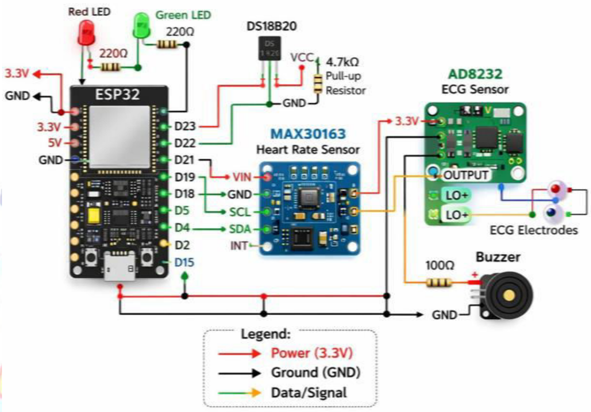

Fig 3.2 Wireless Communication Block Diagram

The block diagram illustrates the structural organization of the system and the interaction between its components. It provides a clear understanding of how data flows through the system.

The input block consists of sensors such as the heart rate sensor and temperature sensor, which collect data from the patient. These sensors send signals to the microcontroller.

The microcontroller acts as the processing unit, where raw data is converted into meaningful information. It performs operations such as signal conditioning, analog-to-digital conversion, and threshold comparison.

The communication block, implemented using the ESP8266 WiFi module, transmits the processed data to the cloud platform. It ensures reliable and secure data transmission.

The cloud platform stores the data and provides visualization tools. It converts raw data into graphical formats, enabling easy analysis. The user interface allows users to access the data remotely.

4 RESULTS

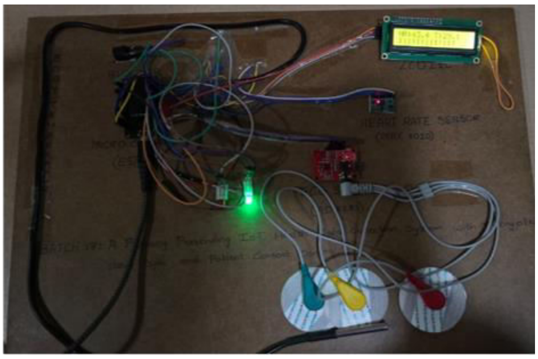

Fig 4.1: Output Display of Normal Readings

The output results of the IoT-based Health Monitoring System represent the final data generated after processing the input collected from various sensors. The system successfully converts raw sensor data into meaningful health parameters and displays them through both a cloud platform and a custom-developed dashboard interface.

The system continuously monitors vital parameters such as heart rate, body temperature, and ECG signals using sensors. These values are processed by the ESP32 microcontroller and transmitted to the ThingSpeak cloud platform. The output observed on the ThingSpeak dashboard is displayed in both graphical and numerical formats, allowing users to easily analyze variations in health parameters over time.In addition to the cloud visualization, a custom web-based dashboard was developed to enhance user interaction and data interpretation. This dashboard displays real-time health data including heart rate, temperature, and ECG values in a structured and user-friendly interface.The dashboard is divided into two main sections: original data and encrypted data. The original data section shows real-time values of health parameters along with the patient status, which is dynamically updated as either **NORMAL** or **DANGER** based on predefined threshold conditions.

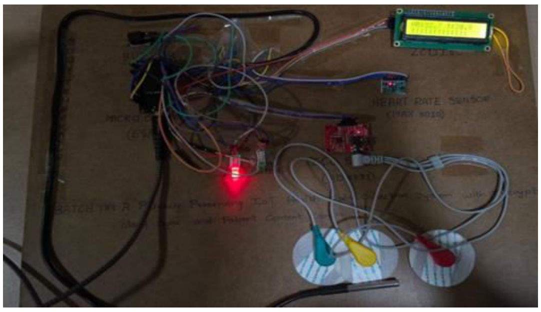

Fig 4.2: Stock Pulse Workspace

The encrypted data section demonstrates data security by converting the original health data into an encoded format using Base64 encoding. This feature highlights the system's capability to protect sensitive health information during transmission and storage.

The dashboard automatically refreshes data at regular intervals (every 20 seconds), ensuring continuous monitoring without manual intervention. The values displayed on the dashboard are consistent with those shown on the ThingSpeak platform, confirming the accuracy and reliability of data transmission.

During testing, the system produced stable and accurate outputs under both normal and abnormal conditions. The real-time updates, clear visualization, and alert indications make it easy for users to monitor patient health effectively.

Overall, the output results confirm that the system successfully delivers accurate, real-time, and secure health data through both cloud-based and custom dashboard interfaces. The integration of visualization and security features enhances the usability and effectiveness of the system for real-world healthcare monitoring applications.

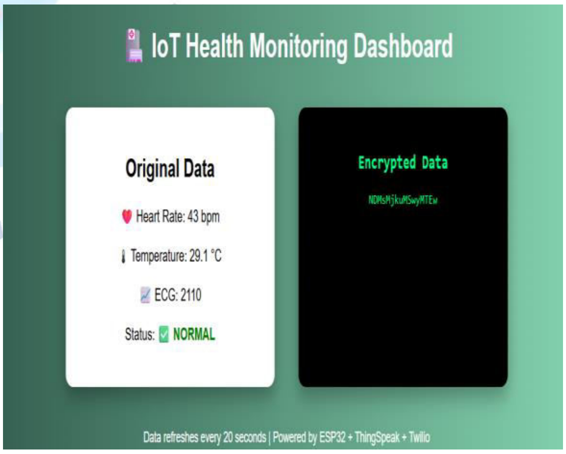

Fig 4.3: Output Display in Dashboard

The output design is responsible for presenting the processed data in a meaningful and user-friendly manner. In this system, the output is displayed through a cloud-based platform such as ThingSpeak. The processed data is transmitted to the cloud, where it is stored and visualized using graphs and charts. These visual representations help users easily understand trends and variations in health parameters over time. The system also includes an alert mechanism that notifies users when abnormal conditions are detected.

For example, if the heart rate exceeds or falls below normal levels, an alert is generated. This enables timely medical intervention. The output can be accessed through various devices such as smartphones, tablets, and computers. The user interface is designed to be simple and intuitive, ensuring that users can easily interpret the data. The output design enhances usability and ensures that the information is accessible, clear, and actionable.

The output design also ensures that the data is updated continuously so that users can always view the latest health information. As new sensor readings are received, the cloud platform refreshes the displayed data without delay. This real-time update feature allows users to observe changes in the patient's condition immediately.

The system supports storage of previous records, which helps in analyzing long-term health trends. Doctors and caregivers can review past data to understand variations and make better medical decisions. This feature is useful for identifying patterns and tracking improvement or deterioration in health.

5 CONCLUSION

The IoT-based Health Monitoring System developed in this project provides an effective solution for continuous and real-time monitoring of vital health parameters. The system successfully integrates hardware components such as sensors and ESP32 microcontroller with software technologies including cloud computing and web-based visualization. This integration enables accurate data collection, efficient processing, and reliable transmission of health information.The system continuously measures important physiological parameters such as heart rate, body temperature, and ECG signals using appropriate sensors. These readings are processed by the ESP32 microcontroller, which ensures proper conversion of raw sensor data into meaningful values. The processed data is transmitted to the ThingSpeak cloud platform using Wi-Fi connectivity, enabling remote monitoring and data storage.

The graphical representation of data on the ThingSpeak platform provides clear insights into variations and trends in health parameters over time. This helps users and healthcare providers to easily analyze patient conditions and identify any abnormal changes. The system supports real-time data updates, ensuring that the latest health information is always available for monitoring.

A custom-developed web dashboard further enhances the usability of the system by presenting real-time data in a structured and user-friendly format. The dashboard displays key parameters along with status indicators such as NORMAL and DANGER, which are determined based on predefined threshold values. This feature simplifies the interpretation of health data and enables quick decision-making in critical situations. The inclusion of encrypted data representation demonstrates the system's capability to handle sensitive information securely.

The alert mechanism implemented in the system plays a crucial role in ensuring patient safety. Whenever abnormal conditions are detected, alerts are generated immediately, allowing timely intervention. This feature makes the system suitable for applications where continuous monitoring and quick response are essential. Extensive testing of the system confirmed its accuracy, stability, and reliability under different conditions. The system was able to operate continuously without significant delays or failures, and it maintained consistency in data transmission and output generation. The ability to handle network interruptions and resume operation further improves the robustness of the system.

6 FUTURE ENHANCEMENT

The current system can be further enhanced by incorporating additional features and improvements to increase its efficiency and applicability in advanced healthcare systems.More health parameters such as blood pressure, oxygen saturation (SpO2), and respiratory rate can be integrated to provide a more comprehensive health monitoring solution. This would improve the system's capability to monitor multiple vital signs simultaneously.

The system can be improved by integrating mobile application support, allowing users and doctors to monitor patient data remotely through smartphones. This would enhance accessibility and convenience.Advanced data analytics and machine learning algorithms can be implemented to predict health conditions based on historical data. This would help in early diagnosis and preventive healthcare.

The security of the system can be further strengthened by implementing advanced encryption techniques and secure communication protocols to protect sensitive health data.

The system can also be enhanced by adding GPS tracking for patient location monitoring in emergency situations. This feature would be particularly useful for elderly patients and critical care cases.Integration with hospital management systems and electronic health records (EHR) can make the system more useful in clinical environments. This would allow seamless data sharing between healthcare providers.

Power optimization techniques can be applied to make the system more energy-efficient, especially for long-term and wearable applications.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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