International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 05, IIRA 5.0 (2026)

Real-time IoT-based Health Monitoring System

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ABSTRACT

In recent years, the integration of the Internet of Things (IoT) in healthcare has opened up new possibilities to improve patient care and medical services. An IOT-based health monitoring system is designed to track a patient's vital health parameters remotely using interconnected smart devices and sensors. These systems provide continuous and real-time monitoring of critical health metrics such as heart rate, body temperature, blood pressure, oxygen saturation (SPO_2) and electrocardiogram (ECG) data. The collected data is sent wirelessly to a cloud server or centralized platform where it can be accessed by healthcare providers, caregivers or patients themselves via a mobile application or web interface.

This system plays a vital role in enabling remote healthcare, especially for elderly individuals, chronically ill patients or in rural or underdeveloped areas where immediate access to medical facilities may be limited. By facilitating early detection of abnormalities or emergencies, IOT-based health monitoring can reduce the number of hospitalizations and lower the overall cost of healthcare services. In addition, real-time alerts and notifications can be generated in case of critical deviations, ensuring quick response to life-dependent situations.

The main components of the system include wearable or implanted sensors, microcontrollers, communication modules (such as Wi-Fi, Bluetooth or GSM) and cloud storage. Data analytics and machine learning can also be integrated to provide advanced diagnosis and

International Journal of Engineering Research & Technology (IJERT)
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future health information. Security and privacy of patient data are also important aspects, which require strong encryption and access control mechanisms.

Keywords: Health Monitoring, Sensors, Wireless Communication, Cloud Storage, Real-time, Wearables.

1 - INTRODUCTION

New technologies in healthcare have greatly changed how patients are cared for and managed, leading to better health outcomes. In the past, healthcare relied on regular check-ups, hospital visits, and manual record-keeping. Now, technology allows for better and continuous health monitoring using devices connected to the Internet (IoT) and wearable sensors[1][2].

The healthcare field has improved quickly due to new technologies that make patient monitoring and treatment better. The increase in chronic diseases, older populations, and the need for quick medical help have pushed traditional healthcare to find more efficient and cost-effective ways to help patients. IoT has changed how patients are monitored, allowing continuous and real-time health data collection. This data helps find health problems early and improve overall healthcare[3], [4].

Real-time health monitoring is very important for improving patient care, especially for those with ongoing health issues like heart disease, diabetes, and breathing problems. Constant monitoring helps doctors spot potential health issues before they become serious, reducing the need for hospital visits and emergency care. This leads to better health outcomes, lower healthcare costs, and a better quality of life[5] [1].

2 – LITERATURE REVIEW

Research on IoT health monitoring systems shows major improvements in healthcare due to IoT technologies, wearable sensors, and data analysis. Provides a broad survey of IoT-based technologies in healthcare, covering communication protocols, architectures, and applications [6]. Some systems focus on specific conditions, like cardiac monitoring, while others track general health metrics.

• IoT Technologies in Healthcare:

- Wireless Sensor Networks (WSNs): These networks collect data from sensors on or in the patient's body[7], [8] [7], [9].

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- Cloud Computing: The cloud helps store, analyze, and share data, making it easy for healthcare professionals to access health data anywhere[9].

• Wearable Sensor Applications in Patient Monitoring:

- Wearable ECG Monitors: These devices track heart activity to find issues in real-time [9].

- Smartwatches and Fitness Trackers: They monitor health signs like heart rate and physical activity [9].

- Wearable Blood Pressure Monitors: Help patients keep track of their blood pressure[9].

• Challenges in Real-Time Health Monitoring:

- Data Accuracy: Some devices may not always give correct readings, which can affect health decisions [1].

- Privacy and Security Risks: Storing and sending health data raises privacy concerns. IoT devices can be vulnerable to attacks [10].

- Battery Life: Continuous monitoring drains power quickly, needing frequent recharging[3].

- Cost: High costs can make these systems hard to access for some patients and providers, especially in developing countries[3].

3 – METHODOLOGY

Describes the methodology for integrating IoT devices with fog computing for healthcare systems, which improves data processing efficiency and reduces latency. The workflow diagram is shown in Figure 1.

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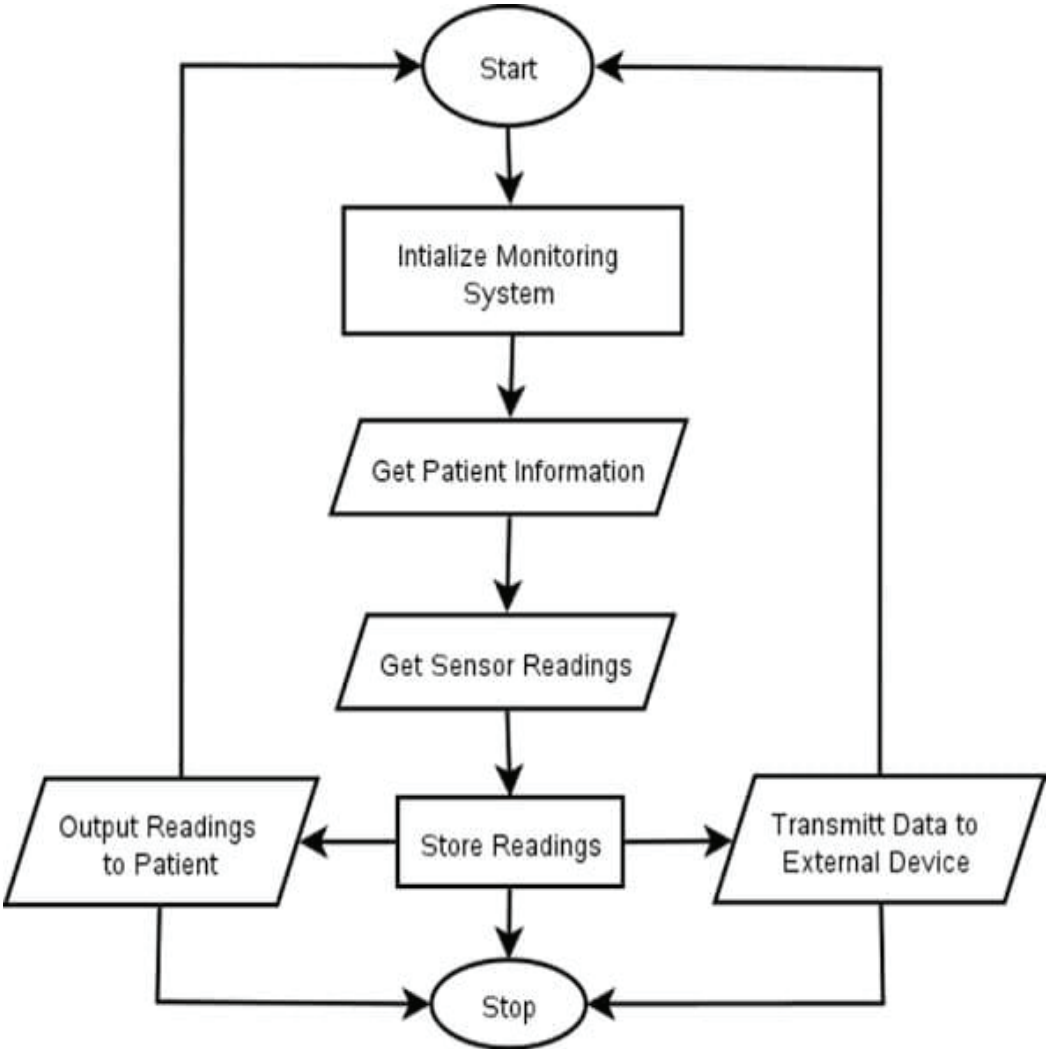

Figure 1. IoT Based Health Monitoring System

This flowchart illustrates the step-by-step operation of a health monitoring system designed to collect, process, and transmit vital patient data. The process begins with the *initialization of the monitoring system, where all components such as sensors, microcontrollers, and communication modules are activated. Once the system is ready, it proceeds to **gather patient information, which may include personal identification and medical history to personalize the data monitoring. Following this, the system **collects real-time sensor readings* for parameters like heart rate, body temperature, and other vital signs using the connected sensors. These readings are then *stored* temporarily within the system. The

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stored data is processed in two directions: it is *transmitted to an external device or cloud server* for remote access and monitoring, and simultaneously, the *readings are output to the patient* through an interface like an LCD display, allowing for immediate feedback. The process ends at the *stop stage*, or it can loop back for continuous monitoring. This systematic flow ensures reliable and real-time health tracking for effective medical assessment and timely interventions.

4 - IMPLEMENTATION AND EXPERIMENTAL SETUP

This circuit diagram illustrates a health monitoring system built using an Arduino Uno microcontroller, which integrates a temperature sensor (LM35), a pulse sensor, an ESP8266 Wi-Fi module, a 16x2 LCD display, and an LED indicator. The system is designed to measure and display a person's body temperature and heart rate (in BPM), while also transmitting the data wirelessly via the ESP8266 module.

The LM35 temperature sensor, located to the right of the breadboard, has three pins: VCC (red wire), GND (black wire), and output (green wire). The VCC is connected to the 5V pin on the Arduino, GND to GND, and the output is fed into analog pin A0 of the Arduino to read the analog voltage corresponding to temperature.

Beside it, the *pulse sensor* measures the user's heartbeat. Its VCC and GND lines are similarly connected to the Arduino's 5V and GND pins, while its signal output is connected to analog pin A1 for capturing pulse data.

The *16x2 LCD display* is used to display the BPM and temperature values. It is connected in 4-bit mode to digital pins 2 through 7 of the Arduino. Pin 1 and 2 of the LCD are connected to GND and VCC respectively, while the remaining connections include a potentiometer for contrast adjustment (not shown), and standard connections like RS, EN, and data lines (D4-D7) are made to the Arduino.

An *LED*, connected via a 1K resistor, is wired to digital pin 8 of the Arduino. It blinks with each detected heartbeat, providing a visual indicator of pulse activity.

The *ESP8266 Wi-Fi module* (top left) enables the system to send sensor data to a server or cloud platform. Since it operates at 3.3V logic levels, the connections are made carefully: VCC is connected to 3.3V, GND to GND, TX of the ESP8266 to RX (pin 10) of the Arduino, and

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RX of ESP8266 to TX (pin 9) of Arduino. A voltage divider using 1K and 2K resistors is used on the TX line from Arduino to step down 5V to 3.3V for safe communication with the ESP8266's RX pin.

Power and ground lines are properly distributed using the breadboard rails, ensuring all components are powered appropriately. This system allows real-time monitoring and display of body vitals, making it suitable for remote health tracking or IoT-based healthcare applications. The circuit diagram is shown in Figure 2.

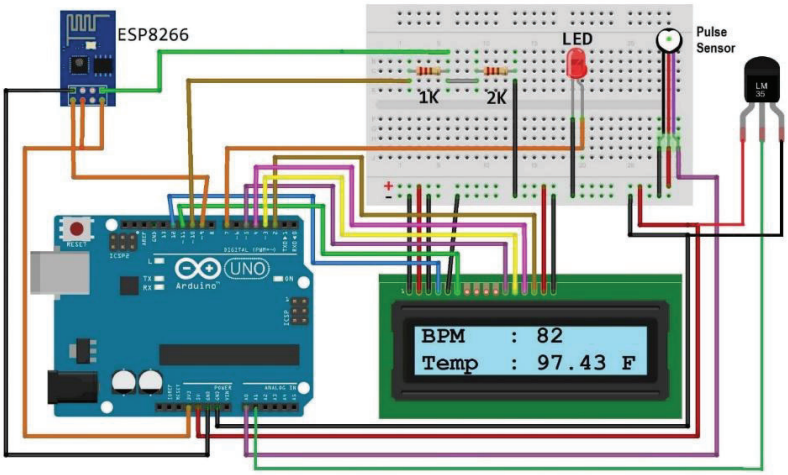

Figure 2. Real-Time IoT-Based Health Monitoring System

5 – RESULTS AND DISCUSSION

The IoT-based health monitoring system demonstrates promising functionality in real-time monitoring of physiological parameters such as heart rate, blood oxygen saturation (SpO_2), and body temperature.

a) Data Visualization :

The data visualization interface generates real-time line graphs that allow both users and healthcare professionals to observe health trends and fluctuations over time. These visualizations provide insights into daily patterns; for instance, heart rate increases during physical exertion are clearly visible, while body temperature remains relatively stable with minor fluctuations due to environmental changes.

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b) System Performance Evaluation:

In evaluating system performance, the device consistently produces accurate measurements when compared with standard medical instruments. Heart rate readings vary within a margin of ±2 beats per minute, SpO_2 values show a deviation of ±1.5%, and temperature readings differ by no more than ±0.3°C. These findings are consistent with benchmarks reported in similar IoT-based health systems.

c) Comparison with existing Solutions :

When compared to existing solutions, the proposed system presents several advantages in terms of cost, accessibility, and customization. Unlike commercial wearable devices such as Fitbit and Apple Watch, which often restrict data access and rely on proprietary software, this system allows open-source customization and integration with platforms like IFTTT for automated alerts. Additionally, hospital-grade monitoring equipment, while highly accurate, is often cost-prohibitive and inaccessible to rural populations. This system, by contrast, achieves comparable basic functionality at a significantly lower cost making it ideal for deployment in low-resource settings.

d) Challenges and Solutions :

Despite these strengths, the system encounters several challenges during implementation. One recurring issue is the proper placement of sensors, especially among elderly users. Improper attachment sometimes results in signal noise or incomplete readings. To address this, ergonomic sensor casings and instructional guides are developed to assist users during setup. Another challenge is the system's dependency on internet connectivity. During outages, real-time data transfer is interrupted. This is mitigated by adding an SD card module for local data logging, allowing offline storage until the connection is restored.

To resolve this, signal smoothing algorithms and threshold calibration are applied to minimize inaccuracies, a solution also explored in other healthcare IoT frameworks.

While challenges remain in sensor ergonomics, data security, and power optimization, the system serves as a scalable and effective solution that aligns with the current shift toward remote patient care and personalized health tracking.

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6- CHALLENGES AND FUTURE DIRECTIONS

As health monitoring systems using IoT grow and become more common, they face some challenges that need to be solved to make sure they work well, are safe, and can expand. This section talks about important challenges and looks at hopeful future steps to improve these systems[11].

• Scalability and Interoperability Issues

Scalability is a problem when using health monitoring systems for large groups of people or healthcare centers. Handling a lot of real-time data from many wearable devices can overwhelm cloud services and networks. Focuses on scalable communication protocols and standards for healthcare IoT applications [11].

Interoperability is difficult because there are no standard ways for devices to communicate and share data. Highlights challenges in IoT-Based healthcare systems such as data overload and latency, while also exploring the future potential of fog computing to mitigate these issues[10].

• Data Security and Privacy Concerns

Patient data is very sensitive and can be exposed when being sent or stored.

IoT devices usually have limited processing power, making it hard to protect them with regular cybersecurity methods [11].

• AI-Driven Health Prediction and Diagnosis

Use of AI and machine learning to analyze health data for predictive analytics, anomaly detection and personalized healthcare[12].

• Energy Efficiency

Development of power- efficient sensors and energy harvesting technologies to ensure longer operation times for IoT devices[1].

7 - CONCLUSION

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This paper studied an IoT-based health monitoring system that allows real-time tracking of health signs using wearable sensors. The results showed that using IoT greatly improves healthcare services, especially in rural areas or places with limited resources. This research adds to the knowledge of smart healthcare by providing a working system that combines sensor technology, data processing, and wireless communication for monitoring health. It also shows how IoT can help in preventing illnesses and managing long-term health conditions. Although the current system shows good results, some areas need more research. Future studies could look into using artificial intelligence and machine learning to improve predictions. Additionally, long-term clinical tests and larger studies are needed to see how the system affects patient care and healthcare processes.

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