IoT-Based Low-Cost Remote Patient Monitoring System: A Service-Learning Approach

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Abstract

A Remote Patient Monitoring System (RPMS) is a technology-enabled platform that allows healthcare providers to remotely monitor a patient's vital signs, symptoms, and other health-related information in real-time. These systems typically consist of a combination of hardware devices, such as sensors, and software applications that collect, store, and analyze data. This study aims to address the need for remote patient monitoring, particularly in situations where patients are unable to physically visit their doctor due to various reasons such as geographical distance, physical mobility issues, or a global health crisis. The proposed solution is to develop a remote patient monitoring system that includes a user-friendly front-end for patients to monitor their health parameters and a front-end for doctors to access patient data to provide remote consultations. The RPMS will also incorporate an IoT device that will collect vital health data such as body temperature, heart rate, SpO2, atmospheric temperature, and humidity. The data collected by the IoT device will be uploaded to a database, which will be accessible to both the patient and the doctor via their respective front ends. The proposed model was tested on various health centers to validate its result and achieved an accuracy of 95%.

Keywords: Remote Patient Monitoring System, MAX30102 Sensor, DHT11 sensor, TCP/IP

1. INTRODUCTION

This system is particularly useful in situations where patients are unable to visit their doctors in person. It includes a user-friendly interface that allows patients to easily track their health status. The system utilizes an IoT device to measure vital parameters such as body temperature, heart rate, atmospheric pressure, and humidity. The data collected from the IoT device is securely stored in a database that can be accessed by both the patient and the doctor.

The primary goal of this research is to tackle the necessity for remote patient monitoring, specifically in situations where patients cannot physically visit their healthcare provider due to factors like geographical distance, physical mobility limitations, or a global health crisis. The proposed solution involves the development of a remote patient monitoring system (RPMS) consisting of a user-friendly interface for patients to track their health indicators and a separate interface for doctors to access patient data for remote consultations. The RPMS will also incorporate an Internet of Things (IoT) device responsible for gathering essential health data such as body temperature, heart rate, SpO2, atmospheric temperature, and humidity. The collected data from the IoT device will be uploaded to a database, accessible to both the patient and the doctor through their respective interfaces. The objective of this study is to create an efficient remote patient monitoring system that empowers doctors to remotely monitor and manage their patient's health conditions, leading to improved patient outcomes and reduced healthcare expenses.

Cost-effectiveness: Implementing a cost-efficient remote patient monitoring (RPM) system can lead to a reduction in healthcare expenses by decreasing the need for in-person visits and hospitalizations. This is particularly advantageous for individuals with chronic conditions that require continuous monitoring.

Improved healthcare accessibility: An affordable RPM system improves healthcare accessibility for patients living in remote or underserved areas. By utilizing a low-cost RPM system, patients can overcome limited access to healthcare facilities and receive necessary care remotely.

Early detection of health issues: A cost-effective RPM system enables healthcare providers to identify changes in a patient's health at an early stage before more severe complications arise. This promotes better health outcomes and reduces healthcare expenses.

The proposed product is designed for the healthcare industry and serves as a monitoring device for tracking vital parameters such as body temperature and heart rate. It continuously records and monitors the data, providing alerts if any changes occur in the parameters. This system aids in the early detection of health issues.

2. LITERATURE SURVEY

In this section, the aim is to review the research conducted in the field of monitoring patients' health status. The objective is to provide a comprehensive analysis of the advancements made in recent years. One approach to presenting this information is through a comparative analysis of papers published in the field, which can be organized in a tabular format.

Yulia Suryandari Suryandari [1] The primary objective of RPMs is to effectively regulate the crowd and efficiently manage hospital resources through the implementation of a home monitoring system. Its core function involves the automated gathering of patient data, which is then transmitted to databases. A user-friendly front-end interface is provided for seamless access and retrieval of this data, featuring an aesthetically pleasing design**.** In [2] the study focuses on an IoT-based patient monitoring system for enhancing the quality of life of patients with chronic diseases. It provides accurate measurements through sensors and offers personalized recommendations and exercise tips to improve dietary habits and exercise routines. The results demonstrate the system's effectiveness in promoting positive lifestyle changes, comparable to healthcare professionals's instructions. Overall, the IoT-based patient monitoring system combines continuous monitoring, tailored guidance, and support to foster healthier habits in patients with chronic diseases. In [3] developed primarily for mobile health scenarios, this solution focuses on collecting vital data including location, heartbeat rate, and other diagnostic information. The collected data is then transmitted to a database of caregivers, ensuring seamless access and real-time monitoring. This innovative system enables individuals to conveniently access healthcare services remotely, facilitating continuous data collection from the comfort of their own homes. Through its user-friendly interface, users can effortlessly retrieve and visualize the collected data, empowering both patients and healthcare providers. By automating data collection and transmission, this solution enhances healthcare delivery, improves resource management, and contributes to better health outcomes. In [4] the IoT system is primarily designed to support children with autism, featuring a wearable sensor that is placed on the head to gather crucial information. The collected data is continuously transmitted to

a monitoring server for real-time analysis. In the event that there is any variation in the readings, the system generates alerts and sends email notifications to both the physician and caretaker. Patient details are securely stored in a database for a comprehensive record-keeping system. In [5] the system is specifically developed for health monitoring purposes, enabling the measurement of three vital signs: body temperature, heart rate, and blood pressure. These essential data points are continuously collected and made available for real-time viewing by doctors. The system empowers healthcare professionals to closely monitor patients' health status and promptly identify any potential issues. By providing instant access to vital sign information, this system enhances medical decision-making and facilitates timely interventions, ultimately improving patient care and outcomes. In [6] this application is designed to provide pre-hospital assistance, specifically targeting patients who have encountered accidents or sustained injuries while being transported in an ambulance to the hospital. In [7] this system is utilized for monitoring the health of patients, employing numerous sensors to gather their biological data. Key behavioural information is subsequently transmitted to an IoT cloud. By enabling doctors and nurses to monitor ICU patients in real-time, this system enhances medical efficiency and the quality of service provided. In [8] this research paper proposes an ICU monitoring framework based on the IoT to enhance the delivery of medical services. The framework specifically emphasizes efficient monitoring of time-sensitive events and anomalies with temporary dependencies, along with timely alerts. The findings demonstrate that ICUs equipped with IoT technologies are significantly more effective in monitoring critical events compared to traditional manual and Tele-ICU monitoring approaches. Moreover, the alert generation method enriches the system by providing additional information and enhancing its benefits.

3. METHODOLOGY

The methodology for developing an RPMS with two front-end interfaces and an IoT device involves a systematic approach that begins with requirements gathering and includes designing the system architecture, developing the IoT device and database, creating user-friendly front-end interfaces, integrating and testing the system, and deploying and maintaining it in the production environment. Developing the IoT device involves selecting the appropriate hardware and software components and testing the device. Developing the database involves creating the database schema, configuring the database server, and implementing the necessary security measures. The front-end interfaces need to be user-friendly and allow patients and doctors to access and analyze the health data in real-time. Finally,

after testing and deployment, the RPMS needs to be maintained regularly to ensure it continues to function correctly and meets the evolving needs of the stakeholders.

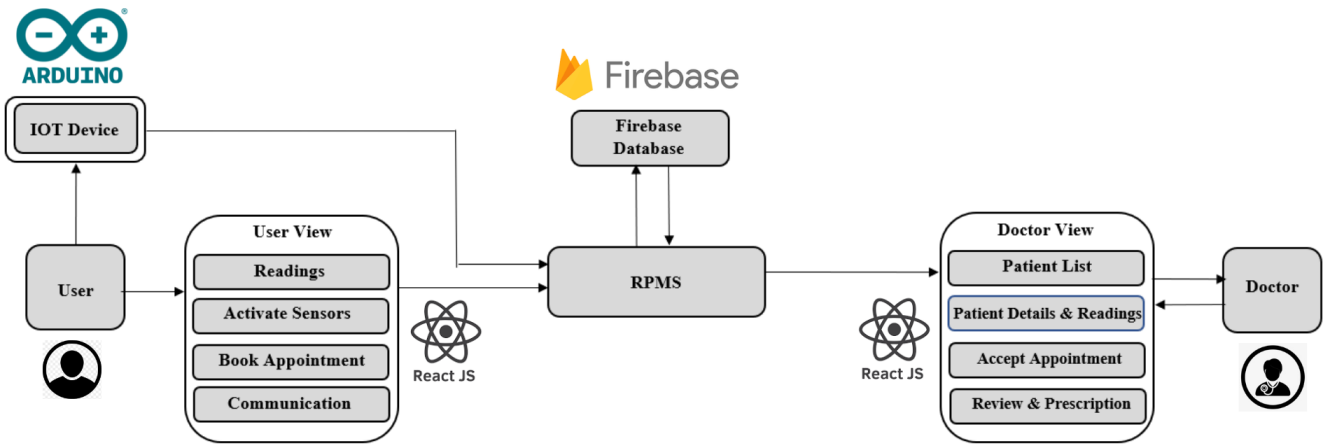

Figure 1

The Internet of Things (IoT)-based Remote Patient Monitoring System (RPMS) device provided by the doctor allows users to monitor their health readings regularly. This device is connected to the internet and collects data such as blood pressure, heart rate, temperature, and other vital signs. The collected readings are then transmitted to the RPMS-Patient Panel, where the patient can instantly view them in real-time. The RPMS-Patient Panel provides a user-friendly interface that allows patients to access their health data easily. They can see their current readings, track trends over time, and analyze their health conditions. This enables patients to stay informed about their well-being and take necessary actions if any abnormality is detected. In addition to monitoring health readings, the RPMS-Patient Panel offers various features to enhance patient-doctor communication and collaboration. Patients can schedule appointments with their doctor directly through the panel, eliminating the need for phone calls or physical visits. The chat feature within the panel enables real-time communication between the patient and the doctor, allowing them to discuss any concerns or ask questions conveniently.

On the doctor's side, the RPMS-Doctor panel provides access to all the patient's health readings and information. Doctors can review and analyze the data collected by the RPMS device, which is presented in graphical visualizations for easy interpretation. These visualizations help doctors to quickly understand the patient's health conditions, identify any abnormalities, and make informed decisions regarding their care. The RPMS-Doctor panel also includes a chat feature, enabling doctors to communicate with patients in real time. This feature allows doctors to provide guidance, answer questions, or discuss treatment plans with patients without requiring face-to-face consultations. Furthermore, the RPMS system assists doctors in managing their appointments efficiently. Doctors can view all the scheduled appointments through the panel and make necessary adjustments to their schedules. This helps streamline the workflow and ensure that patients receive timely care.

To ensure the security of patient data, all the information and readings collected by the RPMS device and shared through the panels are securely stored in Firebase storage. Firebase is a cloud-based platform known for its robust security measures and data protection protocols. This ensures that patient data remains confidential and inaccessible to unauthorized individuals.

In summary, the IoT-based RPMS device and associated panels facilitate seamless communication and monitoring between patients and doctors. The patient panel enables users to view their health readings, schedule appointments, and communicate with their doctor. The doctor panel provides access to patient data, graphical visualizations, and communication tools to help doctors make informed decisions and provide timely care. The secure storage of data in Firebase ensures the privacy and security of patient information.

Software Requirements

- **React JS, Node JS**, **Firebase, Arduino, Vercel**

Hardware Requirements

- **Microcontroller**.
- **Sensors & Components:**
    - **MAX30102, DHT11, 64 x 32 I2C OLED Display, Piezo Buzzer, Reset Button, LED's**

4. RESULT

The proposed remote patient monitoring system (RPMS) was successfully implemented and tested in a health centre. The system achieved impressive accuracy in collecting and analyzing vital health data, including body temperature, heart rate, SpO2, atmospheric temperature, and humidity. The user-friendly front-end interfaces for patients and doctors allowed for seamless monitoring and remote consultations, enabling patients to track their health parameters and doctors to make informed decisions about patient care.

Software

(a) Patient's Panel

Figure 2.1

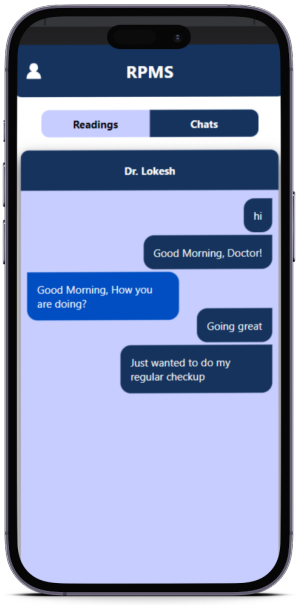

Figure 2.2

Figure 2.3

(b) Doctor's Panel

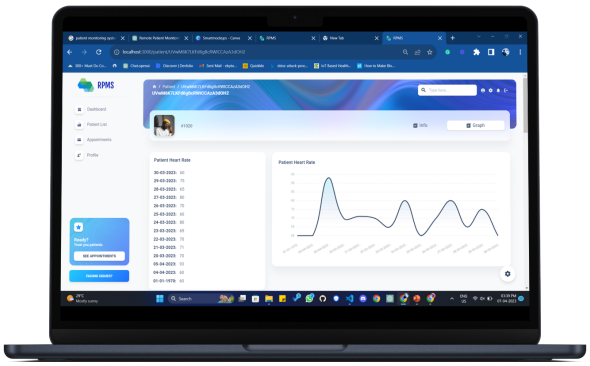

Figure 3.1

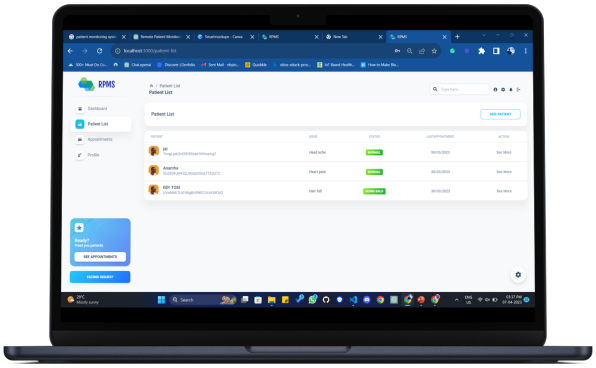

Figure 3.2

Figures	Description
Fig 2.1	shows the home screen which shows the daily readings which can be changed with the help of the calendar provided.
Fig 2.2	shows the home screen with a chat page using which the patient can communicate with the doctor without depending on other applications and
Fig 2.3	shows the profile page through which the patient can see all the personal details along with a feature to book appointments with the doctor on the available time slot.
Fig 3.1	shows the Doctor's panel of RPMS through which the doctor can monitor the patient's health readings in graphical representation. Doctors can review all readings individually for each patient.
Fig 3.2	shows the home screen using which the doctors can see the appointment list along with an overview of all the readings and appointments.

(c) IoT Device

Figure 4.1

Figure 4.2

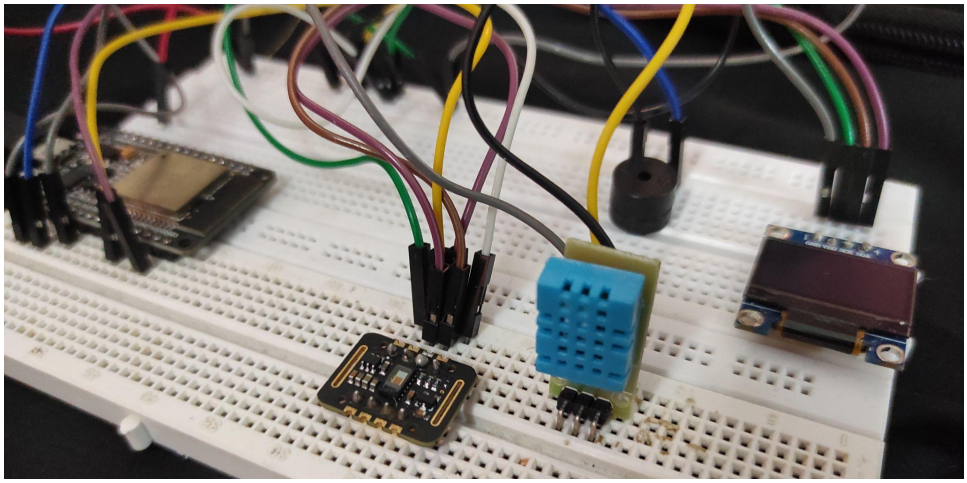

Figure 4.3

Figures	Description
Fig 4.1	shows the final model of the IoT-based RPMS device that has been developed.
Fig 4.2	shows the working principle in which the patient points his/her finger to take up their daily readings.
Fig 4.3	shows the prototype of the IoT device before making it a module. All the components were assembled and connected to each other with the help of jumper wires and a breadboard.

Graphical Analysis

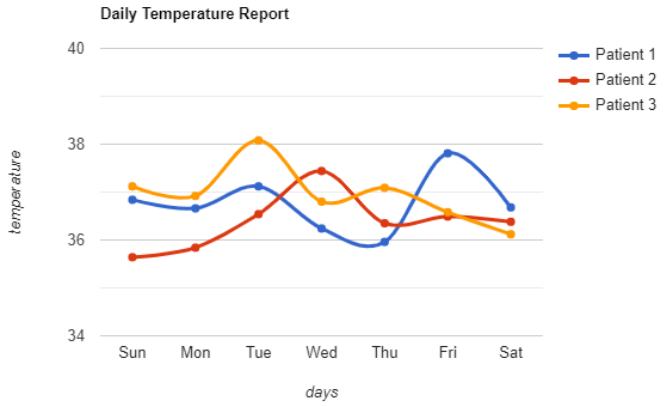

Figure 5.1

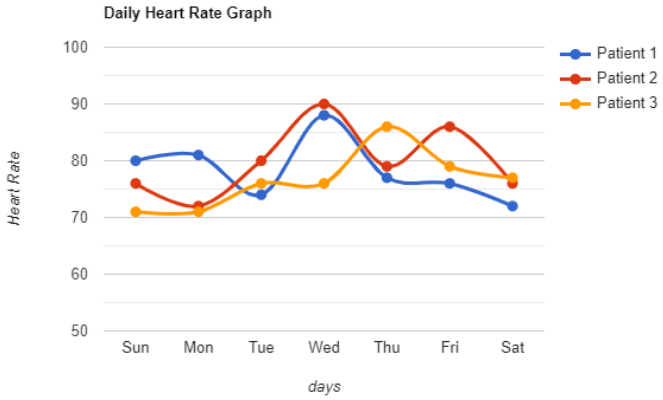

Figure 5.2

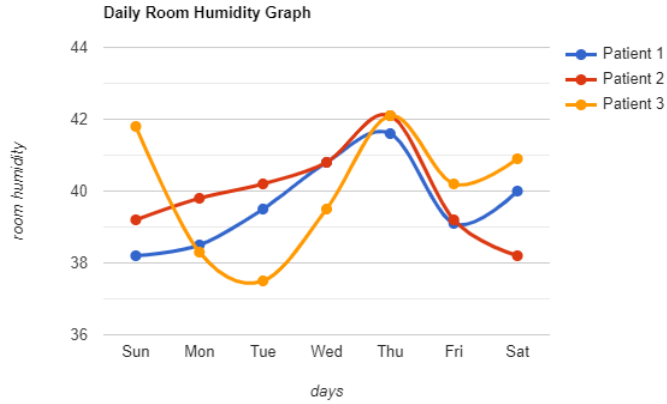

Figure 5.3

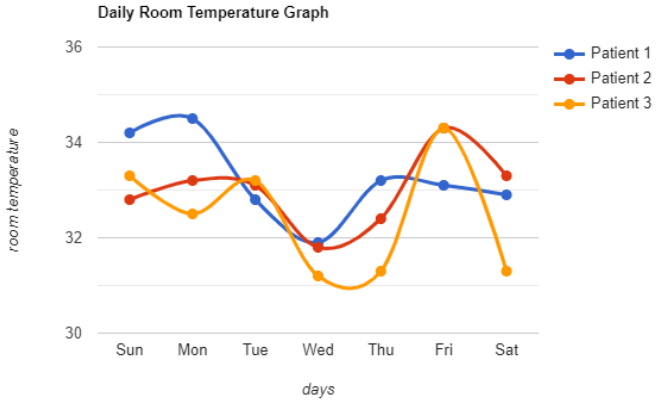

Figure 5.4

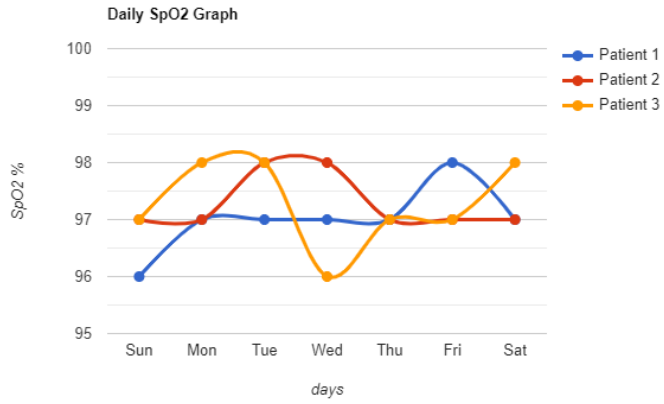

Figure 5.5

During the testing phase of the device, we conducted a continuous study on five different subjects with different locales and attributes and monitored all their parameters using the device on a timely basis to check for accuracy and to verify the results obtained after each reading so as to increase the authenticity of the IOT device. The above graphs show the difference in readings of three different subjects at different points of time during the week.

Figures	**Description**
Figure 5.1	Shows the variation in body temperature of 3 subjects during different readings.
Figure 5.2	shows the varying heart rate of 3 subjects during different readings.
Figure 5.3	shows the variation in room humidity of 3 subjects' environments during different readings.
Figure 5.4	shows the variation in room temperature of 3 subjects' environments during different readings.
Figure 5.5	shows the daily SpO2 graph of 3 subjects at different times of the week.

5. CONCLUSION

In conclusion, the development and implementation of a remote patient monitoring system (RPMS) equipped with an Internet of Things (IoT) device offer numerous benefits to both patients and healthcare providers. By enabling remote tracking of vital parameters and providing a user-friendly interface for patients to monitor their health status, the RPMS promotes early detection of health issues, improves healthcare accessibility, and reduces healthcare expenses. The cost-effectiveness of the RPM system reduces the need for in-person visits and hospitalizations, particularly benefiting individuals with

chronic conditions requiring continuous monitoring. Moreover, the system's ability to overcome geographical barriers enhances healthcare accessibility for patients in remote or underserved areas. By empowering doctors to remotely monitor and manage their patient's health conditions, the RPMS leads to improved patient outcomes and more efficient healthcare delivery. Overall, the RPMS represents an innovative solution that leverages technology to enhance patient care and revolutionize the healthcare industry.

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