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Smart IoT-Based Healthcare Monitoring System

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Abstract: *Many peoples or usually elders peoples needs to regular monitoring of their basic health parameters Heart rate (BPM), Blood oxygen saturation (SpO2), Body temperature. Usually, this monitoring is done manually like only during hospital visits, it takes more time, which is not convenient for continuous observation and also for elders peoples. It makes difficult detect issues, especially when person is at home or far from hospital. In this situation there is a need, simple and*
Affordable and easy to carry health monitoring device, which helps to continuously monitoring these health parameters, shows result display on screen and send alert message on telegram through doctors if health parameters are abnormal and also generate report of these parameters. These report can convert into PDF and that PDF is shareable. This can send to doctors or family members. Health data can be viewed remotely through an IOT dashboard, Which is useful for caretakers and supervisors. In this paper to enhanced performance using ESP32 Dual-core WIFI enabled microcontroller, MAX30105 optical pulse Oximeter & heart-rate sensor, local display for vitals, USB/5V regulated power supply, Required IOT and telegram for WIFI network component, for sending alert message sensors are used for sensing each health parameter, their and different sensors are used. The positives are low cost and affordable, easy to use, Real-time Monitoring, Remote accessibility, alert message.

Keywords: Smart Health Monitoring System(SHMS), Alert Message, BPM, SpO2, Body Temperature, IOT, health parameters, ESP32, MAX30105

I. INTRODUCTION

Healthcare monitoring plays a vital role in maintaining human well-being, especially for elderly people, patients with chronic diseases, and individuals living in remote areas. Regular monitoring of basic health parameters such as heart rate, blood oxygen level, and body temperature helps in early detection of health abnormalities and prevents serious medical conditions. However, traditional health monitoring methods require frequent hospital visits, medical equipment, and continuous supervision by healthcare professionals, which may not always be feasible affordable. With the rapid growth of Internet of Things (IoT) technology, smart healthcare systems have gained significant attention in recent years. IoT enables real-time data collection, processing, and remote monitoring of health parameters through connected devices. By integrating sensors, microcontrollers, and wireless communication, health data can be monitored continuously and accessed from anywhere using the internet. This project presents an IoT-Based Health Monitoring System using ESP32 and MAX30105, designed to measure and monitor essential health parameters in real time. The proposed system measures Heart Rate (BPM), Blood Oxygen Saturation (SpO_2), and Body Temperature using the MAX30105 optical sensor. The ESP32 microcontroller processes the sensor data and displays the measured values on a 16×2 LCD display for local monitoring. Additionally, the ESP32 connects to a Wi-Fi network and transmits the health data to an IoT platform, enabling remote monitoring through a web or mobile dashboard. The system also incorporates a threshold-based alert mechanism. If any health parameter crosses predefined safe limits, alerts are generated to notify the user, enabling timely awareness and preventive action. The proposed solution is simple, low-cost, and easy to use, making it suitable for home healthcare monitoring and educational demonstrations. By combining embedded systems, sensor technology, and IoT communication, this project demonstrates how modern technology can be applied to improve healthcare accessibility and monitoring efficiency. Although the system is intended for educational and

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demonstration purposes and not for medical diagnosis, it effectively showcases the potential of IoT-based smart healthcare solutions in real-world applications.

II. LITERATURE REVIEW

In recent years, smart health monitoring systems have received significant attention due to the growing demand for remote healthcare services. Researchers have proposed various systems using sensors and mobile applications to continuously monitor patient health conditions and improve medical assistance.

Kusakula (2021) developed an Android-based health monitoring system that uses sensors to collect vital health parameters such as heart rate and body temperature. The collected data is displayed on a mobile application, allowing users to monitor their health remotely. Although the system reduces hospital visits and supports remote monitoring, it does not provide effective real-time alert mechanisms during emergency situations.

Durgadevi et al. (2022) proposed an IoT-based healthcare monitoring system that enables remote tracking of patient health parameters. The system improves healthcare accessibility by allowing doctors to monitor patients from distant locations. However, the system requires complex hardware components and continuous internet connectivity, which increases cost and limits usability for common users.

Alruwaili et al. (2023) introduced a smart health monitoring system using an Android mobile application integrated with IoT technology. The system supports real-time monitoring and health data storage for future analysis. Despite its advanced features, the system faces challenges related to data privacy, security, and higher implementation cost.

Obira and Sinde (2021) designed a sensor-based monitoring system for measuring heartbeat and body temperature, especially for chronic patients. The system helps in early detection of abnormal health conditions and improves patient safety. However, it supports limited health parameters and lacks a well-developed mobile application interface for better user interaction.

Vaishnave et al. (2019) proposed a low-cost health monitoring system focusing on heart rate and temperature monitoring. The system provides alerts during abnormal conditions, improving emergency response. However, the system lacks advanced data visualization features and supports limited functionality.

From the literature review, it is observed that existing systems mainly focus on health parameter monitoring using sensors and mobile applications. However, issues such as high cost, complex hardware, limited alert mechanisms, data security concerns, and lack of user-friendly design still exist. Therefore, there is a need for a simple, cost-effective, and reliable Android-based smart health monitoring system with real-time monitoring and alert functionality. The proposed system aims to overcome these limitations and improve remote healthcare services.

III. PROBLEM STATEMENTS

Many people, especially elderly persons and those with long-term health problems, need regular checking of basic health values like heart rate, oxygen level, and body temperature. However, most existing health monitoring methods require visiting hospitals, using costly medical equipment, or depending on doctors and medical staff. This is not always easy, affordable, or convenient for daily monitoring at home. Also, many systems do not show health values instantly or allow monitoring from a distance. Without real-time monitoring and alerts, health problems may go unnoticed until they become serious. Therefore, there is a need for a simple and low-cost health monitoring system that can easily measure basic health parameters, show results instantly, allow monitoring through the internet, and give alerts when values go beyond safe limits. Such a system should be easy to use, require no medical knowledge, and be suitable for learning, demonstrations, and general health awareness.

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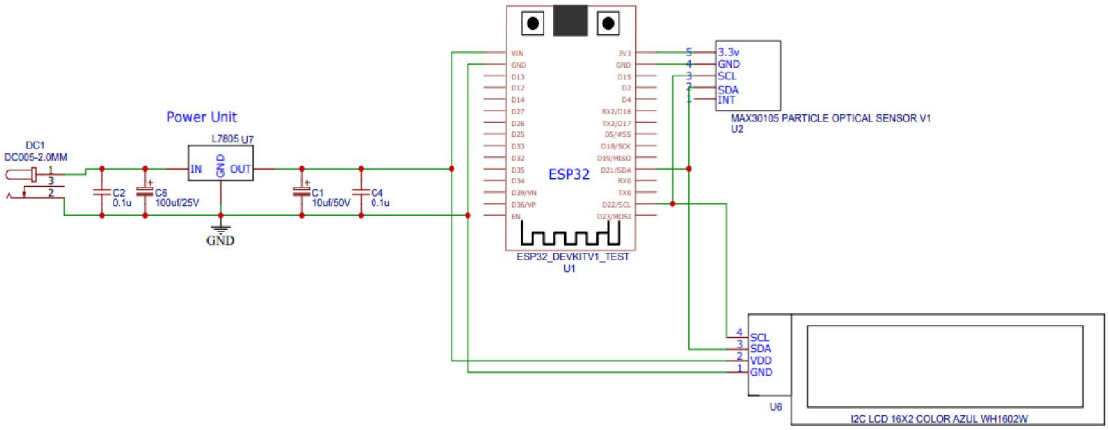
IV. SYSTEM ARCHITECTURE



V. DESIGN OF THE PROJECT

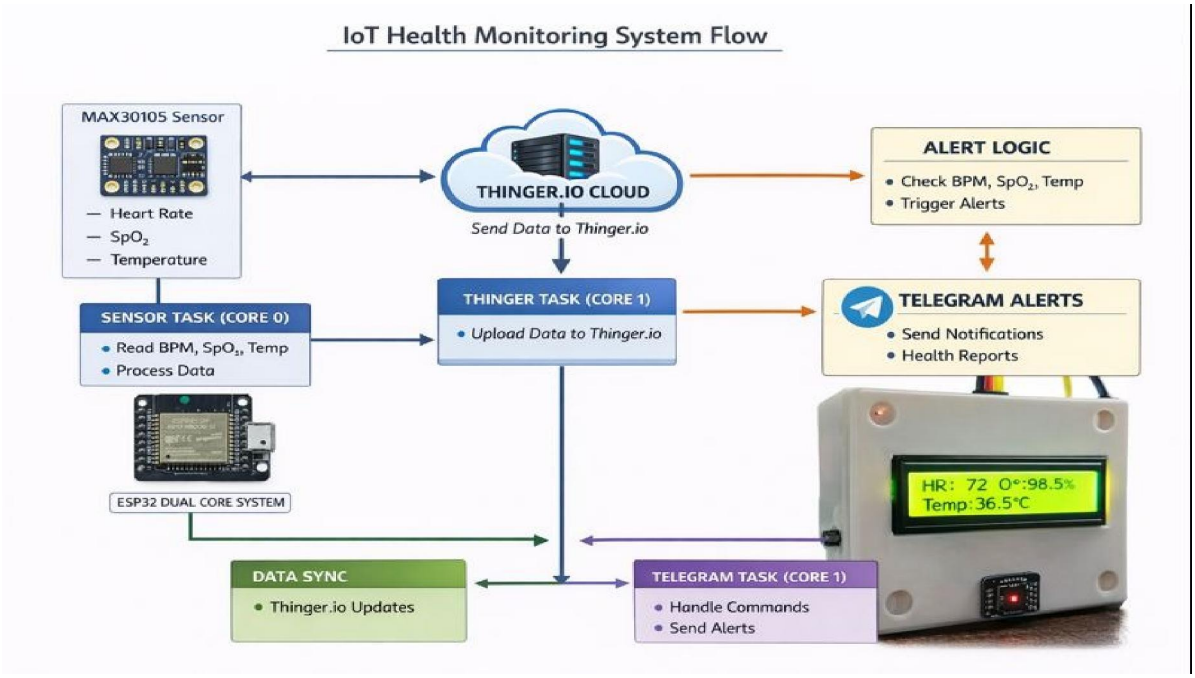


Figure: System flow diagram

VI. DESIGN AND IMPLEMENTATION CONSTRAINTS

There are three major components of the proposed system: sensing unit (hardware), processing and communication unit, and user interface.

6.1 External Interface Requirements

User Interfaces: The system provides a simple local interface using a 16×2 LCD display, which shows real-time health parameters such as heart rate, SpO_2 level, and body temperature. Additionally, users can view health data remotely through a web or mobile-based IoT dashboard connected via Wi-Fi.

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Hardware Interfaces: The system uses an ESP32 microcontroller interfaced with the MAX30105 sensor through I²C communication. The sensor collects physiological data, which is processed by the microcontroller. No complex or medical-grade hardware is required, making the system low-cost and easy to deploy.
Software Interfaces: The software is developed using the Arduino IDE and open-source libraries for sensor data acquisition and processing. The system connects to an IoT platform using standard Wi-Fi protocols to transmit health data for remote monitoring.
Communication Interfaces: Wireless communication is achieved using the built-in Wi-Fi module of the ESP32. Health data is transmitted securely over the internet using standard communication protocols. A stable internet connection is required for real-time remote monitoring.

6.2 Other Non-Functional Requirements

Performance Requirements:
The system is designed to provide near real-time monitoring of health parameters with minimal delay. Sensor readings are updated continuously and displayed instantly on the LCD.

- Safety Requirements: The system poses no major safety risks as it operates at low voltage levels. It is designed for educational and demonstration purposes only and does not interfere with medical devices.
- Security Requirements: Basic security is ensured through Wi-Fi authentication. However, advanced data encryption and authentication mechanisms are limited due to hardware and processing constraints.

Software Quality Attributes:

- Availability: The system remains operational as long as power and network connectivity are available.
- Reliability: Consistent sensor readings are obtained under proper usage conditions, such as correct finger placement and minimal movement.

6.3 Software and Hardware Requirements

Software Requirements:

- Programming Language: Embedded C / Arduino
- Development Tool: Arduino IDE
- Libraries: MAX30105 sensor library, Wi-Fi library
- IoT Platform: Web or Mobile Dashboard

Hardware Requirements:

- ESP32 Microcontroller
- MAX30105 Pulse Oximeter and Heart Rate Sensor
- 16×2 LCD Display
- Power Supply
- Wi-Fi Network

VII. TEST CASES

In this phase, all the modules of the IoT-Based Health Monitoring System using ESP32 and MAX30105 are integrated and tested to ensure proper functionality of the system. Testing is carried out at different levels to verify that each module works correctly and meets the expected requirements. The testing process helps identify errors, improve reliability, and ensure smooth system operation.
The following testing techniques are used in this project:

- Black Box Testing
- Integration Testing
- Scenario-Based Testing

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Requirement Gathering and Analysis

In this phase, the basic requirements of the IoT-Based Health Monitoring System are identified. The system is designed to monitor heart rate, SpO_2, and body temperature using sensors. The need for real-time monitoring, local display, remote access through the internet, and alert generation is analyzed to ensure the system is simple, low-cost, and easy to use.

System Design

During the system design phase, the overall architecture of the system is planned. The ESP32 microcontroller is used for data processing and Wi-Fi communication, while the MAX30105 sensor measures health parameters. An LCD is included for local display, and the system is designed to ensure smooth data flow and reliable performance.

Implementation

Hardware components are assembled and connected. Sensors, controllers, and other devices are programmed.
All components are made to work together as a single system.

Deployment

The system is tested to ensure correct functioning. After successful testing, the system is installed at the required location. The system is made ready for actual use.

Maintenance

Sensors are checked regularly for accuracy. Software is updated when required. Minor faults and issues are identified and fixed. Regular maintenance ensures smooth and reliable operation.

Phases	Cost/hours(□)	Hours	Cost Estimation(□)
Requirement Gathering	200	6	1200
System Design	200	8	1600
Code Planning	200	6	1200
Code Development	200	12	2400
Hardware Integration	200	7	1400
Testing and Debugging	200	6	1200
Documentation and Report	200	5	1000
Total Cost			□10,000

Cost Estimation

Risk Identification:

The Smart Health Monitoring System using an Android mobile application involves several potential risks that may affect its development and performance. One major risk is related to sensor failure, where sensors may produce incorrect readings due to hardware faults, improper calibration, or environmental conditions. This can lead to inaccurate health data and false alerts, which may affect user trust in the system.

Another significant risk is connectivity issues, as the system depends on Bluetooth or internet connectivity to transfer data from sensors to the mobile application. Network interruptions or weak signals can result in delayed or missing health data, reducing the effectiveness of real-time monitoring. Data accuracy is also a concern, as improper data processing may cause incorrect health values to be displayed to users.

Risk Analysis:

The risks for the project are analyzed considering constraints related to time, quality, and system performance.

ID	Risk Description	Probability	Impact
1	Sensor malfunction or incorrect reading	Medium	High
2	Network or Connectivity Failure	Medium	Medium
3	Security and Privacy Breach	Low	Very High
4	Battery or Power Failure	Medium	Medium

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VIII. OVERVIEW OF RISK MITIGATION, MONITORING, MANAGEMENT

The Risk Mitigation, Monitoring, and Management (RMMM) process is applied to identify and control potential risks associated with the Smart Healthcare Monitoring System. One of the major risks identified is internet connectivity issues, which can affect application access and real-time health data transmission. This risk belongs to the development environment category and originates from the web platform used by the healthcare monitoring application. The probability of occurrence is low, while the impact is medium, as temporary network failures may delay data access. To address this risk, it is managed by the administrator through continuous server monitoring and ensuring a stable internet connection. The risk has been monitored regularly, and appropriate strategies are implemented to minimize its effect, ensuring reliable system performance.

Software Requirement Specification:

System Implementation Software Required:

- Arduino IDE – Used for writing, compiling, and uploading code to the ESP32
- ESP32 Board Package – Required to program and manage ESP32 hardware
- MAX30105 Sensor Library – For reading heart rate, SpO_2, and temperature data
- FreeRTOS – For multitasking and parallel task execution
- IoT Cloud Platform (Thinger.io) – For remote data visualization and monitoring
- Telegram Bot API – For sending alerts and health reports
- Wi-Fi Library – For wireless network connectivity

Product Scope:

The Smart Healthcare Monitoring System is designed to continuously monitor essential health parameters such as heart rate (BPM), blood oxygen saturation (SpO_2), and body temperature using sensor-based technology. The system collects real-time data through the MAX30105 sensor and processes it using the ESP32 microcontroller. The measured values are displayed locally on an LCD screen, allowing immediate observation by the user.

In addition to local monitoring, the system uploads health data to an IoT cloud platform, enabling remote access for caregivers, doctors, or family members from any location with internet connectivity. The software also supports alert and report notifications through Telegram when abnormal health conditions are detected or when requested by the user.

The product supports multitasking using the ESP32's dual-core FreeRTOS environment, ensuring smooth operation of sensing, data processing, display updates, cloud communication, and alert handling simultaneously.

IX. RESULT

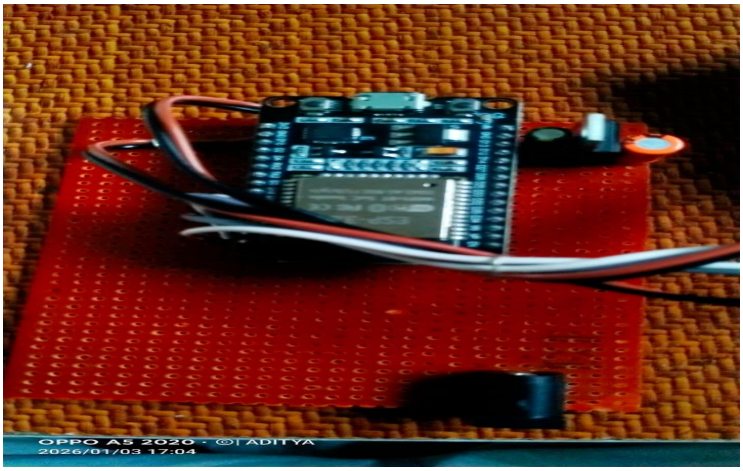

Image: ESP32 Microcontroller

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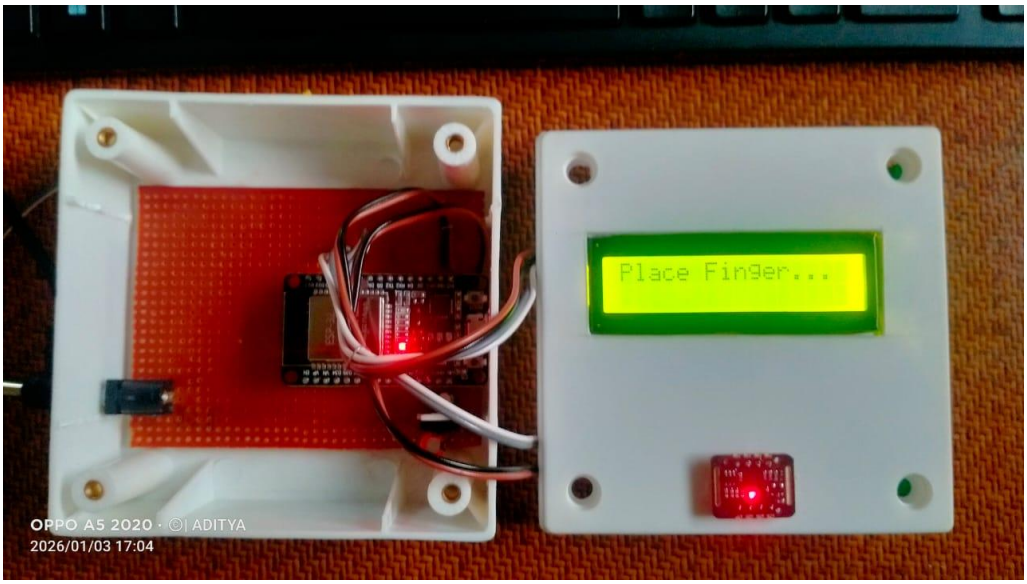

Image: LCD display

Image: LCD Display

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Image: Fingerprint sensor module

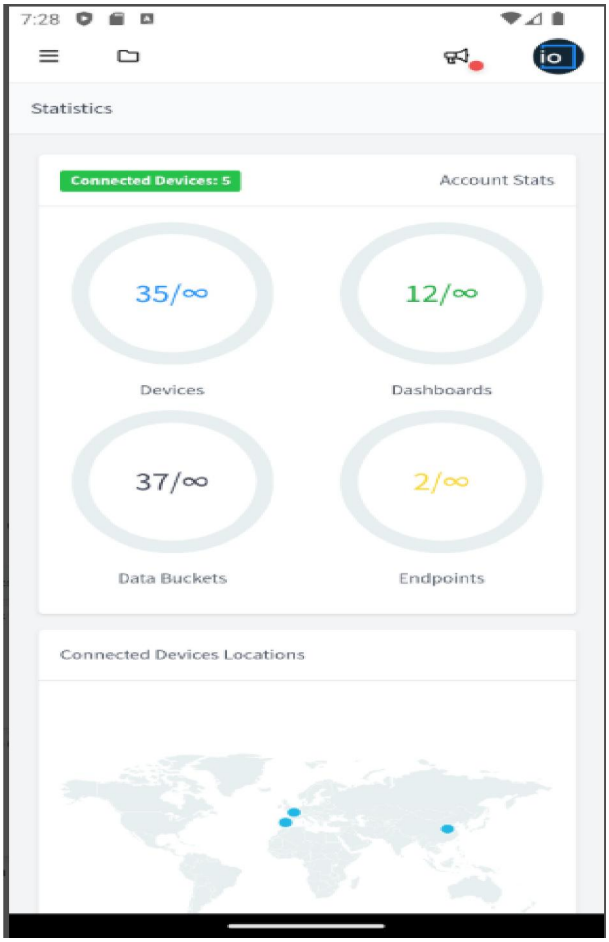

Image: Homepage

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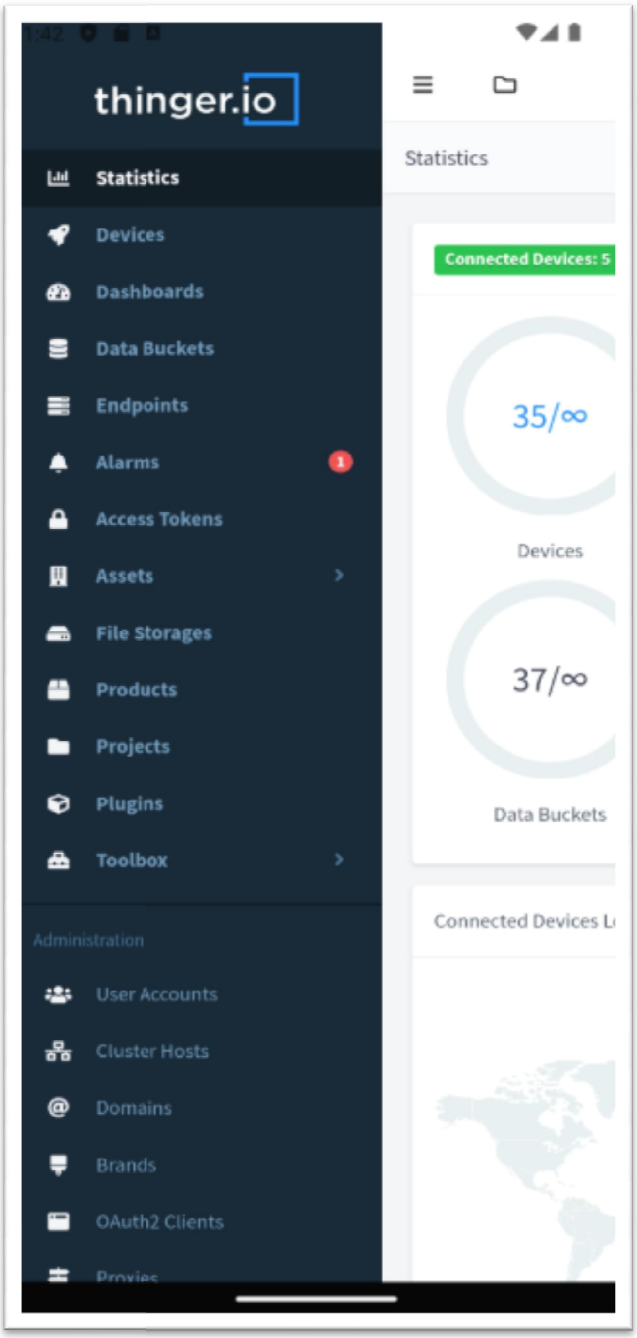

Image: Menu

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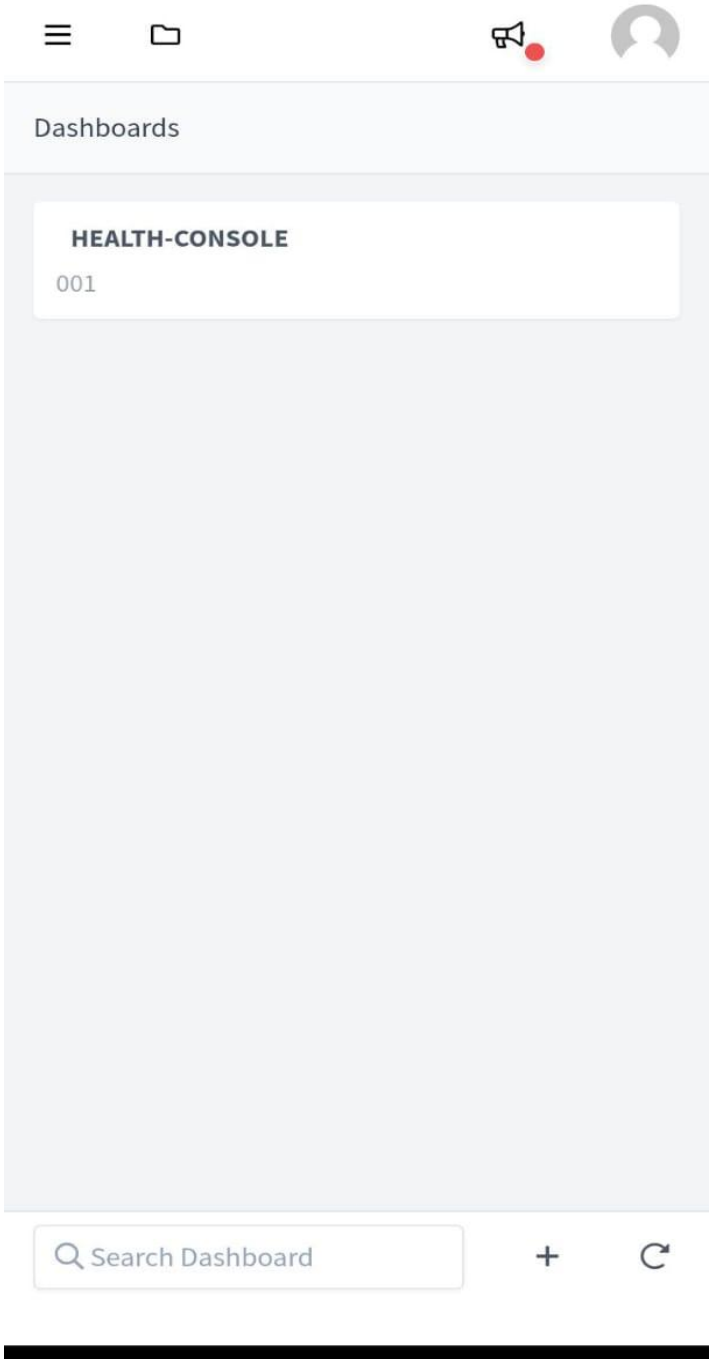

Image: Dashboard

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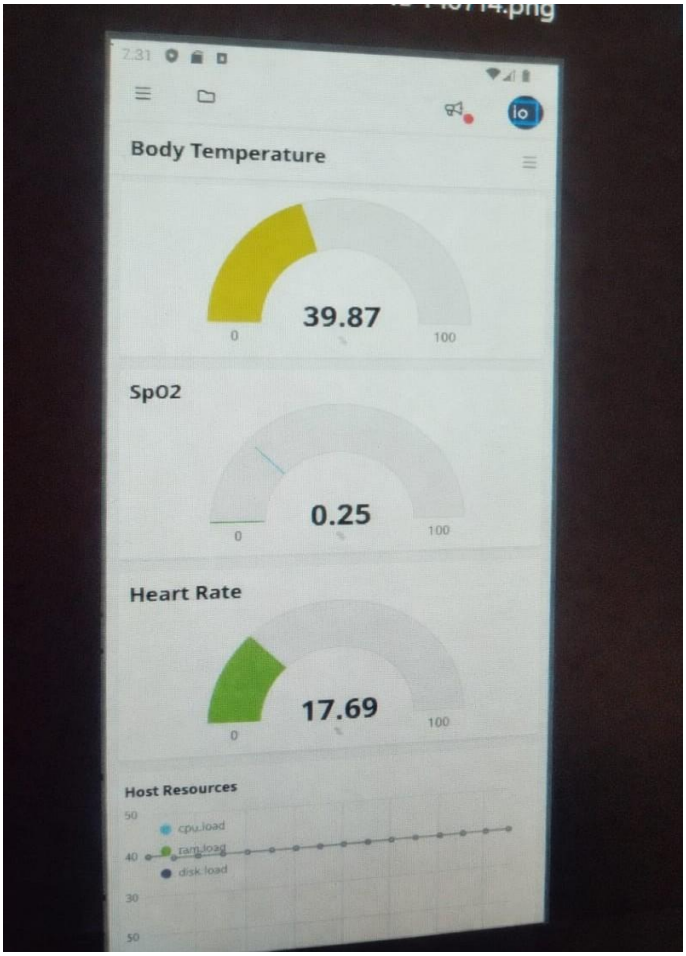

Image: Healthcare Monitoring Dashboard

X. CONCLUSION

The Smart Healthcare Monitoring System successfully demonstrates an effective IoT-based solution for real-time monitoring of vital health parameters such as heart rate, blood oxygen saturation (SpO_2), and body temperature. By using the ESP32 microcontroller and MAX30105 sensor, the system provides accurate data collection, local display, and remote access through an IoT cloud platform. The integration of Telegram alerts enables timely notifications, improving health awareness and response. The project highlights the practical application of embedded systems, IoT, and real-time multitasking using FreeRTOS in healthcare monitoring. Overall, this system proves to be a low-cost, reliable, and user-friendly solution for educational and demonstration purposes, showing the potential of smart technologies in enhancing healthcare monitoring and remote health management.

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