WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Smart Health Monitoring System Using IoT and Cloud Technologies

[1] Sanskar Patil, [2] Samarth Sawant, [3] Rishikesh Patil, [4] Harsh Singh, [5] Prof. Kavita Rathi

[1 2 3 4 5] Manjara Charitable Trust's Rajiv Gandhi Institute of Technology, Mumbai Electronics and Telecommunication Department Juhu Versova Link Road, Andheri (W), Mumbai - 400053, India

ABSTRACT—

Traditional ICU monitoring systems often rely on manual observations, which can lead to delayed responses in emergencies. This paper proposes a Smart ICU Health Monitor- ing System that integrates IoT sensors and cloud technologies for continuous, real-time patient monitoring. The system utilizes an Arduino Mega 2560 to collect ECG, SpO2, temperature, and humidity readings, which are transmitted via ESP8266 to a Node.js backend. Redis is used for caching live data, MongoDB stores historical data, and a React.js frontend visualizes the data in real-time. Docker is used for Redis deployment, ensuring scal- able and portable system architecture. Performance evaluations indicate improved responsiveness and real-time alert generation, enhancing patient care management.

Index Terms—Smart ICU, IoT, Arduino Mega, ESP8266, Node.js, React.js, Redis, MongoDB, Real-Time Monitoring, Docker.

Introduction

Effective ICU management requires prompt detection of patient health anomalies. Traditional methods of manual ob- servation can lead to delays and errors in critical situations. With the rise of IoT and cloud computing technologies, automated, real-time remote patient monitoring systems have been developed. This paper presents a Smart ICU system that utilizes IoT sensors for continuous monitoring and cloud-based infrastructure for real-time data processing and visualization. The proposed system aims to enhance patient care by provid- ing healthcare professionals with accurate, real-time data to make timely and informed decisions.

Literature Survey

Various researchers have explored IoT-based healthcare sys- tems:

- Al Alkeem et al. [1] proposed a secure and energy- efficient healthcare system leveraging Cloud of Things (CoT) for remote monitoring.
- Kim et al. [2] focused on interference issues in wireless body area networks (WBANs) for telemonitoring and provided solutions for efficient coexistence with Wi-Fi.
- Baig and Gholamhosseini [3] analyzed key design strate- gies for smart health monitoring devices, discussing com- ponents like sensors and communication protocols.
- Riazulislam et al. [4] reviewed IoT's transformative role in healthcare, from remote monitoring to predictive ana- lytics.
- Zhang et al. [5] proposed a cloud-based real-time health monitoring system integrating wearable devices for pa- tient vital tracking.
- Garg et al. [6] implemented a wearable IoT health monitoring system for real-time alerts to improve patient safety.

This work builds on these concepts by integrating real- time sensor data with cloud-based storage and dynamic web dashboards for comprehensive ICU health monitoring.

System Model

The system consists of the following components:

- **Sensing Unit:** Arduino Mega 2560 with ECG (AD8232), SpO2 (MAX30100), and DHT11 (temperature and hu- midity) sensors for real-time health data collection.
- **Transmission Unit:** ESP8266 Wi-Fi module for trans- mitting sensor data to the backend server via wireless communication.
- **Processing Unit:** Node.js backend server that handles data caching with Redis and storage with MongoDB. The backend is designed for scalability, allowing efficient processing and storage of sensor data.
- **Display Unit:** A React.js frontend that visualizes patient vitals and provides real-time alerts if sensor readings exceed predefined thresholds.

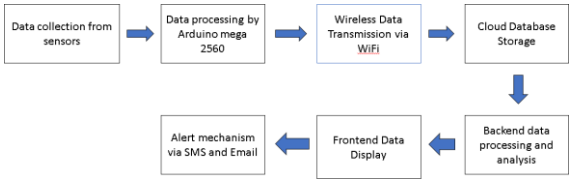

Fig. 1. Smart ICU System Architecture

Proposed Methodology

Sensor Parameters and Thresholds

The following table lists the monitoring parameters and critical thresholds for sensor readings:

Performance Evaluation

Backend Response Time Analysis

The backend server consistently achieved a response time of under 300 milliseconds even under high load conditions. This low latency is crucial for real-time health monitoring, ensuring that alerts are promptly triggered without delay.

Sensor	**Monitoring Details**
Temperature (DHT11)	**Body Temp: 36.1–37.2°C** **Alert: < 35.5°C or > 38°C**
Humidity (DHT11)	**Room Humidity: 30–60% RH** **Alert: < 25% or > 70%**

Data Collection and Transmission

Sensor readings are captured every second and sent via HTTP/WebSocket protocols through the ESP8266. This en- sures that the data reaches the backend server with minimal delay, enabling timely monitoring and intervention.

Backend Processing

The Node.js backend processes incoming sensor data and uses Redis for caching live data. MongoDB is employed for storing historical data, enabling long-term access and analysis. Redis allows for fast retrieval of real-time data, while MongoDB ensures the persistence of sensor readings for further analysis.

Frontend Dashboard

The React.js frontend dynamically visualizes patient vitals in real-time. It provides healthcare providers with a compre- hensive view of the monitored parameters (heart rate, SpO2, temperature, humidity) and triggers alerts if any readings cross the predefined thresholds.

Dockerized Deployment

The Redis server is containerized using Docker, ensuring the system is easily scalable and portable across different plat- forms. This approach simplifies deployment and configuration management, allowing the system to scale as the number of monitored patients and sensors grows.

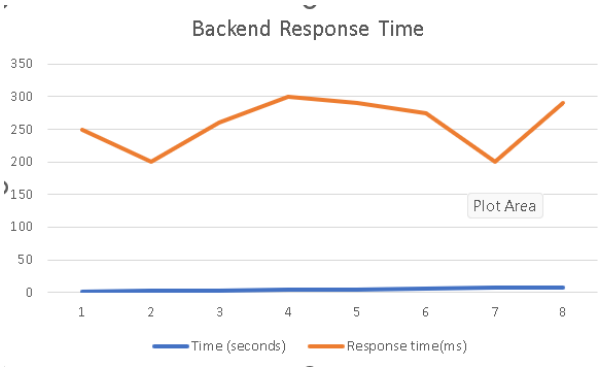

Fig. 2. Backend Response Time vs Time

MongoDB Write Speed Analysis

The MongoDB database consistently handled 1500 sen- sor records per minute under normal operating conditions, demonstrating its capability to manage large volumes of data efficiently.

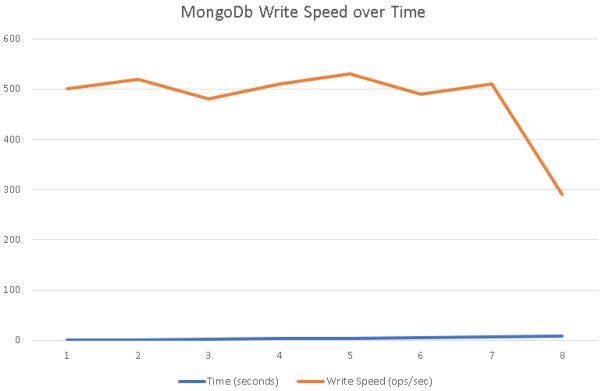

Fig. 3. MongoDB Write Speed over Time

C. System Metrics Summary

Algorithm 1 Real-Time Monitoring and Alert System

1: Initialize sensors and Wi-Fi connection.
2: **while** Monitoring active **do**
3: Capture sensor readings.
4: Transmit data to Node.js backend.
5: Update Redis cache.
6: **if** Any reading crosses threshold **then**
7: Trigger alert notification.
8: **end if**
9: **end while**

The following table summarizes key system performance metrics:

TABLE III
SYSTEM PERFORMANCE SUMMARY

Metric	Result
Sensor Reading Rate	**1Hz**
Backend Response Time	**< 300 ms**
Frontend Update Delay	**< 500 ms**
Redis Access Time	**< 5 ms**
MongoDB Write Speed	**~1500 records/min**

Conclusion and Future Work

This paper presents a Smart ICU Health Monitoring System leveraging IoT sensors and cloud technologies. The system provides real-time patient monitoring, allowing healthcare providers to receive instant alerts based on critical sensor thresholds. The use of Docker for Redis deployment enhances scalability and portability, while the integration of MongoDB ensures efficient storage of historical data.

Future work will focus on:

- Integrating predictive analytics using machine learning models to anticipate health anomalies.
- Adding mobile application access for healthcare providers to monitor patients remotely.
- Expanding sensor capabilities to include blood pressure and respiration rate monitoring for more comprehensive health tracking.
- Optimizing communication security, battery efficiency, and enabling cross-hospital data sharing will also be key areas of future development.

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