# Real-time Health Monitoring Computer System Based on Internet of Medical Things

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#### Abstract

In the era of advanced technology and connectivity, the IoT has revolutionized various realms, including healthcare. This research contributes to the field of intelligent information computer systems and technologies, specifically in the domain of applied information technologies in medicine. This paper presents a health monitoring system development exploiting the Internet of Medical Things (IoMT). The system is built upon the ESP32 platform, integrated with sensors for oxygen saturation, pulse and temperature measurements. Information collected by the ESP32 module is transmitted to IoT cloud-based service for storage, data visualization, and future analysis. The proposed computer system addresses the growing demand for continuous health monitoring, especially for elderly individuals, and provides a solution for remote healthcare management. It focuses to bridge the gap among traditional healthcare and the capabilities offered by IoMT, providing real-time observations of a person's health status. The integration of ESP32 platform and specialized sensors facilitates the collection of vital health data, which can be crucial in identifying health anomalies and improving healthcare outcomes. The results demonstrate the feasibility and effectiveness of an IoMT-based solution for realtime health monitoring, accelerating the way for boosted healthcare services in an increasingly connected world.

#### Keywords

Internet of Medical Things, computer system, IoMT, ESP32, sensors, real-time monitoring, healthcare.

# 1. Introduction

The rapid advancement of information technology and the connected devices propagation have ushered in a new era of innovation, particularly in the healthcare realm. The Internet of Things (IoT) [1] has emerged as a transformative force, enabling the development of intelligent systems that have the potential to revolutionize how we monitor and manage health. In this context, the Internet of Medical Things (IoMT) [2] represents a specialized branch of IoT tailored for healthcare applications, offering unprecedented opportunities for real-time health monitoring and remote healthcare management.

As the global population ages, the demand for continuous health monitoring and personalized healthcare solutions has grown exponentially. Elderly individuals, in particular, often require vigilant oversight and timely intervention to address health concerns. However, the majority of family members and caregivers find themselves constrained by the demands of their daily routines, limiting their ability to provide constant, in-person care. This challenge has been further exacerbated by the constraints imposed by quarantine measures and the need for social distancing in recent times.

In recent years, the medicine development has been characterized by the active introduction of information technology. Automated computer systems are being designed for use in medical institutions. To address these evolving healthcare needs, the development of an effective and reliable

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system for real-time health monitoring becomes relevant. Such a system should not only provide continuous insights into a person's health status but also enable healthcare professionals and caregivers to remotely access and analyze vital health data, facilitating early diagnosis. The IoMT holds the promise of fulfilling these requirements by seamlessly integrating connectivity technologies, medical devices and sensors [3].

The primary goal of this work is to design and implement a cost-effective and accurate health monitoring system (HMS) based on IoMT. This system aims to provide vital signs real-time monitoring, including temperature and pulse oximetry, for patients with chronic illnesses and individuals seeking improved health management. The system integrates IoT devices with data visualization means to provide remote patient monitoring by healthcare specialists. Ultimately, the goal is to enhance the patient care efficiency, decrease healthcare costs and refine overall healthcare outcomes through the seamless integration of IoT and sensor technologies.

#### 2. Related works

The development of real-time HMSs, especially those leveraging the IoMT, has gained great attention in recent years. A variety of IoMT-based HMSs have been proposed in the literature. These systems typically incorporate a sensors network and medical devices to accumulate and transmit health data. Cloud computing plays a pivotal role in health data storage, analysis and accessibility. Numerous cloud-based healthcare services have emerged to handle the vast data amount generated by HMSs. These solutions enable secure data storage and real-time information sharing with healthcare providers.

Researchers have explored diverse IoMT architectures and sensor combinations to cater to specific healthcare needs. Several key contributions in the field of HMSs were reviewed in this section. These studies predominantly revolved around the integration of Internet of Things [4] and sensor technologies for remote patient monitoring [5].

The paper [6] introduces an architecture for monitoring elderly patients using the IoMT. It addresses the need for home-based diagnostic and monitoring systems for the elderly, emphasizing data processing at fog, edge or cloud levels based on workload and confidentiality. While authors offer potential solutions for continuous monitoring and data security through blockchain and AI, it leaves unresolved issues regarding usability and long-term viability, which need further consideration for realworld healthcare implementation.

The article [7] presents an intelligent IoMT-based system designed for real-time patient monitoring. While this system boasts advantages in terms of cost, accuracy, portability, and real-time responsiveness, it lacks a comprehensive discussion of the challenges or limitations faced during its development and implementation. Further solving of potential scalability and usability issues in diverse healthcare settings would enhance the understanding of its practical applicability.

The paper [3] reviews the implementation of IoMT-based remote HMS through wearable sensors, with a focus on diabetic patients. It emphasizes the importance of IoMT in the future of healthcare and highlights the monitoring of vital signs, including glucose levels.

The authors in [8] present an IoT-based HMS designed to continuously track the health function status of elderly individuals living alone. The system employs sensor technology and machine learning classifiers to assess both physiological and behavioral indicators. Although the paper discusses the potential for real-time monitoring, it doesn't provide insights into the practical challenges and considerations when implementing the system in real-world IoT environments.

Research published in [9] focuses on an IoT-based HMS using a wearable glove to detect and analyze heart rate and EEG for stroke management. While the study discusses the reduction in complexity for healthcare providers, it would benefit from a more comprehensive discussion of clinical validation and its impact on stroke prevention and management.

The paper [10] delves into the emerging field of the IoMT and its potential applications in health and sports data collection. It focuses on the use of temperature and acceleration sensors to gather information related to human health and physical activity, with an emphasis on modeling and data analysis. While the article presents promising findings, it highlights the complexity of the IoMT system and the need for further research to address architectural challenges and ensure reliable data acquisition. In [11] the design of a HMS based on IoT has been described. The paper emphasizes the potential of IoT in revolutionizing healthcare. The system is designed to collect and process health-related data from various sensors, allowing for real-time monitoring and prediction of health conditions. While the article presents a promising prototype, it does not delve into the challenges and limitations that may arise during the practical implementation of such a system, particularly in terms of scalability, and user adoption. Further research and development are needed to address these issues and ensure the system's effectiveness and reliability.

The paper [12] introduces an intelligent system based on the IoT for remote health monitoring. While the system presents benefits such as real-time monitoring and instant notifications to healthcare professionals, it doesn't delve deeply into potential challenges and issues that may arise during the widespread implementation of such a system. The system's potential limitations, such as sensor accuracy and reliability, are not discussed in the paper.

In [13] has presented a remote intelligent medical HMS based on IoT for real-time acquisition and storage of patient's physiological parameters. While the system offers benefits in enhanced medical services and remote patient monitoring, further research and practical implementation are needed to ensure the system's effectiveness and its ability to meet the complex requirements of remote medical monitoring.

The research [14] discusses the architecture of a wearable HMS based on IoT technology, highlighting its potential benefits in monitoring and protecting the health of aging populations. However, the paper does not delve into the specific challenges and limitations of implementing such a system. It briefly mentions difficulties related to mastering and predicting health conditions but does not provide in-depth solutions or considerations for addressing these challenges.

The paper [15] presents a monitoring system for vital signs, particularly focusing on sleep quality and heart rate changes, catering to the elderly, sub-health individuals, and those with insomnia. The system employs IoT devices to collect information and transmit it to a cloud platform for analysis and monitoring.

The article [16] addresses the need for cost-efficient HMSs based on IoT and big data technology. It acknowledges the high cost associated with implementing IoT-based healthcare devices on a large scale and the challenge of efficiently managing the information generated by these devices. The proposed design offers a holistic approach that includes affordable sensing hardware and a data management platform based on big data technology. While the paper presents a promising solution to reduce costs in healthcare monitoring, it doesn't deeply explore potential challenges related to data security, which are critical considerations in healthcare IoT applications.

The authors in [17] introduce a visualization system based on the IoMT, aiming to help healthcare professionals monitor patient health condition in real-time. The system's user satisfaction is assessed, showing positive results in terms of usability and user-friendliness. However, the article does not provide technical details regarding the technology used and the testing methodology.

In [18] has proposed the development of a remote HMS based on IoT and the MQTT protocol. It aims to provide accurate real-time vital sign data to healthcare specialists via a web interface. While the study presents a promising solution for remote patient monitoring and highlights the importance of security and privacy, it doesn't delve deeply into potential issues related to the interoperability with existing healthcare systems.

Many researchers have recognized the potential of IoT in transforming healthcare by enabling real-time data gathering and analysis [19]. Some notable works highlighted the importance of data visualization tools [20–22] to aid healthcare professionals in monitoring and diagnosing patients. These related works paved the way for this research, emphasizing the need for cost-efficient, accurate and user-friendly health monitoring solutions, which are addressed through the proposed system.

While these related works offer valuable insights into the development of HMSs, this research distinguishes itself by focusing on the integration of ESP32 platform and specialized sensors for low-cost real-time health monitoring. Additionally, we emphasize the practical application of our system for remote healthcare management, early anomaly detection, and scalability, contributing to the broader landscape of intelligent information technologies and computerized systems in medicine.

### 3. System structure

The designed system leverages the capabilities of the ESP32 platform, coupled with specialized sensors for pulse, oxygen saturation and temperature measurements. The designed HMS is a comprehensive structure that seamlessly integrates various components to enable real-time monitoring and data analysis. The key components of this system include: ESP32 module, MAX30205 temperature sensor, MAX30102 pulse oximeter and heart rate sensor, OLED display, IoT cloud server, laptop, computer or smartphone.

The selection of appropriate sensors, such as the MAX30205 and MAX30102 used in the designed system, was emphasized for accurate and reliable data acquisition. MAX30205 temperature sensor provides precise measurements. It is crucial for monitoring a patient's body temperature, especially for detecting fever or abnormal temperature fluctuations. MAX30102 sensor is responsible for monitoring both pulse rate and blood oxygen saturation levels. It is a valuable component for assessing a patient's cardiovascular health and oxygen levels in the blood.

ESP32-based module serves as the central hub of the system. It facilitates communication with the sensors via the I2C interface and connects to the IoT cloud server via a WiFi interface. OLED display provides a clear and user-friendly interface for displaying vital signs data in real-time. It enhances the user experience by making data easily accessible and readable.

The IoT cloud server acts as the central data repository. It receives data from the ESP32 module via WiFi and stores it securely in the cloud. This server also hosts data processing algorithms and analysis tools. The proposed system architecture for the designed HMS based on the IoMT concept is shown in Figure 1.

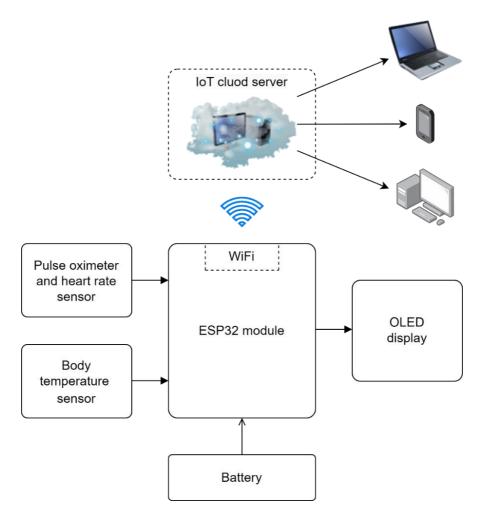


Figure 1: The proposed HMS architecture

The system follows this structure: The MAX30205 and MAX30102 sensors continuously collect vital signs data, including temperature, pulse rate, and blood oxygen saturation. This information is transmitted to the ESP32 module via the I2C interface. The ESP32 module processes the data, displays it in real-time on the OLED display and securely sends it to the IoT cloud server via WiFi. Healthcare professionals and patients can access the data through laptops, computers or smartphones, using user-friendly interfaces. These devices serve as user interfaces, allowing users to monitor vital signs and access real-time health data. The IoT cloud server hosts data analysis algorithms to provide real-time insights into a patient's health status.

Overall, this structured system enables efficient remote patient monitoring, promotes early detection of health irregularities, and enhances healthcare services through IoT technology and data analysis.

## 4. System implementation

# 4.1. Hardware design

An electrical scheme of the designed health monitoring module for the proposed system is shown in Figure 2.

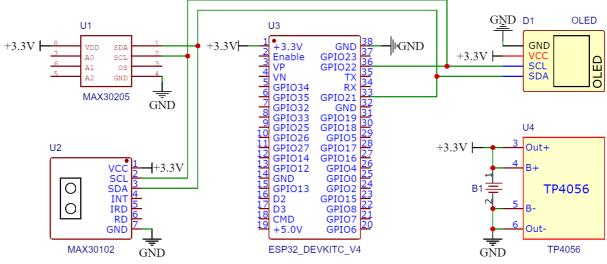


Figure 2: Electrical scheme of the health monitoring module

In this schematic the MAX30205 temperature sensor (U1) is responsible for accurately measuring body temperature. The MAX30102 sensor (U2) concurrently monitors pulse rate and blood oxygen saturation levels. Both U1 and U2 are connected to the ESP32 module (U3) through the I2C communication protocol, enabling seamless data transmission between the sensors and the microcontroller.

The ESP32 module acts as the central processing unit, collecting, processing, and displaying the health data obtained from U1 and U2 on the OLED display (D1). It transmits the collected data wirelessly to an IoT cloud server.

To ensure continuous operation, the system is powered by a rechargeable battery (B1), providing a portable and self-contained solution for health monitoring. The TP4056 module (U4) is responsible for efficiently charging and managing the Li-Ion battery B1 used to power the system. It ensures that the battery remains in good condition and provides a stable power source for the components. This schematic diagram represents a basic setup for monitoring key health parameters, making it a versatile platform for various healthcare and wellness applications.

The hardware prototype of the HMS based on the described scheme is illustrated in the Figure 3. The hardware components of the prototype include the ESP32 DEVKITV1 module, MAX30205 and MAX30102 sensors, and an OLED display. They are arranged on a breadboard and connected using wires. The OLED display shows information related to pulse rate, oxygen saturation, and temperature.

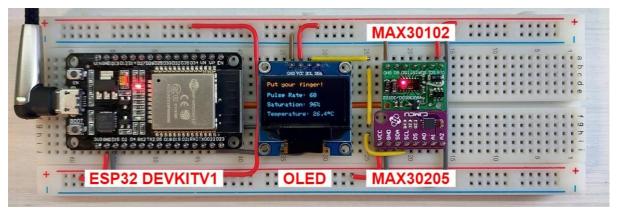


Figure 3: The hardware implementation of the health monitoring module

The ESP32 DEVKITV1 module is a versatile development board that integrates an ESP32-D0WDQ6 microcontroller, and various GPIO pins for extended functionality. The ESP32 microcontroller provides Wi-Fi and Bluetooth connectivity, making it suitable for wireless data transmission in health monitoring applications. It also features a micro USB port for programming and power supply.

The MAX30205 sensor is a vital component in the HMS, providing accurate temperature measurements. With an impressive accuracy of 0.1°C within the critical temperature range of 37°C to 39°C, this sensor ensures precise and reliable monitoring of a patient's body temperature. Its I2C interface seamlessly integrates with the ESP32 module, making it an ideal choice for health monitoring applications where temperature accuracy is paramount.

The MAX30102 sensor plays a pivotal role in our HMS, focusing on pulse and blood oxygen saturation (SpO<sub>2</sub>) measurements. This sensor boasts exceptional accuracy, making it a reliable choice for healthcare applications. Its ability to provide precise readings for pulse rate and SpO<sub>2</sub> levels ensures the system's reliability and effectiveness. The MAX30102 sensor is integrated into the system via the I2C interface.

The OLED display is responsible for real-time visualization of vital signs, making it a robust choice for the designed HMSs.

# 4.2. Software development

The software for the designed HMS plays a crucial role in collecting, processing, and presenting vital signs data efficiently. The software for the microcontroller of the designed system was developed using the Wiring programming language, which is derived from C++, within the Arduino IDE. The code fragment for ESP32, which is responsible for calculating the heart rate and processing the data obtained from the MAX30102 sensor is shown in Figure 4.

```
152
       long irValue = max30102Sensor.getIR();
153
       if (checkForBeat(irValue) == true) {
154
         long delta = millis() - lastBeat;
155
         lastBeat = millis();
156
         beatsPerMinute = 60 / (delta / 1000.0);
157
         if (beatsPerMinute < 255 && beatsPerMinute > 20) {
158
           rates[rateSpot++] = (byte)beatsPerMinute; // Store this reading in the array
159
           rateSpot %= RATE SIZE; // Wrap variable
160
           //Take average of readings
161
           beatAvg = 0;
162
           for (byte x = 0 ; x < RATE SIZE ; x++)
163
           beatAvg += rates[x];
164
           beatAvg /= RATE SIZE;
165
         3
166
```

Figure 4: Wiring code fragment for ESP32

The software for the ESP32 microcontroller interfaces with the MAX30205 temperature sensor and the MAX30102 pulse oximeter sensor via the I2C protocol. It collects real-time data from these sensors. Once the data is collected, the software processes it to ensure accuracy and reliability. This includes error checking and data validation to filter out any anomalies or outliers. The system's user interface is displayed on the OLED display. It provides real-time visualizations of vital signs data, making it accessible to healthcare professionals and patients.

The ESP32 module connects to the IoT cloud server via a WiFi interface. The software manages the secure transmission of vital signs data to the cloud server, where it is stored for further analysis and access from authorized devices. The cloud-based component of the software manages the reception, storage, and retrieval of patient data. It includes database management, security measures, and data analytics capabilities to process incoming data efficiently.

The monitoring results are transmitted to the ThingSpeak cloud-based IoT platform, where they are displayed in real-time as graphical representations. Additionally, the collected data is stored for an entire year, providing a comprehensive historical record. Users have the capability to export the data for further analysis and leverage MATLAB tools for in-depth data analytics.

ThingSpeak is a robust IoT platform that offers various features and functionalities, making it an ideal choice for this HMS. Some of its valuable capabilities comprise real-time data visualization through customizable charts and graphs, data storage with extended retention periods, data export options, and compatibility with MATLAB for advanced data analysis. ThingSpeak simplifies IoT data management, enabling users to effortlessly monitor, analyze, and visualize information from the connected device in a user-friendly and accessible manner.

In the event of critical health conditions or anomalies in vital signs data, the software can generate alerts and notifications. These notifications can be sent to healthcare providers' devices or directly to patients, enabling timely intervention.

The software for the HMS is developed to be user-friendly, secure, and capable of handling realtime data processing and transmission. It facilitates effective healthcare monitoring, enhances patient care and supports in making informed decisions.

### 5. Experimental results and discussion

Figure 5 represents the setup of the designed system with a patient's finger is placed on the sensors that are located side by side. The sensors integrated into the system, including the MAX30102 and the MAX30205, consistently provided accurate and reliable health parameter measurements. As a result of this interaction, the OLED display displays the measured health parameters, including pulse rate, blood oxygen saturation level and body temperature. This image visually demonstrates the functionality of the HMS and how it captures and displays real-time health data when a finger is placed on the sensors. The experimental results are demonstrated a high degree of precision in capturing the vital health data.

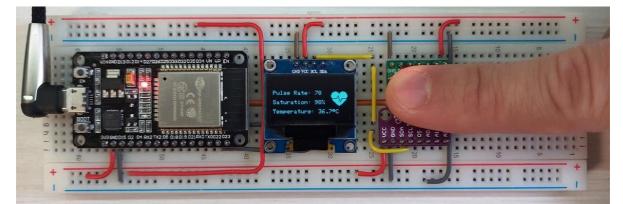


Figure 5: Health parameter measurement process using the developed system

The ESP32 microcontroller effectively accumulated and transmitted health data to the cloud-based platform ThingSpeak in real-time. The measurement results of vital health data are shown in Figure 6.

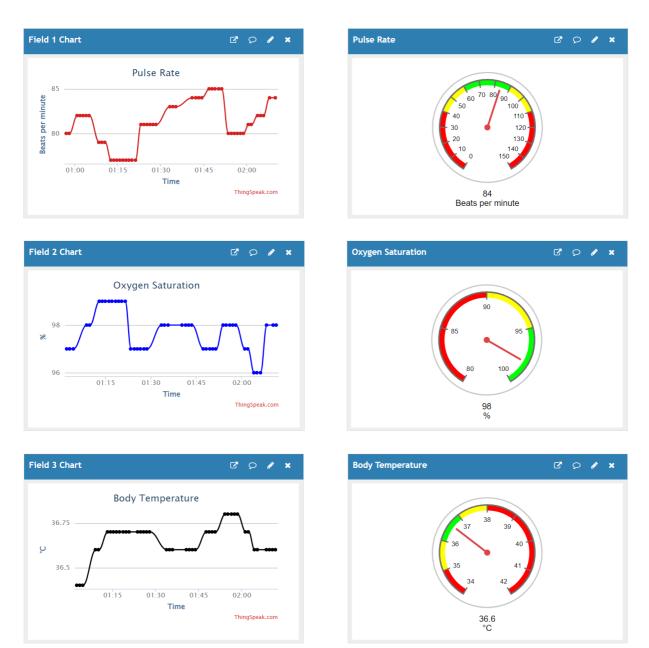


Figure 6: The monitoring results of the human vital health data

The results obtained from our experiments highlight the effectiveness and practicality of the designed HMS. By leveraging IoMT and the ESP32 platform, the proposed system empowers caregivers and healthcare providers with the ability to remotely monitor patient's health parameters. This ensured timely access to health information, enabling rapid responses to changing health conditions. This is especially valuable in situations where in-person monitoring is challenging or impossible.

The collected health data can be leveraged for advanced data analytics and predictive modeling. This opens up possibilities for identifying patterns, trends, and early warning signs of health conditions. The system exhibited minimal response time, enabling quick detection of health anomalies and the generation of timely alerts. This rapid response time is critical for healthcare professionals and caregivers to intervene promptly.

While these results have demonstrated the effectiveness of the proposed system in providing realtime accurate and reliable health data measurements, several avenues for future exploration remain. Further refinement of data analytics algorithms and the integration of telemedicine capabilities are among the directions to consider for future research.

#### 6. Conclusions

In the age of digital transformation and interconnected healthcare, the development of a health monitoring system based on the IoMT using the ESP32 platform has shown remarkable potential and significance. Through this research, it were achieved several key outcomes and drawn noteworthy conclusions. The integration of IoMT technologies, including the ESP32 microcontroller and specialized sensors, provides a robust foundation for real-time health monitoring. The system enables the continuous collection and transmission of vital health data, bridging the gap between traditional healthcare and the digital age.

The proposed system offers a practical solution for remote healthcare management. Caregivers, healthcare professionals, and family members can remotely access and monitor an individual's health status, enhancing the quality of care and enabling timely interventions when necessary. The real-time nature of the system allows for the early detection of health anomalies and deviations from baseline measurements. This capability is particularly valuable in preventing adverse health events and improving healthcare outcomes. The modular architecture of our system allows for scalability and adaptability to different healthcare settings and patient needs. Additional sensors and functionalities can be seamlessly integrated to cater to specific healthcare scenarios.

The designed system offers a promising approach to address the evolving healthcare needs of our society. By leveraging IoMT technologies, it was showcased the potential to transform delivery of healthcare, enhance patient care, and contribute to the advancement of intelligent information systems in medicine.

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