

IoT platform for the monitoring of non-invasive physiological parameters

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Abstract: Currently, the advancement of Internet of Things (IoT) technologies has enabled the development of innovative solutions in the healthcare field; however, many existing devices do not guarantee continuous monitoring or high data accuracy, limiting their use in medical settings. This study aimed to develop a graphical user interface integrated into a non-invasive electronic prototype for real-time monitoring of physiological parameters such as body temperature, heart rate, and oxygen saturation. The methodology was based on the design and implementation of an IoT system using specialized sensors, the ESP8266 microcontroller, and cloud platforms such as Cayenne myDevices and Blynk, allowing for data acquisition, processing, and visualization. The prototype achieved less than 5% accuracy compared to medical equipment, along with an adequate response time for real-time monitoring. Finally, the study concludes that the developed system constitutes a viable, accessible, and efficient alternative for monitoring vital signs, contributing to improved preventive healthcare through the use of low-cost technologies.

Keywords: IoT, physiological monitoring, biomedical sensors, real-time, ESP8266, graphical interface, cloud computing.

1. Introduction

The healthcare sector has experienced significant advancements thanks to the incorporation of new technologies that improve patient diagnosis and monitoring. In this context, the Internet of Things (IoT) has emerged as a key tool for real-time data acquisition and transmission, facilitating the implementation of intelligent healthcare systems [1], [2]. These technologies have enabled the development of devices capable of measuring physiological parameters such as heart rate, body temperature, and oxygen saturation, contributing to more efficient and timely medical care [3], [4].

Despite these advances, many of the devices available on the market have limitations related to data accuracy, continuous monitoring, and high costs, which restricts their use in low-resource settings [5], [6]. Furthermore, cardiovascular and respiratory diseases remain among the leading causes of mortality worldwide, highlighting the need for accessible solutions that allow for the continuous monitoring of vital signs [7], [8]. In this regard, several studies have proposed the use of non-invasive sensors and IoT platforms for remote patient monitoring; however, differences exist in the reliability, accessibility, and ease of use of these systems, highlighting the need to develop more comprehensive alternatives [3], [4].

Therefore, the main objective of this study was to develop a graphical user interface integrated into a non-invasive electronic prototype for real-time monitoring of physiological parameters using IoT technologies. The results obtained demonstrate that the proposed system exhibits high data measurement accuracy, with a margin of error of less than 5% compared to medical equipment, and offers an accessible and efficient solution for monitoring patient health.

2. Materials and Methods

2.1 Materials

The proposed system is based on a non-invasive electronic prototype for monitoring physiological parameters. Specific biomedical sensors were used for data acquisition: the MLX90614 sensor for contactless body temperature measurement and the MAX30100 sensor for obtaining heart rate (BPM) and oxygen saturation (SpO2).

Both sensors were integrated via the I2C communication protocol to a NodeMCU ESP8266 v3 microcontroller, which served as the main data processing and transmission unit. This device incorporates Wi-Fi connectivity and TCP/IP protocol support, enabling its integration into IoT environments.

An OLED screen was used for local data visualization, while the Cayenne myDevices and Blynk cloud platforms were used for remote monitoring, allowing for the reception, storage, and display of data in real time. The software development was carried out in the Arduino IDE environment, using specific libraries for communication with sensors and IoT platforms, including ESP8266WiFi, Wire, Adafruit_MLX90614, MAX30100_PulseOximeter, Blynk and CayenneMQTTESP8266.

2.2 Methods

The system was developed using an applied approach, structured in four main stages: acquisition of physiological parameters, data processing, information transmission, and results visualization. The system architecture and data flow are shown in **Figure 1**, where the interaction between sensors, the microcontroller, IoT platforms, and visualization devices is illustrated.

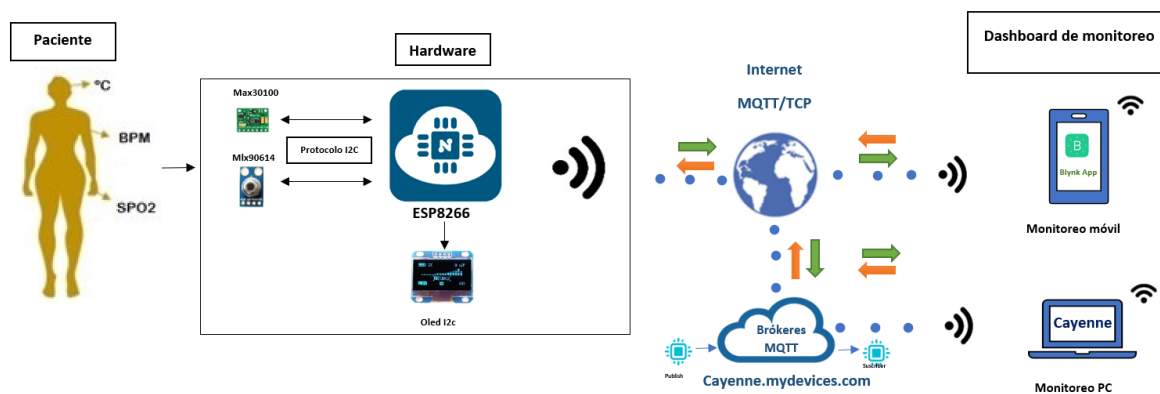


Figure 1: Functional architecture of the proposed system including IoT communication and data visualization.

During the implementation phase, individual tests were performed on each sensor to verify its functionality. Subsequently, both sensors were integrated into a single system, resolving communication conflicts arising from the shared use of the I2C bus by assigning specific addresses to each device. A calibration process was also carried out to reduce measurement errors in **Figure 2**.

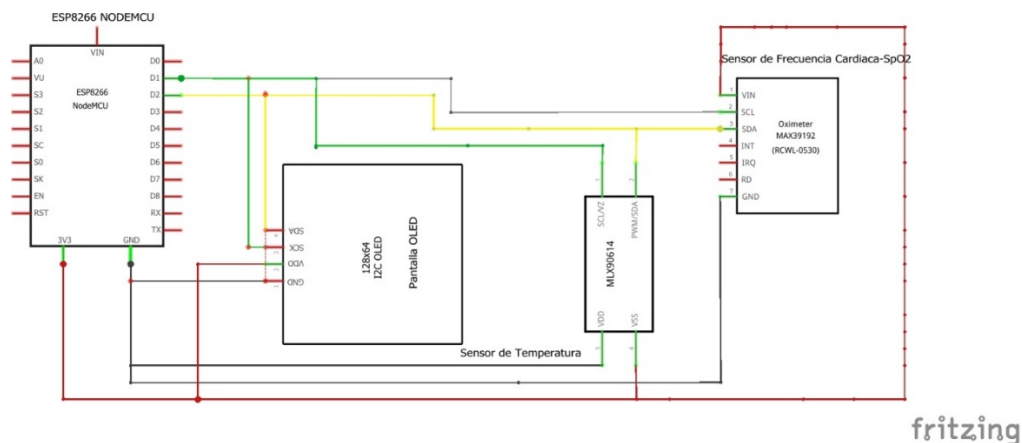


Figure 2: Schematic diagram of the electronic prototype.

The MQTT protocol was used for data transmission via the Cayenne platform, configuring virtual pins for the periodic transmission of information. Additionally, the Blynk application was implemented, allowing data visualization through a graphical interface on mobile devices.

System validation was performed through comparative experimental tests between the data obtained by the prototype and that recorded by conventional medical devices, with the aim of evaluating the system's accuracy. These tests were conducted on human subjects under controlled conditions, with prior informed consent from the participants.

The methods employed are based on techniques previously reported in the literature related to IoT monitoring systems and biomedical sensors [1–3]. No restrictions were identified regarding the availability of materials, data, or source code used in the system's development.

3. Results

The developed system enabled the acquisition, processing, and remote visualization of physiological parameters, including body temperature, heart rate, and oxygen saturation (SpO₂), in real time. The integration of the MLX90614 and MAX30100 sensors with the NodeMCU ESP8266 microcontroller allowed stable data transmission through IoT platforms.

3.1 Visualization and Remote Monitoring

The system successfully implemented the transmission of physiological data via the MQTT protocol to cloud platforms, enabling continuous monitoring in both web and mobile environments.

3.1.1 Cloud Data Management and Storage using Cayenne

The Cayenne myDevices platform was implemented as the central node for the storage and processing of large amounts of data in the cloud. This tool allows for unlimited and efficient information management, facilitating the interpretation of vital signs without incurring additional operating costs.

Through an interactive dashboard in **Figure 3**, the system allows for the real-time visualization of body temperature, oxygen saturation (SpO₂), and heart rate, maintaining constant synchronization with the NodeMCU ESP8266 microcontroller via the MQTT protocol. Additionally, a smart

notification system was configured; this mechanism sends automatic email alerts when the patient's physiological parameters exceed predefined safety thresholds, enabling timely medical intervention.

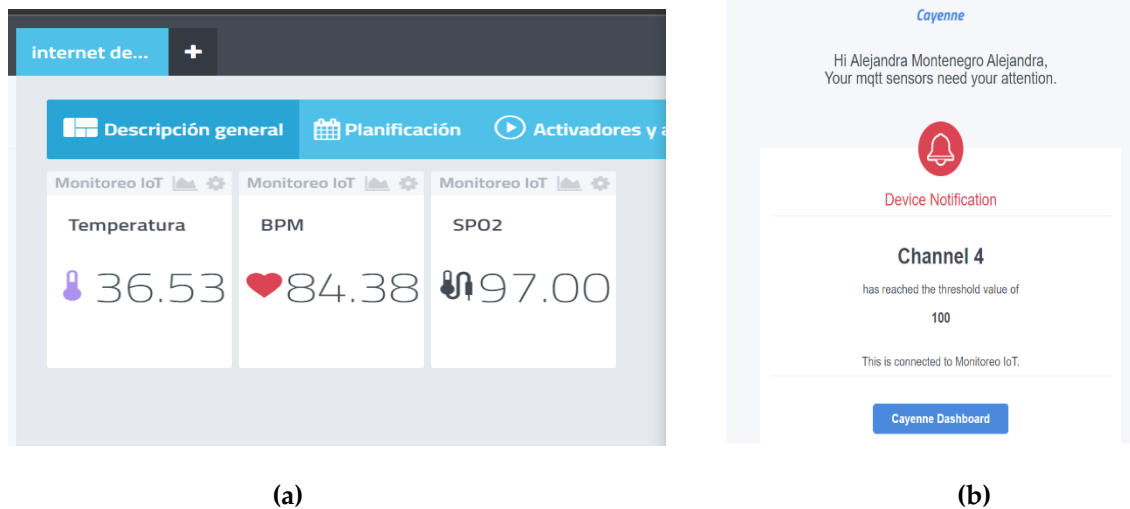


Figure 3: User interface on the Cayenne platform; (a) Control dashboard with real-time physiological parameter indicators; (b) Configuration and receipt of alert notifications for abnormal thresholds.

3.1.2 Mobile Interface with Blynk App

To ensure the system's portability and accessibility, the Blynk mobile application was integrated. It was selected for its widget-based architecture, which allows for an intuitive and functional interface design. This tool facilitates remote monitoring of vital signs without the need for a fixed computer station.

The system ensures constant bidirectional synchronization, with a data update rate of every 3 seconds, allowing both the patient and medical staff to react immediately to fluctuations in parameters. As illustrated in **Figure 4**, the mobile interface prioritizes information readability through a simplified graphical display, optimizing user interaction with heart rate, oxygen saturation, and body temperature data.

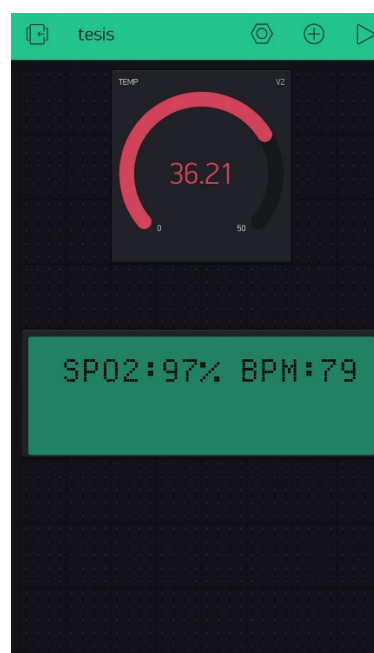


Figure 4: Mobile interface for monitoring physiological parameters in the Blynk

3.2 Prototype Validation and Comparative Analysis

To verify the system's reliability, an experimental phase was conducted with a sample of 17 subjects, comparing the prototype's measurements against certified medical equipment.

3.2.1 Body Temperature Analysis

The MLX90614 sensor was compared to a medical-grade infrared thermometer. As shown in **Table 1**, the average difference was only 0.3 °C, demonstrating high accuracy in non-invasive thermal detection.

Table 1: Comparison of final results for the body temperature parameter

Number of subjects	temp/proto	temp/doctor	Absolute error	Relative error
s1	37	37,5	0,5	1
s2	36	37	1,0	3
s3	36	37	1,0	3
s4	36	36	0,0	-
s5	36,5	37,2	0,7	2
s6	37,1	36,8	0,3	1
s7	35,5	35	0,5	1
s8	36,45	36	0,5	1
s9	36	36,7	0,7	2
s10	27,21	28	0,8	3
s11	36,4	36	0,4	1
s12	36,6	36	0,6	2
s13	36	36	0,0	-
s14	35	36	1,0	3
s15	35,5	36,1	0,6	2
s16	36,1	36	0,1	0
s17	35	36	1,0	3
Average	35,6	35,8	0,3	0,8

3.2.2 Oxygen Saturation (SpO2) Analysis

Table 2 presents the oximetry data. The MAX30100 sensor showed 99.2% agreement with the reference oximeter, with minimal deviation in oxygenation levels.

Table 2: Comparison of final results for oxygen saturation (SpO2)

Number of subjects	SpO2/proto	SpO2/doctor	Absolute error	Relative error
s1	96	97	1	1
s2	95	97	2	2
s3	93	95	2	2
s4	97	96	1	1
s5	97	99	2	2

s6	97	97	0	-
s7	94	96	2	2
s8	97	97	0	-
s9	94	92	2	2
s10	93	98	5	5
s11	97	99	2	2
s12	95	97	2	2
s13	94	96	2	2
s14	96	96	0	-
s15	94	90	4	4
s16	97	97	0	-
s17	97	97	0	-
Average	95,5	96,2	0,8	0,8

3.2.3 Heart Rate (BPM) Analysis

Finally, the heart rate measurement (beats per minute, BPM) showed a margin of error of 1.1%. It was observed that the sensor requires a stabilization time of approximately 3 to 5 seconds to deliver consistent readings, as shown in **Table 3**.

Table 3: Comparison of final results for heart rate (BPM)

Number of subjects	bpm/proto	bpm/doctor	Absolute error	Relative error
s1	78	79	1	1
s2	80	82	2	2
s3	70	73	3	4
s4	64	66	2	3
s5	77	78	1	1
s6	79	79	0	-
s7	85	88	3	3
s8	67	67	0	-
s9	71	72	1	1
s10	70	71	1	1
s11	86	87	1	1
s12	65	65	0	-
s13	72	74	2	3
s14	54	53	1	2
s15	67	68	1	1
s16	73	76	3	4
s17	59	60	1	2
Average	71,6	72,8	1,1	1,5

3.3 Data Quality Assessment (ISO/IEC 25012)

To determine the system's viability, the Accuracy metric (A) was applied, defined by the following equation:

$$A = 1 - \frac{V_m - V_p}{V_m},$$

(1)

Where V_m represents the reference value measured by the certified medical team and V_p is the value obtained by the developed prototype. After processing the collected data, the system achieved 95% effectiveness, validating its reliability for real-time health monitoring.

4. Discussion

The results obtained in this study demonstrate that integrating low-cost sensors with cloud platforms enables physiological monitoring with a level of accuracy comparable to that of certified medical equipment. The 95% effectiveness achieved validates the hypothesis that it is possible to democratize access to telemedicine through open hardware technologies such as the NodeMCU ESP8266.

When comparing these findings with traditional hospital monitoring systems, the main advantage of this prototype lies in its ubiquity and low cost. While clinical equipment is typically static and expensive, the implementation of MQTT protocols and the use of mobile interfaces like Blynk allow patients to remain mobile without interrupting the data flow. This aligns with previous research in the field of the Internet of Medical Things (IoMT), where reducing data transmission latency (3 seconds in this prototype) is critical for the early detection of abnormalities.

A key aspect of the discussion is the accuracy of the MLX90614 and MAX30100 sensors. Although they exhibited minimal variations (0.3 °C and 1.1% in BPM, respectively), these are attributed to environmental factors and hardware stabilization time, rather than errors in data processing. This error margin of less than 5% places the system within acceptable standards for non-invasive preventive monitoring, meeting the data quality requirements established by ISO/IEC 25012.

However, the system has limitations that open up future avenues for research. For example, it relies on a stable Wi-Fi connection and the infrared sensors are sensitive to user movement. Furthermore, the reliability of the sensor data can vary depending on the price and quality of the components, highlighting the importance of rigorous calibration and cross-validation.

5. Conclusions

The developed prototype validates the feasibility of using low-cost hardware and IoT platforms for preventive clinical monitoring. Integrating the sensors with the NodeMCU ESP8266 microcontroller achieved 95% accuracy, a figure that supports the system's technical reliability compared to certified medical equipment.

The proposed architecture, based on the ISO/IEC 25012 standard, confirms that it guarantees comprehensive and accessible real-time data management. This work provides a solid foundation for deploying accessible telemedicine solutions, demonstrating that it is possible to maintain high quality standards through the use of open-source technologies and cloud computing.

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