Smart Healthcare device based on IoT

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***Abstract*—This work presents the development of a very user-friendly smart healthcare device for people of any age. The device is based on the IoT concept. The hardware was designed around the ESP32 development board, which processes the data acquired from four essential and well-known body sensors (temperature, pulse, oximetry, and EKG). The device can be powered from any 5V DC power supply through the micro-USB port of the ESP32 board. We implemented two operation modes for the device: an "online" one where sensor measurements are sent and stored through WiFi internet connection in a database and an "offline" mode without an internet connection where the measurements are shown only on the LCD. In both operation modes, the instructions are given step by step to the user on the LCD screen. In the case of the "online" mode of operation, we structured a database to store the measured data and represent it eloquently on a public website. We developed an Android app with four user data links to permit quick access to the website. In this manner, the measured data can be accessed by the end user and accredited medical personnel. Thus, doctor and patient interaction would be much tighter for better health control.**

Keywords—ESP32, temperature, pulse, oximeter, EKG, database, smartphone app.

I. Introduction

The evolution of smart healthcare technology creates the possibility of easing the work of personnel working in the medical field while simultaneously offering countless benefits and advantages to patients. Considering that in some less developed places, even a minimal level of medical services is considered a privilege, any method of improving this area is a considerable step towards a better future.

Traditional healthcare systems were very inefficient. Each time the patient had to visit the doctor, even for minor complications. This would be added to the cost of the patient's treatment and the time and effort involved. Due to the advent of intelligent healthcare systems, this problem has been addressed.

With the advent of the digital era, intelligent health services based on new-generation information technologies are playing an increasingly important role in improving the quality of people's health. A study was done that analyzed the correlation of the evolution of regional smart healthcare services with survey data from a longitudinal study of retirement and health in China. The results showed that:

- Smart health services have a significant positive impact on the health of residents.

- The availability of hospitalization services mediating the relationship between regional smart healthcare services and residents' health.

-The influence of regional smart healthcare services on the health of residents is different depending on the region. Specifically, the effect of smart healthcare services on residents' health is significant in rural regions and less so in urban regions [1].

Various advances in communication and information technology have led to Internet-connected devices such as smartphones, home appliances, wearable devices, and the "Internet of Things". It is a network environment for analyzing the data collected by these devices on a platform, processing them into meaningful data, and creating various services. The IoT platform is a formalization interface for processing data generated and collected from devices and providing it to application services[2].

IoT (Internet of Things) helps healthcare services evolve and become active intelligent healthcare platforms. IoT was born in 2005 and became the core of future economic development in the Internet, communications, and networks [3].

As the research for IoT is increasing, various development boards have been developed and are now being used in medicine to make medical operations convenient for all people. These IoT-based boards reduce human development efforts, are cost-effective, and use low power. Boards like Arduino, Intel Galileo, and Raspberry Pi are perfect examples of these systems because they can be very interactive. In IoT, sensors can gather information from the environment or a single person. The collected data is then transmitted to a server [4].

It is a perfect model to incorporate various devices with sensors, and processors, which calculate and communicate through the Internet. Smart Healthcare explores the utility of IoT to create life-saving possibilities such as remote diagnosis, monitoring, and treatment of patients. The research that analyzes basic architecture for healthcare systems shows a basic structure described in these 3 main levels [5]:

Level 1 - Sensor Network: Encapsulates the collection of data by several sensors;

Level 2 - Transfer Gateway: The transfer of this data is done through a device that has a direct connection to the network;

Level 3 - Cloud Data Center: This data received from the previous level is stored in the database.

IoT is another major wave of information and communication technology (ICT) after the invention of personal computers (PCs), Ethernet, the Internet, and cellular communication. Many countries worldwide have considered IoT as part of their national sustainable development strategy in their government and public sectors by completing logic and concept studies at the service level. For example, Japan's broadband access is based on ubiquitous and people-oriented technology, providing services to help people communicate effectively, people and things, and direct communication between things. Smart home automation systems in South Korea help residents control many home appliances remotely

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and enjoy two-way multimedia services. IoT domains include healthcare, industry, transportation, education, and emergency response to any natural or human-made disaster under stressful conditions. IoT enables people to interact (see, hear and think) with sensors that help them share information, make intelligent decisions and answer questions effectively [6].

On the other hand, IoT transforms traditional devices into smart objects, changing system technologies such as embedded systems, sensor networks, communication technologies, and internet protocols. The main objective of IoT is to make the Internet, communication, and networks more interesting and persuasive by providing easy interaction with a wide variety of devices. This paradigm is spread across vast domains and covers almost all areas of human occupation. Thus, the concept of "smart cities" is born. Smart urbanization can optimize traditional public service processes by increasing the benefit gained from many services such as transportation, lighting, maintenance, surveillance of public areas, preservation of history and cultural heritage, parking, automation of industries, education, hospitals, garbage collection, and many others. The smart city industry emerges from the interconnection of key industries and service sectors and forms multiple sectors of smart cities, such as smart governance, smart utilities, smart buildings, smart environment, and smart mobility [7].

Another popular implementation recently is "Smart Wearables in Healthcare". A concept in smart healthcare must, of course, be innovative and practical to be successful.

They can generally provide ECG, blood pressure, electromyography, breathing, sleep and movement monitoring data. Having a wide range of uses both in medicine and in everyday life. Not surprisingly, they have a promising future [8].

But currently, the very small dimensions and the fact that they are worn on the body, which is in motion, make it difficult to measure data effectively. Consideration must be given to the price and the quality required to provide useful measurements. It is much more practical for a device of slightly larger dimensions, stationary but which can provide clear, useful medical data and also have a relatively low cost at the same time. And their transfer via the Internet, on a platform where the data can be sent directly by a professional framework, is indispensable.

IoT technology allows computing devices and things to communicate with each other and transport information from one location to another. More importantly, IoT helps improve communication without requiring human-to-human or human-to-device contact.

The growth of the world population has also led to an increase in the number of detections of chronic diseases, which are often problematic to detect. Even the simplest healthcare services may be out of reach for many people and communities, which has led to an increase in the proportion of people affected by chronic diseases. IoT in the healthcare industry has increased the shared hope between patients and service providers and the efficiency of treatment plans. In addition, the IoT-based procedure for diagnosing diseases has significantly improved the quality of therapy. Simultaneous reporting and monitoring, cost, end-to-end connectivity, remote healthcare, data analysis, tracking, and alerting are all advantages of IoT sensor-based healthcare services. Patient workflow is effectively supported by active technologies and facilities, which is the key reason for integrating IoT devices in healthcare equipment. Data transfer, information exchange, and machine-to-machine communication have all improved due to the technologies used. Unnecessary patient visits were reduced due to better use of technology and communication protocols, which improved planning and allocations. For example, a device with a data analysis tool forms a graph based on variations, enabling more accurate decision-making. If the medical data discovered potentially dangerous statistics, the medical gadget notified the medical staff. Appropriate therapy was given in response to the alarm, which directly prolonged the patients' lives. According to the debate, the IoT sensor gadget has successfully observed patient behavior, notifying, tracking, providing better therapy, and completely improving patient care [9].

In our case, the motivation of this work was to create a device that offers any interested person the opportunity to obtain a certain level of self-assessment while providing this information further to qualified personnel (doctors, medical staff). The implementation based on IoT was one of the essential principles that guided the work process. The data transfer measured by the device's sensors is carried out through the Internet connection. This data will be displayed on a website. We used an ESP32 board and various sensors, temperature, oximeter, pulse, and ECG monitoring to implement the device.

II. Device Development

A. Hardware

The starting point is an implementation in the research [10], which uses an Arduino Uno board with only a temperature sensor and display on a 16x2 LCD, and, alternatively, a similar circuit with a pulse sensor. Although ideas with various types of measurement/sensors are proposed in the concept, their implementation remained only theoretical.

The first step to making the final device will be to create an offline version using the ESP32. Another option was to use the ESP2866 module, but we opted for the newer version since it fulfills the same role. The ESP32 also offers Bluetooth connection possibilities, and the probability is much higher that it will be compatible with the sensors I want to use.

The offline version will allow measuring data such as temperature, pulse, and oxygen level without connecting to a network. This device's operation method is practical because it allows you to measure that data even when you can't connect to WiFi. For this reason, it will also be present in the final version of the device.

For the online mode, the data will be sent via the Internet, stored in a database, and visualized on a dedicated website. Thus the user or his doctor will have a practical way to view the measured data without the need for them to come into direct contact every time the user has to (or will want to) use the device.

At the system's center is the ESP-WROOM-32 board, which needs a 5V power supply. Since this board has a micro USB plug, the device has a variety of ways in which it can be powered by:

-using a USB - micro USB cable, it can be connected to any laptop/computer;

- a simple phone charger;

- a battery pack, as we used in our research lab, with six 1.5V alkaline batteries (Figure 1) to provide the user with a more portable power supply for the device.

To connect the ESP 32 board to WiFi, we initially connected it with a smartphone. It allows us to detect the available WiFi networks, and thus we can select the desired one. The name and password will be saved and do not have to be re-entered the next time the device is used. Thus, we can send the obtained values to the database through the connection.

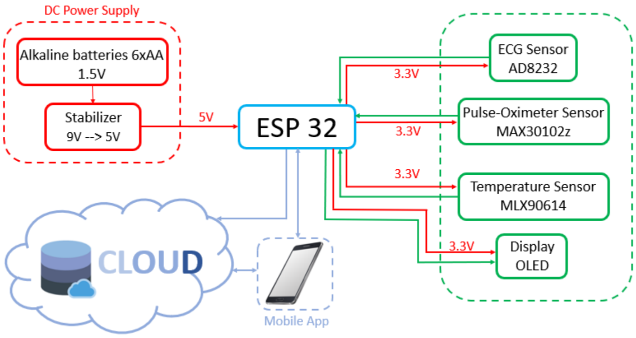


Fig. 1. Block diagram of the electrical circuit.

The electrical circuit of the device is presented in Figure 2, with the following details:

- on the top side, we have the ESP board and the display connected to 3.3V, GND, SDA, and SCL

- at the bottom are the three sensors connected to pins 3.3V, GND, SDA, and SCL.

- on the left are the four buttons: the main button for changing the device's online/offline mode (connected to pin P19) and the three buttons used for resetting the WiFi connection, navigating the menu, and selecting options (connected to pins P17, P18, P23).

- under the sensors is the red LED connected to the limiting resistor and P13

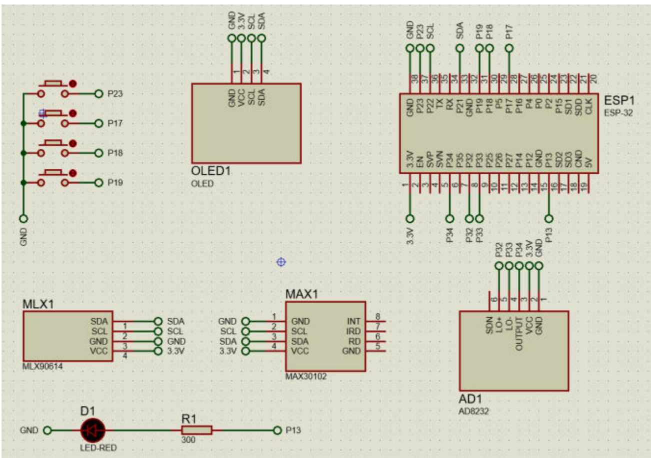


Fig. 2. The electrical diagram of the device in Proteus.

The first hardware implementation of the device, based on the electrical diagram from Figure 2, was done on a breadboard (Figure 3), which gives the possibility to analyze and improve the circuit design before implementing it on a PCB. The markings identify the followings:

- on the large breadboard:

1. ESP32 development board

2. MLX90614 temperature sensor

3. OLED display

4. Button for online/offline modes and for initiating operation

5. MAX30102 Pulse-Oxyment Sensor

- on the small breadboard:

6. AD8232 ECG sensor

7. Red LED to show the functioning stages of the device.

8. buttons for navigation, option selection, and WiFi reset.

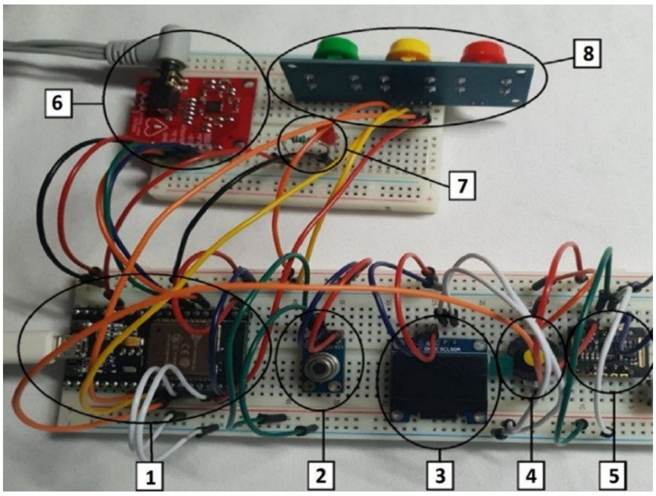


Fig. 3. Device prototype on a breadboard.

The PCB-level implementation is presented in Figure 4. To have a compact device, we 3D designed and printed an enclosure for the PCB assembly, where the user interface (sensors, buttons, LCD, LED, micro-USB port, EKG jack plug) are left out on the lid. This design gives a compact shape to the device. The buttons are black for program initialization, red for WiFi reset, and yellow and green for menu navigation and option selection.

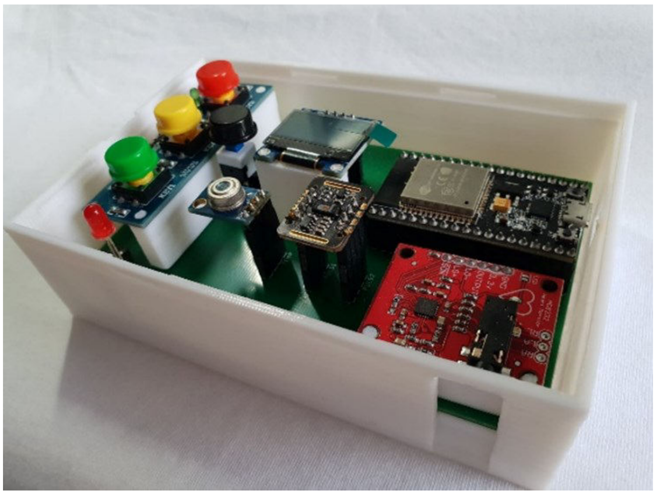
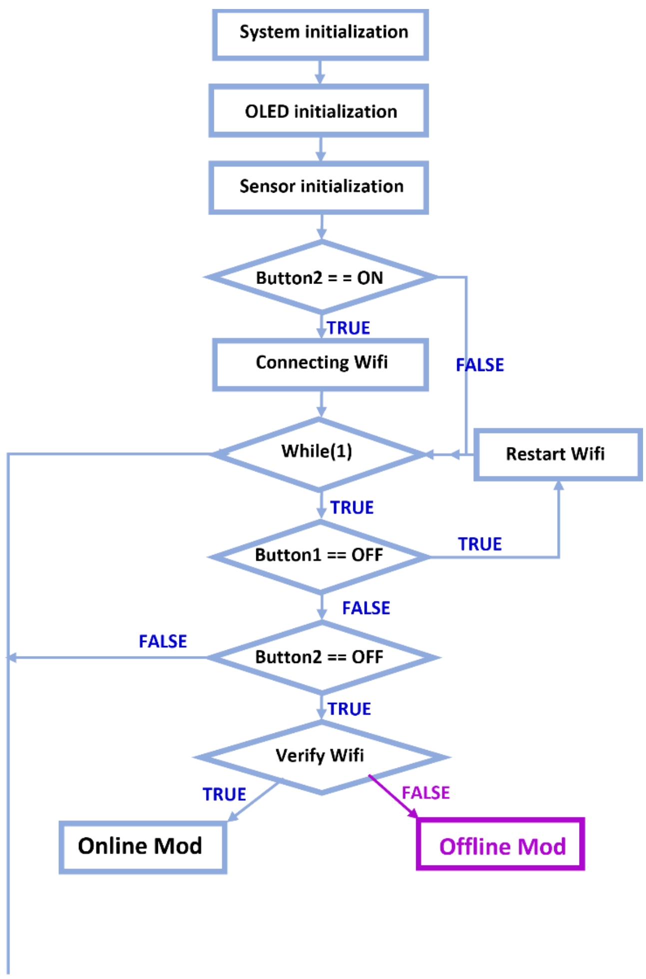


Fig. 4. PCB mounted in the enclosure (top), lid view with the user interface (bottom).

B. Operation mode

The logic diagram of the device is presented in Figure 5, where the two modes of operation (online/offline) are interconnected (the offline mode is marked with violet). It starts with the initialization of the system/components, after which the device will enter "Online" or "Offline" mode, depending on the state in which "Button 2" is located.



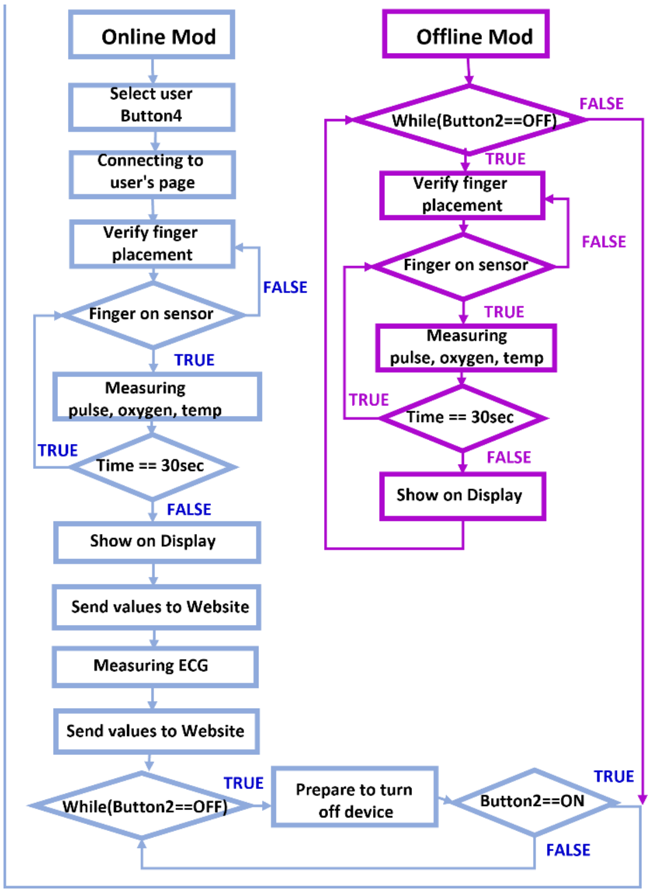


Fig. 5. Logic of operation of the device.

C. Application and Website Implementation

The purpose of the application is to provide users with an alternative method that is both practical and easily accessible to the website where the measured data is displayed. It was created using the "Android Studio" development software.

The application icon, SHCIoT (Smart Healthcare Internet of Things) can be seen in Figure 6 on the left side of the screen. In the middle of Figure 6, we have the application interface "Smart Healthcare Users" with four predefined buttons for selecting the desired user. Once the user is selected, it opens his website with the measurements database (Figure 6-right).

Fig. 6. SHCIoT Android App: icon (left), interface (middle), website (right).

The website was created on the publicly acquired domain "smarthealthcareiot.com", and this device's users can view all the data measured recently or in the past, depending on their preference. The choice of number of measurements being selected by the user (Figure 7). They are giving them a clear and expressive perspective of the evolution of the measured data. The example in Figure 7 is for the last 10 measurements, where the centralized table shows the time stamps of the measured data. The graph of the sensor's data evolution gives a wider view if all the sensors are placed together.

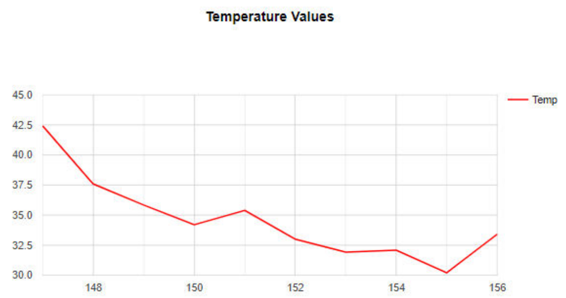
Fig. 7. The main page on the website for the selected user.

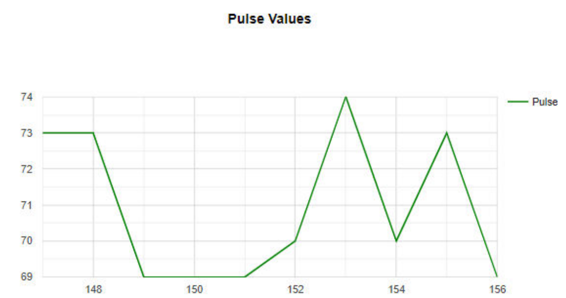
If you wish to view your ECG measurements please click the button below

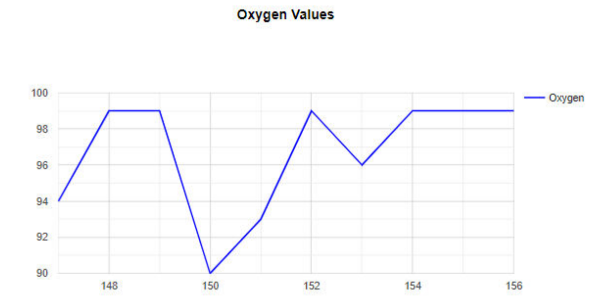
View results

Last 10 Readings

ID	Temperature	Pulse	Oxygen	Timestamp
156	33.41	69	99	2022-09-02 01:23:00
155	30.20	73	99	2022-09-01 16:33:00
154	32.08	70	99	2022-09-01 16:29:00
153	31.92	74	96	2022-09-01 16:21:00
152	33.00	70	99	2022-09-01 16:08:00
151	35.39	69	93	2022-09-01 15:59:00
150	34.20	69	90	2022-09-01 15:55:00
149	35.83	69	99	2022-09-01 15:39:00
148	37.59	73	99	2022-09-01 15:16:00
147	42.41	73	94	2022-08-23 11:21:00







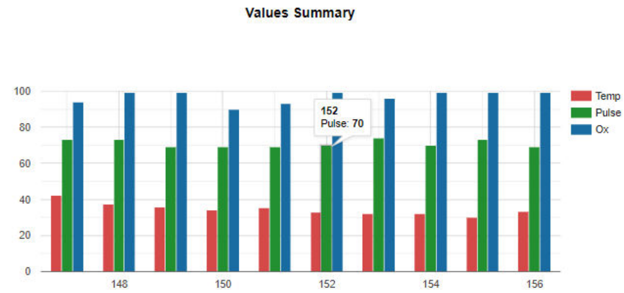


Fig. 8. The last 10 measurements from the sensors: table with time-stamps of the measurements, temperature evolution, pulse evolution, oximetry evolution, and close relationship evolution between the sensors.

To view the EKG graph (Figure 9) the user must press the “View results” button.

Fig. 9. The EKG graph shown on the webpage.

III. Experimental Results

In online mode, after the “Welcome!” message appears, the device tries to connect to a network. If it was previously connected to a network, it would automatically reconnect. It will have to be connected via a mobile phone if it does not find a network. Once connected, the "CONNECTED!" message will appear on display. We will receive the message "PRESS TO START". We can press the black button, and the announcement informs us that we must select a user. With the green button, we navigate the list of users and select the desired user with the yellow button. Next, we select if we want to measure the ECG too. Now the temperature, pulse, and oxygen level are measured the same as in offline mode, as presented in Figure 10. After this data is sent, the measurement with the ECG sensor is taken, which takes three minutes. The data is sent, and then the device can be turned off.

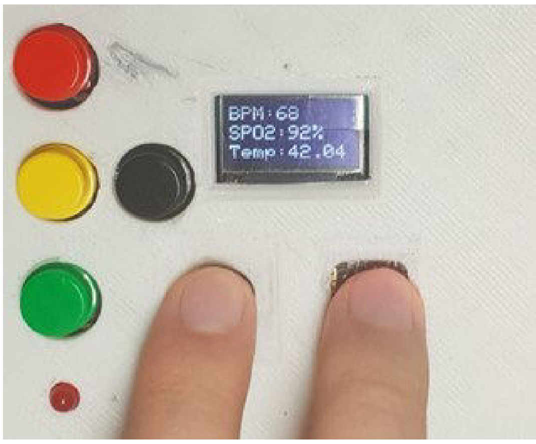


Fig. 10. Measuring examples for temperature, pulse, and oxygen level.

IV. CONCLUSIONS

The development of the Smart Healthcare field is crucial and highly beneficial for the entire population. The constant evolution of new technologies and their implementation guarantees that we are moving toward a promising future. A future with a highly advanced level of medicine implemented in everyday life in ways utterly unimaginable today.

This is the vision that guided our work, to implement a device for measuring a patient's body parameters in a remote mode, simultaneously offering the possibility to send these data practically to be viewed by medical staff. It is handy for the elderly because they frequently experience medical problems and require constant monitoring to avoid unforeseen problems.

The main component used to implement the device is the ESP32 module. It can connect to the Internet, wirelessly sending all the measured data wherever we want. The sensors connected to take body measurements are temperature, pulse, oxygen, and ECG. Measurements follow WiFi connection of the device, and the data is sent to a website where it can be viewed by a medical professional.

The device is very practical because it must be powered with 5V and the connection through the Micro-USB plug offers the possibility to use it anywhere. It has an external battery but can also be powered from a PC/Laptop or any phone charger that uses Micro-USB.

The implementation is done so that the device is as simple as possible for the user. It has a display that shows step by step the stage in which the device is by displaying messages such as "Connecting", "Connected", "Select user", "Measuring", "Sending data", etc., so the user is constantly aware of what is happening and can react as such. Once the data is sent, the user can also view it by accessing the dedicated website. To accommodate this aspect for users, we have created a phone application to select the desired user and direct them to the corresponding website.

If we did not have the opportunity or did not want to connect the device to a network, it also has an Offline mode in which temperature, pulse, and oxygen are measured and shown on display.

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