MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION
Federal State Autonomous Educational Institution of Higher Education
“South Ural State University (National Research University)”

School of Electronic Engineering and Computer Science
Department of Computer Engineering

THESIS IS CHECKED
Reviewer,
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“___”____________________ 2022 г.

ACCEPTED FOR THE DEFENSE
Head of the department,
Ph.D., Associate Professor
_____________ D.V. Topolsky
“___”__________ 2022 г.

Ensuring the interaction of medical cyber-physical devices in IOT for remote areas and in emergency situations

GRADUATE QUALIFICATION WORK
SUSU – 09.04.01.2022.308-643.GQW

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Chelyabinsk-2022

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TASK

of the master graduate qualification work
for the student of the group CE-228
Ahmed Dakheel
in master direction 09.04.01
“Fundamental Informatics and Information Technologies”
(master program “Internet of Things”)

1. The topic (approved by the order of the rector from 24.05.2022): “Ensuring the interaction of medical cyber-physical devices in IOT for remote areas and in emergency situations”.
2. The deadline for the completion of the work: 01.06.2022.
3. System requirements and technical characteristics
   - 3.1. TTGO T-Beam V1.1 ESP32 board.
   - 3.2. The AD8232 ECG Sensor.
   - 3.3. MAX30102 Pulse Oximeter Sensor.
   - 3.4. Temperature Sensor GY-906 MLX90614.
   - 3.5. Screen (Oled).
4. The list of the development issues
   - 4.1. Analyzing the market for existing device.
   - 4.2. Definition detail the set of requirements for the device.
   - 4.3. Design the system.

4.4. Development Architecture and implementation.

4.5. Testing.

5. Issuance date of the task: 25.12.2021.

Supervisor ________________________________/ *D.V. Topolsky* /

Student ________________________________/*A .H .Dakheel* /

CALENDAR PLAN

Phase	Deadline	Supervisor's signature
Introduction and literature review	10.03.2022	
Development of the model, design of the system	21.03.2022	
Implementation of a system	04.04.2022	
Testing and debugging of the system, experiments	25.04.2022	
Full text, normative control	16.05.2022	
Proposal defense	24.05.2022	

Supervisor __________________________________/ *D.V. Topolsky* /

Student __________________________________/*Ahmed. Hasan. Dakheel* /

Annotation

Ahmed. Hasan. Dakheel. Ensuring the interaction of medical cyber-physical devices in IOT for remote areas and in emergency situations – Chelyabinsk: SUSU; 2022, 70 p., 53 pic., bibl. – 24.

This thesis consists of six main chapters: Introduction, definition of requirements, Design of the system, Development Architecture and implementation, Testing, Conclusion, and References.

In the first chapter, we will have the subject area analysis briefly then have an overview of analogues and view advantages and disadvantages.

All the different software platforms to be used will be adequately described.

In the second chapter, there is a description of both functional and non-functional requirements as well as a description of requirements for ergonomics and technical aesthetics, Interfaces requirements well as documentation requirements for the device.

In the third chapter we describe the design and the main protocols and wireless networks used and chosen Hardware sensor, as well as the algorithms for tackling the problem and a description of the data.

In the fourth chapter we will describe main components of the system and how they interact with each other are considered in detail. Implementation for both the software accuracy and the hardware performance and interfacing with a real MCU.

The fifth chapter, functional testing of the device use cases with the system was carried out. the expected result and setting steps are described, with a demonstration of fragments of the user interface. According to the test results

Finally, in the sixth chapter we will have a conclusion for the thesis.

CONTENTS

ACKNOWLEDGEMENTS

I would like to earnestly acknowledge the sincere efforts and valuable time given by my supervisor Dmitry Topolsky. He is valuable guidance and feedback has helped me in this project.

Also, I would like to mention the support system and consideration of my parents, who have always been there in my life.

Last but not the least, my wife who have always been there with my side.

Without them, I could never had completed this task.

INTRODUCTION

The majority of those who perished were from remote areas and were unable to reach the hospital in time.

Aside from that, they did not receive sufficient care due to a shortage of doctors, knowledge, and services. Modern technology must be used to overcome delays in timely service and distribution of information to the appropriate experts and facilitators in order to improve the process of saving the lives of injured people.

The techniques monitoring an injured person's health parameters and sends an automatic response from the ambulance or accident site to the hospital, allowing the prerequisites for the patient's treatment to be prepared ahead of time.

The shortest route to a neighboring hospital is calculated.

A wide range of devices /gadgets /wearables for monitoring various health parameters has been generated thanks to the rapid growth of sensor technology and embedded technologies.

According to surveys, the market for remote monitoring devices for various medical indicators is expected to grow at a breakneck pace. The market for remote patient monitoring and health trackers will reach $60 billion by 2023, according to Juniper Research, with revenue topping $40 billion by 2022 [1].

By 2023, more than 4 million people will be monitored remotely from the standpoint of several health markers, according to Juniper Research Company. [2]. as starting Medical device technology companies are expanding into IoT technologies.

The Internet of Things is based on autonomous data exchanges between numerous embedded devices in our environment, which are enabled by technologies such as Radio-Frequency Identification (RFID) and Wireless Sensor Networks (WSN) [3]. This information is provided by the sensing devices, and then analyzed for decision-making using an automated system as a result, the Internet of Things (IoT) was born in order to process and store data as a Where it was Communication and sensor technologies were developed.

Physical devices with microcontrollers, digital communication transceivers, and stack protocols are all part of the Internet of Things, which allows them to communicate with each other and with people.

The Internet of Things (IoT) offers a wide range of applications, including smart cities, smart homes, buildings and campuses, healthcare, logistics, and so on.

The Internet of Things intends to connect the physical and virtual worlds by leveraging the Internet as a channel for communication and information exchange across networks.

Low-Power Wide-Area Networks (LPWANs) come in a variety of proto-cols where range and processing power being the most important features as 2G, 3G, 4G, and 5G are examples of high-range high-power Ultra-wideband and WiFi are examples of low-range high-power.

ZigBee, Bluetooth, Near-Field Communication (NFC), and Bluetooth Low Energy (BLE) are examples of low-range and low-power applications; LoRa (Long Range), NB-IoT, LTE-M, and SigFox are examples of high-range and low-power devices.

This article focuses on the use of the Great Range Wide-Area Network (LoRaWAN) protocol for long distances with low energy consumption using LoRa technology.

This technology provides a cost-effective and flexible solution. [4]

When it comes to the global problem of the Covid pandemic, we can claim that data transfer over vast distances based on LoRaWAN technology could be a practical and beneficial solution in the future, not only in the healthcare industry but also in fields like automotive, industrial, and smart buildings, [5] and in many others.

The aim of this paper is to design, develop medical device for emergency state and analyze a long-distance communication Relying on the Internet of things

In the event of an emergency, this system delivers prompt and high-quality medical help to the injured person. A configuration with additional devices for ambulances is also proposed for continuous monitoring and communication of the injured person's health data. In his own home, the doctor can keep an eye on the patient's condition. The system is fully automated using IOT Net-work technology.

Currently, there are software products on the market that are similar in terms of the functionality proposed by the author as part of commercial hardware and software systems. Based on the information available in the public domain, we will consider these software solutions in more detail. To do this, we highlight the main criteria that we will pay attention to when re-viewing analogues.

There are several advantages in Deployment of wireless medical device networks based internet of things.

Advances in wireless medical device networks, as well as the advent of a dedicated public safety network and other commercial public safety solutions, have promised quicker network connection speeds and more advanced technology prospects. Agencies can generate efficiencies and assist reduce the everyday difficulties that emergency medical service providers bear by exploiting today's modern wireless networks that provide wide area coverage.

Embracing wireless medical device networks, for example, opens up possibilities like as smart ambulances, telemedicine, automatic vehicle locating (AVL), and telematics, all of which may help EMS teams provide the most efficient and effective treatment for their communities in the real world. EMS crews may transform their emergency vehicles into smart ambulances with cutting-edge technology that includes a wireless network connecting hub for mission-critical communications and secure IoT device connectivity. Faster reaction times, simpler logistical operations, and more efficient inventory control and monitoring are all possible as a result of this. There are several advantages in Deployment of wireless medical device networks:

- the benefit of deploying of wireless medical device networks to address major bottlenecks in the emergency response process;
- for machine-to-machine (M2M) communication, standardized RF data transfer technologies such as IEEE 802.15.4 have been to become cost-effective and widespread. The IEEE 802.15.4 standard has become the technology of choice for low-data-rate and long-battery-life sensors;
- wireless medical sensor network (WSN) technologies It's scalable, so any new nodes or devices can be added at any moment;
- it's adaptable, so physical partitions aren't a barrier;
- a centralized monitoring system can access all of the wireless sensor network nodes.;
- as well as it is wireless in nature, it does not require wires or cables;
- joining medical devices in Internet of Things networks, which adds to them important restrictions related to low energy consumption [6].

The purpose of the research:

- analyzing the market for existing device;
- definition detail the set of requirements for the device;
- design the system architecture;
- implementation of the system;
- testing.

1. SUBJECT AREA ANALYSIS

- Development a portable small medical device to use in case of emergency in remote areas or in disaster areas where communication services are interrupted, for purposes to rescue people's injured device contains medical sensors connected to the injured body that measure its temperature and electrical activity of the heart with the help of electrodes, Heart Rate, blood oxygen saturation Where it transmits medical Parameters wirelessly To the emergency center or hospital relying on the internet of things technology;
- This device transmits vital information Directly to the hospital in a lower cost and lower energy. A device that is easy to use by emergency teams and the patient, flexible updatable in the future.

1.1. OVERVIEW OF ANALOGUES

With the massive advancements in medical technology and Increasing demand for personal emergency response systems, where Medical device companies began To compete effectively in the market, As a product of active collaborations, increasing R&D spending, and operational expansion, firms in this industry are continually creating, developing, and offering innovative solutions for emergency circumstances, If It isn't used to measure the success of a system, it won't improve hospital performance [7].

A broad and multi-layered infrastructure of ubiquitous computing technologies and applications is also evolving. Mobile phones, laptops, Wi-Fi, Bluetooth, PDAs, and a range of sensing devices based on digital and radio frequency identification (RFID) technologies have all found their way into the healthcare industry on Humans (e.g., patients and medical personnel), medical devices, wireless sensors, intelligent wheelchairs and mobile robots are all connected through the Internet of Things. People in the healthcare business rely on technology to provide high-quality, economical treatment, eliminate medical errors, maintain patient safety, and enhance their healthcare procedures. [8]. In sum, using It is in great demand in the healthcare sector.

To make the most of the Internet of Things, hospitals must have the resources they need to provide the most value and avoid failure [9].

So we will show some of the products of leading manufacturers of emergency medical devices to analyze the work of these devices and compare them.

1.1.1. Blue Spark Technologies

TempTraq is a Class II FDA-approved medical device that provides healthcare practitioners with the first wireless continuous temperature monitor a soft, comfortable, in form of soft patches, sensors temperature, records, and transmits body temperature data to a smart device (Apple or Android) running the TempTraq app for up to 72 hours. The TempTraq sensor monitors "axillary" temperature under the arm, which is presented in the TempTraq app on mobile, which connects to cloud services. [10]

TempTraq Connect is a Google Healthcare Cloud Platform-supported cloud service that allows patients and caregivers to monitor body temperature from anywhere. Data from the secure server can be integrated with electronic health records, central nurse workstations, patient bedside monitors, and mobile devices using HL-7 standards, allowing doctors to visualize temperature data and map it to the appropriate patient record fields.

The system may handle a single hospital or a multi-hospital/physician group health system and is scalable. The FDA, CE, and TGA have all given their approval to the system. TempTraq is currently being used in a number of applications where real-time continuous temperature monitoring for fever diagnosis is necessary, including cancer, clinical trials, and where patients are undergoing immunosuppressive medication.

University Hospital in Cleveland, Ohio, has just adopted TempTraq to monitor the temperatures of frontline healthcare workers treating COVID-19 patients. [11]

Figure 1 – Blue Spark

1.1.2. Empatica E4

Empatica E4 is a wrist-worn medical wearable device that measures physiological data in real-time. It includes software, biomarkers, and wrist-worn medical wearables for continuous monitoring of health issues. The FDA has given its Embrace smartwatch certification in the field of neurology. [12] As a response to the COVID-19 pandemic, Care, a remote health monitoring platform based on Empatica's current technologies, was introduced. The Care platform wirelessly gathers and broadcasts vital signs to a user-friendly app and web dashboard, where they may be displayed and used to advise clinicians, researchers, careers, and employers about a user's well-being and whether action is required.

Empatica's legacy E4 wristband is used to collect physiological data. The E4 is CE-certified, noninvasive, and has been utilized in real-world studies on human behavior and physiology by thousands of researchers. [13] It uses a PPG sensor, an infrared thermopile, a 3-axis accelerometer, and an EDA (electro dermal activity) sensor to continually capture essential vitals from the wrist, such as heart rate, heart rate variability, peripheral temperature, and respiration rate [14].

The E4's data is delivered through Bluetooth and visualized on the Care Software, a dedicated patient app that can be downloaded on any iOS or Android phone. The software allows patients to maintain track of their own health and the system's state while also sending real-time data to the Care Portal, an online dashboard hosted on Empatica's HIPAA-compliant cloud.

A doctor, researcher, or caregiver can utilize the Care Portal to rapidly and securely access data generated by numerous people, visualize it, and compare it to patterns. It includes an easy-to-use interface and was created to mimic the setup found in a multisite context such as a hospital, a research trial, or a workplace. Empatica's bespoke digital biomarkers, which can provide extra insight into patient physiology and are especially valuable for monitoring patients with a specific set of disorders, can be used in conjunction with the Care Platform.

Figure 2 – Empatica E4

1.1.3. VitalConnect Sensor

Is a component of the VitalConnect Platform the VitalPatch device is a wireless, battery-operated wearable biosensor, worn on the torso to record heart rate, electrocardiography (ECG), heart rate variability, R-R interval, respiratory rate, body temperature, skin temperature, fall detection, activity (including step count) and posture (body position relative to gravity, including fall detection).

The VitalPatch device continuously gathers physiological data from the person being monitored and then transmits encrypted data via bi-directional communication (Bluetooth) to the Relay device when in range of the Relay device. The encrypted wireless data provided by the VitalPatch device may be downloaded from the Relay device for storage, or integrated into a Third-Party Relay Application via the APIs of the Relay Software Library. Additionally, wireless data may be transferred to and stored on an optional Secure Server for future analysis if there is an active server connection. The data provided by the VitalPatch device is intended to aid caregivers in making diagnoses by providing additional information to standard of care patient monitors.

During normal operation, data is collected by the VitalPatch device and transmitted immediately to the Relay device. A continuous connection is needed between the VitalPatch device and the Relay device in order to facilitate continuous data transmission. The continuous wireless transmission of data occurs with The VitalConnect Platform is a wireless remote monitoring system intended for use by healthcare professionals for continuous collection of physiological data in home and healthcare settings. This can include heart rate, electrocardiography (ECG), heart rate variability, R-R interval, respiratory rate, body temperature, skin temperature, activity (including step count), and posture (body position relative to gravity including fall). Data are transmitted wirelessly from the VitalConnect Biosensor for storage and analysis. The VitalConnect Platform can include the ability to notify healthcare professionals when physiological data fall outside selected parameters. [15]

The device is intended for use on general care patients who are 18 years of age or older as a general patient monitor, to provide physiological information. The data from the VitalConnect Platform are intended for use by healthcare professionals as an aid to diagnosis and treatment. The device is not intended for use on critical are patients [16].

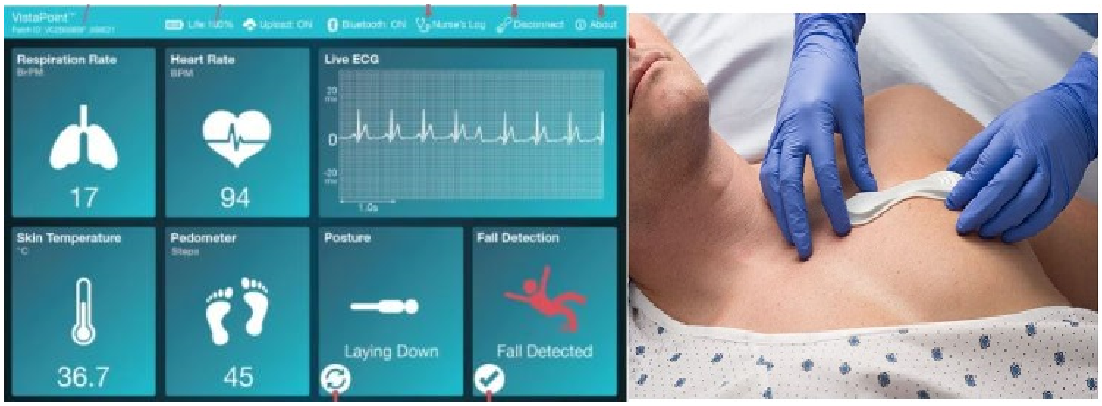


Figure 3 – VitalConnect Sensor

After comparing the different devices Blue Spark Empatica E4, VitalConnect on features Rate to see how they compare to each other, I found out what are their weaknesses are and it helped me to build up on my proposed solution.

Table 1 – Comparison of analogues

Feature	Blue Spark	Empatica E4	VitalConnect
Transmits Data	Bluetooth	No	No
Connect to cloud service	Yes	Yes	yes
Battery life	72 H	24 H	168 H

Table 2 – Continuation

Sensor	Temperature	Temperature, PPG, accelerometer, EDA	Temperature , heart rate,ECG,Respiratory Rate Body Posture, FallDetection, Activity,Blood Pressure,Oxygen Saturation
Memory	No	Yes, recorded 48 H	Yes, recorded 10 H
wearable	patch it on the skin	wristband	patch it on the skin

1.2. ANALYSIS OF THE MAIN TECHNOLOGICAL SOLUTIONS

Analysis of the subject area gave us an idea of the list Solutions in this area.

A comparison of three devices was made personal emergency response systems that relate in some way to health care.

Each personal emergency response systems devices have its advantages and disadvantages.

The main disadvantage of devices depends on short transmission distance as Bluetooth signal Wherein the connection is lost in case of moving away from the source or losing the source such as the mobile device What causes loss of vital information for patient follow-up In the case of disasters, communication and internet services are interrupted, which leads to the cessation of medical platforms, so we need a direct connection to the medical sensors to assess the condition of the injured After the analysis of the medical devices market, the task of the current work is expanded.

1.2.1. Programming Technologies

For this project we will use C and Arduino Platform as our main programming languages for development. Development that tools are required to develop and test/debug the code include:

- compiler;
- debugger.

1.3. CONCLUSION

During the analysis of the subject area, a literature review was conducted,On the market, there are a number of related medical devices that have a similar purpose of measuring physiological data, but are not modules internet of things which will help in the development of the work.

Their advantages and disadvantages are revealed.

Medical devices were considered in terms of data collection and transmission.

2. DEFINITION OF REQUIREMENTS

2. 1. FUNCTIONAL REQUIREMENTS

- measurement of health parameters of the injured body by medical sensors;
- compilation and analysis of health parameters from all sensors in the Sender device and display it on the screen (be Installed in device);
- the ability of the transmitter to send health parameters to the long distance and with the least power;
- view the health parameters of the receiver device on the Screen (be Installed in device);
- receiver device is able to Sharing health parameters on the IOT platform
- the device works with low energy consumption and is capable of self-charging the battery.

2.2. NON FUNCTIONAL REQUIREMENTS

- the system should be easy to use;
- measurement of health parameters for injured in the sender device should be noticeable;
- the delay of data transmission from the device should be minimal (no more than 200ms);
- the transceiver must be light and compact.

In the course of determining the requirements for the hardware and software complex, general, functional, non-functional, requirements for ergonomics and technical aesthetics, Interfaces requirements well as documentation requirements.

It is on these data. work will be built Requirements

The receiving device send the vital signs on cloud and display it website the best practices of building the interface (simplicity, consistency of elements, the system's message about what is happening, etc.) will be taken into account, so that it is clearly perceived by users and does not require additional training.

2.3. REQUIREMENTS FOR ERGONOMICS

The system being developed should be able to quickly receive, process and analyze information, while notifying responsible persons about critical situations. Also, using the system, it should be accessible and easy to view current information on medical equipment and build reports.

2.4. DOCUMENTATION REQUIREMENTS

The user interface must be in English.

2.5. CONCLUSION

The documentation for the device must contain the technical characteristics of the device, which include the following requirements: weight,

dimensions, as well as instructions for the user how to use the system correctly.

In the course of determining the requirements for the hardware and software complex, general functional, non-functional, requirements for ergonomics and technical aesthetics, Interfaces requirements well as documentation requirements

It is on these data. Work will be built.

3. DESIGN OF THE SYSTEM

Design is the process of determining a system's or architecture, components, interfaces, and other features. The end result of the design is a project that contains an integrated set of models, attributes, or characteristics that are stated in a way that can be implemented later.

3.1. FUNCTIONAL COMPOSITION

To describe the functional composition of the system, a functional diagram can be presented. This scheme explains certain types of processes occurring in integral functional blocks. Figure 4 shows the functional diagram of the system.

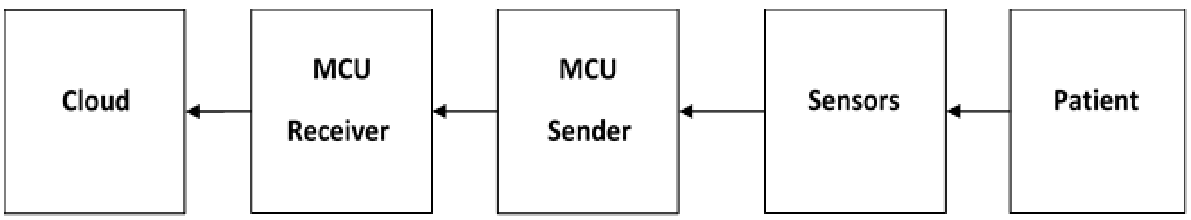


Figure 4 – Functional diagram

3.2. NETWORK PROTOCOLS

A reliable link (of networks) between devices/sensors and the IoT platform is required to set up a medical device-based internet of things..

The Internet of Things (IoT) is a network of physical networked items with smart devices and sensors that connect and publish data with systems and other devices without the need for human interaction. As per the requirements, we will review the network technologies for the purpose of selecting the appropriate components of the device afterward, can move forward with selecting the type of IOT protocol technology and wireless network based on the following criteria:

- the coverage area;

- power consumption;
- the device environment;
- amount and nature of data.

Some types of technologies available for wireless networks can be viewed in the following figure 5.

Standard	ZigBee (WPAN)	Low Power Wi-Fi (WLAN)	6LoWPAN (LPWAN)	LoRaWAN (LPWAN)	NB-IoT (LPWAN - cellular)	LTE-M (LPWAN - cellular)	5G (cellular)
Nominal range	10 -100 m	70 m - 225 m	25 - 50 m	2 - 15 Km	1 - 15 Km	1 - 11 Km	up to 100 km
Max Data Rate (Kbit/s)	250 Kbps	15 Mbps	250 Kbps	50 Kbps	250 Kbps	1 Mbps	599 Mbps
Power consumption	Medium	Low to medium	Low	Low to medium	Low	Low	Low to medium

Figure 5 – Types of technologies of wireless Network

Previous figure 2 has demonstrated that many forms of wireless sensor networks, including as ZigBee and Wi-Fi networks, can be used for monitoring and control [17]. Present LoRa as a new wireless sensor network. LoRa is the abbreviated name for long-range, and it is also a protocol.

A low-power wide-area network (LPWAN) [18] is a type of low-power wide-area network. It stands out because it conserves energy.

Usage, low cost, and capacity to transmit data long distances [19].

These traits and key aspects are quite helpful in the development of a new smart monitoring system.

Without any infrastructure, monitoring health sensors is possible [20].

The system is separated into two parts: the first is a measuring and send Data part that involves the use of three different types of sensors that will be interconnected within one device.

3.2.1. Internal interaction protocol

Based on the requirements in the previous paragraph, it is necessary to choose a protocol for sending data in the local network. The most common in the field of Internet of things today MQTT

3.2.2. Description of The MQTT Protocol

MQTT (Message Queue Telemetry Transport) is a lightweight, compact and open data exchange protocol designed to transfer data to remote locations where a small code size is required and there are channel bandwidth limitations. The protocol is initially focused on applications in M2M (Machine to Machine) systems and therefore has become widespread in the field of IoT. The first version of the protocol was developed by Andy Stanford-Clark (IBM) and Arlen Nipper (Arcom) in 1999 and published under a free license. At the time of writing this work, the version of the protocol 3.3.1 is widely distributed, which in 2014 was standardized by the OASIS consortium, and in 2016 received the status of the ISO/IEC standard with the number 20922. It should be mentioned that in April 2019, a new version of the MQTT -5.0 protocol became available, which, however, has not yet managed to become widespread, so in this work we will use version 3.3.1.

The MQTT protocol works at the application layer on top of TCP/IP (see Figure 3.2) and uses port 1883 by default (8883 when connected via SSL).

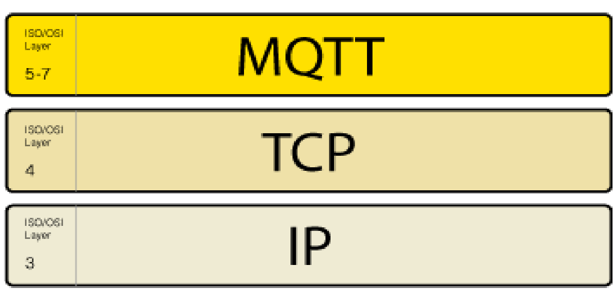


Figure 6 – The place of the MQTT protocol in the ISO/OSI model

3.3. GENERAL HARDWARE PARTS' STRUCTURE

3.3.1. General hardware parts' structure of the sender Device

The sender hardware consists of various electronic elements. It includes the following modules:

- power supply of the part Battery;
- Temperature sensors, EGC sensors, Oximeter Sensor;
- USB exchange of information with the system.

Each of which has a certain functionality, thanks to which the software and hardware complex will be able to act as one. Shows below a block diagram.

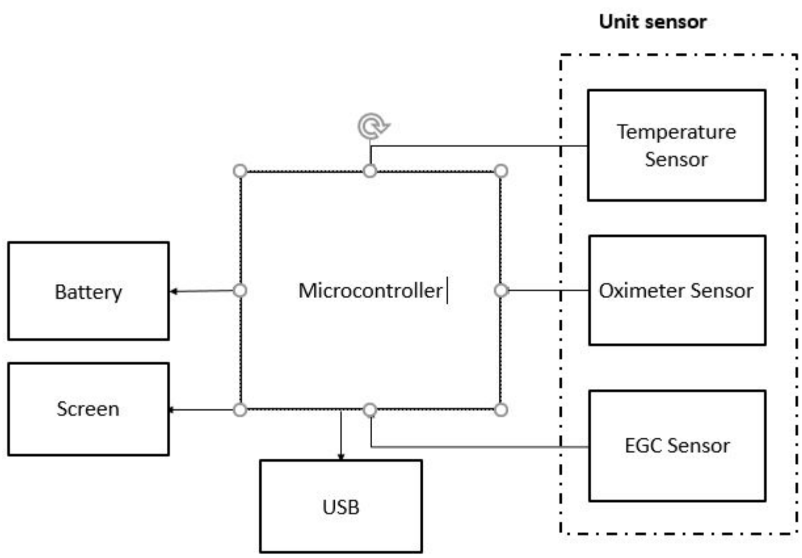


Figure 7 – General hardware parts' structure of the sender Device

3.3.2. General hardware parts' structure of the receiver Deiced

The receiver hardware consists of various electronic elements. It includes the following modules:

- power supply of the part Battery;
- screen;
- USB exchange of information with the system.

Each of which has a certain functionality, thanks to which the software and hardware complex will be able to act as one. Shows below a block diagram.

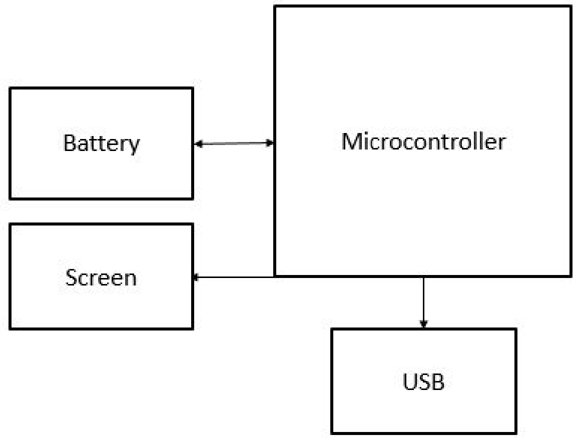


Figure 8 – General hardware parts' structure of the receiver Deiced

3.4. SELECTION OF COMPONENTS

The addition of intelligent functions to modern electronic equipment is based on the use of microprocessors (MCU), programmable logic integrated circuits, system-on-chip devices and other modern digital devices. Such integration makes it possible to automate the processes of measurement, regulation and information processing, as well as to ensure such properties of instrument complexes as multi functionality, modifiability, adaptability.

LoRa technology for data transmission wireless, therefore a high response rate of the transceiver is required, should be MCU a high-performance. In addition, Lora is considered a cheap technology, so when choosing an MCU, its cost will be taken into account in order to minimize costs, but maintain the reliability of the device and ensure sufficient performance. During the search on the Internet, many high-performance MCU were found, it is not possible to conduct a comparative analysis for all within the framework of the work, therefore, the most common ones are selected for analysis.

3.5. FIELD HARDWARE

For the development of sender and receiver devices, an TTGO T-Beam ESP32 – WiFi, Bluetooth, GPS, LoRa, chip board was selected. The appearance of the board is shown in Figure 3.5, and a brief specification in down.

3.5.1. TTGO T-Beam esp32

The board is built around a dual-core ESP32 chip, with 4MB of SPI flash onboard, providing both Wi-Fi and Bluetooth LE via a “3D antenna” on the PCB.

The board’s LoRa support comes in three different variants, operating at 433MHz, 868MHz, and 915MHz depending on region, with an included SMA antenna. While location tracking is provided by the onboard u-blox NEO-6M GPS module with ceramic antenna.

Flipping the board over, there is a battery holder for a 18650 Li-Ion cell.

The TTGO T-Beam offers 26-pin headers with GPIO, ADC, VP/VN, DAC, touch, SPI, I2C, UART, 2×“LoRa” pin, and power signals (5V/3.3V/GND). [20]

The board can be programmed using the Arduino development environment, according to the necessary criteria, the device a low cost, small size, sufficient power

for reading all signals without delay and the ability to connect via wireless (Bluetooth, Wi-Fi) Therefore it fits more.

To read data from connected sensors and sent to a high distance sensors medical was selected.

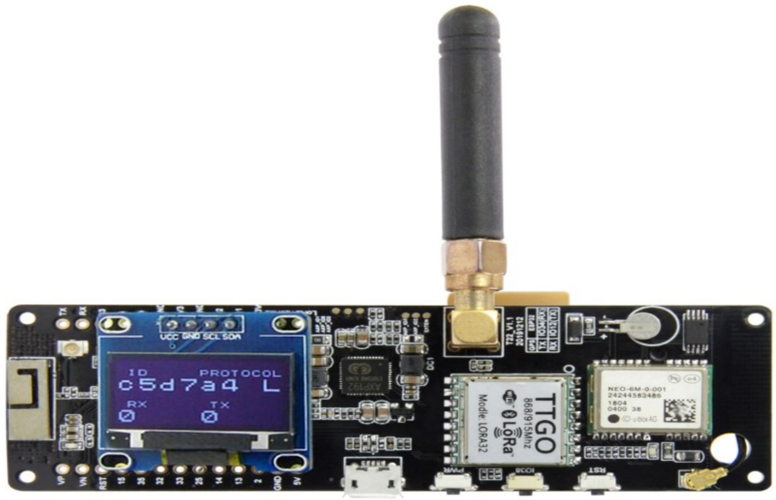


Figure 9 – TTGO T-Beam ESP32

3.5.2. AD8232 ECG Sensor

The AD8232 is a neat little chip used to measure the electrical activity of the heart, Electrocardiography is used to help diagnose various heart conditions.

Fully integrated single-lead ECG front end Low supply current: 170 µA (typical) Common-mode rejection ratio: 80 dB (dc to 60 Hz) Two or three electrode configurations High signal gain (G = 100) with dc blocking capabilities.

pole adjustable high-pass filter Accept up to =300 mV of half full potential Fast restore feature improves filter settling Uncommitted op amp.

pole adjustable low-pass filter with adjustable gain Leads off detection: ac or dc options Integrated right leg drive (RLD) amplifier Single-supply operation: 2.0 V to 3.5 V Integrated reference buffer generates virtual ground Rail-to-rail output Internal RFI filter 8 kV HBM ESD rating Shutdown pin 20-lead 4 mm × 4 mm LFCSP package [21].

Figure 10 – AD8232 ECG Sensor

3.5.3. MAX30102 Pulse Oximeter Sensor

The MAX30100 is a heart rate monitoring sensor along with a pulse oximeter. To detect pulse oximetry and heart rate signals, it incorporates two LEDs, a photodetector, improved optics, and low-noise analog signal processing. The MAX30102 runs on 1.8V and 3.3V power sources, and it may be turned down by software with very little standby current, allowing the power supply to be connected at all times [22].

It has a five pin with an enabled I2C communication protocol to interact with the microcontroller.

Figure 11 – MAX30102 Pulse Oximeter Sensor

3.5.4. Temperature Sensor GY-906 MLX90614

The GY-906 MLX90614 is an Infra-Red thermometer for non-contact temperature measurements. The signal conditioning ASSP and the IR sensitive thermopile detector chip are both housed in the same TO-39 container.

The thermometer achieves exceptional accuracy and resolution because to its low noise amplifier, 17-bit ADC, and powerful DSP unit.

The thermometer comes factory calibrated with a digital SMBus and PWM (System Management Bus) output [23].

The 10-bit PWM is set up to continually communicate the measured temperature in the range of -20...120°C, with an output resolution of 0.14°C, as standard.

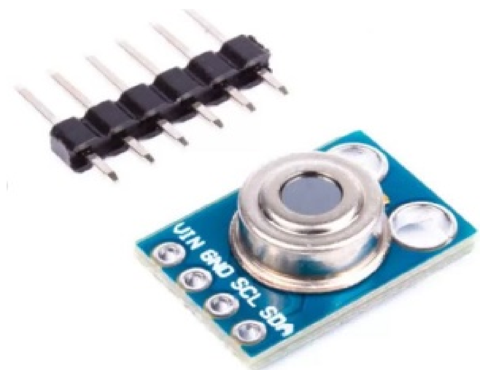


Figure 12 – Temperature Sensor GY-906 MLX90614

3.6. DESIGN DEVICE CASING

The casing must be made material must be strong enough to withstand, for example, a fall of the device from a small height. The materials used for the manufacture of the case must be ergonomic. The case has dimensions of 15x15x8cm.

3.6.1. Design device structure sender

Components of (TTGO Esp32, sensors, battery and screen) are assembled inside a waterproof plastic casing with fixed antenna installation outside the casing shown in Figure 13.

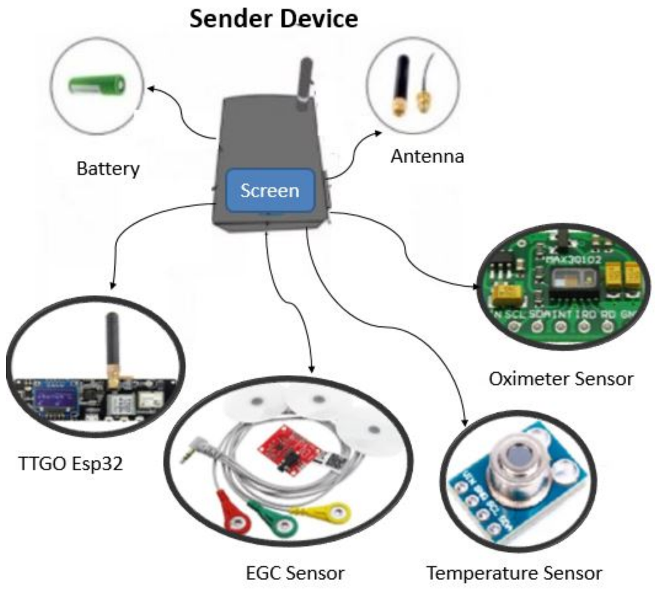


Figure 13 – Device structure sender

3.6.2. Design device structure Receiver

Components of (TTGO Esp32, battery and screen) are assembled inside a waterproof plastic casing with fixed antenna installation outside the casing shown in figure 14.

Figure 14 – Device structure sender

3.7. ALGORITHMS FOR SOLVING THE PROBLEM

The system comprises an integrated Sensing Node connected with sender, Gateway, and Cloud Server. Will transmit data across two different connections: LoRa and the internet. The LoRa connection was chosen because it allows for peer-to-peer communication between the sender and gateway node, making it ideal for use in remote areas with poor signal.

3.7.1. Algorithms for Sender Device

Sensing Node (Sender). This node is functioning as a sensor reading and the sender for transmitting data to the gateway. The devices consist of temperature ,EGC, Oximeter .TTGO T-Beam LoRa 32 as a sender. The Sensors will sense data and transferring to the LoRa Gateway using LoRa Connection with 433 MHz Radio Frequency. The Deep Sleep feature is embedded in this system. After sending data, sensing node has been going to sleep for a while, and wake up afterward. Deep Sleep can reduce power consumption and making the device saving energy. The schematic design of the sender, and the flowchart diagram of a sensing node can be seen in Figure 15.

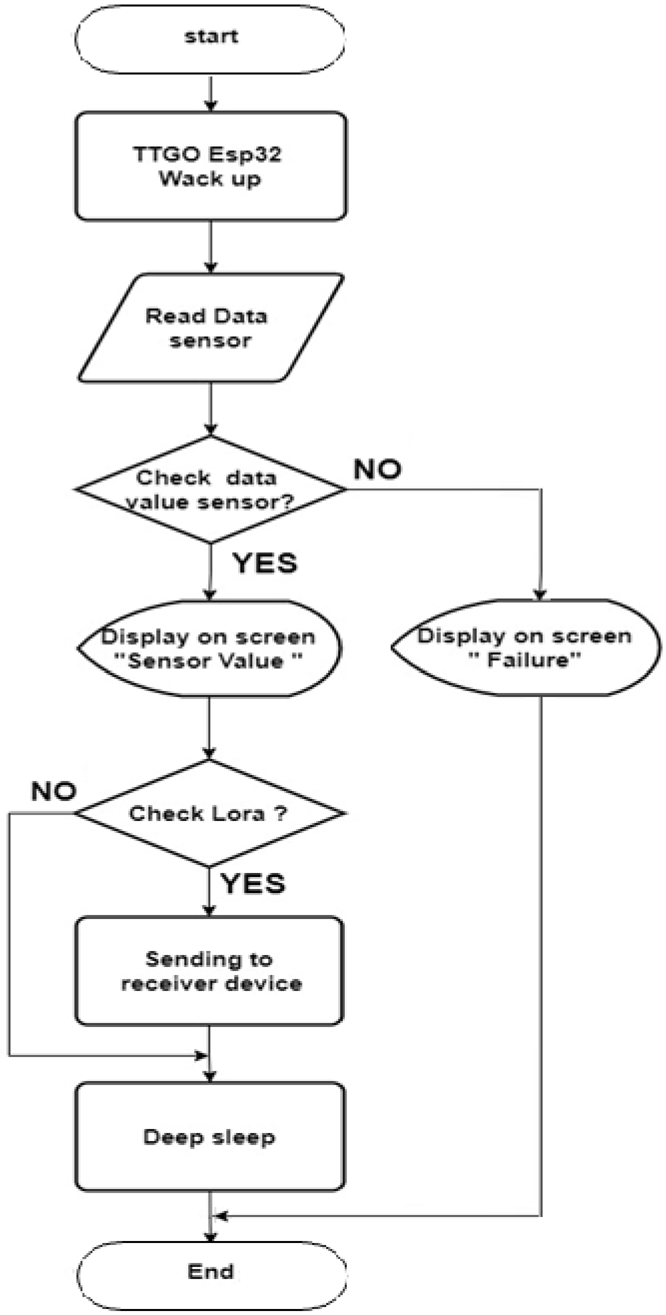


Figure 15 – Flowchart diagram of LoRa Sender

3.7.2. Algorithms for Receiver Device

Gateway System (receiver). In this node, the data received from the sender node will be read and view in screen and forward to the cloud server. This node will check the Internet connection, if the connection is unavailable then will be reconnected, After that, the data will be sent again to the cloud if the Internet is available. . The data are transmitted to the cloud using the Hotspot" with a Wi-Fi feature that is already in the TTGO LoRa32 Receiver. The flowchart diagram can be seen in Figure 15. Data received from the gateway will be viewed to the cloud that can be monitored real-time and accessible based on the website.

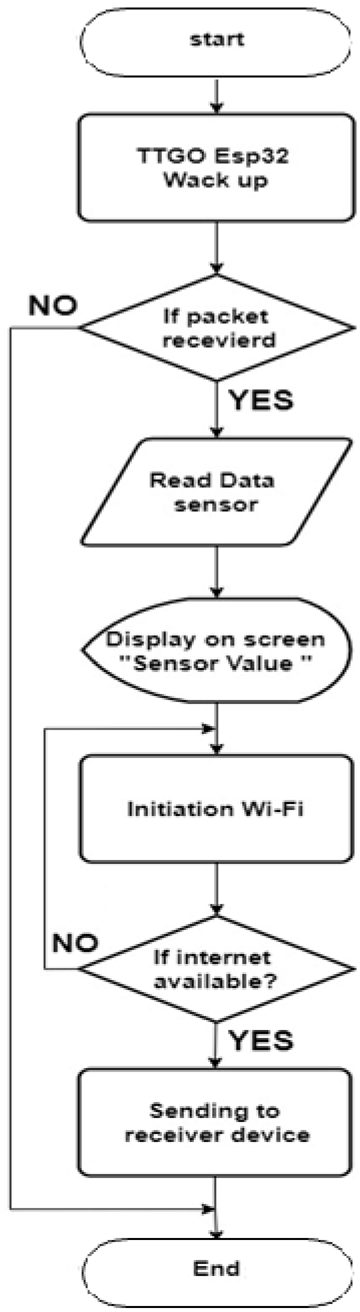


Figure 16 – Flowchart diagram of LoRa Receiver

3.8. CONCLUSION

In the third chapter, the main protocols and wireless networks used in the field of IOT were considered. Based on analysis, the Lora and MQTT protocol was chosen as the most fully satisfying the requirements put forward earlier. Selected Hardware were for sensor (EGC, Temperature, Oximetry) and then All hardware partings and connected it together and put in cover. Description of the sending and receiving algorithms of the device. Here is completed the proposed plan for the development of the device.

4.DEVELOPMENTARCHITECTURE AND IMPLEMENTATION

As already mentioned in paragraph 2, the system consists of a sender device (field device) connected to the medical sensors for reading vital parameters for patient using LoRa Connection will be sending to receiver device in Remote area where receives measurement Vitals parameters and displays it and sends to the cloud at the same time.

This chapter discusses the development of a scheme of interaction between send, receive, sensor, managed devices and a system of interaction between the main components of the system including a system for delivering notifications to the Hospital.

4.1. COMPONENTS SENDER DEVICE

The sender device has three sensors and a display screen with chip Lora built in mainboard and source power (Battery)These components are directly associated with microcontrollers (Esp32 TTGO T-been) as designed to serve the desired purpose.

4.1.1 Temperature sensor (GY-906 MLX90614)

Body temperature measurement by infrared thermometer (non-contact).

- Connecting Hardware.

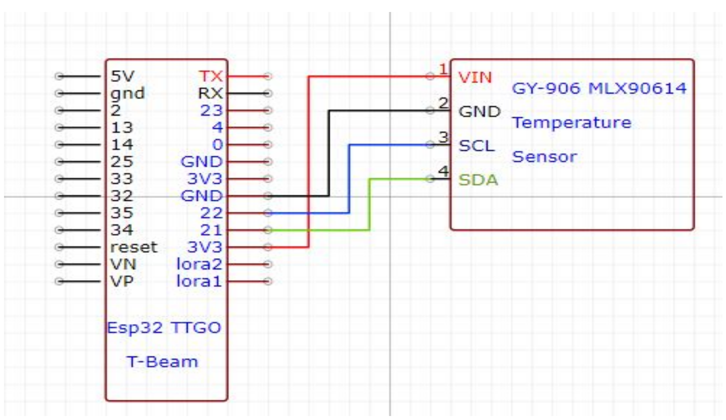


Figure 17 – Connecting Hardwar temperature sensor

Input voltage (VIN) and GND pins temperature sensor is connected to 3.3V, the control line (SCL) line is connected to GIOP 22. the data line (SDA) line is connected to 21, and sensor have a pull-up resistor on the I2C line.

- Set Software.

At first, we start installing the Arduino <Adafruit_MLX90614.h> library required for sensor operation Then we apply main function for reading and displaying the patient's status directly.

Depends on the normal norm of body temperature (36.1-37.2 C):

a) If the body temperature is Smaller than (36.1 C) the alarm will be displayed ("Ready - Place Sensor!").

b) If the body temperature is greater than (37.2 C) will be displayed ("Fever!").

c) If the body temperature is (36.1-37.2 C) will be displayed ("Normal").

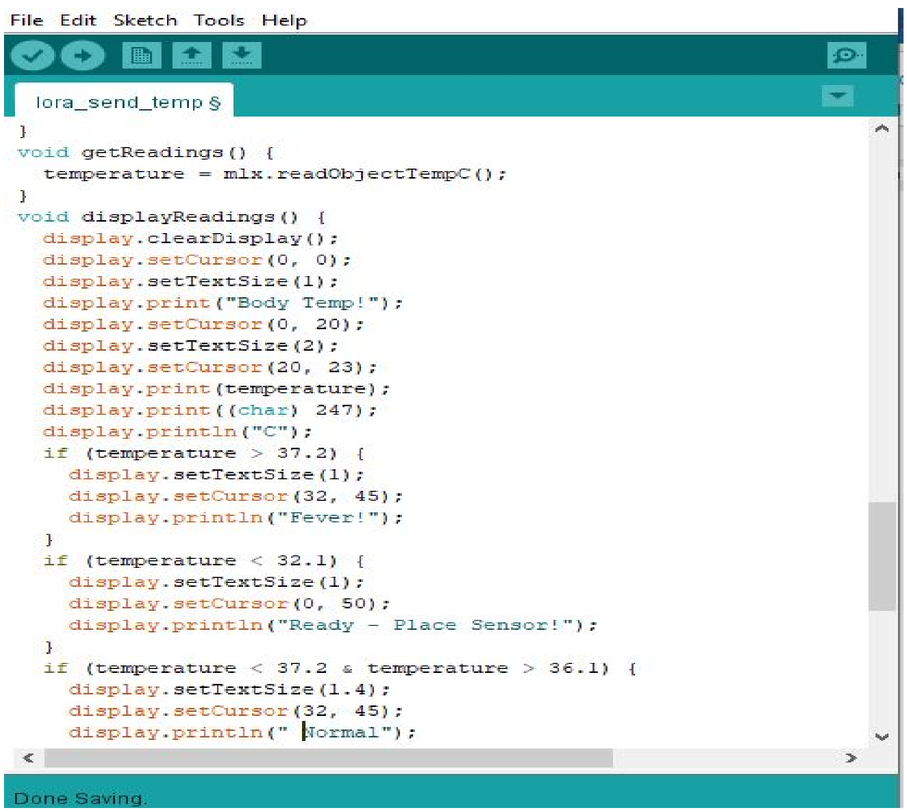


Figure 18 – Main function temperature sensor

4.1.2. MAX30100 Pulse Oximeter Sensor

The MAX30100 sensor contains two functions integrated into it pulse monitoring and measurement of blood oxygen saturation in a non-invasive form. The sensor contains photodetectors and optical elements in which the red LEDs are modulated by pulses. The LED current can be adjusted in the range from 0 to 50mA. The following figure 19 shows the appearance connecting of the MAX30100 sensor.

- connecting Hardware.

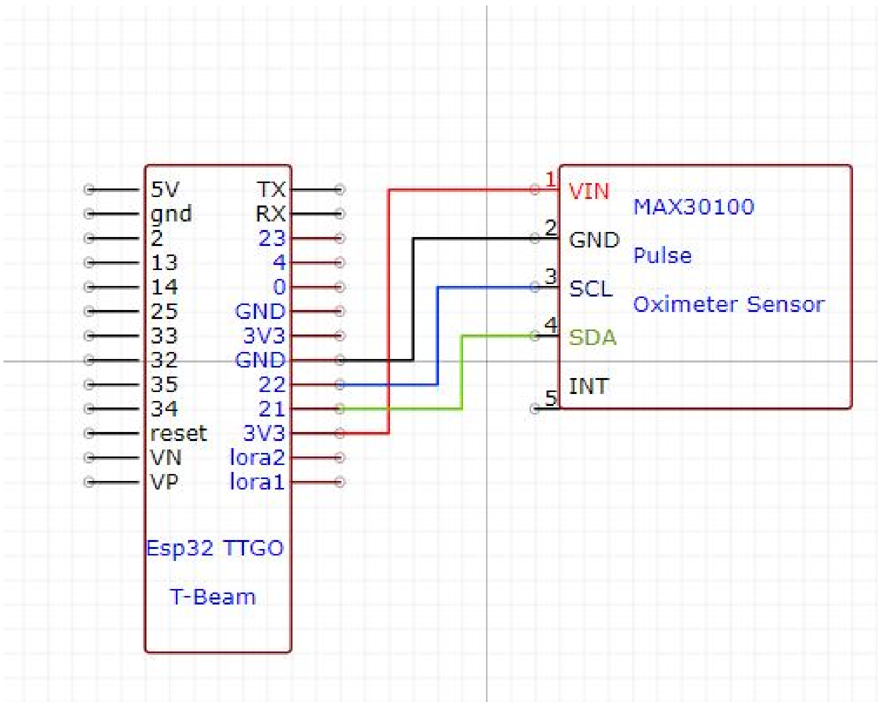


Figure 19 – Connecting Hardwar Oximeter Sensor

Input voltage (VIN) and GND pins and connect interface (SCL, SDA) (GPIO21, GPIO22) to transmit information to the microcontroller via the I2C.

- set Software.

At first, we start installing the Arduino < MAX30100_PulseOximeter.h> library required for sensor operation Then we apply main function for reading and displaying the patient's status directly.

Depends on the normal norm of body Oxygen saturation 95-99% and heart rate 60-100/Minute, the results (Spo2, Hart rate) will also be displayed on the screen directly.

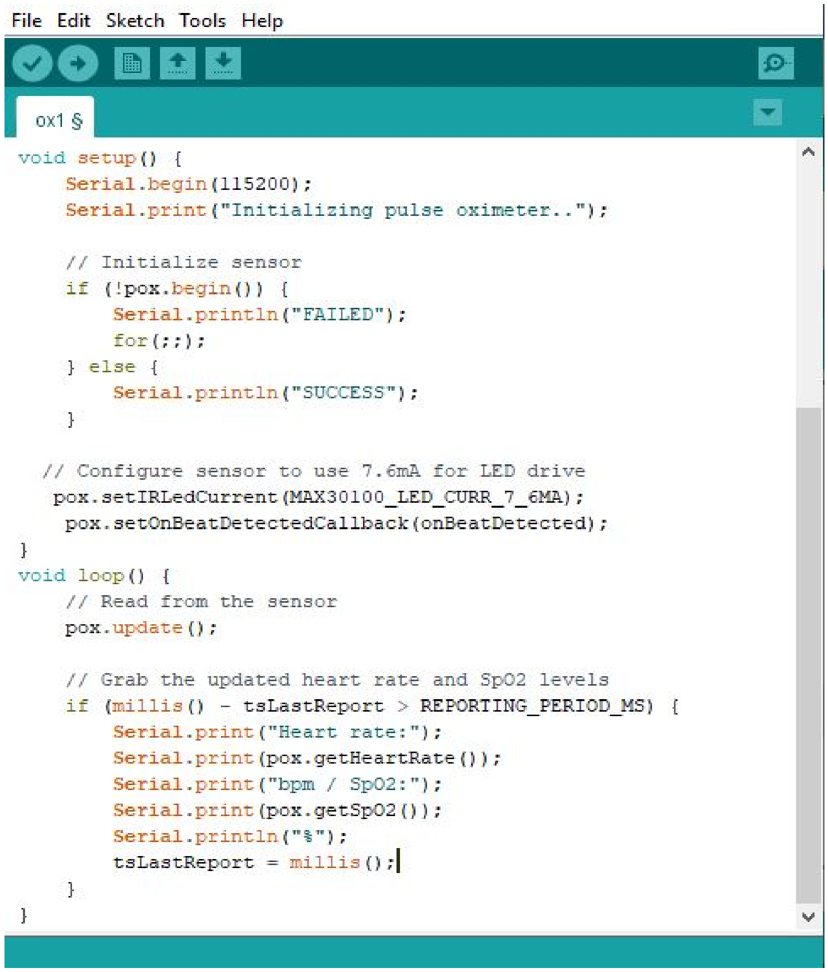


Figure 20 – Main function Oximeter Sensor

4.1.3. AD8232 ECG Sensor

For ECG and other bio potential measurement applications, the AD8232 is an integrated signal conditioning block. Its purpose is to extract, amplify, and filter tiny bio potential signals in noisy environments.

- connecting Hardware.

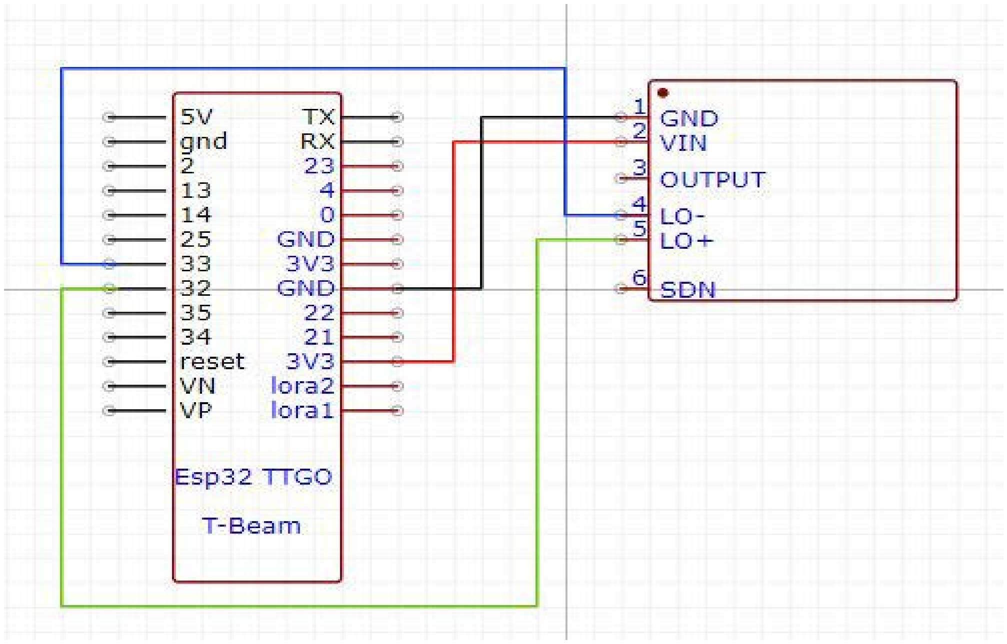


Figure 21 – Connecting Hardwar ECG Sensor

Input voltage (VIN) and GND pins and connect interface (SCL, SDA) (GPIO33, GPIO32) to transmit information to the microcontroller via the I2C.

- set Software.

Then we apply main function for reading and displaying the patient's status directly. Depends on the normal norm of body Normal ECG Parameters:

- P Wave 0.06-0.11 <0.25 PR;
- Interval 0.12-0.20 ;
- PR Segment 0.08;
- QRS Complex <0.12 0.8-1.2;
- ST Segment 0.12;
- QT Interval 0.36-0.44;
- T Wave 0.16 <0.5.

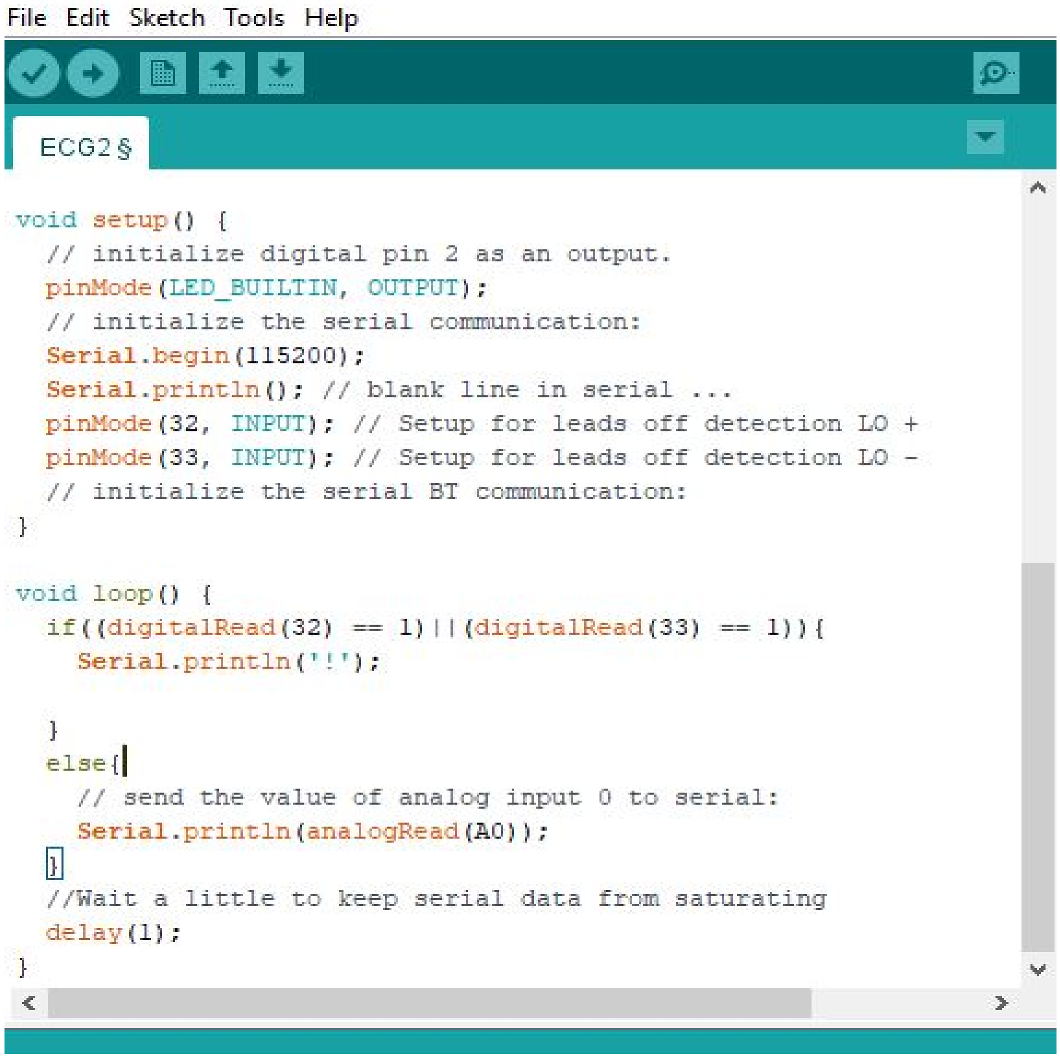


Figure 22 – Main function ECG Sensor

4.1.4. Screen 0.96 Oled

For Display reading the sensors through which we know the patient's current condition.

- connecting Hardware.

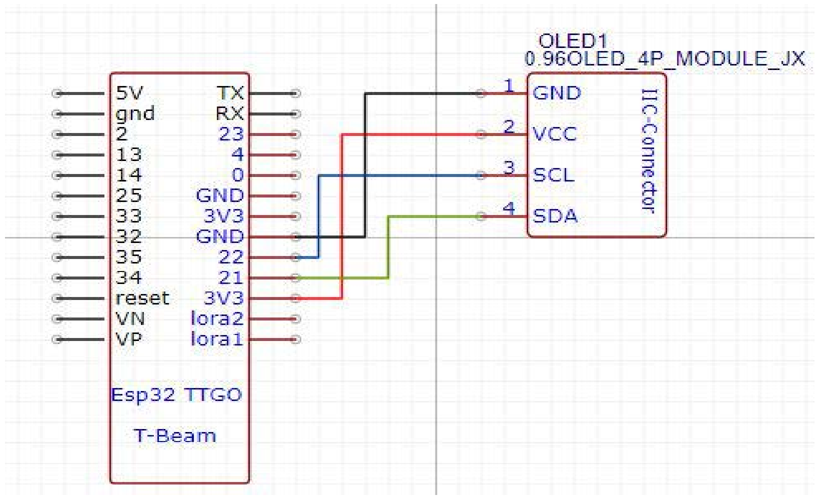


Figure 23 – Connecting Hardwar screen

Input voltage (VIN) and GND pins temperature sensor is connected to 3.3V, the control line (SCL) line is connected to GIOP 22. the data line (SDA) line is connected to 21, and sensor have a pull-up resistor on the I2C line.

- set Software.

Figure 24 – Main function Screen

4.2. DATA TRANSFER

After the sensors data is analyzed and displayed will send to the receiver device by LoRa Connection with 433 MHz Radio Frequency The chip LoRa SX1278 works with SPI communication protocol so it c used with esp 32 microcontroller that supports SPI. It uses an Ariel (antenna).

- connecting Hardware.

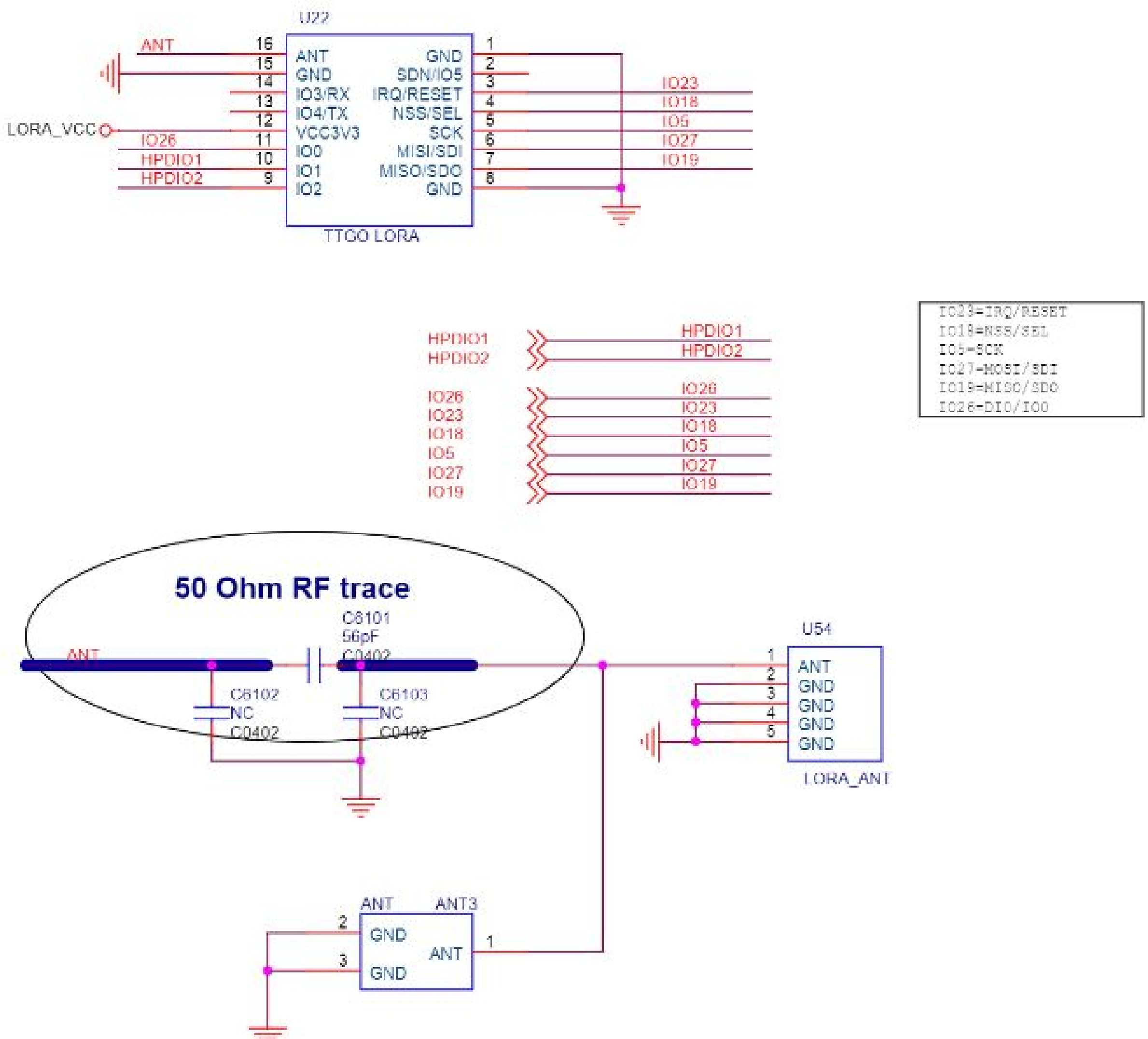


Figure 25 – Connecting Hardwar Lora chip

The module should be powered only with 3.3V and the SPI line can be connected to uP/uC (GPIO 5,26,19) as shown in the finger25.

- set Software.

At first, we start installing the Arduino <SPI.h> <lora.h> library required for operation Lora chip and define pins, define Band (433) then we apply main function for reading and send the data.


```
#include <SPI.h>
#include <LoRa.h>
#define SCK 5
#define MISO 19
#define MOSI 27
#define SS 18
#define RST 14
#define DIO0 26
#define BAND 433E6
void initLoRa()
{
  Serial.println("LoRa Sender Test");
  //SPI LoRa pins
  SPI.begin(SCK, MISO, MOSI, SS);
  //setup LoRa transceiver module
  LoRa.setPins(SS, RST, DIO0);

  if (!LoRa.begin(BAND)) {
    Serial.println("Starting LoRa failed!");
    while (1);
  }
  Serial.println("LoRa Initializing OK!");
  display.setCursor(0,10);
  display.print("LoRa Initializing OK!");
  display.display();
  delay(2000);
}
```

Figure 26 – Main function Lora define

LORA_send §

```
}

void sendReadings() {
  LoRaMessage = String(readingID) + "/" + String(Temperature) + "&" + String(SPO2) + "#" + String(Hart rate) "&" + String(EGC);
  //Send LoRa packet to receiver
  LoRa.beginPacket();
  LoRa.print(LoRaMessage);
  LoRa.endPacket();

  Serial.println("Packet Sent!");
  displayReadings();

  delay(10000);
}

void setup()
{
  //initialize Serial Monitor
  Serial.begin(115200);
  initDHT();
  initBMP();
  initOLED();
  initLoRa();
}

void loop() {
  getReadings();
  sendReadings();
}
```

Figure 27 – Main function Lora sent data

4.3. SENDER DEVICE

The Microcontroller Collect Connected all parts of the sensors Deal with them according to code to work in a coordinated manner as Esp32 TTGO contains a battery type 18650 and able to charge the battery This ensures his work for a long time. Finally, form of the sender device as shown figure 28.

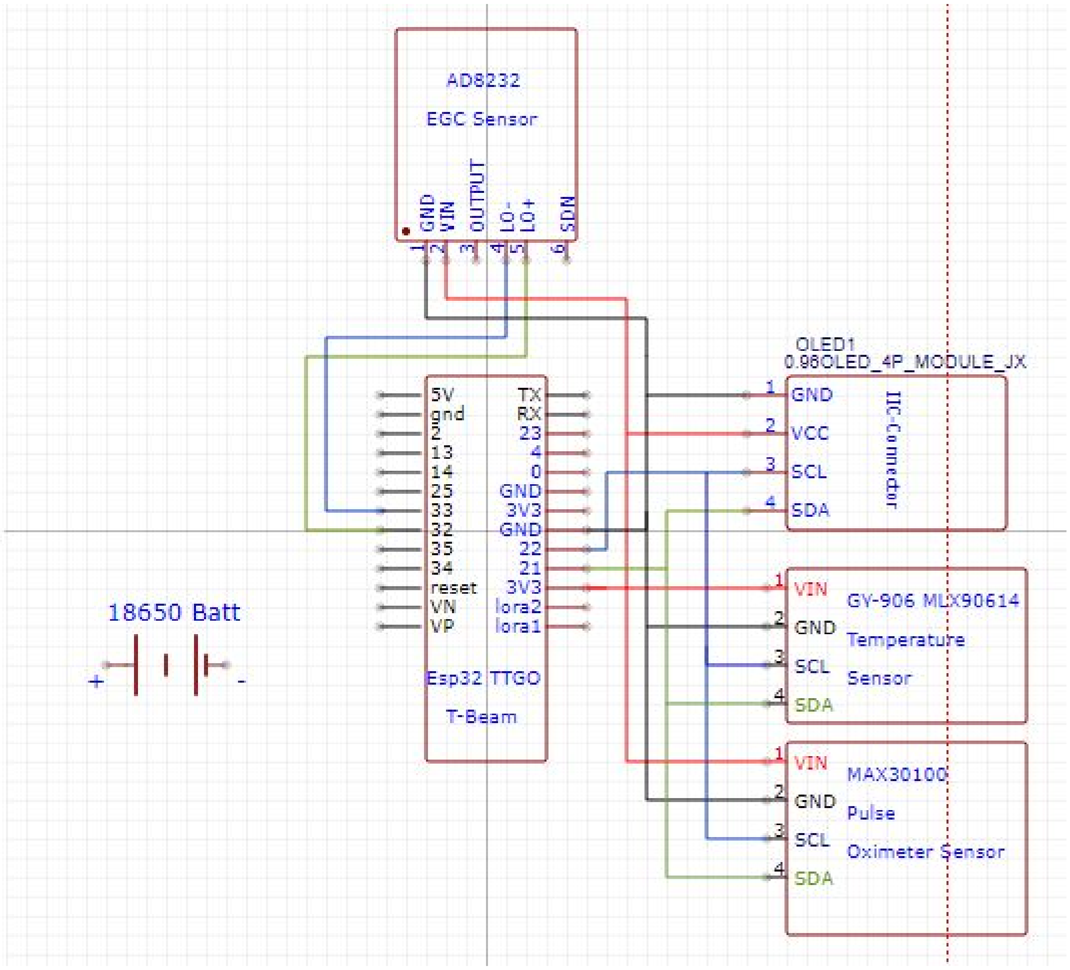


Figure 28 – Sender Device

4.4. COMPONENTS RECEIVER DEVICE

The receiver device has display screen, WiFi and Lora chip built in mainboard with source power

(Battery)These components are directly associated with microcontrollers (Esp32 TTGO T-been) Where receiving vital parameters from the sender's device in the remote area by Lora connection and display them on the screen and send them wirelessly to cloud (ubidots).

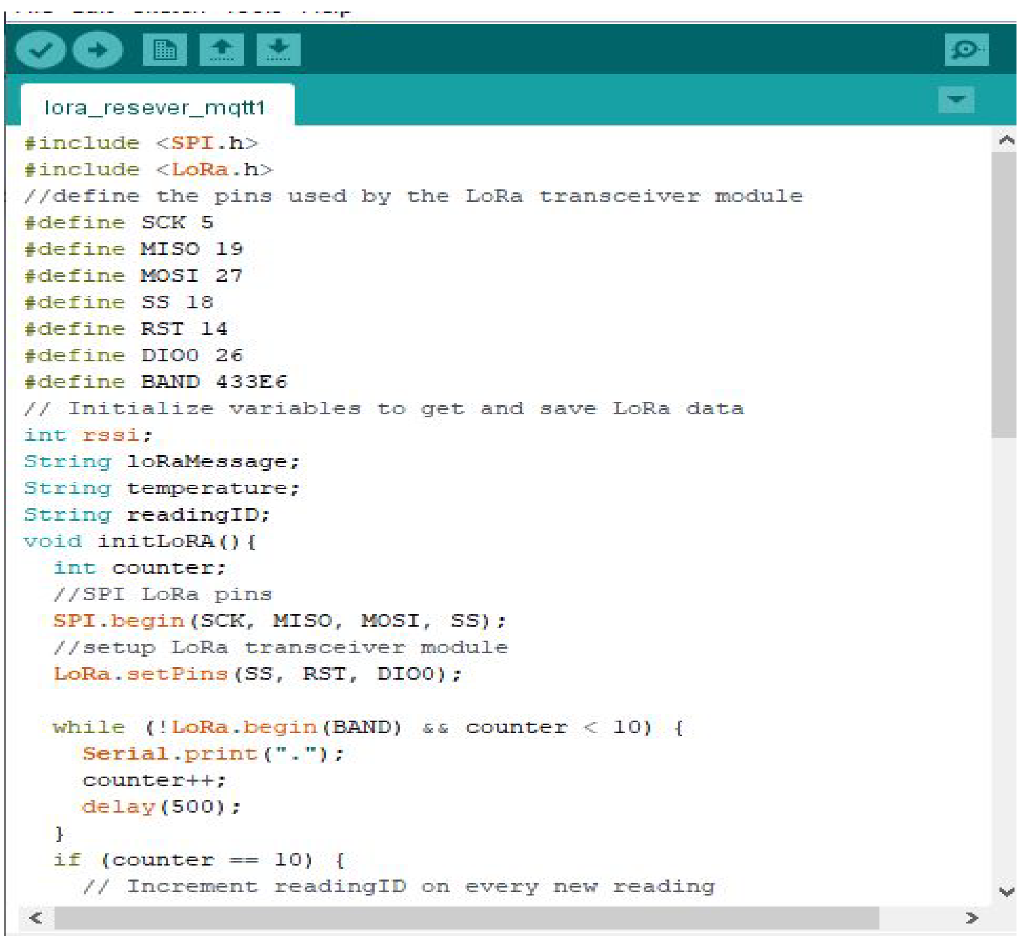
4.4.1 Data receiver

The process of receiving data through Laura connections

where Esp32TTGO contains chip Lora built in main board and Works in contact with the sender device on 433 MHz frequency band according to RSSI (Received Signal Strength Indicator) Where receiving vital parameters from the sender's device in the remote area and display them on the screen and send them wirelessly to cloud.

- set software.

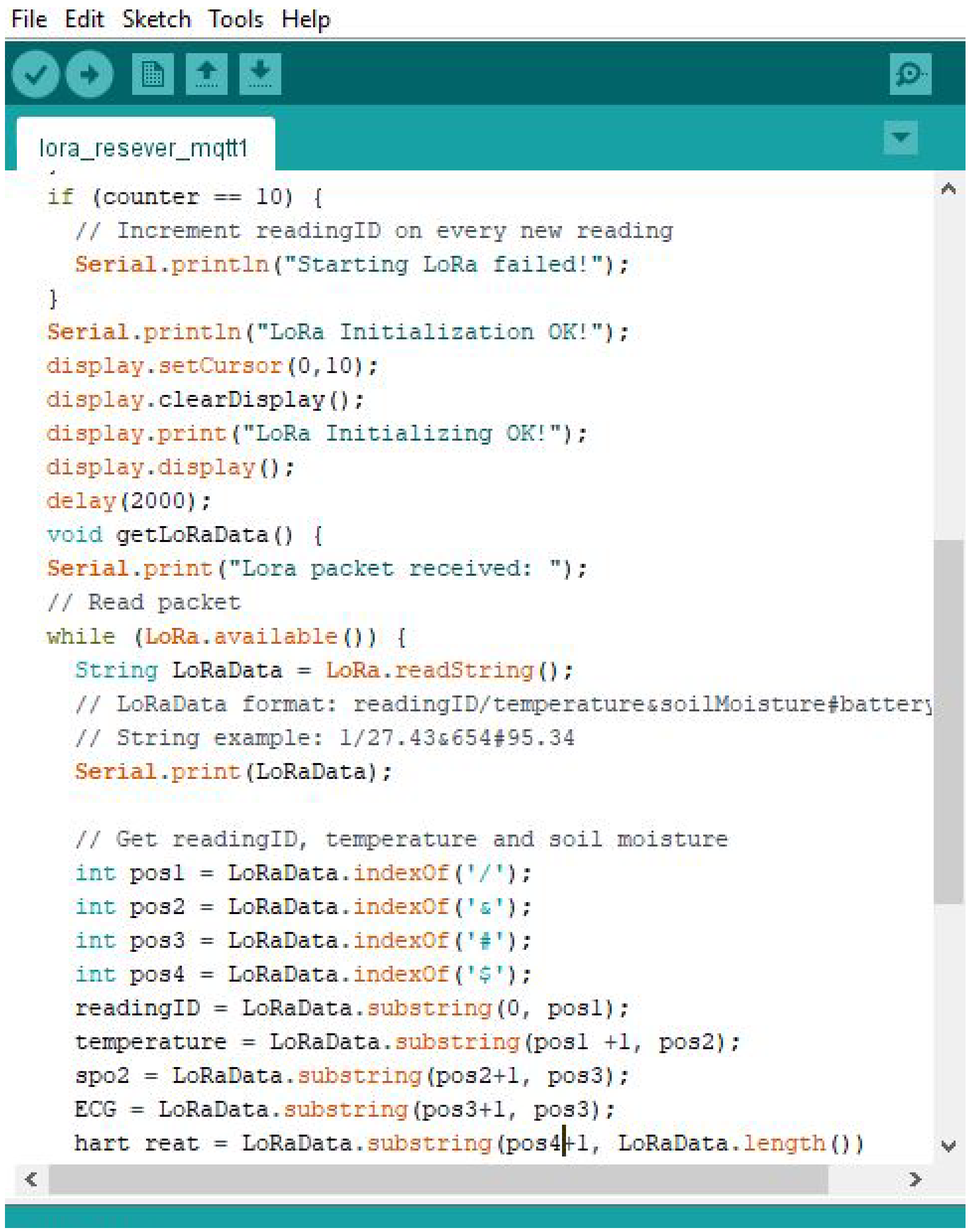
At first, we start installing the Arduino <SPI.h> <lora.h> library required for operation Lora chip and define pins, define Band (433) then we apply main function for reading and send the data.



```
lora_resever_mqtt1
#include <SPI.h>
#include <LoRa.h>
//define the pins used by the LoRa transceiver module
#define SCK 5
#define MISO 19
#define MOSI 27
#define SS 18
#define RST 14
#define DIO0 26
#define BAND 433E6
// Initialize variables to get and save LoRa data
int rssi;
String loRaMessage;
String temperature;
String readingID;
void initLoRA(){
  int counter;
  //SPI LoRa pins
  SPI.begin(SCK, MISO, MOSI, SS);
  //setup LoRa transceiver module
  LoRa.setPins(SS, RST, DIO0);

  while (!LoRa.begin(BAND) && counter < 10) {
    Serial.print(".");
    counter++;
    delay(500);
  }
  if (counter == 10) {
    // Increment readingID on every new reading
```

Figure 29 – Main function Lora define




```
if (counter == 10) {
  // Increment readingID on every new reading
  Serial.println("Starting LoRa failed!");
}
Serial.println("LoRa Initialization OK!");
display.setCursor(0,10);
display.clearDisplay();
display.print("LoRa Initializing OK!");
display.display();
delay(2000);
void getLoRaData() {
Serial.print("Lora packet received: ");
// Read packet
while (LoRa.available()) {
  String LoRaData = LoRa.readString();
  // LoRaData format: readingID/temperature&soilMoisture#battery
  // String example: 1/27.43&654#95.34
  Serial.print(LoRaData);

  // Get readingID, temperature and soil moisture
  int pos1 = LoRaData.indexOf('/');
  int pos2 = LoRaData.indexOf('&');
  int pos3 = LoRaData.indexOf('#');
  int pos4 = LoRaData.indexOf('$');
  readingID = LoRaData.substring(0, pos1);
  temperature = LoRaData.substring(pos1 +1, pos2);
  spo2 = LoRaData.substring(pos2+1, pos3);
  ECG = LoRaData.substring(pos3+1, pos3);
  hart reat = LoRaData.substring(pos4+1, LoRaData.length())
```

Figure 30 – Main function Lora receiver

4.4.2. Data display

For Display reading the vital parameters which received from sender device through which we know the patient's current condition. by Oled screen, the connected it with Esp32 TTGO through Input voltage (VIN) and GND pins temperature sensor is connected to 3.3V, the control line (SCL) line is connected to GIOP 22. the data line

(SDA) line is connected to 21, and sensor have a pull-up resistor on the I2C line. as shown figure 31.

- set software.

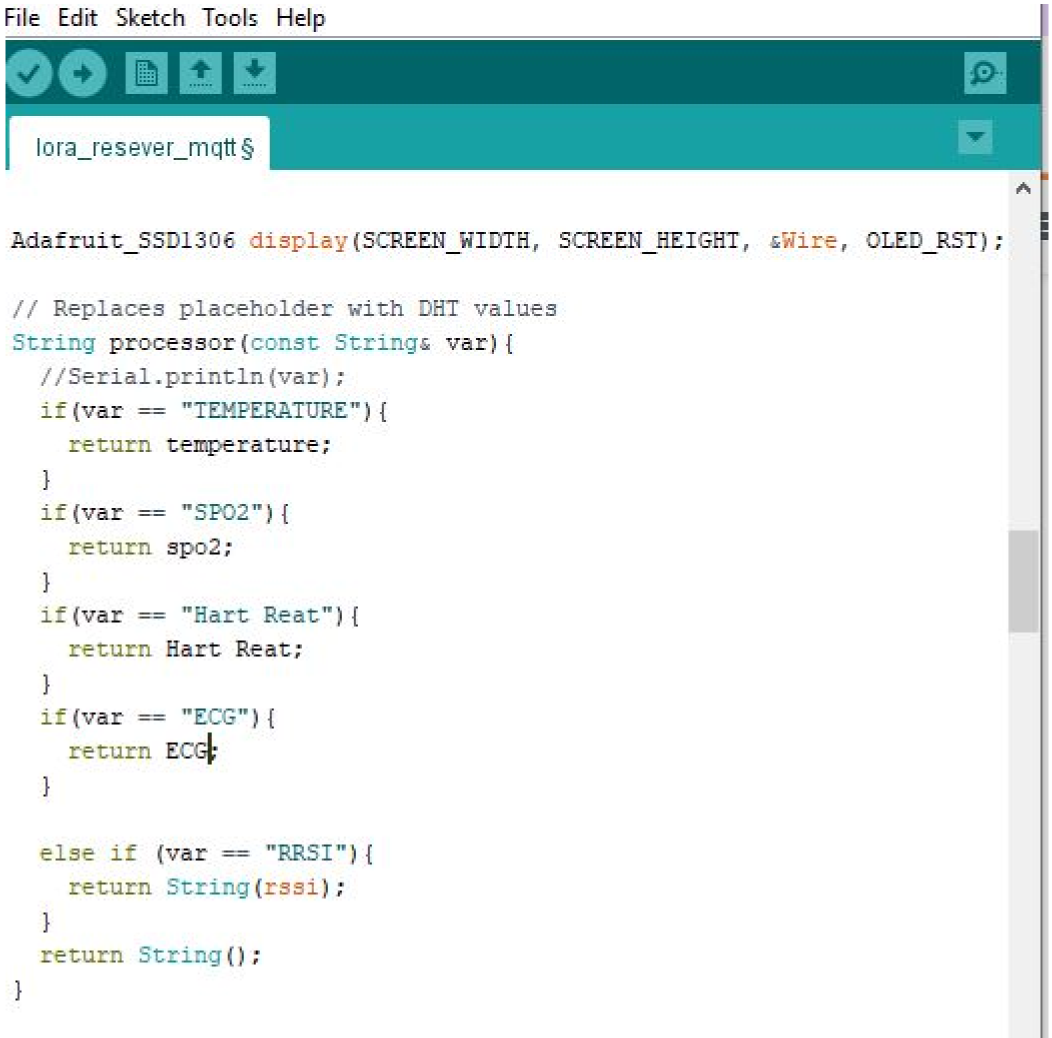


Figure 31 – Main function Oled screen

4.4.3. Wireless connecting

Microcontroller Esp32TTG It contains wireless technology where it can transfer and receive over internet.

The main technical characteristics of the controller

- support for the 802.11 b/g/n protocol;
- Support 802.11n (2.4GHz), up to 72.2Mbps;

- WPA/WPA2 WEP/TKIP/AES encryption support;
- output power +20 dBm in 802.11b mode;
- WiFi mode — STA (station), software access point, software access point + STA (station);
- 3D antenna.

- set Software .

At first, we start installing the Arduino <WiFi.h> library required for operation and then set (SSID, Password) for authentication and check status connect.

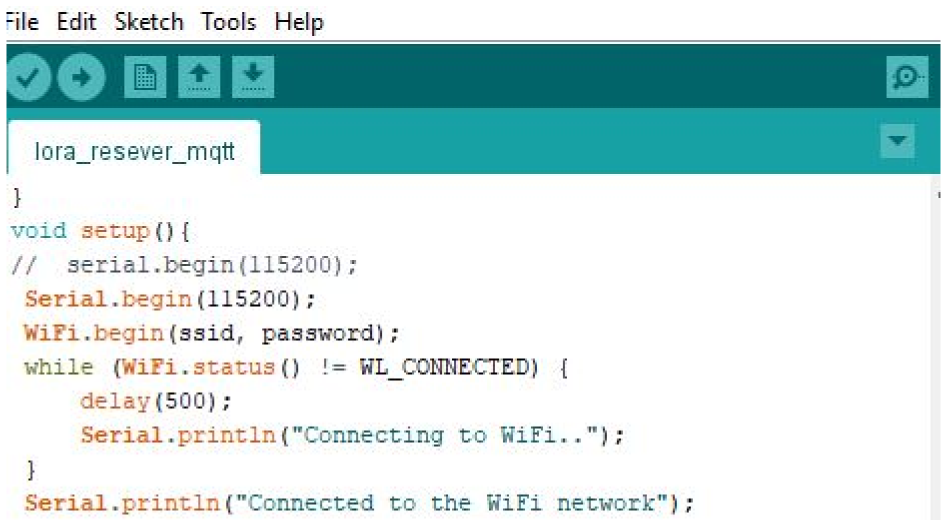


Figure 32 – Main function WiFi

4.4.4. Receiver Device

The Microcontroller activates all parts and OLED screen according to code to work in a coordinated manner as Esp32 TTGO contains a battery type 18650 and able to charge the battery. This ensures his work for a long time. Finally, the form of the receiver device as shown figure 33.

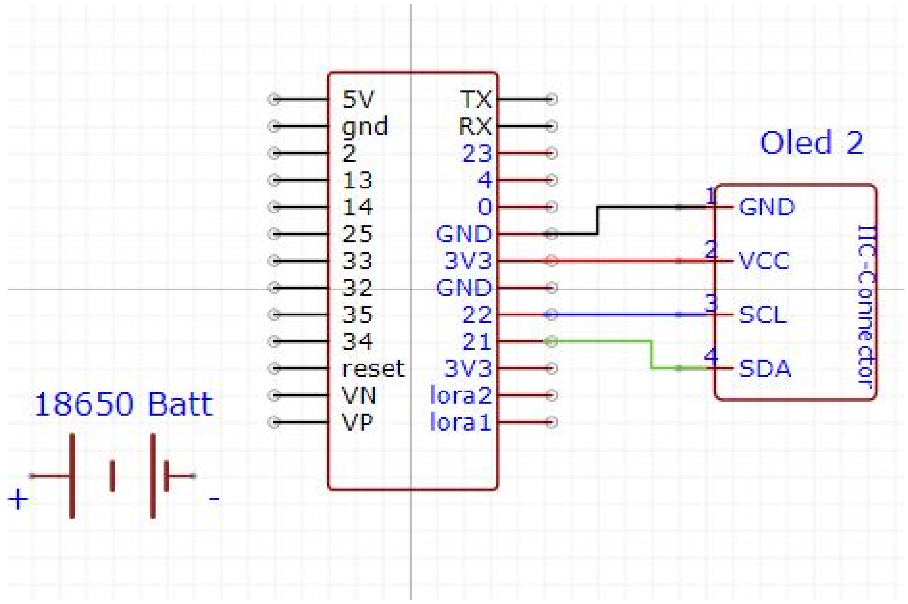


Figure 33 – Receiver Device

4.5. CONNECTING UBIDOTS PLATFORM

Ubidots It a free IOT platform that stores sensor data and publishing it and providing many of the features are Visualize data stock graphs, charts, tables, indicators, maps, metrics, and control widgets or develop using the HTML code and share through public links, or by embedding dashboards or widgets into private web and mobile applications. For the purpose of benefiting from the Ubidots platform, we will share data for receiver device as show figure 34.

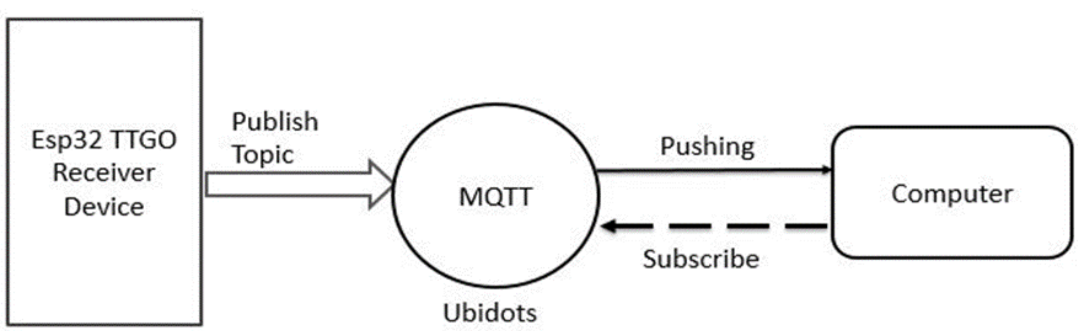


Figure 34 – Connecting Ubidots platform

- Set Software.

  for connection between receiver device and platform ubidots we need to:

- define Arduino library (UbidotsESPMQTT.h);
- WiFi connection Define (SSID, Password);
- define Token;
- define MQTT Client;
- define Variable Label (Temperature, SPo2, Hart Rate, EGC);
- define TOPIC "/v1.6/devices/esp32";
- define SERVER "things.ubidots.com";
- define PORT 1883.

```
#define ssid "ZyXEL_KEENETIC_620" // Put your WifiSSID here
#define password "09101939" // Put your wifi password here
#define TOKEN "BBFF-LamC2X9MfgFypdT0UohUiTCoTliGHh" // Put your Ubidots' TOKEN
#define MQTT_CLIENT_NAME "ESP32_Health_Station" // MQTT client Name, please enter
#define VARIABLE_LABEL1 "Temperature" // Assing the variable label
#define VARIABLE_LABEL2 "SPO2"
#define VARIABLE_LABEL3 "HartRate"
#define VARIABLE_LABEL4 "EGC"
#define DEVICE_LABEL "esp32"
#define SERVER "things.ubidots.com"
#define TOPIC "/v1.6/devices/esp32"
#define PORT 1883
```

Figure 35 – Define ubidots platform

lora_resever_mqtt §

```
while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.println("Connecting to WiFi..");
}
Serial.println("Connected to the WiFi network");
//connecting to a mqtt broker
client.setServer(mqtt_broker, mqtt_port);
client.setCallback(callback);
while (!client.connected()) {
    String client_id = "esp32-client-";
    client_id += String(WiFi.macAddress());
    Serial.printf("The client %s connects to the public mqtt broker\n", client_i
    if (client.connect(client_id.c_str(), mqtt_username, mqtt_password)) {
        Serial.println("Public emqx mqtt broker connected");
    } else {
        Serial.print("failed with state ");
        Serial.print(client.state());
        delay(2000);
    }
}
client.publish(topic, "Hi EMQX I'm ESP32 ^^");
client.subscribe(topic);
 initOLED();
 initLoRA();
}
void callback(char *topic, byte *payload, unsigned int length) {
Serial.print("Message arrived in topic: ");
Serial.println(topic);
Serial.print("Message:");
```

Figure 36 – Main function connection ubidots

4.5.1. Alarm emergency System Setup

The system can diagnose the dangerous condition depending on the value of the data received from the sensors in case the value differs from the normal situation according to medical standards show as figure 37.

- conditions alarm;
- temperature Greater than (37.8) for 2 minutes;
- spo2 less than (95%) for 1 minute;
- hart Rate less than (60) for 2 minutes.

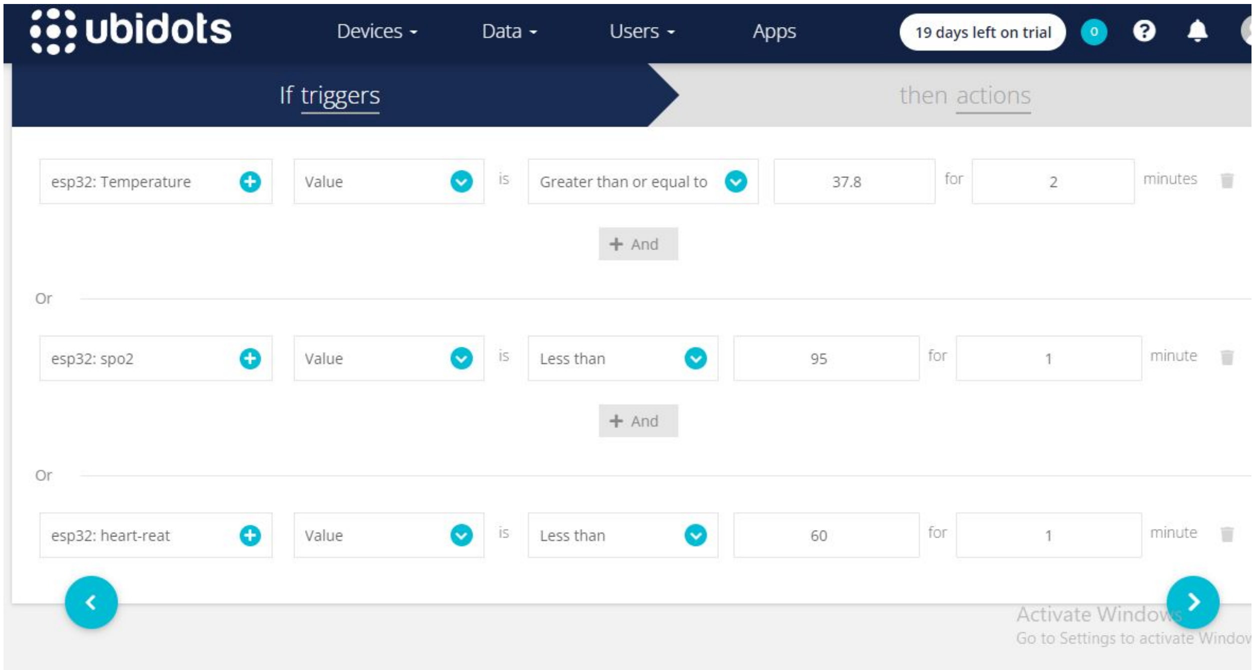


Figure 37 – Conditions alarm Ubidots

- alert Actions :

1. Sent Email Massage.
2. Sent telegram Massage.

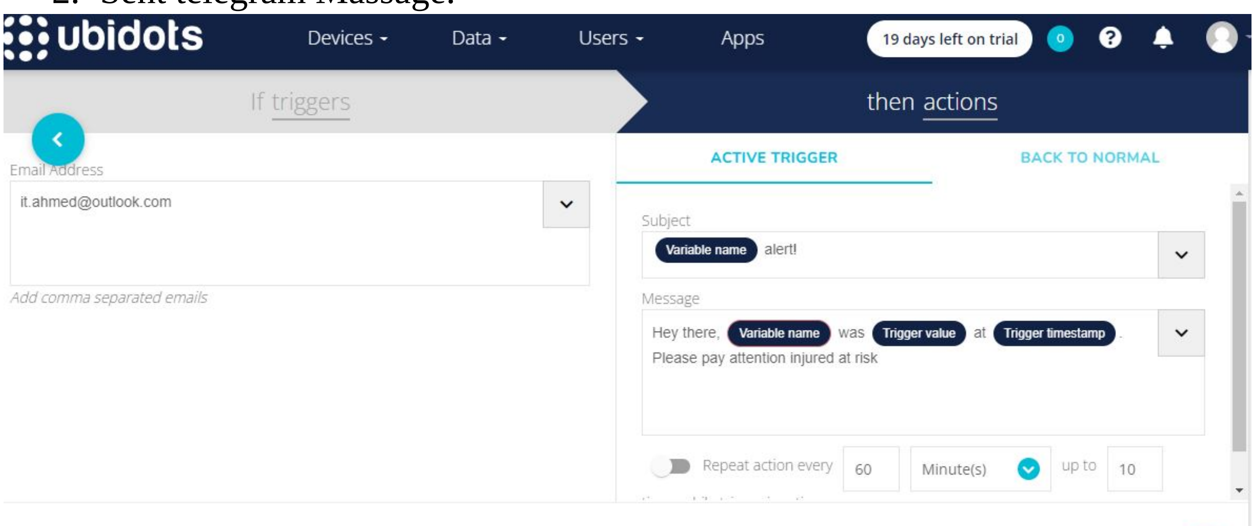


Figure 38 – Alert Actions

4.6. CONCLUSION

In the fourth chapter, the main components of the system (sender device, receiver device, cloud platform) and how they interact with each other are considered in detail. A complete diagram of the system structure is shown in figure (26,30,31).

5. TEST SYSTEM

This chapter will provide functional testing of the user's use cases with the system described earlier.

Functional testing refers to software testing in order to verify the feasibility of functional.

5.1. SENDER DEVICE PARTS

The figure36 shows a device based on a microprocessor Esp32 TTGO T-beam. It consists of the following blocks:

- screen (OLED 0.96);
- temperature Sensor;
- oximeter Sensor;
- ECG Sensor;
- battery (Source Power).

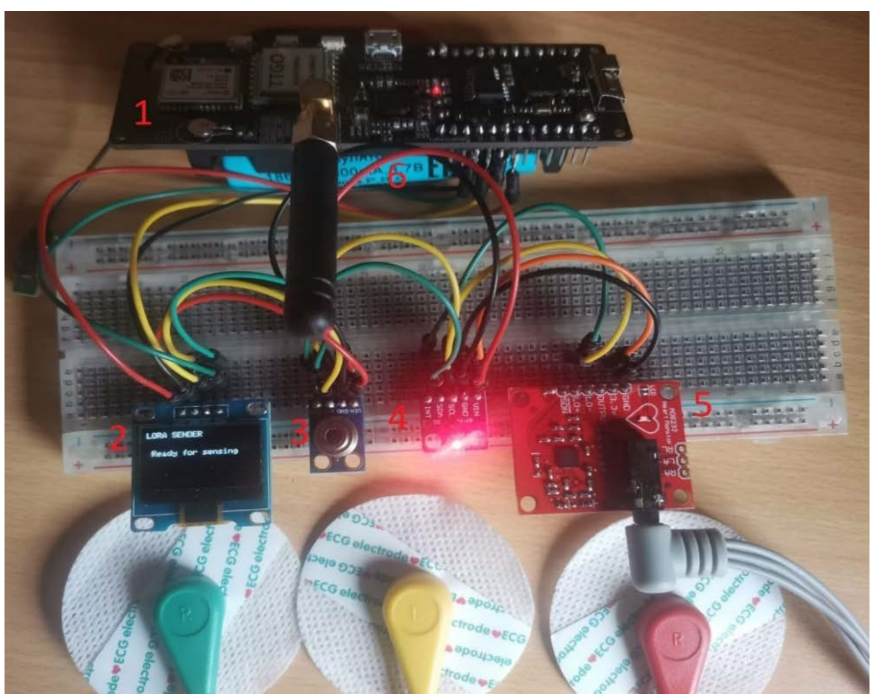


Figure 39 –Sender Device parts

5.1.1. Functional Testing

Measurement of health parameters of the injured body by the device.

- temperature Test.

Use test status display according to temperature measurement as shown figure 40.

1- place temperature, if less than 36.1C.

2- normal body temperature, if 36.1-37.2 C.

3- high temperature if more than 37.2 C.

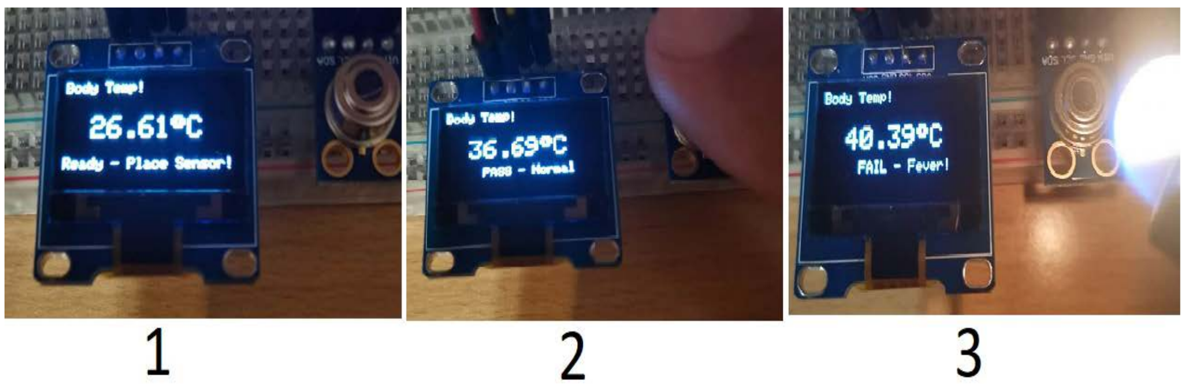


Figure 40 – Temperature Test

- oximeter Test.

Use test status display according to Saturation oxygen blood and Heart rate measurement as shown figure 41.

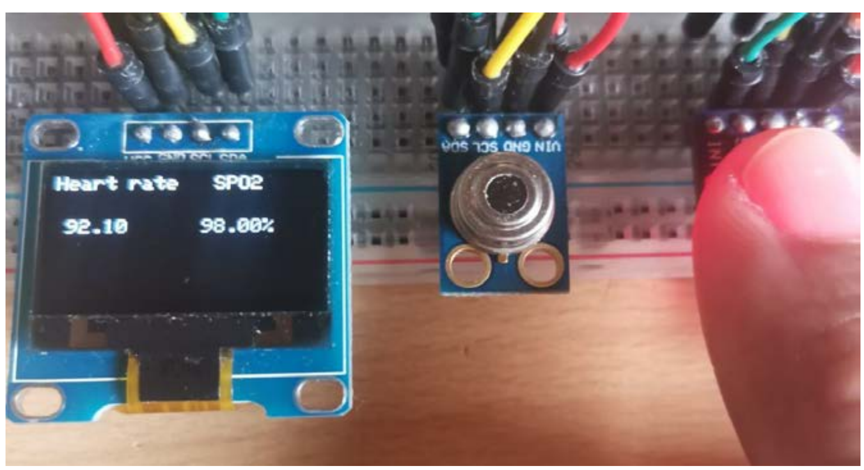


Figure 41 – Oximeter Test sender device

- ECG Test.

Use test status according to electrocardiogram measurement will display result in Ubidots platform because need bigger screen.

- check data sending.

Use test status display according to Lora send packet data as shown figure 42.

Figure 42 – Check data sending

5.2. RECEIVER DEVICE PARTS

The figure 40 shows a device based on a microprocessor Esp32 TT GOT-beam. It consists Lora chip and Wi-Fi Built - in mainboard Displays the received data the show as the following blocks:

- screen (OLED 0.96).

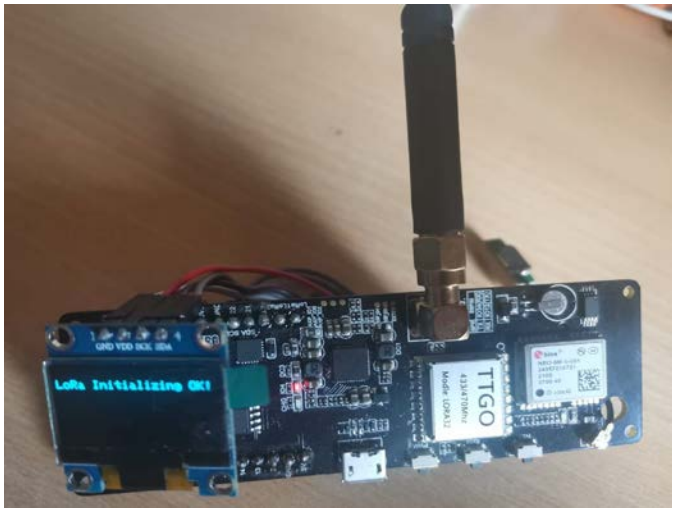


Figure 43 – Receiver Device parts

- receiver Temperature Test.

View Receiver temperature data from the sending device.

Figure 44 – Receiver Device parts

- receiver Oximeter Test.

View Saturation oxygen blood and Heart rate measurement data from the sending device.

Figure 45 – Oximeter Test Receiver Device

5.3. PUBLISHING MEASUREMENT DATA ON UBIDOTS

- device connection Interface test.

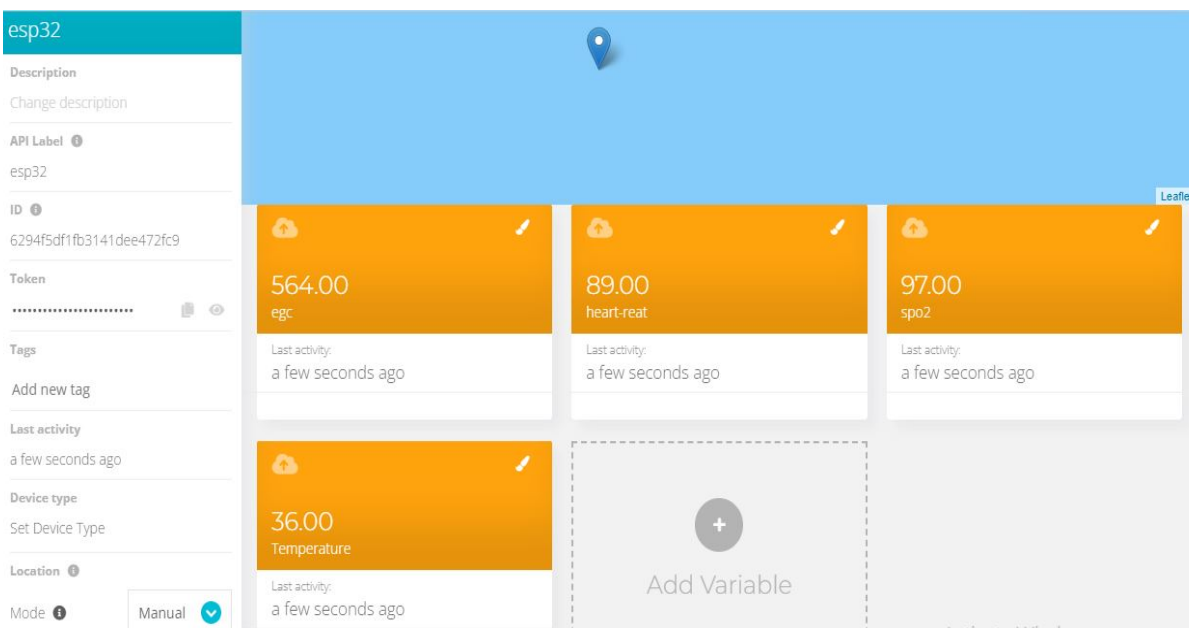


Figure 46 – Device connection Interface test

- dashboard interface.

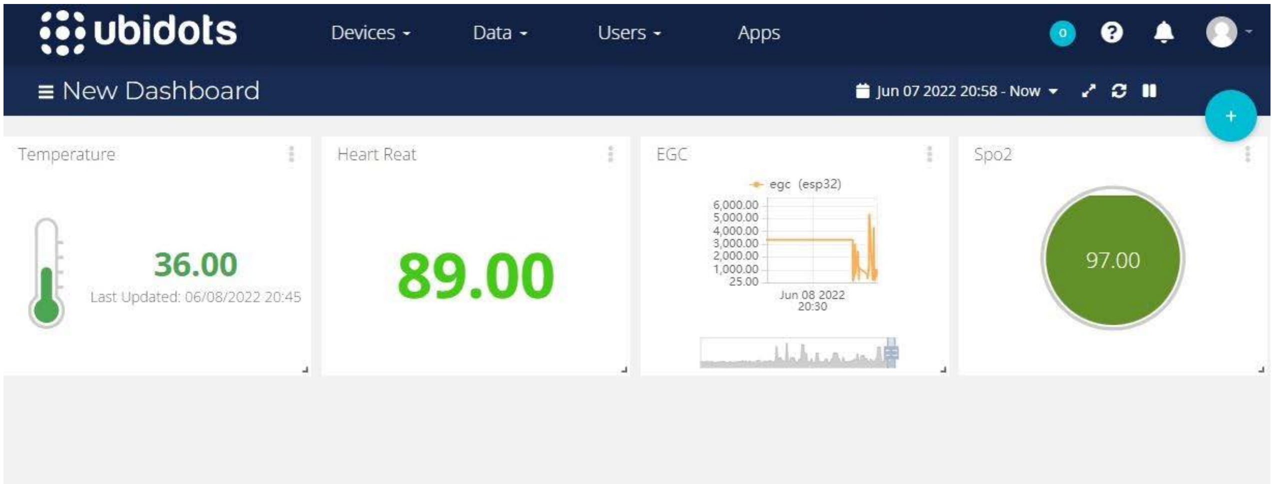


Figure 47 – Dashboard interface

- Temperature interface test.

For three statuses:

1- abnormal status less than 36 C.
2- normal status 36 -37.2 C.
3- abnormal status more than 37.8C.

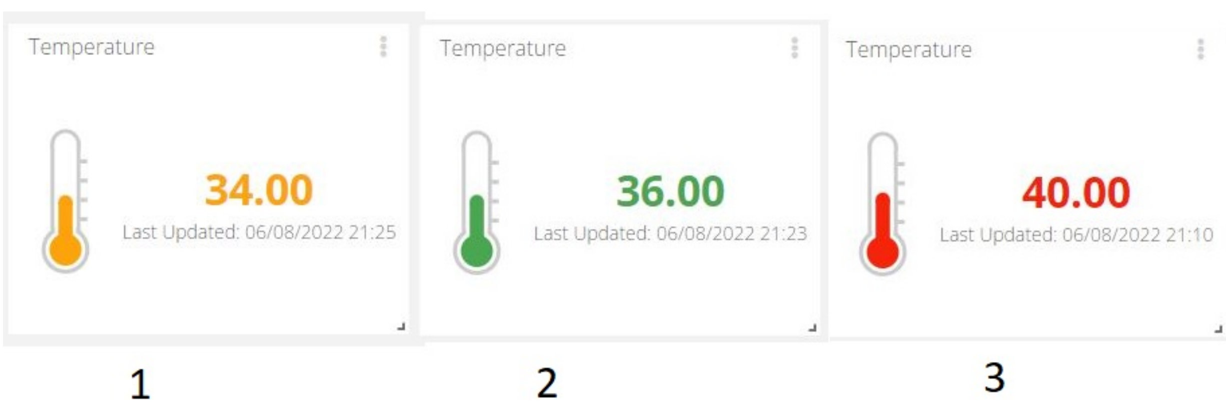


Figure 48 –Temperature interface test

- Hart Rate interface test.

For three statuses:

1- Abnormal status less than 60 bpm.
2- Normal status 60-120 bpm.
3- Abnormal status more than 120 bpm.

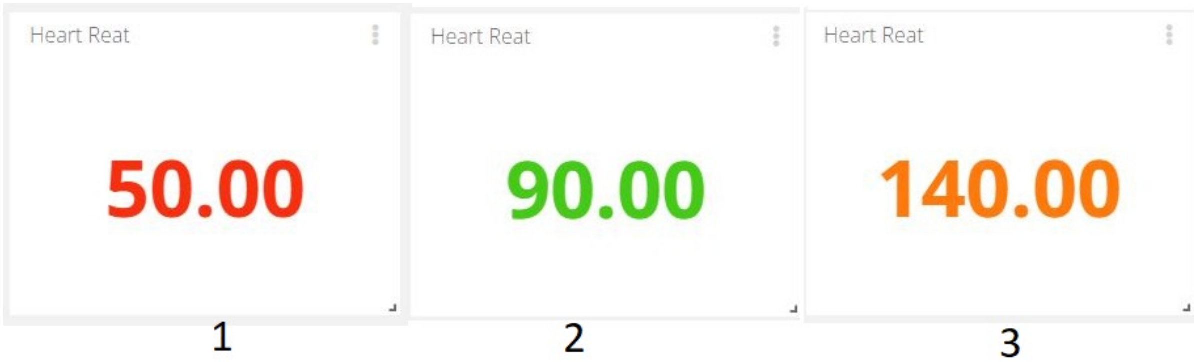


Figure 49 – Hart Rate interface test

- Spo2 interface test.

  For three statuses:

1- Normal status 95-99 %.
2- Abnormal status less than 95%.

Figure 50 –Spo2 interface test

- ECG interface test.

Figure 51 – ECG interface test

5.4. NOTIFICATION SYSTEM ALERTS

- interface alerts test.

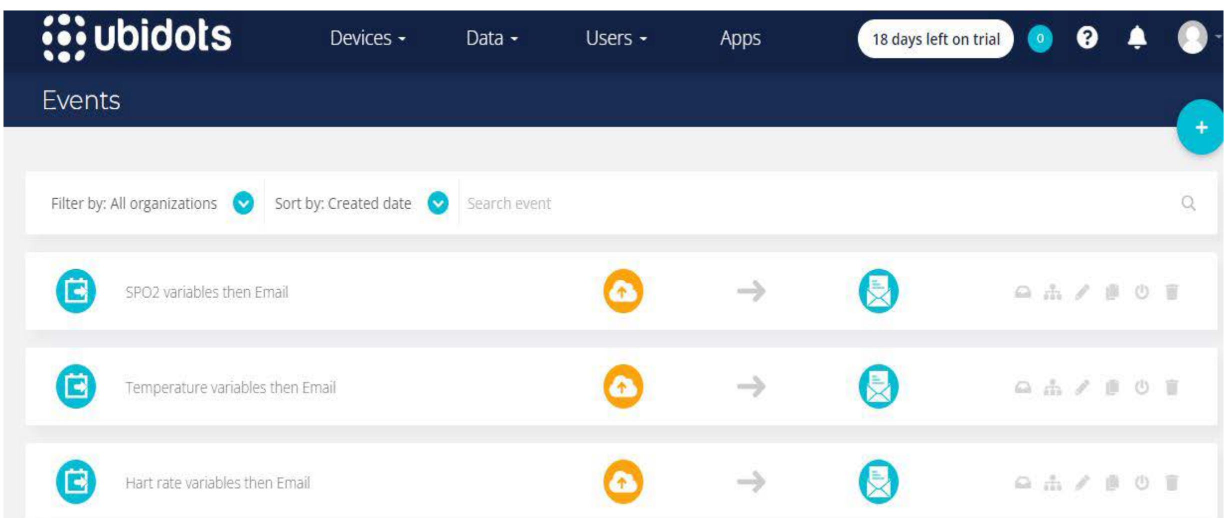


Figure 52 – Interface alerts test

- email Alert Test.

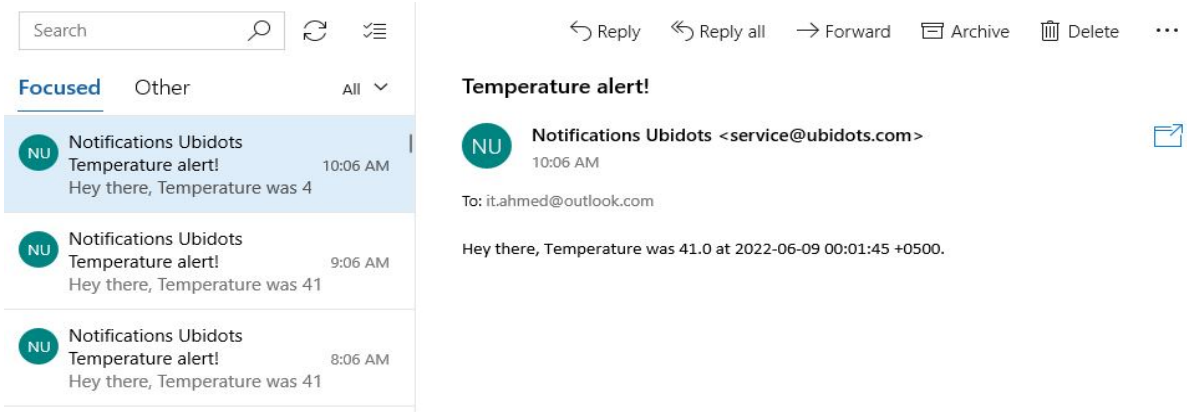


Figure 53 – Email Alert Test

5.5. CONCLUSION

In this chapter, functional testing of the device use cases with the system was carried out.

For each test, the expected result and setting steps are described, with a demonstration of fragments of the user interface. According to the test results, all tests were successfully passed:

- test 1;
  measurement of vital body parameters and analysis it and display on screen sender device.
- test 2;
  send measurements of vital body parameters by Lora connection to receive device.
- test 3;
  display measurements of vital body parameters on receiver device screen.
- test 4;
- send measurements of vital body parameters by Wi-Fi connection to Ubidots platform.

- test 5;

  display measurements of vital body parameters on dashboard Ubidots platform.

- test 6.

Notification system alerts.

6. CONCLUSION

of existing software solutions for the interaction of medical cyber-physical devices based internet of Things for emergency situations of remote area, system of interaction between IoT devices was made, which allows measuring the vital signs of the injured by a device containing medical sensors where sent data measuring to a long distance by the technology of communication Laura to an another device in the medical institution to display internal and send it to cloud for arriving to Persons concerned .

The tasks solved in this thesis include

1. The problem has been set.
2. The analysis of existing devices is carried out.
3. Requirements have been developed.
4. Architecture design has been carried out.
5. The selection of components has been made for required equipment (microcontroller, wireless protocol).
6. Schemes have been drawn up.
7. Software development tools have been selected.
8. The program part has been written.
9. Verification of compliance with the requirements has been carried out.

At the final stage, a prototype of the system was created in which it's all main components were implemented to works to power low and send for distance data.

The current implementation is open source and uses platform IOT components .

The resulting solution can be easily configured, modified and expanded to meet new specific requirements.

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