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A Comprehensive Wearable Health Monitoring System with GPS, GSM and Medication Remainder using NFC

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ABSTRACT:

Today's technology is advancing along with the rise in popularity of health trackers. This paper presents the design and implementation of an advanced wearable health monitoring system based on the ESP32 microcontroller. It is designed to continuously monitor the user's health by measuring blood oxygen saturation levels (S_PO_2), heart rate, and body temperature. When a user's heart rate fluctuates, the suggested methodology for health monitoring not only recognizes and analyses these variations but also has the ability to send location and alert messages to the user's well-wishers using the, Global Positioning System (GPS), and Global System for Mobile Communications (GSM). It also includes a system for rapidly sending acquired health data to a central database or cloud platform for storage and analysis. The collected health data is securely stored and accessible through the ThingSpeak, an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data of the wearer's health status in the cloud. In addition to health monitoring, the wearable device streamlines medication management by allowing users to input medication details, such as drug names, dosages, etc. using an NFC tag to provide these medication details via their mobile phones. This information is conveniently displayed on the wearable device's OLED screen, facilitating medication adherence and overall well-being. This innovative solution aims to provide users with a comprehensive and user-friendly tool for continuous health monitoring and medication management, ultimately leading to improved healthcare outcomes.

Keywords: ESP32 microcontroller, Global Positioning System (GPS), Global System for Mobile Communications (GSM), ThingSpeak, NFC tag, OLED screen.

1. Introduction:

Modern technology has a great impact on our lifestyles, often resulting in physical inactivity, poor nutritional choices, and increased stress levels. As an outcome of these changes, more individuals are suffering from long-term health conditions such as obesity, diabetes, and heart disease. And also, the pandemic situation in the country highlighted the importance of good health in preventing and managing diseases. As a result, staying healthy is critical to neutralizing the adverse effects of these lifestyle changes and pandemic conditions. Due to these changes, more and more people are struggling with health problems that continue for a long period of time. A comprehensive remote health monitoring system is proposed as the ground-breaking solution for all these problems. In our proposed system, it enables us to perform real-time estimation and tracking of vital health parameters such as heart rate, blood oxygen saturation level and temperature.

Monitoring the heart rate involves keeping track of how many times the heart beats in a minute. The normal heart rate range for a healthy person is typically between 60 and 100 beats per minute (bpm) at rest. However, individual factors such as age, fitness level, and overall health can influence this range. The suggested system also includes temperature measurement. The standard normal body temperature is commonly recognized as 98.6°F (37°C). Similarly, the system monitors S_pO_2, which is a measurement of how much oxygen your blood is carrying as a percentage of the maximum it could carry. For a healthy individual, the normal S_pO_2 should be between 96% and 99%. Accurate measurement of S_pO_2 is crucial, especially in serious conditions like COVID pneumonia or heart failure, where low levels can lead to hypoxemia (oxygen deficiency). The traditional method uses pulse oximeters, but the proposed system offers an IoT-based approach, connecting sensors and data flow for remote monitoring. This enables real-time decision-making, prompt medical intervention, and improved quality of care.

The proposed system integrates sensors that are connected to a microcontroller for simultaneously estimating heart rate, blood oxygen levels and temperature. By consistently tracking these health parameters, it helps us detect health issues during their initial phases. Identifying health problems at an early stage makes it simpler to figure out what's going on and choose the best treatment. This speeds up recovery and reduces future complications. The crux of this innovative system lies in its ability to seamlessly gather essential health data and transmit it instantaneously to a centralized database or ThinkSpeak cloud platform. This data is not only stored for comprehensive analysis but also serves as a foundation for informed medical decisions. To enhance accessibility and engagement, the system encompasses a user-friendly mobile application or web interface. This offers a more comfortable and

less invasive option compared to traditional methods. This new wearable approach gives accurate and continuous blood pressure readings throughout the day without causing any discomfort.

This understanding not only encourages decision-making but also encourages proactive steps towards a healthier lifestyle. However, the system's innovation goes beyond just enhancing data visualization. Incorporating cutting-edge GPS technology elevates health monitoring to a whole new level. By incorporating GPS and GSM modules, the system's capabilities expand to include real-time tracking of the user's geographical location. This feature becomes an invaluable asset during emergencies, ensuring rapid responses from caregivers or emergency responders. Whether it's a sudden health crisis or the detection of abnormal vital signs, the system's seamless coordination ensures that aid is dispatched precisely to the right location at the crucial moment. This sophisticated fusion of health monitoring and location tracking not only enhances personal safety but also exemplifies the potential of technology to revolutionize healthcare delivery.

Adding another layer of sophistication, the system introduces RFID-based medicine detection. This innovative step involves strategically incorporating RFID technology to effectively manage medications included in a home health kit. RFID tags, discreetly attached to medication containers, interact with RFID readers, providing comprehensive details about the medicine. This encompasses information ranging from expiration dates to proper dosage instructions. As a result, this technological advancement empowers individuals to proactively take charge of their healthcare journey, enabling them to have greater control over their well-being. This not only contributes to personal health improvements but also enhances the management of medication in an optimized manner. In essence, the proposed remote health monitoring system holds the potential to revolutionize healthcare standards. By bridging the gap between technological advancements and healthcare practices, this system presents a comprehensive approach that seamlessly combines real-time health data with proactive emergency response mechanisms.

2. Related work:

Modern technology has made people's lives much better by using smart apps, sensors, and wireless networks, all connected through the internet. The Internet of Things (IoT) is a crucial part of this, helping share information in areas like engineering, science, and business [1]. Design of a Mobile Healthcare Monitoring System Using IoT This project is about creating a wearable, low-power, real-time remote bio-signal monitoring system using IoT technology. It aims to improve remote health monitoring as the demand for healthcare increases. Traditional monitoring systems require patients to be physically present in hospitals, which can be inefficient, especially for critically ill patients. The project uses a mobile app as an IoT platform to remotely monitor ECG, heart rate, S_pO_2, and body temperature. Data is collected and processed using an Arduino-based device. The main contribution is sending ECG data to a specific smartphone for doctors to monitor, aiding in the early diagnosis of heart diseases [2]. Cutting-edge technologies such as 5G and IoT are swiftly propelling the development of smart cities. They enable swift medical diagnoses through sensor-based systems that transmit critical patient data to hospitals even before the arrival of ambulances. Patients can instantly request ambulances, relay emergency information through SMS, and track ambulance locations for faster response times. This device, equipped with IoT sensors and mobile applications, enhances healthcare monitoring within smart city environments [3]. The healthcare monitoring system in healthcare facilities is evolving rapidly, with a growing focus on portable systems driven by emerging technologies. Internet of Things (IoT) innovations have enabled a shift from traditional face-to-face consultations to telemedicine. It employs five sensors: heart rate, body temperature, room temperature, CO, and CO2 sensors. The system demonstrates high accuracy, with an error rate consistently below 5% in each sensor's measurements. Patient conditions are transmitted through a portal to medical staff, allowing them to analyse and respond to the patients' real-time situation [4]. This paper delves into the latest trends in healthcare monitoring systems leveraging IoT technology. It emphasizes the significance and benefits of IoT-based healthcare, offering a systematic review of recent studies through a literature review. The review assesses the effectiveness, efficiency, data protection, privacy, security, and monitoring capabilities of various IoT-based healthcare systems. The paper also explores wireless and wearable sensor-based IoT monitoring systems and healthcare monitoring sensors. Furthermore, it elaborates on the challenges and open issues related to healthcare security, privacy, and quality of service (QoS) [5]. This paper explores IoT's integration into complex healthcare processes, highlighting the "Mobile Healthcare Management System (HMS)" as a leading IoT application that connects mobile sensors, clinicians, patients, and networks. The IoT-based smart HMS enables continuous remote patient monitoring, even in remote areas. It leverages technologies like wireless sensors. Networks (WSN) using protocols like Coap, 6LoWPAN, and REST, along with radio frequency data, smart mobile devices, and wireless sensor networks for seamless healthcare management [6]. The IoT has revolutionized various sectors, including healthcare, smart cities, and engineering, by enabling remote monitoring and data transmission. This research paper focuses on monitoring body temperature (DS18B20), heart rate, and SPO2 (MAX30100), with the patient location tracked using SIM7600E GSM and GNSS HAT modules, all controlled by a Raspberry Pi 4B. Data is transmitted to the cloud for real-time access, and a cross-platform provides data to both doctors and patients, facilitating synchronous health monitoring and timely medical decisions [7]. The health care system is designed to assist paralyzed patients in conveying their health status and messages to medical professionals and carers. It monitors the patient's data, detecting abnormal values in parameters like blood pressure and oxygen levels. In cases of critical readings, it sends alerts via GSM and uploads data to the cloud, ensuring continuous care even when unattended. The system includes a buzzer for immediate attention upon receiving a risk message, automating and enhancing patient care, especially during periods of minimal supervision [8]. The challenge of continuous health monitoring, particularly for elderly individuals, necessitates innovative solutions. To address this, an IoT based smart health monitoring system has been implemented. It uses heart rate and blood pressure sensors connected to an Arduino Uno board to track a patient's health. If the system detects any unexpected changes in heart rate or blood pressure, it automatically alerts the doctor via SMS through a GSM and displays real-time patient data. Additionally, a GPS module helps locate the patient if they cannot reach the hospital, ensuring timely medical attention. The IoT system effectively monitors patient health and can save lives by providing timely intervention [9]. The paper presents the Remote Patient Monitoring System (RPMS), designed to tackle the healthcare accessibility issues encountered by elderly and rural patients. This system utilizes an affordable wearable wristband to remotely monitor the real-time health data of patients. The RPMS keeps tabs on vital health indicators such as body

temperature, heart rate, oxygen levels, and even the patient's location through GPS, which assists in detecting diseases and planning treatment. In case of emergencies, it enables immediate medical attention. The collected data can be transmitted to the cloud and accessed through a mobile app, which also offers simplified diagnostic capabilities using thresholding methods. This overall improves both the accessibility and quality of health care [10].

3. Methodology:

A Comprehensive Wearable Health Monitoring System with GPS, GSM and Medication Remainder using NFC is the proposed design which uses ESP32 microcontroller with integrated Wi-Fi and dual-mode Bluetooth. The proposed system integrates sensors that are connected to a microcontroller for simultaneously estimating heart rate, blood oxygen levels and temperature. The MAX30100 Sensor is capable of measuring Blood Oxygen Saturation level & Heart Rate. It uses display to view the value of S_pO_2 and BPM. The blood Oxygen Concentration termed S_pO_2 is measured in Percentage and Heart Beat/Pulse Rate is measured in BPM.

The MLX90614 temperature sensor works by measuring the infrared radiation emitted by a body and converting it into temperature readings. The system also includes GSM and GPS modules in which GSM module works by connecting to the GSM network through a SIM card. The SIM card provides the module with a unique identification number, which is used to identify the device on the network.

The GSM module then communicates with the network using a set of protocols, which allows it to send and receive data and GPS receiver uses a constellation of satellites and ground stations to calculate accurate location wherever it is located. Additionally, RFID-based medicine detection helps manage medications in a home health kit, offering detailed information from expiration dates to proper dosages. This empowers individuals to take control of their healthcare, improving personal health and medication management.

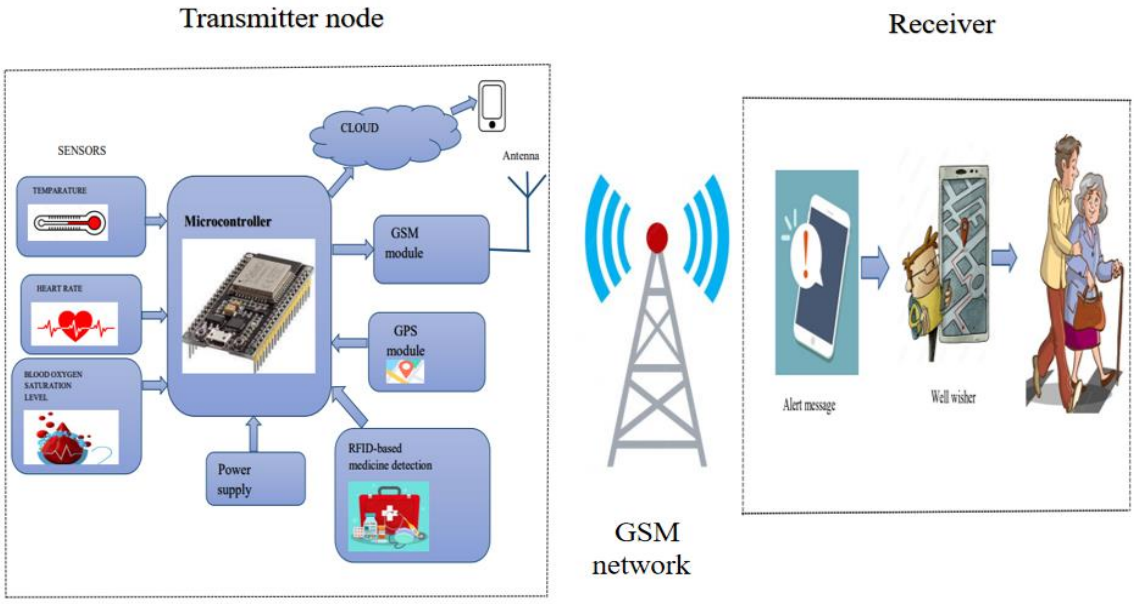

Fig.3.1: Block Diagram

The Fig.3.1, shows the overall design of the proposed design. It displays two nodes: a transmitter node and a receiver node. Looking at the transmitter node, it's clear that the proposed system uses an ESP32 microcontroller. This microcontroller is connected to various sensors. These sensors are responsible for gathering important health measurements such as heart rate, blood oxygen saturation level, and temperature.

The MAX30100 sensor is used to measure a person's heart rate and blood oxygen saturation (S_pO_2) using photo plethysmography (PPG) technology. The MLX90614 is a popular sensor for non-contact body temperature measurement using infrared technology. When power is given to the ESP32 microcontroller, it collects data on the health parameters. Additionally, it provides a mechanism that sends the gathered health data instantly to a central database or cloud platform for storage and analysis. The collected health data is securely stored and accessible through the *ThingSpeak*, an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data of the wearer's health status in the cloud. Moreover, the system will include GPS integration by incorporating GPS and GSM modules.

Furthermore, it supports the use of RFID-based technology to enhance the management of medications. As previously mentioned, RFID (Radio Frequency Identification) medication detection involves the integration of RFID technology to improve the organization of medicines within a home health kit. RFID tags are compact devices that can be affixed to medication containers. An RFID reader is a device that emits radio waves, receives responses from RFID tags, and provides information regarding the medication, including its expiration date, recommended age for consumption, and other relevant details. It not only empowers individuals to take charge of their health but also ensures rapid response during emergencies.

It could make people healthier by providing easy, helpful, and personal healthcare. At the receiver node, if the system detects abnormal health readings or an emergency situation, it utilizes its integrated GPS and GSM modules to transmit the user's location and an alert message to emergency responders or caregivers. If there are abnormal health parameter readings, they arrange for transport to the nearest hospital. They ensure the user receives the required medication by promptly arriving at the user's location. In emergency situations, the caregivers ensure a safe return for the user to their home.

4. Software used:

A. Arduino IDE

The Arduino IDE is used to write the computer code and upload this code to the physical board. The Arduino IDE is very simple and this simplicity is probably one of the main reason Arduino became so popular. We can certainly state that being compatible with the Arduino IDE is now one of the main requirements for a new microcontroller board. Over the years, many useful features have been added to the Arduino IDE and you can now have managed third-party libraries and boards from the IDE, and still keep the simplicity of programming the board. In the proposed design Esp32 microcontroller is used, the installation of ESP32 board in Arduino ide is shown in the below steps:

Step 1: Open the Arduino IDE, go to Files on the task bar, and click on the preferences. After that, you can see a preference on the screen. There, you can enter the "Additional Board Manager URLs" field with the link

https://raw.githubusercontent.com/espressif/arduino-esp32/ghpages/package_esp32_index.json and click on OK.

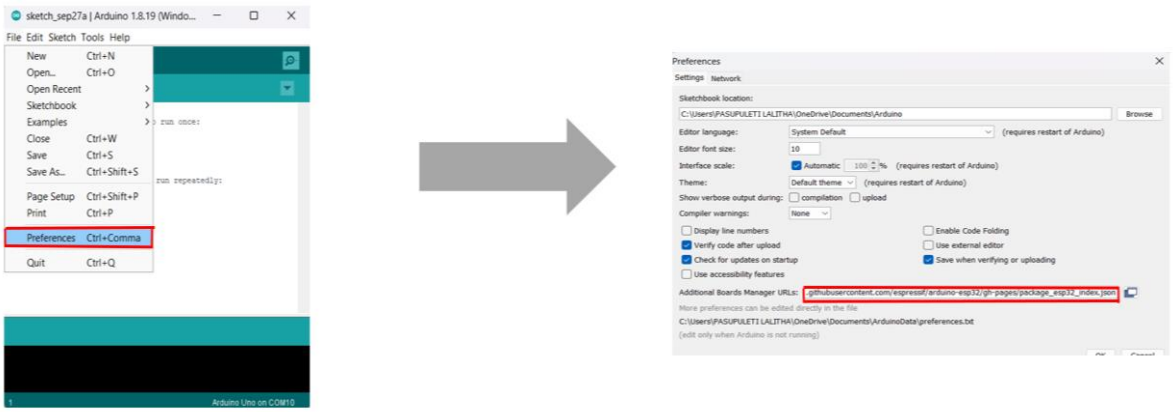

Fig.4.1: Adding Boards Manager URLs

Step 2: Click on the tools present at the top, go to board and then click on board manager. Now search for **ESP32** and press install button for the **ESP32 by Espressif Systems.**

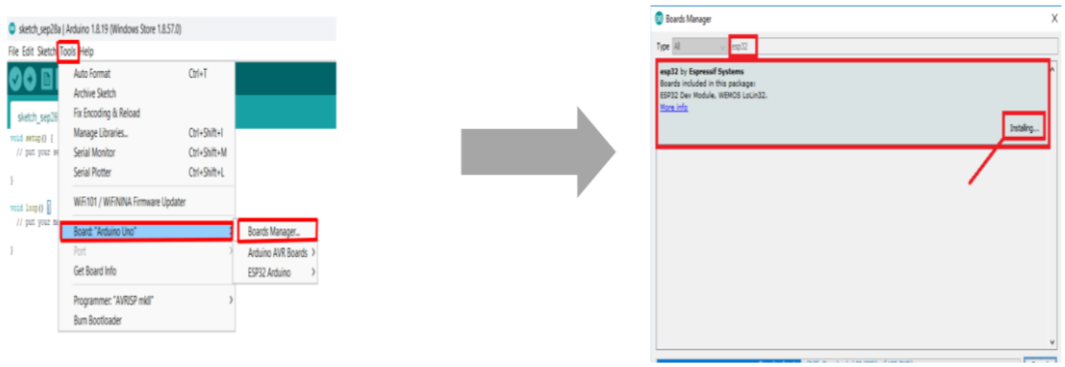

Fig.4.2: Installation of ESP32 Board Manager

Step 3: After the installation of the **ESP32 by Espressif Systems** the code should be uploaded into ESP32 microcontroller.

The libraries of the MLX90614 temperature sensor, MAX30100 Sensor, RC522 RFID module can be downloaded.

The library can be downloaded from within the Arduino IDE Library Manager. To install the library, navigate to the Sketch > Include Library > Manage Libraries… Wait for Library Manager to download libraries index and update list of installed libraries.

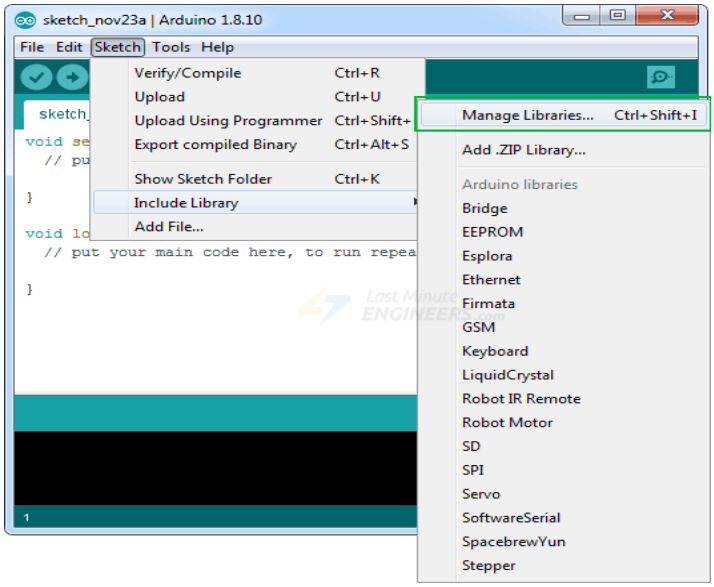

Fig.4.3: Library Manager to download libraries

Filter your search by typing ‘adafruit mlx90614‘. Click on the entry, and then select Install.

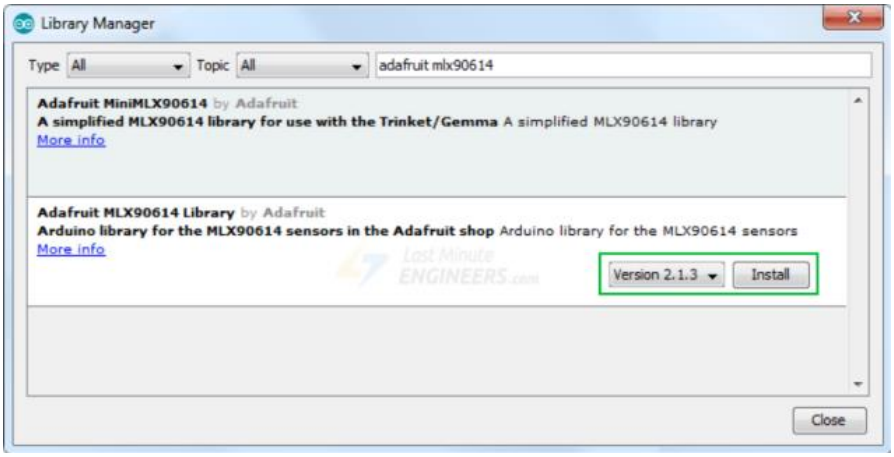

Fig.4.4: Installation of adafruit mlx90614 Library

Filter your search by typing max30100. There should be a couple entries. Look for MAX30100lib Library by OXullo Intersecans. Click on the entry, and then select Install.

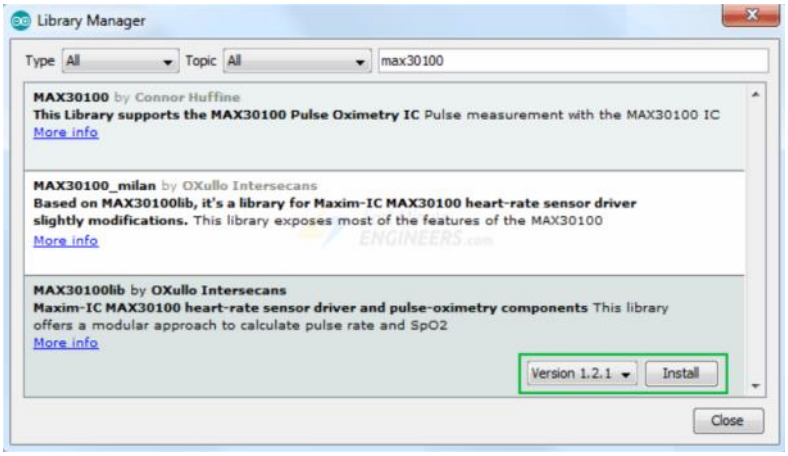

Fig.4.5: Installation of MAX30100lib Library

Search for the MFRC522 Library.Install the MFRC522 library developed by the GitHub Community.

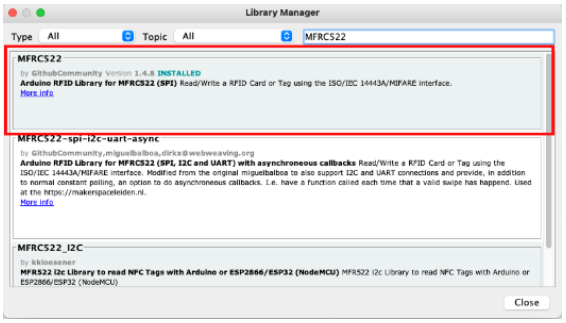

Fig.4.6: Installation of MFRC522 Library

B. ThingSpeak

ThingSpeak is a cloud-based platform that empowers users to seamlessly connect and analyze data from Internet of Things (IoT) devices and sensors. This versatile platform enables individuals and businesses to gather real-time data, process it, and make informed decisions. By offering a range of tools and services, ThingSpeak simplifies the complexities of IoT data management and visualization. Whether you're monitoring environmental conditions, tracking inventory, or optimizing industrial processes, ThingSpeak provides a robust and user-friendly solution to harness the potential of IoT technology. Its cloud-based architecture ensures scalability, accessibility, and flexibility, making it an invaluable resource for organizations seeking to leverage the power of data-driven insights.

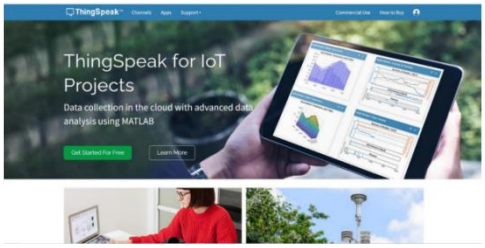

Fig.4.7: ThingSpeak

5. Results:

The prototype of "A Comprehensive Wearable Health Monitoring System with GPS, GSM, and Medication Reminder using NFC" is shown in below Fig.5.1. The prototype includes the sensors like MAX30100 which is used to measure the Heart rate and blood oxygen level. The MLX90614 is used to measure the temperature of the body temperature. The sensors are integrated to the ESP32 microcontroller. The inclusion of GSM and GPS modules ensures rapid response in case of abnormal health readings or emergencies. If the system detects anomalies, it instantly sends the user's location and an alert message to emergency responders or caregivers. This immediate communication can lead to timely medical attention and intervention, potentially saving lives.

Additionally, the integration of RFID-based medication detection simplifies medication management, offering users detailed information about their medications, from expiration dates to proper dosages. This empowers individuals to take control of their healthcare, improving personal health and medication adherence.

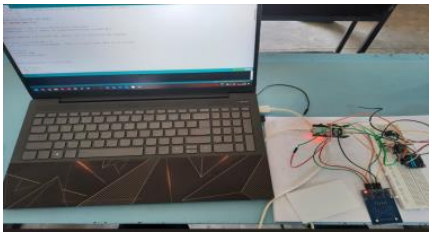

Fig.5.1: Prototype of the proposed design

Displaying the Person's Body Temperature, Heart Rate Readings and Blood Oxygen Saturation Level (S_PO_2) on the OLED Screen

Monitoring a person's body temperature, heart rate readings, and blood oxygen saturation level (SPO2) involves using appropriate sensors and displaying the data in real-time. The heart rate of a person differs age to age. In general, heart rate tends to decrease with age. Blood Oxygen Saturation (S_PO_2), measures the percentage of oxygen-bound haemoglobin in the blood and is typically assessed using a pulse oximeter, with normal readings falling between 95-100%. The blood oxygen saturation level and the heart rate is measured by the MAX30100 sensor. The temperature of body is measured by the

MLX90614 sensor. The range considered more accurate for normal body temperature falls between 97.8°F (36.5°C) and 99.1°F (37.3°C).The below Fig.5.2 represents the Displaying the Person's health parameters.

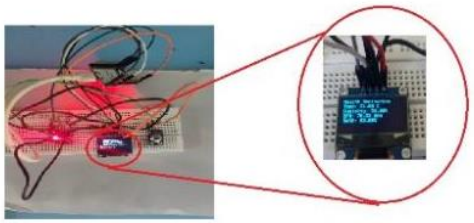

Fig.5.2: Displaying the Person's health parameters

Cloud Interface:

All the available data will be send to the IoT cloud platform (ThingSpeak) by using ESP32microcontroller. This data can be Modified by using respective API keys for different fields.The users can access the this stored data from anywhere in the world by simply logging in into thr ThingSpeak web page which is provided by the MATLAB. This cloud platform also provides graphical tools to visualize the given data. The user only can acess the data from registered account as it is private view, i.e.,if the user use another account to view the data it wont show the data. The data can be accessed by using mobile, tablet, laptop, or desktopbased on the availability as it is a web page. The Fig.5.3 provides a visual representation of the person's temperature and humidity levels.

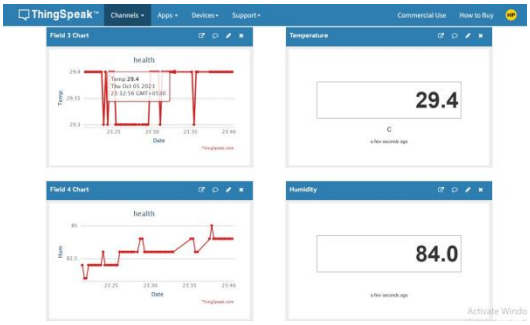

Fig.5.3: Visual Representation of Temperature and humidity of the Person

The Fig.5.4 provides a visual representation of the person's heart rate and Blood Oxygen Saturation (S_PO_2).

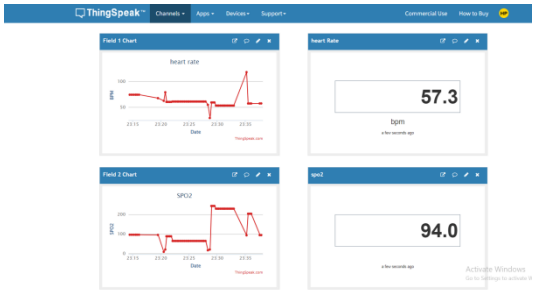

Fig.5.4: Visual Representation of the person's heart rate and Blood Oxygen Saturation (S_PO_2).

Message Alert through GSM and Location of Person through GPS

The proposed design includes using a GSM and GPS module to send message alerts and call alert to registered number of the well-wisher in the emergency situations of the person and also when the readings of health parameters are abnormal. It also features an emergency button that, when pressed, initiates a call and sends a text message to their registered number of the well-wisher.

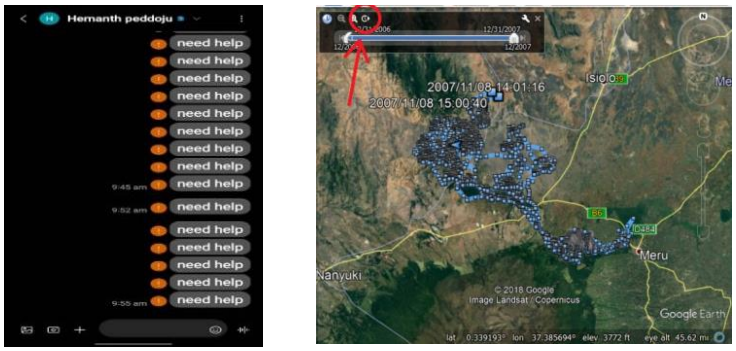

Fig.5.5: Message Alert through GSM and Location of Person through GPS

RFID-based medicine detection

It is a strategically incorporating RFID technology to effectively manage medications in a home health kit. RFID (Radio Frequency Identification) medication detection involves the integration of RFID technology to improve the organization of medicines within a home health kit. RFID tags are compact devices that can be affixed to medication containers. An RFID reader is a device that emits radio waves, receives responses from RFID tags, and provides information regarding the medication, including its expiration date, recommended age for consumption, and other relevant details.

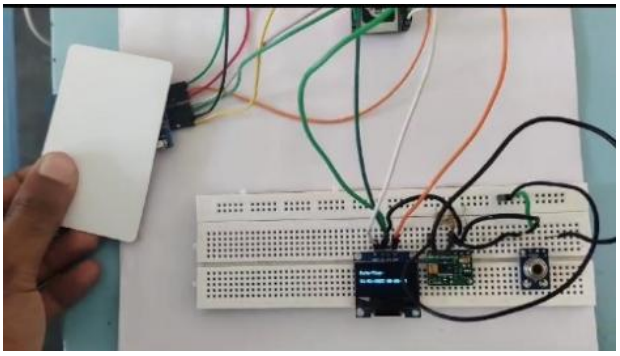

Fig.5.6: RFID-based medication detection

6. Conclusion:

The proposed design, "A Comprehensive Wearable Health Monitoring System with GPS, GSM, and Medication Reminder using NFC," leverages advanced technology to enhance healthcare monitoring and management. It utilizes an ESP32 microcontroller with integrated Wi-Fi and dual-mode Bluetooth to collect vital health data, including heart rate, blood oxygen levels, and temperature, through sensors such as MAX30100 and MLX90614. This data is securely transmitted to a central database or cloud platform for storage and analysis, providing users and healthcare providers with real-time insights into the wearer's health status.

The inclusion of GSM and GPS modules ensures rapid response in case of abnormal health readings or emergencies. If the system detects anomalies, it instantly sends the user's location and an alert message to emergency responders or caregivers. This immediate communication can lead to timely medical attention and intervention, potentially saving lives.

Additionally, the integration of RFID-based medication detection simplifies medication management, offering users detailed information about their medications, from expiration dates to proper dosages. This empowers individuals to take control of their healthcare, improving personal health and medication adherence. In summary, this comprehensive wearable health monitoring system offers a holistic approach to healthcare management by combining real-time health data monitoring, emergency response capabilities, and medication management

In terms of future development, there are several promising avenues to explore. Firstly, machine learning integration can be implemented to harness historical health data, enabling predictive healthcare insights that facilitate early intervention and personalized care. User interfaces should be further enhanced, with the development of user-friendly mobile or web interfaces to provide users with convenient access to their health data, medication reminders, and communication channels with healthcare professionals.

Personalized health recommendations, driven by AI algorithms and tailored to individual health data and lifestyles, can encourage and guide users toward healthier living. Additionally, the system can be expanded to offer remote monitoring capabilities, particularly beneficial for elderly individuals or those managing chronic conditions. Robust data security and privacy measures are crucial to safeguard sensitive health information. Integration with Electronic Health Records (EHRs) can streamline data sharing and collaboration with healthcare providers.

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