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Remote Health Monitoring System Using NodeMCU(ESP8266) and Arduino

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Abstract: IoT, also referred to as the "Internet of Things," is a network of physically connected objects, systems, and tools that have sensors, software, and other technologies integrated into them. This permits data collection and exchange via the Internet. The integration of Internet of Things (IoT) technology with healthcare monitoring systems has significantly revolutionized patient health outcomes. The IoT-based smart healthcare system using Arduino and NodeMCU to detect pulse rates and temperature involves integrating sensors, microcontrollers, and cloud services. The system uses a pulse rate sensor connected to an Arduino board and a temperature sensor connected to a NodeMCU board. The sensors gather live data, which is subsequently processed and sent to a cloud-based platform for analysis and visualization. Data transmission is achieved through the NodeMCU, which collects sensor readings and sends HTTP requests to the cloud server. Here we have used ThingSpeak for Cloud integration which configures API endpoints to receive incoming sensor data. This paper introduces a smart healthcare monitoring system based on IoT technology, utilizing Arduino and NodeMCU platforms to gather, process, and transmit crucial health information, thus enabling more advanced remote monitoring via the cloud.

Keywords: *Internet of Things(IoT), Arduino, Pulse Rate Sensor, Temperature Sensor, Node Microcontroller Unit (Node MCU), Thing Speak.*

1. Introduction

Technological innovation has been a driving force behind a significant leap in the healthcare industry, with healthcare monitoring systems at the forefront of this transformation. These systems have reshaped patient care by enabling remote, real-time monitoring of crucial health indicators and conditions. As a result, they have not only improved patient outcomes but also increased the effectiveness of healthcare delivery. In the era of the Internet of Things (IoT), the intersection of technology and medicine in healthcare signifies a pioneering blend, holding the potential to transform patient care and the way healthcare is administered. At its core, IoT in healthcare involves the integration of interconnected devices, sensors, and data analytics within the healthcare ecosystem. These devices range from wearable fitness trackers and smart medical instruments to advanced hospital equipment, all designed to collect real-time health data.

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The role of IoT (Internet of Things) technology is pivotal in the monitoring of patient health, providing a multitude of benefits that improve healthcare results and the overall patient journey. Continuous monitoring is one of the significant benefits of IoT in healthcare. By employing wearable sensors and medical equipment, the Internet of Things (IoT) allows for the continuous gathering of health information, including metrics like heart rate, blood pressure, and glucose levels [1]. This continuous data stream provides a holistic view of a patient's health, allowing for early detection of any deviations or changes that might require medical attention. The progress in wireless technology has paved the way for creative concepts that facilitate continuous, real-time remote patient monitoring utilizing small wireless body sensors [2].

Assessing a patient's overall health is significantly reliant on monitoring essential health indicators like heart rate and body temperature. This is particularly significant in cases like epilepsy, heart attacks, fever, common cold, sleep apnea, and heart failure, where continuous remote monitoring of these vital signs can prove pivotal in detecting and assessing a patient's condition [3]. In essence, wireless technology facilitates continuous, real-time monitoring of patients, which is especially vital for the timely identification of health issues in various medical conditions.

In our contemporary society, countless individuals experience daily repercussions due to delayed and inefficient medical treatment. Both in clinical settings and real-time scenarios, there are often inaccuracies in monitoring essential health parameters. Keeping regular tabs on patient status can pose a considerable challenge for healthcare facilities, especially when it comes to maintaining continuous surveillance of patients in intensive care units (ICUs). Our approach offers a valuable solution to address these issues. This research paper presents an IoT-based Patient Health Monitoring System that employs ESP8266 and Arduino to continuously gather real-time physiological data, such as heart rate and temperature, from patients. Physicians can access the outcomes on their mobile or desktop devices, and the system is designed to alert doctors when necessary [4]. Our technology offers the flexibility to monitor the well-being of any person through a simple procedure of device connection and data recording.

Structure of the Paper

The paper is organized as follows: - In Section 2, you will find an overview of research conducted by various authors in the realm of smart healthcare monitoring systems. Sections 3 and 4 delve into the topics of hardware, software connections, and experiment test bed setup. Section 5 will present the discoveries and outcomes, while Section 6 and 7 will encompass the Conclusion and Future work. Lastly, Section 8 will cover the references sourced from various authors.

2. Literature Survey

2.1. Glucose Monitoring System

A Glucose Monitoring System in IoT (Internet of Things) through the cloud represents a state-of-the-art approach to the management of blood glucose levels, particularly aimed at individuals with diabetes. This system integrates IoT devices, wireless connectivity, and cloud computing to provide continuous and data-driven glucose monitoring capabilities, ushering in a new era of healthcare management. The foundation of this system lies in specialized IoT devices, such as continuous glucose monitors (CGMs) and smart glucometers [15]. These devices are equipped with highly accurate sensors capable of measuring blood sugar levels, ensuring precise and reliable readings for patients. Continuous data collection is a fundamental feature of this system. IoT devices continuously and unobtrusively collect data on blood glucose levels. Unlike traditional glucose meters that offer isolated readings, these devices provide an uninterrupted stream of data, allowing for a more comprehensive understanding of glucose fluctuations over time.

In this monitoring system, a Continuous Glucose Monitoring (CGM) sensor is placed beneath the user's skin to consistently check glucose levels in the fluid between cells. The sensor communicates wirelessly with a transmitter, which collects and arranges the data for transmission, typically employing wireless technologies like Bluetooth or Wi-Fi. The transmitter also sends the collected data to a cloud-based platform or server. Here, the glucose data is securely stored, and accessible through individual user accounts [26]. Cloud-based data analytics algorithms work behind the scenes, analyzing the data to identify trends and patterns over time. This analytical capability empowers users to make informed decisions about their diabetes management by recognizing factors that influence their glucose levels. Moreover, the cloud platform enhances communication and collaboration. It offers a robust alerts and notifications system, sending timely alerts not only to users but also to authorized parties, including healthcare professionals and family members, ensuring comprehensive care and support. Remote access to glucose data through secure portals or dedicated apps facilitates continuous monitoring and enables healthcare providers to make data-driven recommendations for managing the user's condition effectively.

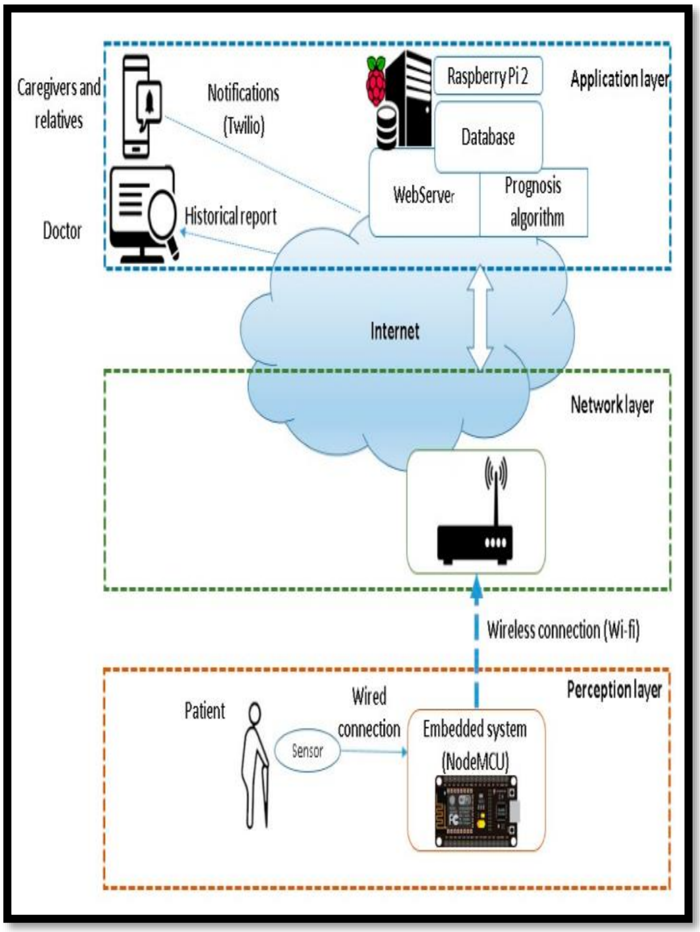

Fig. 1. Glucose Monitoring System Architecture

Throughout this process, data security remains a top priority. The system implements stringent encryption and authentication measures to safeguard the confidentiality of users' health information, ensuring compliance with privacy regulations [27]. An IoT-enabled glucose monitoring system, seamlessly integrated with cloud technology, delivers real-time glucose insights, supports trend analysis, and enables remote collaboration with healthcare teams. It is a transformative combination of medical technology, connectivity, and data analysis that enhances diabetes management and contributes to better health outcomes for individuals living with diabetes.

2.2 Oxygen Saturation (SpO2) Monitoring System

Oxygen saturation (SpO2) monitoring through IoT and cloud technology represents a cutting-edge approach to healthcare. At its core is a wearable SpO2 sensor, typically compact and non-invasive, designed to be clipped onto a fingertip or earlobe. Some modern wearable devices, like smartwatches and fitness trackers, incorporate SpO2 sensors directly into their design. These sensors continuously and painlessly measure a user's blood oxygen levels and pulse rate, forming the foundation of the monitoring process [6]. The gathered SpO2 data is wirelessly transmitted through IoT protocols like Bluetooth Low Energy (BLE) or Wi-Fi. It can be sent directly to the cloud or through a gateway device, like a smartphone or a dedicated hub, This could involve the task of gathering data from numerous sensors within a specific vicinity before transmitting it to the cloud. The cloud platform, a vital component of the system, serves as the central hub for data storage, processing, and accessibility. It securely stores the SpO2 data within individual user accounts to ensure privacy and confidentiality.

In this monitoring system, users have the option to view their SpO2 data in real-time via either a mobile application or a web-based dashboard. These interfaces provide clear visualizations of oxygen saturation levels and pulse rates. Users can customize their own SpO2 threshold ranges and receive immediate alerts if their readings fall outside these predetermined parameters, prompting them to take necessary actions or seek medical assistance. Beyond individual use, healthcare professionals and caregivers can access the SpO2 data remotely through a secure portal or app, enabling comprehensive monitoring of patients with chronic respiratory conditions or those in postoperative or post-illness recovery [7]. Cloud-based data analytics tools can analyze historical SpO2 data, identifying trends and patterns that offer early insights into the user's overall health and can guide medical interventions.

The SpO2 monitoring system calculates the oxygen saturation based on the discrepancy in light absorption between the two wavelengths. When hemoglobin molecules are saturated with oxygen, they absorb less red light and more infrared light compared to hemoglobin with lower oxygen levels. This information is then converted into a percentage value and displayed digitally for easy interpretation. Additionally, these systems often provide the person's pulse rate alongside SpO2, as the same sensor can detect the pulsatile nature of blood flow [25]. These monitoring systems find extensive use across diverse healthcare settings, encompassing hospitals, clinics, and home care environments. Their non-invasive nature and ability to provide real-time data make them invaluable tools for assessing and managing patient’s oxygenation levels, ensuring timely interventions when needed for individuals with respiratory or circulatory issues.

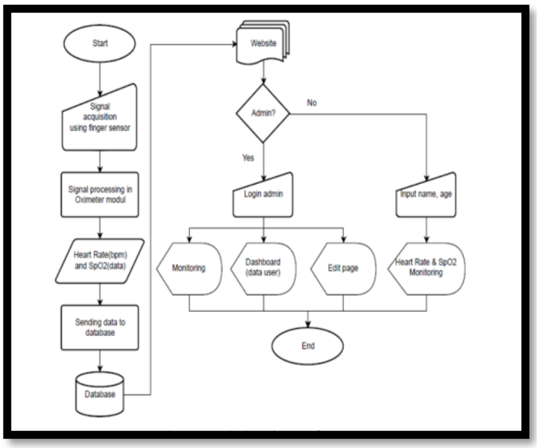

Fig .2. Oxygen Saturation (SpO2) Monitoring System Architecture

Furthermore, the system's capacity to generate alerts and notifications extends to healthcare providers and caregivers, ensuring that critical SpO2 levels are promptly communicated to those who can take immediate action. This capability is particularly critical in emergency situations where timely response can be lifesaving. Ultimately, the essential element of SpO2 monitoring systems is the implementation of strong security measures, which encompass encryption and authentication protocols. These measures are crucial for protecting the confidentiality and authenticity of the sensitive health data stored in the cloud. In essence, the utilization of IoT and cloud technology for SpO2 monitoring empowers individuals to take a proactive role in managing their health. Simultaneously, it facilitates remote monitoring and better coordination with healthcare providers and caregivers, ultimately leading to improved health results, particularly in situations where continuous monitoring is crucial for overall wellness.

2.3 Environmental Monitoring System

The fusion of Internet of Things (IoT) and cloud computing technologies in an environmental monitoring system has transformed our capacity to monitor and comprehend the conditions of our environment. This innovative system employs an extensive network of sensors and devices strategically placed across diverse environmental settings. These sensors are designed to continuously collect data on various environmental factors, including air quality, temperature, humidity, soil conditions, water quality, and more [8]. This comprehensive data collection allows for a holistic and real-time view of the environment, enabling informed decision-making and proactive responses to environmental challenges.

Once the sensors are deployed, they begin their task of collecting real-time data on the targeted environmental parameters. These sensors are equipped with a range of environmental sensors tailored to specific monitoring requirements. For instance, these sensors could encompass gas detectors for monitoring pollutants, temperature and humidity sensors for gathering climate information, and soil moisture sensors for applications related to agriculture [9]. These sensors are designed for low power consumption to ensure long-term operation without the need for frequent maintenance. The information gathered by the sensors is sent wirelessly to a central hub or gateway. This hub serves as the data aggregation point and is equipped with various connectivity options, such as Wi-Fi, cellular, or satellite communication, enabling it to establish a connection with the internet. This step is crucial in ensuring that the collected data can be efficiently transmitted for analysis and storage in cloud.

In cloud, the data is stored and processed securely. Cloud computing platforms provide flexible and dependable storage options capable of managing the extensive data generated by the sensor network. Subsequently, the data undergoes analysis using sophisticated algorithms and machine learning models to identify patterns, trends, and irregularities [22]. This analysis provides valuable insights into environmental conditions, such as detecting pollution spikes, tracking temperature fluctuations, or identifying unusual changes in soil moisture levels. To make the insights accessible and actionable, the analyzed data is presented through user-friendly dashboards and reports. These visualizations can be accessed by a wide range of stakeholders, including environmental agencies, researchers, policymakers, and the general public, through web and mobile applications. These platforms provide real-time updates on environmental conditions, fostering greater public awareness and empowering decision-makers to take informed actions in response to changing environmental parameters [23].

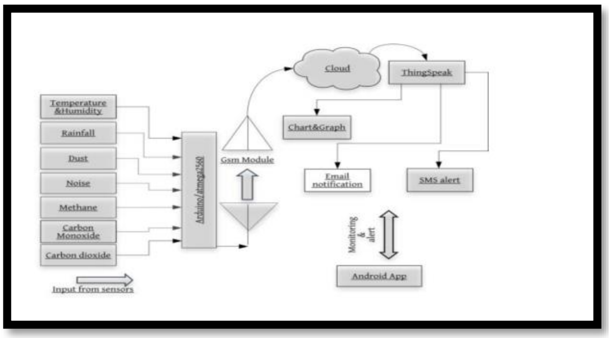

Fig .3. Environmental Monitoring System Architecture

The system can also be set up to issue alerts and notifications when environmental thresholds are surpassed. For instance, if air quality deteriorates beyond a certain level, automated alerts can be sent to relevant authorities, enabling them to respond promptly. Furthermore, historical data is archived in the cloud, facilitating long-term trend analysis and research. Researchers and policymakers can access this historical data to gain insights into how environmental conditions have evolved over time, aiding in the development of sustainable strategies and policies. In some instances, Environmental monitoring systems based on IoT are created to initiate automated reactions. As an example, utilizing up-to-the-minute data, the system has the capability to trigger air purifiers for enhancing the quality of indoor air or fine-tune irrigation systems in agriculture to maximize water efficiency. This automation enhances environmental control and management, promoting more efficient resource utilization and reducing human impact on the environment [25]. IoT and cloud technologies have brought about a transformative shift in environmental monitoring. These systems provide comprehensive, real-time, and actionable data that is invaluable for environmental conservation, disaster management, sustainable development, and improving our understanding of the intricate relationship between human activities and the natural world. As technology continues to advance, IoT-enabled environmental monitoring will play an increasingly pivotal role in addressing global environmental challenges.

2.4 Electrocardiogram (ECG) Monitoring System

ECG (Electrocardiogram) health monitoring is a vital component of modern healthcare, playing a pivotal role in assessing and managing cardiac health. This technology involves capturing and documenting the heart's electrical activity over a period, providing valuable information about the functioning of the heart. ECG monitoring is a versatile method applied across a range of healthcare environments, including hospitals, clinics, and even remote monitoring in ahome [10]. This sophisticated system relies on specialized ECG sensors that are typically integrated into wearable devices like smartwatches, chest straps, or patches [11]. These sensors capture the electrical signals generated by the heart during each heartbeat, providing crucial data about heart rate, rhythm, and potential abnormalities.

In this monitoring configuration, the collected ECG data is later processed and transmitted wirelessly using Internet of Things (IoT) protocols such as Bluetooth or Wi-Fi. This real-time data transmission can occur either to a nearby gateway device or directly to the cloud. IoT guarantees smooth connectivity, allowing uninterrupted data transmission from the sensors to the cloud-based system. Inside the cloud ecosystem, the ECG data is securely stored on servers offered by leading cloud service providers such as AWS, Azure, or Google Cloud. Cloud-based storage offers scalability and reliability, ensuring the data's availability whenever needed for analysis and interpretation.

Advanced algorithms and machine learning models are employed to analyze the ECG data in real-time. These algorithms have the capability to detect irregular heart rhythms, arrhythmias, or other cardiac anomalies. Additionally, they establish baseline ECG patterns for each individual user, enabling the system to identify deviations from normal heart activity promptly. For users, real-time access to their ECG data and insights is made available through user-friendly mobile applications or web-based dashboards [17]. These interfaces provide continuous visualizations of heart rate, rhythm, and any anomalies detected. Users can personalize their heart rate thresholds, and the system can generate alerts should it detect abnormal cardiac activity, empowering users to take proactive measures for their health.

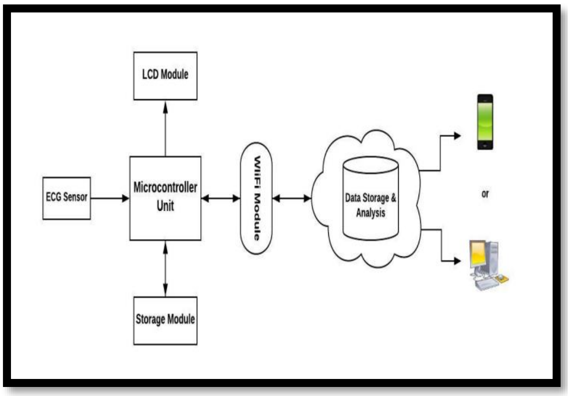

Fig .4. Electrocardiogram (ECG) Monitoring System

Furthermore, authorized healthcare professionals can remotely access the ECG data through secure portals or dedicated applications, enabling continuous monitoring and timely intervention. This is particularly valuable for managing patients with pre-existing heart conditions or those in post-operative care, ensuring that healthcare providers can respond promptly to changes in cardiac health [28]. In essence, ECG monitoring through IoT and cloud technology offers continuous and remote tracking of cardiac health, providing valuable data for individuals and healthcare professionals. This innovative approach enhances patient care by enabling early detection of heart conditions and facilitating timely medical interventions, ultimately improving cardiac health management and overall well-being.

3. Methodology

3.1 Experiment Introduction

A smart healthcare monitoring system developed using Arduino and NodeMCU combines the power of microcontroller technology with IoT capabilities to efficiently track pulse rate and body temperature. This system is designed to offer real-time health data monitoring and transmission, making it a cost-effective solution for healthcare applications. To measure pulse rate, the system employs a dedicated pulse rate sensor, typically based on photoplethysmography (PPG) technology. This sensor is commonly placed on the fingertip or wrist, capturing fluctuations in blood volume with each heartbeat. The Arduino receives and handles analog data from the sensor, computes the pulse rate in beats per minute (BPM), and then sends this information to the NodeMCU using a serial communication interface. Simultaneously, the system incorporates temperature sensing using specialized sensors like the DHT11 or DHT22. These sensors provide precise temperature measurements and are ideal for monitoring body temperature. Arduino reads the temperature data from the sensor and converts it into easily interpretable temperature values, such as degrees Celsius or Fahrenheit.

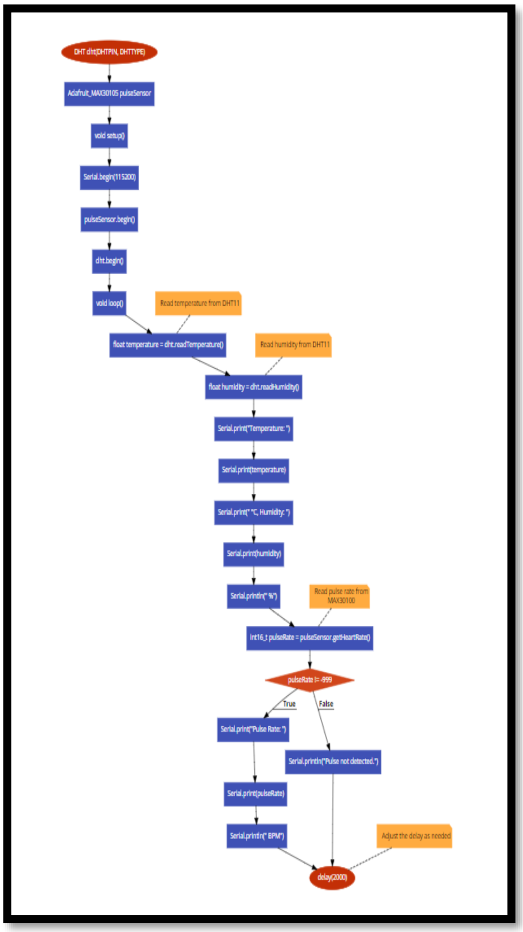

Fig .5. Workflow

3.2 Hardware Components

A. Pulse Sensor: -

The pulse rate sensor operates based on the principles of photoplethysmography (PPG). This sensor is a key component responsible for measuring the user's heart rate or pulse rate. The pulse rate sensor consists of two main components: an infrared light-emitting diode (LED) and a photodetector. When placed on the user's skin, usually on a fingertip or earlobe, the sensor's LED emits infrared light into the underlying blood vessels. This infrared light penetrates the skin and reaches the blood vessels, where it interacts with the blood.

Fig .6. Pulse Sensor

The Pulse Sensor is a heart rate sensor that works seamlessly with Arduino. This versatile tool is appropriate for a wide range of users, including students, artists, athletes, and developers working on gaming and smartphone applications. It is ideal for those seeking to incorporate real-time heart rate data into their projects. At the heart of this sensor system, there is an integrated optical amplification circuit and a noise reduction circuit. To acquire heart rate readings, you can affix the Pulse Sensor to your fingertip or earlobe and link it to your microcontroller. The Pulse Sensor comes equipped with three pins: VCC, GND, and an Analog Pin. Furthermore, within this sensor module, there is an LED situated at the center to aid in the detection of the heartbeat. Below the LED, there is a noise elimination circuit implemented to safeguard the accuracy of the measurements by preventing interference.

B. LM35 Temperature Sensor: -

The LM35 temperature sensor is a widely utilized analog temperature sensor found in numerous electronics and microcontroller projects, including applications like the smart health monitoring system. It is known for its simplicity and high accuracy, making it an ideal choice for measuring temperature in real-time. The LM35 sensor is crafted to produce an analog voltage signal that corresponds directly to the temperature it senses. Consequently, as the temperature rises or falls, the LM35's voltage output adjusts accordingly. The sensor is composed of three pins: VCC (power supply), GND (ground), and VOUT (analog voltage output).

The LM35 series consists of precise integrated-circuit temperature sensors that generate an output voltage directly proportional to the temperature in degrees Celsius. Unlike temperature sensors calibrated in Kelvin, The LM35 provides a benefit as it eliminates the necessity for users to subtract a relatively constant voltage from the output in order to obtain temperature readings in degrees Celsius. This device does not require external calibration or adjustments and can deliver standard levels of accuracy, typically ±¼°C at room temperature and ±¾°C across the entire temperature range spanning from -55°C to 150°C.

Fig .7. LM35 Temperature Sensor

C. NodeMCU (ESP8266): -

NodeMCU is an open-source firmware and development kit created to simplify the creation of Internet of Things (IoT) projects. It relies on the ESP8266 Wi-Fi module and employs the Lua programming language for programming and development purposes. NodeMCU is utilized in the smart health monitoring system to enable wireless connectivity and data transmission. This development board comes with integrated Wi-Fi capabilities, making it a superb option for establishing internet connectivity for the health monitoring system and, in turn, linking it to cloud-based platforms or remote monitoring interfaces. NodeMCU's distinguishing feature is its open-source firmware, which allows developers to leverage its capabilities for various projects. It simplifies the development process by providing a user-friendly environment for programming and interacting with the ESP8266. It provides an excellent platform for exploring the possibilities of the Internet of Things and turning innovative ideas into functional prototypes and projects.

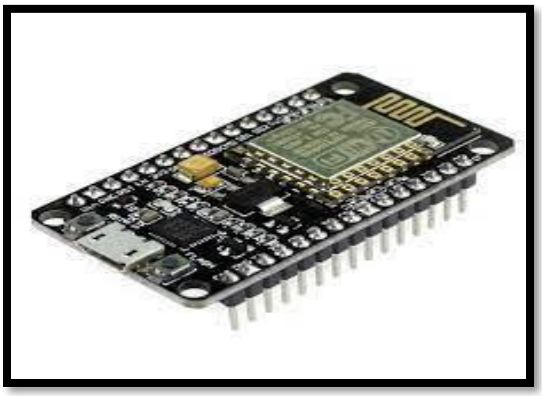

Fig .8. NodeMCU

NodeMCU acts as a bridge connecting Arduino-based sensors, such as the pulse rate and LM35 temperature sensors, with the internet. It enables the transmission of data gathered by these sensors to a distant server or cloud platform, where the data can be securely stored, analyzed, and readily accessed in real-time. This connectivity provides individuals with the capability to remotely monitor their health status or allows healthcare professionals to oversee patients' vital signs from afar.

D. Arduino UNO: -

The Arduino Uno is a microcontroller board developed by Arduino.cc, centered on the Microchip ATmega328P microprocessor. It provides a combination of digital and analog input/output (I/O) pins, allowing for connections to expansion boards (shields) and various circuits. Featuring 14 digital I/O pins, six of which support PWM (Pulse Width Modulation) output, in addition to 6 analog I/O pins, it can be programmed using the Arduino IDE (Integrated Development Environment) through a type B USB cable. The board offers versatility in terms of power sources, as it can be powered either by a USB cable or an external 9-volt battery, accommodating voltage input ranging from 7 to 20 volts. It exhibits resemblances to the Arduino Nano and Leonardo microcontrollers.

Fig .9. Arduino UNO

Arduino UNO is responsible for interfacing with the pulse rate sensor and the LM35 temperature sensor. It processes analog data obtained from these sensors and converts it into comprehensible values, such as heart rate measured in beats per minute (BPM) and temperature expressed in degrees Celsius. This data processing is accomplished through programming, as developers write code that defines how the Arduino UNO should interact with each sensor.

E. LCD: -

An LCD, or Liquid Crystal Display, is a fundamental component in the realm of digital displays, providing a visual interface for a wide range of electronic devices. It serves as a medium to present information, text, numbers, and graphics in a clear and legible manner. LCDs are extensively used in various applications, from simple calculators and digital watches to more complex devices like smartphones, televisions, and, notably, microcontroller-based systems like the Arduino Uno.

Fig .10. LCD Display

An LCD is often employed to provide a user-friendly output interface. These displays come in different sizes, with the 16x2 and 20x4 configurations being quite common. The numbers denote the number of characters each line can display. Arduino-compatible LCDs are available, which can be easily connected to the board's digital pins, extending its capabilities.

3.3 Software Components

A. Arduino IDE Tool: -

The Arduino IDE serves as the main software environment employed for programming and crafting applications for Arduino microcontroller boards, such as the Arduino UNO. It offers an intuitive and user-friendly interface for authoring, compiling, and uploading code to the microcontroller. In the context of the smart health monitoring system, the Arduino IDE serves as the platform where developers generate the code that governs the functioning of the Arduino UNO and the attached sensors.

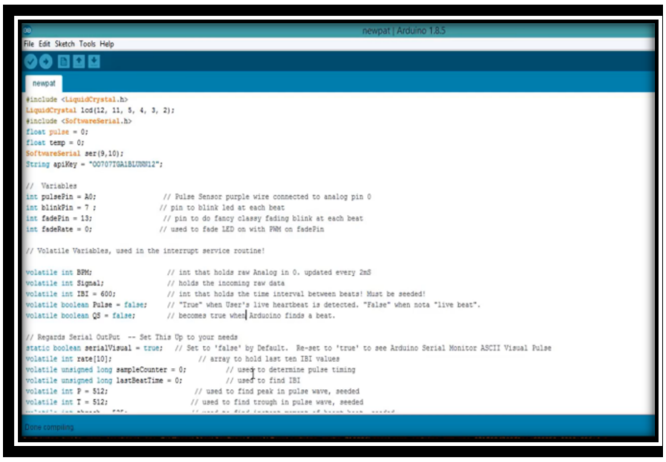

Fig .11. Arduino IDE

Developers create the code that dictates the interactions between the Arduino UNO and both the pulse rate sensor and the LM35 temperature sensor. This code specifies how the Arduino UNO should read data from the sensors, process it, and potentially perform actions or transmit the data to other components of the system, such as the NodeMCU for remote monitoring.

B. ThingSpeak: -

ThingSpeak is an online platform crafted for the Internet of Things (IoT) with the aim of streamlining the procedure of gathering, analyzing, and presenting data from connected devices or sensors. It plays a crucial role in IoT applications, offering a user-friendly way to manage and make sense of the data generated by various IoT devices.

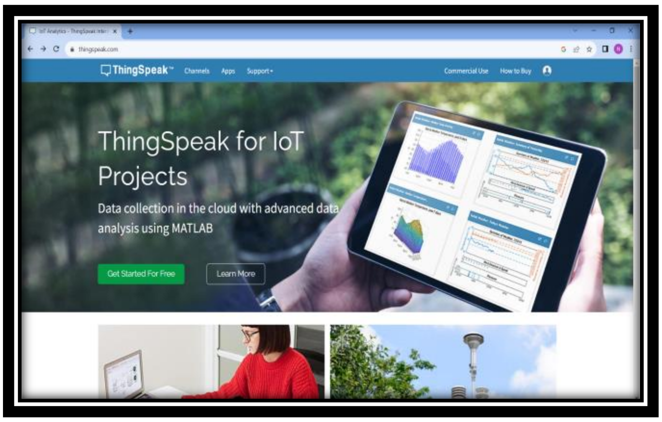

Fig .12. ThingSpeak Platform

ThingSpeak can function as the cloud-based platform where the NodeMCU (ESP8266) sends the health data gathered by the Arduino UNO from sensors like the pulse rate sensor and LM35 temperature sensor. After the Arduino UNO collects and processes the data, it can be forwarded to ThingSpeak through either an HTTP or MQTT (Message Queuing Telemetry Transport) connection using the NodeMCU. ThingSpeak offers APIs and libraries that simplify this data transfer process.

4. Experimental Test-Bed Setup

4.1 Block Diagram of Model

The system's architecture comprises various components working in harmony to monitor a patient's health. The patient's heart rate (BPM) and the environmental temperature are both measured using two key sensors: the Pulse Sensor and the LM35 Temperature Sensor, which play a central role in this process. These sensors feed their data to an Arduino microcontroller, which acts as the central processing unit.

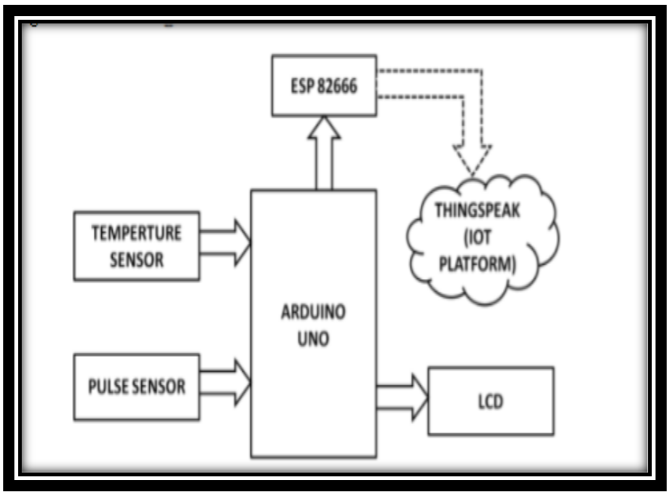

Fig .13. Smart Healthcare Monitoring System

The Arduino processes the incoming data using a programmed code and presents the vital information on a 16x2 LCD Display, providing real-time feedback to healthcare personnel or concerned individuals. For remote accessibility and data sharing, an ESP8266 Wi-Fi module is integrated into the system. This module establishes a connection to a local Wi-Fi network and facilitates the transmission of the collected health data to an Internet of Things (IoT) device server. In this setup, Thingspeak is employed as the IoT server, serving as a centralized repository for health data. By accessing the designated Thingspeak channel, users from anywhere in the world can conveniently monitor the patient's health status. This system enables seamless, real-time health tracking and provides valuable insights to ensure the patient's well-being.

4.2.Hardware Setup:-

- Attach the output pin of the Pulse Sensor to A0 on the Arduino, and ensure the other two pins are connected to VCC and GND.
- Connect the LM35 Temperature Sensor's output to A1 on the Arduino, and make sure its other two pins are joined to VCC and GND.
- To set up the LED, create a connection with Digital Pin 7 on the Arduino and include a 220-ohm resistor in this connection.

- Ensure Pins 1, 3, 5, and 16 of the LCD are linked to GND.
- Provide power to Pins 2 and 15 of the LCD by connecting them to VCC.
- Link Pins 4, 6, 11, 12, 13, and 14 of the LCD to Digital Pins 12, 11, 5, 4, 3, and 2 on the Arduino, respectively.
- Because the ESP8266's RX pin operates at 3.3V and cannot communicate directly with the Arduino's 5V, establish a voltage divider using a 2.2K and a 1K resistor. This setup will transform the Arduino's 5V to 3.3V, enabling the connection of the RX pin of the ESP8266 to Pin 10 on the Arduino via these resistors.
- Lastly, establish a connection between the TX pin of the ESP8266 and Pin 9 on the Arduino.

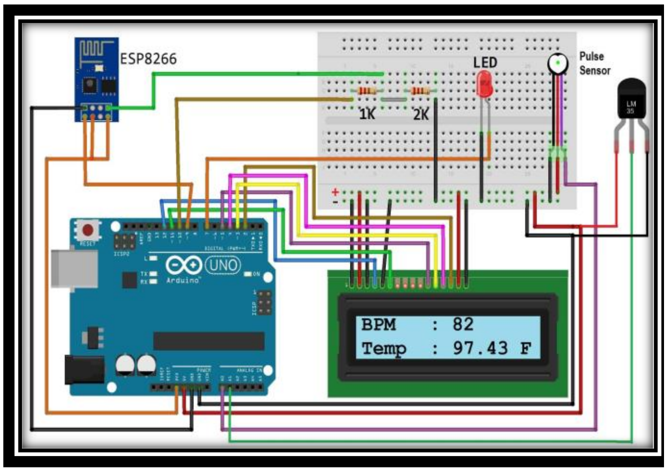

Fig .14. Hardware Setup

4.3 Programming

A. Arduino Programming: -

Create an Arduino sketch that retrieves data from both the pulse rate sensor and the LM35 temperature sensor.

Use analogRead() function to capture analog sensor values.

Convert the analog readings into meaningful units (e.g., heart rate in BPM and temperature in degrees Celsius) using appropriate formulas or calibration factors.

Prepare the data for transmission to the NodeMCU.

B. NodeMCU Programming: -

- Write a NodeMCU sketch using the Arduino IDE (you'll need to install the ESP8266 board support).
- Set up the Wi-Fi connection on the NodeMCU to connect to your local network.
- Establish communication between the Arduino UNO and NodeMCU. You can use serial communication, I2C, or other suitable methods.
- Receive the health data (pulse rate and temperature) from the Arduino UNO through the communication link.

4.4 ThingSpeak Setup

ThingSpeak offers a valuable resource for IoT-oriented projects. Using the ThingSpeak platform, we can efficiently monitor our data and remotely control our system using the provided Channels and web interfaces.

Step 1: - Create a ThingSpeak Account

- Go to the ThingSpeak website (https://www.thingspeak.com/).
- Click on the "Sign Up" link to create a new account.
- Observe the instructions displayed on the screen to establish your account.

Step 2: - Create a New Channel

- Log in to your ThingSpeak account.
- Click on the "Channels" tab at the top of the page.
- Select the "New Channel" option.
- Fill in the required information for your channel:
- Name: Give your channel a descriptive name (e.g., "Health Monitoring").
- Description: Provide a brief description of your channel.
- Field 1: Name it "HeartRate" or "PulseRate."
- Field 2: Name it "Temperature."
- You can leave other fields empty or configure them as needed.
- Make sure "Make Public" is checked if you want to share your data publicly.

Step 3: - Note Your Channel API Key

After creating the channel, you'll be provided with an API key. This key is essential for uploading data to your channel securely. Note it down; you'll need it in your Arduino and NodeMCU code.

Step 4: - Arduino Programming for Data Upload

Within your Arduino code, you should include instructions to transmit data to your ThingSpeak channel. You have the option to utilize the "ThingSpeakClient" library to make this process more straightforward. Make sure to replace "YourWiFiSSID,""YourWiFiPassword," "YourThingSpeakAPIKey," and the sensor data placeholders with your actual information. Similarly, follow the same step for NodeMCU.

Step 5: - Monitor Your Data

You are now able to upload your Arduino and NodeMCU sketches. As these devices gather data from the pulse rate sensor and LM35 temperature sensor, they will regularly transmit this data to your ThingSpeak channel. Logging into your ThingSpeak account grants you access to built-in tools for visualizing and analyzing the data. This configuration enables remote real-time monitoring and analysis of health data through ThingSpeak's visualization and alert features.

5. Result Analysis

In this smart health monitoring system experiment employing Arduino and NodeMCU for pulse rate and temperature detection, the results and analysis revolve around the successful collection and interpretation of real-time health data.

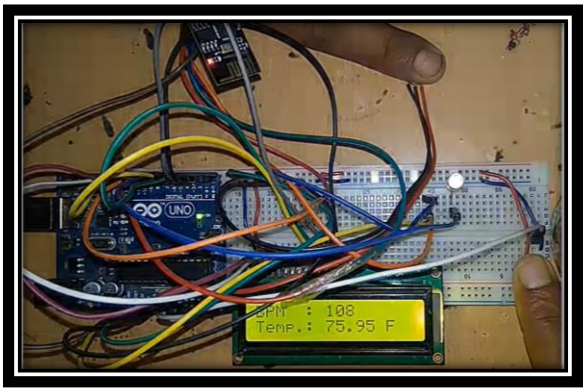

Fig .15. Pule rate and Temperature detection

5.1 Pulse Rate Monitoring

The system effectively acquires real-time pulse rate data through the pulse rate sensor. This data is systematically transmitted to a designated channel on ThingSpeak, where it is logged and timestamped. The visual representation of this data, often in the form of a time-series graph, provides insights into pulse rate variations over time. Analysis of this data can unveil significant trends, including resting heart rate, fluctuations due to physical activity, and recovery periods following exertion.

5.2 Temperature Monitoring

Similarly, the smart monitoring system successfully captures real-time body temperature data using the LM35 temperature sensor. This temperature data is relayed to the same ThingSpeak channel, where it is archived and timestamped. The visualization tools available on ThingSpeak enable the representation of temperature variations over time, including daily temperature fluctuations and potential fever episodes. A deeper analysis can help detect temperature patterns, such as fever spikes, which can be instrumental in identifying early signs of illness or infections.

5.3 ThingSpeak Real-Time Data Visualization

ThingSpeak's user-friendly dashboard provides an intuitive platform for monitoring health data as it unfolds in real-time. Through graphs, charts, and gauges, pulse rate and temperature data are depicted in easily digestible formats. Real-time observation allows for prompt recognition of changes and fluctuations, offering users the opportunity to respond immediately to any unexpected variations in their health parameters.

Fig .16. ThingSpeak Dashboard

6. Conclusion

Continuous monitoring of pulse rate and temperature data offers more than just a snapshot of an individual's current health status. It provides the means to identify long-term trends and patterns, supporting early diagnosis and intervention when necessary. Real-time monitoring empowers users to respond swiftly to abnormal health parameter readings, ultimately enhancing their ability to proactively manage their well-being. Moreover, the system's potential for remote patient monitoring can significantly benefit individuals with chronic conditions or those in need of post-operative care. The smart healthcare monitoring system illustrates the capacity of IoT technology to enhance both personal health management and the delivery of healthcare services. The combination of Arduino, NodeMCU, and ThingSpeak offers an accessible platform for real-time data collection, analysis, and visualization. This experiment marks a foundational step toward the development of more advanced and comprehensive healthcare solutions, with the potential to positively impact individual health and well-being. Future enhancements and refinements in this field hold the promise of further advancing healthcare accessibility and effectiveness.

7. Future Work

Future work in the domain of smart health monitoring using Arduino, NodeMCU, and ThingSpeak holds great potential for further enhancing the capabilities and impact of this technology. One avenue for future work involves the integration of advanced data analytics and machine learning techniques to extract deeper insights from health data, enabling predictive healthcare interventions and more accurate anomaly detection. Creating specialized mobile apps would enable users to conveniently access their health information while on the move, receive instant notifications, and participate in telemedicine consultations. Strengthening security and privacy measures is imperative to safeguard sensitive health information and ensure compliance with healthcare data regulations. Additionally, exploring multi-user support, cloud integration with healthcare-specific platforms, and conducting longitudinal studies and clinical trials will be instrumental in refining the system's effectiveness, scalability, and clinical relevance. Future research in these directions promises to revolutionize personal health management and remote healthcare services, making them more accessible, data-driven, and responsive to individuals' evolving healthcare needs.

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