IoT BASED COAL MINE SAFETY MONITORING AND ALERTING SYSTEM

Project report submitted in partial fulfillment of the requirement for the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

By

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WAKNAGHAT

May 2025

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DECLARATION

We hereby declare that the work and reported in the B Tech Project Report **"IoT BASED COAL MINE SAFETY MONITORING AND ALERTING SYSTEM"** submitted at **Jaypee University of Information Technology, Waknaghat, India** is an authentic record of our work carried out under the supervision of Dr. Emjee Puthooran. We have not submitted this work elsewhere for any other degree or diploma.

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This is to certify that the above statement made by the candidates is correct to the best of my knowledge.

Signature of Supervisor

Dr. Emjee Puthooran

Date: 10/05/2025

Signature of Head of the Department

Dr. Rajiv Kumar

ACKNOWLEDGEMENT

We would like to express our heartfelt gratitude to **Jaypee University of Information Technology** for their generous support in undertaking this project and for its successful completion. We truly appreciate their assistance.

We express our gratitude **to Dr. Rajendra Kumar Sharma**, Vice Chancellor, and **Dr. Rajiv Kumar**, Head of the Department of Electronics and Communication Engineering, for their timely support and information during the ongoing reviews.

We wish to convey our heartfelt appreciation to our Project Guide, **Dr. Emjee Puthrooan**, whose invaluable advice, recommendations, and unwavering support have greatly contributed to the successful completion of our project.

We would like to extend our gratitude to all the teaching and non-teaching staff members of the Department of Electronics and Communication Engineering for their invaluable assistance in completing the project.

LIST OF ACRONYMS AND ABBREVATIONS

1. **LCD:** Liquid Crystal Display.
2. **Wi-Fi:** Wireless Fidelity.
3. **IoT:** Internet of Things
4. **RTDs:** Resistance temperature detectors.
5. **SCL:** Serial Clock Line.
6. **SDA:** Serial Data Line
7. **ICSP:** In-Circuit Serial Programming Header.
8. **12C:** Inter-Integrated Circuit.

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ABSTRACT

Coal mining plays an important role in energy generation and industrial development, it is accompanied by many occupational hazards. Underground coal mines are a unique and risky work environment for work, including toxic gas emissions, high heat, low oxygen, cave-ins, and explosions. Conventional safety monitoring systems based on inspections, manual configurations, and untimely communication were not able to provide the level of safety monitoring necessary to identify emerging hazards. Due to the increasing importance of safety in this environment, developing new IoT solutions to provide the safety monitoring necessary for generating safety alerts is a promising development for safety-related conditions in coal mines. The project consists of an IoT-based Coal Mine Safety Monitoring and Alerting System to continuously monitor safety parameters and identify safe or hazardous conditions by providing issue safety alerts. The monitoring system uses sensors to monitor temperature, humidity, methane gas levels, carbon monoxide and oxygen levels, and sends alerts to mining people in real-time. The sensors are connected to a microcontroller utilizing NodeMCU (ESP8266) as the main processor.

The data recorded is transmitted wirelessly to remote monitoring areas, such as a cloud platform, to enable real-time monitoring from a safe distance. The system is designed to monitor real-time sensor data and compare it to existing safety thresholds. Any time any one parameter exceeds those already established safety thresholds, such as when methane gas concentrations spike or oxygen levels drop below acceptable levels, the system is programmed to generate an alert. Alerts may be generated in many ways including visual alerts (LEDs), audio alerts (buzzers), and digital alerts (SMS or app-based). Because the system is responsive to rapidly, miner and supervisor alerts can occur rapidly to enact any necessary safety protocols including generating evacuations or engaging ventilation. The biggest benefit of utilizing this IoT-based system is that it is working autonomously and continuously and limits the need for periodic manual inspections, thus, reduced reliance on a systematic list of inspection tasks and allows for a more complete mine safety oversight. In addition, data-recorded information can be collated for historical reference, and to assist in making judgements on whether issues are recurring, to evaluate risk (some levels of elevated hazardous gases depending on levels), or provide evidence or assistance with mine planning and audit activities.

In conclusion, this IoT-based coal mine safety monitoring and alerting system represents a significant step forward in ensuring the safety and well-being of mine workers. It showcases how modern technological innovations can be harnessed to create smarter, safer, and more responsive mining environments. This project contributes to the broader goal of digital transformation in the mining industry, emphasizing sustainability, safety, and efficiency through real-time data-driven solutions.

CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION

Coal mining is a vital part of world energy supply and industrial growth for many years, but it is also a very dangerous occupation that puts the miner's health and safety at risk. The subterranean mining condition is usually beset with hazardous conditions like the existence of poisonous gases (such as methane and carbon monoxide), excessive heat and humidity, lack of oxygen, and the possibility of roof falls or explosions. Protecting the lives of workers in these conditions is not only a regulatory requirement but also an ethical and operational imperative. In this regard, using new technologies such as the Internet of Things (IoT) presents interesting solutions to enhance safety protocols and emergency response in coal mines. The Internet of Things (IoT) is a connected web of physical things that contain embedded sensors, software, and communication technologies that enable them to gather and exchange data in real-time. Through an IoT application in the mining industry, especially related to safety monitoring, environmental parameters can be measured continuously and anyone needed can be alerted in real-time about dangerous conditions. This way, safety risks in coal mining operations can be reduced dramatically by preventing accidents, injuries, and fatalities from occurring. A typical IoT-based coal mine safety monitoring and alerting system includes a network of sensing devices located at multiple points in the mine. The sensing devices measure important environmental characteristics including temperature, humidity, gas concentrations (methane, carbon monoxide, etc.), and oxygen concentrations. The environmental characteristics collected by the sensing devices are transferred wirelessly in real-time, often with an electronic device such as NodeMCU (ESP8266) that serves as the controller and communication device. The system can also communicate any collected data to cloud-based devices or to a local monitoring station where data analysis could perform real-time operator action for safety. One of the major advantages of this system is its ability to generate instant alerts when any parameter crosses predefined safety thresholds. For instance, if methane levels rise beyond the permissible limit, an automatic alert—via buzzer, LED, or message notification—can be triggered to warn the miners and the control room. This real-time monitoring and early warning capability help in taking timely actions, such as evacuating the area or activating ventilation systems, thereby preventing disasters.

1.2 MOTIVATION:

Mining operations, especially in underground coal mines, are inherently dangerous due to their confined spaces, poor ventilation, and the possibility of gas accumulations leading to explosions and fires. Historically, numerous tragic mining accidents worldwide have caused massive loss of life and property. Many of these disasters could have been mitigated or prevented if real-time monitoring and early warning systems were in place.

Traditional coal mine safety systems largely depend on manual inspections and rudimentary gas detection equipment, which have significant limitations:

- Delayed Response: Manual inspections are periodic, meaning that sudden hazardous developments can go undetected.
- Human Error: Relying on human judgment increases the likelihood of overlooking critical early warning signs.
- Limited Coverage: Safety equipment may not be evenly distributed, leading to unmonitored regions within mines.
- High Cost and Complexity: Some available automatic systems are expensive, complex to install, and difficult to maintain in rugged mining environments.

The motivation behind this project stems from the desire to overcome these limitations using an affordable, scalable, and intelligent IoT-based solution. The use of wireless sensor networks minimizes the need for complex wiring and enables flexibility in sensor placement. A compact, energy-efficient microcontroller like NodeMCU offers the advantage of processing and transmitting data effectively while keeping operational costs low.

Moreover, advancements in low-cost sensors for temperature, gas concentrations, and environmental parameters make it feasible to design a reliable monitoring system even for small or medium-scale mining operations. Incorporating cloud computing or local servers for data storage further allows predictive analytics, enhancing the preventive safety approach.

1.3 KEY MOTIVATION FACTORS INCLUDE

- Saving Lives: Providing miners with timely information and alerts significantly reduces fatalities and injuries.
- Real-Time Monitoring: Continuous observation of environmental conditions ensures that hazards are detected as soon as they develop.
- Automation: Reducing human involvement in safety inspections helps minimize errors and ensures consistent monitoring.
- Cost Efficiency: Using widely available IoT components keeps system costs manageable, even for resource-constrained mining operations.
- Data Analytics: Historical data can be used to predict trends, schedule maintenance, and improve overall mine design and operational procedures.

By implementing an IoT-based coal mine safety system, mining companies can not only comply with stricter regulatory standards but also demonstrate corporate responsibility towards their workers' well-being.

1.4 IMPORTANCE OF THE PROJECT

- Enhanced Safety: Early warnings and real-time monitoring contribute directly to safer working conditions.
- Accident Prevention: Identifying and responding to hazardous conditions before they escalate prevents accidents.
- Operational Efficiency: Reliable data collection aids in better decision-making and efficient resource management.
- Regulatory Compliance: Helps mining companies meet occupational safety and health regulations.
- Scalability and Flexibility: The modular design allows the system to be easily scaled or adapted to various mine sizes and layouts.

1.5 COAL MINES IN INDIA

Table 1: Coal Mines in India

Mine Name	**Location**	**Type(Open Cast/ Underground)**	**Depth(meters)**	**Major Incidents(Year)**	**Ownership**
Jharia Coalfield	Dhanbad, Jharkhand	Underground	Up to 300	Frequent fires (since 1916)	Bharat Coking Coal Ltd
Raniganj Coalfield	Asansol, West Bengal	Underground/Open Cast	50-400	2006 accident (10 deaths)	Eastern Coalfields Ltd
Korba Coalfield	Chhattisgarh	Open Cast	250	2009 accident (9 deaths)	South Eastern Coalfields Ltd
Singrauli Coalfield	Madhya Pradesh	Open Cast	150-350	NA	Northern Coalfields Ltd
Talcher Coalfield	Odisha	Open Cast/Underground	200-300	2019 accident (4 deaths)	Mahanadi Coalfields Ltd
Bokaro Coalfield	Bokaro, Jharkhand	Underground/Open Cast	150-300	NA	Central Coalfields Ltd
Wardha Velley Coalfield	Maharashtra	Underground/Open Cast	100-200	NA	Western Coalfields Ltd
Makum Coalfield	Assam	Open Cast	150	NA	North Eastern Coalfields
Chirimiri Coalfield	Chhattisgarh		150-250	NA	South Eastern Coalfields
Pench Kanhan Coalfield	Madhya Pradesh	Underground/Open Cast	50-200	NA	Western Coalfields Ltd

1.6 LITERATURE REVIEW:

1.6.1 Traditional Coal Mine Safety Systems

- Early systems relied on manual inspection and portable gas detectors for hazard identification.
- Safety officers performed scheduled checks, but lack of continuous monitoring often led to missed incidents.
- Studies showed that manual methods are labour-intensive, error-prone, and slow to react to sudden dangers ([Singh et al., 2003]).
- The primary limitations included:
    - Delayed hazard detection.
    - Limited area coverage.
    - High dependency on human judgment.

1.6.2 Development of Wireless Sensor Networks (WSNs) in Mining

- Wireless Sensor Networks emerged as an alternative solution to traditional wired systems.
- Researchers like Akyildiz et al. (2002) proposed WSNs for underground applications to enhance flexibility and fault tolerance.
- WSN-based systems allowed real-time monitoring of gases, temperature, and humidity across vast mine areas.
- However, challenges such as signal attenuation, power consumption, and harsh environmental conditions limited their widespread adoption.

1.6.3 IoT Integration in Industrial Safety

- The Internet of Things (IoT) revolutionized how industries monitor their operations.
- According to Gubbi et al. (2013), IoT offers ubiquitous connectivity, real-time data processing, and remote monitoring, making it highly suitable for mining safety.

- Studies show that IoT integration improves:
  - Predictive maintenance.
  - Hazard detection accuracy.
  - Remote supervisory control.
- Application examples:
  - Smart factories using IoT sensors for fire and gas leak detection.
  - Oil and gas fields adopting IoT-based real-time condition monitoring.

1.6.4 Previous IoT-based Coal Mine Safety Systems

Several researchers and engineers attempted IoT-based monitoring systems for mining safety:

- Patel et al. (2016) designed a basic gas and temperature monitoring system using Arduino and Wi-Fi modules.
- Raj et al. (2017) proposed a model where NodeMCU was used to monitor methane and CO levels, but their work lacked a centralized data logging system.
- Sharma and Kumar (2018) developed an IoT system where alerts were sent via GSM modules to supervisors' mobile phones during critical events.
- Li and Zhou (2019) implemented a large-scale deployment of IoT sensors for underground mines in China, combining data analytics for early warning systems.

Key findings:

- NodeMCU microcontrollers proved effective due to low cost, Wi-Fi capability, and ease of programming.
- MQ-series gas sensors (like MQ-2, MQ-7) are widely used for methane, carbon monoxide, and smoke detection.

1.6.5 Use of Sensors in Mine Safety

- Various environmental parameters are crucial for miner safety:

- Methane (CH_4): Highly explosive.
- Carbon Monoxide (CO): Toxic at low concentrations.
- Temperature: Abnormal rises can indicate fires.
- Humidity: Affects miner comfort and equipment operation.

- Common sensors:
  - MQ-2/MQ-7: For gas detection.
  - DHT11/DHT22: For temperature and humidity.
  - IR sensors: For human presence detection.
- Limitations identified in previous studies:
  - Sensor calibration issues.
  - Short sensor lifespans in harsh underground environments.

1.6.6 Communication Technologies in Mining IoT Systems

- Wi-Fi: Good for short-range communication in accessible mine areas.
- LoRaWAN: Preferred for deep mines due to its long-range and low-power operation ([Augustin et al., 2016]).
- GSM/4G modules: Used for emergency alerting to supervisors' mobile devices.
- Past projects often combined Wi-Fi within the mine and GSM modules for external communication.

1.6.7 Data Management and Cloud Computing

- Research by P. Ray (2016) emphasized that collecting data is not sufficient unless analytics and cloud storage are incorporated.
- Cloud platforms like ThingSpeak and Firebase are increasingly used for:
  - Storing environmental data.
  - Visualizing sensor readings.

    - Sending automatic email/SMS alerts.

- Use of cloud computing enhances the system's ability to generate predictive insights over time.

1.6.8 Machine Learning for Predictive Safety

- Advanced projects applied machine learning on historical sensor data to predict accident-prone conditions.
- S. Yadav et al. (2020) demonstrated that neural networks could predict gas leakage events 5–10 minutes before critical thresholds were reached.
- Although promising, machine learning applications require large datasets and more sophisticated hardware, which may not always be feasible in cost-sensitive mines.

1.7 OBJECTIVE:

The primary objective of this project is to design and implement a real-time, low-cost, and reliable IoT-based system that enhances safety in coal mines by continuously monitoring environmental parameters and providing instant alerts in hazardous conditions. The system aims to minimize risks to miners and improve emergency response through automated and intelligent sensing and communication.

CHAPTER 2

SYSTEM DESIGN

2.1 SYSTEM DESIGN

2.1.1 Introduction of existing system

Overview of Current Coal Mine Safety Practices

Coal mining remains one of the most hazardous occupations in the world due to the confined and unstable working conditions in underground environments. Traditional safety practices in coal mines include:

- Manual Inspection Routines Safety officers perform scheduled checks for gas concentration and environmental conditions using handheld devices.
- Wired Monitoring Systems Some advanced mines use wired systems for real-time gas and temperature monitoring, connected to a central console.
- Basic Alarms and Ventilation Controls Mines use fixed alarms and ventilators controlled manually or through timers, often disconnected from real-time data inputs.

2.1.2 Working Principle

1. Data Collection Sensors detect gas levels, temperature, and humidity in the coal mine environment.
2. Data Processing NodeMCU reads the analog/digital values from the sensors, compares them with safety thresholds.
3. Alert Generation If any value crosses the threshold:
    - Buzzer and LEDs are activated immediately.
    - SMS or cloud-based alerts are sent.
4. Data Transmission
    - Safe readings are sent periodically to the cloud server.

- Alerts are sent instantly for critical conditions.

5. Data Logging and Visualization

    - Sensor data is logged on the cloud.
    - Supervisors can access real-time dashboards via mobile or PC.

2.1.3 PROPOSED SYSTEM:

Relays, temperature sensors, and gas sensor modules are all part of the mine safety systems. All of the sensors are integrated within the controller. On the Thing Speak platform, we must create an account. The main components of this system are the control and monitoring systems. We track all of the data from different sensors in a monitoring system. In the coal mine environment, gas is detected via gas sensors. The buzzer will sound to notify the mine workers if the gas level climbs above the typical level. For analysis and future use, these sensor values are continuously transmitted to the cloud. Within the coalmine, temperature and water level readings are also tracked and transmitted to the data control unit, where they are stored in IOT.

2.2 PROJECT DESIGN

2.2.1 BLOCK DIAGRAM:

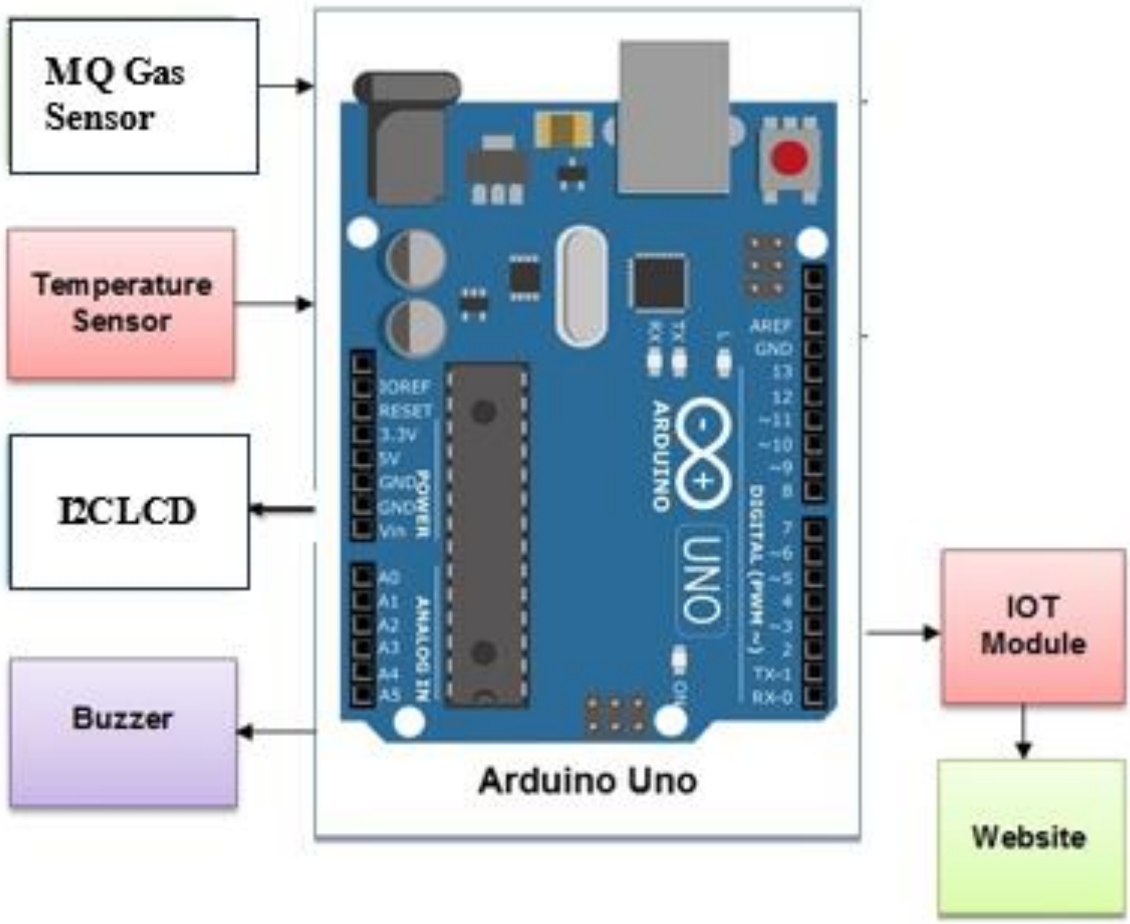

Figure 2.1: Block Diagram.

2.2.2 Hardware Used:

MQ2 sensor

Lm35 Temperature Sensor

LCD Display

Arduino Uno

Piezoelectric Buzzer

Wi-Fi Module

2.2.3 Software Used:

ThingSpeak

2.3 FLOW CHART:

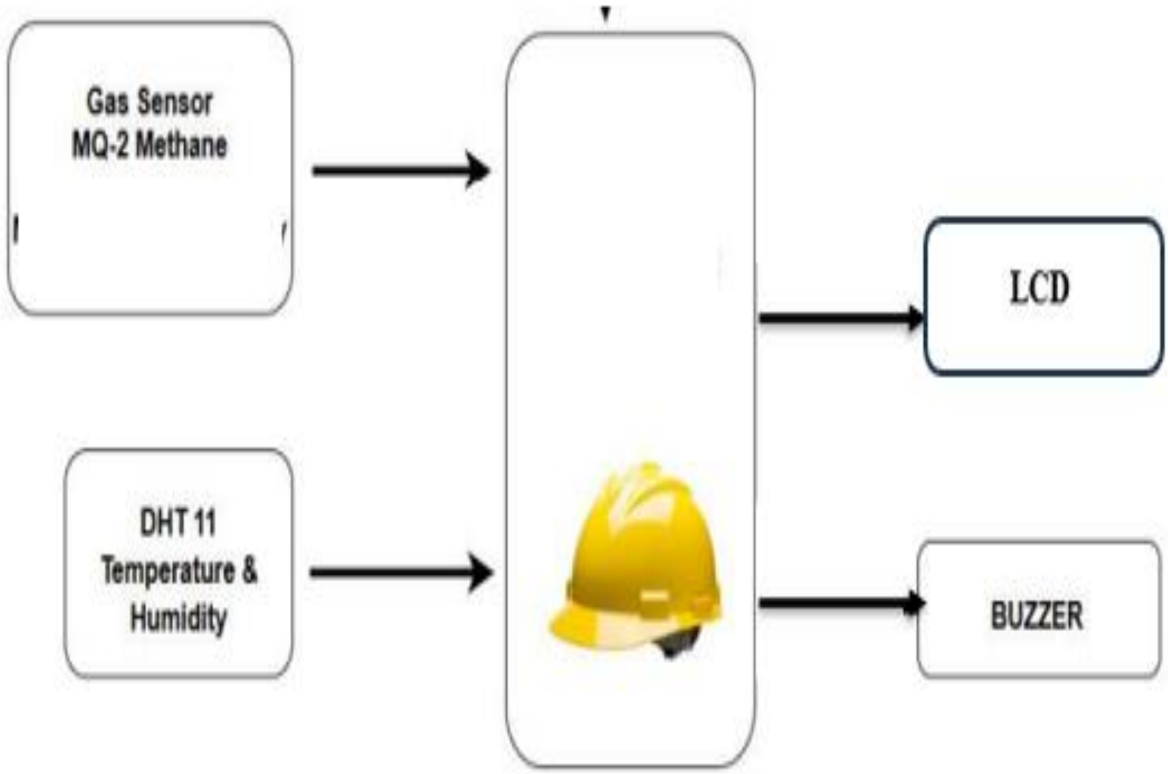

Figure 2.2: Flow Chart Hardware.

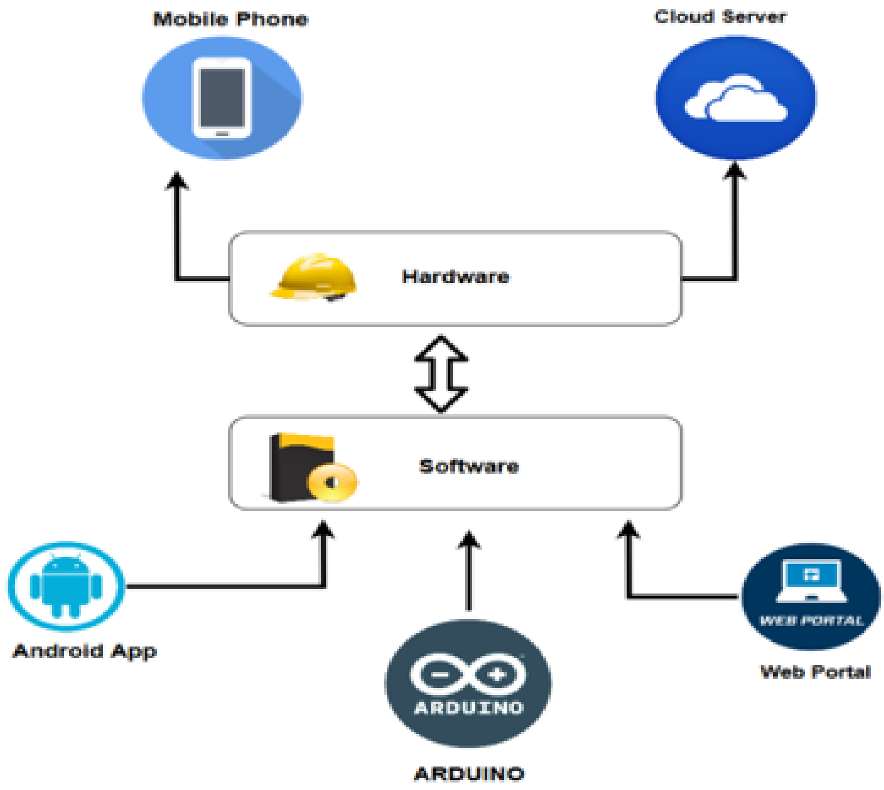

Figure 2.3: Flow Chart Hardware and Software.

CHAPTER 3

HARDWARE COMPONENTS AND SOFTWARE USED

3.1 HARDWARE EXPLANATION

3.1.1 Wi-Fi Module:

The ESP8266 Wi-Fi module, created in 2014 by third-party manufacturers like AI Thinking, is mostly utilized for the creation of embedded applications based on the Internet of Things. It is capable of managing various Wi-Fi network operations from a different application processor. 28The microcontroller can connect to any Wi-Fi network thanks to its System On Chip (SOC) and TCP/IP protocol stack. This page covers the ESP8266 Wi-Fi module's pin arrangement, specifications, circuit diagram, uses, and alternatives.

3.1.1.1 What is the ESP8266 Wi-Fi Module?

A SOC microchip known as a Wi-Fi module is mostly used to develop end-point Internet of Things applications. Known as a standalone wireless transceiver, it is reasonably priced. It makes it possible for numerous embedded system applications to connect to the internet. The ESP8266 Wi-Fi module was developed by Expressif Systems to enable microcontroller and TCP/IP connectivity to any Wi-Fi network. It offers solutions that meet the demands of the IoT market in terms of price, power, performance, and design. It can operate as a stand-alone program or as a slave program. Any microcontroller that supports SPI or UART can use the ESP8266 Wi-Fi as a Wi-Fi adapter if it operates as a slave to a microcontroller host. When the module is used as a stand-alone application, it carries out the tasks of the Wi-Fi network and microcontroller. Amplification, filters, digital baseband, RF baluns, power modules, RF transmitters and receivers, analogue transmitters and receivers, external circuits, and other parts are all included in the ESP8266 Wi-Fi module. This module's 80 MHz CPU is based on the Tensilica Xtensa Diamond Standard 106 micro. Third-party producers have created a variety of ESP module types. These are the eight pins (GPIO pins -2) that the ESP8266-01 has. Eight pins (GPIO pins 3) make up the ESP8266-02. There are 14 pins on the ESP8266-03 (GPIO pins 7). There are 14 pins on the ESP8266-04 (GPIO pins 7).

Figure 3.1: Wi-Fi Module.

3.1.1.2 NodeMCU (ESP8266)

Description:

- NodeMCU is an open-source IoT platform.
- It includes ESP8266 Wi-Fi SoC and supports Lua/Arduino programming languages.
- The board features digital I/O pins, ADC input, and built-in Wi-Fi capability.

Technical Specifications:

- Microcontroller: Tensilica 32-bit RISC CPU Xtensa LX106
- Operating Voltage: 3.3V
- Flash Memory: 4 MB
- Wi-Fi Standard: IEEE 802.11 b/g/n
- GPIO Pins: 17
- ADC Range: 0–1V

Role in Project:

- Acts as the central controller.
- Collects data from sensors.
- Connects to Wi-Fi and uploads data to the cloud.
- Triggers buzzer/LEDs for local alerts.

Advantages:

- Low cost.
- Compact size.
- Easy to program using Arduino IDE.

3.1.2 MQ-2 Gas Sensor

The MQ2 gas sensor continuously samples the air and detects the presence of gases like methane, propane, LPG, CO, and smoke. Inside the sensor, the tin dioxide (SnO_2) sensing layer changes its electrical resistance depending on the gas type and concentration. This change is converted into an analog voltage. The sensor's analog pin is connected to an analog input pin (like A0) of the Arduino. The Arduino converts this analog voltage into a digital value using its internal ADC (Analog to Digital Converter), typically ranging from 0 to 1023.

When the concentration exceeds a predefined threshold (e.g., 300 ppm for methane), the Arduino is programmed to take emergency actions like activating the buzzer, displaying warnings on the LCD, and transmitting data via Wi-Fi.

Description:

- MQ-2 is a high sensitivity gas sensor.
- Detects gases such as:
  - Methane (CH_4)
  - LPG
  - Smoke
  - Hydrogen

- Carbon monoxide (CO)

Technical Specifications:

Operating voltage: 5V.

Load resistance: 20KΩ.

Heater resistance: 33 Ω ± 5%.

Heating consumption: <800mW.

Sensing Resistance: 10 KΩ-60 KΩ.

Concentration Range: 200-10000ppm.

Preheat time: over 24 hours.

Role in Project:

- Monitors methane and smoke levels in coal mines.
- Sends analog values to NodeMCU for real-time analysis.

Advantages:

- Fast response.
- Affordable and durable.
- Easy to interface with microcontrollers.

3.1.2.1 How does a Gas Sensor Work?

High temperatures cause oxygen to be adsorbed onto the surface of a SnO2 semiconductor layer. Oxygen molecules are drawn to the conduction band of tin dioxide by electrons in pure air. This creates a potential barrier by producing an electron depletion layer directly beneath the SnO2 particle surface. The SnO2 coating consequently becomes very resistive, stopping the flow of electric current. As deposited oxygen reacts with reducing gases, its surface density decreases, lowering the potential barrier. Current can flow freely through the sensor as a result of the release of electrons into the tin dioxide.

Figure 3.2: MQ2 Gas Sensor Pin Points.

Figure 3.3: MQ2 Gas Sensor.

3.1.3 DHT11 Temperature and Humidity Sensor

The DHT11 sensor measures two key parameters: temperature and relative humidity. It contains a thermistor and a capacitive humidity sensor. The DHT11 periodically samples air from the environment and provides calibrated digital output through its single data pin. The sensor sends this data in the form of a digital signal with start, data, and checksum bits.

The Arduino receives the data by using a compatible DHT library, interprets the temperature and humidity values, and compares them with safe limits. For instance, if the temperature exceeds 40°C, this may indicate a fire hazard or machinery malfunction. If humidity is too low or too high, it may suggest poor air circulation or excessive moisture—both undesirable in mining environments.

Description:

- A simple, reliable sensor for temperature and humidity measurements.

Technical Specifications:

- Temperature Range: 0°C to 50°C
- Humidity Range: 20% to 90% RH
- Operating Voltage: 3–5V
- Accuracy: ±2°C temperature, ±5% humidity

Role in Project:

- Continuously measures:
    - Ambient temperature.
    - Relative humidity in the mine environment.

Advantages:

- Very low cost.
- Easy digital output for microcontrollers.
- Suitable for low-power applications.

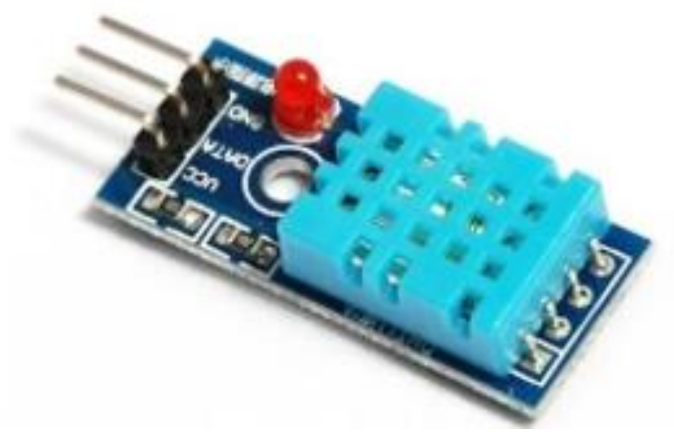

Figure 3.4: DHT 11.

3.1.4 Piezoelectric Buzzer

Beepers and buzzers are examples of audio signaling devices that might be mechanical, piezoelectric, or electromechanical. Its main purpose is to transform the audio signal into sound. Usually, timers, alarms, printers, computers, and other devices are powered by DC electricity. Depending on the design, it can produce a range of sounds, such as siren, melody, alarm, and bell. The buzzer's pin configuration is displayed below. Positive and negative are its two pins. A '+' symbol or a longer terminal is used to indicate this's positive terminal. Six volts powers the positive terminal, while the ground terminal is connected to the negative terminal, which is denoted by the '-' symbol. Beepers and buzzers are examples of audio signaling devices that might be mechanical, piezoelectric, or electromechanical. The main purpose of this is to convert audio signals into sound. Computers, printers, clocks, alarms, and other equipment are frequently powered by DC electricity. Depending on the design, it can make a variety of sounds, including siren, bell, melody, and alarm.

Below is an illustration of the buzzer's pin configuration. Both positive and negative pins are present. A longer terminal or the '+' symbol are used to indicate the positive terminal. Six volts powers the positive terminal, while the ground terminal is connected to the negative terminal, which is denoted by the '-' symbol. In the 1970s and 1980s, Japanese manufacturers created buzzers and incorporated them into a variety of items. The cooperation of Japanese industrial companies was largely responsible for this advancement. The Barium Titanate Application Research Committee was founded in 1951 with the goal of promoting innovation and competitive cooperation in piezoelectric technology.

Description:

- A small audio signaling device that emits a sound when energized.

Technical Specifications:

- Operating Voltage: 3V–12V
- Sound Output: 85 dB typically
- Current Consumption: Low

Role in Project:

- Provides an immediate audible alert if dangerous gas levels or temperatures are detected.

Figure 3.5: Piezoelectric Buzzer.

3.1.5 12C LCD

Liquid Crystal Display is what the term LCD stands for. A flat-paneled display is called an LCD. It uses polarized light and liquid crystals to display the content. LCD makes use of its light modulating capability. Both monochrome and multicolor LCDs are offered. Without a backlight, it is unable to generate light directly. Certain LCDs only use a backlight to display content in low light. Inter-Integrated Communication is referred to by the term I2C or IIC. To connect with other I2C devices, one can utilize the serial communication protocol known as I2C. I2C uses the multi-slave/multi-master strategy. Two lines—SCL and SDA—as well as two lines for the power supply and ground are used for I2C transmission and reception. The I2C address of each device can be used to identify it. Many devices may have identical I2C addresses. The address (example address) is represented as "0x20". The following section explains how to identify the I2C address device. The transmitter and receiver are synchronized using the serial clock (SCL) pin. Data transfer is accomplished via the Serial Data (SDA) pin. The I2C communication interface is used by I2C LCDs to transmit the data required to show the content.An I2C LCD just needs two lines (SDA and SCL) to transmit data. Thus, the complexity of the circuit is reduced.

Figure 3.6: 12C LCD.

3.1.6 Arduino UNO:

The ATmega328P serves as the foundation for the Arduino UNO microcontroller board (datasheet). A 16 MHz ceramic resonator (CSTCE16M0V53-R0), 6 analogue inputs, 14 digital input/output pins (six of which can be used as PWM outputs), a USB connector, a power jack, an ICSP header, and a reset button are all included. Everything required to support the microcontroller is included; all you need to do is plug it in using a USB connection, power it with an AC-to-DC adapter, or use a battery to get going. You can experiment with your UNO without fear of making a mistake; in the worst situation, you can start over by buying a new chip. "Uno" was chosen to honor the release of Arduino Software (IDE) 1.0 since it means "one" in Italian. The Arduino reference versions, which have since developed into more recent versions, were the UNO board and version 1.0 of the Arduino Software (IDE). " To celebrate the release of Arduino Software (IDE) 1.0, the word "uno," which means "one" in Italian, was chosen. The reference versions of Arduino, which have since developed into more recent versions, were the UNO board and version 1.0 of the Arduino Software (IDE). See the Arduino index of boards for a complete list of current, past, and obsolete Arduino boards. The UNO board is the first in a series of USB Arduino boards and is the standard model for the Arduino platform.

The Arduino software (IDE) can be used to program the Arduino UNO. Depending on the microcontroller on your board, choose "Arduino UNO" from the Tools > Board menu. See the tutorials and references for further details. You can upload new code to the Arduino UNO's ATmega328 without a separate hardware programmer because it comes preprogrammed with a bootloader. It uses the original STK500 protocol for communication. You can also use Arduino ISP or a similar tool to program the microcontroller via the ICSP header, avoiding the bootloader; see these instructions for more details.

The ATmega16U2 (or 8U2 in rev1 and rev2 boards) firmware source code is available in the Arduino repository. The DFU bootloader included with the ATmega16U2/8U2 can be activated by:

1. Before reattaching the 8U2, connect the solder jumper on the rear of Rev1 boards (next to the map of Italy).

2. To facilitate booting into DFU mode on Rev2 or later boards, a resistor pulls the 8U2/16U2 HWB line to ground.

3.1.6.1 Pin Configuration

Vin: This is the input voltage pin on the Arduino board, which receives power from an outside source.

5V: The Arduino board's pin acts as a controlled power supply voltage, supplying electricity to the board and its internal components.

3.3V: A voltage regulator on the board provides a 3.3V supply, which is delivered via this pin.

GND: The Arduino board is grounded via this board pin.

Reset: The microcontroller can be reset using this pin on the PCB. Resetting a microcontroller is its purpose.

Digital Pins: The Arduino board's pins 0-13 are used as digital inputs or outputs.

Serial Pins: Another name for these is UART pins. It makes communication easier between computers or other devices and the Arduino board. Pins 1 for the transmitter and 0 for the receiver are used to send and receive the data, respectively.

External Interrupt Pins: External interrupts are produced by the Arduino board's Pins 2 and 3. Analogue Pins: Pins A0 through A5 are utilized as analogue inputs and have a voltage range of 0 to 5V.

PWM Pins: By altering the pulse's width, these board pins convert digital signals to analog signals. For PWM, pins 3,5, 6, 9, 10, and 11 are utilized.

SPI Pins: Using the SPI library, SPI connectivity is maintained via the Serial Peripheral Interface pin.

Among the SPI pins are: Slave select is represented by Pin 10, master out slave in by Pin 11, and master in slave out (MISO) by Pin 12.

SCK: A serial clock is operated via pin 13.

LED Pin: On digital pin-13, the PCB has an LED. Only when the digital pin is high will the LED illuminate.

ARFF Pin: The analogue reference pin on the Arduino board is called the AREF pin. It is employed to supply an external power source with a reference voltage.

Figure 3.7: Arduino UNO.

3.1.7 IoT(Internet of Things):

The **Internet of Things (IoT)** is a system of interrelated physical objects—devices, vehicles, appliances, and other items—embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet.

IoT transforms passive physical objects into smart devices that can collect, send, and receive data. This integration enables better automation, control, efficiency, and decision-making in various domains like smart homes, healthcare, agriculture, transportation, and industry.

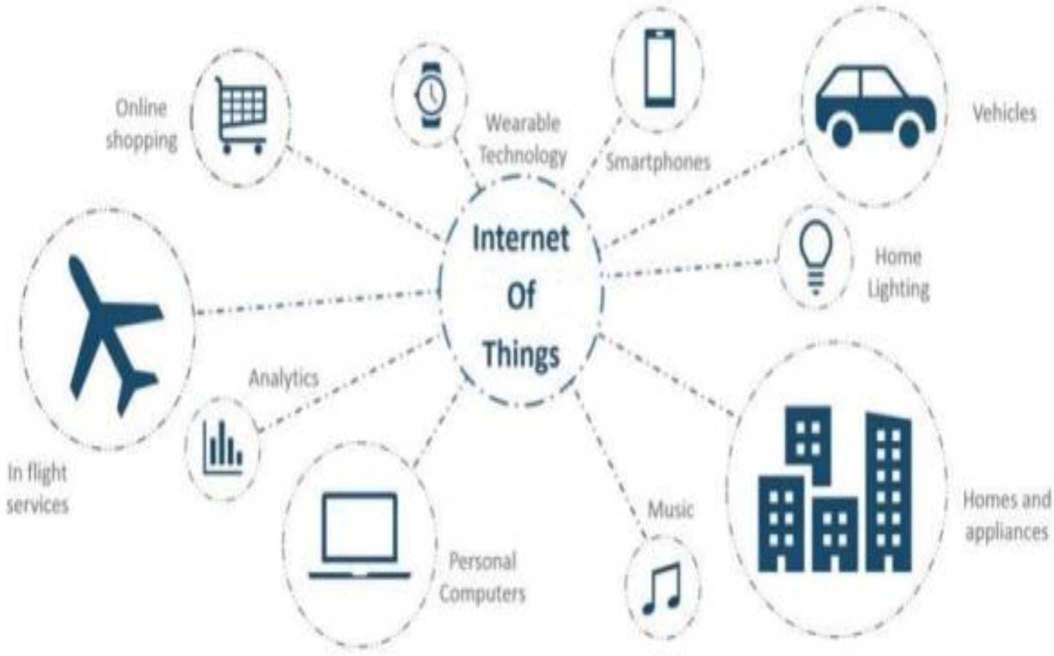

Figure 3.8: IoT.

3.1.7.1 How IoT Works

IoT involves a multi-layered architecture:

1. Devices/Sensors

- These are physical devices embedded with sensors, actuators, and communication hardware.
- They collect data from the environment (e.g., temperature, motion, humidity, pressure).

2. Connectivity

- Devices connect to the cloud or other systems via various protocols: Wi-Fi, Bluetooth, Zigbee, LoRaWAN, NB-IoT, etc.
- Gateways may be used to link local devices with cloud servers.

3. Data Processing

- The collected data is sent to cloud platforms where it's processed using algorithms, AI, or machine learning models.
- Example: A thermostat senses room temperature and uses logic to activate cooling.

4. User Interface

- The processed data is presented to users via mobile apps, dashboards, or alerts.
- Example: A farmer gets soil moisture data from a smart irrigation system via a smartphone.

5. Action

- Based on the data, IoT systems can automatically take actions (e.g., switching on lights) or send notifications to users.

3.1.7.2 Key Features of IoT

1. Connectivity

- Central to IoT; allows seamless communication between devices.
- Involves both local networks (e.g., Bluetooth) and internet/cloud connectivity.

2. Automation and Control

- Devices can operate with minimal human intervention.
- Example: Smart thermostats adjusting room temperature based on time of day.

3. Data Collection and Monitoring

- Real-time monitoring of conditions like temperature, health metrics, or location.
- Enables tracking, diagnostics, and predictive maintenance.

4. Scalability

- Systems can accommodate thousands or millions of connected devices.
- Cloud infrastructure and protocols allow horizontal scaling.

5. Integration with Other Technologies

- Works alongside AI, machine learning, blockchain, and edge computing to increase functionality and intelligence.

6. Intelligence and Analytics

- IoT doesn't just collect data—it helps analyze it to derive meaningful insights.
- Example: Health wearables analyzing sleep patterns and suggesting improvements.

7. Energy Efficiency

- Many IoT devices are designed for low power usage (e.g., using LPWAN technologies like LoRa).

3.1.7.3 Benefits of IoT

- Efficiency and Cost Savings
- Improved Decision Making
- Real-Time Insights
- Remote Access and Control
- Enhanced Customer Experience

3.1.7.4 Future of IoT

- By 2030, billions of devices will be connected.
- Growth in edge computing to reduce latency.
- Increased use in smart cities, autonomous vehicles, and precision medicine.
- More integration with 5G and AI technologies.

3.2 SOFTWARE USED

3.2.1 Arduino IDE

Description:

- Open-source software used to program NodeMCU.

Features:

- Supports C/C++ programming.
- Includes libraries for Wi-Fi, DHT11, and MQ sensors.
- Serial monitor for real-time debugging.

Role in Project:

- Coding and flashing firmware onto NodeMCU.
- Setting up thresholds, cloud uploads, and alerts.

3.2.2 ThingSpeak Platform

Description:

- A free IoT cloud service that stores and visualizes data.

Features:

- Real-time data graphs.
- Email/SMS alerts through IFTTT integration.
- Easy API for data uploads.

Role in Project:

- Displays real-time gas concentration, temperature, and humidity.
- Logs historical sensor data for later analysis.

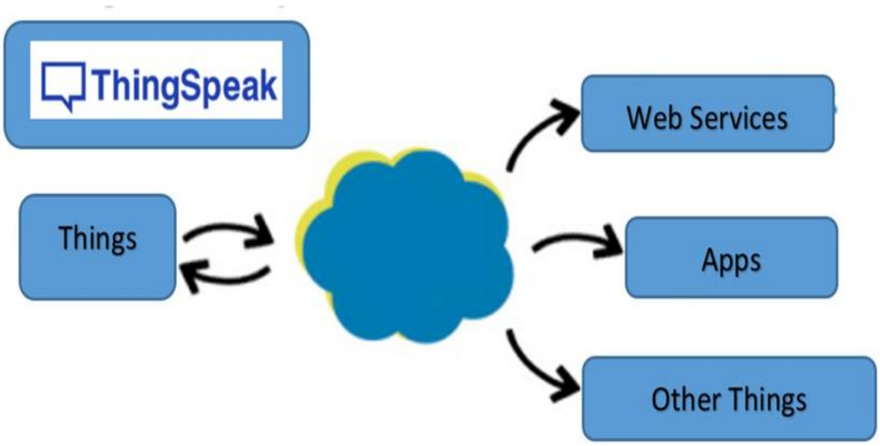

Figure 3.9: ThingSpeak.

CHAPTER 4

RESULTS

4.1 READINGS

Table 2: Specification table for selected sensors.

Sr no.	Parameters	MQ2 Gas Sensor	DHT11 Sensor
1	Sensing variable/Uses	Gas Concentration	Temperature and Humidity
2	Operating Voltage	5V	3.3V to 5.5V DC
3	Operating Current	800mW	500mA
4	Output Voltage	0 TO 10 V	3.3 to 5V
5	Operating Temperature Range	-20 TO 70 C	0 to 50 C
6	Output/Sensing Range	300 to 10000 ppm	0 to 50 C

Table 3: Result analysis of monitoring system for safe condition

Sr no.	Parameter	Threshold value set	Sensor reading	Hardware changes	Remark
1	Temperature (Degree Celsius)	25	24.2 C	Buzzer Off	Safe Condition
2	Gas (PPM)	600	354ppm	Buzzer Off	Safe Condition
3	Humidity (%RH)	45	27	Buzzer Off	Safe Condition

Table 4: Result analysis of monitoring system for unsafe condition

Sr no.	Parameter	Threshold value set	Sensor reading	Hardware changes	Remark
1	Temperature (Degree Celsius)	25	31.05	Buzzer On	Unsafe Condition
2	Gas (PPM)	600	22099	Buzzer On	Unsafe Condition
3	Humidity (%RH)	45	50	Buzzer On	Unsafe Condition

Table 5: Result analysis of Smart Helmet.

Sr no.	Sensor Reading	Hardware changes	Remark
1	0	Buzzer OFF	Safe Condition
2	1	Buzzer ON	Emergency

4.2 Prototype of Project

Figure 4.1: Prototype Helmet.

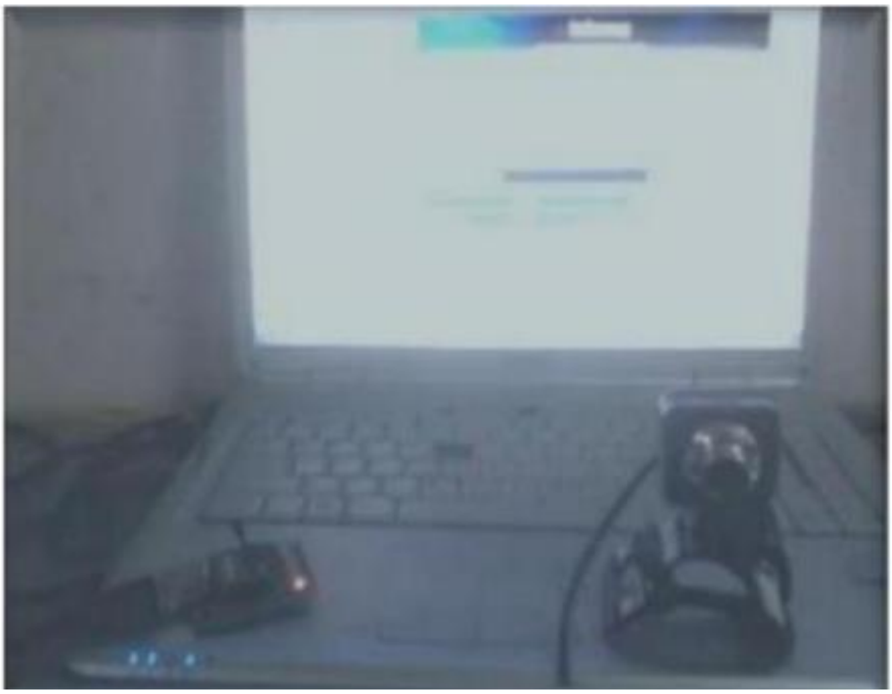

Figure 4.2: Prototype of Monitoring System in Control Room.

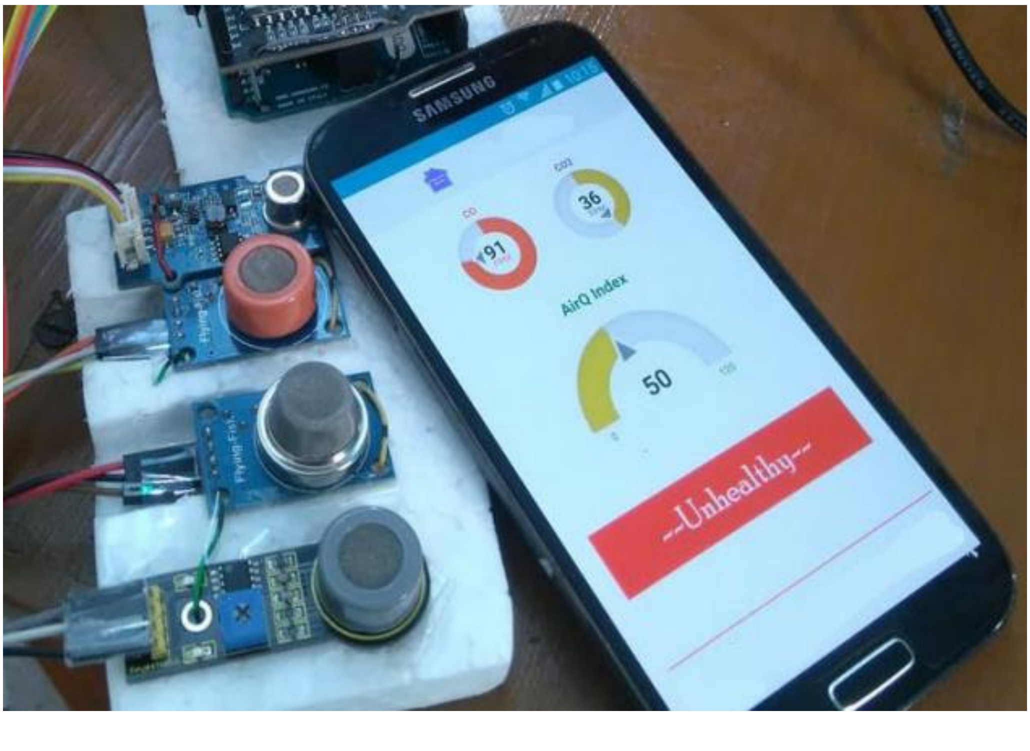

Figure 4.3: Prototype of Monitoring in Phone.

4.3 OUTPUT

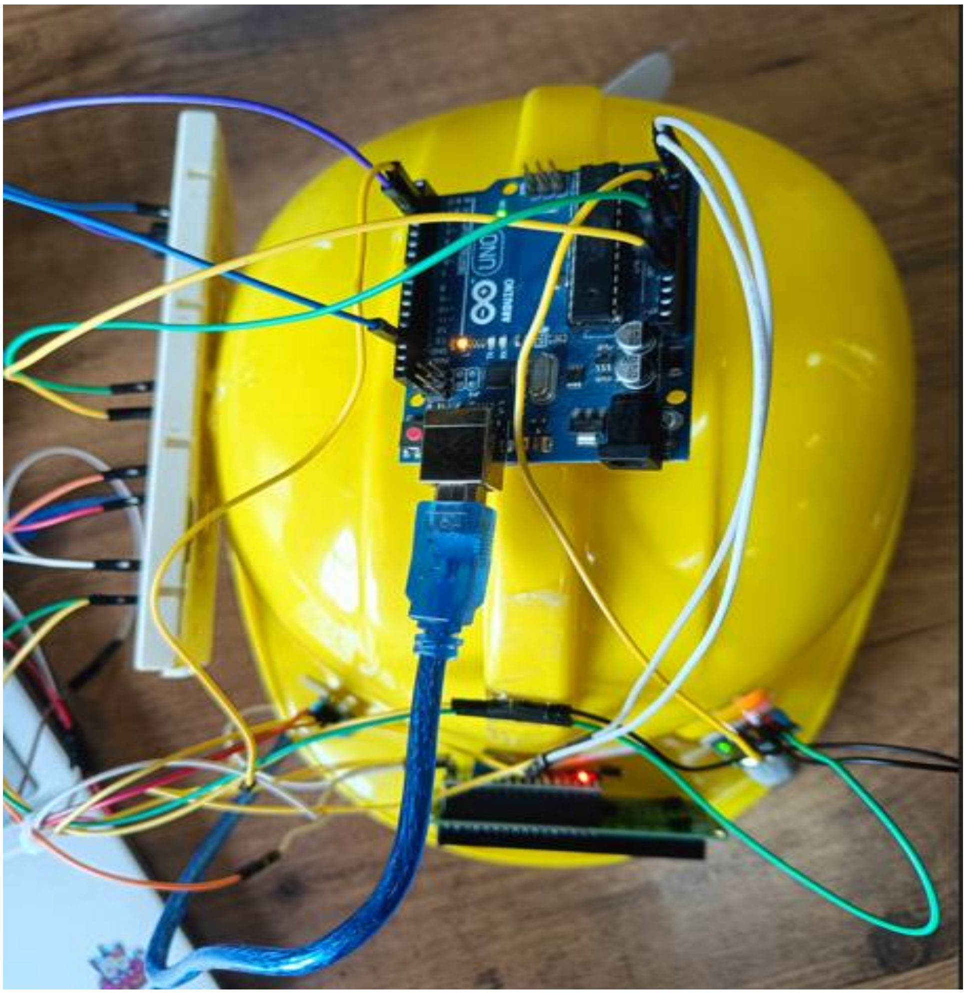

Figure 4.4: Helmet**.**

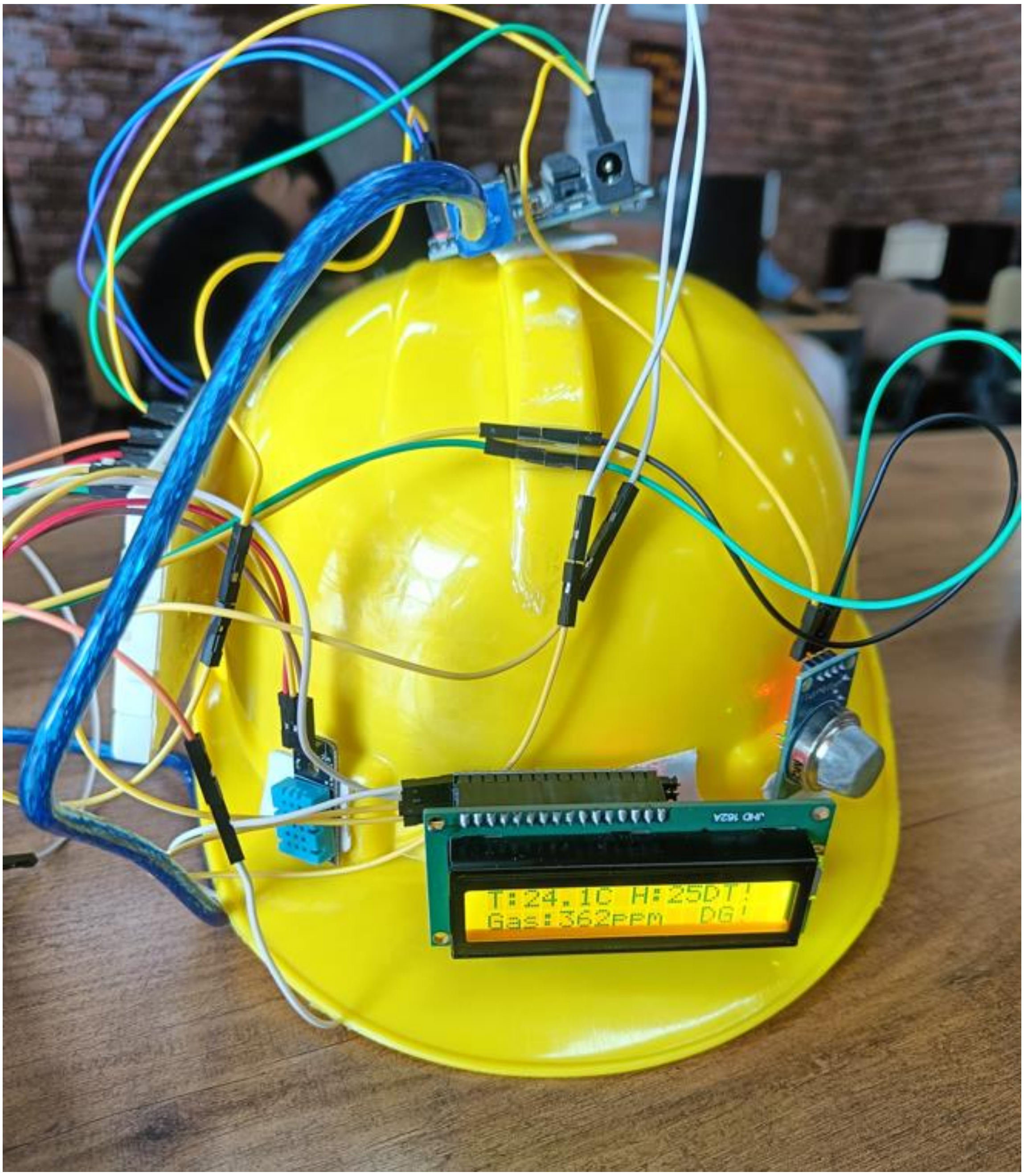

Figure 4.5: Output 1**.**

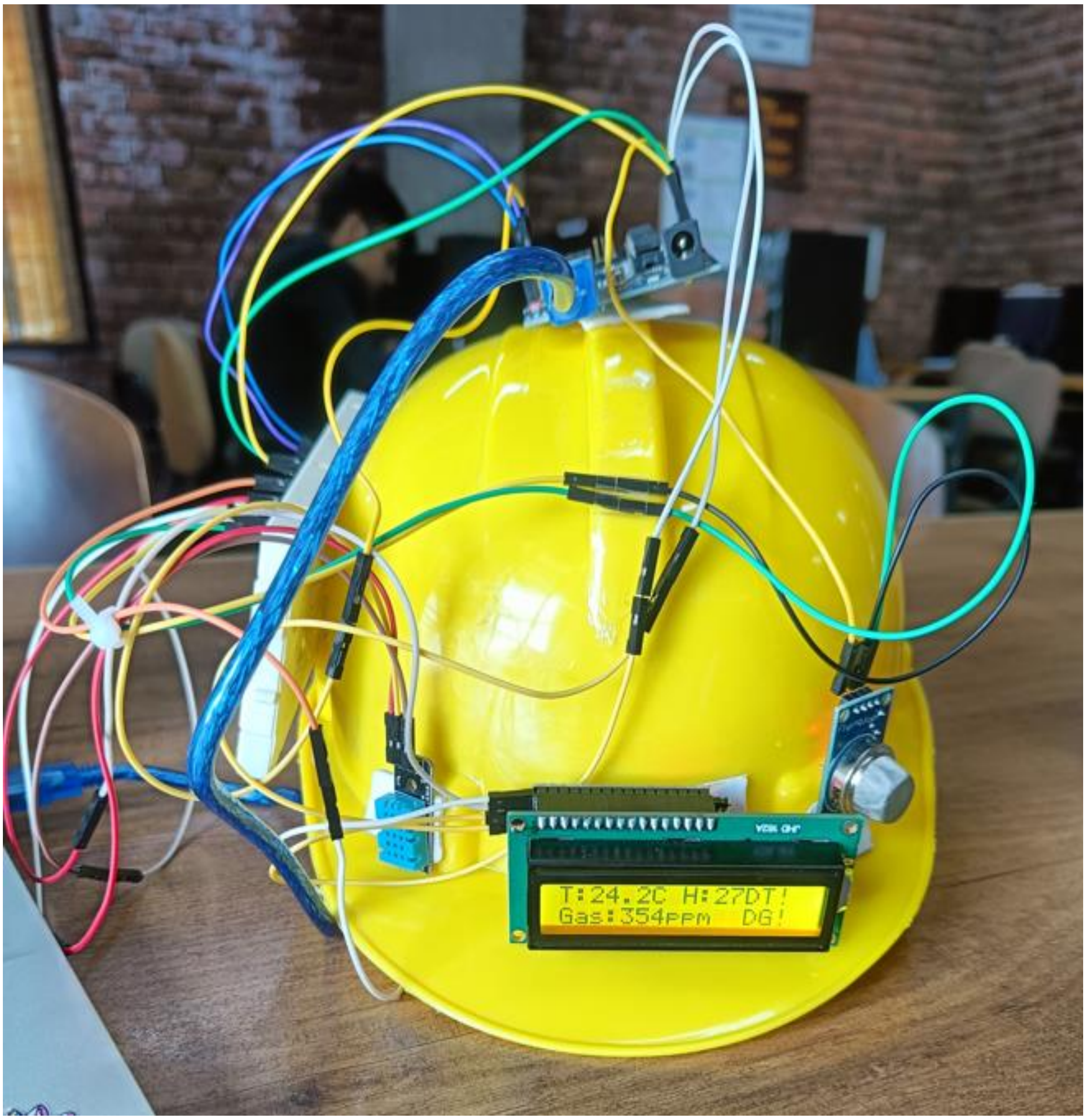

Figure 4.6: Output 2**.**

Figure 4.7: MQ2 Sensor Output**.**

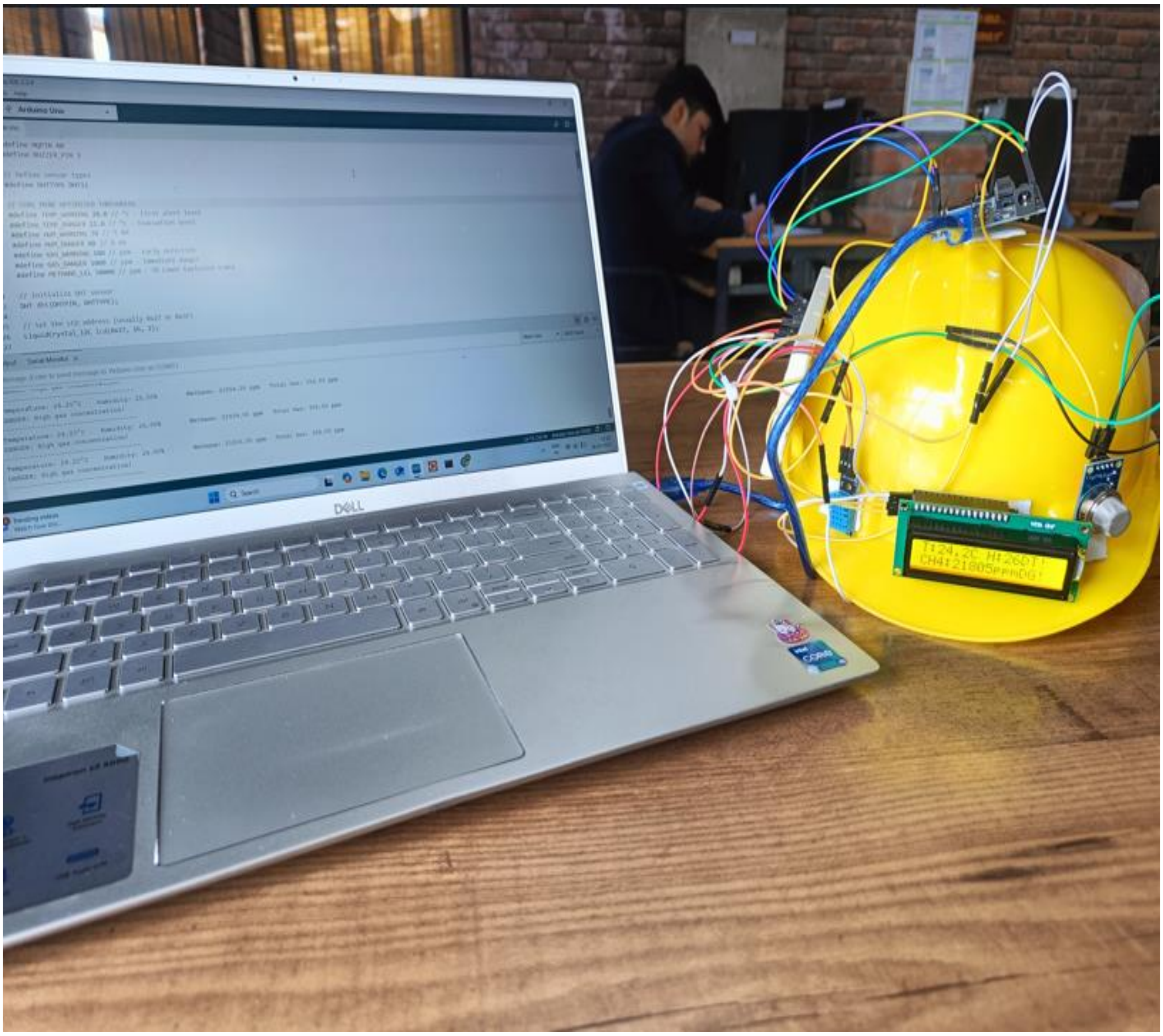

Figure 4.8: Full Set up**.**

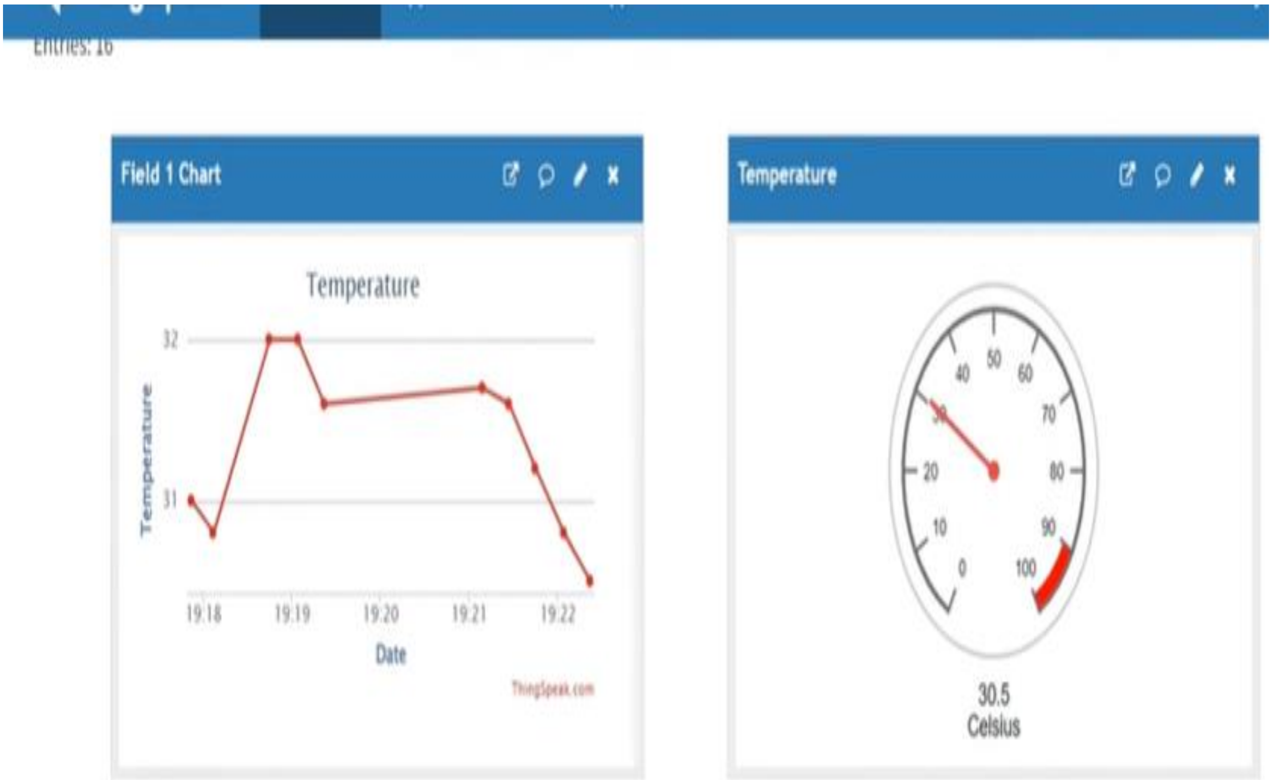

Figure 4.9: ThingSpeak Temperature Output**.**

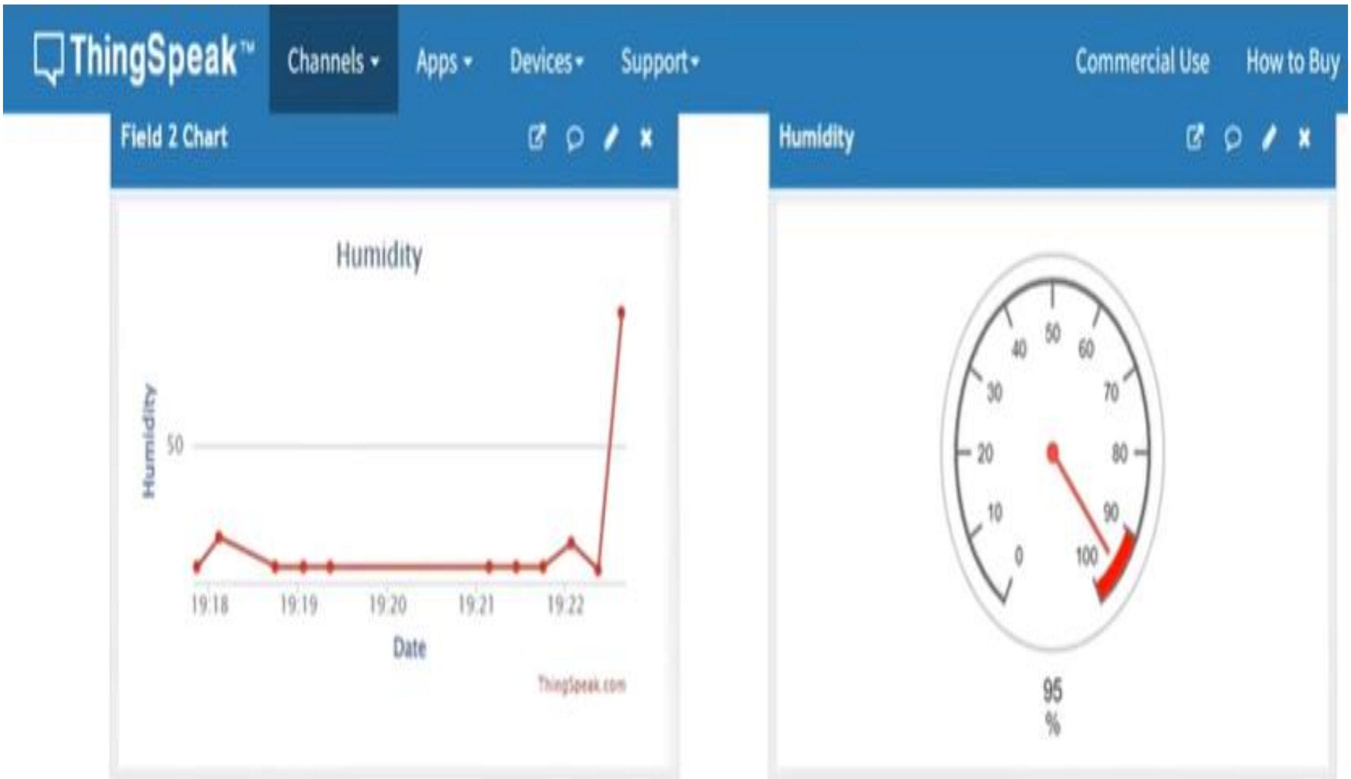

Figure 4.10: ThingSpeak Humidity Output**.**

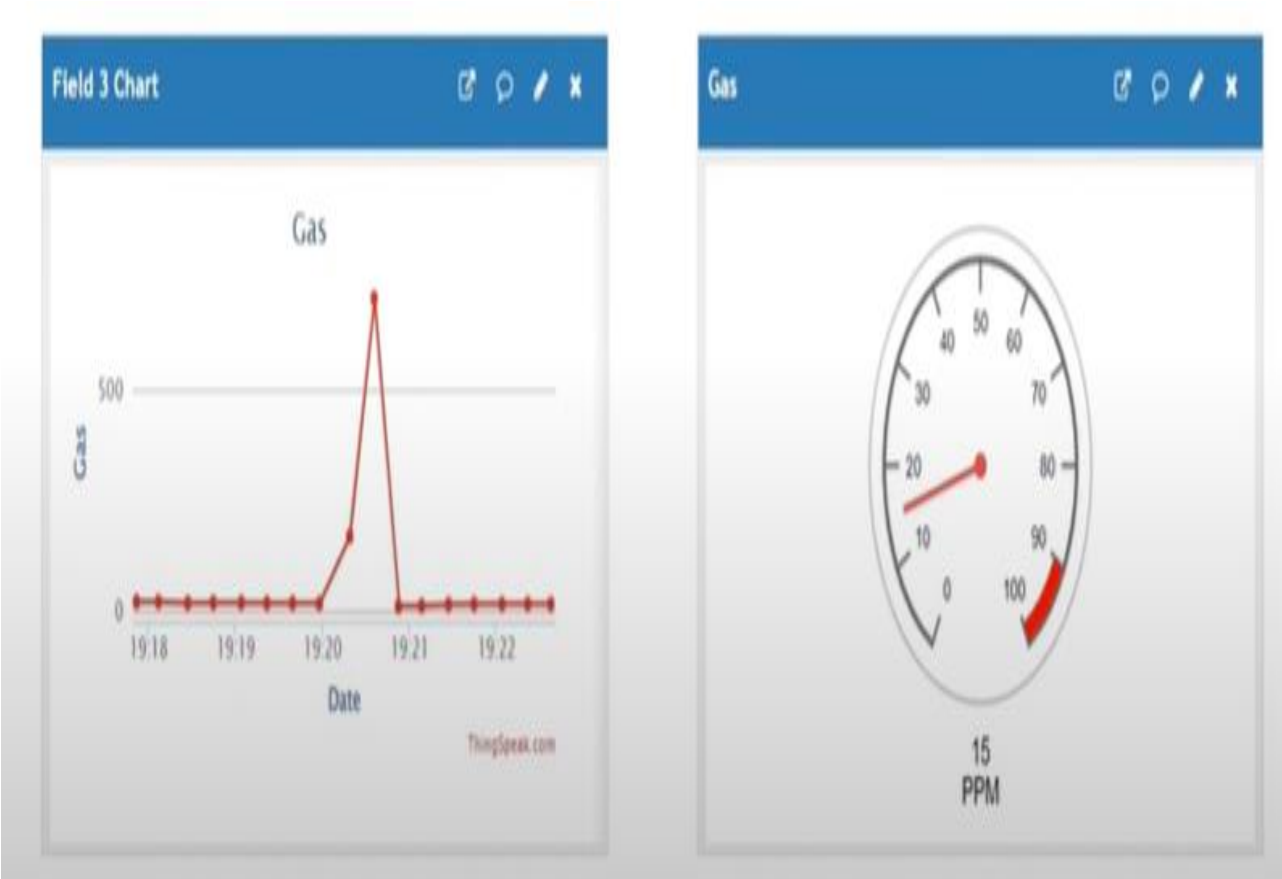

Figure 4.11: ThingSpeak Gas Output

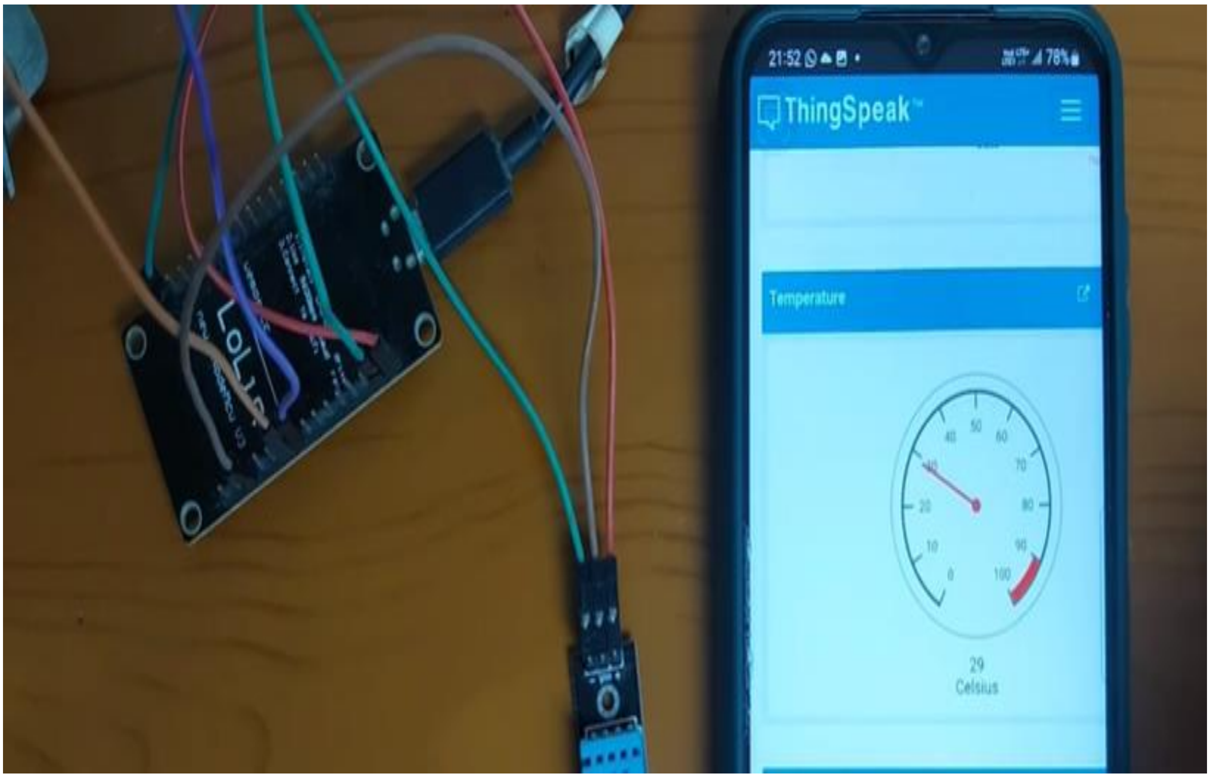

Figure 4.12: Temperature Output Display on Mobile**.**

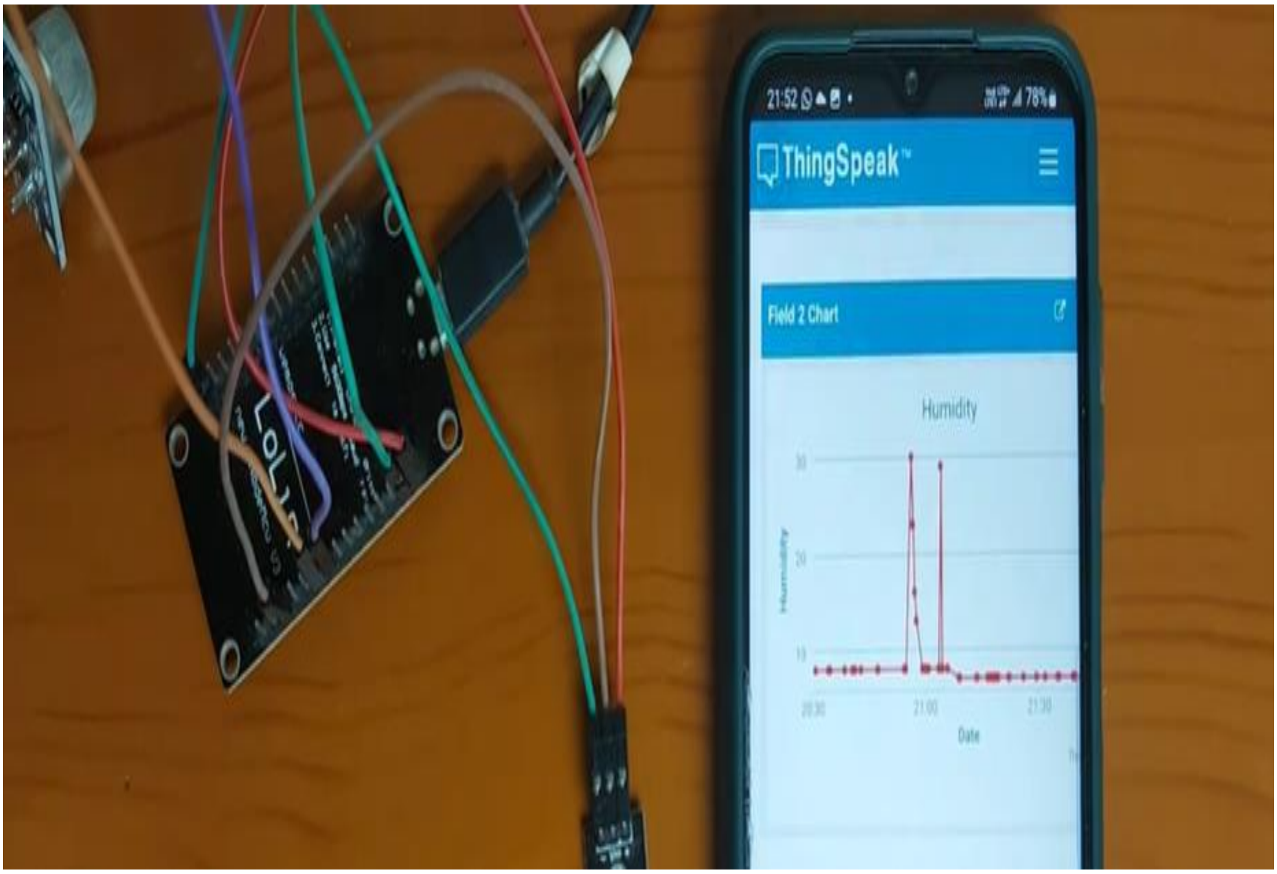

Figure 4.13: Humidity Output Display on Mobile**.**

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

Coal mining has played a major role in enabling industrialization and energy production since the Industrial Revolution. However, it would probably be correct to describe mining as one of the most dangerous professions. The underground environment is typically hostile and unpredictable. Subject to its natural environment, the operator also must deal with the extremely dynamic site conditions (e.g., temperature, humidity, underground gasses) present both at the surface and below the surface in any given mine. This dynamic nature, coupled with the inability of traditional safety measures (e.g., visual inspections, reactive processes) to effectively manage the complexities of safety in today's underground mining operations, has advanced the need for change. The IoT technology and IoT-Based Coal Mine Safety Monitoring and Alerting System in this project has brought about change by beginning the transition from using reactive processes to predictive monitoring and a proactive safety culture using IoT technology.

This project incorporates IoT solutions to realize the mine safety system through cutting-edge real-time data acquisition and wireless transmission technology. The report sets out a simple and highly effective IoT-Based Coal Mine Safety Monitoring and Alerting System. Real-time data acquisition monitors critical variables of operational feasibility, such as temperature, humidity, gas concentration, and oxygen levels, the system will report instantly when limits are exceeded. The real-time platform incorporated various modes of alerts (visual, audio and digital) which will enable immediate action from miners and supervisors reducing risks to life, and damage to property.

The project's success features low-cost, energy-efficient devices such as NodeMCU (ESP8266), and many environmental sensors to develop a portable, scalable, and durable system. Not only were the collected data used in real-time alerts, but they could also be saved, ensuring historical collection trending. By implementing a data-driven approach, trends defined by information could allow for a more comprehensive prediction of potential hazards, and based on the historical data, informed decisions could ultimately be made in respect to mine planning, ongoing maintenance and overall emergency preparedness.

System architecture is flexible that can ensure improvements in future potential developments, such as wearable technology for miners, tracking via GPS technology, predictive analytics through machine learning, and mobile application interfaces for remote access. These developments can build upon the present system of reliability while emphasizing expanded usability to reduce hazard in any given environment.

The system does have some inherent limitations, such as reliance of the system on network availability, sensor capabilities - maintenance - and power tools. However, these limitations will be resolved through technological fixes (e.g., mesh networking; solar-powered batter backs; and ruggedised sensor hardware rated for underground conditions).

In summary, this project demonstrates the potential of IoT for improving mine safety; moreover, it lays the groundwork for the larger adoption of smart technologies in high-risk industries in general. The adoption of this type of system acts as a statement about worker care, sustainable operations, and the advancement of technological services. The acceptance of IoT-based safety systems represents a realization for most mining operations of their future vision of very few accidents, intelligently managed risks, and the recognition that human lives rest paramount.

In summary, the IoT-based coal mine safety monitoring and alerting system represents a significant step forward in addressing the long-standing safety challenges of the mining industry. It demonstrates how modern engineering solutions can be leveraged to create safer workplaces, mitigate the risk of human error, and provide a better, safer and more efficient future for industry.

Future Scope:

There is a great deal of room for improvement in this area. Artificial intelligence (AI) for predictive analytics may be incorporated into future versions of the system, enabling even more precise forecasting of hazardous situations. The system might become more complete by adding more sensors to track water contamination and identify seismic activity. Both the integration of wearable IoT devices for personal health monitoring and the development of self-healing networks to solve connectivity issues are appealing research and development strategies. These advancements could make the system crucial for high-risk industries other than coalmining.

ADVANTAGES

1.System for Real Time Monitoring

A prime benefit of an IoT-based coal mine safety system is the real-time monitoring of key parameters of the environment, including temperature, gas concentrations (methane and carbon monoxide), humidity, and oxygen concentrations. Real-time monitoring means the detection of hazardous conditions can be quickly pursued.

2.Instant Alerts System

If any parameter exceeds a safety pre-set limit, the system can give instant alerts to miners and supervising staff by, for example, buzzer, LED, or mobile alert, to allow immediate action to be taken thus preventing an accident.

3.Remote Connect and Monitor

As the system can work with cloud computing and provide wireless communications, a supervisor can monitor underground conditions from a distance, thereby not requiring as many visits to high-hazard mining locations.

4.Data Logging and Analysis

The system can log historical data for safety audits, trend analysis and preventative measures to be taken. These and others data-driven practices can enhance decision making and result in better safety practices.

5.Cost-Effective and Scalable

Utilizing inexpensive microcontrollers (e.g. NodeMCU) and sensors allows the system to be inexpensive and easy to deploy. It can scale to reach large mining areas and can potentially be expanded using additional modules (e.g. GPS or even wearables).

6.Improved Safety for Workers

The core objective of the system is to preserve human life. The system reduces the response time on that mysterious "/SOS/" situation, whilst supporting enhanced situational awareness, the system improves safety for workers overall.

LIMITATIONS

1.Network Access Issues

Connectivity is often weak in underground contexts. Even if deployed with a functional wireless device, there can now be interference with the wireless signal caused by rock disturbance by a drill, shovel or any piece of mining equipment.

2.Power Supply Limitations

It is not always easy to maintain a robust power supply to both the sensors and the controller when there is no permanent access. Therefore, strong power management or battery-access items are needed.

3.Reliability of Sensors

Sensors can deteriorate or malfunction over time depending on existing mining conditions, and in these cases regular maintenance or calibration may be required.

4. Upfront and Upkeep Costs

The system is not expensive on its own but will usually involve the initial outlay of labor and hardware for installation and ongoing maintenance.

5.Data Security and Privacy

Since the system measures variables remotely via the internet, it also carries some risk for data breaches or unauthorized access and steps will need to be taken around cybersecurity.

APPLICATIONS

1.Underground Coal Mines

The best application of the system is within underground coal mines because environmental monitoring is directly related to the safety of workers and the ability to operate equipment safely.

2.Other Mining Industries

The system could be used in addition to coal mines but can also be applied in other types of mines (gold, copper, iron, etc.) that have similar risks associated with worker safety.

3.Industrial Safety Monitoring

Similar systems could be used for monitoring safety risks in factories and processing plants to prevent leaks and explosions from hazardous gases and liquids.

4.Oil and Gas Sector

The oil and gas industry can implement IoT-based safety systems related to gas leak detection and environmental control to remotely monitor operations associated with drilling, gas pipeline transportation, and refineries.

5. Disaster Management & Rescue Operations

The enabled system can help aid the work of rescue teams by providing them with real-time data while recovering from the disaster in the mines or tunnels, involving locating survivors and monitoring air quality.

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