# SMART HELMET FOR MINING INDUSTRY

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## ABSTRACT

*The mining industry is a critical sector in the global economy, yet it is fraught with complex processes and hazardous conditions that pose significant safety risks to workers. Recent incidents, such as the mining disaster in Dhanbad, have highlighted the devastating impact on both employees and businesses. External environmental factors, including temperature fluctuations and pressure changes, further exacerbate these risks, often leaving miners unaware of imminent dangers. These conditions can lead to catastrophic events such as mine collapses, exposure to toxic gases, and explosions, underscoring the urgent need for advanced safety measures. To address these challenges, this study proposes a smart helmet system integrated with IoT technology to enhance mine safety. The system is designed to detect hazardous gases in real-time and provide early warnings to miners and supervisors. Equipped with sensors, the helmet monitors environmental conditions and transmits data via a radio frequency transmitter to a central base station. Upon detecting toxic gases, the system triggers an alarm and displays critical performance metrics on an LCD screen in the supervisor's unit. By leveraging IoT, wireless sensor networks, and edge computing, this innovative solution aims to mitigate risks, safeguard miners, and improve overall operational safety in the mining industry.*

**Keyword:** - *Internet of Things (IoT), Radio Frequency, Wireless Sensor Networks, Monitoring Systems, Augmented Reality, Edge Computing.*

## 1. INTRODUCTION

In the rapidly evolving landscape of industrial safety, the integration of advanced technology with workplace equipment has given rise to the innovative domain of Smart Helmet Monitoring Systems. Picture a miner navigating the challenging environment of a mining site, equipped not with an ordinary helmet, but with a state-of-the-art wearable device designed to ensure safety and provide real-time critical information. This is the essence of the Smart Helmet Monitoring System, a groundbreaking solution that merges cutting-edge technology with the urgent need for enhanced workplace safety. Previous research has laid the foundation for such systems. Behr C et al. [1] proposed a safety mechanism that monitors air quality and detects helmet removal using off-the-shelf sensors. In [2], a smart system incorporating multiple sensors, including temperature, infrared (IR), gas, pressure, and force sensors, was discussed to improve mining safety.

These sensors monitor environmental conditions, detect collisions, and identify toxic gases, while GPS ensures precise location tracking during emergencies. [3] developed a helmet with an integrated electronic unit for extreme sports, featuring modules such as GPS, accelerometers, gyroscopes, temperature sensors, and display units. In [4], the focus was on addressing safety-critical aspects in mining, emphasizing the need for tools and equipment that prioritize worker safety and minimize casualties through precautionary measures. In mining environments, workers often face unpredictable hazards, such as exposure to toxic gases or sudden disasters, which can lead to life-threatening situations. Traditional safety measures fall short in providing real-time alerts or assistance during such emergencies. To address these challenges, this study proposes a secure smart helmet system leveraging IoT technology. The system is designed to detect hazardous gases, monitor environmental conditions, and track the miner's location using GPS. It employs devices such as the NodeMCU(ESP8266) as the central controller, a power supply for energy management, an MQ-2 gas sensor for toxic gas detection, a DHT-11 temperature sensor for environmental monitoring, and a water sensor to detect flooding or liquid presence. Communication is facilitated

through the NRF24L01 module, while the NodeMCU ESP8266 enables IoT connectivity for real-time data transmission to the Blynk server. Alerts are provided via a buzzer and displayed on a 16x2 LCD screen, ensuring timely warnings to both miners and supervisors. The proposed system continuously monitors hazardous conditions, such as gas leaks or extreme temperatures, and tracks the miner's heartbeat using the MAX30100 sensor. By integrating these components, the smart helmet acts as a comprehensive safety solution, reducing the risk of fatalities and enhancing overall safety in mining operations. This project represents a significant step forward in industrial safety, combining IoT, wireless communication, and sensor technology to create a reliable and efficient monitoring system for mining environments.

## 2. LITERATURE SURVEY

The mining industry is one of the most hazardous sectors, with workers frequently exposed to life-threatening conditions such as toxic gas leaks, extreme temperatures, flooding, and structural collapses. To mitigate these risks, smart helmet systems have emerged as a critical solution, integrating advanced sensors and IoT technologies to monitor environmental conditions and provide real-time alerts. In this proposed work, a smart helmet has been designed using the Arduino Nano as the central controller, which interfaces with a range of sensors and communication modules to ensure the safety of miners. The MQ-35 gas sensor is employed to detect hazardous gases such as carbon monoxide (CO) and methane (CH4), which are commonly found in mining environments. This sensor provides early warnings about gas leaks, enabling miners to take immediate precautions and avoid potentially fatal situations. Additionally, the DHT-11 temperature sensor is integrated to monitor ambient temperature, alerting miners to extreme temperature variations that could indicate fires or other dangerous conditions. This ensures that miners are aware of their surroundings and can respond promptly to changing environmental factors. Another critical component of the system is the water sensor, which detects flooding or the presence of liquids in mining areas. Flooding is a significant hazard in underground mines, and early detection can prevent catastrophic incidents by allowing miners to evacuate or take necessary precautions. The system also incorporates the NRF24L01 module for wireless communication, enabling real-time data transmission between the smart helmet and the base station. This ensures that critical information, such as gas concentrations and temperature readings, is relayed to supervisors without delay, facilitating timely decision making. For IoT connectivity, the NodeMCU ESP8266 is utilized, transmitting sensor data to the Blynk server for remote monitoring. This cloud-based platform allows supervisors to monitor mining conditions in real-time and receive alerts on their smartphones or computers, ensuring timely intervention in emergencies. The integration of IoT technology enhances the system's efficiency and provides a robust framework for remote supervision and control. To ensure immediate awareness of hazardous conditions, the system includes a buzzer that provides audible alerts in case of toxic gas detection, high temperatures, or flooding. This feature is particularly useful in noisy mining environments, where visual alerts might go unnoticed. Additionally, a 16x2 LCD screen is integrated into the helmet to display real-time sensor data, such as gas levels, temperature, and water presence. This enhances miners' situational awareness by providing them with critical information at a glance. The combination of these components creates a comprehensive safety solution that addresses the most pressing challenges in the mining industry. The proposed smart helmet system represents a significant advancement in mining safety, leveraging the Arduino Nano, MQ-35 gas sensor, DHT-11 temperature sensor, water sensor, NRF24L01, NodeMCU ESP8266, buzzer, LCD 16x2, and Blynk server to create a reliable and efficient monitoring system. By integrating these technologies, the system ensures early detection of hazards, real-time communication, and remote monitoring, ultimately reducing the risk of accidents and fatalities in the mining industry. This literature survey highlights the effectiveness of the chosen devices and technologies in addressing critical safety challenges, making the smart helmet an indispensable tool for modern mining operations. The proposed framework not only enhances miner safety but also contributes to the overall efficiency and productivity of mining activities by minimizing downtime caused by accidents and emergencies.

## 3. SYSTEM DESIGN

The smart helmet is equipped with multiple sensors to monitor environmental parameters. The MQ-35 gas sensor is used to detect hazardous gases such as carbon monoxide (CO) and methane (CH4), which are common in mining environments. This sensor provides analog output, which is processed by the Arduino Nano microcontroller to determine gas concentrations. If the gas levels exceed predefined thresholds, the system triggers an alarm to alert the miner. The DHT-11 temperature and humidity sensor is integrated to monitor ambient temperature and humidity levels. Elevated temperatures may indicate fire or equipment overheating, while high humidity levels can signal poor ventilation or flooding. The sensor provides digital data to the Arduino Nano, which processes the information and displays it on the 16x2 LCD screen for real-time monitoring. Additionally, a water sensor is incorporated to

detect the presence of water or flooding in the mining area. This sensor provides analog output, which is analyzed by the Arduino Nano to determine water levels. If flooding is detected, the system triggers an alarm to warn the miner. The Arduino Nano serves as the central processing unit, interfacing with all sensors and output devices. It continuously reads data from the MQ-35 gas sensor, DHT-11 temperature sensor, and water sensor, processing the information to detect hazardous conditions. If any parameter exceeds safe limits, the Arduino Nano activates the buzzer to provide an audible alert and displays the relevant information on the LCD screen. The Arduino Nano also logs the sensor data for further analysis, providing valuable insights into environmental conditions over time. For wireless communication, the system utilizes the NRF24L01 module, which enables short-range data transmission between the smart helmet and a base station. This module ensures that critical information, such as gas concentrations and temperature readings, is relayed to supervisors in real-time. Additionally, the NodeMCU ESP8266 is integrated into the system to facilitate IoT connectivity. The NodeMCU transmits sensor data to the Blynk server via Wi-Fi, enabling remote monitoring and control. The Blynk server processes the data and displays it on a customizable dashboard, allowing supervisors to monitor mining conditions from a remote location. In case of emergencies, the Blynk app sends instant notifications to supervisors, ensuring timely intervention. The system is powered by a compact and portable power supply, such as a lithium-ion battery, ensuring uninterrupted operation in remote mining areas. The Arduino Nano, sensors, and communication modules are connected to the power supply, with appropriate voltage regulation to ensure stable operation. The integration of all components into a compact and lightweight helmet design ensures ease of use and portability for miners. The embedded sensors and communication modules work together to provide a comprehensive monitoring solution. The MQ-2 gas sensor measures gas concentrations with a sensing period of 3 seconds, while the DHT-11 sensor monitors temperature and humidity with a sensing period of 2 seconds. The water sensor detects flooding or water presence, providing real-time data to the Arduino Nano. The NRF24L01 module and NodeMCU ESP8266 ensure seamless communication between the smart helmet and the Blynk server, enabling real-time data transmission and remote monitoring. The implemented system prototype consists of an embedded gas sensor, temperature and humidity sensor, water sensor, and a printed circuit board (PCB) housing the Arduino Nano, NRF24L01, and NodeMCU ESP8266. The system is powered by a 9V battery, ensuring portability and ease of use. The 16x2 LCD screen displays real-time sensor data, while the buzzer provides audible alerts in case of emergencies. The Blynk server processes the data and provides a user-friendly interface for remote monitoring, ensuring that supervisors are informed of any potential risks or emergencies as soon as they occur. In summary, the proposed smart helmet system leverages advanced sensors, a microcontroller, and IoT technology to monitor environmental conditions and provide real-time alerts. The integration of the Arduino Nano, MQ-35 gas sensor, DHT-11 temperature sensor, water sensor, NRF24L01, NodeMCU ESP8266, buzzer, LCD 16x2, and Blynk server ensures a robust and reliable solution for enhancing safety in the mining industry. The system's ability to detect hazardous conditions, provide real-time alerts, and enable remote monitoring makes it an indispensable tool for modern mining operations.

| Sr.No | Parameter | Measuring Range | Sensing Period |
|---|---|---|---|
| 1. | NRF24L01 | 2.4GHz Frequency Band | Continuous |
| 2. | DHT11 | 0°C to 50°C | 2 seconds |
| 3. | NodeMCU | 3.3V Operating Voltage | Continuous |
| 4. | Cloud Integration | Real-Time Data Upload | 1 seconds |

**Table-1**: Parameter Ranges of the Components

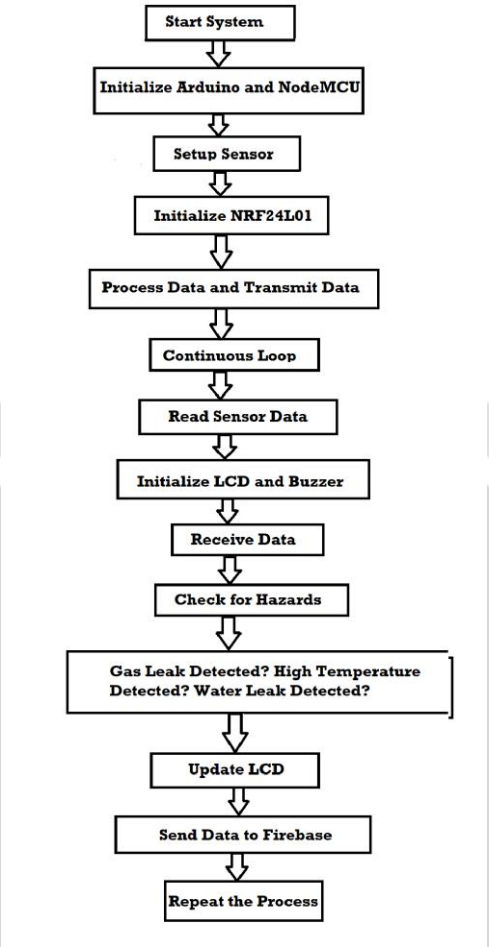


**Fig-1:** Flow Chart

## 4. HARWARE DISCRIPTION

A. NodeMCU

The nodeMCU acts as the receiver in the Smart Helmet system. It is an open-source IoT platform based on the ESP8266 Wi-Fi module, which provides built-in Wi-Fi connectivity. The NodeMCU receives data from the Arduino via the NRF24L01 module and uploads it to the cloud for real-time monitoring. It is programmed using the Lua scripting language or the Arduino IDE, making it enables seamless integration with cloud platforms like Firebase, allowing for remote monitoring and data analysis. Its compact size, low cost, and ability to handle multiple tasks simultaneously make it a preferred choice for IoT based projects like the Smart Helmet.

B. nRF24L01 Transceiver Modules

The NRF24L01 transceiver module is a highly efficient component for wireless communication, making it ideal for the Smart Helmet project. This module operates on the 2.4 GHz ISM band and supports data rates of up to 2 Mbps, ensuring fast and reliable communication between devices. It has a range of up to 100 meters in open spaces, which is sufficient for mining environments. The NRF24L01 is known for its low power consumption, making it suitable for battery-operated systems. It uses the SPI (Serial Peripheral Interface) protocol for communication with microcontrollers like Arduino and NodeMCU. The module is compact, cost-effective, and widely used in IoT applications, remote control systems, and wireless sensor networks. Its ability to handle multiple channels and addresses makes it versatile for implementing communication between the helmet and the base station in mining scenarios

C. Cloud Integration (Firebase)

Firebase is a cloud-based platform used for real-time data storage and synchronization in the Smart Helmet project. It provides a scalable and secure backend for storing sensor data, such as gas levels, temperature, and miner location. Firebase's real-time database ensures that data is updated instantly across all connected devices, enabling timely monitoring and decision-making. It also supports authentication, analytics, and notifications, which can be used to enhance the functionality of the Smart Helmet system. Firebase's ease of integration with IoT platforms like NodeMCU makes it a reliable choice for cloud-based applications in mining safety

D. Alerting Mechanisms

The alerting mechanisms in the Smart Helmet system are crucial for ensuring miner safety. These mechanisms include buzzers, LEDs, and vibration motors that provide immediate alerts in case of hazardous conditions, such as high gas concentrations or low oxygen levels. The alerts are triggered based on data received from sensors and processed by the Arduino or NodeMCU. Additionally, the system can send notifications to a central monitoring station via the cloud, enabling quick response to emergencies. The combination of visual, auditory, and tactile alerts ensures that miners are informed of dangers even in noisy and low visibility mining environments.

## 5. PROPOSED SYSTEM

The proposed system for the Smart Helmet for Mining Industry is designed to ensure the safety and well-being of miners by continuously monitoring environmental conditions and providing real-time alerts in case of hazardous situations. The system consists of two main components: the transmitter, which is integrated into the helmet, and the receiver, which acts as the base station. The transmitter collects data from various sensors, processes it, and transmits it wirelessly to the receiver. The receiver then processes the data and uploads it to a cloud platform for real-time monitoring and analysis. The transmitter unit is equipped with sensors such as the MQ2 Gas Sensor, DHT11 Temperature and Humidity. Sensor, and a Water Sensor. The MQ2 Gas Sensor detects hazardous gases such as methane, carbon monoxide, and LPG, providing an analog output proportional to gas concentration. The DHT11 Sensor measures ambient temperature and humidity, ensuring that miners are working within safe environmental conditions. The Water Sensor detects the presence of water or flooding in the mining area and provides a digital output based on water detection. The NodeMCU ESP8266 microcontroller processes the sensor data and transmits it wirelessly using the nRF24L01 module. The receiver unit receives data from the transmitter via the nRF24L01 module. The NodeMCU ESP8266 processes the received data and uploads it to the Blynk IoT platform for real-time monitoring. The Blynk platform displays parameters such as temperature, humidity, gas concentration, and water detection status. Alerts are triggered on the Blynk app and locally using a buzzer and LCD display in case of hazardous conditions. For example, if the temperature exceeds 38°C, a notification is sent to the Blynk app, and the buzzer is activated. Similarly, if the gas concentration exceeds 90% or water is detected, alerts are triggered. An LCD display is integrated into the receiver unit to display real-time sensor data, ensuring that miners and supervisors are immediately aware of hazardous conditions, even without access to the Blynk app. A buzzer is used to provide audible alerts in case of emergencies. The system is designed to operate efficiently on battery power, making it suitable for use in remote mining areas. Additionally, the system is scalable and can be easily expanded to include additional sensors or features as needed. The working process of the system begins with data collection. The MQ2 Gas Sensor, DHT11 Sensor, and Water Sensor collect data from the mining environment. The transmitter processes the sensor data and sends it wirelessly to the receiver using the nRF24L01 module. The receiver processes the data and uploads it to the Blynk IoT platform. Sensor data is displayed on the Blynk app and the local LCD display. In case of hazardous conditions such as high temperature, gas leakage, or flooding, alerts are triggered on the Blynk app, and the buzzer is activated. The proposed Smart Helmet for Mining Industry system provides a comprehensive solution for ensuring the safety of miners by continuously monitoring environmental conditions and providing real-time alerts. The integration of sensors, wireless communication, and cloud-based monitoring makes the system highly effective and scalable for use in mining environments. The system’s low power consumption and user-friendly interface further enhance its practicality and usability.

## 6. RESULTS

The proposed smart helmet prototype is designed to enhance the safety of miners by integrating IoT-based sensors and wireless communication. The helmet is equipped with an MQ2 Gas Sensor to detect hazardous gases, a DHT11 Sensor to monitor temperature and humidity, and a Water Sensor to identify flooding conditions. These sensors are

connected to a NodeMCU ESP8266 microcontroller, which processes the data and transmits it wirelessly to a base station using the nRF24L01 module. The base station displays real-time data on an LCD and uploads it to the Blynk IoT platform for remote monitoring. In case of hazardous conditions, such as high gas concentration, extreme temperature, or water detection, the system triggers alerts via a buzzer and sends notifications to the Blynk app.

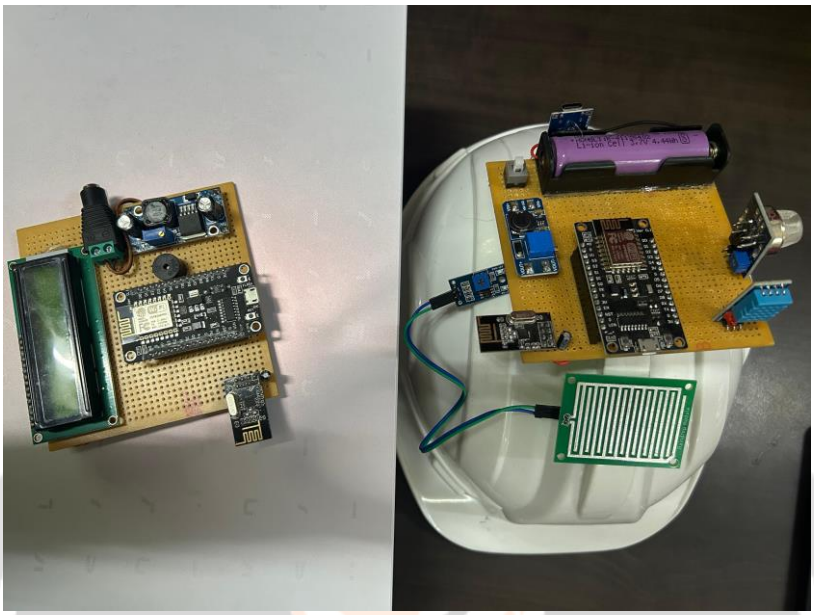

**Fig-2**: Hardware Setup

## 7. REFERENCES

[1] Behr, C. J., Kumar, A., & Hancke, G. P. “A Smart Helmet For Air Quality and Hazardous Event Detection for the Mining Industry”, In 2016 IEEE International Conference on Industrial Technology (ICIT) pp. 2026-2031, Mar 2016.A. Mammeri, A. Boukerche and M. Almulla, “Design Of Traffic Sign Detection, Recognition, And Transmission Systems For Smart Vehicles,” IEEE Wireless Communications, pp. no. 36-43, Dec. 2013.

[2] M. Priyatharishini and M. Thillai Rani, "Smart Safety Helmet for Protecting Lives of Workers in Mining Industry," in 2023 7th International Conference on Electronics, Communication and Aerospace Technology (ICECA), 2023, doi: 10.1109/ICECA58529.2023.10394840.

[3] T. Senthil Kumar, P. Kumar, R. M, R. K. S, and S. Kumar, "Smart Helmet for Mining Industries," in 2024 International Conference on Science Technology Engineering and Management (ICSTEM), 2024, doi: 10.1109/ICSTEM61137.2024.10561018.

[4] V. Kumar, K. Kathirvel, D. M, D. K, and J. G, "Smart Helmet and Tracking System for Coal Miners Using IoT," in 2022 IEEE 2nd International Conference on Mobile Networks and Wireless Communications (ICMNWC),2022, doi: 10.1109/ICMNWC56175.2022.10031283.

[5] P. J. Patil, S. Nadgaundi, M. Bhole, R. Pawar, D. N. Pawar, and A. Mhatre, "Smart Helmet for Coal Mine Workers," in 2023 International Conference on Integration of Computational Intelligent Systems (ICICIS), Pune, India, Nov. 1-4, 2023, doi: 10.1109/ICICIS56802.2023.10430243.

[6] V. K. Senthil Kumar, D. K. Devi, K. C. Kathirvel, J. G. Janani, and D. M. Dharani, "Smart Helmet and Tracking System for Coal Miners Using IoT," in 2022 IEEE 2nd International Conference on Mobile Networks and Wireless Communications (ICMNWC), 2022, doi: 10.1109/ICMNWC56175.2022.10031283