Smart Underground Mine Safety System Using LoRa and IoT Technology

Prof. B L Pundareeka[1], Archana A[2], Inchara S[3], Tejaswini G M[4]

[1]*Assistant Professor, Electronics and Communication, East West Institute of Technology, Bengaluru, India.*
[2]*Student, Electronics and Communication, East West Institute of Technology, Bengaluru, India.*
[3]*Student, Electronics and Communication, East West Institute of Technology, Bengaluru, India.*
[4]*Student, Electronics and Communication, East West Institute of Technology, Bengaluru, India.*

---***---

Abstract -This project proposes a Smart Safety System for Underground Mining using IoT and LoRa technologies to enhance worker safety. The system integrates sensors for air quality, methane detection, temperature, humidity, fire detection, and GPS tracking. An ESP32-CAM provides live video streaming, while sensor data is transmitted to a remote node via LoRa and displayed on an I2C LCD. Data is also uploaded to Google Firebase RTDB, enabling remote monitoring and alert notifications through a custom mobile app. This system provides real-time monitoring and alert mechanisms to improve situational awareness and worker safety in underground mining environments. Alerts can be sent promptly.

Key Words**:** Internet of Things (IoT), LoRa (long range) wireless communication, sensors, environmental parameters, real time system, underground mine.

1. INTRODUCTION

Underground Mining is a high-risk industry with numerous hazards that pose threats to the safety and well-being of workers. Miners often work in confined spaces where they are exposed to toxic gases, fire hazards, extreme temperatures, and poor ventilation. Despite technological advancements, traditional safety measures in underground mining are largely reactive, relying on periodic checks and alarms that may not provide immediate or reliable warnings during critical situations.[2] The need for continuous and real-time monitoring of mining environments has never been more crucial. While there have been efforts to introduce smart technologies for enhancing safety, many existing solutions fail to integrate multiple sensors into a unified, wearable system. This project introduces a Smart Helmet for Underground Mining, which aims to improve miner safety by integrating IoT technology and advanced wireless communication. The helmet is equipped with a variety of sensors that monitor key environmental parameters, including gas concentrations, temperature, humidity, and the presence of fire. Also, the helmet integrates a GPS module for location tracking and an ESP32-CAM for live video streaming.[3][4] The data collected by these sensors is wirelessly transmitted using LoRa communication, which is well-suited for long-range and low-power applications, making it ideal for underground environments where other communication technologies, such as Wi-Fi or Bluetooth, are often ineffective.[6] The collected data is then displayed on an I2C LCD screen at the monitoring station and uploaded to a cloud platform, Google Firebase, for remote access and real time monitoring via a mobile app.[9][7] The Smart Helmet for Underground Mining system provides a comprehensive solution for detecting potential hazards such as toxic gas leaks, fire, and extreme temperature fluctuations, and ensures that mining personnel can take preventive actions before accidents occur. This innovative solution not only improves safety for miners but also empowers supervisors and safety officers to monitor conditions remotely and respond to emergencies faster.[8]

2. BODY OF PAPER

SEC 2.1 OBJECTIVES

1. Real-time Environmental Monitoring: Continuously monitor underground conditions, including gas concentrations, temperature, humidity, and flames, to ensure a safe working environment.
2. Enhanced Safety and Alert System: Provide timely alerts and notifications to miners and surface personnel in case of hazardous conditions, enabling prompt action to prevent accidents.
3. Accurate Location Tracking: Utilize GPS technology to track miner locations in real-time, facilitating quick response and rescue operations in emergency situations. 4. Remote Monitoring and Data Analysis: Leverage IoT and cloud-based platforms to enable remote monitoring of

underground conditions, data analysis, and informed decision-making.

SEC 2.2 METHODOLOGY

The Smart Underground Safety System's methodology is designed to ensure the development of a robust and reliable safety solution for underground mining environments. This section outlines the approach and techniques used to design, develop, and implement the system. The system design phase involves a comprehensive analysis of the requirements and needs of the underground mining environment. This includes identifying the critical safety parameters to be monitored, such as temperature, humidity, and gas concentrations. The system architecture is designed to integrate advanced sensors, microcontrollers, and LoRa communication modules for real-time data transmission and analysis. The hardware components of the system include advanced sensors for monitoring environmental parameters, microcontrollers for processing data, and LoRa modules for long- range communication. The sensors are selected based on their accuracy, reliability, and suitability for underground mining environments. The microcontrollers are programmed to process data from the sensors and transmit it to the central server using LoRa communication modules. The software components of the system include data collection, analysis, and alert systems. The data collection software is designed to collect data from the sensors and transmit it to the central server. The data analysis software uses sophisticated algorithms to analyze the collected data and detect anomalies or hazards. The alert system is designed to send notifications to miners and safety personnel in case of hazards or anomalies. The testing and validation phase involves rigorous testing of the system's hardware and software components. This includes unit testing, integration testing, and system testing to verify the system's performance and reliability. The system is tested in simulated underground mining environments to ensure its functionality and effectiveness. The implementation phase involves deploying the system in underground mines and providing thorough training to miners and safety personnel. Regular maintenance is scheduled to ensure optimal system performance and longevity. The system is regularly updated to incorporate new features, security patches, and technological advancements. The Smart Underground Safety System's methodology is designed to ensure the development of a robust and reliable safety solution for underground mining environments. By following this methodology, the system can be developed to meet the requirements of miners and safety personnel, providing a safer and more efficient working environment. The system's effectiveness in enhancing miner safety, reducing risks, and improving operational efficiency can be ensured through rigorous testing and validation, and regular maintenance and updates.

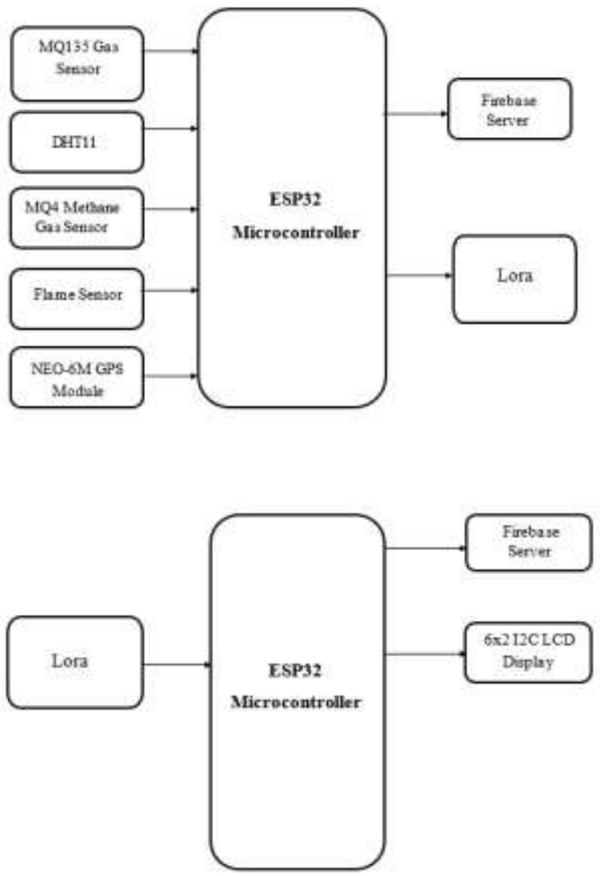

Fig 1: Block diagram of Transmitter and Receiver

SEC 2.3 IMPLEMENTATION

The design is based on the implementation of a wireless monitoring system employing ESP32 microcontrollers in both the receiver and transmitter sections. In the transmitter section, various sensors such as MQ135 (air quality), MQ4 (methane sensor), DHT11 (humidity and temperature), flame sensor, and NEO-6M GPS module are interfaced with the ESP32. The sensors constantly monitor environmental parameters, and ESP32 processes the information before sending it. The data is both sent to a Firebase server for cloud monitoring and locally transmitted via a LoRa module. Within the receiver module, another ESP32 is utilized to receive the data from the LoRa module, and the data is then displayed on a 6x2 I2C LCD for real-time monitoring while also being updated to Firebase. The dual mode communication provides local monitoring of the data along with remote monitoring, offering reliability, long-range wireless connectivity, and quick access to environmental and safety information.

Algorithm for Transmitter

Step 1: Power on the ESP32 and run setup ().
Step 2: Initialize Serial monitor, LoRa UART, LCD, and set the buzzer pin as OUTPUT.
Step 3: Connect to Wi-Fi and initialize Firebase.
Step 4: Enter the main loop () (repeat forever).
Step 5: Check if LoRa has incoming data.
Step 6: If data is available, read one line (up to \n) and trim whitespace.
Step 7: If the line is not empty, parse it into seven values by splitting on commas and taking the part after: for each token (store in sensor Values [0...6]).
Step 8: Upload each parsed value to Firebase (convert to int/float as needed).
Step 9: Check alarm conditions: If Flame value < 1 → flame detected → sound the buzzer. If MQ4 value > 1100 → methane detected → sound the buzzer. If MQ135 value > 1100 → smoke detected → sound the buzzer.
Step 10: Every 2 seconds (if data exists), update the LCD to show the next page of readings.
Step 11: Buzzer on () produces a short beep (HIGH 300 ms, LOW 50 ms).
Step 12: Return to step 5 and repeat.

The algorithm of this project starts with the initialization of all sensors, the LCD display, GPS module, and LoRa communication. After setup, the system continuously works in a loop. First, it reads the GPS data to get the latitude and longitude; if GPS data is not available, it uses default values. Then, the DHT11 sensor measures temperature and humidity, the MQ4 and MQ135 sensors check for gas levels, and the flame sensor detects whether fire is present or not. All these values are collected and displayed on the LCD for the user. Next, the data is combined into a single string and sent wirelessly through the LoRa module for remote monitoring. This process repeats continuously, ensuring real-time monitoring of environmental and safety conditions.

Algorithm for Receiver

Step 1: Connect to Wi-Fi and Firebase – So the device can send data to the cloud.

Step 2: Initialize LoRa and LCD– To receive data and display it.

Step 3: Check for incoming LoRa data Read the data when it arrives.

Step 4: Parse the data Split the information into separate sensor readings.

Step 5: Show data on the LCD Display sensor values, changing every 2 seconds.

Step 6: Send data to Firebase Upload the readings for remote monitoring.

Step 7: Check for danger signals If flame, methane, or smoke is detected, turn on the buzzer.

Step 8: Repeat Keep looping to continuously receive, display, upload, and check the data.

This program receives sensor data from another device using LoRa communication and connects to Wi-Fi and Firebase to store the data online. It reads values like air quality, temperature, humidity, location, and flame detection, then displays them on an LCD screen, changing the information every 2 seconds. The program also checks for dangerous conditions like fire, smoke, or gas leaks, and sounds a buzzer to alert users when a problem is detected. All the information is continuously updated and sent to Firebase so it can be monitored remotely, helping to ensure safety and keep track of environmental conditions.

SEC 2.4 RESULT

This is a smart safety helmet transmitter, designed to monitor environmental and safety conditions in real-time. The helmet is fitted with multiple sensors including temperature, humidity, gas detection, and flame sensors, which are connected to a microcontroller through wires. These sensors continuously collect data from the surrounding environment. The information is then sent wirelessly using a LoRa module to a receiver system for further processing and alert generation. The helmet's compact design allows it to be worn comfortably while providing critical safety monitoring, especially in hazardous areas like construction sites or industrial environments. By detecting dangerous gases, extreme temperatures, or flames, the helmet ensures that workers are alerted early, helping prevent accidents and ensuring their well-being. This setup is a practical example of using IoT (Internet of Things) technology for occupational safety.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 11 | Nov - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

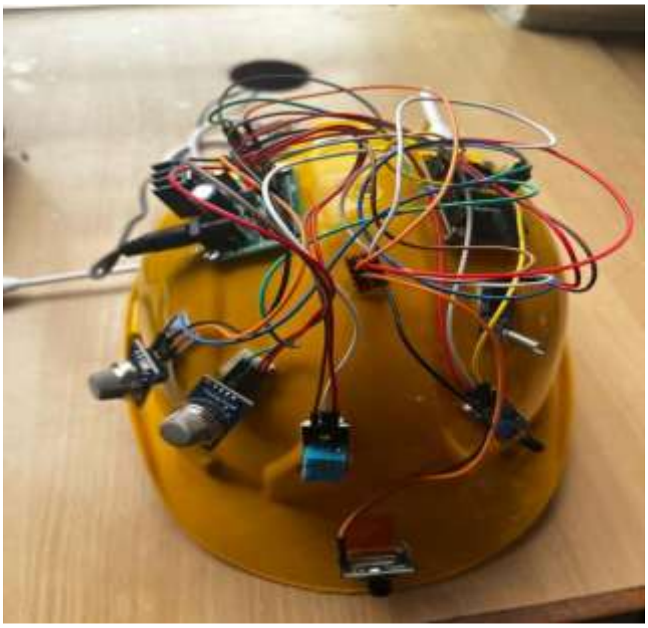

Fig 2: Transmitter Setup

Fig 3: Receiver Setup

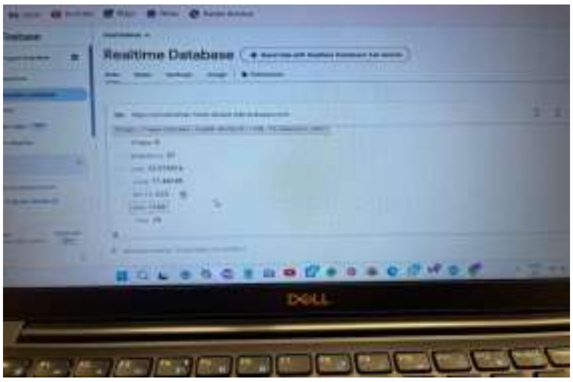

Fig 4: Firebase Data Result

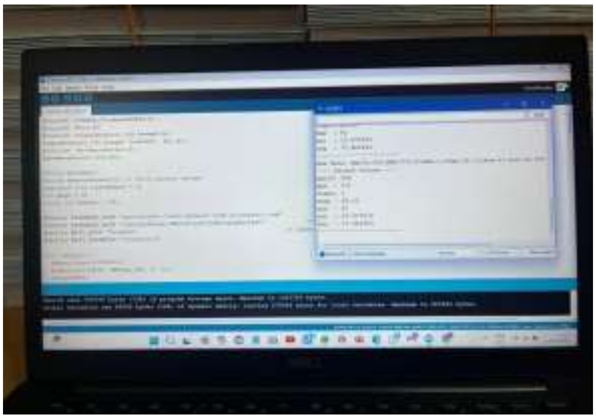

Fig 5: Data on Serial Monitor

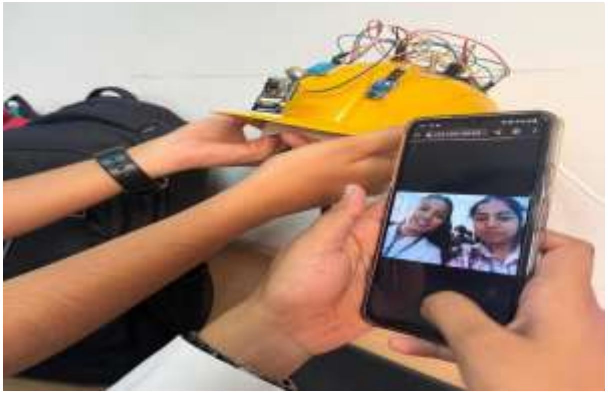

Fig 6: Live streaming videos

3. CONCLUSION

The Smart Underground Mine Safety System using LoRa and IoT technology greatly enhances safety in mining operations. It continuously monitors dangerous conditions like gas leaks, high temperatures, and fire using sensors, and sends this information wirelessly over long distances with LoRa. The data is stored and accessed through IoT platforms, allowing supervisors to monitor conditions in real-time and respond quickly to emergencies. This early warning system helps prevent accidents, ensuring the safety of workers in hazardous underground environments. It also provides valuable data for improving safety protocols and making informed decisions. The system's lightweight design makes it easy to deploy without disrupting mining activities. Overall, this technology offers a practical and effective solution for protecting miners and improving safety in underground operations.

ACKNOWLEDGEMENT

We would like to express my sincere gratitude to all those who have supported and guided me throughout the course of this project. First, we would like to thank our project guide and faculty members for their valuable insights, continuous support, and encouragement. Their expertise and guidance were instrumental in the successful completion of this project. We also grateful to the technical staff and colleagues who helped with the hardware setup, troubleshooting, and system integration. Their collaborative efforts and suggestions were crucial in overcoming several challenges faced during the development of the project. A special thanks to our family and friends for their unwavering support and motivation, which kept us focused and driven throughout this journey. Lastly, we would like to acknowledge the resources and tools provided by the university and the online platforms, which played a significant role in enhancing our learning experience and ensuring the project's success. This project would not have been possible without the contributions of all these individuals, and we truly grateful for their support.

REFERENCES

[1] S. K. Reddy, A. S. Naik, and G. R. Mandela, ''Development of a reliable wireless communication system to monitor environmental parameters from various positions of underground mines to the surface using ZigBee modules,'' J. Inst. Eng., India, D, pp. 1–25, Apr. 2023.

[2] A. Ranjan, H. B. Sahu, and P. Misra, ''Modeling and measurements for wireless communication networks in underground mine environments,'' Measurement, vol. 149, Jan. 2020.

[3] M. Sharma and T. Maity, ''Low-cost low power smart helmet for realtime remote underground mine environment monitoring,'' Wireless Pers. Commun., vol. 102, no. 1, pp. 149–162, Sep. 2018.

[4] S. Saha, S. C. Bakshi, A. Pramanik, and R. Lakshmanan, ''On underground coal mine environment monitoring with LoRa range extension,'' in Proc. 5th Int. Conf. Energy, Power Environ., Towards Flexible Green Energy Technol. (ICEPE), Jun. 2023,.

[5] M. S. Hidayat, A. P. Nugroho, L. Sutiarso, and T. Okayasu, ''Development of environmental monitoring systems based on LoRa with cloud integration for rural area,'' IOP Conf. Ser., Earth Environ. Sci., vol. 355, no. 1, Nov. 2019.

[6] T. Porselvi, C. S. S. Ganesh, B. Janaki, K. Priyadarshini, and S. S. Begam, ''IoT based coal mine safety and health monitoring system using LoRaWAN,'' in Proc. 3rd Int. Conf. Signal Process. Commun. (ICPSC), May 2021.

[7] H. Zhang, B. Li, M. Karimi, S. Saydam, and M. Hassan, ''Recent advancements in IoT implementation for environmental, safety, and production monitoring in underground mines,'' IEEE Internet Things J., vol. 10, no. 16, pp. 14507–14526, Aug. 2023.

[8] M. Theissen, L. Kern, T. Hartmann, and E. Clausen, ''Use-case-oriented evaluation of wireless communication technologies for advanced underground mining operations,'' Sensors, vol. 23, no. 7, p. 3537, Mar. 2023.

[9] P. K. Mishra, R. F. Stewart, M. Bolic, and M. C. E. Yagoub, ''RFID in underground- mining service applications,'' IEEE Pervasive Comput., vol. 13, no. 1, pp. 72–79, Jan. 2014.

[10] B. Ziętek, A. Banasiewicz, R. Zimroz, J. Szrek, and S. Gola, ''A portable environmental data- monitoring system for air hazard evaluation in deep underground mines,'' Energies, vol. 13, no. 23, p. 6331, Nov. 2020.

[11] P. K. Mishra, S. Kumar, M. Kumar, and J. Kumar, ''IoT based multimode sensing platform for underground coal mines,'' Wireless Pers. Commun., vol. 108, no. 2, pp. 1227–1242, Sep. 2019.

[12] J. Pramanik, A. K. Samal, S. K. Pani, and C. Chakraborty, ''Elementary framework for an IoT based diverse ambient air quality monitoring system,'' Multimedia Tools Appl., vol. 81, no. 26, pp. 36983–37005, Nov. 2022.