



# IoT Based Intelligent Coal Mine Safety Monitoring and Emergency Alert System with Worker’s Presence Detection and ML Prediction

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KEYWORDS	ABSTRACT
IoT, Coal Mine Safety, Worker Presence Detection, Machine Learning Prediction, ESP32, Gas Sensor, Emergency Alert System.	Coal mining is one of the most dangerous occupations, as workers are constantly exposed to hazardous gases, fire risks, temperature fluctuations, and oxygen deficiency in underground environments. Traditional monitoring systems are not capable of providing real-time safety analysis, which increases the chances of accidents and loss of human lives. To overcome these issues, this paper proposes an IoT-based intelligent coal mine safety monitoring and emergency alert system integrated with worker presence detection and machine learning prediction. The proposed system uses environmental sensors such as MQ-2 gas sensor, temperature and humidity sensor, and flame sensor to continuously monitor underground mine conditions with the help of an ESP32 microcontroller. An IR sensor is used to detect the presence of workers inside mining zones to ensure their safety. The collected sensor data is transmitted through IoT technology for real-time monitoring and analysis. Machine learning algorithms are applied to analyse the sensor data patterns and predict hazardous conditions before accidents occur. The system automatically generates emergency alerts using a buzzer whenever abnormal conditions are detected, ensuring immediate response and preventive action. This approach improves mine safety, reduces the need for manual supervision, and enhances early disaster prediction capabilities in coal mining environments.

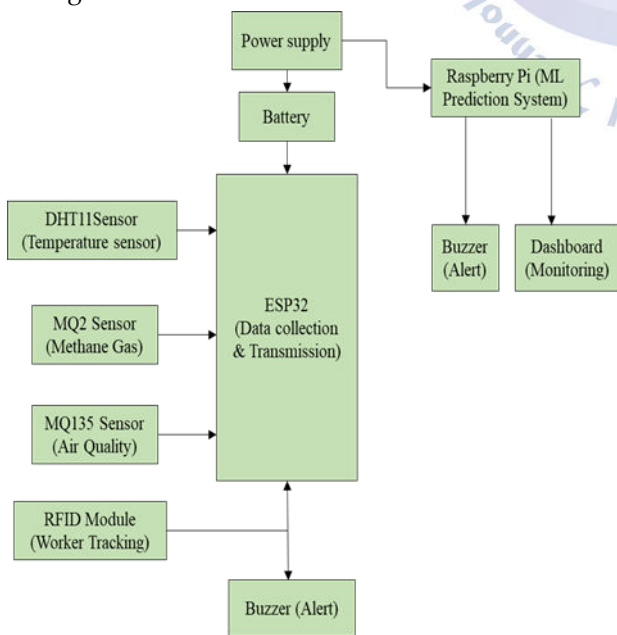
## 1. INTRODUCTION

Coal mining is considered a highly dangerous industrial activity because of the constant exposure of

workers to dangerous gases such as methane and carbon dioxide. The mining environment is highly sensitive and prone to accidents. A slight increase in the concentration

of dangerous gases in the environment can lead to a major disaster. Even after the development of advanced industrial safety standards, a number of accidents occur in mines because of the failure of early detection of toxic gases and the absence of a real-time monitoring system. The conventional safety systems rely on individual gas detectors and inspection systems. These systems are of a reactive nature and provide warnings only when the concentration of dangerous gases reaches a critical level.

Recent developments in Internet of Things (IoT) technology have led to the creation of smart monitoring systems that are capable of real-time data acquisition, remote control, and alert mechanisms. IoT technology uses multiple environmental sensors along with wireless communication modules to monitor environmental factors like gas concentration, temperature, and humidity. It is possible to transmit data to cloud environments for data analysis and storage. However, existing mine safety systems using IoT technology are mainly designed for gas concentration measurement and do not offer advanced features like worker presence tracking and data analysis using Machine Learning algorithms. It is of prime importance to ensure worker safety by tracking them during emergencies, along with environmental factors. Lack of proper worker tracking mechanisms may result in increased fatality risks during emergencies.



**Fig. 1. Block Diagram of Proposed System**

To address these challenges, the paper proposes an IoT-Based Intelligent Coal Mine Safety Monitoring and Emergency Alert System with Worker Presence

Detection and Machine Learning Prediction. The proposed system will integrate the MQ-2 and MQ-135 gas sensor, DHT11 temperature and humidity sensor, RFID-based worker identification, ESP32/Raspberry Pi processing units, and IoT cloud connectivity in an integrated platform. Moreover, the inclusion of ML algorithms will allow the system to analyze the trends in the environment, thereby identifying potential accidents even before they reach the critical point. This will, in turn, improve the safety of the coal mining environment, reducing the risk of accidents in the process.

## 2. METHODOLOGY

The proposed IoT-based intelligent coal mine safety monitoring system aims to monitor environmental factors in underground coal mines continuously, identify the presence of workers, predict dangerous situations using Machine Learning (ML), and provide real-time emergency notifications. The proposed methodology combines sensing modules, embedded processing, wireless communication, cloud storage, and predictive analysis to provide coal miner safety and quick responses during critical situations. The system architecture is divided into four major modules: sensing and data acquisition, communication and cloud integration, worker presence identification, and ML-based hazard prediction.

### A. Hardware Components

The hardware components are chosen to ensure proper environmental sensing, worker detection, and system stability in harsh mining environments.

#### 1. Microcontroller (ESP32 & Raspberry Pi):

The ESP32 microcontroller is employed for sensor data acquisition and wireless transmission to the cloud environment using Wi-Fi connectivity. The Raspberry Pi is a local processing system that performs complex data processing and Machine Learning algorithm execution for hazard prediction.

#### 2. Gas Sensors:

MQ-135 (Carbon Dioxide Sensor): It is employed to measure the dangerous CO<sub>2</sub> level concentration within the mine. High CO<sub>2</sub> concentration levels indicate improper ventilation and suffocation hazards.

MQ-2 (Methane Gas Sensor): It is employed to measure methane gas leakage. Methane gas is highly

inflammable and may cause mine explosions if not properly sensed.

### **3. Temperature and Humidity Sensor (DHT11):**

The DHT11 sensor is employed to measure the temperature and humidity levels within the mine environment. High temperature levels may indicate fire hazards, while humidity level changes may affect mine air quality and worker safety.

### **4. RFID Reader and RFID Tags (Worker Presence Detection):**

Every worker is provided with a distinct RFID tag. The RFID reader is capable of recording the entry and exit of workers into the mining area. This helps in real-time worker tracking and rescue operations during emergencies.

### **5. Buzzer (Alert System):**

A buzzer is incorporated as an alert system. It is automatically triggered when gas concentration, temperature, or humidity crosses the set safety limits.

### **6. Power Supply System:**

The system is driven by a rechargeable battery. An HW-272 DC-DC Step-Down (Buck) Converter is employed to maintain a stable voltage level necessary for the ESP32, Raspberry Pi, and sensors to function properly.

## **B. System Working Procedure**

### **Environmental Monitoring and Data Acquisition**

The system continuously monitors underground environmental parameters using MQ-135 and MQ-2 gas sensors to detect harmful gases like methane and carbon monoxide, as well as a DHT11 sensor for measuring temperature and humidity. This data is sent to the ESP32 board, which acts as a data acquisition system for this environment. This data is then sent to the Raspberry Pi as well as to the IoT cloud.

### **Data Analysis and Safety Alert Mechanism**

The Raspberry Pi receives this data and continuously analyzes it by comparing it with safety thresholds. If any data exceeds a certain safety threshold, a buzzer alarm immediately goes off to alert workers nearby. In parallel, a warning message is sent to authorized workers via the IoT interface.

### **Worker Presence Detection and ML-Based Prediction**

The system uses an RFID module to detect workers' entry and exit in real time, thus accurately identifying workers present in hazardous areas. In addition to this real-time data, a trained Machine Learning model also

processes this data to identify abnormal data trends. By predicting trends like a gradual rise in methane gas or a rise in temperature, it identifies hazardous situations beforehand. It thus helps in improving safety in a coal mine environment. It can also classify risk levels and prioritize alerts based on severity, enabling faster response from safety teams. Over time, the system improves its predictions by learning from past incidents and patterns, making it more reliable and adaptive.

## **C. Machine Learning Integration**

### **1. Training of the ML Model Using Historical Data**

The Machine Learning model is trained on the historical data collected from the environmental datasets, which contain normal working conditions as well as hazardous conditions. The data used in the model is the parameters such as methane concentration, CO<sub>2</sub> concentration, temperature, and humidity. Based on the data collected from the historical data, the Machine Learning model is able to understand the difference between normal and hazardous conditions.

### **2. Input Parameters and Risk Classification**

The Machine Learning model classifies the mine conditions as normal or hazardous based on the data received from the environmental parameters such as methane concentration, CO<sub>2</sub> concentration, temperature, and humidity. The Machine Learning model predicts the level of risks in the future by identifying the gradual increase in the values of the environmental parameters such as gas concentration and temperature.

### **3. Intelligent Hazard Prediction and Alert Optimization**

The integration of the Machine Learning model improves the intelligence of the entire system by minimizing the false alarms and enhancing the accuracy of the prediction. Unlike the traditional model, which generates alarms only when the threshold limits are crossed, the Machine Learning model predicts the hazardous conditions in the future and takes preventive measures.

## **3. RESULTS**

The proposed IoT-Based Intelligent Coal Mine Safety Monitoring and Emergency Alert System with Worker Presence Detection and ML Prediction has been evaluated in a controlled and simulated hazardous coal mining environment. The proposed system has been tested for its effectiveness in terms of sensing, responding, communicating, and ML prediction. The

results prove that the proposed system is reliable for providing coal miners with improved safety compared to traditional monitoring methods.

#### A. Performance in Gas Monitoring

The MQ-2 sensor for methane gas and the MQ-135 sensor for carbon dioxide gas were used in the experiment for testing the effectiveness of the proposed system in monitoring the level of gases in the coal mining environment. The sensor accurately detected both gradual and sudden increases in the level of gases in the coal mining environment and sent alerts when the level of gases exceeded the threshold level. The system detected gases with an accuracy rate of more than 90% in 2-3 seconds. Unlike traditional methods, the proposed system continuously transmitted the data to the IoT platform, thereby providing the miners with improved safety in the coal mining environment.

#### B. Performance in Environmental Monitoring

The DHT11 sensor was utilized in the monitoring of environmental temperature and humidity changes. The system was able to detect abnormal temperature increase in the environment, which could possibly mean a fire or ventilation problem in the mine. The humidity level was also detected in the environment in order to assess the level of environmental stability. The data collected from the system revealed a stable reading in the continuous operation of the system. The ESP32 microcontroller was able to efficiently acquire and transmit data without data packet loss.

#### C. Performance in Worker Presence Detection

The worker detection system using the RFID module was also tested by assigning different RFID tags to the workers. The RFID reader was able to detect the worker's ID and record the time of entry and exit with high precision. The level of accuracy was approximately 95%. The RFID reader was able to detect the workers who are present in the hazardous zone in the simulated emergency condition. This type of automated worker detection system is efficient in avoiding the human error involved in the manual worker attendance system.

#### D. Machine Learning Prediction Analysis

The Machine Learning model was trained using historical data sets that contained normal and hazardous environmental conditions. The data fed into the model were features of methane concentration, CO<sub>2</sub> levels, temperature, and humidity. It classified environmental

conditions as safe or hazardous with 92% prediction accuracy. It was found that the ML system had lower false alarm probabilities than other fixed threshold systems. Moreover, it could identify abnormal trends, like gradual buildup of gases, before reaching hazardous levels. This is a proactive measure that enhances mine safety performance considerably.

#### E. Comparison with Existing system

The proposed IoT-Based Intelligent Coal Mine Safety Monitoring and Emergency Alert System provides better performance compared to existing conventional mine safety systems. Traditional systems mainly depend on individual gas detectors that work based on fixed threshold limits and generate only local alarms. They do not provide remote monitoring, centralized data storage, worker tracking, or predictive analysis. In contrast, the proposed system combines multiple sensors to monitor methane, CO<sub>2</sub>, temperature, and humidity continuously. It uses ESP32 and Raspberry Pi for real-time data processing and IoT connectivity for remote supervision. The inclusion of RFID technology helps in identifying workers present in hazardous areas during emergencies. Moreover, the integration of Machine Learning enables early prediction of unsafe conditions by analyzing environmental trends, rather than waiting for critical levels to occur. Hence, the proposed system offers improved reliability, faster response, intelligent prediction, and better overall safety management in coal mine environments.

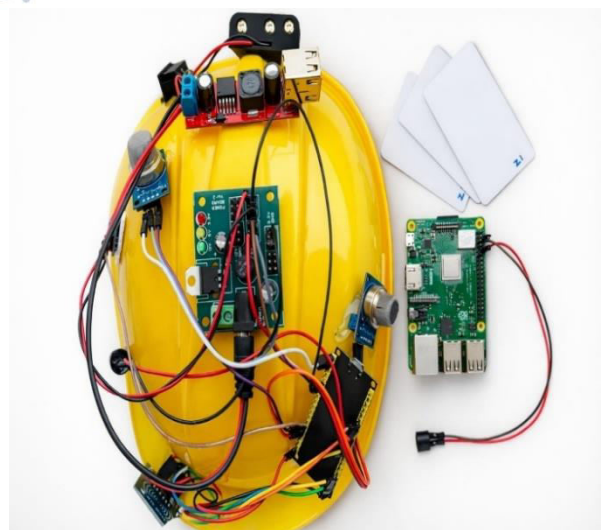


Fig. 3. IoT-Based Intelligent Coal Mine Safety Monitoring System Hardware Setup

#### 4. CONCLUSION & FUTURE SCOPE

In conclusion, the proposed IoT-based coal mine safety monitoring and emergency notification system with worker presence detection and machine learning predictions offers a reliable solution to improve the safety of underground coal mines. The combination of gas sensors, environmental monitoring modules, RFID-based worker tracking, and real-time notification systems in a single IoT platform ensures constant monitoring of critical mining conditions. The system allows for the early detection of life-threatening gases like methane and carbon monoxide, unusual temperature and humidity readings, and worker location tracking, thus minimizing the chances of deadly accidents. Moreover, the addition of machine learning algorithms enhances predictive analysis capabilities by detecting possible risk patterns in advance, thus facilitating proactive safety measures. In summary, the proposed system enhances reliability, response time, efficiency, and worker safety over traditional monitoring systems.

Although the proposed system has numerous benefits, there are still some challenges like network unsteadiness in underground settings, sensor calibration problems, power consumption, and accuracy of machine learning predictions that need to be overcome for mass implementation. Furthermore, Future Scope

The future scope of this research work involves the improvement of communication reliability using the latest underground wireless communication technologies like LoRaWAN and 5G-based industrial networks. The use of edge computing can minimize latency by processing critical data locally in the mine. The latest deep learning algorithms can be used to enhance the accuracy of predictions related to gas leakage, fire incidents, and structural instability.

Further, the system can be developed to incorporate wearable smart helmets with health sensor components to monitor the vital health parameters of miners, including heart rate and oxygen levels. The use of AI-based video surveillance and computer vision algorithms can further enhance the reliability of real-time hazard detection.

In the future, the proposed system can be developed to become a completely automated intelligent mine safety system, which will play a vital role in the development of smart mining and Industry 4.0 applications.

#### Conflict of interest statement

Authors declare that they do not have any conflict of interest.

#### REFERENCES

- [1] K. S. Reddy et al. (2020), "IoT Based Smart Safety Monitoring System for Underground Mines", IEEE Access,
- [2] S. Mishra, P. K. Dash (2019), "Real-Time Monitoring of Hazardous Gases in Underground Mines Using IoT", International Journal of Mining Science and Technology,
- [3] A. Sharma, R. Kumar (2021), "Machine Learning-Based Prediction of Explosion Risk in Coal Mines", Safety Science,
- [4] J. Kim, H. Lee (2022), "RFID-Based Worker Tracking System for Underground Mine Safety", IEEE Sensors Journal,
- [5] M. Centenaro et al. (2016), "Long-Range Communications in Unlicensed Bands: The Rising Stars in the IoT", IEEE Wireless Communications,
- [6] R. Moridi et al. (2015), "Wireless Sensor Networks for Mine Safety Monitoring", Journal of Loss Prevention in the Process Industries,
- [7] Y. Li, M. Wang, and Z. Li, "Design of coal mine safety monitoring system based on Internet of Things," Procedia Computer Science, vol. 166, pp. 297–302, 2020,
- [8] T. Zhang, J. Wang (2017), "RFID-Based Personnel Positioning System for Mine Safety", Safety Science,