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IoT Based Coal Mine Safety Monitoring and Alerting Helmet System

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ABSTRACT

Coal mines are considered one of the most dangerous working environments because miners are continuously exposed to toxic gases, low ventilation, extreme temperature conditions, and unexpected fire hazards. Many accidents occur due to the late detection of unsafe environmental parameters and the absence of real-time warning systems close to the worker. This paper presents an Internet of Things (IoT) based coal mine safety monitoring and alerting helmet system that continuously observes critical parameters such as temperature, humidity, toxic gas concentration, flame presence, and miner body temperature. A Global Positioning System (GPS) module is also integrated to provide real-time location tracking during emergency rescue operations. Sensor readings are displayed locally on a Liquid Crystal Display (LCD) and simultaneously uploaded to an IoT monitoring platform for remote supervision. Whenever hazardous conditions exceed the safe threshold values, the system activates a buzzer and relay-based emergency alert mechanism and can also support ventilation through a fan system. The proposed helmet system is a low-cost, reliable, and effective safety solution that improves worker protection and reduces accident risk in underground coal mine environments.

Keywords: IoT, Smart Helmet, Coal Mine Safety, MQ-135, Flame Sensor, GPS, DHT11, DS18B20, ESP8266, Miner Tracking.

1.INTRODUCTION

The Coal mining is one of the most important industries for meeting the growing demand for energy and supporting industrial development. Even though it plays a major role in the economy, underground mining remains a highly dangerous working environment. Miners often face life-threatening conditions due to low oxygen levels, high temperature, increased humidity, and the presence of poisonous and combustible gases. In many cases, gases such as carbon monoxide (CO), methane (CH_4), and carbon dioxide (CO_2) accumulate in confined mine areas and can lead to suffocation, explosions, or major fire accidents. Another serious issue is coal dust, which can ignite easily and cause sudden combustion inside the mine.

In most coal mines, safety monitoring is still based on manual inspection or limited centralized systems. These traditional methods are not always reliable because they may fail to provide immediate warning to workers, especially when miners are located deep inside underground tunnels. As a result, there is a strong need for a portable and real-time safety

monitoring system that can continuously check mine conditions and alert workers instantly during emergencies.

With the rapid growth of the Internet of Things (IoT), it has become possible to design smart monitoring systems by combining sensors, microcontrollers, and wireless communication technologies. IoT based systems allow continuous data collection, remote monitoring, and fast alert generation. In this paper, an IoT based smart safety helmet is proposed to enhance coal mine worker protection by monitoring parameters such as gas concentration, flame detection, temperature, humidity, and miner location tracking using GPS.

2. PROBLEM STATEMENT

Coal mine workers face several safety challenges, such as:

- Leakage of harmful gases leading to suffocation or explosion.
- Fire accidents due to methane ignition or coal dust combustion.
- Poor ventilation conditions affecting air quality.
- High temperature and humidity causing health issues.
- Difficulty in locating miners during emergency rescue operations.
- Lack of real-time monitoring for supervisors.

Due to these problems, mining accidents continue to occur. Hence, a smart helmet-based monitoring system is required to provide immediate alerts and real-time safety information.

3. PROPOSED SYSTEM

The proposed system is a smart safety helmet designed using IoT technology to protect miners working in underground coal mines. The helmet continuously monitors the surrounding environment using multiple sensors. The collected sensor readings are processed using a microcontroller and compared with predefined safety threshold values.

The system measures temperature and humidity using a DHT11 sensor, detects harmful gases using an MQ-135 sensor, identifies fire hazards using a flame sensor, and monitors miner body temperature using a DS18B20 sensor. A GPS module is integrated to provide the real-time location of the miner. The sensor data is displayed on an LCD screen attached to the helmet and also uploaded to an IoT dashboard through wireless communication.

If the system detects unsafe conditions, it activates an alarm buzzer and relay output to warn the miner and trigger emergency actions such as ventilation fan operation. This system helps improve worker safety by providing early warning and continuous monitoring.

4. SYSTEM ACHITECTURE

The proposed coal mine helmet system consists of different functional units which work together for monitoring and alerting.

A. Processing Unit

The processing unit includes a microcontroller such as ESP8266 NodeMCU or Arduino, which reads sensor data, checks safety conditions, and controls outputs.

B. Display Unit

An LCD display is used to show real-time sensor readings, allowing the miner to observe current conditions directly.

C. Alerting Unit

The alerting unit includes:

- Buzzer for warning sound alerts.

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• Relay module for controlling external safety devices.
• Fan system for ventilation support.

D. IoT Monitoring Unit

Using IoT connectivity, the sensor readings are uploaded to a web-based dashboard. This enables supervisors to monitor mine conditions remotely.

E. GPS Tracking Unit

The GPS module provides latitude and longitude coordinates, which can be used for tracking the miner's location in emergency situations.

5. HARDWARE REQUIREMENTS

The major hardware components used in the system are listed in Table I.

TABLE I.

Component	**HARDWARE COMPONENTS USED**
	Function / Purpose
ESP8266 NodeMCU	Main microcontroller and Wi-Fi communication for IoT
DHT11 Sensor	Measures surrounding temperature and humidity
MQ-135 Gas Sensor	Detects harmful gases and smoke presence
Flame Sensor	Detects flame/fire in the environment
DS18B20 Sensor	Measures miner body temperature
GPS Module (NEO-6M)	Provides real-time latitude and longitude location
LCD 16×2 Display	Displays sensor values locally on helmet
Relay Module	Controls external devices such as fan/alarm system
Buzzer	Produces warning alarm during unsafe conditions
DC Fan	Provides ventilation support during hazardous gas detection
Battery/ Power Supply	Supplies power to complete system

A. Sensing Unit

The sensing unit contains sensors to collect environmental and health-related data:

- DHT11 for air temperature and humidity.
- MQ-135 for detection of harmful gases.
- Flame sensor for fire detection.
- DS18B20 for body temperature monitoring.

7. SOFTWARE REQUIREMENTS

The software tools required for the implementation are:

- Arduino IDE for coding and programming.
- Embedded C for microcontroller programming.
- IoT dashboard platform such as Firebase, ThingSpeak, or Blynk.
- Google Maps interface for location tracking.

8. WORKING METHODOLOGY

The operation of the proposed system is explained as follows:

1) The system is powered on and all sensors are initialized.
2) Sensors continuously monitor temperature, humidity, gas concentration, flame presence, and body temperature.
3) The microcontroller processes the sensor readings and compares them with safety limits.
4) The readings are displayed on the LCD screen in real time.
5) Data is uploaded to an IoT dashboard for remote monitoring.
6) If gas concentration increases beyond a safe threshold, the buzzer and relay are activated.
7) If flame is detected, the alarm is triggered immediately.
8) GPS coordinates are continuously updated and sent to the monitoring dashboard.

9. ALGORITHM

Step 1: Start the system.
Step 2: Initialize DHT11, MQ-135, flame sensor, DS18B20, GPS module.
Step 3: Read temperature and humidity from DHT11. Step 4: Read gas sensor output from MQ-135.
Step 5: Read flame sensor status.
Step 6: Read body temperature from DS18B20.
Step 7: Read GPS latitude and longitude coordinates. Step 8: Display all values on LCD.
Step 9: Upload sensor data to IoT monitoring platform. Step 10: If gas value exceeds threshold, activate buzzer and relay.
Step 11: If flame detected, activate buzzer and relay immediately.
Step 12: Repeat the process continuously.

10. RESULTS AND DISCUSSION

The proposed IoT based coal mine safety helmet system was implemented and tested under different environmental conditions. During testing, the system successfully monitored parameters such as air temperature, humidity, gas concentration, flame presence, and miner body temperature. The sensor readings were displayed on the LCD screen and uploaded to the IoT monitoring dashboard.

The MQ-135 sensor showed increased readings when exposed to smoke or gas, and the system immediately activated the buzzer and relay output when the threshold value was crossed. Similarly, the flame sensor detected fire presence and generated an alert instantly. The GPS module provided real-time location coordinates, and a Google Maps link could be used to locate the miner. The relay module was able to activate the ventilation fan for improving air circulation. The results indicate that the proposed helmet system provides a reliable solution for continuous monitoring and early hazard warning in coal mine environments.

11. ADVANTAGES AND APPLICATIONS OF PROPOSED SYSTEM

The main advantages of the proposed system are:

- Continuous real-time monitoring of my conditions.
- Early detection of harmful gases and fire hazards.
- Immediate warning alerts using buzzer and relay.
- IoT based remote monitoring for supervisors.
- GPS tracking for rescue operations.
- Low-cost and portable safety equipment.

- Improved ventilation support using fan activation.

The proposed system can be applied in:

- Underground coal mine safety monitoring.
- Chemical and industrial gas detection.
- Fire detection systems in hazardous areas.
- Implementing AI based hazard prediction models.
- Oil refinery and petrochemical industries.
- Smart worker monitoring and safety equipment.

12. CONCLUSION

This paper presented an IoT based coal mine safety monitoring and alerting helmet system designed to improve miner safety. The helmet continuously monitors environmental conditions such as gas concentration, temperature, humidity, flame presence, and miner body temperature. The system also provides GPS based location tracking, which is useful during rescue operations. Sensor readings are displayed locally and transmitted to an IoT dashboard for remote supervision. In hazardous situations, the system activates buzzer and relay alerts and can also trigger ventilation support. The developed system is cost-effective, reliable, and can reduce the risk of accidents in coal mines.

13. FUTURE SCOPE

The proposed system can be enhanced further by:

- Adding methane sensor (MQ-4) for improved gas detection.
- Integrating GSM module for SMS alert when WiFi is unavailable.
- Using LoRa communication for long-distance underground monitoring.
- Adding heart rate and oxygen sensors for miner health tracking.
- Adding accelerometer for fall detection

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