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Iot Based Coal Mine Safety Monitoring And Alerting System

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Abstract- Coal mining is one of the most hazardous industries, with risks such as gas leaks, rising underground temperatures, flooding, poor air quality, and structural hazards. This paper presents an IoT-based Coal Mine Safety Monitoring and Alerting System that continuously monitors environmental conditions and provides real-time alerts to miners and supervisors. The system employs sensors to detect gases (MQ-4, MQ-7, MQ-135), temperature and humidity (DHT11, DHT22), water levels (float switch, conductivity sensor) all integrated with an ESP32 microcontroller. Sensor data is transmitted via LoRa communication modules to a central monitoring unit, where it is analysed for any signs of danger. When hazardous conditions are detected, alerts are sent instantly through visual, auditory, or wireless notifications. Compared to conventional wired systems, this IoT-based approach offers greater reliability, faster response times, and reduced costs. By enabling proactive safety management, the system helps prevent accidents and injuries while improving operational oversight, ultimately supporting safer and more sustainable mining practices.

Keywords: IoT, Coal Mine Safety, ESP32, LoRa Communication, Gas Detection, Environmental Monitoring, Real-Time Alert System, Smart Mining.

I. INTRODUCTION:

At the moment, coal mining is considered one of the most hazardous industries in the world because of the high possibility of accidents due to toxic gases, high temperature, fire, flooding, and structural failures. Traditional wired safety systems are less efficient, require manual inspections, and cannot provide real-time monitoring. This exposes miners to serious life-threatening risks. To overcome these problems, modern technologies like the Internet of Things (IoT) and Embedded Systems are used to develop intelligent monitoring and alerting solutions that enhance safety in underground mining operations. The IoT-based Coal Mine Safety Monitoring and Alerting System aims to continuously observe environmental parameters such as gas concentration, temperature, humidity, water level, and obstacles in mining tunnels. The collected data is transmitted wirelessly to a central monitoring station for analysis and quick decision-making.

II. IOT AND EMBEDDED DOMAIN:

This project belongs to the IoT and Embedded Systems domain, which focuses on integrating sensors, microcontrollers, and wireless communication technologies to create intelligent, automated systems. The ESP32 microcontroller acts as the core processing unit, interfacing with various sensors to collect data in real-time. Using LoRa communication modules, the sensor data is transmitted wirelessly to the control room. The embedded system ensures efficient processing and quick response, while the IoT connectivity enables long-range communication and cloud-based monitoring. Together, these technologies make the system reliable, scalable, and suitable for real-world industrial applications such as mining safety, environmental monitoring, and automation.

III. GAS LEAKAGE DETECTION:

Gas leakage is one of the main causes of coal mine explosions and suffocation. Hazardous gases like methane (CH_4) and carbon monoxide (CO) are commonly present in mines. In this system, gas sensors such as MQ-4, MQ-7, and MQ-135 are used to detect the concentration of gases. When gas levels exceed the safe limit, the ESP32 microcontroller triggers immediate alerts through buzzers, indicator lights, or wireless messages to ensure the safety of workers.

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IV. TEMPERATURE AND HUMIDITY MONITORING:

Excessive underground temperature and humidity levels affect miners' health and can lead to fires or equipment failure. Sensors like DHT11 and DHT22 are used to measure these parameters continuously. When the readings cross the predefined safety range, the system notifies supervisors for corrective measures such as ventilation adjustment or cooling.

V. WATER LEVEL DETECTION:

Flooding is a critical issue in underground mines that can cause major accidents. To monitor this, float switches and conductivity sensors are used to detect the water level in tunnels. When the level rises beyond the safe limit, the system sends a real-time alert, helping prevent water-related hazards.

VI. DISTANCE AND OBSTACLE DETECTION:

Navigating narrow and dark tunnels is risky due to possible collapses or obstacles. The water sensor measures distance and detects nearby obstructions. This information helps operators and miners avoid collisions and identify unsafe tunnel conditions.

VII. IOT COMMUNICATION AND CONTROL:

All sensor data is collected and processed by the ESP32 microcontroller, which forms the heart of the embedded system. The processed data is transmitted through LoRa communication modules to a central monitoring unit, where it is displayed and analysed. In case of abnormal conditions, alerts are generated instantly via visual, auditory, or wireless notifications.

VIII. EXISTING METHODOLOGY:

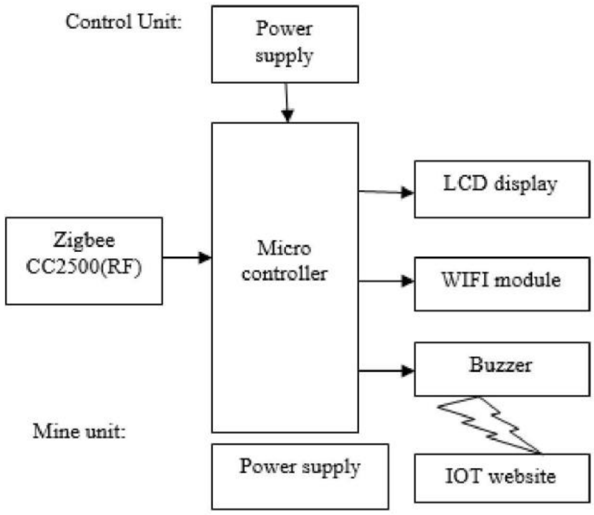
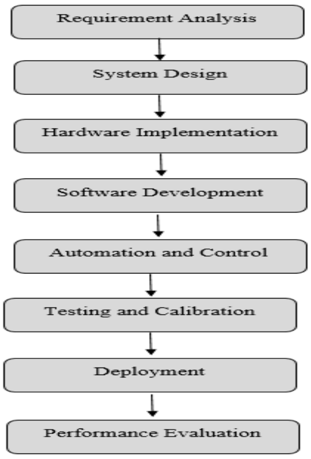


Fig.1.Block Diagram of the System

The study "IoT Based Coal Mine Safety Monitoring and Alerting System" by Prof. A. H. Ansari et al. aims to improve safety for workers in coal mines by using Internet of Things (IoT) technology. It describes a system to monitor the risks that miners face, such as high temperature, methane gas leaks, and rising water levels, using an automated, wireless monitoring and alerting system. The proposed system includes a PIC microcontroller, Zigbee module, a GSM/Wi-Fi communication module, and various other sensors (gas, temperature, and water level sensors).

When abnormal conditions are detected, the warning system will activate a buzzer, and an alert will be displayed on an LCD report while also sending information to the cloud via ThingSpeak for remote monitoring. This system allows for continual environmental monitoring of underground conditions as well as alerts to assess risk. The authors contrast previous systems (Bluetooth and RS485 communications) that suffered from high maintenance and reliability, in the former case, has poor reliability and has a lack of a good communication system, while Zigbee has low energy, secure data transmission, and low cost of deployment.Experimental results demonstrate that the system accurately measured levels and then sent alarms when these threshold levels were met (e.g. temperature > 50°C or gas level> 50 ppm.). The project ultimately demonstrates a reliable, low-cost IoT-based solution for in-situ monitoring of operator safety in underground coal mining applications.

IX. PROPOSED METHODOLOGY:



The proposed IoT-Based Coal Mine Safety Monitoring and Alerting System is designed to enhance the safety and security of miners by continuously monitoring environmental conditions and generating real-time alerts during hazardous situations. The analysis involves a comprehensive study of system requirements, design, hardware–software integration, and performance evaluation to ensure the project's efficiency and practicality. Each stage in the flowchart represents a structured phase in the development and implementation process.

1. Requirement Analysis:

The first step involves identifying the critical safety parameters that need continuous monitoring in underground coal mines. Parameters such as methane (CH_4) and carbon monoxide (CO) gas concentration, oxygen level (O_2), temperature, humidity, and water level are considered crucial for miner safety.
During this phase, the hardware and software requirements are also analyzed. This includes selecting suitable microcontrollers (ESP32/PIC), sensors (MQ-4, MQ-135, ZE03-O2, DHT11, LM35, water level sensor), and communication modules (LoRa, GSM). The analysis also focuses on determining the threshold values for each parameter and defining appropriate alert mechanisms such as buzzer alarms, LCD notifications, and IoT-based messages to supervisors.

2. System Design:

In this phase, a reliable IoT architecture is developed to interconnect all sensing and communication units. The design integrates the sensors with a central processing unit (microcontroller) capable of collecting, processing, and transmitting data. LoRa and GSM modules are used for long-range communication and data transmission to a centralized monitoring system. A cloud-based dashboard is designed to display real-time sensor data, graphical trends, and alert notifications. The design ensures low power consumption, modular expandability, and fault tolerance, allowing the system to function efficiently in rugged underground conditions.

3. Hardware Implementation:

The hardware stage involves assembling all components and ensuring stable communication between sensors, the microcontroller, and output peripherals. Gas sensors (MQ-4, MQ-135) detect the presence of methane and carbon monoxide, while the DHT11/LM35 monitors temperature and humidity.
Water level sensors track potential flooding risks. These readings are processed by the ESP32 microcontroller. Output devices such as buzzers, LCD displays, and relays provide local alerts and can trigger ventilation fans automatically when unsafe conditions are detected.

4. Software Development:

Software implementation is carried out using the Arduino IDE, where the firmware is programmed to read sensor data, filter noise, and communicate wirelessly. The program continuously compares real-time readings with preset safety thresholds. If abnormal values are detected, the software initiates automatic control actions, such as activating buzzers, switching on ventilation, or sending alerts via GSM/LoRa to the cloud dashboard. Additionally, the system logs all readings for later analysis and visualization.

5. Automation And Control:

This phase focuses on enabling automatic response mechanisms to minimize human error and reaction time. When gas levels exceed safe limits or water levels rise beyond thresholds, relay modules are triggered to turn on alarms or exhaust fans automatically.
Simultaneously, SMS and IoT alerts are sent to supervisors and control rooms through GSM/LoRa modules. The automation ensures quick preventive action, preventing potential accidents and protecting workers in real-time.

6. Testing And Calibration:

To ensure accuracy, all sensors are tested and calibrated under controlled, mine-like environments. Calibration ensures the sensors provide reliable readings even in varying humidity, temperature, and pressure conditions. During this phase, each sensor's output is compared with standard reference instruments, and the threshold values are fine-tuned to reduce false positives and false negatives**.** The communication range and data transmission reliability are also verified.

7. Deployment:

After successful testing, the complete system is installed in a mine-simulated setup. The hardware modules are placed at critical mine points where environmental changes are most likely to occur. Workers and supervisors are trained to understand the dashboard interface, interpret sensor readings, and follow safety protocols during alarms. The deployment phase ensures that the system operates seamlessly under real conditions and that all stakeholders can effectively utilize the technology.

8. Performance Evaluation:

In the final phase, the system's performance is evaluated based on accuracy, reliability, communication speed, and alert response time**.** The analysis includes checking data transmission consistency, power efficiency, and ease of maintenance.
Feedback is collected from mine workers and supervisors to assess the practicality and user-friendliness of the system. Based on the observations, improvements are suggested for future scalability, such as adding AI-based prediction models, cloud analytics, and improved battery management for sensor nodes.

X. RESULT:

The proposed IoT-based coal mine safety monitoring system was successfully developed and tested. The system continuously monitored key environmental parameters such as temperature, methane (CH_4), carbon monoxide (CO), humidity, and water level using appropriate sensors (MQ-4, MQ-135, DHT11, and water level sensor).

When any parameter exceeded the preset safety threshold — for example:

Temperature > 50°C

Methane concentration > 50 ppm

Air Quality (<19.5%)

High water level detected

The system automatically activated the buzzer and warning lights, displayed alert messages on the LCD, and transmitted notifications via LoRa and IoT cloud (ThingSpeak/dashboard) to supervisors.The real-time data visualization confirmed that the system provides accurate and reliable readings with fast response time. It effectively detected hazardous conditions and alerted both miners and surface control rooms, minimizing accident risks. Thus, the system proved to be cost-efficient, reliable, and highly effective for real-time underground mine safety monitoring and emergency alerting.

XI. ADVANTAGE:

The proposed IoT-based system continuously monitors critical mine parameters such as gas concentration, temperature, humidity, and water level in real time. It provides instant alerts through buzzer, LCD, and GSM/LoRa modules to warn workers and supervisors about hazardous conditions, ensuring timely action. The system is cost-effective, energy-efficient, and easy to install, making it suitable for both small and large-scale mining environments. Its low bandwidth requirement and wireless communication enhance reliability in underground conditions. Overall, it improves worker safety, reduces accident risks, and enables remote supervision through a centralized dashboard.

XII. CONCLUSION:

The IoT-based coal mine safety system effectively monitors gas, temperature, humidity, oxygen, and water levels in real time. It provides instant alerts through buzzers, LCD, and IoT notifications when unsafe conditions occur. This low-cost, reliable system enhances miner safety, improves emergency response, and ensures safer mining operations using modern IoT technology. It reduces manual inspection and human errors by automating the monitoring process. The system's cloud connectivity allows supervisors to track conditions remotely at any time. It uses low-power sensors and modules, making it efficient and cost-effective. The project proves that IoT and embedded systems can transform traditional mine safety management. Overall, it ensures continuous protection for miners and helps prevent major accidents in underground mines.

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