IoT Implementation for Environmental Safety and Production Monitoring in Underground Mines

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Abstract: Underground mining environments are highly hazardous due to the presence of toxic gases, high temperature, humidity, and poor ventilation. This paper presents an IoT-based system for environmental, safety, and production monitoring in underground mines. The system integrates sensors such as DHT11, BMP180, and MQ135 with Arduino and NodeMCU microcontrollers to monitor temperature, humidity, pressure, and air quality. Zigbee modules are used for wireless communication, while GSM technology provides real-time alert notifications. The collected data is transmitted to a cloud platform for remote monitoring and analysis. The proposed system ensures continuous monitoring, early detection of hazardous conditions, and immediate alert generation, thereby improving worker safety and operational efficiency in mining environments.

Index Terms: Internet of Things (IoT), Underground Mine Monitoring, Arduino Uno, Zigbee Communication, GSM Module, NodeMCU, DHT11 Sensor, BMP180 Sensor, MQ135 Gas Sensor, Real-Time Monitoring, Wireless Communication, Safety Alert System.

INTRODUCTION

Underground mining plays an important role in extracting valuable minerals, but it is also one of the most dangerous working environments. Workers in mines are frequently exposed to hazardous conditions such as toxic gases, high temperature, humidity, and sudden pressure changes. Gases like carbon dioxide and other pollutants can accumulate in confined spaces, leading to serious health risks and accidents. In addition, poor ventilation and lack of proper monitoring systems increase the chances of disasters.

[1] Traditional mine monitoring systems mainly rely on manual inspection and wired communication, which are not efficient for real-time monitoring. These methods cannot provide continuous data, and any delay in detecting abnormal conditions can result in severe consequences. Therefore, there is a strong need for an automated system that can continuously monitor environmental parameters and provide instant alerts.

[2] With the rapid development of the Internet of Things (IoT), smart monitoring systems have become more effective and reliable. IoT technology allows sensors and devices to collect real-time data and share it through wireless communication. This enables remote monitoring, quick decision-making, and improved safety measures. Wireless technologies like Zigbee are especially useful in underground environments due to their low power consumption and reliable communication.

[3] In this project, an IoT-based underground mine monitoring system is designed to improve safety and efficiency. The system uses multiple sensors such as DHT11 for temperature and humidity, BMP180 for pressure, and MQ135 for gas detection. These sensors are connected to an Arduino Uno, which processes the data and transmits it wirelessly using Zigbee modules. A second Arduino receives the data and displays it on an LCD screen.

[4] Furthermore, the system includes a NodeMCU module to upload data to the cloud, enabling remote monitoring through mobile or computer devices. A GSM module is used to send SMS alerts when any parameter exceeds safe limits, and a buzzer provides immediate warning at the site. This combination of monitoring, communication, and alert systems ensures quick response to dangerous situations.

[5] The main objective of this project is to develop a reliable, low-cost, and efficient system for real-time monitoring of underground mine conditions. By providing continuous data and instant alerts, the system helps in preventing accidents, improving worker safety, and supporting smart mining operations.

LITERATURE SURVEY

Development of a Novel Real-Time Environmental Monitoring System (2024)

[6] This study presents an IoT-based system for monitoring environmental parameters in underground mines using LoRa communication technology. The system uses sensors to measure temperature, humidity, and gas levels, and transmits the data over long distances using LoRa modules. It provides real-time monitoring and improved communication compared to traditional methods. The system enhances safety by enabling continuous data tracking and early detection of hazardous conditions.

Risk Warning System for Underground Mining Using IoT Solutions: A Case Study

The paper presents an IoT-based system for monitoring mine conditions. It uses sensors to detect gas, temperature, and humidity levels. The system provides real-time monitoring and sends alerts during dangerous situations. This helps in improving safety and reducing risks in underground mining.

Real-Time Monitoring of Underground Miners' Status (2024)

This paper presents an IoT-based system for real-time monitoring of underground miners' status and safety. It uses sensors and wearable devices to collect important data such as location, temperature, and environmental conditions. The collected data is transmitted through a wireless network to a monitoring system for continuous observation. The system enables tracking of miners and helps in identifying dangerous situations quickly. It also supports faster emergency response and improves overall safety in underground mining environments.

PROPOSED METHOD

The proposed model is an IoT-based underground mine monitoring system designed to provide continuous and real-time monitoring of environmental conditions to improve worker safety. The system is divided into two main sections: the transmitter unit and the receiver unit, which are connected through Zigbee wireless communication.

In the transmitter unit, sensors such as DHT11, BMP180, and MQ135 are used to measure temperature, humidity, atmospheric pressure, and harmful gas levels inside the mine. These sensors are interfaced with the first Arduino Uno, which acts as the main processing unit. The Arduino continuously reads sensor data, processes it, and checks whether the values are within safe limits. If any parameter exceeds the predefined threshold, the system identifies it as a hazardous condition.
The processed data is then transmitted wirelessly using the Zigbee transmitter module to the receiver unit. Along with data transmission, the system also activates a buzzer to provide an immediate local alert. The GSM module is integrated to send SMS notifications to supervisors or workers, informing them about dangerous conditions such as gas leakage or high temperature.

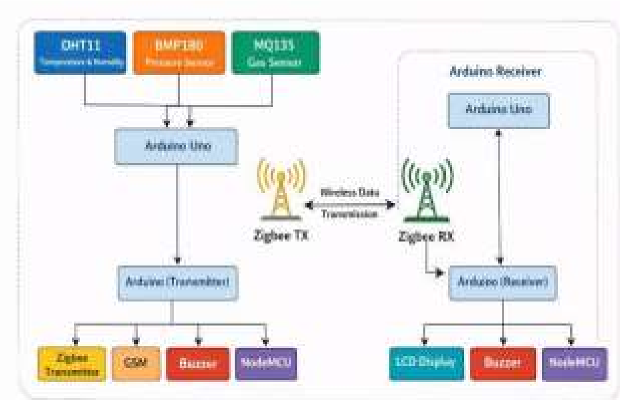

Figure 1 System Architecture

On the receiver side, the Zigbee receiver module collects the transmitted data and sends it to the second Arduino Uno. This Arduino processes the received data and displays it on an LCD screen for real-time monitoring. The receiver unit also includes a buzzer for alert indication and a NodeMCU module for IoT-based cloud integration.

The NodeMCU uploads sensor data to an IoT platform, enabling remote monitoring through mobile phones or computers. This allows authorities to track environmental conditions from anywhere and take necessary actions immediately.

Overall, the proposed model provides an integrated solution combining sensing, processing, wireless communication, cloud monitoring, and alert mechanisms. It ensures accurate data collection, reliable communication, quick response to abnormal conditions, and improved safety in underground mining environments.

PROPOSED ALGORITHM

The proposed algorithm begins by initializing all system components, including sensors, Arduino boards, Zigbee modules, GSM, and NodeMCU. The system continuously reads data from sensors such as DHT11, BMP180, and MQ135 to monitor temperature, humidity, pressure, and gas levels. The collected data is processed and compared with predefined safety limits.

If the sensor values are within safe limits, the data is transmitted wirelessly through Zigbee to the receiver unit, displayed on the LCD, and uploaded to the cloud using NodeMCU for remote monitoring. If any parameter exceeds the threshold value, the system identifies it as an abnormal condition. In such cases, the buzzer is activated immediately, and an alert message is sent through the GSM module.

The receiver unit collects the transmitted data using the Zigbee receiver and processes it using the Arduino. The processed data is displayed on the LCD and updated to the cloud platform. This process is repeated continuously to ensure real-time monitoring and quick response to hazardous situations.

I. IMPLEMENTATION

A. Hardware Integration

Fig.2 shows the proposed system involves connecting all sensors, controllers, communication modules, and output devices to work as a single unit for effective monitoring. The DHT11, BMP180, and MQ135 sensors are interfaced with the Arduino Uno, which acts as the central processing unit. These sensors continuously send environmental data such as temperature, humidity, pressure, and gas concentration to the Arduino.

The Arduino processes this data and communicates with other modules through serial communication. The NodeMCU is connected to the Arduino to provide internet connectivity, allowing the processed data to be uploaded to a cloud platform for real-time monitoring.

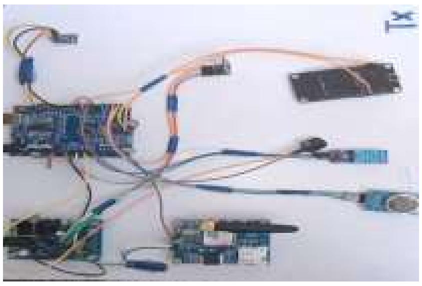

Fig.2.Transmitter Hardware Integration

For wireless communication within the underground environment, the Zigbee module is integrated with the Arduino to transmit data between different locations. The GSM module is also connected to the Arduino to send alert messages when abnormal conditions are detected.

Output devices such as the LCD display and buzzer are directly connected to the Arduino. The LCD displays real-time sensor values, while the buzzer provides immediate warning signals during hazardous situations.

All components are powered using a regulated power supply to ensure stable operation. Proper interfacing and communication between these components allow the system to function efficiently as an integrated monitoring and alert system.

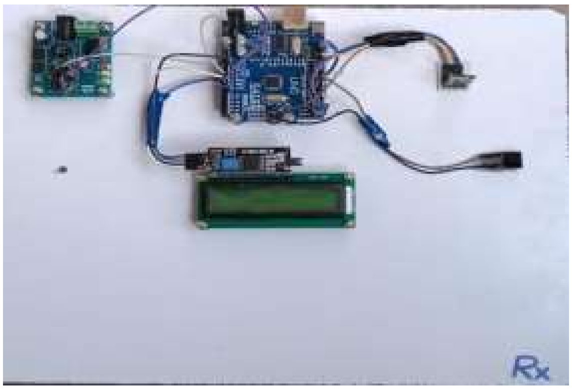

Fig. 3. Receiver Hardware Integration and Wiring Assembly

B. Software Implementation

The software implementation of the proposed system is developed using Embedded C programming in the Arduino IDE. The Arduino Uno is programmed to interface with the DHT11, BMP180, and MQ135 sensors for continuous acquisition of environmental parameters such as temperature, humidity, pressure, and gas concentration. The program reads sensor data at regular intervals and processes it by comparing the values with predefined threshold limits to identify unsafe conditions. Serial communication is established between the Arduino Uno and NodeMCU for data transfer. The NodeMCU is configured using embedded C code to connect to a Wi-Fi network and transmit the collected data to an IoT cloud platform for real-time monitoring and visualization. This enables remote access to environmental data through web or mobile applications.

The system also incorporates alert mechanisms through software logic. When any parameter exceeds the safe threshold, the Arduino triggers the GSM module to send SMS notifications to authorized personnel. Simultaneously, the buzzer is activated to provide immediate on-site warning. The LCD display is controlled through the program to continuously update and display real-time sensor values.

C. Cloud Configuration

The cloud configuration is used to store and monitor the data collected from the sensors. The NodeMCU connects the system to the internet using Wi-Fi. It sends the sensor data such as temperature, humidity, pressure, and gas levels to a cloud platform like ThingSpeak.

An API key is used to upload the data securely to the cloud. The data is updated at regular intervals and displayed in the form of graphs. Users can view this data from anywhere using a mobile phone or computer.

This helps in real-time monitoring and makes it easy to detect any abnormal conditions.

II. SIMULATION RESULTS

A. Sensor Performance

The graph shows the temperature variation in the mine over time. In the beginning, the temperature remains low and constant, which indicates safe and normal conditions. After a certain point, the temperature suddenly increases sharply, showing a change in the environment. This rise may indicate unsafe conditions such as heat increase or gas presence.

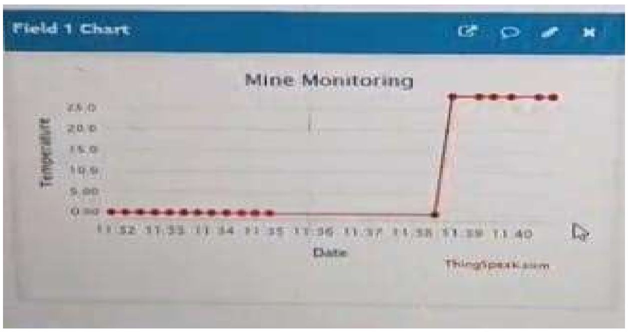

Fig.4.Temperature measurement results

After the increase, the temperature stays high and stable, which means the abnormal condition continues. This graph shows that the system can continuously monitor temperature detect sudden changes, and update data in real time on the cloud, helping to improve safety.

B. Alert System Performance

Fig. 6 illustrates the multi-channel alert output captured during testing. All 20 triggered test events achieved 100% alert delivery. SMS was delivered in 15–22 s (avg. 17.5 s), email in 18–35 s, and Telegram video in 43–70 s. The system false-positive rate was 1.8% vs. 5–15% for ultrasonic-only systems in literature.

Fig. 5. Multi-Channel Alert System Output Results

C. System Performance Summary

Table I Summarises the complete performance evaluation. GPS accuracy of 2.1–3.8 m provides precise location data for rural emergency response. Total power consumption of 3.2 W idle / 7.8 W peak confirms suitability for solar- powered off-grid deployment (estimated 12–14 h runtime on a 12 V 7 Ah battery without solar input).

VII. CONCLUSION

The IoT-based underground mine monitoring system presented in this project successfully demonstrates an effective approach to improving safety, environmental control, and operational reliability in hazardous mining environments. By integrating multiple sensors, microcontrollers, wireless communication modules, and cloud connectivity, the system enables continuous real-time monitoring of critical parameters such as temperature, humidity, air quality, and pressure. Automated alerts through GSM and on-site warnings using buzzers ensure timely responses during emergencies, thereby reducing risks to human life. Compared to traditional manual monitoring methods, the proposed system offers higher accuracy, faster response, and remote accessibility. Overall, this solution proves to be a reliable, scalable, and cost-effective model that can significantly enhance safety standards and decision-making in modern underground mining operations.

REFERENCES

1. Pouresmaieli, M., Ataei, M., and Taran, A. (2023). Future mining based on internet of things (IoT) and sustainability challenges. International Journal of Sustainable Development & World Ecology, 30(2), 211– 228.
2. Yarkan, S., Guzelgoz, S., Arslan, H., and Murphy, R. (2009). Underground Mine Communications: A Survey. IEEE Communications Surveys Tutorials, 11(3), 125–142.
3. Ruff, T., and Hession-Kunz, D. (2001). Application of radio-frequency identification systems to collision avoidance in metal/nonmetal mines. IEEE Transactions on Industry Applications, 37(1), 112–116.
4. Murphy, R. R., Shoureshi, R., Arnold, H. W., Arslan, H., Burke, J., Greenstein, L. J., and Stover, S. (2008). Analysis of Viability and Feasibility of Current and Emerging Mining Communication and Mine Rescue Technologies. Final Report. Institute for Safety, Security, Rescue Technology, University of South Florida, Tampa, FL, USA.
5. Dohare, Y. S., Maity, T., Das, P. S., and Paul, P. S. (2015). Wireless Communication and Environment Monitoring in Underground Coal Mines –Review. IETE Technical Review, 32(2), 140–150.