



International Journal of Innovative Research in Computer and Communication Engineering

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)





MineGuard: Emergency Survival Jacket for Mines Using IoT

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ABSTRACT: Mining is one of the most hazardous occupations where workers are exposed to dangerous conditions such as toxic gases, extreme temperatures, and fire hazards. This paper presents MineGuard, an IoT-based emergency survival jacket designed to improve safety in underground mining environments. The jacket integrates multiple sensors including DHT11 for temperature and humidity monitoring, MQ2 for gas detection, and a flame sensor for fire detection. All sensor data is processed by an Arduino Nano microcontroller and displayed on an LED screen. Emergency buttons allow miners to manually send alerts during health emergencies, gas leakage, or fire incidents. Communication between the wearable jacket and monitoring station is achieved using LoRa technology, enabling long-range wireless communication without internet dependency. The receiver module uses an ESP32 microcontroller to display alerts, trigger alarms, and optionally upload data to the Blynk IoT platform for monitoring and analysis. The proposed system provides a reliable, cost-effective, and efficient solution for improving miner safety and ensuring timely emergency response.

KEYWORDS: IoT, MineGuard, Safety Jacket, LoRa Communication, Arduino Nano, ESP32, Gas Detection, Flame Sensor, Industrial Safety

I. INTRODUCTION

Mining is among the most vital but hazardous industries globally. Miners tend to be subjected to extreme environmental conditions like extreme heat, humidity, lack of ventilation, and exposure to toxic gases [1], [3], [5]. Gas leaks, fire, and equipment malfunction can cause severe injuries or death [2], [4]. Hence, maintaining the safety of mine workers has become a pressing concern in today's industrial activities [6], [8], [9]. In response to these issues, the use of Internet of Things (IoT) technology in safety devices offers an intelligent and dependable solution [7], [10], [12]. IoT facilitates continuous monitoring, real-time data transfer, and immediate alert systems without any intervention on the part of humans [13], [14]. Under ground mines where internet connectivity is missing, conventional wireless communication techniques are unable to produce reliable performance [2], [11]. Therefore, LoRa (Long Range) communication technology is employed in this project to facilitate long-range, low-power data transmission without internet connectivity [6], [9], [12]. The system introduced here, MineGuard, aims at improving miners' safety by constant monitoring of the environment and rapid emergency response [15], [17]. The jacket is also provided with sensors like DHT11 for temperature and humidity, MQ2 for gas and fire detection, and a flame sensor for detecting fires [3], [14], [18]. All these sensors are linked to an Arduino Nano microcontroller to analyze the data and present it on an LED screen for the miner to refer to [1], [16]. Besides, three panic buttons enable miners to trigger manual alerts in case of health problems, gas leaks, or burning hazards [17], [19]. All miner's jacket data is communicated wirelessly over LoRa to the receiver module, which is governed by an ESP32 microcontroller [5], [7], [11]. The receiver shows all the data received on an LED display, triggers a buzzer during emergencies, and transfers the data to the Blynk IoT platform for graphical visualization and analysis [13], [18], [20]. The dual-layer alarm system provides immediate alerts to both the miner as well as surface-level monitoring staff about any dangerous situation [17], [19]. MineGuard is designed to be an offline, cost-saving, and effective safety solution for underground miners operating under rugged and hard-to-reach conditions [1], [3], [5], [9]. Through the integration of IoT-sensing, wireless data communication, and real-time alert systems, this project greatly improves the safety of underground mining activities [2], [4], [6], [10], [15].



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II. RELATED WORK

Several studies have proposed wireless monitoring systems for improving mine safety. Traditional systems relied on wired sensors and manual monitoring which had limited flexibility and delayed response time.

Recent research introduced IoT-based monitoring systems using wireless communication technologies such as Zigbee, Bluetooth, and GSM networks. However, these technologies often require internet connectivity and have limited communication range in underground environments.

LoRa technology has emerged as an effective solution for long-range communication with low power consumption. Researchers have explored LoRa-based safety monitoring systems for industrial environments.

However, many existing solutions are stationary and do not provide wearable safety systems for individual miners. The MineGuard system addresses this limitation by integrating wearable technology, IoT sensors, and LoRa communication into a portable safety device.

III. SYSTEM ARCHITECTURE

The MineGuard system consists of two main modules: the Sender Module and the Receiver Module.

A. Sender Module (Wearable Jacket)

The sender module is built into a wearable jacket with multiple sensors and control elements [14, 17, 18].

1. Sensors

2. **DHT11 Sensor:** The DHT11 sensor detects temperature and humidity in the ambient environment [6, 10].

3. **MQ2 Gas Sensor:** The MQ2 gas sensor detects harmful gases such as methane, LPG, and carbon monoxide in mining regions [1, 12, 20].

4. **Flame Sensor:** The flame sensor detects possible fire or spark risks in the surrounding environment [13, 19].

5. Emergency Buttons

Three dedicated emergency switches allow miners to manually alert critical conditions such as health emergencies, gas leakage, or fire hazards [4, 7, 15].

6. **Health Emergency:** Activated when the miner feels unwell or faints.

Gas Leakage Alert: Activated when gas leakage is detected.

7. **Fire Alert:** Pressed in case of fire or smoke accidents.

8. Microcontroller (Arduino Nano)

Arduino Nano acts as the main control unit. It collects real-time data from sensors and monitors the emergency buttons. Based on detected conditions, it activates the buzzer and displays information on the LED display. The processed data is transmitted to the receiver module through the LoRa transmitter [2, 3, 17].

9. Buzzer and LED Display

The buzzer provides immediate audible alerts, while the LED display shows sensor readings and system status for the miner [9, 19].

10. LoRa Module (Transmitter)

The LoRa transmitter sends sensor data and emergency alerts to the receiver module in the control room. LoRa communication is selected due to its low power consumption and long-range capability, making it suitable for underground mines where Wi-Fi or cellular networks are unreliable [2, 5, 7, 12]. It ensures reliable real-time communication even in low-signal conditions [9, 11].

B. Receiver Module

The Receiver Module is mounted in the monitoring area or mine control room. Its main function is to receive, decode, and display the data transmitted by the wearable sender device [3, 5].

1. Microcontroller (ESP32)

ESP32 is a compact and efficient microcontroller widely used in IoT applications [6, 10, 15]. In the MineGuard system, the ESP32 acts as the central controller at the monitoring station. It receives data from the miners' wearable jackets through the LoRa wireless module, displays sensor readings on the LED display, and activates the buzzer when emergency conditions occur. The ESP32 can also transmit data to the Blynk application for easy visualization. It is



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reliable, energy-efficient, and capable of handling multiple sensor inputs simultaneously, making it suitable for underground mine safety monitoring [18, 19].

2. IoT Integration (Blynk Platform)

The MineGuard system integrates the Blynk IoT platform to enhance monitoring capabilities [11, 14, 20]. Data collected from the miners' jackets is received at the receiver module and can be connected to Blynk for displaying real-time readings of temperature, humidity, gas concentration, and flame detection on a computer or smartphone.

- I. The platform presents data in the form of charts, graphs, and alerts to enable effective safety monitoring [8, 13].
- II. Although the primary communication operates offline using LoRa, remote visualization is possible through Blynk when a local Wi-Fi network is available [10, 11, 19].
- III. This feature allows supervisors to quickly respond to emergency situations and maintain a proactive safety environment [18, 20].

C. Flow of Communication

Communication between the wearable jacket (Sender Module) and the monitoring station (Receiver Module) is established using LoRa wireless technology [2, 3, 6].

1. Sensors on the jacket continuously monitor temperature, humidity, gas concentration, and fire detection [1, 13, 19].
2. The sensor data and emergency button signals are transmitted wirelessly in real time to the receiver module.
3. The ESP32 processes the received data, displays it on the LED display, and activates the buzzer if hazardous conditions are detected [5, 9, 15].
4. The system works offline, ensuring reliable long-distance communication even in underground mine environments [7, 10, 17].
5. Optionally, the collected data can also be visualized through the Blynk IoT platform for easier monitoring and analysis [11, 14, 20].

D. IoT Integration

The system connects to the Blynk IoT platform which allows supervisors to monitor environmental data through graphs and alerts.

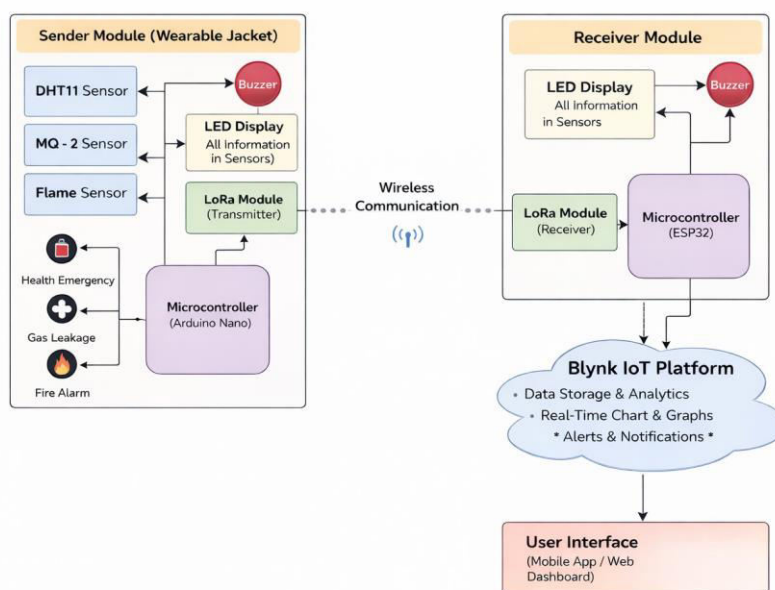


Figure 1: System Architecture of MineGuard



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IV. IMPLEMENTATION

The MineGuard Emergency Survival Jacket is implemented as a complete IoT-based safety system consisting of two main modules: the Sender Module worn by miners and the Receiver Module located at the monitoring station. In the Sender Module, an Arduino Nano microcontroller collects real-time data from multiple sensors integrated into the wearable jacket. These sensors include the DHT11 sensor for measuring temperature and humidity, the MQ2 gas sensor for detecting harmful gases, and the flame sensor for identifying potential fire hazards in underground mining environments.

The system also includes three emergency push buttons that allow miners to manually send distress alerts during critical situations such as health emergencies, gas leakage, or fire incidents. When any abnormal condition is detected, the microcontroller processes the sensor readings and activates a buzzer and LED display to provide immediate local alerts to the worker.

For wireless communication, the system uses LoRa (Long Range) technology. The collected sensor data and emergency alerts are transmitted through a LoRa transmitter module to the receiver unit installed at the monitoring station.

The Receiver Module is built using an ESP32 microcontroller, which receives the transmitted data through a LoRa receiver module. The received information is displayed on an LED screen for monitoring purposes. If any hazardous condition or emergency signal is detected, the system immediately activates a buzzer alarm to alert safety personnel.

For enhanced monitoring and analysis, the system can also be integrated with the Blynk IoT platform. This allows real-time visualization of sensor data through graphs and gauges on a mobile application or web dashboard. Supervisors can monitor environmental conditions remotely and receive instant notifications if dangerous situations occur.

The entire MineGuard system operates wirelessly and does not depend on continuous internet connectivity inside underground mines. This ensures reliable communication even in remote mining areas where traditional communication networks are unavailable.

The system was tested to evaluate sensor accuracy, LoRa communication stability, emergency alert functionality, and IoT visualization. Experimental results demonstrate that the proposed system can effectively provide real-time monitoring, early hazard detection, and rapid emergency alerts, significantly improving the safety of miners working in underground environments.



Figure 2: Sender Module

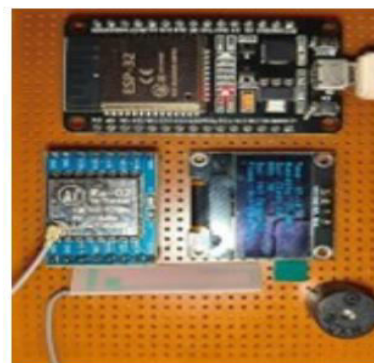


Figure 3: Receiver Module

V. RESULTS AND DISCUSSION

The MineGuard Emergency Survival Jacket was tested under simulated underground mining conditions to evaluate the performance of the proposed safety monitoring system. The testing focused on verifying the accuracy of the sensors, the reliability of LoRa communication, and the effectiveness of real-time alert generation.



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The DHT11 sensor successfully monitored environmental parameters such as temperature and humidity. The MQ2 gas sensor accurately detected the presence of hazardous gases and generated alerts when gas levels exceeded the predefined safety threshold. Similarly, the flame sensor was able to detect fire sources and trigger immediate warning signals. The system also allowed manual emergency alerts through dedicated push buttons for health emergencies, gas leakage, and fire incidents.

The collected sensor data was transmitted wirelessly from the wearable jacket to the monitoring station using LoRa communication technology. The ESP32 receiver module successfully received the transmitted data and displayed real-time readings on the LED display. Whenever abnormal conditions were detected, the buzzer alarm was activated to alert safety personnel.

For remote monitoring and visualization, the system was integrated with the Blynk IoT platform. The Blynk mobile application displayed real-time sensor data in the form of graphs and gauge widgets. These graphical representations allowed supervisors to easily monitor environmental conditions and analyze historical trends of sensor data.

Experimental results confirmed that the system operates reliably even in environments without continuous internet connectivity. The LoRa communication provided stable long-range wireless transmission, ensuring that sensor data and emergency alerts were successfully delivered to the monitoring station.

Overall, the results demonstrate that the MineGuard system effectively provides real-time monitoring, early hazard detection, and rapid alert mechanisms. This significantly improves situational awareness and safety for miners working in hazardous underground environments.



Figure 4: Blynk IoT Graph Showing Real-time Sensor Data



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Figure 5: Blynk IoT Gauge Display

VI. CONCLUSION AND FUTURE WORK

A. Conclusion

The MineGuard Emergency Survival Jacket is a fully functional IoT-based safety system designed to enhance the safety of miners working in underground environments. The system integrates multiple sensors including the DHT11 sensor for temperature and humidity monitoring, the MQ2 sensor for gas detection, and flame sensors for fire detection. In addition, three emergency push buttons are provided for Health Alert, Gas Leak Alert, and Fire Alert situations.

Sensor data is collected and processed by an Arduino Nano microcontroller embedded in the wearable jacket. The processed information is transmitted wirelessly using LoRa communication technology to a receiver module built with an ESP32 microcontroller. The receiver unit displays real-time sensor readings on an LED display and activates a buzzer alarm when hazardous conditions are detected, ensuring that supervisors are immediately notified.

The system is further integrated with the Blynk IoT platform, which provides graphical visualization of sensor data through charts, graphs, and real-time notifications. This allows supervisors to remotely monitor environmental conditions and review historical data for safety analysis.

Experimental testing confirmed that the sensors, LoRa communication modules, and IoT integration operate reliably and provide accurate real-time monitoring even without continuous internet connectivity. The MineGuard system demonstrates how IoT technology combined with wireless communication and visualization tools can significantly reduce response time during emergencies and improve situational awareness in underground mining environments.

B. Future Work

Although the current system successfully monitors environmental hazards and alerts supervisors, several improvements can further enhance its functionality:

1. **Additional Sensors:** Integrate sensors for heart rate monitoring, oxygen level detection, vibration sensing, and dust particle measurement to monitor both miner health and environmental safety conditions.
2. **GPS Tracking:** Incorporate real-time location tracking to monitor the position of miners inside the mine, which can greatly assist rescue teams during emergency situations.
3. **Compact Design:** Develop a lighter and more ergonomic jacket design to improve comfort and mobility for miners working long underground shifts.
4. **Predictive Analytics:** Apply machine learning techniques to analyze sensor data trends and predict potential hazards before they occur, enabling proactive safety measures.
5. **Enhanced IoT Platform:** Upgrade the Blynk interface to support monitoring of multiple miners simultaneously, generate automated alerts, and produce detailed safety reports for management and safety audits.



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6. **Energy Efficiency:** Improve battery management and implement low-power operating modes to extend the operational life of the system during extended mining shifts.

By implementing these enhancements, the MineGuard system can evolve into a more comprehensive, proactive, and intelligent safety solution that not only detects hazards but also predicts potential risks, thereby ensuring maximum safety in underground mining environments.

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