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IOT Based Safety Helmet for Coal Minors

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Abstract - Coal mine safety is a critical concern due to hazardous conditions like explosions, toxic gases, flooding, and collapses. Traditional monitoring and communication methods are inadequate, making modern solutions essential. The use of wireless networks, IoT devices, and sensor systems enables real-time monitoring of gas, temperature, humidity, and airflow. These technologies provide continuous data and instant alerts, ensuring faster response and improved miner safety.

Keywords: Smart helmet, coal mining, IoT, safety, environmental monitoring.

1.INTRODUCTION

Coal mining is a vital industry that meets global energy demands while supporting employment and GDP, particularly in developing economies. However, underground mining environments remain extremely hazardous, with risks such as gas explosions, toxic buildup, flooding, and rockfalls posing constant threats to workers' safety. Traditional safety measures like wired communication and manual reporting are increasingly seen as inadequate due to their maintenance challenges and delays in emergency response. To overcome these issues, modern mining operations are adopting wireless technologies such as Wi-Fi, LoRa, Zigbee, and 4G/5G, which provide more reliable and flexible communication. The integration of IoT-enabled safety helmets has further transformed mine safety by embedding sensors that monitor gas levels, temperature, humidity, and miners' real-time locations. This data is wirelessly transmitted to control centers for continuous monitoring and rapid hazard detection. In emergencies, the system triggers instant alerts, enabling faster rescue operations while also supporting predictive hazard prevention through analytics. By improving communication, situational awareness, and proactive safety measures, IoT-based smart helmets significantly reduce mining accidents and fatalities. Ultimately, such innovations modernize coal mining safety infrastructure, aligning with global trends toward smarter and more sustainable industrial practices.

2. LITERATURE REVIEW

The reviewed literature highlights significant advancements in the design and development of smart helmets aimed at improving miner safety. One work presents a sensor-integrated helmet with machine learning capabilities, using an Arduino microcontroller and Support Vector Machines (SVM) for hazard prediction. Another emphasizes a power-efficient smart helmet for monitoring both environmental conditions and miner health. Several studies propose helmets equipped with sensors to measure temperature, humidity, and hazardous gases such as methane and carbon monoxide, with ZigBee technology enabling real-time data transmission and emergency alert mechanisms like panic buttons. Other research also focuses on real-time monitoring of hazardous conditions, while some introduce early prediction and warning of potential calamities to improve safety measures. Further contributions integrate sensor networks and communication technologies for real-time monitoring and tracking of miners' health and location. Some works employ IoT and ARM Cortex-M for predictive alerts, reducing risks and ensuring rapid emergency response. Finally, one study demonstrates an IoT-enabled helmet capable of monitoring health and environmental conditions with up to 96% accuracy, significantly enhancing safety through early hazard detection and timely alerts. Collectively, these studies underline the growing role of IoT, wireless communication, and intelligent systems in creating proactive safety solutions for the mining industry.

3. METHODOLOGY

The proposed system is designed with two main units: a transmitter worn by miners and a receiver located in the control room. The transmitter integrates multiple sensors with an ESP32 microcontroller to continuously collect environmental and health-related data such as temperature, humidity, and toxic gas levels (e.g., benzene or ammonia). This ensures early detection of hazardous conditions like overheating, excessive air moisture, or toxic gas leaks. The collected data is processed by the ESP32 and transmitted using LoRa technology, which provides low-power, long-distance communication, making it highly effective in underground environments where traditional internet connectivity is unreliable. When sensor readings cross predefined safety thresholds, the system immediately triggers alerts, allowing quick response actions to prevent accidents and safeguard miners' lives. The receiver unit in the control room displays real-time data on an OLED screen, giving operators continuous visibility of underground conditions. Additionally, the data is sent to ThingSpeak, an IoT analytics platform, where it is aggregated, stored, and visualized through graphs and trends. This enables operators not only to monitor live data but also to analyze historical records, identify recurring risks, and plan preventive measures.

The software implementation uses Arduino IDE for programming and configuring the ESP32 and sensors, ensuring easy customization and flexibility. ThingSpeak serves as the cloud-based analytics platform, providing powerful tools for remote monitoring, pattern detection, and predictive safety analysis. Together, this combination of hardware and software creates a robust, efficient, and scalable solution that enhances miner safety, improves decision-making, and contributes to more reliable and sustainable mining operations.

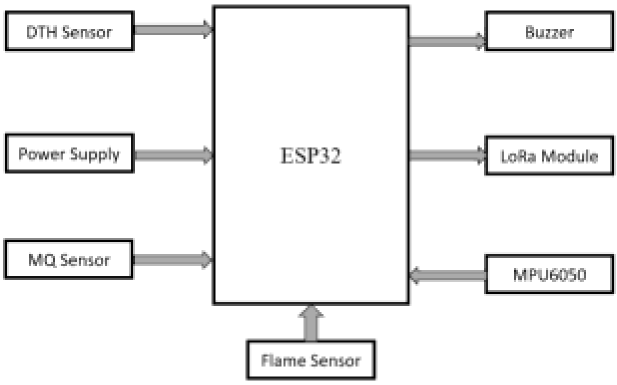

Fig -1: Block diagram of Transmitter End

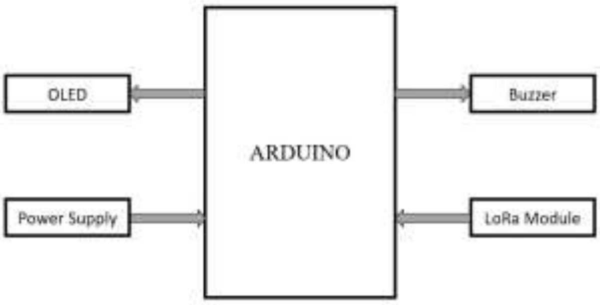

Fig -2: Block diagram of Receiver End

4. RESULTS – SYSTEM DEMONSTRATION

Fig -4(a): Hardware setup

All sensor data is processed by a microcontroller (ESP32/Arduino) and transmitted using LoRa, which is well-suited for underground mines due to its low power use and long range. The helmet continuously sends real-time data to the base station, enabling early detection of hazards and ensuring worker safety.

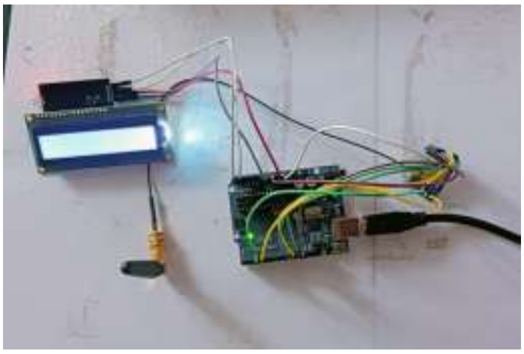

Fig -4(b): Prototype of receiver side

The base station monitors mine conditions in real time using an Arduino Uno with a LoRa module that receives data from the helmet transmitter. It processes temperature, humidity, air quality, and flame detection signals, triggering LED alerts when hazards are detected. The system can be expanded with an LCD display or cloud-based IoT platform for remote monitoring, ensuring quick response and improved worker safety.

Fig -4(c): Temperature data displayed in cloud-based IoT platform

Fig -4(d): Humidity data displayed in cloud-based IoT platform

Fig -4(e): MQ135 gas sensor data displayed in cloud-based IoT platform

The IoT-based coal mine safety system monitors temperature, humidity, and gas levels in real time. Readings showed stable values but sudden drops to 0 on December 21 indicated sensor or transmission faults. Humidity remained high at 95%, posing corrosion and air quality risks, while gas concentration spiked to 1000 PPM, suggesting a possible leak. The system is effective but needs better sensor reliability, data stability, and automated alerts for improved safety.

5. CONCLUSIONS

Wireless networks in coal mines enable real-time monitoring of gas, temperature, and humidity for early hazard detection. They ensure reliable communication between miners and control centers, support quick emergency response, and provide automated alerts and tracking for rescue operations. In addition to improving safety, these systems reduce manual inspections, optimize workflows, and enhance overall efficiency

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