Life Protection Mechanism by Monitoring the Operations of Miners

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ABSTRACT: The life protection mechanism by monitoring the operations of miners with low-cost smart helmet for real-time, remote monitoring of underground coal mine environments. The helmet integrates sensors for body temperature, oxidation state, and hazardous gas (such as methane) leakage, enhancing safety and well-being. Utilizing LoRa technology facilitates reliable long-range communication and localization of Miners, ensuring seamless data transmission from the smart helmets worn by miners to a centralized monitoring system . Employing LoRa and IoT technologies, the system enables centralized data analysis and instant alerts. Additionally, a TiO2(Titanium Dioxide) filter and activated carbon is incorporated to reduce the toxic impact of hazardous gas . This innovative solution addresses the unique challenges of subterranean conditions, ensuring proactive safety measures, and represents a cost-effective and scalable approach for efficient underground mining operations.

Keywords: Smart Helmet, Real-time Monitoring, Titanium Dioxide , LoRa Communication, Internet of Things (IoT), Low-cost Technology, Safety Monitoring

1.Introduction

Coal is the foremost broadly utilized asset in power era industry as well as in the steel generation; subsequently, it is of awesome significance to numerous nations economies. The significance of coal is seen by uncommon development rates in its utilization and generation, specific in Asia. In India a huge stock of the coal goes for the power era companies. So, to satisfy the prerequisite the generation of coal businesses needs to meet their request. And for the way better efficiency in any industry, the work environment should have zero resilience towards the accidents and hazards.

Underground mining could be a mechanical action. The cruel physical environment and particular topology that creates mining unsafe act as a prevention or imperative to the exceptionally methods and innovations that may make strides security and efficiency. There's no formally set up administrative criterion for chance to work force within the mining industry. Person organizations have created criteria for representative chance, the concepts originally emerging from the chemical handle businesses and oil and gas businesses. Potential gas dangers such as gas start, blast, and defilement are the most risks in the Mine.
Observation with the assistance of remote sensor organize is getting to be a need of positive drift towards the security in underground mines. As different detecting hubs, introduced in underground mine can persistently sense the limits of different gasses, there would be ceaseless time based observing of the underground mine environment.

Mining environment regularly has covered up threats inside such as poisonous gasses, which may show extreme wellbeing exposures to the individuals working inside mining. These glasses have to be recognized at times and educated the perilous circumstance in right time for the security of diggers. Wired arrange observing systems have helped the mine security essentially, but it isn't thought for all sorts of mining environment.

A real-time observing frameworks may help in checking and control over the mining environment. Lora based innovation offers its most of the preferences perfect for the genuine time localization and farther checking framework. Hence, the essential objective of this extend is chosen to design an effective genuine time checking framework so that different spilled mine gasses might be distinguished at times and preventive measures can be formulated appropriately. Here we proposed a TIO2 channel based cover which is executed the diggers head protector it is actuated by the Driven.

1.1 Background and Context

The historical tapestry of the mining industry is woven with narratives of resilience, innovation, and, unfortunately, the persistent challenge of ensuring the safety of those toiling beneath the Earth's surface. In the context of underground coal mining, where adverse conditions and potential hazards are a constant companion, the need for advanced safety solutions has never been more pressing.

1.2 Redefining Safety Parameters

At the heart of this innovation lies a profound commitment to redefine the very parameters of safety within the intricate underground coal mine environment. The conventional tools and methods, while undoubtedly effective to a certain extent, are being augmented by the infusion of intelligence, real-time monitoring capabilities, and a cost effective design that promises accessibility on a broad scale. The Smart Helmet, equipped with sensors measuring vital physiological indicators - body temperature and heart rate - alongside environmental factors like oxidation state and methane gas leakage, heralds a new era of proactive safety protocols.

1.3 Technological Synergy: LoRa and IoT

The crux of this technological marvel lies in the seamless integration of Long Range (LoRa) communication and the Internet of Things (IoT). LoRa, renowned for its prowess in establishing robust long-range connections, ensures that critical real-time data collected by the Smart Helmet finds its way to a centralized monitoring system on the surface. Meanwhile, the intricate web of the Internet of Things facilitates an intelligent network where each piece of information contributes to a comprehensive understanding of the underground environment. This symbiotic relationship between LoRa and IoT forms the backbone of a system poised to usher in a new era of safety and efficiency in the underground coal mining landscape.

1.4 Unlocking Safety in the Depths:

In the labyrinthine depths of underground coal mines, safety concerns and occupational hazards have long been formidable challenges for the mining industry. As the pursuit of extracting vital resources delves deeper into the Earth's crust, the necessity for advanced safety measures becomes increasingly urgent. This research navigates the uncharted terrain of safety innovation, presenting a comprehensive study on the Low-Cost Smart Helmet for Real-Time Remote Underground Coal Mine Environment Monitoring and Alert System. Embracing the tandem technologies of Long Range (LoRa) communication and the Internet of Things (IoT), this groundbreaking smart helmet emerges as a beacon of hope in a domain marred by risks. Through a meticulous exploration of its functionalities, including the real-time monitoring of body temperature, heart rate, oxidation state, and methane gas leakage, this research unveils a transformative solution poised to redefine safety protocols in underground coal mining.

2.Related work

A coal mine security framework is executed employing a thinger parcel stage as a medium to transmit the information. The framework is actualized to screen and control different parameters within the coal mines such as light discovery, spillage of gas, temperature and mugginess conditions, Fire discovery within the coal mine. These all sensors are together considered as one unit and are put within the coal mines. All the regards of the sensors are continuously uploaded to the thinger for investigation. Here the gas is persistently checked in the event that any instabilities within the level of gas emerge, at that point buzzer is utilized to alarm the specialists.

In this framework LDR sensor is utilized to distinguish the nearness of light. Consequently light gets one and can be controlled utilizing the driven button. In case in case any fire happens within the coal mine, at that point an caution notification is send to the mail of the authorized individual. Temperature and mugginess values are moreover persistently observed and shown on the serial screen additionally within the thinger stage. The created framework is primarily actualized to make strides the working condition interior the coal mines conjointly to guarantee laborers security.

While Zigbee technology facilitates the transmission of data between locations, it does come with certain limitations. Primarily, its effective range is limited to around 300 meters, constraining its utility in scenarios requiring longer-distance communication. Moreover, one significant drawback is the inability to accurately localize miners or assets within this range, posing challenges in scenarios such as mining operations where precise location tracking is crucial for safety and efficiency. Despite its advantages in data transmission, these drawbacks highlight the need for alternative solutions or supplementary technologies to address specific use case requirements effectively.

TiO2 has garnered significant attention for its exceptional photocatalytic properties, particularly in the degradation of pollutants in the air. However, the effectiveness of TiO2 in photocatalysis is profoundly influenced by its structural characteristics and morphological features. The study begins with an in-depth review of the existing literature, exploring the various structural designs and morphologies adopted for TiO2 in photocatalytic applications.

This endeavors to provide novel insights into ground control practices within the realm of intelligent mining, focusing on the integration of Internet of Things (IoT) technologies. As mining operations [14] evolve toward greater automation and connectivity, ensuring effective ground control becomes paramount for the safety, stability, and overall efficiency of mining activities. This study explores emerging trends, challenges, and innovative solutions in ground control, driven by the transformative capabilities of IoT in the context of intelligent mining.

In the dynamic and hazardous environment of coal mining, ensuring the safety of workers and optimizing production processes are paramount concerns. This [1] leveraging the capabilities of Wireless Sensor Networks (WSNs). The system integrates advanced sensor technologies with realtime data communication to enable continuous monitoring of various parameters crucial for safety and operational efficiency. The Wireless Sensor Networks deployed in this system provide a distributed network of intelligent sensors strategically placed throughout the coal mine.

3.Proposed Method

The proposed system aims to enhance safety in the mining industry through the integration of various sensors and LoRa (Long Range) technology for data transmission and localization of miners. LoRa technology utilizes chirp spread spectrum modulation to encode information on radio waves, allowing for long-distance communication with low power consumption.

In this system, different sensors are employed to monitor various parameters critical to miners' safety. For instance, a CH4 sensor is utilized to detect methane gas levels in the mine. When the gas concentration exceeds a threshold, an alarm is triggered to alert officials, and a TiO2 filter is automatically activated to mitigate the hazardous gas presence.

Additionally, an SPO2 sensor is used in cold mining environments to monitor oxygen levels and prevent inhalation of toxic gases. The sensor readings are displayed on an LCD screen for real-time monitoring by personnel.

The collected sensor data is transmitted to a microcontroller, which serves as the central processing unit. The microcontroller then communicates with a LoRa transmitter to send the data to a receiver unit located outside the mine. This setup enables remote monitoring of environmental conditions and miners' health status in real-time.

Moreover, the proposed system includes RSSI (Received Signal Strength Indication) based localization using the LoRa module. By measuring the signal strength of the master module at different locations within the mine, the exact positions of miners can be determined. This localization feature enhances safety by enabling rapid response in emergency situations and facilitating efficient rescue operations.

Furthermore, the system's graphical user interface (GUI) is designed to accommodate up to 255 slave nodes, allowing for comprehensive monitoring of multiple miners simultaneously. Overall, this integrated approach aims to significantly improve safety measures for mining workers by providing timely alerts, accurate localization, and comprehensive data monitoring capabilities.

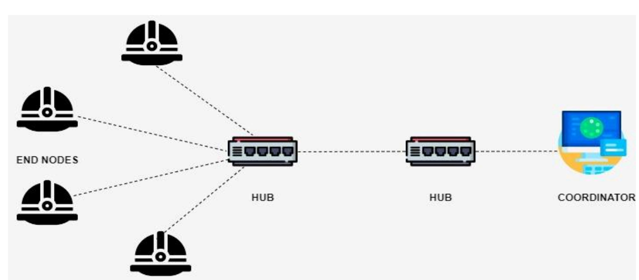

Fig 1 Proposed Network

In the context of this network, hub serve as the devices responsible for directing traffic between different networks. They act as intermediaries, facilitating communication between devices within the network and potentially with external networks. In fig1, there are two hub depicted, one positioned at the top and another at the bottom.

The coordinator device plays a crucial role in mesh networks by overseeing and coordinating communication between other devices within the network. It serves as a central hub, managing the flow of data between end nodes and routers nodes represent the devices that users connect to in order to access the network. These could include sensors, monitoring devices, or other equipment used in the mine environment. nodes interact with hub and other devices in the network to transmit and receive data, enabling various applications..

3.1 Architecture of Proposed Model

In the fig 2 Gas Sensor is responsible for detecting the presence and concentration of hazardous gases in the environment, such as methane (CH4).MAX30102 is commonly used for measuring physiological parameters such as heart rate and blood oxygen levels (SpO2). LM35 is a temperature sensor that measures ambient temperature. These sensors continuously collect environmental and physiological data relevant to the safety and well-being of the worker.The ADC converts the analog signals from the sensors into digital data that can be processed by the microcontroller.This conversion process ensures that
the data collected from the sensors can be accurately represented and analyzed by the digital systems.

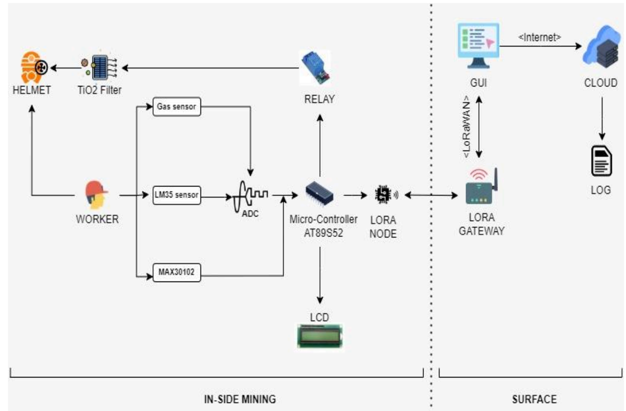

Fig 2 Architecture

In the fig 2 The microcontroller receives the digital sensor data from the ADC and processes it. It perform tasks such as monitoring gas concentration levels, analyzing physiological parameters, and controlling other components. For example, when the gas concentration exceeds a predetermined threshold, the microcontroller triggers an alarm and activates the TiO2(Titanium Dioxide) filter to mitigate the hazardous gas presence.

The LORA node is responsible for wirelessly transmitting the processed sensor data to the LORA gateway.It utilizes LORA (Long Range) communication technology, which is suitable for long-distance, low-power communication in industrial environments like mines. The LORA gateway receives the data transmitted by the LORA node. It serves as a bridge between the local sensor network and the cloud infrastructure.The gateway relays the data to the cloud for storage, analysis, and visualization.The cloud platform stores the sensor data collected from the mine workers' helmets.

The GUI display provide real-time feedback to the worker, displaying relevant environmental and physiological data.This information allows the worker to monitor their own health and safety status while working in the mine.The system send alerts to surface personnel or control centers in case of critical events, such as a sudden increase in gas concentration or a worker experiencing physiological distress.These alerts enable timely responses to potential safety threats, helping to mitigate risks and ensure the well-being of the workers.

Overall, this system integrates sensors, data processing, wireless communication, and cloud-based analytics to create a comprehensive safety monitoring and alerting solution for workers in mining environments. It enables real-time monitoring of environmental conditions and worker health, facilitating proactive measures to ensure safety and mitigate risks.

3.2. Sensitivity curve of methane sensor

The fig 3 illustrates the sensitivity of an MQ-4 gas sensor to various gases, including methane (CH4), liquefied petroleum gas (LPG), smoke, air, and hydrogen (H2). The x-axis of the graph is labeled "Rs/Ro," which represents the ratio of the sensor's resistance in clean air (Ro) to its resistance in the presence of a gas (Rs). This ratio is often used in gas sensor applications to quantify the sensitivity of the sensor to different gases. A higher Rs/Ro value indicates greater sensitivity of the sensor to a particular gas.

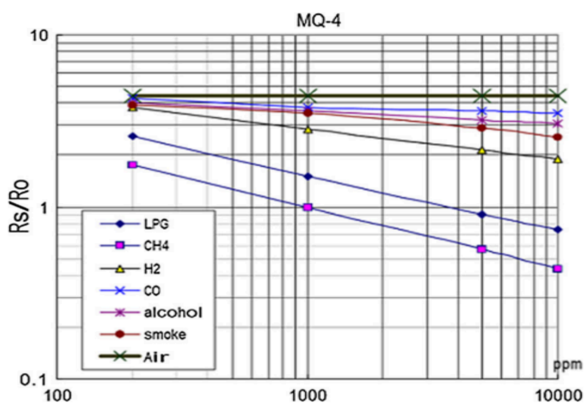

Fig 3 sensitivity curve of mq4

The y-axis represents the concentration of the gas being detected, measured in parts per million (ppm). This unit indicates the proportion of the gas present in a million parts of air. it shows the sensitivity of the MQ-4 sensor to different gases at varying concentrations. The sensor's sensitivity is depicted by the magnitude of the Rs/Ro value for each gas concentration. Higher Rs/Ro values indicate greater sensitivity of the sensor to the respective gas.

Fig 3 illustrates that the MQ-4 sensor is most sensitive to methane (CH4), followed by liquefied petroleum gas (LPG), smoke, hydrogen (H2), and air. This sensitivity ranking provides valuable information about the sensor's performance and its ability to detect different gases.The graph also demonstrates how the sensor's sensitivity to each gas increases as the concentration of the gas increases. This relationship is crucial for understanding the sensor's response to varying gas concentrations in the environment. For example, the sensitivity of the sensor to methane increases significantly as the concentration of methane increases from 100 ppm to 10,000 ppm.

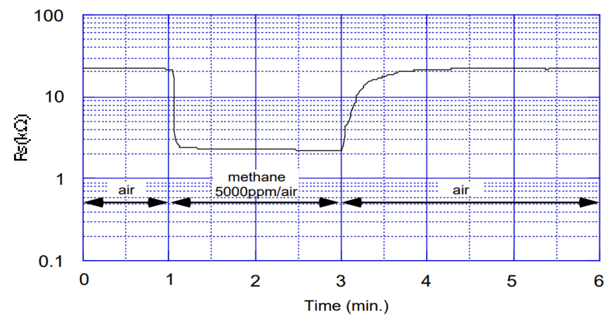

Fig 4 response to methane

In fig 4 The x-axis represents time elapsed in minutes. This axis allows us to track changes in the sensor's response over time, providing a timeline of events from the initial exposure to methane until the sensor's response returns to baseline levels.The y-axis measures the sensor's resistance, typically in kilo ohms. Each major tick mark on the y-axis likely represents 1 kΩ, as indicated by the text near the top of the y-axis.

Initially, the sensor's resistance is high and stable at around 10 kΩ. This value represents the baseline resistance of the sensor in clean air, where there is no presence of methane or other gases. Around the 1-minute mark on the graph, the sensor's resistance starts to decrease. This decrease indicates that the sensor is being exposed to methane, causing its resistance to drop.The resistance continues to decrease rapidly for about 2 minutes, reaching a minimum value of around 2 kΩ. This significant decrease in resistance suggests that the sensor is detecting a substantial concentration of methane in the environment.

3.3 Work flow

In Fig 5, labeled gas sensor, is likely an MQ-4 sensor . It employments metal oxide to distinguish the nearness of different gasses, counting methane (CH4). The sensor's resistance changes depending on the sort and concentration of gas present.The ADC piece, or

Analog-to-Digital Converter, takes the analog voltage flag from the gas sensor and changes over it into an advanced flag that the microcontroller can understand.

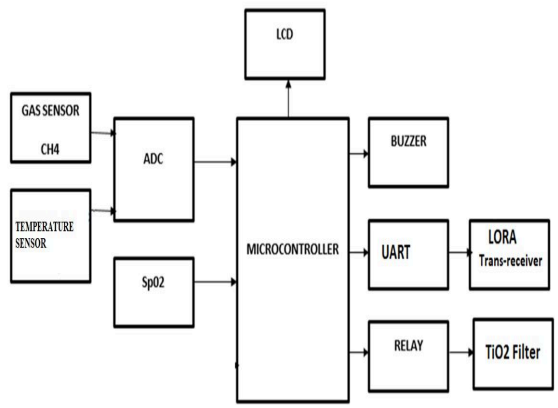

Fig 5 block diagram

The microcontroller is the brain of the indoor regulator. It gets the computerized flag from the ADC, forms it, and makes choices based on the modified rationale. It moreover controls the other components of the indoor regulator, such as the transfer and the buzzer.Universal Nonconcurrent Collector Transmitter, may be a interface that permits the microcontroller to communicate with other gadgets, such as a computer or a smartphone. This can be utilized for observing or arranging the thermostat.

The LORA handset could be a low-power remote communication module. It permits the indoor regulator to communicate with other gadgets over long separations, indeed in zones with destitute flag quality. This might be utilized for farther checking or control of the thermostat.Liquid Gem Show, is utilized to show data on the indoor regulator, such as the current temperature, the set temperature, and any blunder messages.

The buzzer is an capable of being heard caution that can be utilized to caution the client to potential issues, such as a gas spill or a moo battery.The transfer is an electromechanical switch that controls the warming or cooling framework. The microcontroller turns the transfer on and off based on the temperature readings and the modified settings.

The temperature sensor measures the surrounding temperature. This data is utilized by the microcontroller to decide on the off chance that the warming or cooling system has to turned on or off.Overall, the gas sensor based indoor regulator employments a combination of sensors, a microcontroller, and other components to screen gas levels, temperature, and other natural variables.

3.4 Prototype Developed

The prototype comprises two key units: the sensing unit and the transceiver unit. The sensing unit incorporates essential components such as the Arduino UNO controller board, the MQ4 methane sensor, Spo2 sensor, and LM35 temperature sensor. To comply with safety regulations in underground mines, the battery power supply is meticulously designed to be intrinsically safe. All components are seamlessly interconnected, forming a robust system, as depicted in Fig. 6.

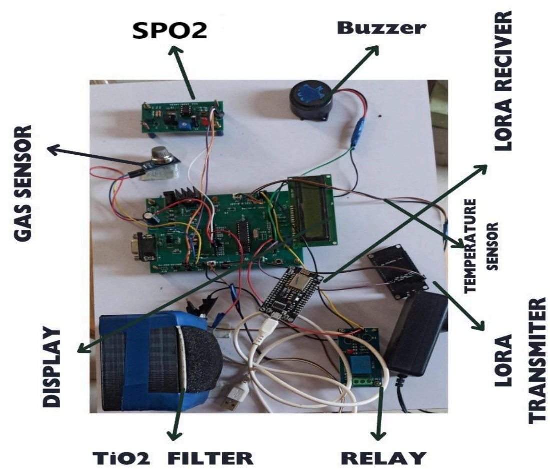

Fig 6 Prototype

Additionally, a sophisticated data monitoring and management application has been crafted to seamlessly collect and display the sensed data in real-time as shown in fig 7. This application, developed using Visual Basic, offers a user-friendly interface to visualize and plot the data values. Visual Basic, renowned for its object oriented approach,facilitates swift development of web,mobile apps, and web services, enhancing the efficiency and effectiveness of the overall system.

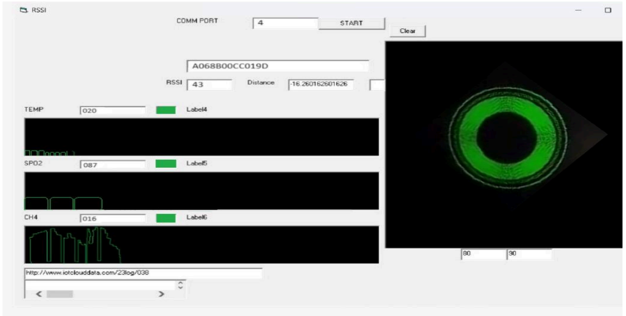

Fig 7 screenshot of GUI

3.4.1 Condition 1 (value is normal)

Figure 8 provides crucial real-time data readings, meticulously verified using calibrated laboratory meters. At the recorded instance, the temperature stands at a comfortable 28°C, while the methane level registers at 16 analog value units. Simultaneously, the oxidation level is determined to be 87%. Additionally, valuable spatial information is relayed, indicating the end node's distance from the surface as 16.26 meters. Moreover, the signal strength received from the node is quantified at a robust 43 units, enhancing the reliability of the transmitted data.

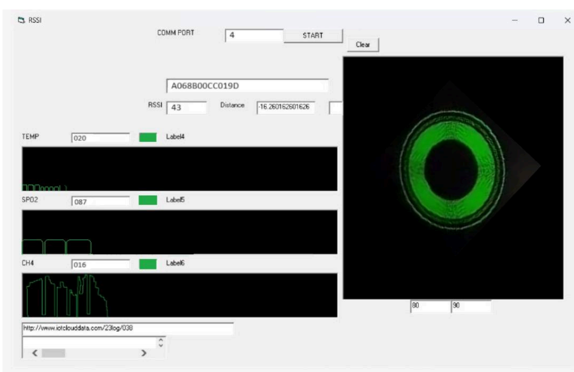

Fig 8 screenshot of GUI

3.4.2 Condition 2(value is not normal)

Figure 9 presents pivotal real-time data, meticulously validated using precision laboratory meters. At the moment of recording, the temperature reports a comfortable 42°C, with methane levels detected at 360 analog value units. Simultaneously , the oxidation level reads 91%, indicating the environmental conditions. Furthermore, spatial data reveals the end node's distance from the surface as 16.26 meters. Notably, the signal strength received from the node remains robust at 43 units, underscoring the reliability of the transmitted data.

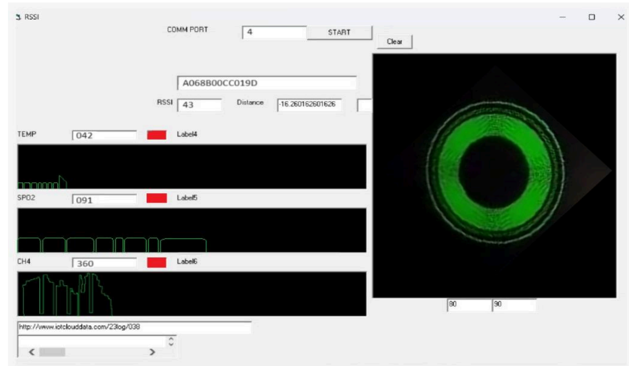

Fig 9 screenshot of GUI

4 Conclusion

In conclusion, the development of a low-cost smart helmet for real-time remote underground coal mine environment monitoring and alert system using LoRa and IoT represents a significant stride towards enhancing safety, efficiency, and overall operational excellence in underground mining operations. The integration of cutting-edge technologies addresses the unique challenges posed by the subterranean environment, ensuring a holistic approach to worker well-being and environmental sustainability.The utilization of LoRa (Long Range) communication technology, coupled with Internet of Things (IoT) principles, forms the backbone of this innovative system. The low-cost aspect ensures scalability and accessibility, making it feasible for widespread adoption across mining operations, regardless of scale or budget constraints. The deployment of sensors within the smart helmet, including those for body temperature, heart rate, oxidation state, and methane gas leakage, provides a comprehensive real-time monitoring solution.The LoRa communication network enables seamless and long-range data transmission, allowing mining operators to remotely monitor the conditions of underground environments. The integration with IoT facilitates centralized data management, analysis, and the generation of actionable insights. This real-time monitoring capability empowers mining personnel with the information needed to respond promptly to potential hazards, ensuring a proactive approach to safety.

The system's alert mechanism serves as a critical component, providing instant notifications in the event of abnormal conditions or emergencies. The incorporation of LoRa ensures reliable communication even in the challenging conditions of underground mines, where traditional communication methods may falter.Moreover, the low-cost smart helmet promotes a cost-effective solution without compromising on the quality or breadth of monitoring capabilities. This affordability factor is crucial for widespread implementation, especially in resource-constrained environments.

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