

Smart Helmet For Mining Workers Using Iot

V. Nanda Gopal Reddy¹, M. Vishnu Vardhan Reddy², Asish Panigrahi^{3*}, DR.CH. Bhupathi⁴

¹K L Deemed to Be University, Guntur, India, 2100100030@kluniversity.in

² K L Deemed to Be University, Guntur, India, 2100100023@kluniversity.in

^{3*} K L Deemed to Be University, Guntur, India, 2100100016@kluniversity.in

⁴ Department IOT, KL UNIVERSITY, Guntur (522303), Andhra Pradesh, bhupati@kluniversity.in

*Corresponding author: 2100100016@kluniversity.in

ABSTRACT

Mining is one of the most dangerous professions, with miners frequently exposed to harmful environmental conditions like poisonous gases, high temperatures, and low oxygen levels. In order to improve the safety of miners, this project suggests the creation of a smart helmet based on LoRa (Long Range) technology and the ESP32 microcontroller. The intelligent helmet is equipped with several sensors, such as gas sensors (for detecting toxic gases like carbon monoxide and methane), temperature sensors, and humidity sensors, as well as a GPS module for real-time tracking. The data collected from these sensors is processed on the ESP32 microcontroller and wirelessly transmitted over long distances via LoRa technology so as to provide continuous monitoring from a centralized control room. During critical situations, like the presence of toxic gases or hazardous temperature levels, the helmet produces audible and vibrational signals to alert the worker and, at the same time, sends an emergency signal to the monitoring system. This preventive measure minimizes the chances of accidents and facilitates timely intervention. The suggested system is energy-efficient, light in weight, and can work in harsh mining conditions. By taking advantage of LoRa's long-distance communication and ESP32's computing power, this intelligent helmet greatly enhances the safety and monitoring efficiency of workers in the mining field.

Key words: Smart Helmet, Mining Safety, LoRa Technology, ESP32 Microcontroller, Gas Detection, Real-Time Monitoring, Emergency Alert.

INTRODUCTION:

Mining is one of the most dangerous industries, with workers being exposed to hazardous conditions like toxic gases, heat, low oxygen levels, and the ever-present threat of accidents. Maintaining the safety and health of mining workers is a key challenge that needs innovative and trustworthy solutions. To solve this problem, this project suggests a Smart Helmet based on LoRa technology and the ESP32 microcontroller. The helmet also incorporates gas sensors to detect toxic gases such as methane and carbon monoxide, temperature and humidity sensors for environmental monitoring, and GPS modules for location tracking in real time. The data obtained is processed using the ESP32 and sent wirelessly over long ranges using LoRa, thus allowing the monitoring process to be continuous and be done from a remote-control centre. In the case of dangerous conditions, the system produces audible and vibration signals to notify the worker immediately while at the same time alerting the monitoring system to take instant action. The helmet is lightweight, energy-efficient, and strong, enabling it to withstand harsh underground conditions. The data can also be recorded and analyzed to determine possible safety risks and improve mining operations. The employment of long-range LoRa communication guarantees safe data transfer in deep underground regions where traditional networks are inoperative. Through the use of LoRa's long-distance communication and ESP32's processing power, the smart helmet greatly improves workers' safety, minimizes accident occurrence, and provides quick response during emergencies, thereby making the mining operation safer and more secure.

LITERATURE REVIEW

Several smart safety systems for protecting the miners have been designed in recent times with the help of technologies like Zigbee, Wi-Fi, Bluetooth, GSM, GPS, and RFID. Systems based on Zigbee and Wi-Fi offer real-time monitoring but are plagued with the issues of low range and interference of signals within underground environments. Smart helmets using Bluetooth technology for short-distance communication are not ideal for

application in extensive areas of the mine. GSM and GPS-based systems provide broad coverage but consume a lot of energy and can fail in heavily underground environments with poor cellular reception. RFID-based safety solutions are restricted to proximity detection and do not possess robust environmental sensing abilities. However, LoRa (Long Range) technology with the ESP32 microcontroller has proved to be an effective solution as it supports long-range, low-power communication that is apt for harsh mine environments. While LoRa-based systems have been utilized in agriculture and environmental monitoring, their use in mining safety is comparatively less explored. In addition, most existing smart helmets lack holistic safety features like gas sensing, temperature measurement, and real-time location tracking within a single system. Most traditional safety systems are also cumbersome, uncomfortable to wear, and offer limited battery life, rendering them unsuitable for extended mining operations. The suggested smart helmet solves these problems by using miniaturized and power-saving devices that ensure real-time tracking without sacrificing comfort. Utilizing LoRa and ESP32, this system provides a stable data transmission even under adverse underground conditions, providing a holistic and efficient solution to protect mining workers and lower the accident risk.

Barua et al. [1] came up with a design of a smart helmet to provide safety for underground miners, highlighting the implementation of integrated sensors within the helmet to identify dangerous conditions like the presence of methane, carbon monoxide, and other dangerous gases. Their design consists of wireless communication to notify the worker and a central monitoring station. The article adds value to accident-preventing early detection systems, which are essential for mines. The helmet system developed by Eldemerdash et al. [2] using IoT showcases the seamless integration of embedded systems and cloud services. Their design was centered on real-time gas sensing and internet-based communication for remote monitoring and control. The authors showed how IoT platforms could offer scalable solutions to improve mine worker safety and proposed a systematic data analysis approach to handle environmental measurements. Zigbee-based systems have also been extensively researched. Bhagat et al. [3] implemented a smart helmet with Zigbee for wireless short-range communication. Their system comprised gas sensors, a vibration sensor, and a microcontroller to generate alerts. Joshi and Das [4] also simulated a coal mine scenario with Zigbee-based helmet systems, looking to minimize data latency and increase reliability in communication. Whereas Zigbee was effective for indoor short-range communication, both studies cited limitations in underground range and handling of obstructions. Mardonova and Choi [5] presented a thorough review of wearable technologies for mining. They presented the development of sensors and communication systems and indicated the increasing contribution of wearable IoT devices in real-time monitoring of safety. They also stressed the importance of energy-efficient, rugged, and flexible solutions to operate in severe mining conditions. Their research emphasized the promise of LoRa technology for long-distance, low-power communication in underground and remote areas. Roja and Srihari [6][9] proposed an IoT-based smart helmet focusing on air quality monitoring, incorporating gas sensors like MQ-135 and temperature sensors to detect environmental changes. Their system utilized Wi-Fi for data transmission and provided alerts through mobile applications. This approach allowed supervisors to monitor multiple miners simultaneously and enabled real-time decision-making during emergencies.

Mishra et al. [7] also added advanced functionality to smart helmets with the inclusion of smart algorithms to process sensor data. Their system tracked multiple parameters and utilized threshold values for the generation of alerts. The research presented a nicely balanced hardware-software integration, with potential application towards continuous monitoring in underground environments. Revindran et al. [8] and Ramya et al. [10] designed sophisticated helmets that incorporated mobile apps for visualization of data. These systems, in addition to monitoring environmental parameters, also featured GPS modules to track the location of the miners. Their study highlighted the role of UI/UX design in making safety systems more user-friendly and manageable for workers as well as safety officers. Mobile-based monitoring was also brought into focus in the research of Dr. V. Balaji Vijayan et al. [11] and Talpur et al. [14], who designed smart helmets with specialized mobile apps. Their models provided instant alerts and real-time logging of data, facilitating easy monitoring of historical data and trends regarding miner health and environmental hazards. These studies pointed

towards increasing synergy between embedded systems and mobile technologies. A few other research works experimented with different sensor combinations and safety aspects. Hazarika [12] and Rudrawar et al. [13]

integrated modules that tracked physical activity and health metrics such as heart rate, motion, and falls. These designs focused on low-cost development on platforms such as Arduino, making the systems more practical for widespread use in resource-limited mining areas. Dhanalakshmi et al. [15] emphasized increasing miner awareness and safety through smart helmets with sensor-based alerting systems. Their system provided audible alerts based on gas detection or unusual temperature readings. Deokar et al. [17], Godsea et al. [18], and Swetha et al. [19] created similar models based on combinations of gas sensors, accelerometers, and heart rate monitors to continuously monitor working conditions and worker health.

One significant development in communication protocol was made by Porselvi and Gopalakrishnan [20], who designed a LoRaWAN-based smart helmet for coal mine safety. LoRaWAN provides long-range, low-power communication that is suitable for underground environments where conventional wireless technologies such as Wi-Fi and Zigbee are not feasible. Their solution featured a central gateway to receive and process data from various helmet units, highlighting enhanced network scalability and fault tolerance. This mechanism resolves the vital challenge of signal degeneration in mining regions deep within, and LoRa thus stands as a strong contender for upcoming safety systems.

The block diagram illustrates a Smart Helmet system that was created in order to promote the health monitoring and safety of mining employees by employing LoRa (Long Range) wireless technology. The system is segmented into two distinct segments: the worker's Smart Helmet and the remote Monitoring Station. The Smart Helmet is provided with a detailed *Sensor Unit* comprising multiple sensors like a gas sensor for the detection of toxic gases, a temperature sensor to sense ambient temperature, a humidity sensor to sense moisture content, a motion/vibration sensor to sense movement or falls, and a heart rate sensor to sense the physical condition of the worker. The information from these sensors is relayed to a Microcontroller housed in the helmet. The sensor information is read and prepared by the microcontroller for transmission. This ready-to-transmit data is then communicated wirelessly by a *LoRa Transceiver*, which due to its ability to communicate far distances at low power, suits best the conditions underground or deep within mines. On the other hand, the *Monitoring Station* gets the transferred data via a *LoRa Gateway*. The gateway acts as a receiver and sends the data to another **Microcontroller, which processes the information and sends it to a **Display/Alert User Interface*. This user interface, either through a PC or mobile app, enables safety personnel or supervisors to view real-time situations like presence of toxic gas, abnormal heart rate, or immobility of workers. When any unsafe situation arises, the system may provide alerts to instigate quick response. In total, this Smart Helmet system facilitates real-time and remote monitoring of employees in dangerous workplaces. It guarantees rapid response to emergencies, enhances situational awareness, and improves worker safety extensively through the employment of efficient and reliable LoRa-based communication.

The flowchart illustrates a smart safety monitoring system that incorporates helmet detection together with gas leak and air quality monitoring to facilitate rider safety. The process initiates from the Start block where the system initializes. The first decision block monitors the status of the Helmet Removal Sensor to determine if the helmet has been taken off. If the helmet is found to be worn (NO), the system is in the monitoring state and keeps on monitoring the sensor for the occurrence of any variation.

If the helmet is taken off (YES), the system instantly triggers a set of Gas Sensors to determine the environment around it. These include the MQ-2 to detect methane and flammable gases, the MQ-7 to sense carbon monoxide (CO), and the MQ-135 to check carbon dioxide (CO₂) levels and overall air quality. All these gas values are important in detecting adverse situations that can threaten the safety of the rider.

Following data acquisition, the system conducts Hardware Analysis to analyze and interpret the sensor data. The analyzed data is then sent to an Android application, enabling users to remotely view safety parameters in real time. Furthermore, the system triggers a Buzzer Alert to give instant audio alerts, allowing for timely awareness of any risks detected. This dual alarm system, which pairs remote application notifications with audible alarms, offers greater safety management by ensuring that the rider and outside witnesses are both

immediately alerted to possible threats. The cycle then repeats to the beginning, providing ongoing vigilance for increased safety

The table gives a general report of gas levels and their corresponding safety levels as measured by particular sensors. It emphasizes four important gases: Methane (CH₄), Carbon Monoxide (CO), Carbon Dioxide (CO₂), and General Air Quality, along with sensors for detecting them (MQ-2, MQ-7, and MQ-135). The target range for Methane is 0-1000 ppm, with anything above 1000 ppm being hazardous because it can explode and particularly above 5000 ppm. Carbon Monoxide, as sensed by the MQ-7 sensor, is harmless in the range of 0-50 ppm, but anything above 50 ppm can lead to headaches and dizziness and above 400 ppm is fatal. In Carbon Dioxide, the standard level is 400-1000 ppm, though higher than this can induce sleepiness, while levels higher than 5000 ppm are enough to cause suffocation. For general air quality, monitored through MQ-135 sensor, figures lower than 100 ppm is good quality while figures above 300 ppm could mean poor quality air with dangerous health effects.

CONCLUSION

Smart Helmet for Mining Personnel based on LoRa Communication is a major milestone toward improving safety in dangerous underground conditions. It combines several gas sensors like MQ-2, MQ-7, and MQ-135 to efficiently identify the presence of dangerous gases like methane, carbon monoxide, and carbon dioxide. These gases are dangerous to health and can cause fatal accidents if not identified early. The helmet, driven by the ESP-32 microcontroller, runs real-time sensor data processing and applies LoRa technology for low-power, long-range communication. This enables effective transmission of environmental information from underground regions to surface observation stations, triggering timely alarms and immediate emergency response. The helmet is made to be light in weight, affordable, and resilient enough for harsh mining environments. Automating environmental monitoring, it reduces human error and improves decision-making in the event of emergencies. The data obtained can also be retained and analyzed for enhancing safety measures and maintenance planning. The minimal power usage offers long operating hours without the need for constant recharging. Moreover, the system promotes preventive safety instead of reactive safety. Upgrades in the future could be in the form of biometric health sensors, fall sensing, and GPS-based location tracking. This renders the solution scalable and compliant with different industrial requirements. Finally, this project proves how IoT and intelligent communication technologies can be deployed to enhance worker safety and work efficiency in the mining industry.

This Figure 1 depicts a serial monitor and plotter interface (presumably from the Arduino IDE) connected to an ESP32 Dev Module through COM17, with real-time data from an MQ135 gas sensor. The console log entries consistently report a sensor reading of 1678, with the system deciding the air quality is safe, represented by the green dot and message. The graph area is currently blank, though numerous value channels are enabled and interpolation is on, indicating it's primed for plotting data when it begins to stream. The baud rate is 115200, and there's a message input field to transmit messages to the ESP32 module.

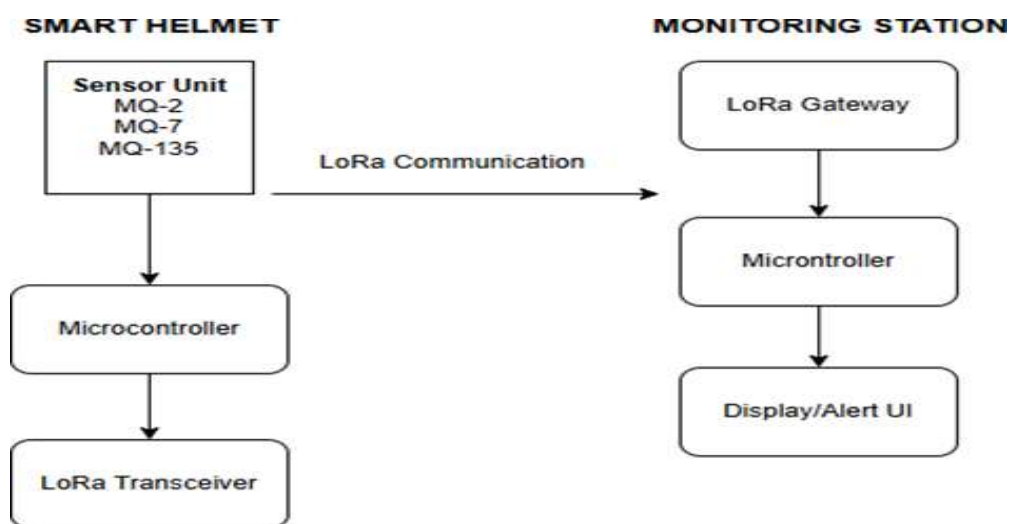
This Figure 2 shows the Arduino serial monitor and plotter interface connected to an ESP32 Dev Module via COM17, receiving data from an MQ2 gas sensor. The console displays sensor values ranging between 752 and 756, consistently followed by the message "No harmful gasses found," indicating that the air is safe. The graph area is blank, possibly due to no selected value for plotting, though interpolation is enabled and channels value 2, 3, 4, and 5 are checked. The baud rate remains at 115200, and a text box is available for sending commands to the ESP32.

The Smart Mining Worker Helmet is a wearable safety device that ensures protection for miners in dangerous working conditions through communication and real-time monitoring. The system revolves around an ESP32 microcontroller that gathers information from an MQ gas sensor used to sense harmful or combustible gases that are normally present in mines. It incorporates a LoRa module for long-range low-power wireless communication, enabling the helmet to relay key environmental information to a remote monitoring station

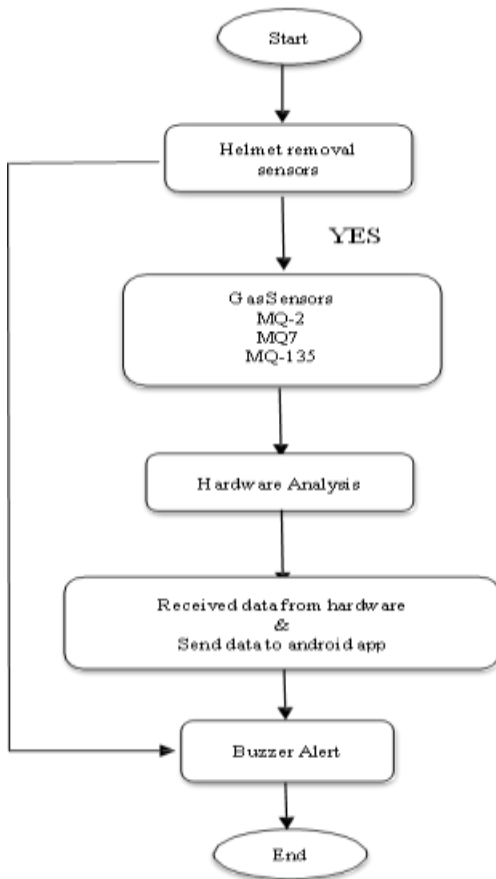
even in remote or deep areas. By incorporating these elements in a standard safety helmet, the device provides constant monitoring of gases and stable communication, far enhancing worker safety and situation awareness in mining activities.

Table 1: Gas Monitoring and Safety Thresholds

Gas	Sensor	Normal Range	Danger ous Range	Effects at Dangerous level
Methene (CH ₄)	MQ-2	0-100ppm	Above 100ppm	Explosive risk above 500ppm
Carbon Monoxide (CO)	MQ-7	0-50 ppm	Above 50 ppm	Headache, dizziness at 50-200 ppm, life threatening above 400 ppm
Carbon Dioxide (CO ₂)	MQ-135	400-1000 ppm	Above 1000ppm	Drowsiness at 1000-2000 ppm, suffocation risk above 5000 ppm
Air Quality (General)	MQ-135	Below 100 ppm	Above 300 ppm (Poor quality)	Health effects for sensitive individuals



Block diagram



Flowchart



Figure 1: Output of MQ-135 sensor

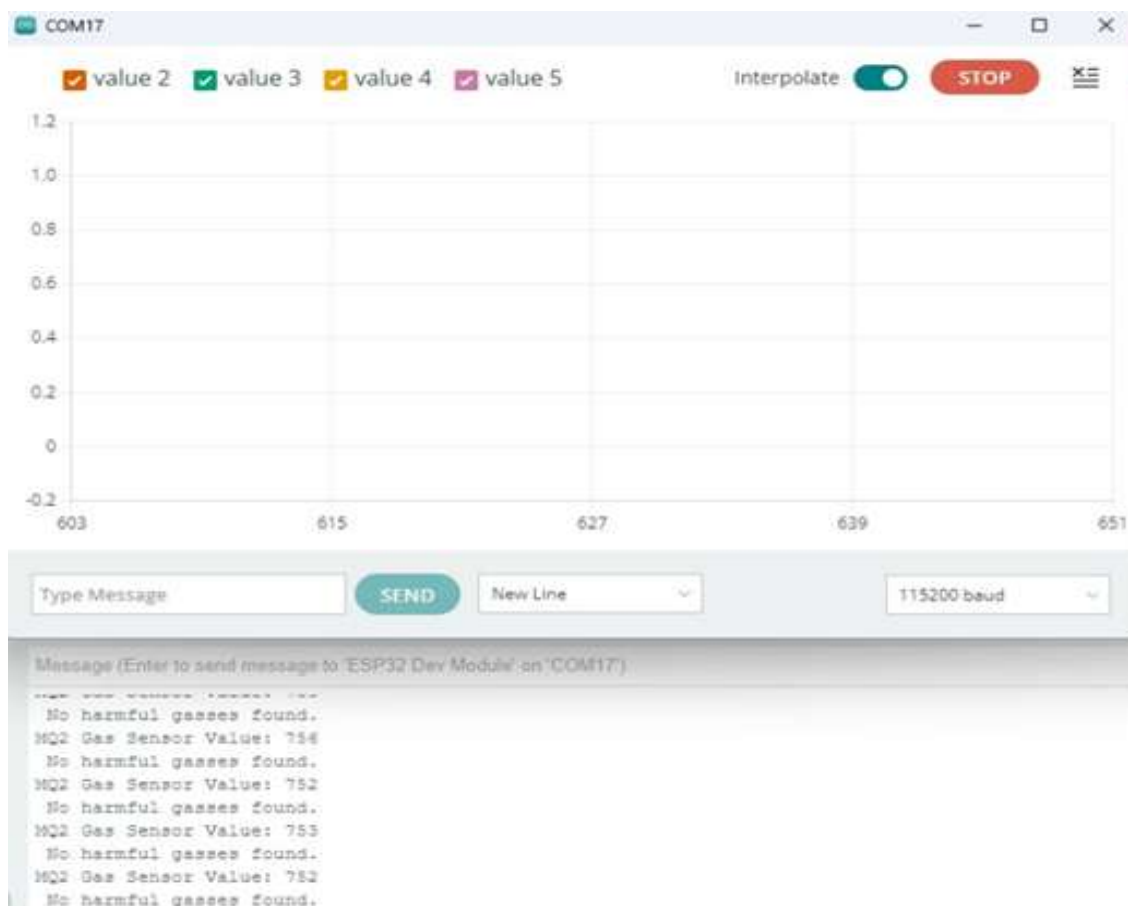


Figure 2: Output of MQ-2 sensor

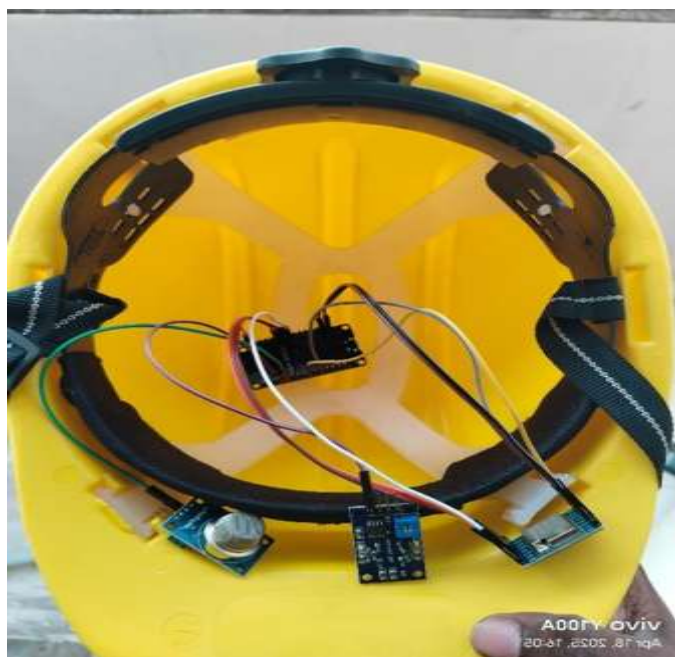


Figure 3: Project prototype

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