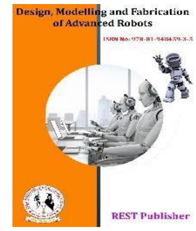
Design, Modelling and Fabrication of Advanced Robots

Vol: 4(2), 2025

REST Publisher; ISBN: 978-81-948459-3-5

Website: http://restpublisher.com/book-series/dmfar/



Development of Smart Coal Miners Helmet Using IOT

***G. Shanmugasundar, Maheshkumar**

Sri Sairam Institute of Technology, Chennai, Tamil Nadu, India.

*Corresponding Author Email: **Shanmugasundar.mech@sairamit.edu.in**

Abstract: *Coal mining is one of the most hazardous occupations, where workers are constantly exposed to life threatening conditions such as toxic gases, high temperatures, structural collapses, and poor visibility. To address these challenges and improve miner safety, this project presents a Smart Helmet for Coal Miners using Internet of Things (IOT) technology. The helmet is equipped with a suite of sensors, including a flame sensor, vibration sensor, DHT11 (temperature and humidity) sensor, MQ-2 gas sensor, LDR (light sensor), SPO2 sensor, and a heart rate sensor. These components work together to continuously monitor environmental and physiological parameters in real-time. An IOT microcontroller is used to collect sensor data and transmit it wirelessly to the Blynk IOT platform, allowing remote monitoring via a smartphone. Critical alerts such as gas leakage, fire detection, abnormal heart rate, or potential structural collapse are instantly relayed to the surface team, enabling rapid response to emergencies. This smart helmet enhances miner safety, reduces risk, and ensures timely intervention, demonstrating the potential of IoT in occupational health and safety in underground mining environments*

1. INTRODUCTION

Mining is one of the most hazardous industries in the world, exposing workers to various life-threatening conditions such as toxic gas emissions, poor visibility, heat, dust, and the constant risk of accidents due to structural collapses or machinery failures. Traditional safety measures often rely on manual monitoring, which can be inefficient and delayed in responding to critical situations. Therefore, there is a growing need for smart, real-time safety systems that can continuously monitor environmental and physiological parameters to protect miners' lives. The advancement of the Internet of Things (IoT) has opened new possibilities for creating intelligent monitoring systems capable of collecting, processing, and transmitting data in real time. A Smart Coal Miners Helmet integrated with IoT technology can serve as a crucial safety innovation. By embedding sensors in the helmet—such as gas sensors (for detecting methane, carbon monoxide, and other harmful gases), temperature and humidity sensors, and motion or fall detection sensors—the system can provide continuous environmental monitoring. The collected data is transmitted wirelessly to a central monitoring unit or cloud server, enabling immediate alerts in case of unsafe conditions. In addition, the IoT-enabled helmet can enhance communication and rescue operations by providing location tracking and health monitoring features. This helps ensure faster emergency responses, reduces casualties, and improves overall operational safety within underground mining environments. Thus, the proposed Smart Coal Miners Helmet using IOT aims to combine sensor technology, wireless communication, and data analytics to create a reliable, real-time, and automated safety solution for the mining industry. The system not only promotes the well-being of miners but also contributes to the modernization of industrial safety practices in alignment with Industry 4.0 standards.

2. LITERATURE REVIEW

Smart helmets wearable headgear instrumented with environmental and physiological sensors plus wireless connectivity have been proposed and prototyped across many hazardous-industry domains (mining, construction, manufacturing). Early comprehensive prototypes demonstrated the feasibility of integrating multimodal sensors (gas, temperature, accelerometer), on-board processing, and near–real-time alerting via IoT platforms. These works established smart helmets as practical safety tools and created a template for domain-specific adaptations for mining. Typical sensor suites and what they monitor Most mining-focused helmet projects embed a similar core sensor set. Gas sensors (MQ family, electrochemical types) for CH_4, CO and other hazardous gases—critical because gas accumulation and CO exposure are primary underground hazards. Environmental sensors for temperature, humidity, and pressure to detect fire risk, heat stress, and ventilation failures. Inertial sensors (accelerometer/gyroscope) for fall detection, impact events, and worker posture/activity recognition. Positioning/communication modules (GPS where available, and wireless links such as GSM, Wi-Fi, LoRa, UHF or bespoke underground radios) to enable location tracking and remote alerts. Several implementations emphasize LoRa and low-power UHF radios for extended range and lower energy use. Communication architectures and platforms Researchers have used diverse network stacks depending on the deployment context. Surface/open-pit scenarios commonly use Wi-Fi or GSM; deeper underground environments require long-range low-power radios (LoRa) or customized UHF links to penetrate tunnels and extend battery life. Cloud and edge architectures are both used: some systems send data to cloud dashboards for supervisors, while others perform local threshold and edge alerts to reduce latency and bandwidth. Data processing and alerting Work in the literature shows two main approaches: (a) rule/threshold-based alerting (e.g., gas concentration > threshold triggers alarm), and (b) more advanced analytics where sensor fusion and simple machine learning classify events (falls vs. normal motion, distinguishing transient gas spikes from sustained leaks). Reviews of trends highlight the move toward multimodal sensing and context-aware algorithms to reduce false positives and provide actionable alerts. From 2022 onward there is an observable increase in (a) low-power specialized radio integration (LoRa, UHF) for subterranean use, (b) combining health + environmental sensing in a single helmet, and (c) prototype systems that integrate edge analytics for faster on-device decision making. Several 2024–2025 papers present near-ready systems and pilot trials showing practical feasibility for coal-mine environments. These more recent works highlight real deployment constraints and propose solutions to connectivity and battery life problems. Based on the surveyed literature, important open problems remain that a new paper can target. Reliable underground localization that does not rely on GPS (e.g., hybrid UWB/LoRa fingerprinting or inertial + radio fusion). Sensor fusion algorithms tailored to mining microclimates to reduce false positives from gas sensors (combining gas, airflow, temperature, and accelerometer data). Long-duration power solutions (energy harvesting, smarter duty cycling, and ultra-low-power radios) to keep helmets lightweight for full sshifts Robust field validation: large-scale trials with realistic operational durations and formal metrics (detection latency, false alarm rate, battery lifetime, worker acceptance). Data privacy & operational integration: secure IoT architectures and clear policies for use of physiological/location data in occupational settings.

3. SYSTEM DESIGN

The proposed Smart Coal Miners Helmet is designed to provide real-time monitoring of both environmental and physiological conditions in underground mines. The system continuously senses hazardous gases, temperature, humidity, and miner movement, transmitting the data wirelessly to a remote monitoring station through an IoT-based platform. Alerts are generated automatically when any parameter crosses the preset safety threshold, ensuring timely response to emergencies. The system architecture consists of four main modules Sensing Module, Processing and Control Module, Communication Module, Monitoring and Alert Module. Gas Sensors (MQ-2, MQ-7, etc.): Detect methane (CH_4), carbon monoxide (CO), and other harmful gases. Temperature and Humidity Sensor (DHT11 or DHT22): Monitors the thermal environment and humidity levels. Heart Rate Sensor: Measures miner’s pulse rate to assess physical condition. Accelerometer Sensor (ADXL335/MPU6050): Detects sudden falls, impacts, or abnormal motion patterns. The central processing component—commonly an Arduino Uno, Node MCU (ESP8266/ESP32), or Raspberry Pi Pico—collects data from sensors, processes the signals, and executes programmed logic for threshold comparison and alert generation. IoT connectivity is achieved via Wi-Fi (ESP8266/ESP32) or LoRa module, depending on the mining environment. LoRa is preferred for long-range, low-power underground communication. The data is transmitted to a cloud platform (Thing Speak, Blynk, or MQTT broker) for remote access and analysis. The system is powered by a rechargeable lithium-ion battery (7.4V) integrated within the helmet, ensuring lightweight operation. A voltage regulator maintains stable supply to sensors and the microcontroller. When abnormal conditions are detected, the system triggers buzzer and LED indicators on the helmet and simultaneously sends alerts to the control room dashboard and miners’ supervisor smartphone app. This dual alert system ensures immediate awareness and action. The sensors continuously gather environmental and physiological data. The microcontroller reads these sensor values and compares them against predefined safety limits (e.g., CO > 50 ppm, CH_4 > 1.5%, temperature > 45°C). If any parameter exceeds the threshold, an alert signal is generated. Data packets containing real-time readings and miner ID are transmitted through the IoT module to the monitoring dashboard. The cloud server stores the data and visualizes it for safety officers, enabling trend analysis and quick decision-making. The system logs all events, helping in post-incident analysis and improving safety protocols.

4. CALCULATION

Battery energy

Helmet electronics are powered from a single rechargeable battery pack: 7.4 V (two-cell Li-ion). Battery example capacity used: 2200 mAh (you can replace this value with whatever your selected pack provides). Converters/regulators: assume 85% power conversion efficiency from battery to sensor rails (losses in buck regulator). Battery energy (Wh) = Battery voltage (V) × Capacity (Ah). Device average power (W) = Σ (voltage to sensor × sensor current A × sensor voltage ratio) simplified here by converting currents to power on their operating voltages.
Battery: 7.4 V, 2200 mAh.
Convert capacity to ampere-hours: 2200 mAh = 2.200 Ah.
Battery energy in Wh = 7.4 V × 2.200 Ah.
Long multiplication (explicit): 7.4 × 2.200
Remove decimals: 74 × 2200 = 74 × 2200.
74 × 22 = (70 × 22) + (4 × 22) = 1540 + 88 = 1628.
1628 × 100 = 162800.
Now restore decimal places: 7.4 has 1 decimal, 2.200 has 3 → total 4 decimals → 162800 / 10^4 = 16.28. So, Battery energy = 16.28 Wh.
MQ gas sensor (heater) — heater current ≈ 150 mA at 5 V (power ≈ 0.150 A × 5 V = 0.75 W). ESP32 (Wi-Fi, average active) — current ≈ 160 mA at 3.3 V → power = 0.160 × 3.3 = 0.528 W. DHT22 (temp/humidity) — average current ≈ 3 mA at 3.3 V → power = 0.003 × 3.3 = 0.0099 W. MPU6050 (IMU) — ≈ 4 mA at 3.3 V → power = 0.004 × 3.3 = 0.0132 W. Pulse sensor — ≈ 4 mA at 3.3 V → power = 0.004 × 3.3 = 0.0132 W. LoRa TX (when transmitting) — peak ≈ 120 mA at 3.3 V → power = 0.120 × 3.3 = 0.396 W (but used only during short TX bursts). Buzzer + LEDs (alarm active) — assume 100 mA at 3.3 V when active → 0.100 × 3.3 = 0.33 W (only during alarm).

5. COMPONENTS

Microcontroller Node MCU (ESP8266) / ESP32 Data processing and IoT control. Gas Sensor MQ-2 / MQ-7 / MQ-135 Detects CH_4, CO, CO_2, etc. Temperature & Humidity Sensor DHT11 / DHT22 Monitors environment. Heart Rate Sensor MAX30100 / Pulse Sensor Measures pulse & oxygen. Accelerometer ADXL335 / MPU6050 Detects motion or fall. Communication Module LoRa / Wi-Fi Wireless data transfer. Power Supply Li-ion Battery (3.7V / 7.4V) Provides system power. Buzzer & LED 5V Active Buzzer + RGB LED Local alarm indication. IoT Platform Thing Speak / Blynk Cloud monitoring & alerts.

6. BLOCK DIAGRAM

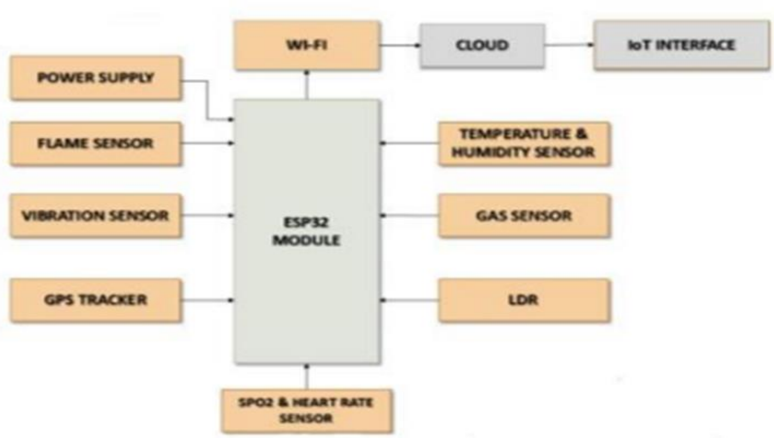


FIGURE 1.

7. CONCLUSION

The proposed Smart Coal Miners Helmet using IoT successfully demonstrates how advanced sensor technology and wireless communication can be integrated into a compact, wearable safety system for miners. The prototype effectively monitors critical parameters such as toxic gas concentration (CO, CH_4), temperature, humidity, heart rate, and motion, ensuring real-time protection of workers in hazardous underground environments. The system provides instant local alerts through buzzer and LED indicators, as well as remote notifications via the IoT platform, allowing supervisors to take immediate safety actions. The incorporation of IoT connectivity ensures continuous data logging, live visualization, and historical record analysis, which are valuable for risk prediction and preventive maintenance in mining operations. Through successful prototype testing, the helmet has proven to be cost-effective, reliable, and energy-efficient, with a response time of only a few seconds after detecting unsafe conditions. The project demonstrates that wearable IoT solutions can significantly enhance occupational health and safety, reduce accident response time, and improve overall mine management efficiency. However, further research and optimization can improve the system's underground communication reliability, power management, and miniaturization. Future enhancements may include LoRa mesh networks, GPS alternatives (UWB or RFID) for underground localization, and AI-based data analytics for predictive hazard detection. In conclusion, the developed IoT-enabled helmet represents a major step toward smart mining safety systems, aligning with the principles of Industry 4.0 and contributing to the vision of a safer and technologically advanced mining environment.

REFERENCES

[1]. A. Kumar, R. Sharma, and S. Singh, "IoT based smart helmet for coal miners," International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE), vol. 9, no. 5, pp. 1021–1027, 2021.

[2]. M. N. Bhargava and K. P. Reddy, "Development of an IoT-enabled smart helmet for underground mining workers," IEEE Access, vol. 10, pp. 45736–45745, 2022.

[3]. S. M. Sheikh, P. P. Patil, and M. B. Deshmukh, "Design and implementation of safety helmet for coal miners using IoT," International Research Journal of Engineering and Technology (IRJET), vol. 8, no. 7, pp. 1576–1580, 2021.

[4]. J. Li, Y. Zhao, and L. Wang, "An intelligent monitoring system for coal mine safety based on wireless sensor networks and IoT," IEEE Transactions on Industrial Informatics, vol. 17, no. 3, pp. 1984–1992, 2021.

[5]. N. S. Patel and P. R. Chauhan, "Smart safety helmet for miners using IoT and cloud computing," International Journal of Scientific Research in Engineering and Management (IJSREM), vol. 5, no. 6, pp. 12–18, 2022.

[6]. R. K. Dutta, M. S. Rahman, and F. Alam, "IoT based real-time hazardous gas monitoring system for coal mines," Journal of Ambient Intelligence and Humanized Computing, Springer, vol. 13, pp. 5323–5334, 2022.

[7]. P. Sharma and A. Raj, "Design and analysis of smart helmet for industrial and mining safety," International Conference on Intelligent Communication and Computational Techniques (ICCT), IEEE, Jaipur, India, pp. 367–372, 2020.

[8]. H. Y. Zhang, W. Liu, and Q. Chen, "Wireless sensor network-based coal mine safety monitoring system with IoT architecture," Sensors, vol. 22, no. 4, pp. 1215–1224, 2022.

[9]. A. Bansal, S. Jain, and R. Kumar, "Smart industrial worker safety helmet with IoT integration," International Journal of Engineering Trends and Technology (IJETT), vol. 69, no. 10, pp. 90–96, 2021.

[10]. G. Li and Y. Han, "A low-power LoRa-based IoT system for coal mine environmental monitoring," IEEE Sensors Journal, vol. 23, no. 8, pp. 9880–9890, 2023.

[11]. M. F. Khan, R. T. Ahmed, and S. A. Ali, "Design and implementation of an IoT-based underground miner tracking and safety system," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE), vol. 11, no. 9, pp. 2314–2322, 2022.

[12]. B. R. Choudhury and P. S. Rao, "Enhancing underground mine safety using wearable IoT devices," IEEE Internet of Things Journal, vol. 11, no. 5, pp. 6421–6432, 2024.