# CRANIUMGUARDPRO

# AN IoT-BASED SMART HELMET FOR COAL MINER'S SAFETY

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## ABSTRACT

Coal mining remains one of the most dangerous occupations, exposing workers to toxic gases, extreme temperatures and the risk of cave-ins. This paper presents Cranium Guard Pro,an IoT-enabled smart helmet that enhances miner safety through real-time environmental and motion monitoring. Gas sensors, a temperature and humidity sensor ,and an accelerometer are integrated with an ESP32 microcontroller. When hazardous thresholds are exceeded, local alerts are provided via buzzer and LED indicators, while wireless communication modules transmit real-time data to the surface monitoring station. The proposed system offers a cost-effective and portable solution to safeguard miners and reduce fatalities.

## KEYWORDS

*Smart Helmet ,IoT, Coal Mining Safety, Gas Detection, Wireless Monitoring, Hazard Prevention.*

## INTRODUCTION

Coal continues to supply a significant portion of the world's energy needs, yet underground mining exposes workers to methane and carbon monoxide leaks, extreme heat, and sudden cave-ins. Traditional safety equipment cannot provide continuous, real-time alerts, often leading to delayed responses during emergencies. With the growth of Internet of Things (IoT) technologies and low-cost sensors, it is now feasible to design intelligent safety systems. This work introduces *Cranium Guard Pro*, a smart helmet capable of detecting toxic gases, abnormal temperature or humidity levels, and sudden impacts, thereby improving both individual and group safety in underground mines.

## LITERATUREREVIEW

Coal mining has long presented severe occupational hazards, motivating decades of research into technologies that enhance worker safety. Early approaches focused on fixed gas detection systems within mineshafts, but these often failed to provide real-time protection for individual miners. To understand prior work, Madhuri et al. (2023) proposed a sustainable smart helmet using IoT technology to detect methane and carbon monoxide; their design highlighted the potential of low-power wireless transmission but required periodic sensor recalibration for accuracy. Yadav and Jaiswal (2023) implemented a wireless sensor network for coal mine monitoring and demonstrated how multi-hop communication can maintain connectivity in deep underground environments. Singh and Kumar (2021) reviewed a broad range of smart helmet systems and emphasized the need for multi-sensor integration and predictive analytics to identify areas requiring further investigation.

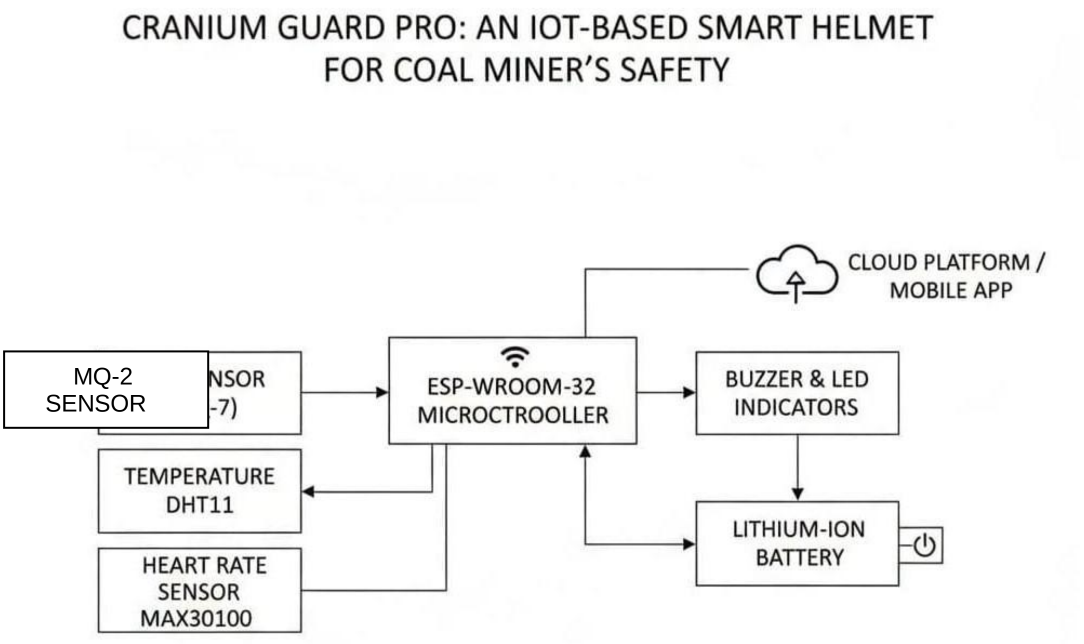
Beyond mining, Kartik and Manimaran (2023) described an IoT-based helmet for general industrial hazard detection, showcasing the value of combining accelerometers with environmental sensors to detect falls and collisions. Babu et al. (2025) explored gas monitoring and alerting systems using GSM modules, illustrating the trade-off between wireless range and energy consumption. To provide context and justification for this study, other researchers have examined complementary technologies such as LoRa-based long-range communication and energy harvesting to overcome power limitations in remote environments.

These investigations collectively demonstrate that while significant progress has been made in wireless hazard detection, challenges persist in ensuring reliable operation under harsh underground conditions—especially regarding signal attenuation, battery life, and real-time multi-parameter monitoring. The *Cranium Guard Pro* system builds on these findings by integrating multiple sensing modalities—gas, temperature/humidity, and motion—while employing an ESP32 microcontroller with versatile communication options (LoRa/GSM). This approach seeks to overcome the key limitations identified in prior literature: limited wireless range, frequent battery replacement, and the absence of an integrated, portable solution for individual miners.

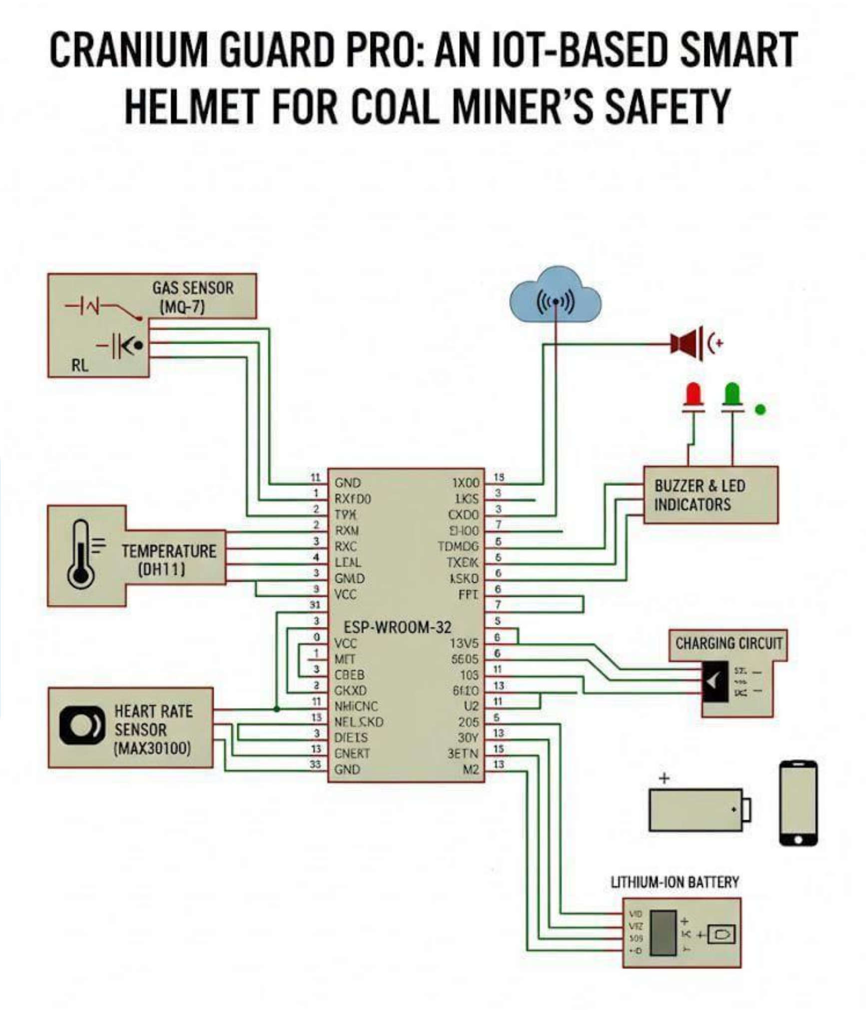
## SYSTEMARCHITECTURE

The system architecture integrates multiple sensors with an ESP32 microcontroller. Sensor data are continuously acquired and transmitted via a wireless module (LoRa/GSM) to a surface monitoring station.

**BLOCK DIAGRAM-**



**CIRCUIT DIAGRAM-**

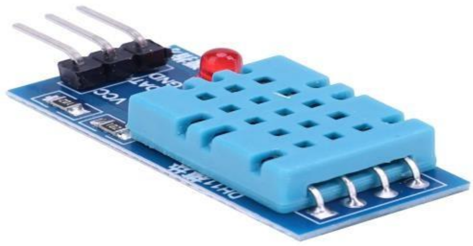



## HARDWARE REQUIREMENTS AND SPECIFICATIONS

**1. MQ-2Gas Sensor:**


It detects carbon monoxide and methane concentrations in parts per million (ppm). The sensor outputs an analog signal proportional to the gas level, enabling early detection of hazardous leaks and triggering alerts to prevent suffocation or explosions.

**2. DHT11 Temperature & Humidity Sensor:**



The DHT11 Temperature and Humidity Sensor is a low-cost digital sensor that measures both temperature and relative humidity in the surrounding environment. It uses a capacitive humidity sensor and a thermistor to detect air conditions and provides calibrated digital output signals. The DHT11 is easy to interface with microcontrollers such as Arduino or ESP32, making it widely used in weather monitoring, smart home, and IoT applications. It operates within a voltage range of 3.3V to 5V and communicates through a single-wire digital signal, ensuring simple data transmission. The sensor provides reliable readings with a temperature range of 0°C to 50°C and a humidity range of 20% to 90% RH.

**3. ESP32 Microcontroller**:


It serves as the system's processing unit, collecting sensor data, applying threshold logic, and controlling wireless communication. Integrated Wi-Fi, Bluetooth, and low-power features make it ideal for underground environments. The ESP32 is a versatile, low-cost, and low-power family of System-on-Chips (SoCs) from Espressif Systems, designed for IoT applications. It integrates Wi-Fi and Bluetooth connectivity with Tensilica Xtensa or RISC-V processors. Key features include a wide array of GPIOs, ADC/DAC converters, touch sensors, and support for various communication protocols. The ESP32 comes in different series (Original, S, C, H, P), each offering unique features such as single or dual-core processors, different connectivity options, and external memory support—making it suitable for a diverse range of projects, from simple sensor nodes to complex industrial applications.

**4. Heart Rate Sensor MAX30100:**


The MAX30100 Heart Rate Sensor is an integrated pulse oximeter and heart rate monitoring module that combines two LEDs (red and infrared), a photodetector, and low-noise analog signal processing. It works by emitting light through body tissue, such as a fingertip, and detecting the reflected light to measure pulse rate and blood oxygen saturation ($SpO_2$). The sensor operates at a voltage range of 1.8V to 3.3V and communicates via the I²C interface, making it easy to connect with microcontrollers such as Arduino and ESP32. It features low power consumption, making it suitable for wearable and portable health-monitoring devices.

**5. Buzzer and LED Indicators:**

Buzzers and LEDs provide immediate local alerts to the miner when unsafe conditions are detected. Visual and audible warnings enable quick evacuation or protective action. Both components are easy to interface with microcontrollers. Together, buzzers and LEDs enhance user interaction, improve system monitoring, and ensure timely alerts in real-time applications such as security systems and health monitoring.

**6. Lithium-ION Battery:**

The lithium-ion battery is a highly efficient rechargeable energy storage device that operates through the movement of lithium ions between its anode and cathode during charging and discharging cycles. It offers several advantages, including high energy density, low self-discharge rate, and a long lifespan compared to traditional battery types. Due to its lightweight design and reliable performance, it is extensively used in portable electronics, electric vehicles, and Internet of Things (IoT) applications. The safety and performance of lithium-ion batteries continue to improve with advancements in materials and battery management technologies.

## WORKING

The sensors continuously monitor environmental and motion parameters, while the ESP32 compares each reading against predefined safety thresholds. When a toxic gas level or temperature exceeds the limit, or when a fall is detected, the microcontroller activates the buzzer and LED for an immediate warning and simultaneously sends an alert via the wireless module to the surface control station. This enables operators to initiate emergency procedures without delay.

The system offers numerous advantages, such as real-time monitoring, immediate alert generation, and portability. It ensures early detection of hazardous gases and dangerous conditions, thereby reducing response time during emergencies. The helmet’s modular design allows its application beyond coal mining, including use in construction sites, oil refineries, chemical plants, and tunneling operations. Its IoT-based connectivity supports real-time data visualization on remote dashboards, enabling predictive analytics and safety trend analysis. The integration of environmental and motion sensing enhances operational safety and improves decision-making efficiency in hazardous industrial environments.

## RESULT

A prototype helmet was tested in a controlled laboratory environment. The MQ-2 successfully detected simulated carbon monoxide leaks, while the DHT11 accurately monitored temperature and humidity variations. The accelerometer reliably detected sudden impacts. Alerts were transmitted in under two seconds, demonstrating the system’s effectiveness in providing both local and remote warnings.

## FUTURESCOPE

The future of coal miner smart helmets includes advanced gas and seismic detection, integration with AI for predictive analytics, enhanced real-time communication with noise filtering, and improved miner health monitoring for fatigue and dehydration detection. The scope also extends to asset tracking with GPS, robust communication across challenging terrains, and integration with broader IoT systems for emergency coordination and autonomous safety inspections using drones.

## CONCLUSION

*Cranium Guard Pro* demonstrates how IoT and multi-sensor technology can significantly enhance safety in underground coal mines. By providing real-time detection of toxic gases, temperature anomalies, and accidental falls, and by transmitting immediate alerts both locally and remotely, the system offers a cost-effective and portable solution to protect miners and reduce fatalities.

## REFERENCES

i. Madhuri,A.,Ramesh,K.,&Sreelatha,K.(2023).SustainableSmartHelmetforCoalMinersusingIoT Technology. E3S Web of Conferences, 01099. Retrieved from https://www.e3sconferences.org/articles/e3sconf/abs/2023/67/e3sconf_icmpc2023_01099/e3sconf_icmpc2023_01099.htmlhttps://www.e3s-conferences.org/articles/e3sconf/abs/2023/67/e3sconf_icmpc2023_01099/e3sconf_icmpc2023_01099.html

ii. Babu, V.A., Raju, R., & Kumar, P. (2025). Harmful Gases Monitoring with Smart Helmet andAlerting System. International Journal for Research in Applied Science and Engineering Technology (IJRASET). Retrieved from https://www.ijraset.com/research-paper/harmful-gases-monitoring-with-smart-helmet-and-alerting-system

iii. Yadav, R., & Jaiswal,A. (2023). SmAart Helmet for Coal Mine Monitoring Using Wireless Sensor Network. In: Smart and Sustainable Computing Techniques (pp. 25–37). Springer. Retrieved from https://link.springer.com/chapter/10.1007/978-981-19-1976-3_3

iv. Kartik,R., &Manimaran, M.(2023).IoTbased SmartHelmetforHazard Detection in MiningIndustry.arXiv preprint. Retrieved from https://arxiv.org/abs/2304.10156

v. Singh, N., & Kumar,A. (2021).AReview on Smart Helmet Systems for MiningApplications.Applied Sciences, 11(11), 5039. Retrieved from https://www.mdpi.com/2076-3417/11/11/5039