ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr1279

Seamless Communication for Mining Workers Using IoT-Enabled Smart Helmets

Saroj Shambharkar[1]; Manisha Chaudhari[2]; Tannu Uikey[3]; Sumaiya Sheikh[4]; Janhvi Khadotkar[5]; Shreyash Dubey[6]

[1]Head of Department, Information Technology,
Kavikulguru Institute of Technology and Science, Ramtek
[2–6]Students, Department of Information Technology,
Kavikulguru Institute of Technology and Science, Ramtek – 441106

Publication Date: 2025/05/15

Abstract: The integration of IoT-based smart helmets is transforming the mining industry by enabling uninterrupted communication and connectivity for on-site workers. These helmets come embedded with advanced sensors that continuously track health parameters and surrounding environmental data. Utilizing wireless communication networks and real-time data transfer, these helmets maintain a steady link between miners and central monitoring units. This ensures that any hazardous situation is detected early, allowing for instant alerts and quick action. Such innovations significantly enhance workplace safety and boost operational productivity. As the mining sector advances toward automation and smart technologies, these helmets are becoming essential tools in fostering safe, efficient, and digitally connected operations. The ability to communicate and make decisions instantly in emergencies drastically reduces the likelihood of serious incidents. Traditionally, incident detection relied heavily on manual checks or scheduled observations, often leading to delayed responses. These delays can aggravate injuries or even be fatal during emergency situations. Moreover, traditional communication tools often fail in the noisy, unstable conditions of mines. This can lead to miscommunications and sluggish responses. The IoT smart helmet overcomes these limitations by ensuring clear, real-time communication and continuous tracking of both the worker and the environment.

Keywords: *Gas Sensor, Temperature and Humidity Sensor, NodeMCU, GSM Module, LCD Screen, Emergency (Panic) Button.*

How to Cite: Saroj Shambharkar; Manisha Chaudhari; Tannu Uikey; Sumaiya Sheikh; Janhvi Khadotkar; Shreyash Dubey (2025). Seamless Communication for Mining Workers Using IoT-Enabled Smart Helmets. *International Journal of Innovative Science and Research Technology*, 10(4), 3820-3826.
https://doi.org/10.38124/ijisrt/25apr1279

I. INTRODUCTION

➢ *Mining Safety Background:*

Mining remains among the most hazardous industries worldwide, with workers facing threats such as exposure to toxic gases, cave-ins, and extreme environmental conditions. While traditional safety equipment provides basic protection, it lacks the ability to respond instantly to changes in the surroundings.

➢ *Why Smart Helmets are Necessary:*

Smart helmets are enhanced with advanced sensors and communication systems that help reduce risks by supplying miners and their supervisors with real-time data, instant alerts, and efficient communication methods.

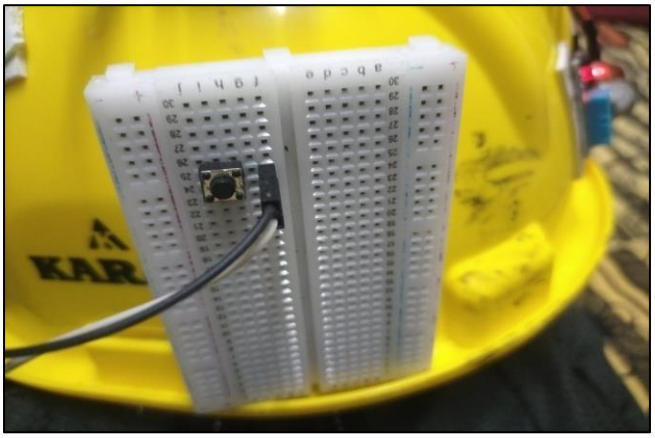
II. DESIGN AND KEY FEATURES OF THE SMART HELMET

➢ *Smart Helmet Capabilities:*

- **Live Health Monitoring:** Tracks vital signs such as heart rate, body temperature, and oxygen levels to ensure worker safety.
- **Environmental Gas Detection:** Monitors the presence of hazardous gases like methane and carbon monoxide.
- **Impact Recognition:** Sends alerts when the helmet detects sudden falls or heavy impacts, ensuring timely response.
- **Two-Way Wireless Communication:** Facilitates seamless interaction between miners and supervisory teams for quick coordination.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr1279

Fig 1 Coal Mining Setup



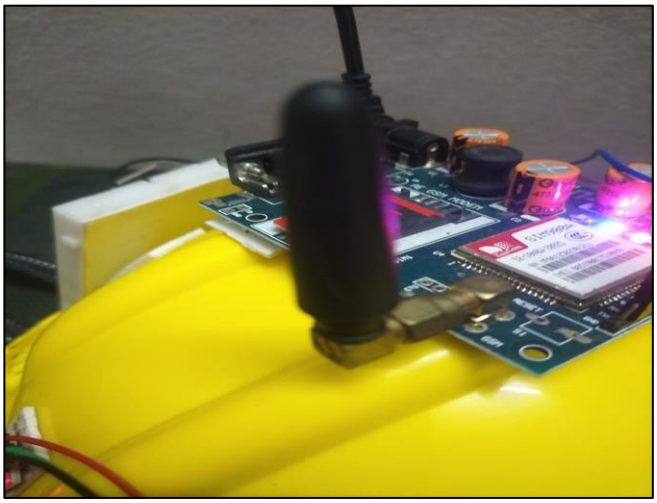


Fig 2 IoT-Enabled Smart Helmet

➢ *Thing Speak Overview:*

Thing Speak is an IoT-based analytics platform that allows users to collect, visualize, and analyze real-time data in the cloud. Devices equipped with sensors can send data directly to ThingSpeak, where it can be instantly visualized, analyzed, and used to trigger alerts. This platform acts as a cloud-based server, enabling remote monitoring of sensor data.

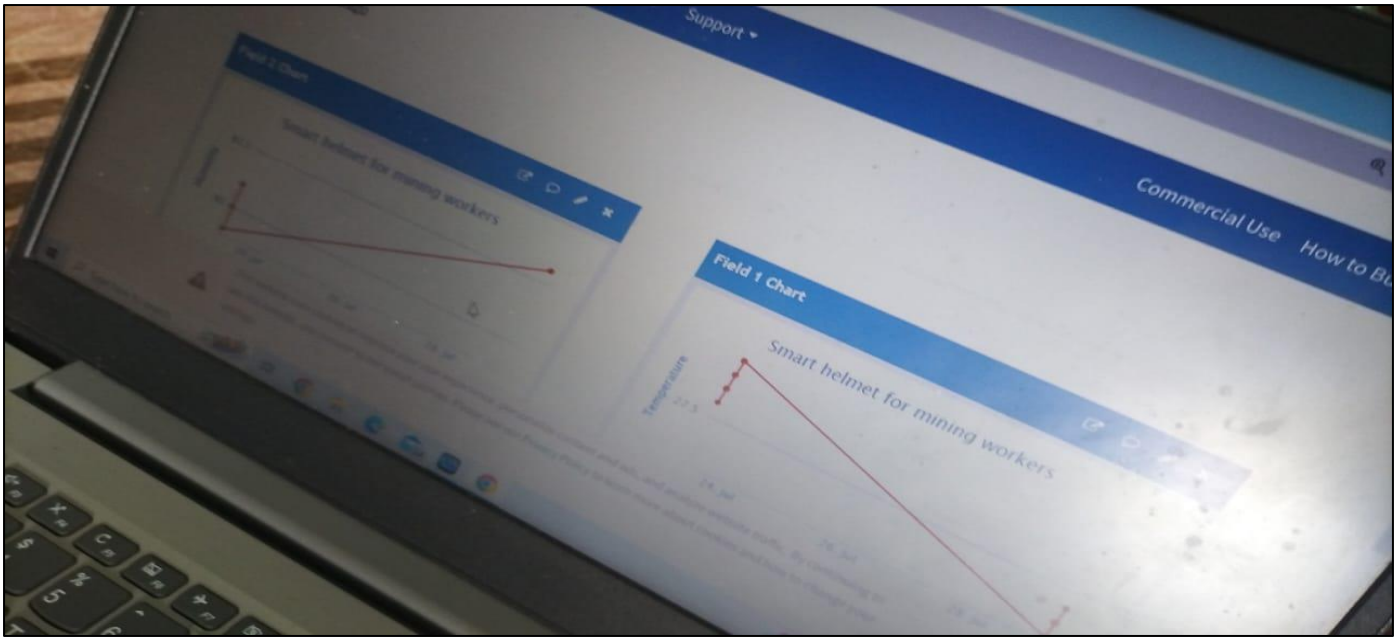


Fig 3 Thing Speak Cloud Based Server

➢ *Sensors and Technologies used*

The smart helmet is embedded with multiple advanced sensors that enhance the safety and awareness of miners in hazardous environments. These sensors include:

- **Gas Detection Sensors:** These sensors identify the presence of harmful gases such as methane (CH_4) and carbon monoxide (CO), which are common in mining environments and can be fatal if undetected.
- **Temperature and Humidity Sensors:** These components continuously monitor the ambient temperature and moisture levels in the mine, helping to detect overheating or extreme humidity that could indicate unsafe conditions.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr1279

- **Pressure Sensors:** Used to detect variations in atmospheric or structural pressure, which can be early indicators of potential mine collapses or ventilation failures. These integrated sensors play a crucial role in collecting real-time data, which is then transmitted for monitoring and action.

➢ *Communication Framework*

To ensure uninterrupted and responsive communication, the smart helmet is equipped with:

- **Bluetooth & Wi-Fi Modules:** These allow for wireless connectivity between miners and the control room or supervisors. Bluetooth facilitates short-range communication, while Wi-Fi ensures long-range data transmission to cloud servers for continuous monitoring.
- **GSM Module:** In the absence of internet access, the GSM module provides cellular connectivity for sending alerts through SMS or calls to emergency contacts. This hybrid communication system ensures that miners can stay connected, even in remote underground conditions.

➢ *Safety Mechanisms*

The smart helmet is designed with multiple layers of safety features:

- **Instant Alerts:** When toxic gases or abnormal temperature/humidity levels are detected, the helmet sends immediate alerts to designated personnel.
- **Emergency Panic Button:** In the event of an accident or distress, miners can manually press a built-in panic button. This sends an emergency message and triggers visual/audible indicators such as LEDs or buzzers on the helmet.
- **Fall and Impact Detection:** Accelerometer-based sensors monitor sudden impacts or falls, alerting supervisors if a worker becomes immobile for a certain duration.
- **Vital Sign Monitoring:** Continuously tracks the wearer's physical condition to avoid health-related risks such as heatstroke or oxygen deficiency.
- **Two-Way Communication:** Allows real-time exchange of voice or text information between the miner and the control station, which is especially useful during emergencies or when providing instructions.

III. SYSTEM ARCHITECTURE AND IMPLEMENTATION

The IoT-based smart helmet is engineered to enhance worker safety using a combination of hardware, sensors, and cloud technology. The primary goal is to detect and respond to dangerous environmental conditions in real-time.

- **Microcontroller – NodeMCU ESP8266:** This is the core unit of the helmet, responsible for collecting data from sensors and transmitting it to the cloud. It uses its built-in Wi-Fi capabilities to connect with platforms like ThingSpeak**,** a cloud-based IoT data analytics service.
- **Sensor Integration:** Sensors for gas, temperature, and humidity are wired to the NodeMCU's analog input (A0) and digital pins using jumper wires on a breadboard. They continuously send environmental data to the microcontroller.
- **Data Transmission:** The gathered data is transmitted wirelessly via Wi-Fi to ThingSpeak, where it can be visualized, analyzed, and stored. Alerts can be automated based on set thresholds.

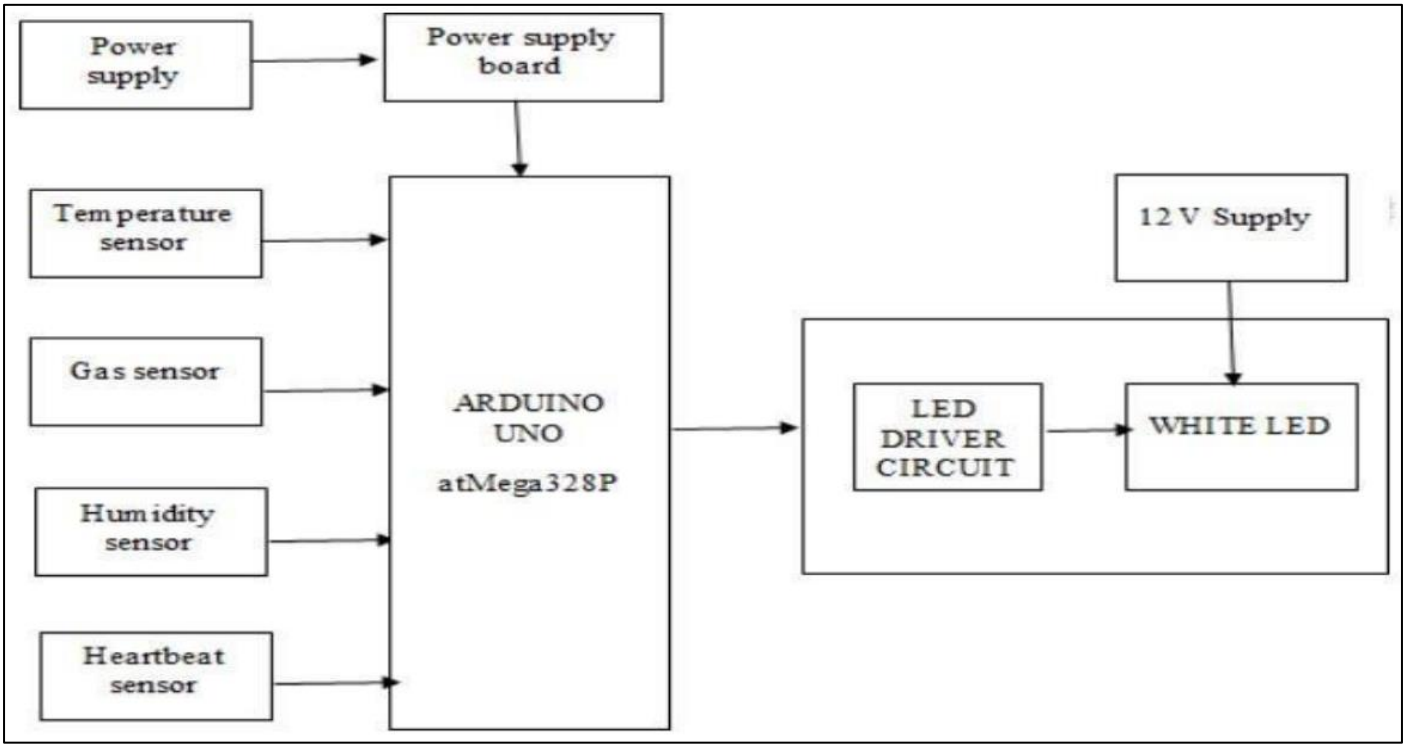


Fig 4 Block Diagram – Operational Flow

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr1279

➢ *Power Activation:*
Turning on the helmet supplies power to the NodeMCU and all connected sensors.

➢ *Data Acquisition:*
The temperature and humidity sensors, along with the gas sensor, begin recording environmental readings at fixed intervals.

➢ *Condition Analysis:*

- Temperature Threshold: If the temperature exceeds 50°C, an alert is triggered.
- Humidity Threshold: If humidity goes beyond 80%, the system notifies the supervisor.

➢ *Emergency Notification:*
If any parameter crosses the danger threshold:

- An SMS or call is sent via the GSM module.
- Optional cloud-based alerts (emails, push notifications) are activated when Wi-Fi is available.

➢ *Panic Button Response:*
Upon pressing the panic button:

- An immediate alert is sent via GSM.
- LEDs or buzzers on the helmet activate to indicate distress.

➢ *Ongoing Surveillance:*
The system continuously gathers sensor data and monitors the panic button. It can shift to low-power mode during inactivity and wake on sensor or button triggers.

➢ *User Feedback:*
Visual (LED) or auditory (buzzer) feedback notifies the user of system status—alerts sent, danger detected, or safe condition confirmations.

➢ *Wiring Instructions:*

- *Sensors to NodeMCU:*
Connect the temperature and humidity sensors to analog/digital pins using jumper cables on a breadboard.

- *GSM Module to Arduino Uno:*
The GSM module is integrated with an Arduino Uno board to enable SMS and call functions.

- *Panic Button to Digital Input:*
The emergency button is connected to a digital pin on the Arduino for immediate response detection.

➢ *Sensor Network and Data Collection*
The smart helmet is equipped with an integrated network of advanced sensors including gas, temperature, humidity, and motion sensors that continuously monitor the surrounding environment. These sensors gather critical real-time data and transmit it wirelessly to a centralized control system. This setup enables continuous tracking of environmental conditions and worker status, forming the backbone of a robust safety infrastructure.

➢ *Data Processing and Artificial Intelligence*
The sensor data is processed locally using edge computing, reducing latency and enabling real-time decision-making on-site. This approach ensures that alerts are generated instantly in the event of detected anomalies such as toxic gas leaks or sudden temperature spikes. AI-driven analytics further enhance the system by predicting potentially hazardous conditions using historical data trends, machine learning algorithms, and pattern recognition techniques. This predictive capability transforms the helmet from a reactive device into a proactive safety solution.

IV. APPLICATIONS AND CASE STUDIES

A. Applications

➢ *Real-World use Cases:*

- **Motorbike Safety:** The smart helmet can be adapted for motorcycle riders, incorporating crash detection, navigation assistance, and emergency alerts.
- **Automobile Integration:** The underlying safety technology can be incorporated into seatbelt systems in cars to detect driver drowsiness or monitor cabin air quality.
- **Construction Sites:** During metro or infrastructure development, the helmet can assist workers by providing real-time environmental feedback and safety alerts.
- **Industrial Safety:** Ideal for chemical plants, oil refineries, or any high-risk environment where toxic exposure or mechanical hazards exist.
- **Firefighter Assistance:** Sensors can monitor air quality and temperature, alerting firefighters when conditions become life-threatening.

B. Field Testing in Mines
Field trials conducted in various mining environments such as coal, gold, and copper mines demonstrated the effectiveness of the smart helmet system. These pilot programs reported a significant decrease in workplace accidents and injuries. Additionally, the technology helped improve operational efficiency by ensuring early detection of hazardous conditions, better resource management, and reduced downtime due to unplanned evacuations.

V. BENEFITS AND CHALLENGES

➢ *Benefits*

- **Enhanced Worker Safety:** Real-time detection of environmental threats ensures immediate response, significantly reducing the risk of accidents.
- **Seamless Communication:** Integrated modules like GSM or LoRa enable uninterrupted communication between workers and control centers, especially in underground environments.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr1279

- **Predictive Maintenance and Analytics:** Data insights support predictive maintenance of equipment and preemptive measures against environmental risks.
- **Operational Efficiency:** Automating safety checks reduces manual labor and increases productivity.

➢ *Challenge*

- **Initial Investment:** The development and deployment of smart helmets require substantial financial resources, particularly for mass adoption.
- **Ongoing Maintenance:** Periodic calibration, software updates, and hardware servicing are essential to maintain accuracy and functionality.
- **User Adaptability:** Comprehensive training programs are necessary to familiarize workers with the helmet's functions and safety protocols.
- **Connectivity Issues:** Underground or remote areas may pose communication challenges due to signal interference or lack of network infrastructure.

VI. FUTURE SCOPE

With the continuous evolution of IoT, AI, and wearable technologies, smart helmets are poised to become standard safety gear across industries. Future versions may include enhanced biometric tracking, real-time language translation for multinational teams, augmented reality displays for on-site instructions, and integration with blockchain for tamper-proof safety logs. The scope extends beyond mining to applications in logistics, aerospace, healthcare, and even disaster management.

VII. CONCLUSION

The smart helmet represents a paradigm shift in occupational safety. By merging sensor technology, edge computing, and artificial intelligence, it provides a holistic solution for real-time hazard detection and worker protection. As industries progress toward digital transformation and automation, smart helmets will be integral to fostering safer and more efficient workplaces.

REFERENCES

[1]. Cheelasani, P., & Gudla, M. (2021). *IoT Based Safety System in Mines*. International Journal of Innovative Research in Science, Engineering and Technology, 9(7), e-ISSN: 2395-0056, p-ISSN: 2395-0072.

[2]. Mankapure, A., Patil, S., Chavan, B., Arikar, S., & Desai, L. (2023). *Smart Helmet for Worker Safety using IoT*. International Journal of Advanced Research, 11(5), ISSN: 2320-2882.

[3]. Shinkar, D., et al. (2019). *IoT Based Smart Helmet for Coal Mining Tracking*. International Research Journal of Engineering and Technology (IRJET), 6(12).

[4]. Singh, N., Gunjan, V. K., Chaudhary, G., Kaluri, R., Victor, N., & Lakshmanna, K. (2022). *IoT Enabled Helmet to Safeguard the Health of Mine Workers*. Computer Communications, 193, ScienceDirect.

[5]. Jayasree, V., & Kumari, M. N. (2020). *IoT Based Smart Helmet for Construction Workers*. IEEE 7th International Conference on Smart Structures and Systems (ICSSS).

[6]. Nandhini, M., Priya, G. V., Nandhini, S., & Dinesh, K. (2023). *IoT Based Smart Helmet for Safety in Industries*. IJERT, 11(5), ISSN: 2320-2882.

[7]. Noorin, M., & KV, S. (2019). *Wearable Device using WSN Technology for Miners*. IEEE RTEICT Conference.

[8]. Garad, S. S., Joshi, M. S., Nimbhorkar, K. A., & Patel, A. R. (2019). *IoT Based Smart Helmet for Coal Mining*. IRJET, 6(12).

[9]. Tajane, P. S., Shelke, S. B., Sadgir, S. B., & Shelke, A. N. (2020). *IoT Mining Tracking & Worker Safety Helmet*. IRJET, **7**(4).

[10]. Deokar, S. R., Kulkarni, V. M., & Wakode, J. S. (2022). *Smart Helmet for Coal Mines Safety Monitoring and Alerting*. International Journal of Advanced Research in Computer and Communication Engineering, 6(7).

[11]. Dube, N., & Ingle, K. S. (2021). *Intelligent Mining: Monitoring & Security System for Workers*. International Journal of Advanced Research in Electrical, Electronics, and Instrumentation Engineering, **5**(1).

[12]. Gupta, S., & Vashisth, R. (2017). *Implementation and Analysis of Smart Helmet*. IEEE International Conference on Signal Processing, Computing.

[13]. Jeong, M., Lee, H., Bae, M., Shin, D. B., Lim, S. H., & Lee, K. B. (2022). *Development and Application of the Smart Helmet for Disaster Safety*. IEEE ICTC.

[14]. Dhame, M. G., & Qureshi, R. (2016). *Smart Helmet for Coal Miners Using ZigBee Technology*. Imperial Journal of Interdisciplinary Research (IJIR), **2**(6), ISSN: 2454-1362.

[15]. Wei, Y., & Ying, H. (2007). *Wireless Sensor Network Based Coal Mine Monitoring Information System*. Sixth International Conference, pp. 13–17.

[16]. IEEE (2009). *Multi-parameter Monitoring System for Coal Miners Using WSN*. International Conference on Industrial Mechatronics and Automation, pp. 225–227.

[17]. Forooshani, E., Bashir, B., Michelson, D. G., & Noghanian, S. (2013). *Wireless Communications in Underground Mines*. IEEE Communications Surveys & Tutorials, 15(4), 1524–1545.

[18]. Qiang, C., Ji-ping, S., Zhe, Z., & Fan, Z. (2009). *ZigBee Based Intelligent Helmet for Coal Miners*. World Congress on Computer Science and Information Engineering.

[19]. Eldemerdash, T., Abdulla, R., Jayapal, V., Nataraj, C., & Abbas, M. K. (2020). *IoT-Based Smart Helmet for Mining Industry Applications*. International Journal of Advanced Science and Technology, **29**(1).

[20]. Singh, V. K., Poojari, K., Rathod, K., Prabhune, S., & Shinde, R. (2021). *Safety Helmet for Coal Miners Using IoT for Tracking*. International Research Journal of Modernization in Engineering Technology and Science, E-ISSN: 2582-5208.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr1279

[21]. Dhanalakshmi, A. (2021). *A Smart Helmet for Improving Safety in the Mining Industry*. International Journal of Innovative Science and Research Technology, ISSN: 2456-2165.

[22]. Choudhari, W. M., & Meghe, D. (2021). *Coal Mine Security System*. International Journal of Applied Information Systems (IJAIS), 4(10), ISSN: 2249-0868.

[23]. Patel, H. K., Desai, D. H., & Badheka, T. G. (2013). *GSM Based Flexible Calling System*. International Journal of Engineering Trends and Technology (IJETT), 4(4).

[24]. Vishwakarma, A., Yash, A., Singh, A., Awasthi, D., & Yadav, R. (2024). *IoT Mining Tracking & Worker Safety Helmet*. International Journal for Research in Applied Science and Engineering Technology (IJRASET).
This study focuses on developing a next-generation smart helmet system that continuously monitors environmental parameters like temperature, humidity, and gas levels, enhancing miner safety through real-time data analysis.

[25]. Patel, S., Goyani, A., Dhameliya, R., & Naiya, B. (2023). *Smart Helmet for Mining Workers*. IJRASET.
The paper discusses the design of a smart helmet integrating sensors for gas detection, temperature monitoring, and communication systems to improve safety in mining environments.

[26]. Yashaswini, J. R., Pavan, P., Basha, M. T., & Divya, P. (2023). *Mine Safe: IoT-Based Smart Helmet for Mining Workers*. Srinivasa Ramanujan Institute of Technology.
This project report presents the development of a smart helmet equipped with various sensors and a voice interface module, aiming to enhance miner safety by providing real-time alerts and monitoring.

[27]. Kartik, B., & Manimaran, P. (2023). *IoT-Based Smart Helmet for Hazard Detection in Mining Industry*. arXiv preprint arXiv:2304.10156.
The research introduces a smart helmet system utilizing wireless sensor networks to monitor hazardous gases and environmental conditions in real-time, aiming to reduce mining accidents.

[28]. Kunekar, P., Karna, S., Banik, A., & Kumar, S. V. (2023). *IoT-Based Smart Helmets for Mining Workers*. International Journal of Creative Research Thoughts (IJCRT).
This paper presents various smart helmet designs incorporating IoT technologies for automated monitoring, enhanced protection, and tracking systems to ensure miner safety.

[29]. Chen, Y., Wang, S., & Liu, L. (2018). *Advancements in Sensor Technologies for Smart Helmets in Coal Mining.*

[30]. Dhanalakshmi, A., Lathapriya, P., & Divya, K. (2017). *A Smart Helmet for Improving Safety in Mining Industry*. International Journal of Innovative Science and Research Technology(IJISRT),2(3).
This paper details the development of a smart helmet featuring two-way communication, hazardous gas detection, and emergency notification systems to enhance miner safety.

[31]. Ravindran, R., & Vijayaraghavan, R. (2023). *IoT-Based Smart Safety Helmet for Mining Workers Using NRF Module*. Journal of Emerging Technologies and Innovative Research(JETIR),10(6).
The study proposes a smart helmet incorporating humidity, temperature, and gas sensors, utilizing NRF modules for wireless communication to monitor and ensure miner safety.

[32]. Hazarika, P. (2016). *Implementation of Safety Helmet for Coal Mine Workers*. 1st IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems.
This conference paper discusses the implementation of a safety helmet designed for coal mine workers, focusing on enhancing safety through technological integration.

[33]. Pradeepkumar, G., & Sanjay, S. (2021). *Smart Helmet for the Mining Industry Using LoRaWAN*.IJRASET.
The research introduces a smart helmet utilizing LoRaWAN technology for real-time monitoring of air quality and miner safety in the mining industry.

BIOGRAPHIC

Saroj Shambharkar HOD, Information Technology Department, Kavikulguru institute of technology and science Ramtek-441106

Manisha Chaudhari final year Student, Dept. Information Technology, Kavikulguru Institute of Technology & science Ramtek-441106

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr1279

Tannu Uikey final year Student, Dept. Information Technology, Kavikulguru Institute of Technology & science Ramtek-441106,

Shreyash Dubey Student, Dept. Information Technology, Kavikulguru Institute of Technology & science Ramtek-

Sumaiya Sheikh Student, Dept. Information Technology, Kavikulguru Institute of Technology & science Ramtek-441106,

Janhvi Khadotkar Student, Dept.Information Technology, Kavikulguru Institute of Technology & science Ramtek-441106,