iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL
FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: IV Month of publication: April 2025

DOI: https://doi.org/10.22214/ijraset.2025.68405

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Design and Implementation of an IoT-Based Coal Mine Safety and Alert System for Improved Miner Safety

Prof. Paritosh Nagarnaik[1], Damini Talmale[2], Priyanka Meshram[3], Kashish Kesharwani[4], Sujal Musale[5]
[1]Asst. Professor, [2, 3, 4, 5]Research Scholar, Department of Computer Science and Engineering, Priyadarshini J.L. College of Engineering, Nagpur, India

Abstract: ***Coal mining is one of the most hazardous industrial activities, often exposing workers to life-threatening conditions such as toxic gas leaks, high temperatures, and equipment failure. To enhance miner safety and minimize accidents, this paper presents the design and development of an IoT-based coal mine safety and alert system [1]. The system integrates various sensors to monitor environmental parameters including methane gas concentration, carbon monoxide levels, temperature, and humidity [1]. Data collected from the sensors is transmitted in real-time to a central monitoring system using wireless communication modules [2]. In case of abnormal conditions, immediate alerts are sent to both miners and surface control units through alarms and mobile notifications [2]. The system enables early detection of potential threats, facilitating timely evacuation and response. By leveraging IoT technology, the proposed solution aims to improve operational safety, reduce manual inspections, and enhance decision-making [3]. The design is cost-effective, scalable, and adaptable to various mine environments. This approach contributes significantly to building a smarter and safer mining ecosystem [3].***
Keywords: IoT, coal mine safety, real-time monitoring, automated alert system, gas detection.

I. INTRODUCTION

The coal mining industry is one of the most hazardous sectors, where workers are frequently exposed to life-threatening risks such as gas leaks, temperature fluctuations, and cave-ins. Ensuring the safety of miners in such an environment is a critical concern that demands advanced and reliable solutions [1]. Traditional monitoring systems often fall short due to their inability to provide real-time data and instant alerts during emergencies [1]. With the evolution of smart technology, the Internet of Things (IoT) offers a promising approach to enhance safety measures in underground mining operations. IoT enables the seamless connection of sensors and devices to monitor environmental conditions continuously [2]. By collecting and transmitting data in real-time, IoT systems can instantly detect abnormal changes such as gas leakage, high temperature, or harmful vibrations [3]. An IoT-based coal mine safety and alert system focuses on improving miner safety through automation and rapid response mechanisms. The integration of various sensors like gas detectors, temperature monitors, and motion sensors ensures that every critical parameter is tracked [4]. When dangerous conditions arise, the system can immediately notify the control room and miners through alarms or messages, minimizing response time. Furthermore, the data collected can be stored and analyzed for future improvements and risk assessments.

The goal of this system is not only to protect lives but also to reduce the long-term costs associated with accidents [4]. Overall, implementing such technology transforms coal mines into safer workplaces by enabling proactive and preventive safety measures [5].

A. *Problem Statement*

Coal mining is a highly hazardous industry where miners face significant risks due to unpredictable environmental conditions [3]. The presence of toxic gases such as methane and carbon monoxide, extreme temperatures, and potential structural collapses pose serious threats to worker safety [4]. Traditional monitoring methods rely heavily on manual inspections and outdated alarm systems, which often fail to provide real-time alerts during emergencies [5].The lack of an efficient and automated system results in delayed responses, increasing the likelihood of accidents and fatalities [4]. Additionally, ineffective communication between miners and control rooms further complicates rescue operations. To address these challenges, an advanced monitoring and alert mechanism is needed to enhance safety measures [5]. This project aims to design and implement an IoT-based coal mine safety and alert system that continuously monitors environmental conditions using smart sensors [6].

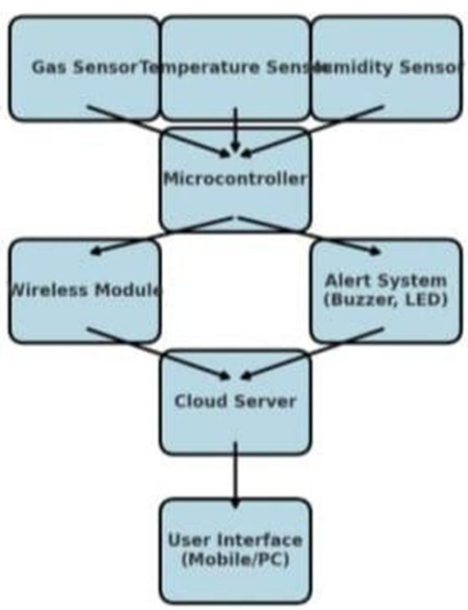
By detecting harmful gas levels, temperature variations, and structural instabilities in real-time, the system will provide instant alerts to miners and authorities, enabling quick evacuation and preventive actions. The implementation of IoT technology will significantly reduce workplace hazards, ensuring a safer and more secure mining environment [6].

B. Methodology

An IoT based coal mine monitoring system makes use of real-time sensors that can provide live updates, making hazard detection extremely fast [7]. The first step in developing such an application is to conduct an overall assessment. Primary safety risks should be defined in detail, in which the more dangerous ones would include: harmful gas leakage, acute humidity changes, excessive temperature levels, and even physical fracturing of the mine [7]. Threats of such magnitude require powerful monitoring systems, hence, gas sensors MQ-2, MQ-7, DHT11 for temperature and humidity, and vibration sensors are optimal choices [6]. The design of the system hardware is done using versatile microcontrollers as Arduino or Raspberry Pi. The goal of this stage is to integrate the outlined previously listed sensors with a central controlling unit that contains a processor capable of receiving input data and sending the computed output data. It is a two-way communication block [8]. The sensors are tasked with supervising the state of the underground atmosphere of the mine. This data is relayed to a microprocessor, which then stores it for processing during scheduled polling intervals [8]. The processed information is forwarded via Protocol Adapter Interface to either a cloud server or a standalone local server for remote querying and control, wi-fi, Zigbee or LoRa could be used as well.

The data processing together with the alert systems constitutes a key section of the system. The system generates automated alerts as alarms, warning lights, and text messages through mobile apps or dashboard access in the control room when sensor readings surpass established safety limits [8]. These alerts enhance faster decision making, enabling timely evacuation of miners, and immediate action from authorities. To improve system reliability, data logging and analysis capturing all sensor data is integrated for further analysis. This assists in effective identification of long term patterns, risk forecasting, and implementation of mitigatory actions [9]. The addition of backup batteries and emergency communications modules ensures continuous system operation when there is a loss of power. Comprehensive validation and testing is done in controlled mining scenarios prior to full implementation [9]. The system undergoes evaluation in the parameters of its precision, response duration, reliable network connection, and overall performance in practical situations demonstrable conditions [10].

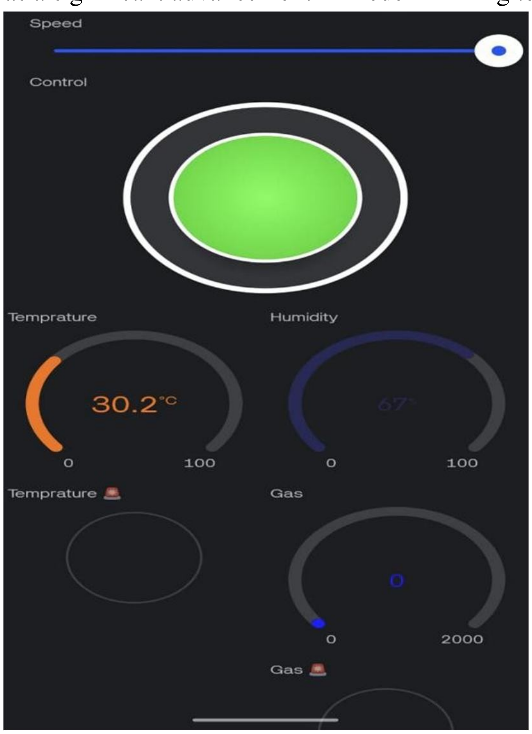
C. Block Diagram

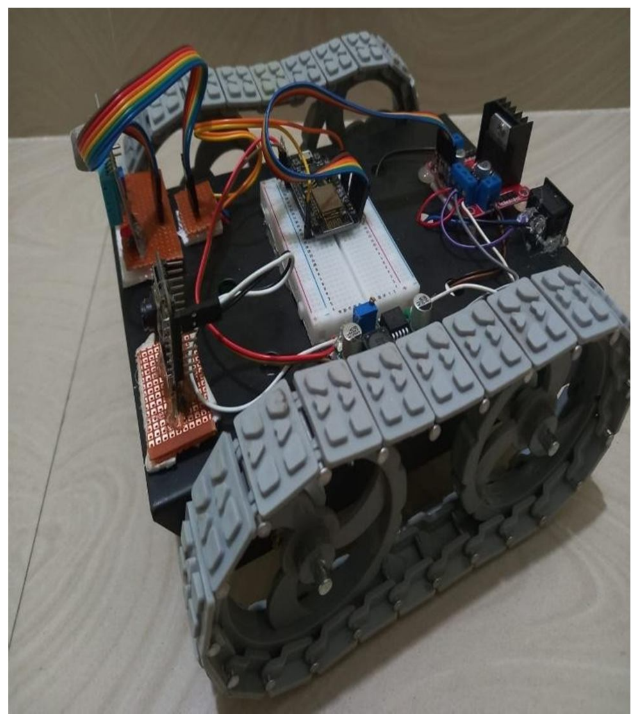


II. RESULTS AND DISCUSSION

The implementation of the IoT-Based Coal Mine Safety and Alert System has shown improvement in facilitating miner safety through real-time monitoring and pre-emptive hazard identification [8]. The system successfully monitored and sent data concerning vital environmental factors such as methan (CH_4), carbon monoxide (CO), oxygen (O_2), temperature, humidity, and vibrations [8]. The installation of sensors with a microcontroller facilitated monitoring of underground conditions which made it possible to detect dangerous conditions in good time [9]. The analysis of the results proved that the system was able to detect abnormal concentrations of gases and thermal changes, activating prompt audio-visual and mobile notification alarms [9]. The link between the sensors, microcontroller, and central monitoring system was stable, and data transfer through wireless connections like Wi-Fi, Zigbee, or LoRa was smooth. This provided instant updates that aided in averting possible accidents. The discussion emphasizes still challenges related to miner safety system usability and its impacts [8]. The automated alarm system greatly improved safety by providing instant alerting to miners and supervisors about toxic gas levels and other hazardous conditions enabling preventative measures to be immediately undertaken [9]. The system proved effective in monitoring the environmental parameters and issuing computed alerts which improved safety management in the mine.

Sensor calibration, underground network connectivity, and power draw issues present challenges that must be overcome for long-term implementation. To further augment safety measures, future advancements could integrate AI-powered predictive analytics to address risks prior to them reaching a worrying stage [10]. Regardless of these drawbacks, the IoT-enabled safety and alert systems offer a remarkably economical, easily expandable, and effective method to enhance the safety conditions in coal mines, which stands as a significant advancement in modern mining technology [10].





III. FUTURE SCOPE

1) AI-Powered Hazard Prediction – By incorporating AI and machine learning technologies, predicting potential hazards like gas leaks, temperature surges, and structural failures is now possible. Through continuous analysis of sensor data, AI models can give predictive notifications that allow miners and supervisors enough time to make preemptive measures to avert potential accidents. [4]
2) Wearable Smart Safety Devices – The development of IoT-enabled smart helmets and vests can considerably augment safety protocols for miners. These wearables are capable of providing real-time monitoring of health indicators such as heart rate, oxygen concentration, and toxic gas levels. If an abnormality is detected, an alert can automatically be transmitted to the control room for immediate intervention. [5]

3) Autonomous Drone Surveillance – Thermal imaging and gas sensing drones can be used for constant surveillance of mining areas to improve accessibility and safety. These UAVs can access dangerous areas that are hard for humans to reach so they can assess if there are potential risks such as gas leaks or destructive damages. They can also assist significantly in emergency search-and-rescue missions. [6]

4) IoT-Integrated Smart Rescue Robots – In case of mining accidents, these autonomous rescue robots with cameras, sensors, and AI powered navigation can be used. These robots have the ability to navigate dangerous or collapsed spaces, locate trapped miners, and transmit important information to rescue teams, which improves the response to emergencies [7].

5) Real-Time Location Tracking for Miners - A Bluetooth, RFID, or Ultra-Wideband (UWB) indoor positioning system (IPS) can be used for real-time location tracking of miners. This system can pinpoint the location of injured or trapped miners in an emergency, which aids in expediting rescue operations and lowering associated fatalities [8].

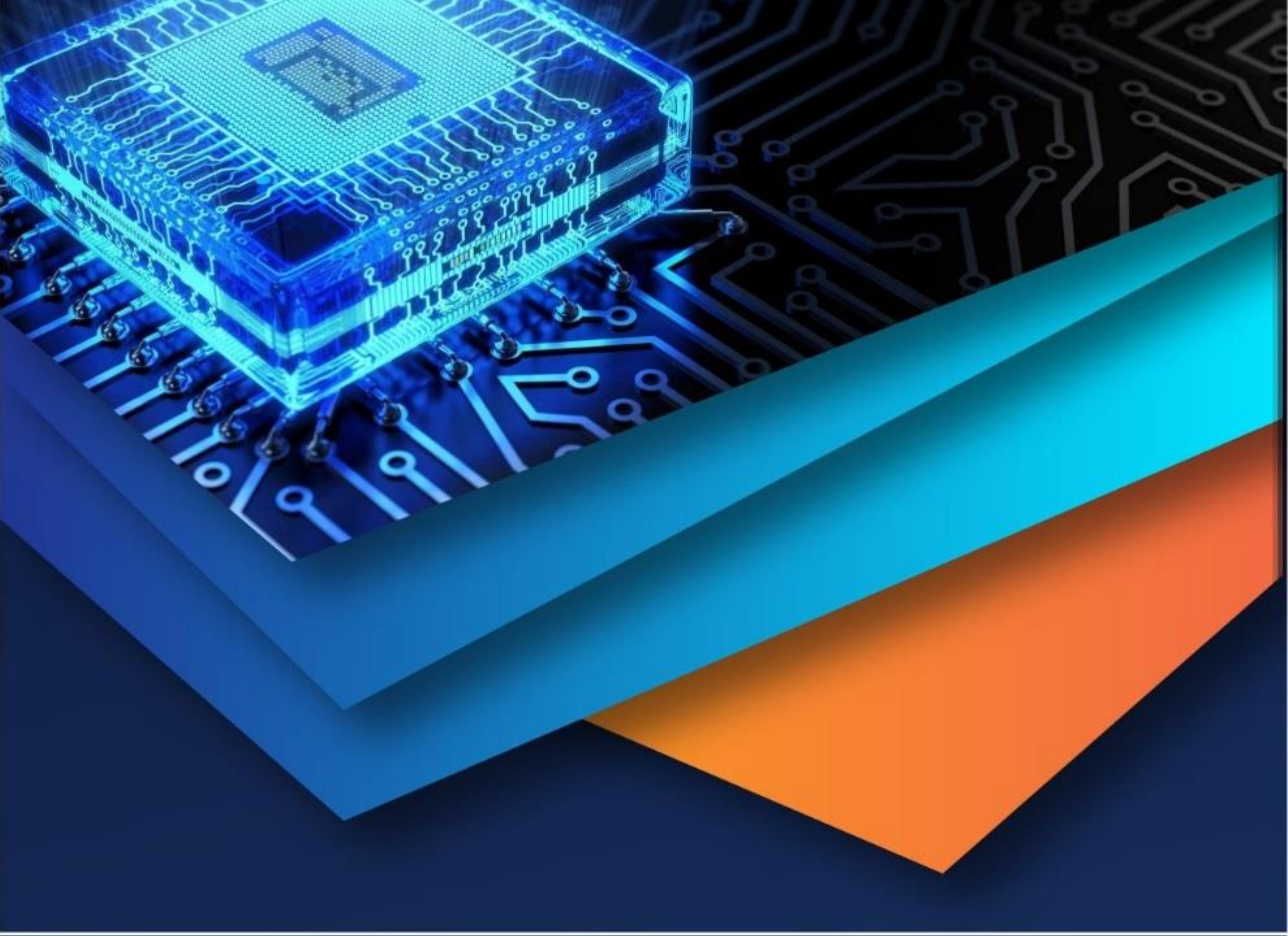
6) Predictive Maintenance for Mining Equipment – The condition of mining machinery can be monitored continuously with the use of IoT sensors. Through the use of AI, predictive maintenance can analyze operational equipment performance data to identify emerging problems, thus minimizing undetected machinery malfunctions and optimizing operational efficiency [9].

IV. CONCLUSION

The Design and Implementation of IoT Based Alarm Systems and Security Camera Framework fosters mineworker security solutons by providing real time monitoring and early warnings. Conventional coal mining operations face numerous hazardous conditions for example, toxic gas exposure, structural failure, and poor ventilation which are dangerous to mineworkers. Combination of IoT technology with this system provides environment monitoring, immediate danger identification and computerized alarming, thereby reducing mishaps and improving emergency response times. The use of smart sensors, AI analytics, remote sentry guns, and military grade defense systems further enhance security making coal mines safer and more efficient. Moreover, other advancements like smart enabling wearables, predictive maintenance, and AI powered threat detection help improve the safety of workers. As technology continues to grow, this IoT based system has limitless possibilities to revolutionize mining security and create an economical working environment for mineworkers globally. As technology continues to evolve, this IoT based system stands limitless possibilities to revolutionize mining security and create a cost effective working environment for miners around the globe. The combination of having a blockchain technology for secure information logging, along with automated response systems, can enhance security measures.

REFERENCES

[1] S. JayaChitra, S. Kavin, S. Sasi, and R. Sethupathi, "IOT Based Coal Mine Workers Safety Monitoring and Alerting System," International Journal of Intellectual Advancements and Research in Engineering Computations, vol. 10, no. 2, pp. 188–191, 2022.
[2] Saurao Dashrath Rathod, Yash Khose, Shruti Pandhare, and N. R. Dhumale, "Design of Coal Mine Safety and Monitoring System Using Sensors and IOT," Journal of Thermal Engineering and Applications, vol. 11, no. 1, pp. 1–7, 2024.
[3] V. Mercy Rajaselvi, V. Siva Chandran, T. Sowndarya, and S. Varssha, "Coal Mine Safety Monitoring and Alerting System," International Journal of Advanced Science and Technology, vol. 29, no. 5, pp. 6643–6653, 2020.
[4] M. K. Mishra and S. K. Das, "An Event Reporting and Early-Warning Safety System Based on the Internet of Things for Underground Coal Mines: A Case Study," Applied Sciences, vol. 7, no. 9, article 925, 2017.
[5] N. Sathishkumar, A. M. Manoj, K. Muniraj, M. Naveenkumar, and C. Praveen, "Safety Monitoring System in Coal Mine Using IoT," Journal of Physics: Conference Series, vol. 1716, no. 1, article 012053, 2021.
[6] S. Porselvi, S. G. CS, J. B., P. K., and S. B. S., "IoT Based Coal Mine Safety and Health Monitoring System using LoRaWAN," 2021 3rd International Conference on Signal Processing and Communication (ICPSC), pp. 49–53, 2021.
[7] B. Rollakanti, B. Naresh, A. Manjusha, S. Sharma, U. Somanaidu, and S. Prasad, "Design of IoT Based Coal Mine Safety System Using LoRa," 2022 International Conference on Advancements in Smart, Secure and Intelligent Computing (ASSIC), pp. 1–4, 2022.
[8] N. Sainadh and P. Dass, "Health Monitoring System for Mine Areas," International Journal of Engineering and Advanced Technology (IJEAT), vol. 8, no. 6S, pp. 224–227, 2019.
[9] Madhu, "Coal Mine Safety Monitoring System," International Journal of Mechanical Engineering and Technology (IJMET), vol. 8, no. 12, pp. 756–761, 2017.
[10] Wakode, "Coal Mine Safety Monitoring and Alerting System," International Research Journal of Engineering and Technology (IRJET), vol. 4, no. 3, pp. 1801–1804, 2017.
[11] S. Herur, C. Leema, and G. M. G., "IoT Based Coal Mine Safety Monitoring and Control Automation," International Journal of Engineering Research & Technology (IJERT), vol. 10, no. 11, pp. 1–5, 2022.
[12] M. K. M., N. C. D. C., P. S. V., S. P., and R. K. I., "IoT Based Coal Mine Safety Monitoring and Alerting System," International Journal of Engineering Research & Technology (IJERT), vol. 10, no. 11, pp. 1–5, 2022.



10.22214/IJRASET

INDEX COPERNICUS

45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY