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Lora Based Smart System For Unsafe Event Detection In Mining Industry Using Iot And Tinyml

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ABSTRACT

Ensuring employee safety is paramount for businesses across various industries, with a particular emphasis on mining. It holds significance not only for the welfare of the workers but also for the overall prosperity of the corporation. The provision of clean and fresh air is imperative for the health and well-being of mining personnel. A conventional intelligent system model has beenformulated specifically for the mining sector, incorporating LoRa technology to recognize potential hazards within the mining environment. The developedprototype has the capability to monitor air quality, humidity, temperature, as well as the temperature and heart rate of workers. The air quality is assessed by determining the saturation level of harmful gases like methane using an MQ4 gas sensor.Additionally, the DHT11 sensor measures atmospheric temperature and humidity. Monitoring for mining zone fires and landslides is facilitated through flame and accelerometer sensors. The prediction of accidents is achieved by employing.

TinyML and a machine learning model trained on data from various sensors within a sensor node. TinyML allows devices to make intelligent decisions locally, enhancing efficiency and preserving privacy by avoiding the need to upload data to the cloud. The IoT can be employed to automatically notify and respond to incidents at the scene. The monitoring system for mining industries involves two main components: the transmitter module and the receiver module, both utilizing IoT through LoRa technology. The transmitter module integrates a microcontroller with sensors such as ds18b20 for temperature and Pulse Sensors for heart rate, alongside a LoRaWireless Transmitter. On the other hand,the receiver module comprises a microcontroller with LoRa reception capabilities and WIFI connectivity. The system facilitates online parametermonitoring and issues emergency warnings in the event of a hazardousincident, ensuring the safety of miners. We strongly recommend the implementation of this monitoring system in mining industries as a proactive measure. By utilizing the monitoring system, prompt actions and control measures can be implemented, enabling the examination of the impact of regulatory actions and facilitating scientific studies.

Keywords: *Internet of Things, LoRa, WIFI, Mining, Sensor, TinyML.*

I INTRODUCTION

The global mining sector plays a vital role in driving worldwide socioeconomic development due to thewidespread demand for mineral resources across various industry value chains. Nevertheless, this industry faces[1] economic challenges, including substantial initial investments [1] and the volatility of commodity prices. Additionally, itencounters demanding mining conditions,characterized by deeper and steeper deposits. The global mining industry facesa complex terrain shaped by social and environmental considerations,encompassing safety issues for mining workers. To address these obstacles, the mining industry has adopted several newtechnologies with the goal of improving efficiency and safety while reducing environmental hazards. A mining industry is also in the process of digitizing to accomplish automation. Intelligent mining has emerged as a prevailing operational trend, concentrating on

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enhancing the underground mining operations for mineral extraction, the initiative aims to improve machine autonomy and integratelive monitoring of the surroundings, machinery and personnel in real time [1].

Mining stands as one of the most ancient industries globally. The techniques utilized in mining production have swiftly evolved, moving from manual, mechanized, and on-site remote-controlled production to intelligent and fully automated production. Tools of mechanization have been introduced topropel the mining sector into the future, automating individual equipment and independent systems, ultimately leading to significant automation throughout the entire mining production process [3]. The swift progress of intelligent mining technology, resulting from the fusion of information technology with the industrialization of mining technology, has resulted in the emergence of mechanizedand automated mining. Consequently, there has been a gradual enhancement of intelligent processes in mining equipment, with the practical implementation ofunmanned and centralized mining equipment. This significant step forward is poised to advance both mine automation and information technology in the mining industry.

Intelligent mining, characterized by the integration of information technology and industrial processes, and grounded in mechanized and automated mining technologies, has transformed the coal sector [4]. This groundbreaking technology enables automatic mining through intelligent environmental sensing at the work face, intelligent managementof each mining machine, and the automated navigation of mining equipment. Intelligent mining encompasses three key facets: Firstly, mining machinery demonstrates autonomous capabilities, allowing it tooperate independently. Secondly, the swift capture and updating of real-time data, including geological information, dynamic coal and rock boundary lines, Integral tothis are the positions of machines and mining processes. Finally, machinery, defined as an "intelligent mining work face," can automatically control and adjust its operations based on the conditions of the work face when decision-making and machine operation are automated.

II LITERATURE REVIEW

Huili Zhang et al. [1] have extensively utilized IoT technology in underground mines to facilitate real-time monitoring of environmental conditions, safety measures, and productivity levels. The article describes the basic structure ofa MIot system for mining employs astandard three tier IoT architecture. This categorizes sensor types frequently utilized in underground mines based on their specific applications and provides a summary of both physical and wireless connectivity solutions, along with applicable network topologies suitable for use in underground mining environments. This article offers an in-depth evaluationof the latest progress in utilizing IoTapplications to monitor various environmental factors in underground mines. The characteristics include mining gas and dust concentrations, temperature,humidity, airflow, groundwater levels, ground support, and seismic activity. Furthermore, MIoT applications have been examined for activities such as fire and hazard detection, personnel and equipment location monitoring, and industrial safety oversight. The article identifies key obstacles hindering the widespread adoption of IoT technology in underground mines, such as operational disruptions, increased costs, limited battery life, suboptimal underground connectivity, and challenges in data management.

The research conducted by KaiZhan and Jian-guo Li [3], the current state of intelligent technology developmentspecifically designed for underground metal mines in China is evaluated. These technologies aim to facilitate the extraction of mineral resources in a manner that prioritizes safety, efficiency, andenvironmental responsibility. The authors conduct an analysis and concise overview of the existing research landscape in underground metal mining technology, both within China and internationally.

We showcase state-of-the-art machinery and tech for self-directed mining operations, featuring advancedcontrol systems for various equipment like rock-drilling jumbos, DTH drills, underground scrapers, mining trucks, andcharging vehicles. Each of these systems is developed with exclusive intellectual property rights. Our focus lies on three key platforms – precise positioning and navigation, efficient data gathering andcommunication, and optimized scheduling and management of operations [3].

In the last five years, notable progress in technological innovations within the realm of intelligent mining has been observed in China. This involves the integration of longwall automationtechnology, a system endorsed by the Longwall Automation Steering Committee, as highlighted by Jinhua Wang and Zenghua Huang [4]. During this period, China successfully completed the development of an intelligent system featuring hydraulic-powered supports, showcasing proprietary intellectualproperty.

An enhanced intelligent mining model was created, enabling for automated operations while expediting single-person inspections at the work site. As a result of these technological developments, the number of miners required at the worksite has decreased significantly. Miners may now supervise mining machinery from either the highway or the surface control centre, demonstrating the viability of intelligent mining for extracting middle- thick or thick coal seams.

In this paper by Zhigao Liu[5], apioneering personnel positioning system is introduced for tunnel networks featuring blind spots. This scheme, in contrast to many existing alternatives, presents a combination of cost-effectiveness and high precision.

III PROBLEM STATEMENT

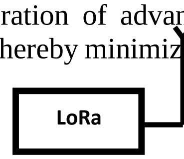
Mining sector inherently carries substantial safety risks for workers and equipment integrity, despite safetyadvancements. Accidents and hazardous incidents persist, challenging traditional safety systems lacking real-time monitoring capabilities. Detecting andresponding promptly to unsafe events remains a hurdle. In this context, proposing a LoRa-based intelligent system incorporating IoT and TinyMLtechnologies aims to address these issues. Traditional mining monitors often lackreal-time capabilities, causing delays in event detection, elevating risks to personnel and equipment. Remote mining locations with limited network connectivity further hinder existing systems, impacting safety measures. Large, diverse mining environments require scalable systems for efficientcoverage, posing a considerable challenge. The integration of Machine Learning models at the edge (TinyML) becomes crucial for swift decision-making. Tailoring TinyML models to address the mining industry's safety concerns presentsa complex task. A seamless incorporation of various IoT devices, such as sensors and wearables, becomes pivotal forcomprehensive monitoring. The proposed solution involves developing a LoRa- based intelligent system for mining, leveraging IoT and TinyML technologies. This entails implementing a network of sensors and cameras for continuous monitoring, employing LoRa technology for long-range, low-power communication in remote areas, and creating TinyML models for edge devices to analyze sensor data rapidly. The ultimate goal is to enhance safety through real-timemonitoring and immediate responses to unsafe events.

IV EXISTING WORK

Coal stands as a pivotal primary energy source crucial for national economic development, emphasizing the need for secure production practices and effective oversight. Presently, the coal mine safety monitoring system allows local observation but lacks the capabilityto facilitate remote and centralized supervision by supervisory departments. The current mechanism informs ground stations of incidents, aiding rescuers in strategizing and preparing for rescueefforts. However, it falls short in alerting miners about incident status in specific zones or escape routes. The RF-baseddevice employed detects accidents only over short distances, and crucial indicators for miners' safety are not continuously monitored.

V PROPOSED WORK

The mining industry inherently involves numerous risks for workers, making safety a paramount concern. To address these challenges, this proposedsystem introduces an innovative solution that utilizes Long Range (LoRa), IoT, and TinyML technologies for real-time detection of unsafe events. This integration of advanced technologies enables a swiftand efficient response to potential dangers, thereby minimizing risks to personnel and assets within the mining environment.



Given the substantial safety challenges in mining due to various hazards, traditional safety systems often fall short in providing timely responses to emerging threats. The goal of this proposed system is to overcome theselimitations by employing LoRa communication, IoT devices, and TinyML for rapid detection of unsafe events. Sensors that monitor parameters such as temperature, gas levels, humidity, and flame detection.

LoRa technology is employed to connect the Fig.1.Sensor nodes to the central processing unit, enabling long- range and low-power data transmission. The server, responsible for receiving andprocessing data from the sensor nodes, implements TinyML algorithms for real- time analysis and event detection. TinyML models are trained to recognize patterns indicative of unsafe events, and they areoptimized for deployment on resource-constrained IoT devices. This comprehensive system enhances safety measures by providing a proactive approach to identifying and responding to potential hazards in real-time, thereby contributing to a safer mining environment.

ARCHITECTURE

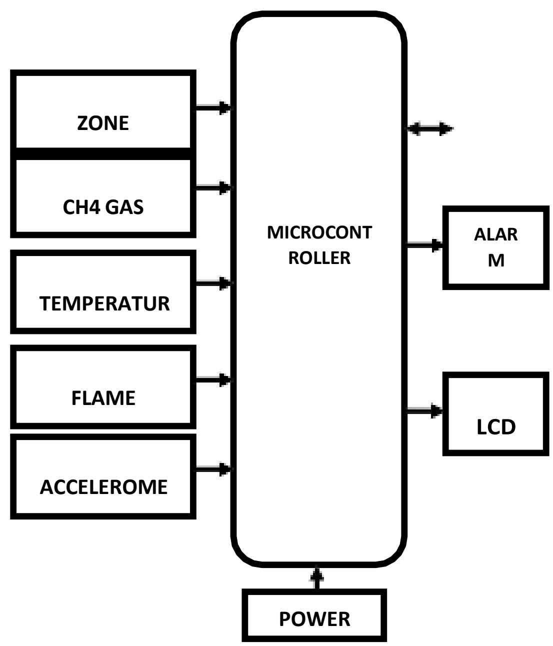


Fig.1.Sensor Node

Fig.1. Sensor nodes monitor environmental parameters andcommunicate data to the central processing unit using LoRa technology.

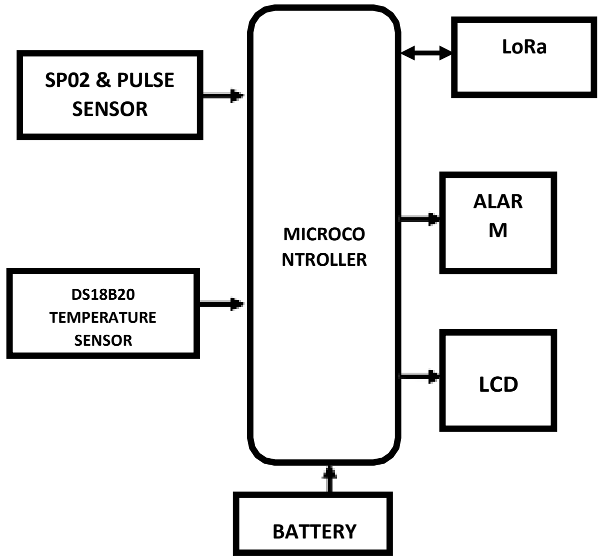
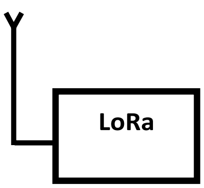
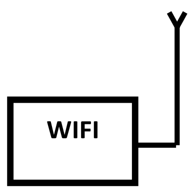


Fig.2.Miner Node

Fig.2. Miner nodes are wearable sensors that miners use to monitor their vital signs and surroundings in real time. These sensors communicate with a central processing unit.

VI EXPERIMENTAL RESULTS





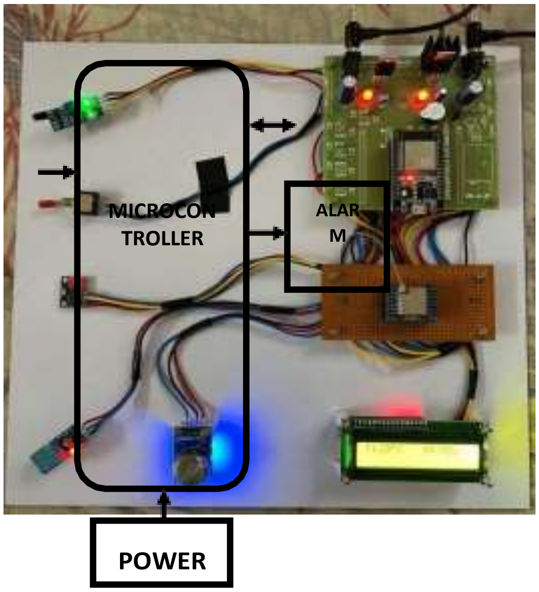


Fig.3. Receiver Node

Fig.3. Receiver nodes gather sensor data and relay it to the central processing unit for analysis, facilitating real-time monitoring and response in the mining environment.

Fig.4.Online Monitoring

Fig.4. Online monitoring entails real-time surveillance of mining operations using sensors to collect data on equipment, environment and worker activities, enabling rapid hazard detection, responseand operational optimization.

Fig.5.Hardware Prototype Module Fig.5.(a). Sensor Node

Sensor nodes are deployed to measure specific parameters related to underground mining environments in different zones. These parameters include fire, temperature, methane levels, humidity, and potential landslide risks.Fig.5.(a) It shares its data's with miner and master nodes about their zonal warning parameters and also about other zone based alerts makes them to easily evacuate to save their lives. Sensor node uses Machine Learning Based predicting system which uses real time sensor data's given to Machine Learning Models to predict emergency alert in precise way.

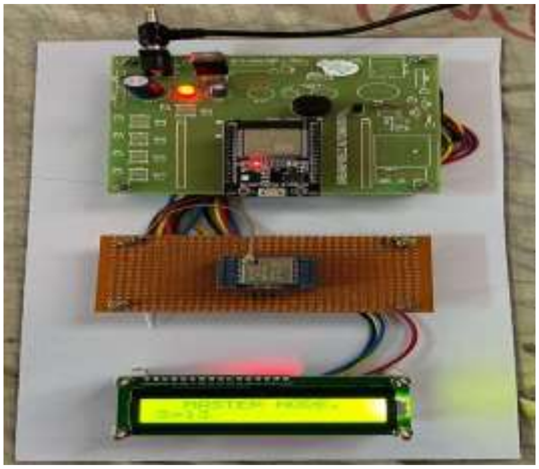


Fig.5.(b).Master Node

Master node gets data from Zones based Sensor Nodes and also miner's vital parameters are used to monitor in ground station in order to react to any emergency situations that occur in underground mines. Fig.5.(b) Master node also facilitates with remote monitoring systemhelp the supervision department to realize the remote supervision and centralized supervision. Establishing a corresponding coal mine safety monitoring network system has become an urgent need of coal mine safety supervision helps to involve national emergency disaster management team to take control on any emergency situation in coal mines.

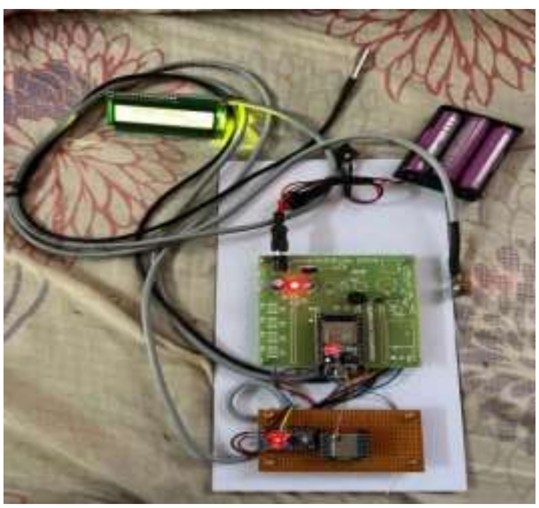


Fig.5.(c).Miner Node

Miner node measures miner's vital parameters such as Heat Pulse, SPO2 and Temperature to ensure miner is safe in mining environments. Fig.5.(c) This system exchange data between Master node in order to monitor miner remotelyhelps to initiate rescue operation immediately in any emergency situations of miner.

Fig.6.Perfomace Graph

Fig.6. Performance graph has been used to display the Accuracy of ML model for training data.

VII CONCLUSION AND FUTUREWORK

The integration of LoRa, IoT, and TinyML technologies in the mining sector signals a paradigm shift in safety protocols. Leveraging LoRa's extensive reach, the system facilitates seamless communication across vast miningterrains, overcoming geographicalobstacles for efficient data transmission. IoT is instrumental in seamlessly connecting and coordinating diverse sensor nodes, gathering data on parameters like gas levels, temperature, humidity, and other environmental factors. Through IoT integration, a network of sensor nodes collaborates to gather a spectrum of crucial environmental data, empowering comprehensive safety assessments. Meanwhile, TinyML's on-the-edge processing capability enables real-time analysis, curtailing latency and conserving energy resources. Maintaining collaborative efforts, diligent monitoring, and proactive maintenance routines areimperative to sustain the system's efficacy and reliability, fostering an environment of continuous safety enhancement within the mining industry.

Safety measures in mining areas

primarily focus on ensuring safety but do not effectively address powered haulage accidents. Mining sites house various powered haulage equipment like scoops, front end loaders, shuttle cars, locomotives, etc. MSHA records indicate that 46.3% of mining-related accidents are attributed to powered haulage equipment.Implementing robust surveillance and safety monitoring systems can play a crucial role in preventing such accidents.AI plays a crucial role in enhancing safety measures in mining operations. Through the capabilities of AI video analytics, stakeholders can receive alerts for human- vehicle accidents, identify operator distraction, and manage on-road fleets inreal-time. Moreover, harnessing the power of AI, as opposed to traditional sensors, enables vision intelligence for preventing catastrophic fire incidents in mines. Thisincludes instantaneous fire and smoke detection, real-time fire alarms, severe temperature alerts, and more.

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