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NEXT-GENERATION SAFETY HELMET FOR COAL MINING OPERATIONS

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ABSTRACT
Worker safety is essential in the hazardous mining industry. This study looks at a new type of safety helmet incorporating a long-range (LoRa) module for low-cost long-range communication, with the aim of improving monitoring and welfare of miners. The helmet is equipped with several additional sensors to provide continuous monitoring of the worker's health status (heart-rate and activity), as well as environmental factors such as temperature, humidity, and toxic substances present in the work atmosphere. Even though traditional means of communication might fail, the LoRa module guarantees safe and reliable data transmission of information coming from the deep remote areas of mines straight to a control center. This ensures monitoring and control of public health and environmental conditions to facilitate quicker responses in emergencies and improve occupational health and safety. The use of LoRa technology in the innovative safety helmet design is meant to provide robust connectivity and longer range; thus, the surface communication problems in underground operations are solved in an unprecedented way. The helmet, with safety and monitoring technologies advancing to ensure improved protection of the miner's health, ushers in a newer era of monitoring and communication enhancement.

Keywords:
Worker Health Monitoring, Mining Safety, Toxic Gas Detection, Temperature and Humidity Monitoring.

I. Introduction
By providing the necessary raw materials that form the basis of industries like manufacturing, energy generation, and construction, the mining sector plays a critical role in propelling global economic growth. However, mining, particularly subterranean activities, carries significant risks. Mining is still one of the most dangerous occupations in the world, with a high rate of serious and fatal accidents, even with advancements in safety procedures and protective equipment. Extensive wired communication systems and manual environmental condition assessment are two examples of safety risk management techniques that have failed to provide miners with a sufficiently safe environment. These approaches frequently lack the timely knowledge required to stop disasters before they happen, making them inefficient or laborious in emergency situations. Two safety management techniques that have not successfully guaranteed a safe working environment for miners are the manual evaluation of environmental conditions and the deployment of extensive wired communication networks. These methods frequently lack the timely knowledge required to stop disasters before they happen, making them difficult or ineffective in emergency situations. The smart helmet’s lightweight and comfortable design addresses the issue of miners often disregarding safety protocols. Technological advancements that enhance safety are essential to reducing accidents and fatalities in the mining industry. In this context, the next-generation safety helmet offers a practical, effective, and reliable solution that marks

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substantial progress in overcoming traditional safety challenges, significantly advancing worker protection

Time frame	Av. Fatal Accidents		Av. Serious Accidents		Av. Fatality Rate		Av. Serious Injury Rate	
	Accident	Fatalities	Accident	Injuries	Per Mill. Te	Per 3 Lac Manshifts	Per Mill. Te	Per 3 Lac Manshifts
1985-89	133	150	550	571	0.98	0.30	3.70	1.15
1990-94	120	145	525	558	0.694	0.30	2.70	1.19
1995-99	98	124	481	513	0.50	0.29	2.06	1.14
2000-04	68	82	499	526	0.28	0.22	1.80	1.47
2005-09	60	80	328	339	0.22	0.25	0.92	1.04
2010-14	56	62	219	228	0.138	0.23	0.49	0.80
2015-19	33	43	107	112	0.08	0.18	0.19	0.47
2020	29	30	73	80	0.05	0.14	0.13	0.37
2021*	23	25	55	58	0.05	0.13	0.11	0.30

Fig.1. Comparative Accidents Statistics of CIL

II. Literature Survey

K. Lalitha, G. Ramya, and M. Shunmugathammal present a paper titled "AI-based safety helmet for mining workers using IoT technology and ARM cortex-M" [1]. The advantages and disadvantages of various technologies can be classified into four categories: emergency evacuation, doing fine, not good, and good. This study investigates techniques for enhancing mine safety. Miners can communicate with hand signals thanks to a system that uses convolutional neural networks to recognize specific motions. These gestures are divided into four categories: good, not good, doing fine, and emergency evacuation. Miners can also commence rescue efforts in the event of an emergency by pressing the panic button on their helmet, which alerts the control center. After processing the data, the STM32 microcontroller forwards it to the control unit, which shows the outcomes and takes precautions against mining [1]. An overview of current IoT-based wearables intended to increase the safety of coal miners is given in "Smart Helmet: Early Calamity Prediction and Warning System for Coal Miners"* [2] by S. R., G. S., S. S. Tippannavar, P. S. Yadav, R. R. Gowda, and M. Z. Salman. Numerous sensors are built inside the helmet, such as the DHT11 for temperature and humidity monitoring, the MQ-4 gas sensor for identifying dangerous substances like methane, and additional infrared sensors to verify that the user is wearing the helmet. An Arduino microcontroller handles data from the helmet, while the nRF24L01 transceiver module, known for its low cost, speed, and robustness, maintains the connection between the helmet and the base station. The helmet's LEDs alert miners to a variety of concerns, including temperature, humidity, and gas levels. Instead of simply transferring information, the system alerts the base station and helmet, allowing them to respond proactively to detected risks. [2]. In their article "Smart Helmet for Coal Mines Safety Monitoring with Mobile App [3]," Talpur, Mir Sajjad Hussain, and colleagues discuss a number of wearable IoT devices targeted at increasing coal miner safety. The helmet's sensors monitor temperature and humidity and detect harmful gases such as methane and carbon monoxide..

The sensors are linked to an ESP32 microcontroller, which decodes the data and establishes a Wi-Fi connection with a monitoring system. Miners can use the device's emergency SOS button to broadcast their coordinates as an emergency signal if they need help. Real-time data flow between a cloud-based monitoring system and a mobile application enables prompt situational responses. During an emergency, this resource broadcasts, records, and mines data in real time [3]. V. B. Baru and Shruti P. Borkar, "Internet of Things-based smart helmet for underground mines." [4] explains a Raspberry Pi 3-based system that uses Internet of Things technologies to gather, process, and send sensor data to the base station.If hazardous conditions are found, it will also notify the miner and the control station.

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Supervisors will be able to react swiftly in case of an emergency thanks to these Internet of Things sensors, which will allow them to continuously monitor environmental indications via a web interface. The design of the helmet guarantees that the physical structure is rarely changed, preserving miner comfort in addition to providing necessary safety elements. [4]. A. Dhanalakshmi, P. Latha Priya, and K. Divya. "A smart helmet for improving safety in the mining industry." [5] There is also discussion of a safety helmet equipped with sensors that monitor environmental parameters, including temperature, pressure, and the presence of dangerous chemicals.A protection system in the helmet immediately closes it and gives the miner an internal oxygen supply if it detects hazardous environmental conditions. When the helmet is taken off, an infrared sensor recognizes it and alerts the control room, triggering the miner's safety gear. When an object hits a miner, a force sensor picks it up and sends warning information to the control room alerting them to a potentially injured miner. Miners and the control room can communicate in both directions thanks to the headgear. The helmet has two GPS sensors that allow for two-way communication and real-time position tracking. The miner can notify the control room of an emergency by using the manual panic switch on the helmet.[5].

III. Methodology

A. Hardware

The Smart helmet is divided into 2 parts, namely:

a) Transmitter Part

b) Receiver Part

These portions are also configurable as master and slave devices. The detecting part on slave devices, according to mining personnel, is equipped on smart helmets gassed by three types of sensors, namely the MQ-9 gas sensor for CO and methane detection, the DHT sensor for temperature and humidity, and the MQ-4 gas sensor for toxic gas levels. The MAX30102 blends a pulse oximeter with a heart rate monitor in a biosensor module. It includes an electronic circuit with very low noise, optical components, a photodetector, a red LED, an infrared LED, and ambient light suppression. Another important aspect of integration into the target object is forming a connector for computing and data collection and fast data processing for sensor data. The fusion algorithms of these sensors treat infrared data, temperature, humidity, and gas sensors.

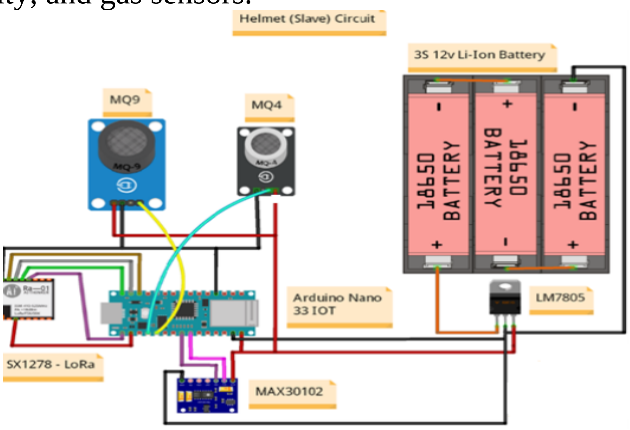

Fig. 2. Slave device circuit

It is a base station transmitter that has been built for the case of minimum possible latency, being used to relay sensory data to the smart helmet and display action signals back to the base station. This base station basically serves as a receiver part that utilizes the LoRa module for the transmission and reception of alarm signals from system to system.

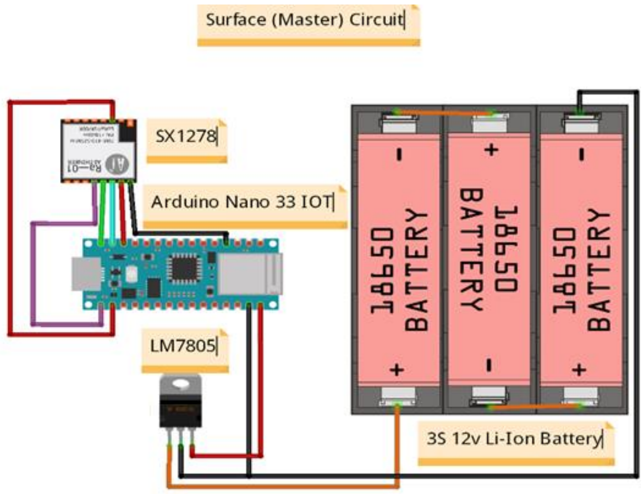

Fig. 3. Master device circuit

The master node will simply consist of the LoRa module and the Arduino board. The four pins on the LoRa module—MOSI, MISO, SCK, and NSS—are used for communication because it operates on the SPI communication protocol. By combining all of the sensors and utilizing an Arduino Board to mount a LoRa module on the helmet, the smart helmet is demonstrated. To interface with the smart helmet, a base station that functions as a transceiver with the shortest sensory data and actuation signal transmission and reception time has been developed.

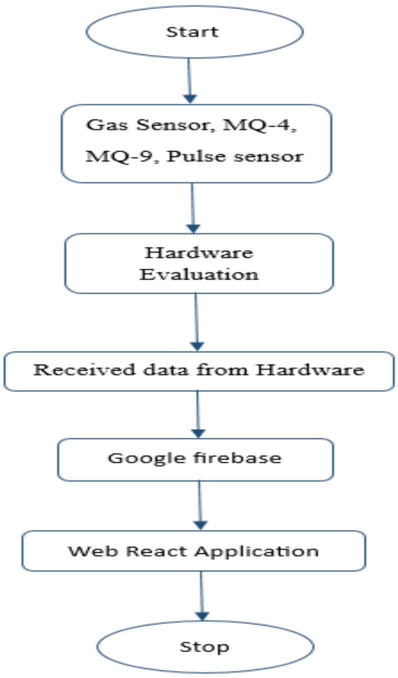

Fig. 4. Proposed system Block diagram

The LoRa module for transmitting and receiving alarm signals from one system to another is part of the base station, which will function as a receiver portion. The master node will simply consist of the LoRa module and the Arduino board. The four pins on the LoRa module [12] —MOSI, MISO, SCK, and NSS—are used for communication because it operates on the SPI communication protocol. By combining all of the sensors and utilizing an Arduino Board to mount a LoRa module on the helmet, the smart helmet is demonstrated

B. Software

1) The Arduino IDE

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Arduino IDE allows developing, compiling, and uploading software code to Arduino boards and other compatible devices. Writing and uploading code is done without an open web connection. Currently, there are two versions of Arduino IDE. It shall be user-friendly and suitable for beginners in the engineering world while providing additional functionalities for expert developers.

2) Google Firebase

Google Firebase supplies tools for developing web applications. It provides the backend as a service (BaaS) for applications required to provide real-time processing, authentication, and data storage. It provides benefits of scalability and cost-effectiveness and seamlessly integrates with Google Services.

3) Node.JS

Node.js is an open-source runtime environment that allows running JavaScript code outside of a web browser. Where it is extensively used is in real-time analytics, interface design, web development, and application programming.

HARDWARE DISCRIPTION

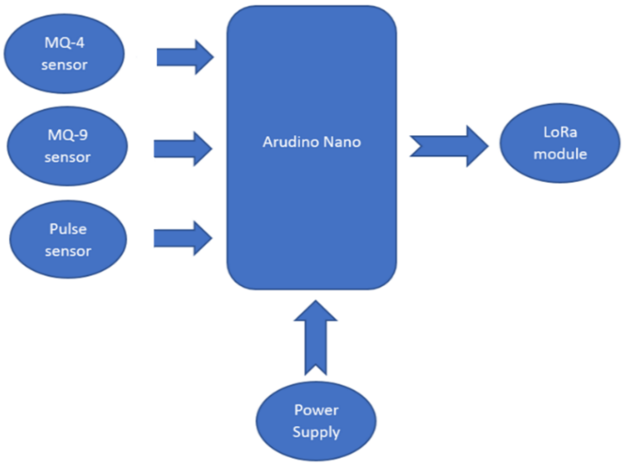

Fig. 5. Proposed system Block diagram

1) IoT Arduino Nano 33

The Arduino Nano 33 IoT microcontroller utilizes a 32-bit ARM Cortex-M0+ ATSAMD21G18A 48 MHz microcontroller that is Arduino, using either Bluetooth or Wi-Fi connectivity (802.11 b/g/n), operable at 3.3 V, powered via the Vin pin (for voltages ranging from 4.5 V to 21 V) or through USB 5 V. The incorporated characteristics like temperature, humidity, light, and air pressure sensors are rather of great use for IoT applications.

2) MQ4 sensor

MQ-4 is a semi-conductor type gas sensor that can be used for the detection of methane (CH_4) and so well suited for domestic gas leak and industrial gas monitoring applications. Other notable distinctive features are low-cost, ruggedness, and the sensible ability to detect gases such as propane and butane. The device is based upon an aluminum oxide base ceramic sensing element coated with tin dioxide.

3) MQ9 sensor

As a semiconductor gas sensor capable of detecting methane (CH_4), the MQ4 is suitable for monitoring gas levels at the industrial level and for the home gas leak detection in residential areas. The MQ-4 is rugged, cost-effective, and able to detect butane and propane as well as many other gases. It contains a ceramic sensing element that consists of aluminum oxide coated with tin dioxide.

4) Pulse Sensor

The MAX30102 is a modular pulse oximeter and heart rate biosensor module. Two LED's (red and infrared) are utilized for the photodetection of ambient light. The module is placed on the fingertip, earlobe, or wrist. The software allows for module shutdown at any point.

5) LoRa module

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LoRa is an extremely range-efficient and less-energy-hungry, Wi-Fi-enabled long-range module that lends itself well for IoT devices. The integration of the LoRa Wi-Fi module is possible at existing wireless networks. The LoRa module is compact and simple to operate. It operates in both 2.4 GHz and other bands including 915 MHz, 868 MHz, and 433 MHz

IV. Results

The recommended system is made up of Arduino Nano 33 IoT devices that can interconnect with a computer. You may program this Arduino board with any available and open-source IDE. This project will implement Arduino IDE to connect several sensors like the MQ-4 and MQ-9 for pulse sensors. Programming may be done using the MAX3010x library, and then the gas sensors can be read using the analog values of individual gas concentrations. After this, we tried to put together all the sensors and LoRa codes to make them work together [12]. All the sensor values will keep being monitored over cloud services. After this, you can go through Google Firebase for navigation to real-time databases on monitoring the sensor data.

Fig. 6. Proposed system (a)

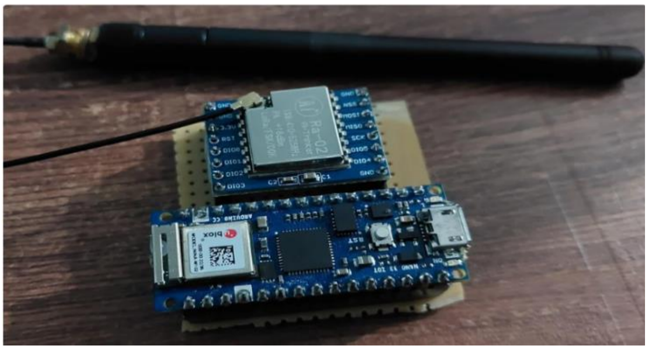

Fig. 7. Proposed system (b)

The aforementioned Firebase support was built into Arduino programming by The Firebase Arduino libraries based on the WIFI NINA library. This is important, particularly because the present project is based on an Arduino Nano 33 IoT board, which uses NINA DB Wi-Fi functionality for the u-box chip [12]. This allows the system not only to receive data via LoRa connection, but also efficiently to upload the data to Firebase for real-time dasiy changes, thus improving the project functionality [12].

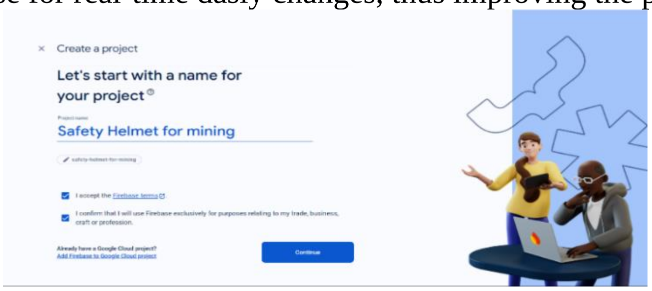

Fig. 8. Google firebase

Firebase being configured, the next step is to build a user interface in the form of a web application powered by React. In the case that any of the sensor values reached a threshold, then emergency protocol would be followed using the Web React application, which would be developed using NodeJS

V. Conclusion and Future scope

This means that a smart helmet equipped with gas sensors, pulse monitoring, humidity, and temperature detection sensors could share the work with the DHT sensor and respond to high levels of CO and CH4. Emergency action was initiated when a sensor surpassed the prescribed threshold value. Furthermore, a Firebase system allows base managers to obey the live stream of this information and issue an emergency warning using a React web app built on NodeJS as stakeholders may tell when abnormalities occur at the workplace. Future goals of this project dictate creating augmented reality for hands-free worker experiences, allowing mapping views in mines and providing information about them, and further diagnosis of equipment, amongst others. Other developments include the addition of GPS, making it extremely easy to track a worker in the case of, for example, roof collapse inside the mine. Other technologies would offer environmental noise cancelation to decrease noise, protecting workers' hearing in the event of working with noisier machinery.

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