International Journal of Interdisciplinary Innovative Research &Development (IJIIRD)
ISSN: 2456-236X
Vol. **08** Special Issue **01** | **2023**

Coal Mine Health and Safety Monitoring System Using IoT

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***Abstrac* : The coal mining industry presents significant risks to worker's safety and health. coal mine health and safety monitoring system using IoT technology can help address these risks. The proposed system consists of sensor nodes distributed throughout the mine to monitor environmental parameters such as temperature, humidity, and gas concentration. Wearable devices are used to monitor workers' health, such as heart rate, body temperature, and blood oxygen levels. All data is transmitted to a cloud-based platform for real-time monitoring and analysis. The platform generates alerts if any sensor readings indicate a hazardous situation, enabling early intervention to prevent accidents before they occur. The proposed system can significantly improve safety and reduce risks associated with coal mining, ultimately leading to a safer and healthier workplace for coal miners.**

Keywords— LoRaWAN, Sensors, ZigBee, IOT, SMP

I. INTRODUCTION

The technological advancements since the last few decades have conveyed a new face to the industries in achieving greater productivity, value, safety and quality and has made a great impact on reducing the time constraints in achieving the desired industrial goals. The large variety of industries in the sectors like Information Technology, Construction, Transportation, Telecommunications.

Financial Services, Energy, Chemical, Biotechnology, Pharmaceutical, Entertainment and Recreation, Public Administration etc., contributes in its own way in developing a country. The sector is the coal mine, which has contributed about 65% to India's growth as its distance from the earth has increased. The use of various mining techniques by the miners to extract various minerals is the cause of the hazardous mining activities. The risk is more obvious the longer the excavation. The execution of safety steps is extremely lacking, particularly in the coal mining sectors. High temperatures, high humidity, and the release of deadly fumes are just a few of the hazardous conditions that coal mine workers must contend with. Many workers are leaving their jobs in coal mines. The coal extraction business faces many difficulties in hiring workers as a result. Through technology, the security of workers in the coal mining industry is steadily improving. The harsh environments and hazardous working conditions are the major causes of mishaps and disasters in coal mines. Because of this, coal mines have a significant need for mine checking devices. It can be challenging to physically monitor every aspect of the atmosphere in a coal mine on a continuous basis. The use of reasonably feasible wireless communication devices at the necessary location in coal tunnels makes it simple to complete this task. The suggested model uses less energy and more effective instruments to detect a worker's heartbeat, amount of respiration, and any significant environmental releases of hazardous gases. These dangerous gas concentrations are constantly monitored, and timely warnings of dangerous conditions are communicated for the protection of mine workers. For many years, wire-based observational equipment has assisted in mine safety. Wireless networks are greatly favoured in the current environment due to the intricacy and viability of wired networks. This proposal's main goal is to monitor the health indicators for miner and the amount of hazard gas in the mining area.

A. Methane Sources in Coal Mines

The methane can be obtained from the UCMs in different ways such as the coal bed methane and the coal mine methane which are abbreviated as CBM and CMM respectively. The CBM obtained from the coal mines is a term used to represent high rich methane gas with the methane proportion in the range 80% to 95% with carbon dioxide, propane, nitrogen and ethane in the low proportions in accordance with the statistics and data presented by UNECE. The amount and the rate of methane releases depends on factors such as the content of gas in the coal[3], the amount of coal seam in terms of thickness and distribution getting disturbed by mining activity, coal production rate, magnitude of the coal bearing layers, permeability of the coal seam and the geometry of the coal mine workings etc. Developing an Automated Detection and Communication. The uppermost ten coal producing countries around the world are as given in the below table. The data is obtained from the IEA coal information published and made available in the year 2015.

COUNTRY NAME	COAL PRUDUCED (Mt)
PR China	3748
United States	916
India	668
Australia	491
Indonesia	471
Russia	334
South Africa	253
Germany	187
Poland	137
Kazakhstan	116

Fig 1: Uppermost ten coal production

Through the Internet of Things (IoT), LoRaWAN technology is used to update the data from the sensor on the website with information from the underground [10] laborer area. Working in coal mine is well-thought-out as one of the

most hazardous occupation than many other occupations because most of the coal production work is carried out in the underground and in the narrowed places. Apart from the danger even in the roadway the miners take to move inside the coal mine, the coal mine environment has a menace of poisonous gases leakage Monitoring system. Moreover, the accidents [5] that occur in the surface based industries are less severe when parallel to the losses both to human life and infrastructure that might happen due to an accident in the coal mine; example the accident in the surface industry can cause a loss to one or few due to the widespread position of machines whereas a small ignorance consequential in explosion or a mine fire can effect a lot more lives and property. The use of cutting-edge technologies has significantly decreased fatalities and major accidents in coal mines.

B. Coal Mining and Major Accidents in Coal Mines

Indian Scenario India has been efficacious in dipping the number of coal mine accidents since the past two decades. The coal demand has grasped a great height by the year 2019 which is faraway more than any coal producer produces today. To run into such a high demand, India is dependent on Coal India Limited (CIL), the world's largest coal producing company contributing to more than 80% of India's coal production and Singareni Collieries Co. Ltd. (SCCL). Below list shows the measures taken up by CIL to increase safety:

- Safety Management Plans (SMP) based on risk assessment.
- Increased usage of state of the art technologies wherever suitable.
- Formulation of guidelines grounded on past accidents record to overcome such accidents.

Company	Fatal accidents						Serious accidents					
	No. of Accidents			No. of Fatalities			No. of Accidents			No. of Injuries		
	2014	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016
WCL	9	8	5	10	8	5	36	24	14	38	27	14
SECL	11	10	8	12	10	9	31	33	25	32	35	27
NCL	6	1	4	6	1	4	9	18	13	9	20	13
MCL	0	3	2	0	3	2	13	4	7	13	4	7
ECL	6	7	9	6	7	26	69	39	42	69	40	44
CCL	5	2	4	5	2	4	7	5	7	7	5	8
BCCL	7	7	6	7	7	6	17	9	5	17	9	5

Fig 2: Major Accidents in India

C. Principal Causes of Accidents in Coal Mines

It is important to know what are the major factors which can result in causing accidents in the coal mines. The chief factors which can cause accidents in coal mines are listed below:

i. Methane explosion.
ii. Fire.
iii. Falls of roof, ground or side walls.
iv. Accidents closely connected with loading or abandoning.
v. Surge in gases such as CO, CO2 etc.

II. LITERATURE REVIEW

Gothane, Suwarna [9], Working in subterranean coal mines has always been challenging and fraught with concern for worker safety. Extreme humidity and high temps are easily produced in the underground environment and can have a detrimental effect on the health and welfare of the workers. The top limit for human existence is believed to be found in underground coal mines, where the typical temperature runs from 27°C to 30°C and the humidity is between 70% and 75%. For a variety of causes, temperature and humidity can increase, which can lead to severe mishaps in a subterranean mine. Additionally, the fact that electrical devices hardly ever work correctly at those high temperatures and humidity levels makes the situation worse. However, more recent communication tools have made it possible for us to create systems that are more effective than the earlier human ones. Therefore, this article offers a method for creating a monitoring device to stop these temperature and humidity-related accidents by creating a reliable, cost-effective electronic measurement system using cutting-edge communication methods.

Prabhu, D., Nikhil, V [16]. Produced a large amount of electricity using coal. During its production, transit, and ingestion, respirable dust particles are produced, which is now a worldwide worry due to its harmful health effects on living things. To keep the dispersed particulates, including coal dust, under control. For physical water misting, government and industrial organizations use water trucks. It is burdensome to deploy water trucks everywhere to reduce dust. When the amount of respirable dust surpasses the allowable limit, we proposed an Internet of Things model and a spontaneous technique to perform automatic of pressurized water gathered from rain. In this approach, after gathering real-time particulate matter data from the entire area of interest using sensor networks that are wireless, the micro-controller decides how to direct the misting process based on information from a few other sensors. This structure not only effectively suppresses dust but also minimizes the loss of high-quality water, which is one of a coal mining district's main worries.

Deokar, S., & Wakode, J.S, [17] Coal mining operations are very hazardous due to the extreme temperatures and a variety of diverse gases compositions in the air below coal mines. As a consequence, numerous accidents happen and many skilled workers and laborers pass away. The two Node MCUs we are using in this system are made to function as wearable [8] devices (clients), which are constantly getting information, and the gases and temperature monitoring node (servers), which are constantly transmitting a warning to the client if a gas content is higher at a high temperature. With the Node MCU, we are creating a wearable that continuously gathers data on temperature, gas content, warning messages, and sound.

Mukherjee, T. Maity [11], in this article, a wireless sensor network with low power consumption and reasonable costs is presented. It is built on the ZigBee protocol and offers an intelligent safety and monitoring system for subterranean coal mines. A wireless link between several components makes up the system. A high-performance, low-power microcontroller is combined with a low-power, ZigBee protocol-based CC2530 transceiver to create the sensor node's primary component. RF connection on the

smartRF05 Battery Board was used to attach this embedded device. It is simple to connect this tiny, low-power gadget with required miniature size gauges. ZigBee-based [14] wireless sensor networks are produced when wireless sensor nodes combine with other nodes in a particular multi-hop mesh network topology.

III. RELATED WORK

The implementation of safety measures in port operations is primarily focused on protecting the equipment that is in use, which uses sensors and controls to provide employees with safety. With current technology, it is impossible to monitor and observe the port employees due to their high levels of movement and danger. In this piece, a warning system utilizing Identification by Radio Frequency (RFID), Internet of Things (IoT) [7], and smart alert system is used to ensure safety. There will be choking, suffocation, inundation, gas poisoning, mine collapses, or blasts if these factors rise above a certain threshold. The worker health parameters used in this article are based on the personal health factors of the worker, including their BMI, age, asthma attack, and miner family background of notifiable illnesses. If the levels of these gases go over a certain threshold, the warning goes off right away, and an alert [18] message is sent to the person who needs to know. The primary function of this system is to quickly respond to and accurately identify emergency situations. It also diffuses gas by turning toxic gas into pure air. This method is very useful for creating smart communities, which reduces the number of fatalities among people.

A. Challenges and Constraints in Underground Communication

The communication in the UMs undergoes a lot of challenges and faces many constraints. The various constraints or the difficulties faced in the UCM in order to develop a communication system are listed below:

- The signal goes through various paths and losses occur in the communication system due to various factors such as humidity [4], path losses which increases with the distance between the receiver and the transmitter.

- At certain values of frequencies, the coal mine tunnel acts as the waveguide and results in reflecting or refracting the signals due to which some signals are refracted and results in loss of energy and some signals gets reflected.

The noise generated from various sources such as the power lines, electric motors, lightings, mining machinery etc., also adds in reducing the signal strengths other than the noise from external sources or other miscellaneous sources.

Shi Wei et al. The study project presented in this article has a plan that, according to the author, confirms its demonstrated viability and excellent stability. In the work that is being given, a flexible design that can accommodate the addition of sensors and improve the reliability of the tracking software is demonstrated. Through the use of the RS 485 communication protocol system, developing an automated detection and transmission [13] system for enhancing safety in coal mines 56 process. The research work provides an idea of keeping track of the mine workers about their position inside the mine in order to let the managers distribute the staff inside the coal mine and to keep worker's trajectory so as to manage and schedule with the miners reasonably. The proposed research work multi – parameter monitoring system [2] can monitor and alert against the safety issues that can arise due to the multi – parameters such as humidity, underground gas, temperature variations etc.

IV. METHODOLOGY

The suggested method has two sections: one to track the health of the miners, and the other to track everything. Two smoke sensors are used in the miner area to keep track of the various kinds of smoke levels there, and each sensor records values sent to the microcontroller. In the event that the gas sensor values exceed the limit range, the alert message send to IoT webpage application and the data via the Lora transceiver to the controlling unit and alert to the user via the buzzer. Through IOT, the collected data is transmitted to the website. Additionally, respiratory and heartbeat monitors are used to keep track of the health state of the underground employees.

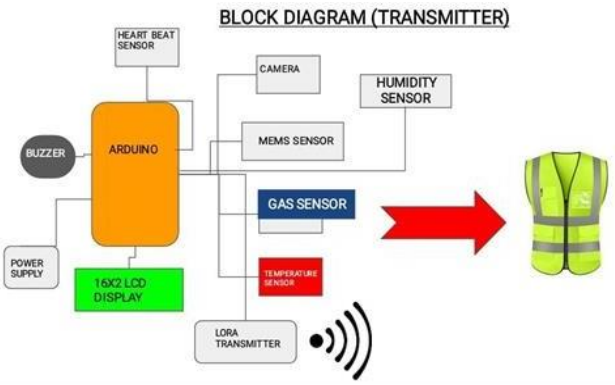

Fig 3: Block Diagram (Transmitter)

For the coal mine employees, the suggested system monitors health indicators like heartbeat and respiration rates [12]. The relevant metrics are constantly sent to the IoT webpage by each sensor, which also watches them. An alarm is activated when a sensor's output crosses over or below a predetermined range of values that are set into the sensors. A pulse is the quantity of heartbeats that occur over the course of 60 seconds. Everybody's pulses beat at a different pace. A healthy pulse rate for an adult is between 60 and 100 beats per minute; when it exceeds or falls below this range, it is considered irregular.

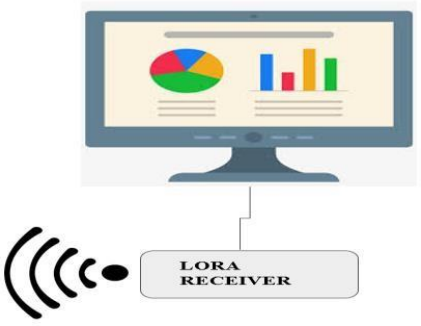

Fig 4: Block Diagram (Receiver)

A respiratory rhythm that lasts two to three seconds for intake and expiration indicates a healthy respiratory system. People's respiratory rates differ from one another depending on their degree of fitness and physical activity. Normal respiration rates are also affected by age. The proposed gadget starts tracking the mineworkers' respiratory rates right away. Depending on whether the breathing rate is higher or lower than the limit range of numbers, the alert sounds. The atmosphere in caves is contaminated by gaseous like methane, sulphur dioxide, and carbon dioxide. Because to the limited space, these gaseouss do not continuously spread at the caves. In the underground setting, they consequently loop. The Internet of Things (IoT) enables remote [6] monitoring and management over the existing network architecture. This device uses an IoT board with a Lorawan transceiver to display the info live. The information is also updated on a special website that only the approved individual can view. The proposed system contains a buzzer, an LCD display, an Arduino UNO microcontroller, the LoRaWAN networking protocol, smoke sensors, pulse sensors, respiratory sensors, and a buzzer.

A. *LoRaWAN transceiver*

The LoRaWAN protocol had only a few revisions after its initial introduction in 2015. The lowest physical layer, or LoRa, fills in the gaps left by the more advanced networking levels. The network's top levels are defined by LoRaWAN, which is more sophisticated. All nodes in LoRaWAN networks connect to a central gateway via a star architecture, which is the usual configuration. However, LoRaWAN can also be used to create a mesh network where devices can communicate with one another to increase the network's dependability and coverage area. The system design for the network and the transmission protocol are specified by LoRaWAN. Assisting the long-distance data connection is the LoRa physical layer. Additionally, LoRaWAN controls [15] how fast data is transmitted, as well as how loudly devices can communicate and how much power they use. As soon as they are prepared, network devices send data. Multiple ports receive the data packets that an end-node computer transmits and then send the packets to a central network server. The program servers are subsequently informed of the details. For moderate load circumstances, this technology is more dependable. But there are also a few small efficiency issues with this technology when it comes to reporting the acknowledgments. Support for various network topologies, such as point-to-point, star, and mesh networks, is one of LoRaWAN's main characteristics.

LoRaWAN can be applied in a variety of IoT applications thanks to its versatility, including asset monitoring, industrial automation, smart cities, and agribusiness. The unlicensed frequency regions where LoRaWAN works are usually at 868 MHz in Europe and 915 MHz in North America. LoRaWAN networks are a common option for IoT apps because they are made to be affordable, scalable, and simple to implement. Because LoRaWAN is an open standard, anyone can create and implement networks and products using the technology without having to purchase a license. It is possible for nodes to transmit and receive data in both directions thanks to LoRaWAN's support for bi-directional connectivity. Because of this, nodes can transmit status updates and sensor data to other nodes, as well as receive instructions or setup changes from the network. The post-disaster communication, decentralized networks, network administration, and adaptive data rate problems can be resolved by scientists and engineers through a few gaps in the literature on this technology.

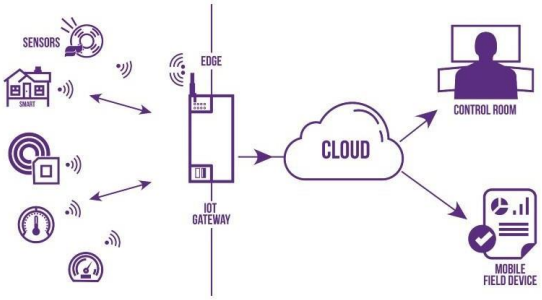

Fig 5: LoRaWAN transceiver Arcitecture

B. *Respiratory Sensor*

The use of the respiratory sensors includes monitoring abdominal and thoracic respiration as well as biofeedback applications like tension reduction and relaxation training. Additionally, the sensor reports the current state of the proportional profundity of respiration[1]. The worker's clothes can be used to connect the respiration monitors. Most of the abdomen region contains the Respiratory Sensors, with the middle of each sensor just above the navel. To avoid tensile damage, the gauge needs to be installed firmly enough. Wearing a jacket that can recognize variations in the breadth of the thorac or belly brought on by breathing is the concept. The monitor can notify the user and/or a supervisor to take action to avoid respiratory distress if it notices any anomalies or deviations in the wearer's respiration. This might entail altering the working atmosphere, supplying respiratory safety gear, or contacting emergency services. A safety jacket's respiratory tracker is a tool that can track a wearer's breathing and identify any possible respiratory trouble. It is frequently used in workplaces where employees might be subjected to dangerous substances or fumes that could lead to respiratory issues. A monitor that measures changes in airflow or other physiological cues is usually connected to a body-attached device, such as a chest strap or a nasal cannula. Respiratory monitors can be combined with other sensors and devices, such as movement tracking or environmental sensors, in Internet of Things apps to provide a more complete image of health and wellbeing. For instance, respiratory monitors can be used to track air quality and pollution levels, which can affect lung health.

C. *Heartbeat Sensor*

When a finger is placed on a pulse sensor, the sensor's engineering produces a digital representation of the heartbeat. These digital impulses are instantly received by the microcontroller, which then determines BPM. The foundation of this method is the idea that each heartbeat in the finger causes a change in the amount of light. Medical cardiac sensors can be used to view the vascular regions through the part of the earlobe or the tip of the finger [20]. They are primarily used for health-related purposes,

particularly when observing how the human body responds to physical exercise before and after it. A sensor is a photodiode or phototransistor. The epidermis is illuminated by visible red light, which is then transferred and reflected to enable identification. The slight variations in reflectivity or transmittance brought on by differences in blood volume in human tissue are essentially undetectable. Multiple sources of noise produce obtrusive signals with amplitudes that are comparable to or even greater than the magnitude of the pulse signal. Therefore, adequate pre-processing of the original signal is necessary in order to determine an appropriate pulse. The innovative signal processing technique described in this article combines analog and digital signal processing, both of which can be completed quickly and efficiently when used together to reduce disruptive signals.

D. Smoke Sensor

A smoke detection and warning device called the MQ-9 Carbon Monoxide, Methane and LPG Gas Sensor Module H9 is used. It converts the difference in the output signal with regard to the conductivity of gas concentration using a straightforward circuit. The gas monitor MQ-8 is very delicate. Another accomplishment is the detection of additional hydrogen-mixed vapors. It is widely used in hydrogen leak detection devices in both domestic and commercial settings [19]. With ethanol mist, soot, carbon monoxide, and other substances, they never interact. Additionally, it has a gas-resistance characteristic. The enveloped MQ-8 has 6 ports, of which 4 are used to receive data and the other 2 to supply heating current. The MQ-35 sensor can be used for a variety of uses besides smoke detection because it is responsive to a broad spectrum of gases and VOCs. However, it is crucial to keep in mind that variables like humidity, temperature, and other environmental circumstances can have an impact on the sensor's sensitivity and precision. Therefore, when using the sensor for a particular purpose, it is crucial to calibrate it and take these things into consideration.

E. Humidity Sensor

The humidity sensor (DHT22) of the air around a device is measured using a humidity sensor. It frequently appears in a variety of uses, including monitoring of indoor air quality, food processing, weather monitoring, and HVAC systems. There are several varieties of humidity sensors, each with unique benefits and drawbacks.

Capacitive humidity these sensors assess changes in capacitance brought on by variations in humidity using a thin film capacitor. They are extensively employed because of their great accuracy, quick reaction, and affordability.
Resistive humidity sensors: These sensors change resistance in response to variations in humidity by using a hygroscopic substance, like a polymer or salt. Compared to capacitive sensors, they are less precise and respond more slowly, but they are less costly.

V. CIRCUIT DIAGRAMS & WORKING DESCRIPTIONS

The majority of the mine accidents fatal or non - fatal occur due to fires and explosions, roof falls, slips, electrical hazards, human errors in using machinery and following safety procedures, fatigue etc. The other reasons can be improper functioning of equipment, insufficient healthy and safety procedures, negligence of threats which may result in explosions or other severe accidents, repetitive nature of work which may sometime increase ignorance towards safety etc.

This will avoid human errors and can result in a system which can perform better safety operations. To check the present security and safety system procedures, I have visited a very famous and very productive coal mine, SCCL in order to increase my understanding towards my research work. In the coal mine, I observed that only supervisors or allocated staff were given multi gas detectors and flame safety lamps. The supervisors or allotted staff were heading a group of workers in different parts of the coal mine threat is detected.

Both the methods require concentration from the supervisor failing which a danger can result. Moreover, both the methods cannot transfer the mine data to the outside monitoring unit and require the supervisor or other workers to call the safety team with the help of a phone available in the mine. However, there were other sensor units available in the mine, but kept at only a few places which doesn't fulfil the need for total mine security.

The controller upon receiving this data sends alert messages through RF transmitter to the internet communication module. The internet communication module receives this data with the help of RF receiver and sends it through the Ethernet module to the Wi – Fi router which can be accessed by the officials, management, government regulatory agencies etc., around the world[18].

The circuit diagrams representing the connections between the various components, modules and controllers is shown and described in this chapter. The order in which the circuit diagrams are explained here is similar to the block diagram description explained in the beginning of this chapter. The breakdown and description explained in this part of the chapter is in the order mentioned below

• Sensors and actuators connections with the controller describing the interfacings between the sensors and actuators with the controller.

• Power supply circuit connections showing the role of rectifier, filter and regulators in developing the DC power supply to provide required voltages as output.

• The connections between the actuators and the driver ICs describing the role and working of the actuators

VI. RESULTS

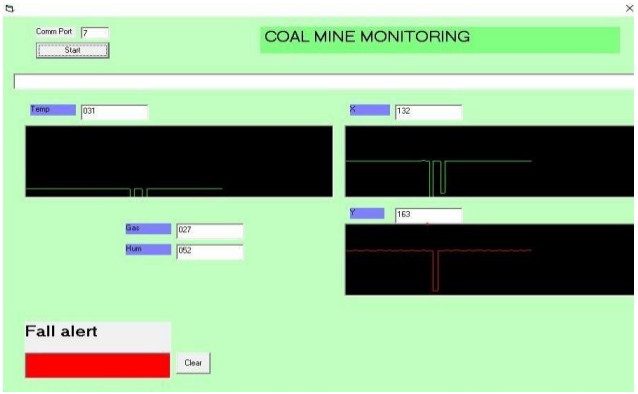

Fig 6: Output

When the data from the gas sensors exceed 100, the surroundings is deemed unusual, and beeper are switched ON. The amount of gas sensors is fixed at 100. Respiratory sensors have an 18 to 24 threshold range. The buzzer is switched ON the results from the respiration detector go outside or inside the maximum, indicating that the individual is unusual. Similar to this, the heartbeat sensor's threshold range is set between 90 and 100. The individual is deemed abnormal and the buzzer is switched ON when the heartbeat sensor values fall either above or below the threshold range. With LoRaWAN, the monitoring section is regularly updated with information from coal mine workers and the mining environment.

VII. CONCLUSION

The research work is targeted on detection of critical environmental factors such as methane, fire and carbon dioxide; it also has room for providing assistance in the rescue operation with the availability of the PIR sensor module to detect the presence of miners or live human beings in the mines which helps the rescue team to reach to the miner in a quick time without wasting time in searching for the injured or trapped miners. All the above mentioned functions are performed by the project work with an additional advantage of wireless communication capable of reaching worldwide distance and allowing the collected information from the sensors to be accessed on a large number of portable and desk based devices such as laptops, notebooks, mobile phones, computers etc., with the help of the internet. This system uses LoRaWAN technology to constantly watch the mining and alert the employee and authorized person from an underground station. The surroundings and the miner health status is continuously updated on the IoT application. The system that collects and uses the mine worker's medical information for additional artificial intelligence-based medical prediction is efficient and cost-effective. As a result, the suggested method lowers the mortality rate and illness warnings for mining industry employees. The data is then processed by the main controlling unit based on the instructions stored in the microcontroller unit. Based on the collected information from the sensors, the microcontroller unit or the main controlling unit takes necessary actions such as operating the fire blocking door, water sprinkler and the buzzer in the case of fire accidents etc. The availability of the buzzer component in the proposed research work can help the miners to get an alert of a possible emergency situation and can warn the miners to escape or perform the actions as instructed and formulated in the safety guidelines of the respective underground coal mine.

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