International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-6 Issue-5, November 2017

Design and Development of Smart Rescue System for Workers in Land Mines through Wireless Sensor Networks and IoT

Babburi Santhoshi, Santhosh B Panjagal, Balakrishna Masanam

Abstract*: *The objective of this paper is to develop a wireless networked embedded system to monitor the health conditions of the worker in underground land mining, for providing immediate rescue in case of emergency. This system also provides the working Zone of the miner to speed up the rescue operation under emergency situations like landslides, equipment failure etc. and also monitor the emission of the marsh gases like methane and carbon monoxide and also monitor the temperature of the mining environment. The land miner is continuously monitored by using heartbeat sensor and fall detection techniques to provide him emergency rescue if needed. Emission parameter like CH4, CO etc. is continuously monitored by using Gas sensors, temperature monitored by temperature sensor and these values are sent to the database using ZigBee module. The ad-Hoc Wireless sensor network forms the backbone of underground communication; an intelligent mesh network is constructed to pass on the underground and miner conditions to the control room using ZigBee protocol. In the control room every worker status can be monitored through the Real-Time database application. Because of the recent advantages in the internet connectivity like IoT, every worker is connected to the IoT for remote monitoring and management operations. The interpreted data in the control room will be uploaded to the IoT to safeguard and better protect against any disastrous situations.

Index Terms*: *WSN, IoT, MSP430, Mesh Topology, Gas Sensors, Heart Rate sensor.

I. INTRODUCTION

Safety is one of the main aspects of the mining industry. Communication is the main key factor for any industry today to monitor different parameters and take necessary actions accordingly to avoid any types of hazards. To avoid loss of material protection system as well as faithful communication system is necessary inside the underground mines. To increase the safety in mines, a reliable communication must be established between workers in the mine, and a fixed base station. Inside mines, the wired communication system is not so effective and costly. The Reliability and long life of conventional communication systems in harsh mining

Environment has always been a problem[4]. Inside mines due to uncomfortable situation the installation cost as well as maintenance cost is high for wired communication networks. It is very difficult to reinstall the wired communication system inside mines after a landslide or damage due to any reason.

Generally, the miners are facing lot of problems in coal mines due to harmful emissions like CO and methane gases, etc. and fire accidents [1]. Due to this, many of the people lost their lives and so much property (machinery) loss also arises. There is a system to help the workers when they inform that they are in need of help. But there is no system designed to help the worker when he goes to unconscious state.

As the advancements in the wireless sensor networks lead to develop complex networks using low cost, low power and reliable communication modules for remote monitoring, control by establishing communication between neighbor nodes covering larger geographical area. Wireless network is built of from several nodes, where each node is connected to one or more intermediate nodes and coordinating nodes. By using mesh technology communication between different nodes is also possible which helps for long distance monitoring. Each node has several parts like microcontroller unit, electronic circuit for interfacing with wireless radio network, energy source etc. Such tiny node collects the data from the underground workers and sends the collected information to the master station for analysis, monitoring and command signal and further can be sent to the Internet of Things IoT [6].

Internet of Things (IoT) has become a remarkable spotlight among the diversified interest groups. The growth of the number and variety of devices that are collecting data is incredibly rapid. A study by Cisco1 estimates that the number of Internet-connected devices overtook the human population in 2010, and that there will be 50 billion Internet-connected devices by 2020.

IoT provides real-time data analysis, storage of user data in the Cloud over the period, event generation, control operation for remote monitoring. IoT is a new of interaction between the Machine-to-machine or device-to-device communication eliminating the human intervention for monitoring and control operations.

Revised Manuscript Received on 30 November 2017.
* Correspondence Author
Ms. Babburi Santhoshi*, Asst. Professor, Department of Electronics and Communication Engineering, Visvesvaraya College of engineering technology, Hederabad (A.P.), India, E-mail: santhosibabburi@gmail.com
Mr. Santhosh B Panjagal, Asst. Professor, Department of Electronics and Communication Engineering, Kuppam Engineering College, Kuppam (A.P.), India, E-mail: santupanjagal@gmail.com
Mr. Balakrishna Masanam, Research Scholar, Department of Electronics and Communication Engineering, JNTU-Anantapur, (A.P.), India. E-mail: balumasanam490@gmail.com

This system is designed by considering all these parameters i.e. it can sense temperature, carbon monoxide and Methane gas levels, also detects the working zone of the miner, predicts whether the person has gone to unconscious state or not and respond to the emergency situations like landslides, equipment failure, underground water etc. Therefore the designed system gives very good solution for most of the problems faced in the mines. Finally adding wireless capability to establish underground communication makes it ease in monitoring and providing rescue operation under abnormal conditions. Connecting every worker in mining to IoT makes it still better monitoring and rescue operation making miners to feel safety and secure against disastrous emergency situations.

The proposed system is designed to give an alert to the respective authorities if the miner goes unconscious by sensing biological parameters such as temperature of the body, pulse rate etc., and also using the fall detection techniques and it also gives the working zone of the miner so that he can be medicated as soon as possible.

II. SYSTEM DESIGN

Complete plan to implement the smart rescue system for workers in land mining involves the design of smart device for every miner, incorporating biological sensors, gas sensors, detectors and emergency indicators etc. to monitor the changing parameters in selected zones. The individual node data will be routed through wireless coordinating nodes to the Control room personal computer, which runs the real-time data monitoring user interface application to monitor every worker in land mining environment. Finally the processed data is sent to the IoT cloud via gateway, for remote monitoring of every worker. The complete overview of the smart rescue system is as shown in figure 1.

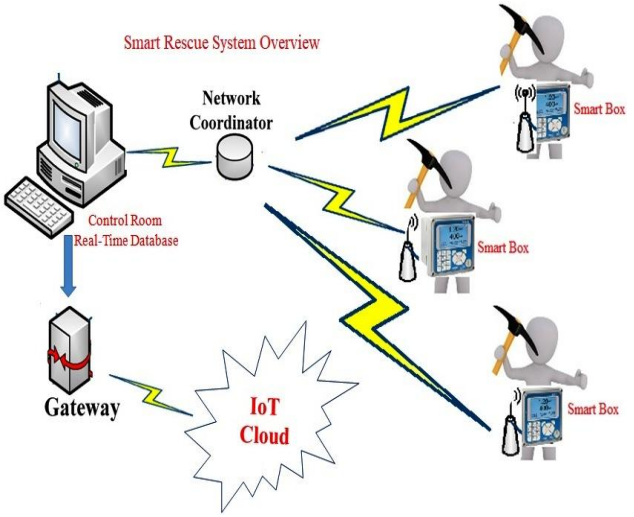

Figure 1: Overview of Smart Rescue System

Every node consists of various sensors like Heart rate, accelerometer, gas sensor, zone detector, emergency indicator and ZigBee communication module. The following figure 2 shows architecture of individual nodes. Figure 3 shows the Control Room block diagram with IoT connectivity.

Every node data will be received at the control room via one or more coordinating nodes, a real-time application is used to monitor the worker health status and other disastrous conditions at the control room. For allowing remote access and monitoring, every worker data shall be forwarded to IoT cloud, where the data is stored in Cloud and real-time tracking is shown in the dashboard.

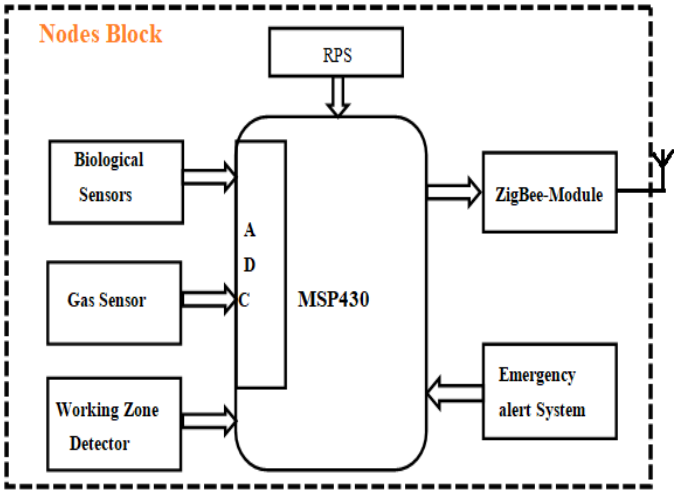

Figure 2: Reference block diagram of Wireless Nodes

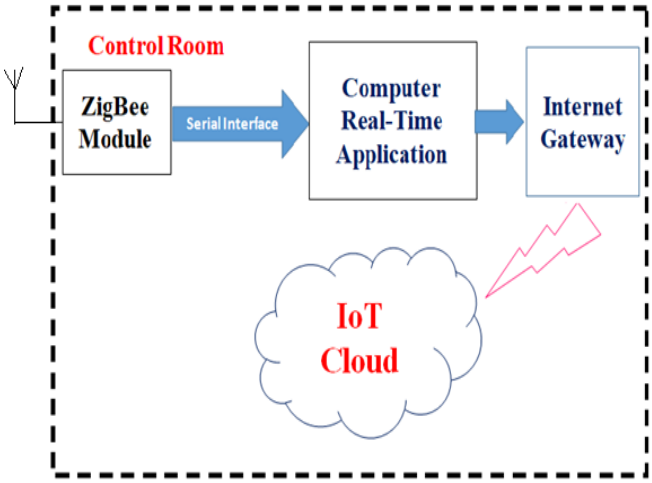

Figure 3: Control Room block diagram with IoT Connectivity.

A. ***MSP430:*** The Texas instruments Mixed Signal Processor (MSP) excels where low power consumption is important, it finds very important role in ultra-low power applications, which can run for long years on a single cell battery. It has various industry leading features over conventional controllers like, various Ultra-low Power modes (0.1uA power down, 0 .8uA standby mode, 250uA / 1MIPS etc.), high integrations, flexible clocking system, On-Chip analog comparator, Hardware multiplier operates on 1.8V to 3.6V and 1.8V Fast USB system andso on.

B. *Heart beat sensor:* The heart rate, also referred to as pulse rate is directly related to a person's cardiovascular health, works on the principle of transmission photo-plethysmography (PPG) to sense the pulse signal from a fingertip. The PPG signal has two components, frequently referred to as AC and DC. The AC component is mainly caused by pulsatile changes in arterial blood volume, which is synchronous with the heartbeat.

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C. So, the AC component can be used as a source of heart rate information. This AC component is superimposed onto a large DC component that relates to the tissues and to the average blood volume. The DC component must be removed to measure the AC waveform with a high signal-to-noise ratio. The sensor operates at 3.3V-5V @100V.

D. Accelerometer (ADXL335): The ADXL335 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The output signals are analog voltages that are proportional to acceleration. The accelerometer can measure the static acceleration of gravity in tilt-sensing applications as well as dynamic acceleration resulting from motion, shock, or vibration. It operates at a supply voltage of 1.8 V to 3.6 V @ 350 µA (typical).

III. SOFTWARE DESIGN

The entire hardware system alone cannot serve the purpose, unless the real-time program instructions are flashed into the hardware. The software part plays an important role to coordinate and control all the peripherals connected with the controller, the system becomes functional by configuring and initializing the peripherals as per the software instructions. Once the initialization completes, the system measures the gas concentration, heartbeat, fall detection status, emergency situation and working zone detector.

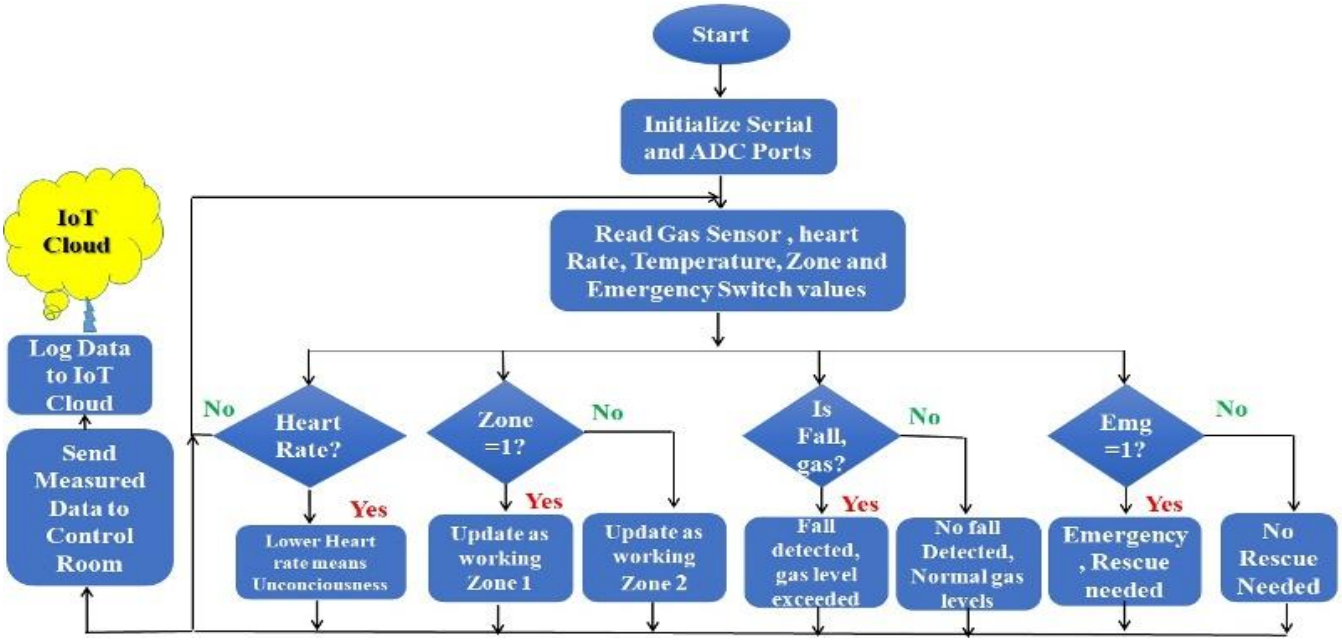

Figure 4: Software flowchart for Smart rescue system

The measured data will be sent to the control room using ZigBee mesh network through coordinating nodes. The Real-time monitoring application software running in the computer acquires every worker status data, displays all the necessary data for real time tracking. If any of the parameters shows abnormal condition, immediately notifies the authorities of rescue operation. To speed up the rescue operation during emergency and/or disastrous situations working zone detection algorithm is also implemented. Finally the processed data in the control room shall be sent to the IoT cloud for remote access for monitoring of every worker. The IoT connects every worker by storing all the parameters data in the cloud platform for knowing the parameter variation and working environment conditions changes over the period of time. IoT cloud server provides powerful processing and analytical tools for real-time monitoring and triggering the calls, mails, SMS etc. to authorized used. The complete software flowchart for the propose system is as shown in figure 4.

A. To design the real-time embedded software for MSP430 target processor, we used Code composer studio as a cross compiler, which is a integrated development environment based on eclipse. It is powerful IDE supports multi-platforms devices families like, MSP430, ARM, DSP processors in a single IDE. It has Integrated "Debugger" and "Editor", Edit and Debug have the own "perspectives" (menus, windows) and Contains all development tools – compilers, TI-RTOS kernel and includes one target – the Simulator.

A real-time windows application has been built on Microsoft visual basic, to monitor the workers health condition and surrounding environment by updating in real time. Microsoft visual basic is the fastest and easiest way to create applications for Microsoft Windows. It has evolved from the original BASIC language and now contains several hundred statements, functions, and keywords, many of which relate directly to the Windows GUI. Internet of Things (IoT) is one of the transformational trends to shape the future of connected devices with the internet. All these connected devices will have the potential of offering a rich stream of data that will then be used by product and service owners to interact with their consumers.

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The IoT solutions being built on modern Micro services provides visualizations, analytics, processing, event trigger and remote access through API keys. Further, machine-learning cloud services and Artificial Intelligence will be put to use to mine the data that would be coming in from IoT devices.

IV. RESULTS & DISCUSSION

The Complete working module of smart rescue system has been developed to monitor the workers in underground land mining, by incorporating Heart rate sensor, Gas sensors, WSN, IoT etc., in which all the individual modules are designed, analyzed and tested before assembling the entire system. The working module is as shown in figure 5.

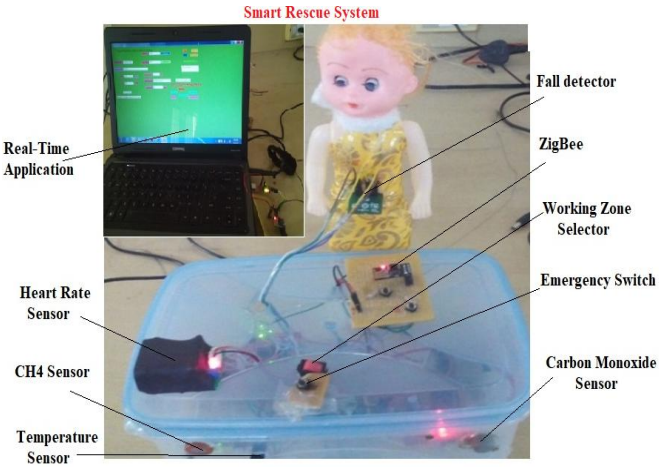

Figure 5: Complete Module of Smart rescue system

All the sensors data acquired from the land mining workers have been displayed on the windows real-time monitoring application as shown in figure 6.

Figure 6: Real-Time system Application

The real-time application displays working zone of the miner, emergency alert, Heart rate, temperature, fall detection condition and CH4, CO gas sensor concentrations.

Working zone allows easier tracing of a worker in underground mining, worker health conditions like conscious state is determined with the help of heart rate, if the heart rate goes beyond or below threshold level (<60 BBP) then the person is unconscious state and also if fall is detected in the working area it will be updated and intimated to the working supervisor to monitor the situation. Under emergency conditions like landslides, blockage, water entry etc emergency switch helps the worker to seek rescue immediately. Temperature and gas concentrations are measured to keep the worker under safe and secure against any disastrous situations leading to equipment failures etc.

The following figure 7 shows heart rate values of various persons in underground environment under normal situation;

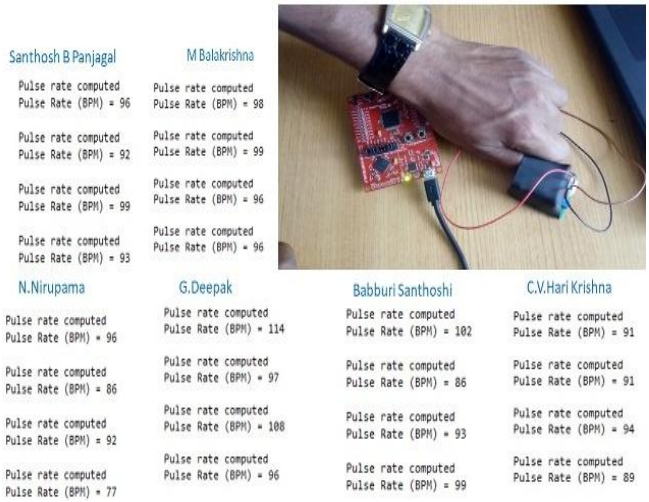

Figure 7: Heart Rate testing of various persons in under underground

Finally the processed data in the control room will be sent to ThingSpeak.com IoT cloud for remote monitoring of every workers tagged with smart rescue system, anyone who is authorized to access the worker data of respective worker in the land mining can able to monitor remotely with login permissions and also emergency events are triggered to notify the tragic situations. Following figures shows the field charts for various sensor data of Smart Rescue System.

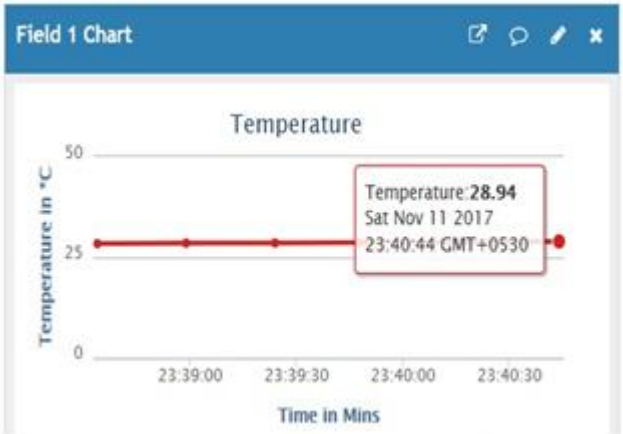

Figure 8: Plot of Temperature in Thingspeak

Figure 9: Plot of Heart Rate in Thingspeak

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Emergency conditions are coded as '1' and '0', '1' indicates emergency condition over the time, which demands immediate rescue and '0' indicates normal condition with no emergency, as shown in figure 10 and 11.

Figure 10: Plot of Emergency Condition for emergency rescue indication

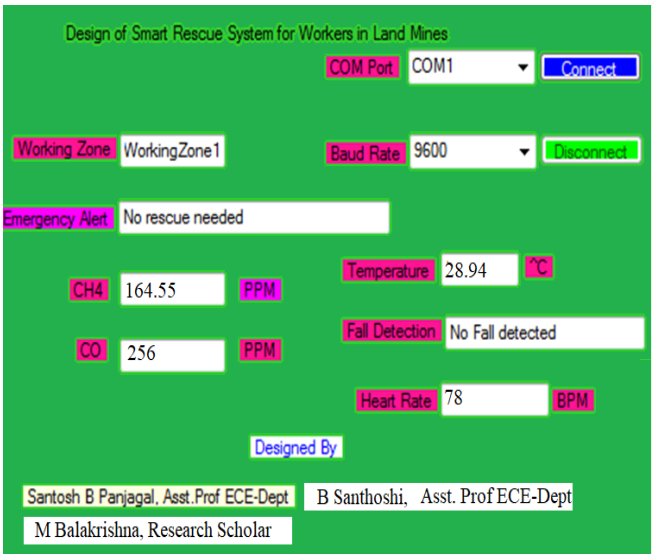

Figure 11: Plot of Emergency Condition for No emergency rescue indication

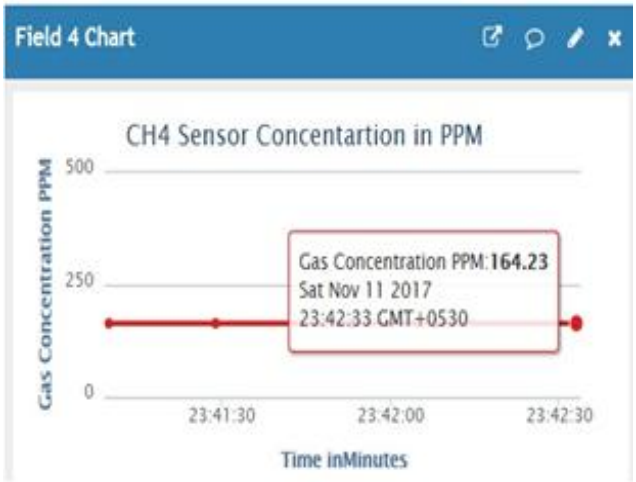

Figure 12: Figure 12: Plot of CH4 gas concentration

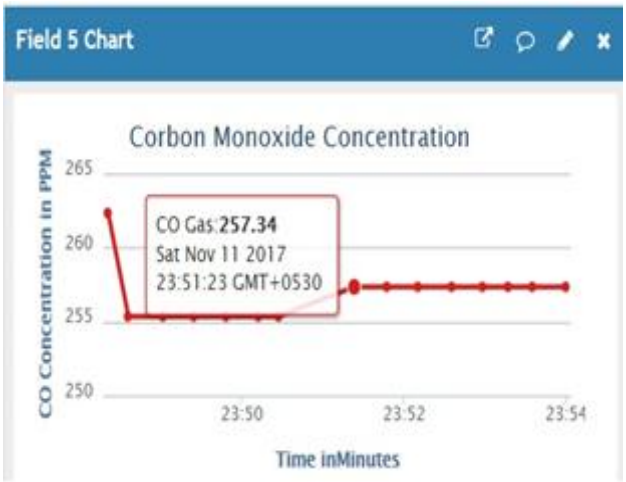

Figure 12: Plot of CO gas concentration

An Ad-Hoc wireless mesh network has built to cover entire range of land mining area and collect the workers status through the smart system fitted on them, and finally the collected information is passed onto control room via the coordinating nodes.

V. CONCLUSION

Thus the proposed smart rescue system is the best choice to provide security and safety to the workers in land mines. It demonstrates the importance of building intelligent underground communication network, where the current communication networks don't work in undergrounds. Building ZigBee mesh to cover entire mining area provides secure and reliable private network to tag the workers with the smart rescue system provided to them. The performance of the rescue system for variation in all parameter under different situations proves to be good. The incorporation of Internet of things (IoT) and Wireless sensor Networks (WSN) into the rescue system had demonstrated the ease of monitoring health status of workers in land mines at remote places in real-time.

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Introduction of IoT allowed the family members of workers to monitor their loved one anywhere in the world. The main advantage of this work lies in providing more importance to the human life by introducing embedded and wireless technology to enhance the security and safety of workers in land mining.

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