Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 7, July 2021: 6506- 6521

Research Article

# Smart Health Monitoring Gadget For Underground Workers

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## Abstract

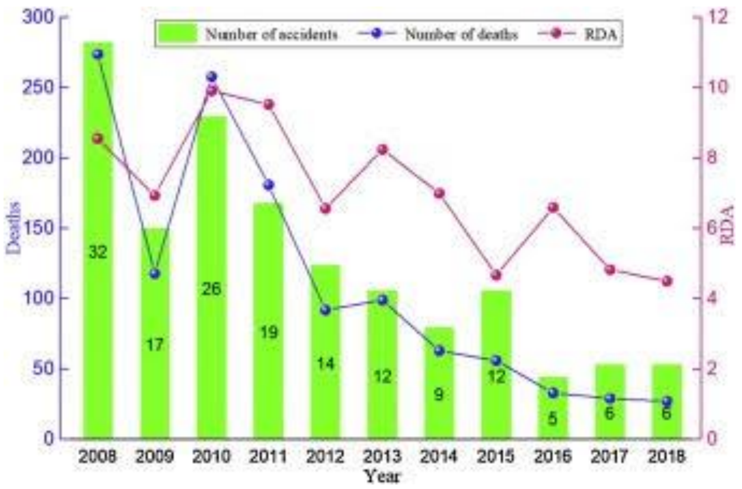
Coal Mining has been a very dangerous activity for underground workers. During mining operations, hazardous gas explosions, roof collapse, and fire hazards occur from time to time. So, in order to overcome these difficulties, we have designed a gadget which is equipped with sensors that monitors the parameters like pulse rate, temperature, humidity, $O_2$ concentration, hazardous gases and broadcasts those data to the centralized system without Internet, which in turn detects any abnormal conditions and report to the authority to take necessary actions and activate the alarm in the worker's gadget. An early warning is given by the gadget to the workers in worst case. In order to get the data of the workers working in deep to the monitoring system each gadget will have a wi-fi module which can receive and send data at the same time and each module will be connected to each other by a network which is arranged in a tree topology manner, where one node is the base, and all other nodes are children of either that node or of another. Each node (wi-fi module) can have up to 5 children, and this can go 5 levels deep, which means we can create a network of total 3125 nodes. Which means a total of 3125 workers can be monitored. If monitoring system detects any abnormal conditions it will communicate with the necessary authority and activate buzzer. Also data can be passed from outside to the workers inside. Thus, proposed system ensures safety and offline reliable wireless communication inside the underground mines.

***Keywords:*** *Wireless sensor network, offline, health monitor, wi-fi module*

## Introduction

Mining is the process of extraction of worthy minerals as well as other geological materials from the underground Earth, that's most probably from an ore body, placer deposits, reef etc. These deposits form a mineralized commodity that is the economic interest of miner. Mining is known to be one of the most hazardous sectors worldwide because of the severity of the enviromental conditions at the working area. The underground workers are prone to several hazardous condition during their work, which may lead to severe injury or even lost of lives. This condition is not only for employees, but also for the employers too.

A report from the Mine Safety and Health Administration (MSHA) regarding the fatalities that occur in coal as well as metal and nonmetal mines reported that around 317 miners lost their lives in the period of 2006-2020 and many were injured during work, related in both surface as well as underground operations. Of which, major fatalities occur at coal mining. Fig.1 gives the statistical report of the fatalities that occur in mining. From this, we can infer that death rates are decreased when compared to the previous year, but even our ultimate motto is not to lose even a single person's life. So, safety factor plays a vital role here.




**`Fig.1 Coal Fatalities report 2008 – 2018**

To ensure safety inside the mining area, Communication plays a important role. A continuous and reliable communication should be employed between the worker inside the mining area and the base control station. It is known that wired communication is not much reliable and effective in underground mine as it is very tedious to repair or reinstall the wire if any damage occurs due to the hazardous situation. As well as we cannot expect Internet facility inside mining area. So, the requirement of continuous offline wireless communication is most important here.

For the successful offline wireless Data transmission, a wide range wireless Fidelity module is utilized.

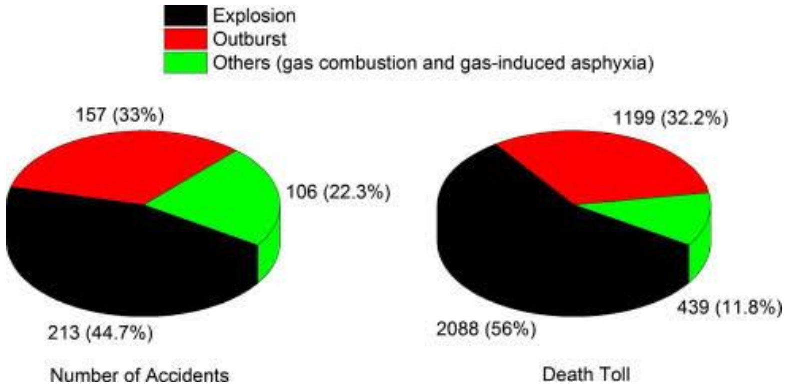



**Fig.2 Major cause for Coal Fatalities**

The above chart is from the report of last decade of Mining fatalities. From the Fig.2, it is inferred that the majority of the accidents in the mining work is due to the Explosion and outburst of poisonous gases. So our objective is to design a cost effective gadget comprising of various sensors for monitoring the accident causing parameters like surrounding temperature, humidity, pressure and poisonous gases, in additional to that pulse rate of the workers and oxygen concentration is also are monitored and the data of the worker is transferred to the base control station using wi-fi module.

## Literature Survey

To prevent the mining accidents, analyzing the environment parameters and predicting the situations before hand is the only way. For our paper, we have observed and analyzed from different reference papers developed by researches in order to make our project most effective and productive.

Laixia, Yang & Yingbao, Xue & Xuegang, Zhou proposed a “Development of coal mine safety supervision system of methane monitoring substation” in which the system is a flameproof and intrinsically safe power supply that monitors the harmful gases in the mining area and for communication RS485 is used for data exchange. In our paper, we have implemented the detection of the harmful gases along with other accidents causing parameters and warned.

Ravi K Kodali proposed “IoT based Safety System for Coal Mines” in which a model has been developed that senses the hazardous environmental conditions from various locations in the mining area and alerts the mine control room, so that respective actions are carried over whenever there seems to be a dangerous situation. Here NodeMCU acts as a Telemetry Transport i.e., MQTT publisher for all these sensed parameters. These sensed values from different mine locations are transmitted via MQTT. The Telemetry Transport is held by a Raspberry Pi which acts as an MQTT broker here. When the sensed parameter values exceed certain threshold conditions, an alert by email is sent to the mine control office so that certain actions are undertaken. Along with the email, an alarm is also generated for the workers, so that they can evacuate the place.

Pranjal Hazarika proposed a paper on “Implementation of safety helmet for coal mine workers”. The helmet proposed here is equipped with gas sensor detecting methane and carbon monoxide. This sensor reports the status of the gas and the data is transferred to the control room, all these transmission is completely wireless through a module called X-Bee connected that is subscribed with the helmet. When the methane or carbon-monoxide gas concentration exceeds the threshold, the controller in the control room triggers an alarm and intimates the workers for a safe recovery.

Y.S. Dohare, T. Maity, P.S.Paul and P.S. Das proposed a paper on the “Design of surveillance and safety system for underground coal mines based on low power WSN”. Here a cost-effective, low power system is deployed along with the ZigBee protocol based on a network of wireless sensor that provides an intelligent surveillance and a system of safety for underground coal mines. The system is connected with several wireless nodes. Sensor node mainly accustomed with a low power high performance ZigBee protocol module. This integrated chip connected on smartRF05 battery Board. This arrangement is made in order to have a easy placement in underground mines and to provide a real-time data communication between miner and surface control room which is highly secure, reliable wireless nodes.

Mr. Kumarsagar. M. Dange, Prof. R. T. Patil proposed “Design of Monitoring System for Coal Mine Safety Based on MSP430” in which the system able to detect the hazardous events in the mining industry. But in this paper, worker’s pulse rate is not monitored and no oxygen supply at the time of urge which is done in ours. In addition to that we have implemented two way communication between the gadgets so the we can send and receive data simultaneously.

In most of the proposals, we can see that most of them made use of the ZigBee wireless communication technology. But in our proposal, we made use of wi-fi modules, which has many advantages when comes to the scenario of underground when compared to ZigBee. Like data transfer speed is lower than wi-fi; ZigBee’s maximum speed is just 250kbps much lower than the lowest speed of wi-fi that offers. And Bandwidth of wi-fi is much higher than ZigBee. So, when compared to ZigBee, wi-fi will be more reliable and productive for the underground environmental condition.

## System Architecture

*Proposed Idea*

The structural overview of the whole system is shown in Fig.3 as follows.

The operation of the overall project is as follows:

The miners at the work encounters various environmental harmful situations. They have the danger of harmful gases like methane, carbon monoxide, temperature and pressure rise and so on. So, we need to improve a security of the coal miners.

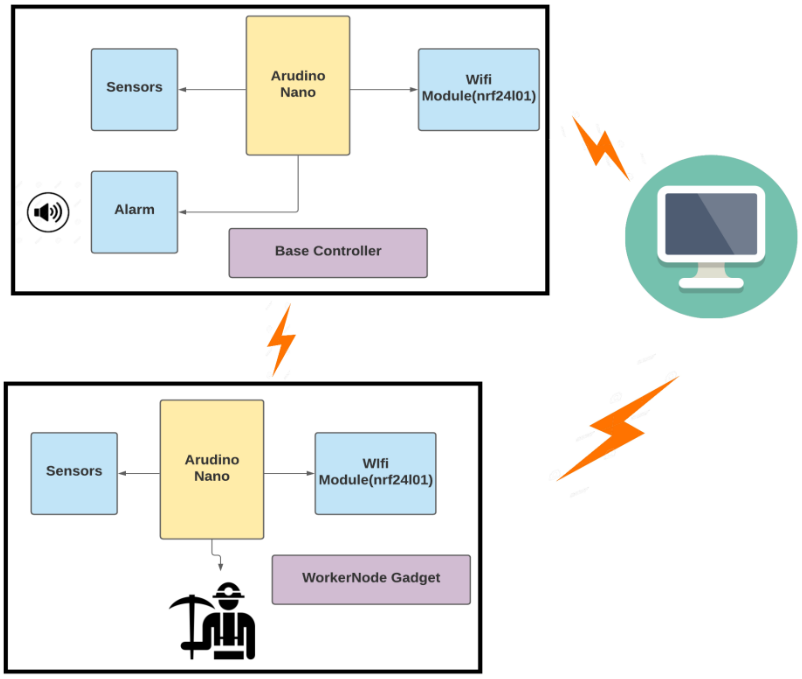



**Fig.3 System Architecture**

The workers at the coal mining have to face various environmental harmful situations during work. They have the danger of harmful gases like methane, carbon monoxide, temperature and pressure rise and so on. So we need to improve a security of the coal miners.

The objective of this project is to provide a wireless communication and safety monitoring gadget in a hand-sized totally effective for the underground workers. Since the size of the gadget is small, it increases users satisfaction and productivity.

The arrangement of the circuit should be in such a way that all the environment monitoring sensors connected along with the microcontroller and wi-fi module is packed in a single kit i.e., Gadget.

The Block diagram of a single gadget which is held by

The user (underground workers) is shown in Fig.4

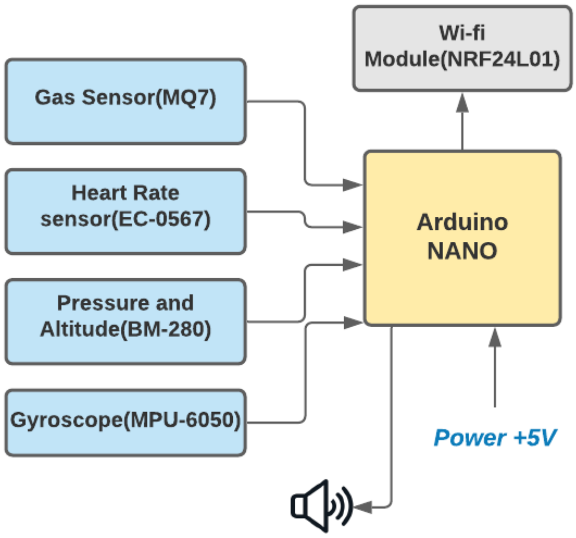



**Fig.4 Block Diagram of a single Gadget**

Each gadget has a microcontroller Arduino NANO and various sensors like pulse rate sensor, gas sensor (detect CO, CH4, So2), gyroscope sensor, temperature and pressure sensor are connected to it. The microcontroller constantly receives the data from the sensor and checks the data for any hazardous situations and sends the data to centralized monitoring system which is the master node in our case. The data reaches the master through the wi-fi.

*Data Transmission through NRF24L01*

In order to achieve long range reliable full duplex communication, we employed wi-fi technology. All the gadgets will be connected in a Tree-topology as shown in the Fig.4. Each gadget represents a node and each node have a unique address to it. Among all those nodes, the base node acts as a master node.

In general, a wireless communication between the Arduino boards is made using the NRF24L01 and RF24 library. In addition to this, we will use RF24 Network library in order to make two or more Arduino boards to communicate each other. A single NRF24L01 module can actively listen up to 6 other modules simultaneously as shown in the fig.5

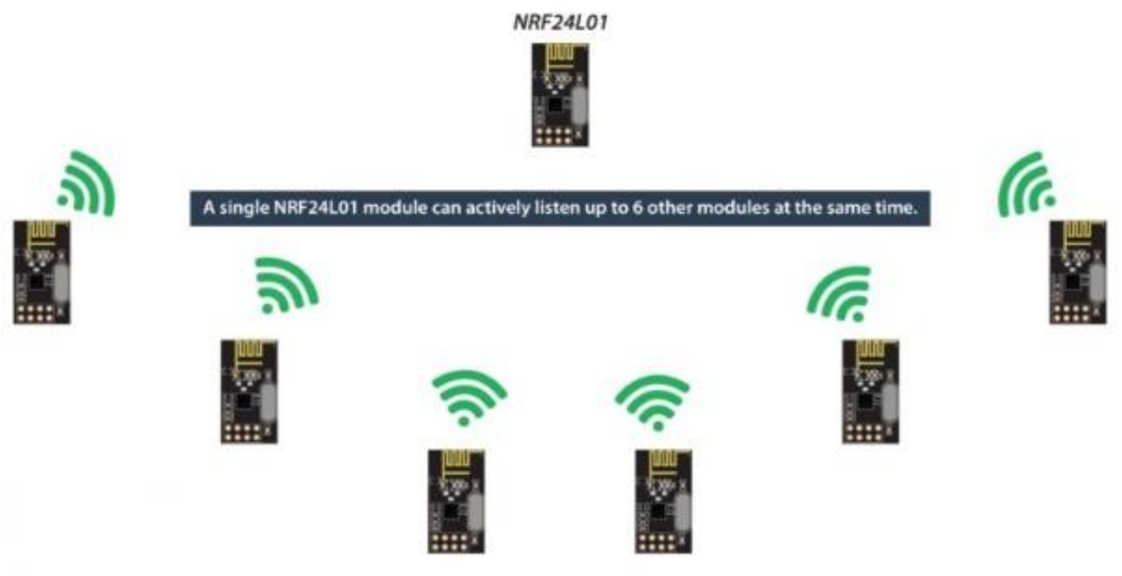



**Fig.5 NRF24L01 master-slave concept**

So, in order to achieve a Tree network one of the 6 modules acts as a base module and the other 5 acts as the child. Then each will have another 5 sub-child and the tree continues. This can go 5 levels deep, which means we can create a network of total 3125 nodes i.e., a total of 3125 workers can be monitored.

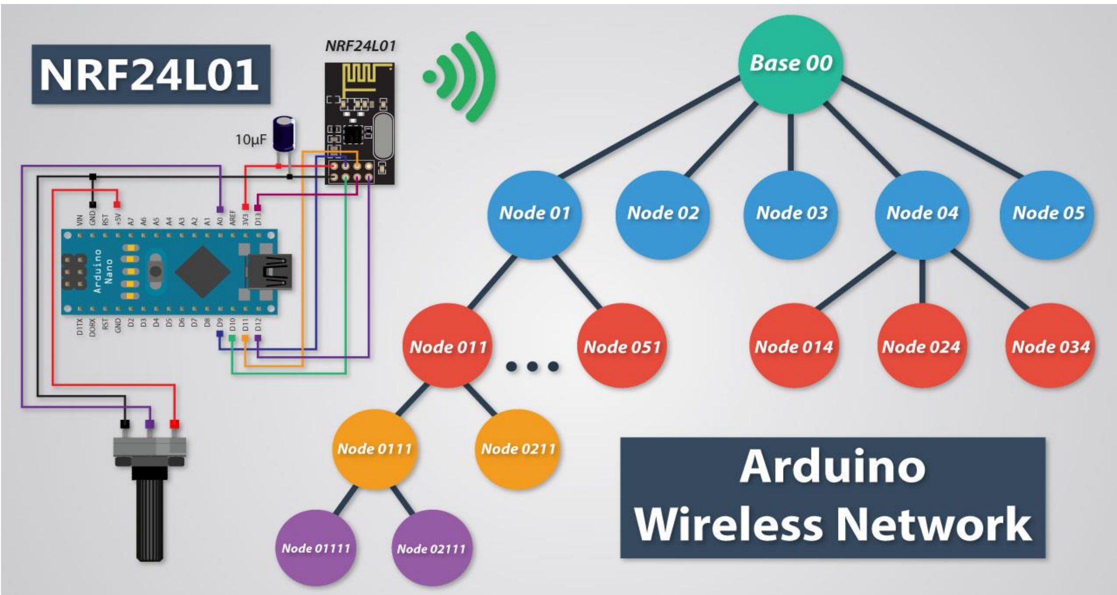



**Fig.6 Tree Topology**

*Gadget's Communication*

Assume that if Node011 wants to send data to Node051.

- It checks whether sender and receiver nodes are in same layer. Yes, both are in same layer.

- So Node011 will approach its base i.e., Node01 and then transfer data to the Node051 as shown in the fig.7

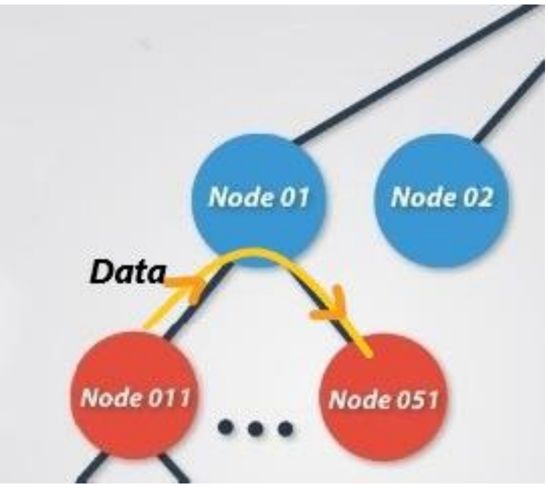



**Fig.7 Child Gadget Communication**

Let's say that if Node011 wants to communicate with Node02.

- At first, Node011 and Node02 are not in same layer. So, the data of the Node011 will jump to its higher node i.e., Node01
- Then again it checks for same layer, if yes, the data first contacts its higher node Node00 and then to the Node02 as explained below in the Fig.8.

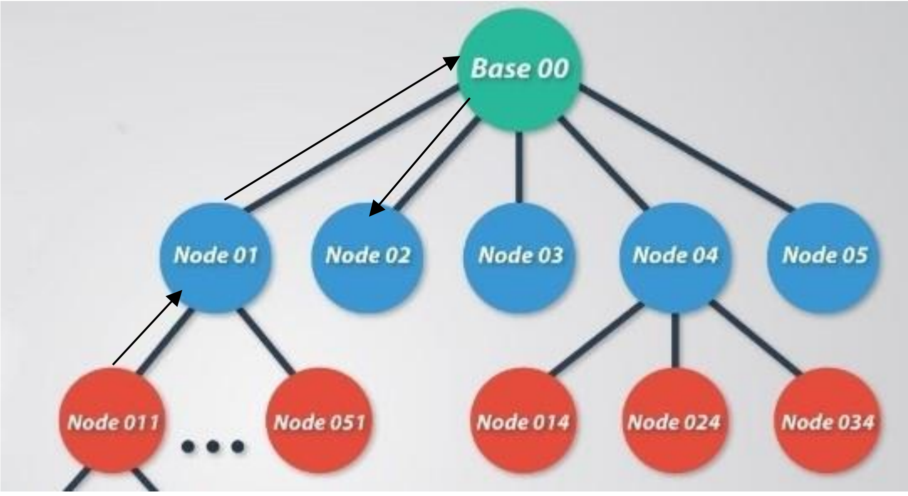



**Fig.8 Gadget Communication with super-child**

By this way, all the nodes communicate with each other nodes in an effective and productive manner. Here the node represents a Gadget.

**Circuit Diagram**

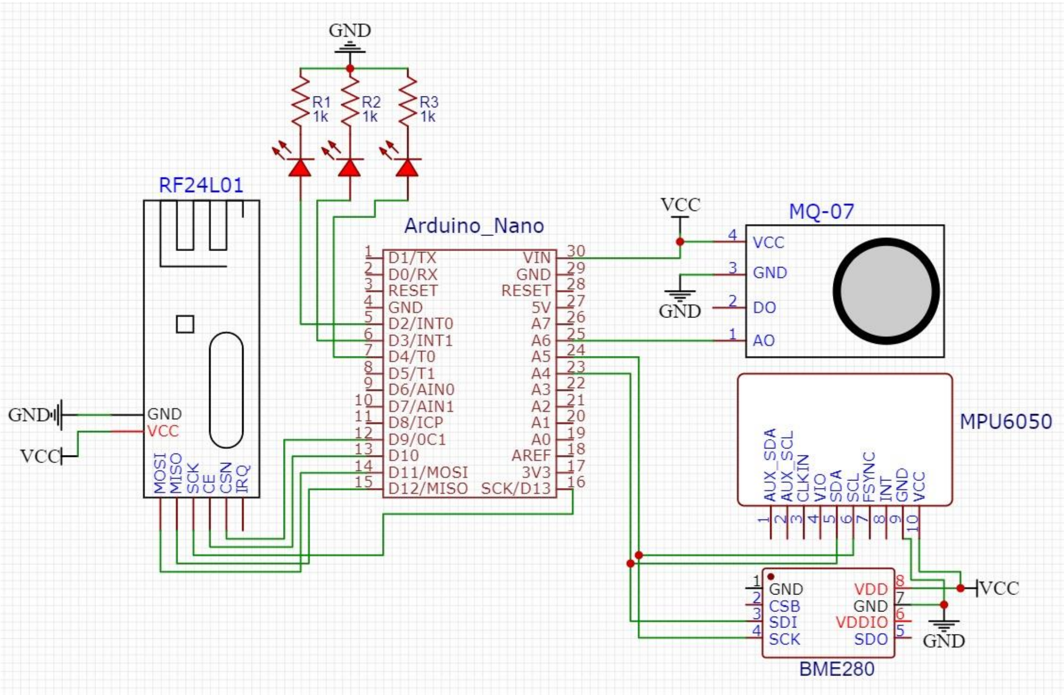



**Fig.9 Circuit Diagram of a Gadget**

The circuit diagram of the gadget is shown in the fig.9. In this circuit, we use a couple of sensors like pulse rate sensor, oximeter for getting the real time data for monitoring the health of the workers. Other than that, we have also included gas sensor, altitude and pressure sensor heart rate sensor and gyroscope. Here except heart rate and gas sensor all are i2c sensors, so we need to connect it in the i2c bus line and hence the SDA and SCL pins of the Arduino are connected to the SDA and SCL pins of the sensors respectively.

In Arduino nano analog pin A4 and A5 are assigned for SDA and SCL respectively. Then the analog sensors are connected to the analog pins of the Arduino. Then to transfer the data we are using a Wi-fi Module (nrf24l01) which is a wi-fi transreciever. The module uses SPI communication for data transfer and so this involves 5 pins i.e., MISO, MOSI, SCK, CE and CSN these pins are connected to the respective pins in the Arduino nano. Wi-fi module is powered by a 3.3v power supply from the Arduino. The sensors are supplied by a 5v supply individually. The total Arduino system is supplied by a 5v external supply.

We have also fixed three LED's to check whether the nodes are connecting either wise these LED's are activated by a push button. This is the circuit diagram of the gadget the higher nodes will also have a Arduino and a wi-fi module to communicate to the higher nodes so there also same connections follows. To see the data collected underground in a user friendly environment we need to send the data to the cloud and retrieve where ever we want. For this we need a node MCU and a wi-fi module for getting the data from underground and send this data to the cloud. The Node MCU connections are also similar to the connection of Arduino and wi-fi modules.

## Hardware Infrastructure

The Smart Health Monitoring Gadget for underground workers is equipped with NRF24L01 wi-fi module, array of environment and health monitoring sensors, central processing unit, buzzer and a LCD Display.

*Microcontroller:*

The microcontroller that we have employed in this project is Atmega328P (Arduino Nano). It operates on 5v, has 32 KB of flash Memory. It provides serial communication, supports I2C and SPI communication. It is equipped with 14 digital pins and 8 analog pins. It can be programmed by using Arduino IDE and the board can be powered by using a type-b micro-USB cable or can be powered using a external power supply. Clock Speed-16MHz, EEPROM-1KB, SRAM-2KB

*Gas Sensor:*

The Sensitive material of MQ-7 gas sensor is Stannic dioxide SnO2, with which lower conductivity is seen in clean air. The detection is made by the method of cycle high as well as low temperature, and detects CO and CO based other harmful gases when low temperature. The sensor’s conductivity is higher when there is a rise in gas concentration. When temperature is high, it cleans the other gases that are adsorbed under low temperature.

*Gyroscope:*

The MPU-6050 is the first integrated 6-axis motion tracking device across worldwide and this device is the combination of a 3-axis gyroscope, a 3-axis accelerometer on the single silicon die, which is assembled with a onboard digital motion processor that processes complex 6-axis motion fusion algorithms.

*BME280:*

It is a precision sensor that can measure relative humidity from a range 0 to 100% with ±3% accuracy and the range of barometric pressure varies from 300 Pa to 1100 hPa with ±1 hPa absolute accuracy. When it comes to temperature, the range is from -40$^{o}$C to 85$^{o}$C with ±1.0 accuracy. The measurements are so precise that’s why the name precision sensor which can also be used as an altimeter with ±1 meter accuracy. Along with this module, an on-board

LM6206 3.3V regulator and I2C voltage level translator is also present, so that we can use it with a 3.3V or 5V.

*Pulse Sensor:*

This sensor clips onto a finger tip or earlobe and plugs right into Arduino. On the front, there is an LED and right below that an ambient light sensor is placed. The led illuminates into the fingertip of the user who possess the gadget and the sensor reads data from the light that bounces back. With that data pulse rate can be detected.

*NodeMCU:*

It is an open source platform which is completely reliable and low cost. This firmware initially runs on the ESP8266 Wi-fi SoC from Espressif System which is built on the Espressif Non-Os SDK Systems. The language used here is Lua scriptinh. Later, support for the 32-bit ESP32 was also implemented.

## Implementation

The overall mine monitoring system that is developed here is to have an interactive platform between the miners and the base control station and experience a reliable monitoring and processing of sensed data to intimate the workers with the alarm unit at the time of hazardous situation. The sensed data is evaluated internally by the gadget and the alarm is enabled automatically at the time of hazard. The development phase of the gadget is shown in the fig.10

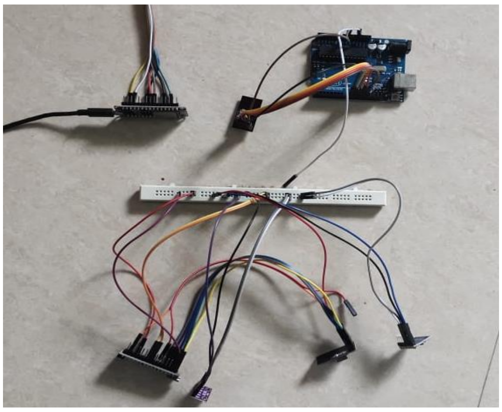


**Fig.10 Gadget Development**

In addition to that, the data will also be transferred to the mining supervisor via wi-fi modules and displayed in a Serial Monitor. A serial monitor is a part of the Arduino IDE software. Its job is to send data from the computer to the Arduino as well as receive data from the Arduino to the computer. The different environment parameters from each of the node is displayed in the serial  monitor. The parameters includes temperature, pressure, humidity, concentration of methane and carbon monoxide, pulse rate, $O_2$ content.

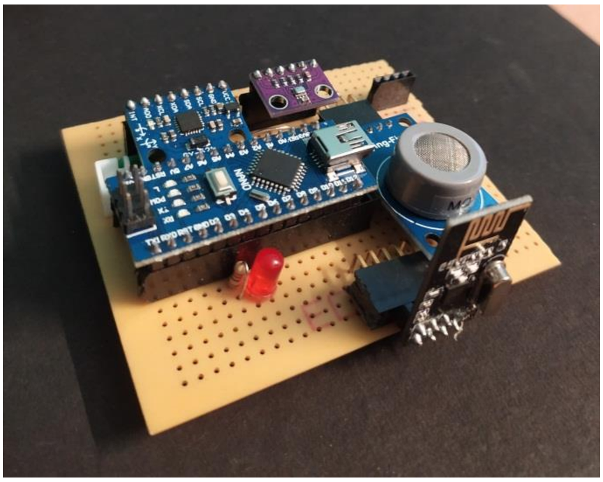


**Fig.11 Final Gadget**

The final Gadget is shown in fig.11 with all the sensors connected and the wi-fi module.  If any of the environmental parameters exceeds the safe limit or if the supervisor predicts any abnormalities, he can alert the particular Node worker or whole group. When there is  a alarm, the workers get out from the drill holes and respective control actions are taken for the safeguarding of workers lives.

But one thing is that in serial monitor, we cannot expect the UX/UI design. If the user (mining supervisor) wishes for an attractive User Interface, the data from the base controller can be stored in the Cloud Realtime Database and retrieved in the respective web page. Each node gadget's data is retrieved in a well designed UX manner and if the supervisor needs to alert the workers, he can click on the alert button in the web page. Basically in Cloud Database the alert variable is a Boolean datatype and in default it is 0. If the supervisor clicks the alert button, the alert variable becomes 1 and intimates the base microcontroller which activates the alarm and safeguards the workers.

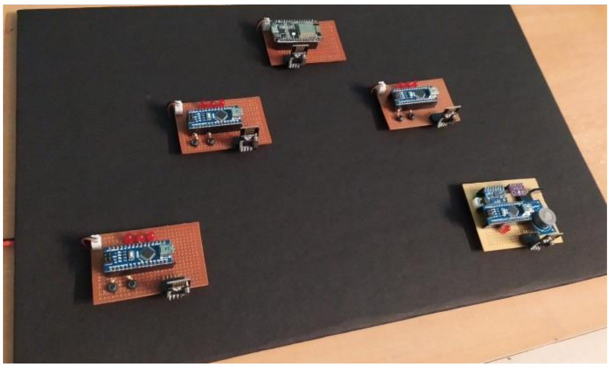


**Fig.12 Final Tree Structured System**

## Results

We tested our gadget with hazardous environment and the response of the gadget is shown in the fig.13

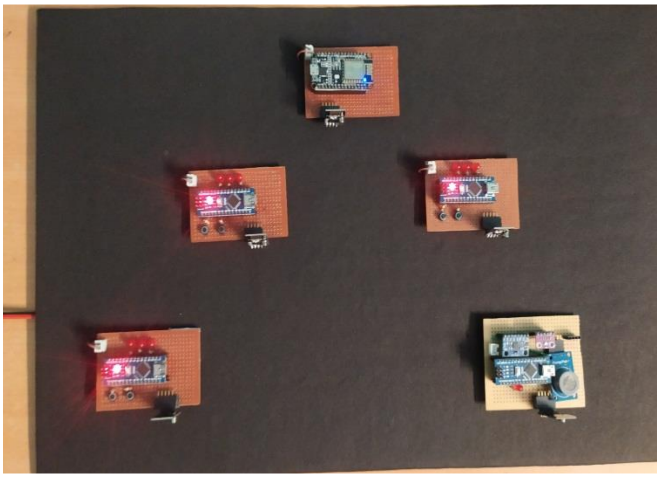


**Fig.13 Gadget Response**

The end node i.e., Node011 is experienced under hazardous condition. So, the Gadget of Node011 is alerted and also its corresponding master node gadget Node01 as well as the nearby gadgets is also alerted by blinking the LED as well as the buzzer successfully.

Each of the gadget's data, is also sent to the base control station, so that the supervisor can also monitors the worker's environment as well as the health conditions. If the supervisor predicts any abnormalities, he can alert the particular worker or the level or the whole system by simply clicking on a alert button in the webpage as shown in the fig.14,15.

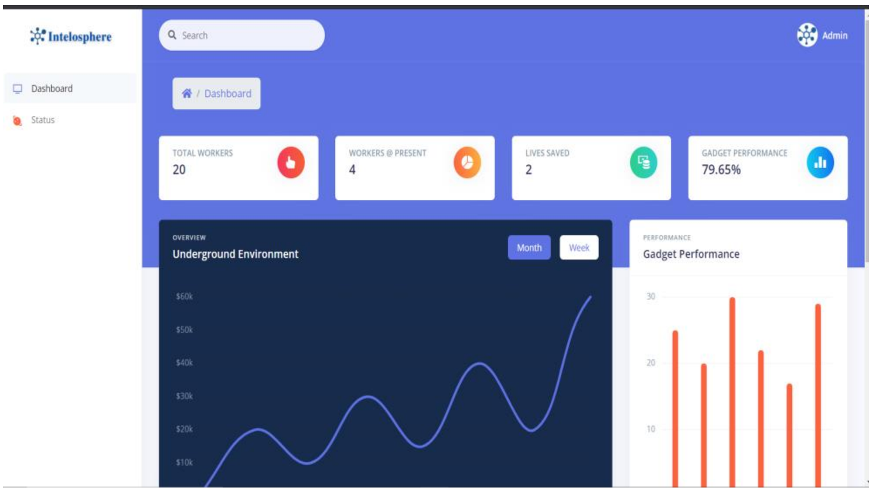



**Fig.14 Dashboard**

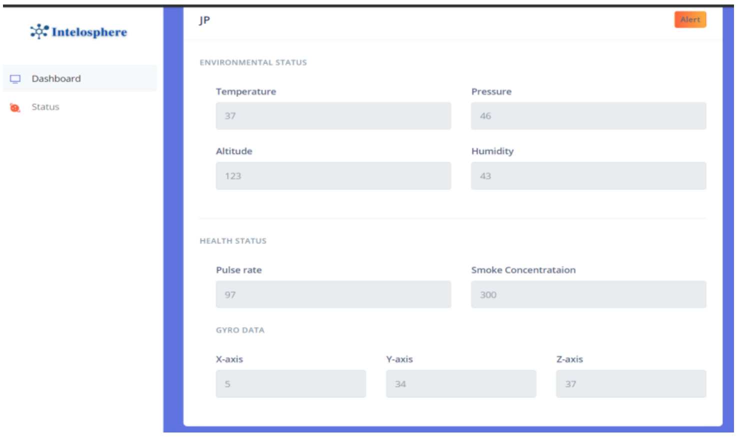



**Fig.15 Output for Supervisor**

The supervisor can also record these data of the worker by exporting the page and also a complete reports and analytics are given based on the environment and health conditions of the workers.

## Conclusion

Underground workers may undergo various hazardous environment conditions which are considered as risk parameters for major accidents. In this paper such a risk parameters are identified and monitored continuously using our novel gadget. In our proposed system, key risk parameters such as temperature, pressure, humidity, pulse rate of workers, oxygen level in work place and also concentration hazardous gases such as methane, carbon monoxide are recorded interminably and prompt alert will be given. This proposed system is completely cost effective and reliable way of transferring data with full duplex wi-fi modules. So once implemented this project provides a complete security for the underground workers and will definitely save many people’s lives in a effective manner.

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