International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9, Issue-7, May 2020

Safety Monitoring System for Coal Mine Workers

K Rama Gangadhar, C V Guna Shankar, C H Monik Ram, Ravikumar CV, Kalapraveen Bagadi

Abstract: ***The coal mine operations are very risky due to high temperature and different amount of different gas compositions in air underground coalmine. Due to this, there are so many accidents taking place which leads to killing many skilled workers and laborers. This definitely need a monitoring system to sense the gas concentration and temperature. In this paper we are developing a safety monitoring system for coal mine workers with NodeMCUs and IoT. In this system, we are using two NodeMCUs as a communicating device in which one is developed as wearable device (client) which always receives the information and the second one is used to gas and temperature sensor node(server) which always sends the alert to the client if the gas concentration is more at high temperature. We are developing a wearable device with NodeMCU which always gets the alert messages/alert buzzer and information regarding gas concentration and temperature. This system is a combined action of the temperature, humidity, some gas sensors and IOT module to detect all the information in the coal mine and log all the data into cloud and communicate with the workers wearable device to send the information(alert messages if any accident is about to happen) continuously.***

Keywords: NodeMCU, IoT, temperature sensor, gas sensors, wearable device, alert system.

I. INTRODUCTION

Coal is one of the most important natural resources for generating electricity, steel, iron, fossil fuel and used for many industrial applications. So the coal mine operations are very important for the economic growth of the country. Coal mine operations are sometimes very dangerous due to conditions like increases in temperature, humidity, pressure, certain gas leaks, dust explosion and water flood inside the coal mine etc. Basically in coal mine operations, methane gas and carbon monoxide gas leaks are very common and if the temperature in this situation is also increased, then explosion will take place which leads to hundreds of deaths. By monitoring the temperature and gas compositions, we can take precautions before an explosion happen.

Revised Manuscript Received on May 30, 2020.
***** Correspondence Author
Kantipudi Rama Gangadhar*, Electronics and Communication Engineering, Vellore Institute of Technology, Vellore, India. Email: krama.gangadhar2016@vitstudent.ac.in
C V Guna Shankar, Electronics and Communication Engineering, Vellore Institute of Technology, Vellore, India. Email: cvswamy.gunashankar2016@vitstudent.ac.in
C H Monik Ram, Electronics and Communication Engineering, Vellore Institute of Technology, Vellore, India. Email: chavvakulamonik.ram2016@vitstudent.ac.in
Ravi Kumar CV, School of Electronics Engineering, Vellore Institute of Technology, Assistant Professor Sr. Grade 1, Email: ravikimar.cv@vit.ac.in
Kalapraveen Bagadi, School of Electronics Engineering, Vellore Institute of Technology, Associate Professor Sr., Email: bkpraveen@vit.ac.in

We are developing a safety monitoring system for coal mine workers which is connected to the IoT and worker's wearable device for continuously sending the alerts and information about the temperature and gas composition in the air inside the coal mine. This system usually consists of two NodeMCU's, for cloud connection (IoT). NodeMCU is an open-source IoT platform that runs on ESP8266 Wi-Fi that supports both hardware and software development. This system works on communication between two NodeMCU's (One server and one client). A Client Device is a wearable device that receives information from the server sensors node. This wearable device connects to the nearer server node to get the information. The sensors node (sensors connected to the server NodeMCU which is producing Wi-Fi) will monitor the situations and send the data to the cloud via the internet. The complete data will be stored in the cloud and monitored by the persons outside the coal mine and also to take the measures if any accident is about to happen with the past reference situations.

II. PROPOSED SYSTEM

The system developed consists of both hardware and software components combined.

Hardware Module

The Proposed system with hardware module is shown in the Fig. 1. The hardware consists of gas sensors (MQ-2, MQ-135, MQ-9) GS-1, GS-2, GS-3 and temperature and humidity Sensors (T & H) connected to inputs ports of NodeMCU (Server) which communicates via Wi-Fi with NodeMCU (Client) which are connected to LCD display and Buzzer. This hardware module is combined with software in which a way that server always communicates with the client.

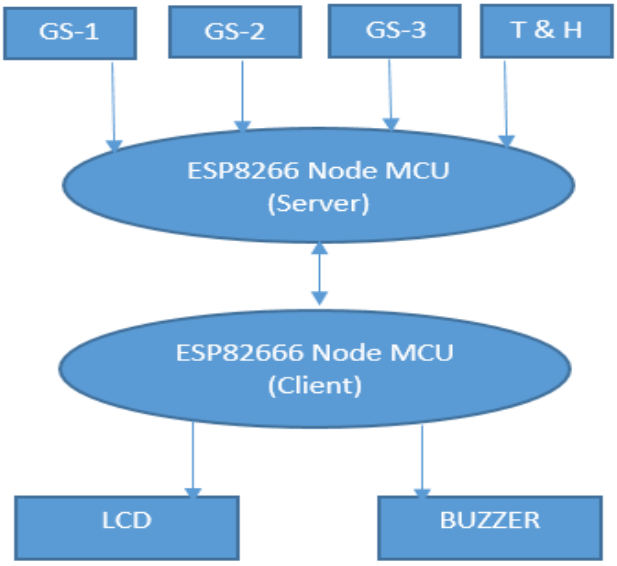


Fig. 1 Block Diagram

Software in Arduino UNO

The software of the system is written in c/c++ programing language using Arduino software. Both server and client NodeMCUs are uploaded with different programming codes which helps them to communicate. The temperature and gas sensor outputs are given as inputs to the server NodeMCU where threshold values are given and develop some logics (relation between gas composition in air and temperature values that result in explosion) to send the alert messages and information to the client NodeMCU and this code is written and uploaded to the server NodeMCU. The software on the client NodeMCU only helps to retrieve information from the server NodeMCU.

III. WORKING PRINCIPLE

The main working principle of the proposed system is two NodeMCUs communicating with each other and sending the information. As shown in the working model (fig.2), all the gas and temperature sensors are connected to the server NodeMCU which can detect the gas composition in the air and temperature at respective ranges of the server node.

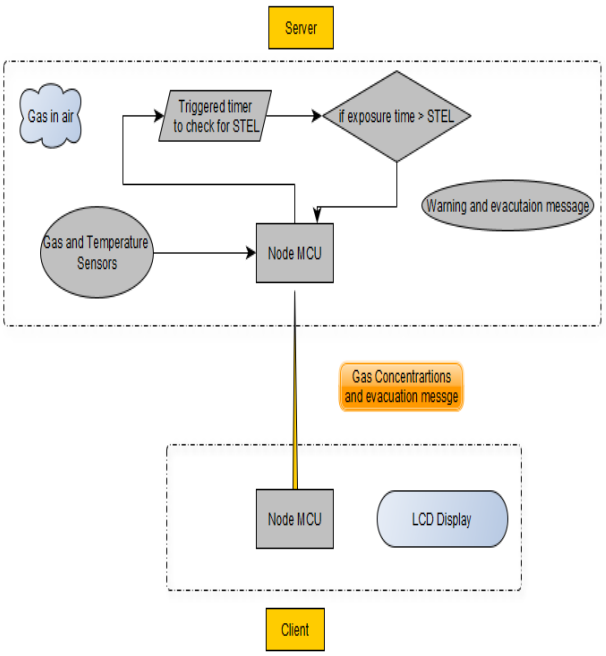


Fig. 3 Working Model

On the basis of the STEL by the threshold values if the temperature and gas composition the entire project depends. STEL is programed with logic using threshold values into the server NodeMCU. If the exposure time (gas composition and certain high temperature is observed by the server node) the server NodeMCU send the evacuation message to the client NodeMCU. Alert can be send by both buzzer and LCD display message. A Client Device is a wearable device that receives information from the server sensors node. This wearable device connects to the nearer server node to get the information. And all the information from the server NodeMCU will be sent to the cloud where all the information is stored for the future reference for a particular situations.

IV. EXPOSURE LIMIT FOR GASEOUS POLLUTANTS

There are some associations/agencies like ACGIH (American Conference of Governmental Industrial Hygienists) and NIOSH (National Institute for Occupational Safety and Health) suggested some Threshold values for gas composition in air (STEL and TWA) values for safety measures for coal mine operations

Table 1 TWA Values

TWA Values	CO2	CO	NO2	NO
ACIGH	0.5%	25ppm	25ppm	3ppm
NIOSH	0.5%	35ppm	25ppm	-
OSHA	0.5%	50ppm	25ppm	-
MSHA	0.5%	50ppm	25ppm	5ppm
MSHA MNM	0.5%	50ppm	25ppm	5ppm

Table 2 STEL Values

STEL Values	CO2	CO	NO2	NO
ACIGH	3.0%	-	-	5ppm
NIOSH	3.0%	200ppm	-	1ppm
OSHA	-	-	-	1ppm
MSHA	3.0%	400ppm	-	
MSHA MNM	1.5%	400ppm	37.5ppm	

Table 1 and Table 2 shows the standard threshold values for the coal mine operation as STEL (Short-term exposure limit) and TWA (Time weighted average). CO2, NO2, CO and NO are the main gases that exposed to air during the coal mine operations.

V. THRESHOLD VALUES USING ARDUINO

How gas sensor works with Arduino? It's the same, like every other sensors. The voltage will changes with different gas composition values of gas in air. The sensors sends the output voltage value proportional to the concentration of gas. Greater the output voltage (analog value), the greater the gas composition in the air. To calculate the gas concentration in terms of ppm, we have to find the sensor resistance. It is done by using the formula of voltage divider. RS/RL = (V-Vs)/Vs, where RL is the load resistor. The relation between the RS/R0 and ppm is given on the log-log scale.

VI. HAZARDOUS GAS MONITOR

Calculate Gas Sensors PPM

When the gas sensors senses the gas concentration, the sensors sends the output analog voltage which value from 0 to 4095.

We can use an Equation (1) to covert the voltage value to ppm of gas concentration.

Equation (1): Voltage = Analog Reading * 3.3V / 4095

Once we have sensor voltage, we can covert the output analog voltage to the ppm using the sensitivity calibration curve. For every gas sensor we are using, there are sensitivity characteristics plots for both the temperature and ppm plot to the voltage output. Equation (2, 3&4) are used in the code to find the threshold values of the gas concentration of air. We are plotting ppm on y-axis and voltage (V-RL) on the x-axis. Using the exponential equation for finding the relation between the ppm and V-RL to get the following equations for different gas sensors.

Equation (2) CO sensor: PPM = 3.027*e^(1.07*V-RL)

Equation (3) LPG sensor: PPM = 26.572*e^(1.28*V-RL)

Equation (4) CH4 sensor: PPM = 10.938*e^(1.80*V-RL)

Gas Sensors

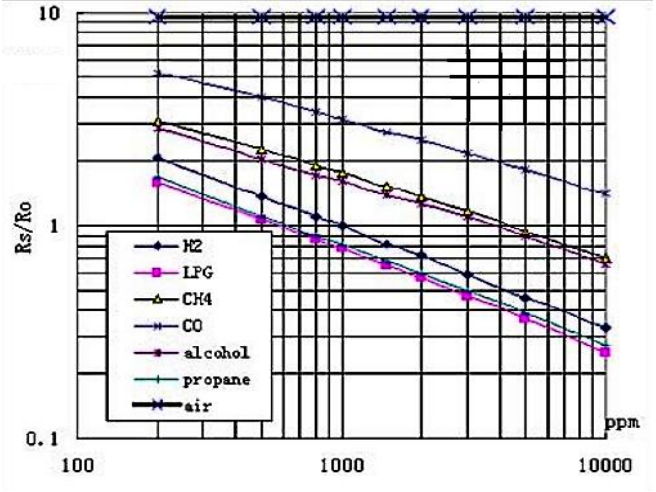
MQ–2 Semiconductor Gas Sensor and its Characteristics

This sensor is made up of a sensitive material SnO2 which has lower conductivity in the air. Whenever the gas concentration is higher, the conductivity of the sensor increases. This sensor is high sensitive to the gases like LPG, Propane, Hydrogen and Methane. And this sensor has a good sensitivity of combustible gas in wide range.

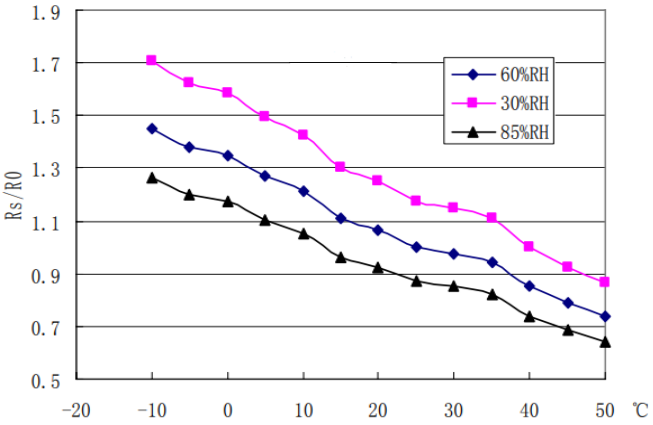
Table 3 Technical Data of MQ-2

Sensor Type	Semiconductor
Detection gas	Combustible gas and Smoke
Concentration	300-10000ppm
Loop Voltage	<24V DC
Heater Voltage	5.0V+0.2V/5.0V-0.2V AC
Heater Consumption	<900mW
Sensing Resistance	2Kohm-20Kohm

Graph 1and Graph 2 shows the sensitivity characteristics of the MQ-2 in which the concentration of the gas shown as abscissa and the sensor's resistance ratio is shown in y-axis (ordinate). Rs/Ro is the resistance ratio of the sensors where Rs is the resistance of all the other gases and Ro is the resistance of the Hydrogen gas. These are the standard conditions we are using to detect the gas concentration. X-axis shows the concentration of the gas in terms of ppm. Rs/Ro in the graph gives the relation with the voltage.



Graph 1 Characteristics of MQ-2



Graph 2 Temperature/Humidity

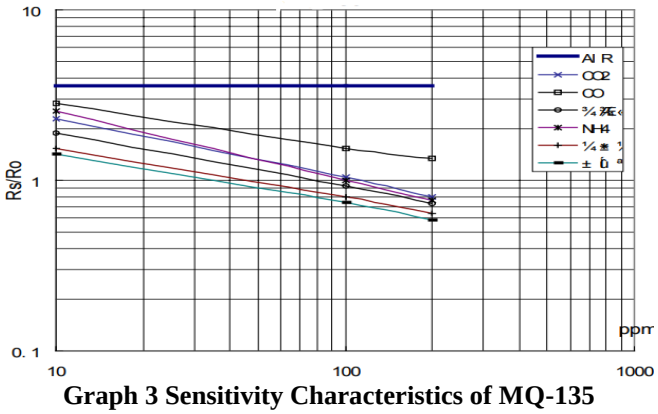
MQ-135 Gas Sensor

This MQ-135 is also made up of a semiconductor material SnO2 which also has lower conductivity in the clean air. And it has high sensitivity to the gases like Ammonia, Benze Steam, sulfide and other harmful gases. This senor has a good scope of wide detecting and it has very high sensitivity.

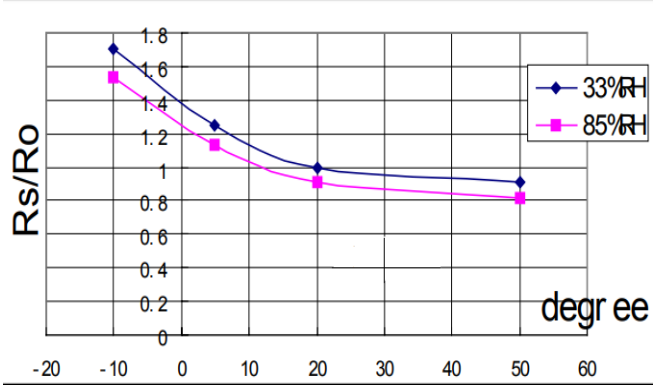
Table 4 Technical Data of MQ-135

Sensor Type	Semiconductor
Detection gas	NH3, Sulfide, CO2, Smoke
Concentration	10-1000ppm
Heater Consumption	<800mW
Heater Voltage	5.0V+0.1/5.0V-0.1AC or DC
Sensing Resistance	30Kohm-200Kohm
Circuit Voltage	5.0V+0.1/5.0V-0.1AC or DC

Graph 3and Graph 4 shows the sensitivity characteristics of the MQ-135 in which the concentration of the gas shown as abscissa and the sensor's resistance ratio is shown in y-axis (ordinate). Rs/Ro is the resistance ratio of the sensors where Rs is the resistance of all the other gases and Ro is the resistance of the Hydrogen gas. These are the standard conditions we are using to detect the gas concentration. X-axis shows the concentration of the gas in terms of ppm. Rs/Ro in the graph gives the relation with the voltage.



Graph 3 Sensitivity Characteristics of MQ-135



Graph 4 Temperature/Humidity Characteristics

VII. SERVER NODE

This proposed system has a limited number of server nodes connected at a certain distance to detect the gas concentration and temperature up-to that certain distance. This server node is connected with different gas sensors as per the requirement in the coal mines and temperature sensors. The NodeMCU is used as a server node with a C/C++ Arduino UNO code in it. This code is written as whenever the client comes within the close range, the server node will connect with the client NodeMCU. This is connected at the top of the wall like the Wi-Fi routers. So whenever there is a high STEL with high temperature at certain server node, it will send the alert message to the workers in the range and outside examiners using IoT. Also, we connect the monitoring node to the IOT cloud to save the data at all kind of situations for future reference which helps to detect the hazard before it actually happens.

VIII. CLIENT WEARABLE DEVICE

The alert evacuation messages are sent to client wearable device by server NodeMCU. This wearable device is a compact wrist watch with a LCD display. To make the device compact, we have to use the EasyEDA software to cut the PCB with certain required dimensions and covert the PCB into NodeMCU. The client node is given a code C/C++ Arduino UNO code in it. This code is written as whenever the client node is closer to one server node, it will connect to that respective server node. This wearable device connects to the nearer server node to get the information about the temperature and gas concentration values. This wearable device are given to the coal mine workers to get the alert and evacuation messages

IX. COMPACT WEARABLE DEVICE

Design of the Client Wearable Device

NodeMCU is a Wi-Fi microcontroller which is not in a compact size to make a wearable device. As to make the NodeMCU compact, we used EasyEDA software to get the dimensions of small PCB board and connect all the teared down parts of NodeMCU to that PCB. Using EasyEDA, we have designed the wearable watch as show in fig. 4 with the help of the PCB with certain dimensions required as show in fig. 5.

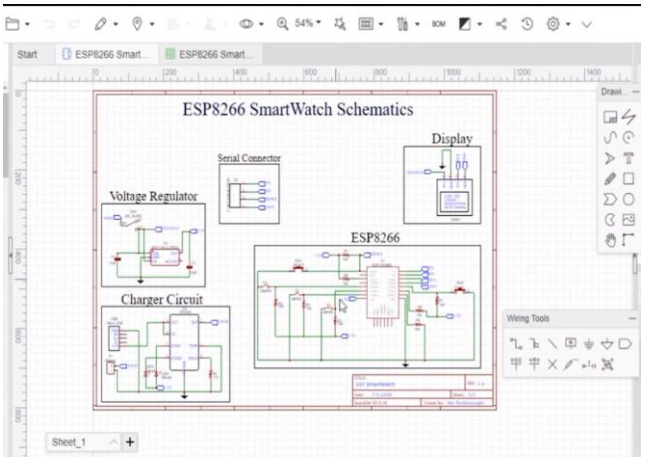


Fig. 4 Design of the Wearable Watch

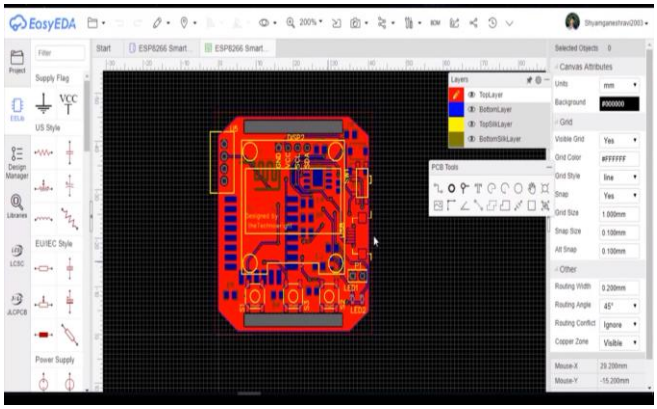


Fig. 5 PCB of the Wearable Watch

This PCB is designed in a way that all the teared down components of the NodeMCU is connected along with the liquid crystal display. We used standard dimensions of the wearable wrist watch to make this client wearable device as to make it more compact and easy to use. The evacuation messages are seen on the LCD display. This client wearable device is always communicates with the server node to send and receive the information.

Dimensions of the Wearable Watch (Client Node)

To make a compact wearable watch, we have to take very small dimensions. So making PCB is very difficult as it involves a cutting process with very small dimensions. We used jlcpb to give the PCB dimensions and get the board ready.

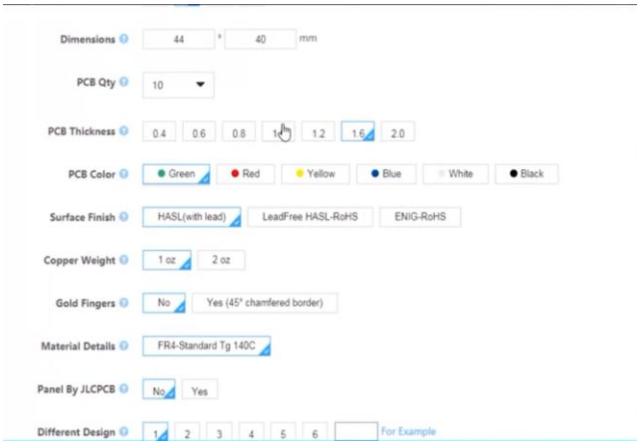
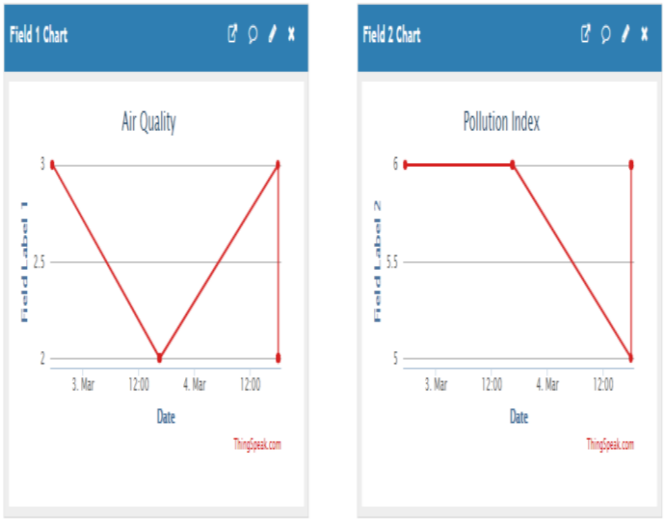


Fig. 6 Dimensions of Watch

X. EXPERIMENTAL RESULTS

Using the correct logics using the threshold values of gas concentration and temperature into the codes using Arduino UNO in the server NodeMCU. When these gas sensors detects the high STEL (higher ppm of gas sensor at certain temperature), the proposed system will designed in a way that the server NodeMCU will send the evacuation message to the client wearable device. And also the monitoring server node send the data of temperature and gas concentration continuously to the outside examiner via IoT cloud using internet. We are using thingspeak to get the access of the IoT cloud. And some of the data storing at different conditions is shown below in graph 5 and 6.



Graph 5 Data stored into IoT Cloud

We are using temperature, MQ-2, MQ-135 and MQ-8 sensors to detect the temperature and gas concentration in the air. So graph 1 and graph 2 are the information that we stored in the IoT cloud. As we shown in the graphs, we have tested the system at different conditions (much traffic, air conditioned room and complete green trees area) and it seems to working fine. Air quality sensor is MQ-135 which is used to much sensitive to smoke and harmful gases at high temperatures. And the pollution index is used to detect the gases like LPG, CH4, CO and some other industrial gases.

Graph 6 Data stored in IoT cloud

XI. COCLUSION

Coal is one of the most important natural resources for generating electricity, steel, iron, fossil fuel and used for many industrial applications. So the coal mine operations are very important for the economic growth of the country. The present underground Mines system can be usefully substituted by this IoT Safety Monitoring System. A real time monitoring system is developed to provide clearer and more point to point perspective of the underground mine. This system is very accurate in collecting all the data using temperature and gas sensors and sending the evacuation messages which is done by the communication of two NodeMCUs. It will be helpful to all miners present inside the mine to save their life before any casualty occurs. This system alerts when sensor values crosses the threshold level and also stores all the data in the computer for future reference. The current required implementations for the need of observation under the coal mines is explained in this paper. This system uses two NodeMCUs as server NodeMCU with sensors connected and client device NodeMCU that is communicated with the server to get all the information regarding the gas concentration, temperature values and any evacuation messages. This system is so far better than many monitoring systems, because we are using NodeMCUs for communication. A certain number of NodeMCUs (only server) are kept at certain distance within the entire mining area. Server node works as Wi-Fi router connecting to the client device and sending the alert and evacuation messages will be so accurate and fast compared to the other safety monitoring systems. This system gives an all-round instrumentation coordinate framework to track the area, quality of air, ventilation conditions, water floods and release of hazardous gases.

REFERENCES

1. Rong Yan. Design of Mine Safety Monitoring System Based onthe Wireless Network [0). Ji'nan: Shandong University, 2007.
2. Jian Wang, Peng Wang. Based on Wireless Sensor Network Coal Mine Gas Monitoring System. International Conference on Industrial Control and Electronics Engineering, 2012.
3. G. Prabhakar Reddy, M.Vijaya Lakshmi. IoT in Mines for Safety and Efficient Monitoring. International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), 2015, India, Volume-4, 4232–4236.
4. Shi Wei, Li Li-li. Multi-parameter Monitoring System for Coal Mine based on Wireless Sensor Network Technology. International Conference on Industrial Mechatronics and Automation, 2009, China, 225–227.
5. Q. Xianli, F. Mingchao, and S. Bin, "Coal Mine Gas Wireless Monitoring System Based on WSNs," in 2011 Second International Conference on gital Manufacturing and Automation (ICDMA), , 2011, pp. 309 - 312.
6. M. Li and Y. Liu, "Underground coal mine monitoring with wireless sensor networks," ACM Transactions on Sensor Networks, vol. 5, Mar. 2009.
7. G. Mulligan, "The Internet of Things: Here Now and Coming Soon," IEEE Internet Computing, vol. 14, pp. 35-36, 2010.
8. L. Atzori, A. Iera, and G. Morabito, "The Internet of Things: A survey," Computer Networks, vol. 54, pp. 2787-2805, 2010.
9. Shushan Hu,Cunchen Tang, Riji Yu, Xiaojun Wang. Intelligent Coal Mine Monitoring System based on the Internet of Things. IEEE-2013, China, 380–384.

10. Rajkumar Boddu, P. Balanagu, N. Suresh Babu. Zigbee Based Mine Safety Monitoring System with GSM. International Journal of Computer & Communication Technology, 2012, India, Volume-3, 63–67.

AUTHORS PROFILE

Kantipudi Rama Gangadhar did his B.Tech in Electronics and Communication Engineering from Vellore Institute of Technology, Vellore. His area of interest is Microcontroller and Embedded System. He has done so many projects based on Microcontroller and Embedded System. He has been awarded for his project called dual-axis sun light tracking solar panel system.

C V Guna Shankar did his B.Tech in Electronics and Communication Engineering from Vellore Institute of Technology, Vellore. His area of interest is Digital and Analog Communications and done so many projects based on them.

Monik Ram CH did his B.Tech in Electronics and Communication Engineering from Vellore Institute of Technology, Vellore. His area of interest is Digital and wireless and sensor networks. He has done so many projects based on wireless and sensor networks

Ravikumar CV completed his M. Tech in Communication Engineering and he has PhD in Communication Systems. His research interest includes communication. He is currently working as Assistant Professor Sr. Grade 1 in Vellore Institute of Technology, Vellore. He assisted so many students in publishing their research papers

Kalapraveen Bagadi .did his M. Tech in Communication Engineering. His research interest includes communication. He is currently working as Associate Professor Sr. in Vellore Institute of Technology, Vellore. He assisted as a guide for so many students to publish their research papers.

.