Design and Implementation of Coal Mine Physiological Parameters Monitoring Protocol

Swarup S. Mathurkar
Assistant Professor,
Department of Electronics & Telecommunication
Government College of Engineering, Amravati
Amravati, India
swarup.mathurkar@gmail.com

Shubhada S. Thakare
Assistant Professor,
Department of Electronics & Telecommunication
Government College of Engineering, Amravati
Amravati, India
shubh_diwan@rediffmail.com

***Abstract*—** Modernization in the industries also concerns with the safety of workers especially for underground mining's. This paper mainly deals with surveillance and safety measures for mine workers, which is most essential in underground mining areas. Here, a concept of wireless sensors network is used to monitor the environment parameters of underground mine area and all sensed parameters are sent to host computer. Arduino Microcontroller is a heart of a system used to build a fully automated measuring system with reliability, high accuracy and smooth control. Upon detecting critical conditions, alert system starts and the same information is transmitted to remote location by ZigBee Communication. The observed changes in the parameters will also be displayed on the host computer at base station which makes it easier for the underground control center to monitor and to take necessary immediate action to avoid damages.

Keywords- *Wireless Sensor Network (WSN), ZigBee, Arduino Microcontroller, ARM7, CAN, GSM*

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I. INTRODUCTION

Automation has been achieved; humans have been replaced by machines. Science and technology has proved its importance in many fields. Therefore there is need to use science and technology in the field for higher production and effective working in coal mines. Most of the papers signifies the use of wireless sensors network which collects the data from different types of sensors and then send it to main server using wireless protocol. The collected data provides the information about different environmental factors which in terns helps to monitor the system. This paper provides the information related to previous work that had been done in the field of underground coal mining using the wireless sensor network over a period of past few years as well as the proposed system which is useful in monitoring as well as controlling the data which provides the flexibility. Also wireless communication using ZigBee avoids limitations of short ranges and enhances the working in underground coal mines.

The primary objective of this project is to study and manipulate the monitoring system in a coal mines which will automatically sense the temperature, humidity, smoke and vibration in it. A user interface is given in the hardware which will help the user to interact with hardware and allow setting a threshold value for different parameters to have safety conditions with the use of ZigBee module for communication. If sensed values exceed the threshold values then automatically coal mine safety monitoring system based on wireless sensor network timely and accurately reflect dynamic situation of staff in the underground regions to the ground computer system. To enhance both production and safety in mines, an authentic communication is established between a fixed base station and workers involved in the underground mining.

II. LITERATURE REVIEW

Over the year's researches in the mining field, researchers found that the yield of coal mining is large but it is utilized inefficiently. To reduce the cost and improve the productivity along with product quality, the atomization in the field of coal mine is indeed necessary which will also reduce the mine workers efforts. Some of the researches tried for betterment of mine workers and provides the systems that use technologies which are helpful for increasing the mining production. Some of such researches carried out in field of underground coal mining are summarized here.

N. Krithika and R. Seethalakshmi have developed a safety system for coal mining industry using sensors and ZigBee that builds safety scheme with precise remote monitoring and tracking the most suitable lifesaving system for underground mining environment. This system includes the tracking module helps to locate workers through the signal relayed by ZigBee protective device. Thus the safety system for coal mining regions with ability to track and alert via voice command forms a complete protective system for underground labors. The LPC2148 based underground sensor module continuously monitors and transmits data to the tracking module using ZigBee. The voice unit attached to underground sensor module gives an emergency command based on the analysis of monitored parameters. CAN bus is utilized to transfer the information between the monitoring unit and underground unit. [1]

A wireless coal mine safety monitoring system based on ZigBee wireless sensor network and GPRS wireless remote transmission was established by J. Cheng, D. Gao, J. Wang and D. Wen. With this mature GPRS technology, remote data transmission was achieved and associated director can be informed through short message sent to his cell phone, which contributes to the early identification of serious accidents and real-time treatment, thus increasing the safety of coal mining. The feasibility of conversion between ZigBee protocol data

and TCP/IP protocol data in GPRS network was discussed, and GPRS as well as ZigBee gateways were designed. [2]
In a work presented by Y. P. Zhang and G. X. Zheng, a hybrid tunnel radio propagation model consisting of the free space propagation and the modified waveguide propagation is proposed. But using this radio communication inside mines has some disadvantages. When radio signals are transmitted diffraction, attenuation, multipath and scattering are often presents and Detroit the signal strength and quality. [3]
T. Kumar and K. Sambasiva Rao developed a Mine safety monitoring and alerting system using ZigBee and CAN bus. The developed system can be divided into two sections. First is a hardware circuit that will be attached with the body of the mine workers. This may be preferably fitted with the safety helmet of the workers. The circuit has a sensor module consisting of some MEMS based sensors that measures real-time underground parameters like temperature, humidity and gas concentration. Communication through these encoding and decoding of voice and alarm signals is effectively established with the help of microcontroller. The system uses CAN protocol. [4]

M. Dange, R.Patil and M. Kumarsagar have designed a system of coal mine safety based on MSP430. The designed system uses wireless sensor networks which can improve the level of monitoring production safety and reduce accident in the coal mines. The MSP430 controller used in the project is low power and cost effective and uses five low-power modes. [5] A coal mine monitoring system is developed by R. Boddu, P. Balanagu and N.Babu which implements the use of GSM communication. The system described details about the design and instrumentation of wireless sensor network and real time in field sensing and control by using appropriate software. The whole system was developed using four in field sensor stations which collects the data and send it to the base station using GSM where necessary action was taken for controlling irrigation according to the database available with the system. The system provides a promising low cost wireless solution as well as remote controlling for precision mining. [6]

Coal Mine Monitoring Using ARM7 and ZigBee is designed and developed by V. Pandit, U. Rane using ARM7 and ZigBee. A sensor node is developed for sensing different environmental parameters of underground mine. The sensor node has feature of wireless communication using ZigBee transceiver. All sensed data is digitized by internal ADCs of LPC2148 microcontroller which gives low power platform with fast execution. The system prototype developed has many advantages that make it convenient to work in harsh environment of underground mine, monitoring concentration of deadly gases in its atmosphere along with temperature and humidity. The ZigBee communication is noise free and LPC2148 provide low power platform. [7] K. Archana, A. Mudasser developed a network called ZigBee and Wi-Fi based Mine Safety Application. The paper developed an ARM based embedded system which monitors the critical parameters inside the mine and transmits the data in wireless manner for better monitoring and visualization safety system for underground and open cast mines using wireless communication and microcontroller. Real time values of temperature, gas readings (in ppm) and light intensity is monitored inside the mine and is sent via a wireless media to a base station situated outside the mine, which eventually updates the current information in a local web server and updates the website. [8] A wireless surveillance and safety system for mine workers based on ZigBee was designed by T. Maity and P. Das. The design proposed a cost effective, flexible solution of underground mine workers safety. A module of MEMS based sensors are used for underground environment monitoring and automatic progression of measurement data through digital wireless communication technique is proposed with high accuracy, smooth control and reliability. [9] A new decision making approach to coal and gas outburst prediction with multisensory information fusion is proposed by X. Mao, Z. Zhao. Two o f the multisensory information fusion method- neural network and the dempster-shafter evidence theory were taken into account and the improved combination rules in fuzzy sets was given for decision fusion. But, those communication methods having specific technology lacks in practical application in underground mines. [10]

III. DEVELOPED MONITORING SYSTEM

A coal mines monitoring system is developed which will automatically sense the temperature, humidity, gas concentration and vibration occur in the mines. The proposed system can be studied in two parts i.e. The Mining Unit and The Monitoring Unit. Both the units consist of Arduino as core microcontroller. The communication with each other is through ZigBee transreceiver. The transceiver used in the mining unit and the monitoring unit is of same type. LCD section is basically meant to show up the status of the underground mining section. The block diagram of the system is shown in Fig. 1.

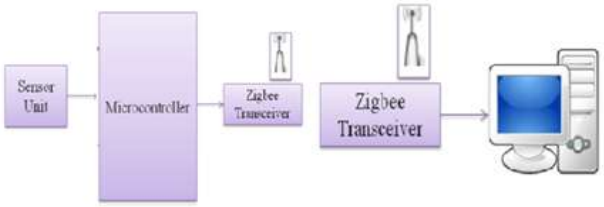

Fig.1 Mining and monitoring unit

It consists of different types of sensing unit such as temperature sensor, relative humidity sensor for measurement, gas sensor, microcontroller for collecting data obtained from different types of sensors as well as for converting the analog data into the digital one, ZigBee modules for wireless data transfer and receiver, a serial protocol for interfacing the data obtained from ZigBee modules to the computer. The data monitoring status of various parameters in coal mine can be seen on host computer.

IV. DISSCRIPTION OF DEVELOPED MONITORING SYSTEM

The developed system comprised of sensing unit, monitoring unit, auxiliary unit and wireless unit. The sensing unit made up of different types of sensors such as temperature, humidity, gas concentration and vibration sensors. Monitoring unit consists of the microcontroller. The auxiliary unit includes LCD whereas wireless unit comprises of ZigBee module both at the transmitter and receiver side. The system is described in details as follows.

A. *Temperature Sensor*

Temperature is very important factor while considering the environmental parameters. It affects the plant growth so it is necessary to monitor such factor using some means. National Semiconductor's LM35 is best option for sensing the temperature shown in Fig. 2. The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling.

Fig. 2 LM35 Temperature sensor

B. *Humidity Sensor*

The DHT11 Temperature Humidity Sensor features a temperature humidity sensor complex with a calibrated digital signal output. By using the exclusive digital-signal acquisition technique and temperature humidity sensing technology, it ensures high re-liability and excellent long-term stability. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost effectiveness. Its small size, low power consumption and up-to-20 meter signal transmission making it the best choice for various applications, including those most demanding ones. The component is 4-pin single row pin package. It is convenient to connect and special packages can be provided according to users' request. The DHT11 sensor is as shown in Fig. 3.

Fig. 3.DHT11 Humidity and temperature sensor

C. *Gas Sensor*

Sensitive material of MQ-2 gas sensor is SnO_2, which has lower conductivity in clean air. When the target combustible gas exists, the sensors conductivity is higher along with the gas concentration rising. MQ-2 gas sensor has high sensitivity to Propane, Butane and LPG, also response to Natural gas. The sensor could be used to detect different combustible gas, especially Methane; it is with low cost and suitable for different application. MQ-2 gas sensor can detect kinds of flammable gases, especially has high sensitivity to LPG (propane). It is a kind of low-cost sensor for many applications. Fig.4 shows the front view of gas sensor MQ-2.

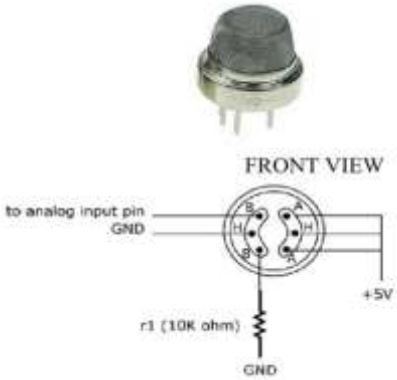

Fig. 4 MQ-2 Gas sensor

D. *Vibration Sensor*

The vibration sensor acts like a normally closed switch which chatters open and closed as it is tilted or vibrated. Unlike other rolling-ball sensors, the 200 is truly an omnidirectional movement sensor. It will function regardless of how it is mounted or aligned. When at rest, it normally settles in a closed state. When in motion, it will produce continuous on/off contact closures. It is sensitive to both tilt (static acceleration) and vibration (dynamic acceleration). The sensor can be easily used to produce a series of CMOS or TTL level logic level or pulse train using a single resistor to limit current. The signal level can be read directly by a digital input. This can be used to interrupt (wake up) a microcontroller or can be counted to estimate the amount and duration of activity. The sensor is fully passive, requires no signal conditioning, and draws as little as 50 nA of continuous current. The module of vibration sensor is given in Fig. 5.

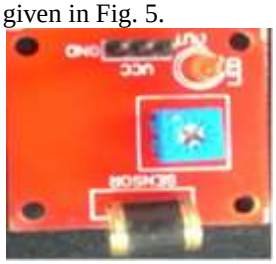

Fig. 5 Vibration sensor

E. *Microcontroller Arduino Uno*

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver

chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. "UNO" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards. The module of Arduino Uno is given in Fig. 6.

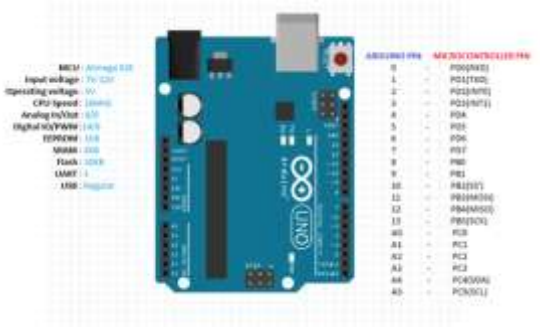

Fig.6 Arduino Uno board and pin description

F. ZigBee Module

ZigBee is a new wireless technology guided by the IEEE 802.15.4 Personal Area Networks standard. It is primarily designed for the wide ranging automation applications. It currently operates in the 868 MHz band at a data rate of 20 Kbps in Europe, 914 MHz band at 40 Kbps in the USA, and the 2.4 GHz ISM bands worldwide at a maximum data-rate of 250 Kbps. The ZigBee specification is a combination of Home RF Lite and the 802.15.4 specification. The specification operates in the 2.4 GHz (ISM) radio band the same band as 802.11b standard, Bluetooth, microwaves and some other devices. It is capable of connecting 255 devices per network. Range of the transceiver module can be 30-70 m in urban areas and 1-1.5 km in outdoor (LOS). The transceiver has an on chip wire antenna and it operates at a frequency of 2.4 GHz. The specification supports data transmission rates of up to 250 Kbps at a range of up to 30 meters. ZigBee technology is slower than 802.11b (11 Mbps) and Bluetooth (1 Mbps) but it consumes significantly less power. The ZigBee transceiver module is given in Fig. 7.

Fig.7 ZigBee transmitter-receiver

G. Liquid Crystal Display (16 x 2)

Alphanumeric displays are used in a wide range of applications, including palmtop computers, word processors, photocopiers, point of sale terminals, medical instruments, cellular phones, etc. The 16x 2 intelligent alphanumeric dot matrix displays is capable of displaying 224 different characters and symbols. A full list of the characters and symbols is printed on pages 7/8 (note these symbols can vary between brand of LCD used). This booklet provides all the technical specifications for connecting the unit, which requires a single power supply (+5 V). LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits (Fig. 8). These modules are preferred over seven segment displays and other multisegment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special even custom characters (unlike in seven segments), animations and so on.

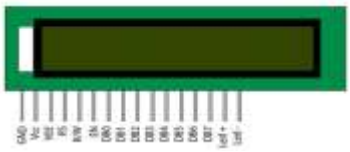

Fig.8 Liquid Crystal Display (16x2)

V. RESULT AND ANALYSIS

The system is based on different sensors such as temperature sensor, vibration sensor, gas concentration sensor and relative humidity sensor. These sensors are deployed in the underground coal mine to sense the environmental conditions. The data sense by the sensors has to be analyzed so that the results obtained are accurate and precise one. Analysis of different sensors has done experimentally in different environmental conditions. This also includes the analysis of wireless module used in the development of system.

A. Temperature sensor

Temperature plays an important role in the coal mines. Efficiency of the workers in the mines mainly depends on the temperature condition at working field, so it is necessary to study this parameter.LM35 is used as temperature sensor to measure the temperature of atmosphere in terms of voltage. The Fig.9 shows the graph of the voltage across sensor which varies with change in temperature. As the temperature increases, the voltage across the sensor increases linearly. Table 1 shows the variation in voltage with respect to temperature.

Table 1: Relation between Temperature and Voltage across Sensor

Temperature	Voltage across sensor
25	0.24
30	0.29
35	0.34
40	0.39
45	0.46
50	0.49
55	0.54
60	0.59
65	0.64
70	0.69
75	0.74
80	0.79
85	0.85
90	0.89

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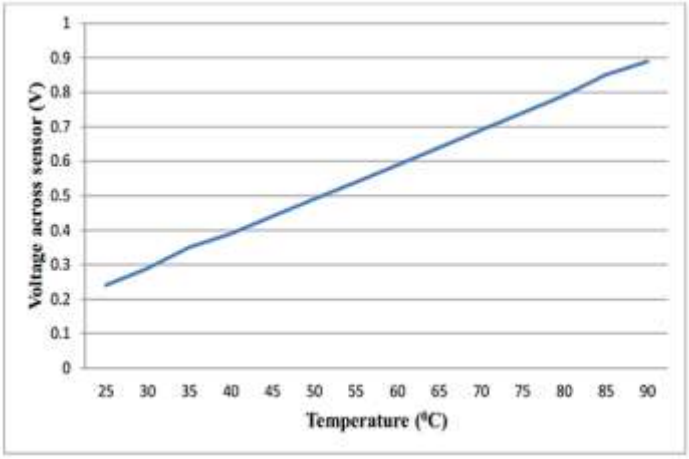


Graph.1 Relationships between Temperature and Voltage across sensor

B. *Relative Humidity sensor*

Humidity is nothing but the water content in the air. The sensor used in the development of the system is DHT11 relative humidity sensor. Analysis of sensor is done in different environmental conditions. It provides the output in terms of voltage shown in Tables 2 and 3.

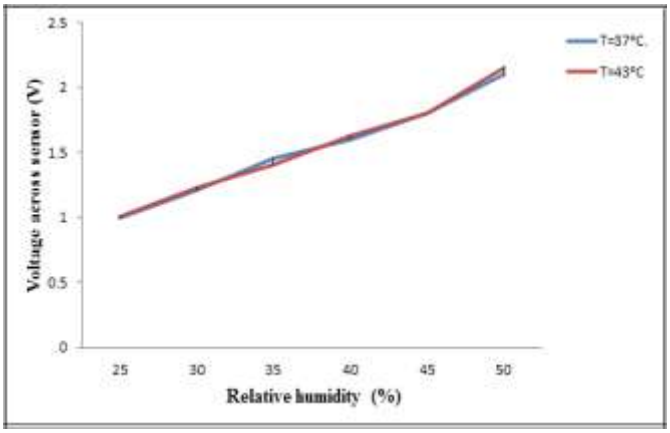
Table 2: Relative Humidity and Voltage across sensor at 37°C

Relative Humidity(%)	Voltage across sensor(V)
25	1.00
30	1.21
35	1.40
40	1.54
45	1.79
50	2.00
55	2.21
60	2.41
65	2.59
70	2.79
75	2.99
80	3.15
85	3.40
90	3.61
95	3.75
100	4.01

Table 3: Relative humidity and Voltage across sensor at 43°C

Relative Humidity(%)	Voltage across sensor(V)
25	1.01
30	1.23
35	1.41
40	1.63
45	1.80
50	2.05
55	2.23
60	2.44
65	2.63
70	2.83
75	3.00
80	3.23
85	3.44
90	3.63
95	3.78
100	4.05

Graph.2 shows the relative humidity changes with change in temperature. As the temperature increases the relative humidity goes on decreasing. This is because at higher temperature, the water vapour content in the environment goes on decreasing.



Graph.2 Relationships between Relative humidity and Voltage across sensor

C. *Current analysis of ZigBee*

The relationship between the voltage across sensor, transmitter current and receiver current is given in Table 4. As the voltage across the ZigBee increases transmitter and receiver current increases accordingly. The specified voltage range of ZigBee is 2.2 to 3.6 V.

Table 4: Relationship between Voltage across sensor, Transmitter current and Receiver current

Voltage Across ZigBee(V)	Transmitter current (mA)	Receiver current (mA)
2.54	38.50	27.20
2.80	39.20	29.40
3.00	40.10	35.30
3.21	42.00	36.50

VI. CONCLUSION

Mining in India is a major economic activity which contributes significantly to the economy of India. Safety of the workers is much important factor in this mining field. The sensors based monitoring system for mining has been used to increase the safety of workers by monitoring the underground coal mine parameters. This paper presents a coal mine safety monitoring system based on wireless sensor networks. This system can detect concentration of the gas, temperature, humidity, smoke and vibration occurs in the underground mine tunnels. Wireless sensor networks applied in monitoring coal mine security breaks through the traditional methods and ideas, which improves the practical ability of monitoring system. The sensors that has used in the developed system are easy to relocate anywhere in the field as per the requirement and are précised too. The coal mine safety monitoring system put forward, quite meets the need of coal mine safety monitoring.

REFERENCES

[1] N. Shah and I. Das, "*Precision Irrigation Sensor Network Based Irrigation*", a book on Problems, Perspectives and Challenges of Agricultural Water Management, IIT Bombay, India, pp. 217– 232, April 2008.

[2] J. Cheng, D. Gao , J. Wang and D. Wen, "*Coal mine safety monitoring system based on ZigBee and GPRS*", Applied Mechanics and Materials, Vol. 422, pp. 215-220, 2013

[3] N. Krithika and R. Seethalakshmi, "*Safety Scheme for Mining Industry using ZigBee Module*", Indian Journal of Science and Technology, Vol. 7(8), pp. 1222-1227, August 2014.

[4] T. Kumar and K. Sambasiva Rao, "*Integrated Mine Safety Monitoring and Alerting System Using ZigBee CAN Bus*", IOSR Journal of Electrical and Electronics Engineering, Vol. 8(3), pp. 82-87, December 2013.

[5] M. Dange, R.Patil and M. Kumarsagar, "*Design of Monitoring System for Coal Mine Safety Based on MSP430*", International Journal of Engineering Science Invention, Vol. 2(7), pp. 14-19, July 2013

[6] R. Boddu, P. Balanagu and N.S. Babu, "*ZigBee Based Mine Safety Monitoring System with GSM*", International Journal of Computer Communication Technology, Vol. 3(5), pp. 9-13, 2012

[7] V. Pandit and U. Rane, "*Coal Mine Monitoring Using ARM7 and ZigBee*", International Journal of Emerging Technology and Advanced Engineering, Vol. 3(5),pp. 352-359, May 2013

[8] K. Archana and A. Mudasser, "*ZigBee and Wi-Fi based Mine Safety Application*", International Journal of Scientific and Research Publications, Vol. 4(1), pp. 01-04, January 2014

[9] G. Divya and S. Manohar Babu, "*Rescue System for Coal Mine Workers using Different Sensors Based on GSM and RF-PRO*", International Journal of Advanced Research in Computer Engineering Technology, Vol. 3(7), pp.2540-2544, July 2014

[10] G.Venkata, A.Bujji Babu and U.Yedukondalu, "*Surveillance system for Coal Mines based on Wireless Sensor Network*", International Journal of Ethics in Engineering Management Education, Vol. 1(11), pp. 33-36, November 2014

[11] [11] A. Pethkar and S. Pawar, "*ZigBee Based Environment Monitoring and Controlling the Gas Plant using ARM*", International Journal of Advanced Research in Electronics and Communication Engineering, Vol. 3(12), pp.1909-1914, December 2014