A Wireless Safety System for Underground Mine Workers Based on WSN

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***Abstract*- This Traditional underground mine workers safety and security system addresses a cost-effective, flexible solution. A module Wireless based sensors network are used for underground environment monitoring and automating progression of measurement data through digital wireless communication technique is proposed with high accuracy, smooth control and reliability. A microcontroller is used for collecting data and making decision, based on which the mine worker is informed through alarm as well as buzzer. An effectively communicate wirelessly with the ground control centre computer for monitoring purpose. ZigBee, based on IEEE 802.15.4 standard is used for this short distance transmission between the hardware fitted with the underground coal mine workers working area and the ground control centre. Continuous monitoring and conversation is possible between the workers and the staff which can help to take appropriate actions more rapidly and smartly.**

Keywords: Wireless sensor networks, Coal mine safety, Zigbee.

I. INTRODUCTION

Mine is an excavation made in the earth to extract minerals. So Mining is the activity, occupation, and industry concerned with the extraction of minerals. An analysis of the Mine Safety and Health Administration (MSHA) accident and injury database for coal and metal/nonmetal mines showed that, from 2001 to 2012, nine fatalities and 1,247 injuries were associated with machine guarding. Furthermore, between 2000 and 2008, MSHA reported 40 fatalities related in both surface and underground operations. Industrial safety is one of the main aspects of industry specially mining industry. In the mining industry safety is a very vital factor. To avoid any types of unwanted phenomena all mining industry follows some basic precaution and phenomena.

Communication is an essential factor for any type of industry today to monitor different kind of parameters and take necessary actions accordingly to avoid any kind of hazards. To avoid loss of material and damaging of human health, protection system as well as faithful and continuous communication system is necessary inside the underground mines. To increase both safety and productivity in mines, a reliable and continuous communication must be established between workers, moving in the mine, and a fixed base station also needed. In Underground mine, the wired communication system is not so much effective. It is very difficult to reinstall the wired communication system inside mines after a landslide or damage due to any reason of mine workers. The continuity of the communication system is very much important to know. According to that information, the development of continuous mine monitoring system to accurately detect temperature, humidity, metal, fire and poisonous gas and to track underground miners and vehicles on real-time has significant meaning to safety production and rescue of coal mine disaster. This ideas proposed by different people on wireless communication. A new decision making approach is online monitoring of geological CO2 storage and leakage based on wireless sensor networks is proposed in. But, those communication methods having specific technology lacks in practical application in underground mines.

For the successfully wireless data transmission, in this work the ZigBee specification is utilized. A cost effective ZigBee-based wireless mine supervising system with early-based intelligence on temperature, humidity, methane, fire and metal in mining area is proposed. ZigBee specification is incorporated by many manufacturers in their devices because of its low power consumption and decreasing development cost. In the work presented here, Digi make CC2530 product is used here for transmitting and receiving data through wireless communication.

II.THE OVERALL DESIGN OF COAL MINE UNITS

A. The structure of Underground coal mine setup

The developed system can be divided into two sections. First is a hardware circuit and second is coding should be coded in CCS. The hardware circuit setup will be attached with the body of the mine workers. This may be preferably fitted with the safety gadgets like helmet, goggles, gloves, glasses, protective shoes, jackets of the workers. The circuit has a sensor module consisting wireless based sensors that measures real-time underground parameters like temperature, humidity, fire, metal and gas.

Gas concentration is meant for the harmful gases like methane and carbon-monoxide. A microcontroller is used with the sensors to receive the sensor outputs and to take the appropriate decision. Once temperature is more than the safety level preprogrammed at microcontroller, microcontroller decodes

beep alarms through the buzzer with controller. Again, once the measured humidity value is more than the safety level preprogrammed at microcontroller, it decodes different type of beep alarms through buzzer. Similarly when gas concentration crosses the safety level, microcontroller decodes siren alarms. In all such cases, this will send an alarm through an urgent message and alarm sound to the ground control terminal through zigbee. With its robust and selectable coding algorithms, 8kbps to 128kbps data/sampling rates, supported internal clock signals makes it versatile. It has analog input interface with encoder that connects the microcontroller and also an analog output interface with decoder that connects microcontroller. A communication signal is effectively established with the help of microcontroller. The microcontroller data is transmitted through two separate boards i.e. ZigBee transrecevier module to the data collector or receiver module. The microcontroller used here is PIC 16F877A with 20MHz operating frequency. It has five I/O ports, eight A/D input channels and 368 bytes data memory. The data receiving terminal of zigbee XB_RX and data transmitting terminal XB_TX are cross connected to the microcontroller corresponding transmitter and receiver terminals TxD and RxD respectively. We used component like MAX 232 and MAX233 is required between these connections. The main use is a signal level convertor. This is the advantage of PIC 16F877A .If the structure of UART (Universal Asynchronous Receiver Transmitter) system is in-build completed, sending and receiving signal is possible using ZigBee, after installing necessary software. The RESET pin of Zigbee is used to provide an optional reset facility of user through a reset button. A transistor is used for this purpose.

The CC2530 is a true system-on-chip (SoC) solution for IEEE 802.15.4, Zigbee fig.3 and RF4CE applications. It enables robust network nodes to be built with very low total bill-of-material costs. The CC2530 combines the excellent performance of a leading RF transceiver with an industry-standard enhanced 8051 MCU, in-system programmable flash memory, 8-KB RAM, and many other powerful features. The CC2530 has various operating modes, making it highly suited for systems where ultralow power consumption is required. Short transition times between operating modes further ensure low energy consumption.

The system structure overview of the whole unit is shown in the figure 1 and the block diagram is shown in figure 2. The main purpose of this project is spitted in to three units. They are Underground unit, Worker unit, Monitoring unit.

The Overall project we spitted the units working in following steps. They are:

a. The persons who are in the coal mining have to face various environmental parameters in their mining. They have the danger from methane, carbon monoxide and temperature. So we need to improve a strong security for the people who are working in the coal mining.

b. The purpose of this project is to provide a solution to mining a wireless communication and safety monitoring. The person must use the gadgets while working in the coal mining.

c. Here we have to arrange the circuit within the kit to provide a safety to the person who is working in coal mining. We are going to use microcontroller and sensors like temperature, humidity, fire, proximity, gas sensor.

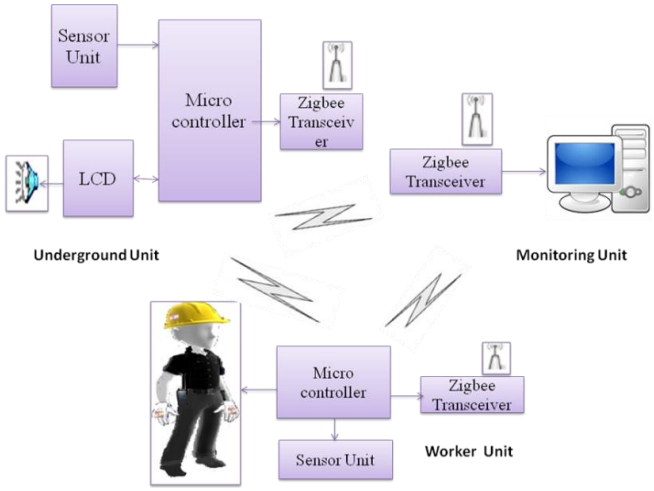

Fig. 1. System structure of the whole unit

d. These sensors observe the change in environment parameters and they will give the information to microcontroller. The microcontroller will verify these values up to date, if any of the value exceeds than rated it will alert to person through the buzzer. Then the department at the base station will take the safety precautions to safe the persons who are working in the coal mining.

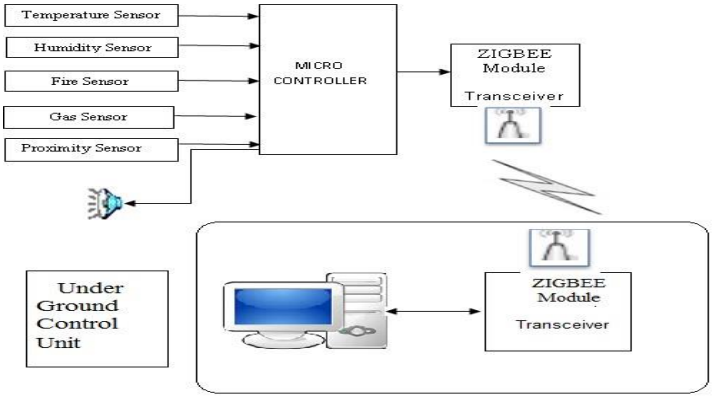

Fig. 2. Block Diagram

B. Data transmission through zigbee

The main characteristics of ZigBee network are simple implementation, low power consumption, low cost interface, redundancy of devices, high node density per physical layer (PHY) and medium access control layer (MAC). Besides, they allow the network to work with a great number of active devices. ZigBee is based on IEEE 802.15.4 standard in terms of the PHY and MAC layers [12]. IEEE 802.15.4 defines two kinds of devices: the Full Function Device (FFD) and the Reduced Function Device (RFD). The FFD has the function to coordinate the network and consequently has access to all other devices. The RFD is limited to a star topology configuration, not being able to work as a network coordinator, so it does not have all the protocol services. The FFD and RFD devices can operate in three different ways at the ZigBee standard as the ZigBee coordinator (ZC), ZigBee Router (ZR), or ZigBee End Device (ZED). The network layer supports three topologies: star, cluster tree and mesh as shown in Fig. 3. A star topology consists of a coordinating node and of one or more FFD or RFD which communicates with the ZC. At the cluster tree, the final devices can be associated to the network by the ZC and the ZR helping the increasing of number of nodes and the network scope. At the mesh topology, the FFD can distribute messages directly to other FFD. To enter the network, each device receives an address given by ZC or a ZR.

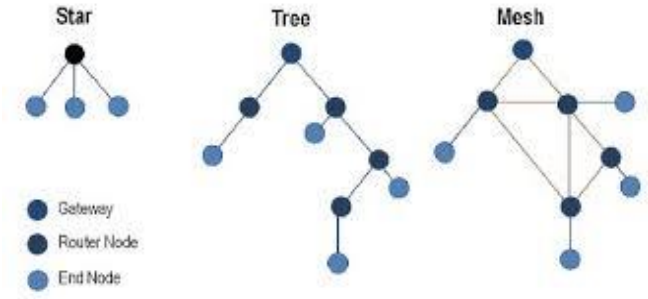

Fig. 3. Different topologies of ZigBee network

III. DATA MANAGEMENT SOFTWARE

Proteus is a high-performance simulator for multiprocessors. It is fast, accurate, and flexible. It is one to two orders of magnitude faster than comparable simulators, it can reproduce results from real multiprocessors, and it is easily configured to simulate a wide range of architectures. Only design should be done in this software and also checking purpose, whether the coding is right or it to be evaluated and then to dump the coding into hardware. Intelligent and highly optimized CCS C compilers contain Standard C operators and Built-in Function libraries that are specific to PIC registers, providing developers with a powerful tool for accessing device hardware features from the C language level. The PIC C Complier software details will be explained here. First of all double click on PIC C Compiler software.

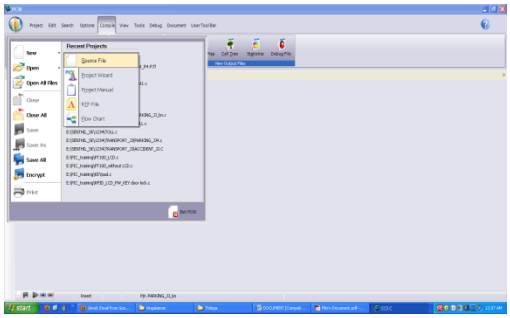

Fig. 4. Source file

From Source file first type the program in pic c compiler. That is denoted as a source file. Save that program in any name that is stored as a HEX file and COF file. We just use only as HEX file. This will be complied in CCS C Complier. The program will be complied successfully.

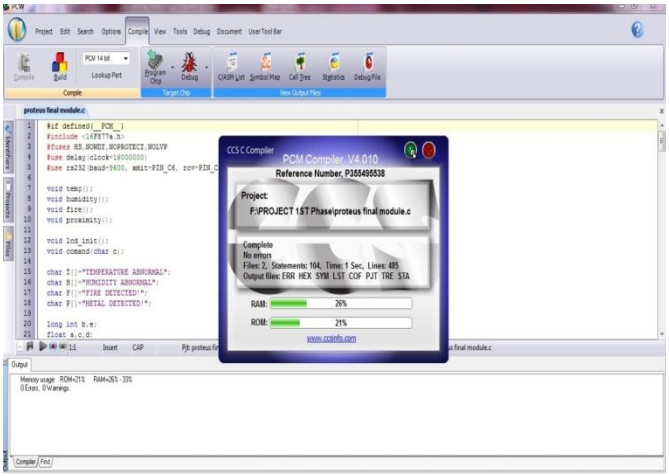

Fig. 5. Compiled with CCS C Compiler

This PIC Bootloader should be used to interface the program in PIC C complier and hardware. Finally boots the program and send the information through system via RS232.

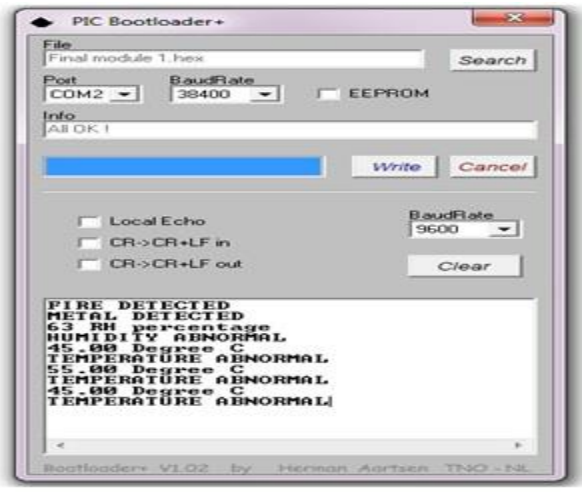

Fig. 6. PIC BootLoader Plus Output

IV. HARDWARE INFRASTRUCTURE

A wireless system for underground mine workers based on WSN are mobile devices used by humans. The equipment is composed of the air environment sensors array, Zigbee transrecevier module, central processing unit, LCD display module and buzzer.

A. Microcontroller

The microcontroller that has been used for this project is from PIC series. PIC microcontroller is the first RISC based microcontroller fabricated in CMOS (complementary metal oxide semiconductor) that uses separate bus for instruction and data allowing simultaneous access of program and data memory. Only 35 single word instructions to learn. All single cycle instructions except for program branches which are two cycle. Operating speed: DC - 20 MHz clock input DC - 200 ns instruction cycle. Up to 8K x 14 words of Flash Program Memory.

B. Sensor Specifications and Circuit Design

An environmental information acquisition sensors array includes: Temperature sensor, humidity sensor, fire sensor, gas sensor and proximity sensor. These sensors, respectively, provide real-time collection of air data to the central processing unit. Each sensor is described in the following.

Temperature sensor

The LM35 series are precision integrated-circuit temperature sensors, with an output voltage linearly proportional to the Centigrade temperature. Thus the LM35 has an advantage over linear temperature sensors calibrated in ° Kelvin. The LM35 is rated to operate over a-55°C to +150°C temperature range, while the LM35C is rated for a -40°C to +110°C range (-10° with improved accuracy).

Humidity Sensor

Humidity sensor is used for acquiring humidity sensor data. The measurement range is of 1~99% RH and voltage input of 5 V DC. Capacitor frequency conversion is applied so as to reach the connection to the central processing unit.

Fire Sensor

This sensor detects the early detection of a fire and the signaling of an appropriate alarm remain the most significant factors in preventing large losses from occurring. There are lot of detectors are available in fire based sensor.

Proximity Sensor

The Inductive Proximity Sensor (IPS) is a solid state device that generates an output signal when metal objects are either inside or entering into its sensing area from any direction. Voltage – DC 5 to 36V,Output type – 3-wire PNP positive logic output, Detection Distance – 0 to 4mm, Switch Type – Electronic sensor, high frequency oscillator.

Gas Sensor

Sensitive material of MQ-6 gas sensor is SnO2, which with lower conductivity in clean air. When the target combustible gas exist, the sensor's conductivity is higher along with the gas concentration rising. Please use simple electro circuit, Convert change of conductivity to correspond output signal of gas concentration.

V. IMPLEMENTATION

The overall underground mine unit developed here is to make an interactive, reliable monitoring and management of sensed data and alarm. The system software is made using CCS which helps to form of embedded c code. Also, it generates and prints the reports of the parameters. The different environmental parameters received by the ground control PC are displayed in those manners in the LCD screen. The parameters include the temperature, humidity, concentration of methane and carbon monoxide, fire and metal. The computer stores the parameters in the hard disk and ground staff can choose any of the parameters for recording and replaying. When it is found that the parameters received have exceeded the limit set, the microcontroller will control the alarm buzzer to ring in time, and the computer at ground control centre also gives the alarm ring and the alarm pictures. Based on the alarm received ground staff takes decision and establish voice communication with the underground workers. The safety department people are sent alarm. Respective control and safety measures are taken accordingly based on the continuous monitoring of situation and voice communication with underground people.

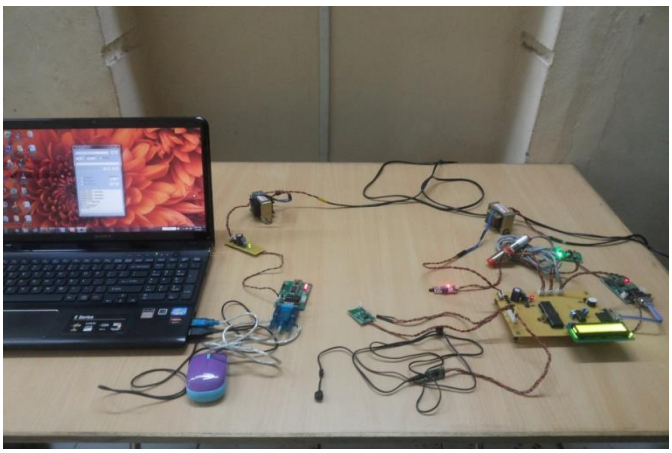

Fig. 7. Hardware Overview of zigbee transmission to real time monitoring

VI. CONCLUSION

Traditional mine security system can be effectively replaced by the surveillance and safety system proposed in the project. A larger area and more depth inside hazardous underground mines are now can be covered and potential accidents can be controlled

effectively. The system combined the low power, low cost, based on high frequency wired data transmission technology based on small size sensors. The sensor can be preferably installed over the helmets and other gadgets of mine worker. Proper monitoring and conversation is possible between the workers and the ground staff which can help to take appropriate actions more rapidly and smartly. The system was communicated with ZigBee wireless transmission. This scheme also can be extended with Bio-Medical Analysis facility in future; it will improve scalability of underground environment and extend accurate position of miners.

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