Coal Mine Safety Monitoring and Alerting System

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Abstract – Today, safety of miners is a major challenge. Miner's health and life is vulnerable to several critical issues, which includes not only the working environment, but also the after effect of it. To increase the productivity and reduce the cost of mining along with consideration of the safety of workers, an innovative approach is required. Coal mine safety monitoring system based on wireless sensor network can timely and accurately reflect dynamic situation of staff in the underground regions to ground computer system and mobile unit. The air pollution from coal mines is mainly due to emissions of particulate matter and gases include sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) etc. To monitor the concentration level of harmful gases, semiconductor gas sensors are used. Due to any reason miner's falls down and lose consciousness also proper treatment is not provided them at that time, so number of miners are died. To overcome this problem the system provide emergency alert to the supervisor if person fall down by any reason. Some workers are not aware for safety and they are not wear helmet. A Limit switch was then used to successfully determine whether a miner has removed his helmet or not. This system also provides an early warning, which will be helpful to all miners present inside the mine to save their life before any casualty occurs. The system uses Zigbee technology and GSM for transmission of data. There is alert switch at receiver and transmitter side for emergency purpose.

Key Words: **Zigbee, GSM, WSN, Miner Safety, Alert Switch.**

1. INTRODUCTION

The safety issues of coal mines have gradually turned into a major concern for the society and nation. Since 1900, over 100,000 workers have been killed in coal mines in the U.S. (Alford, 1980) and many more have been injured and disabled [1]. Underground coal miners are exposed to a wide range of hazards including gas explosions, shifting rock, falls, and machinery and mobile equipment accidents [1]. Coal as an important source of energy in industrial production, it plays a pivotal role in the national economy. So the miner safety is very important factor to be considered. Presently miner have only helmet for purpose of protecting the head. In this project to develop a smart helmet for monitor the concentration level of harmful gases and hazardous event of coal mines and transmit the data to the base station using Zigbee. To monitor the concentration level of harmful gases present in coal mine like SO2, NO2, CO etc. the semiconductor gas sensor are used. We are also considering the health condition of person using fall detector accelerometer. The removal of miner helmet is also a important factor under consideration. The limit switch is used to detect the miner's wear the helmet or not. All data is transmitted from helmet to base station using Zigbee. The data at receiver side is transmitted on the web using GSM.

Alerting miners in a mine can be a difficult process bearing in mind the everyday working conditions that are encountered in a mine. Underground mines are very dark places and therefore the miners use safety helmets with attachable mining lights. The equipment used in underground mines can create a lot of noise and vibrations, which are compounded by the cramped conditions in the underground tunnels. The problem associated with the noise is that warning a miner with a speaker, alarm, vibration unit and LED system when a fellow miner is experiencing a hazardous event would most probably be in vain as the miner would not hear the alarm. It was therefore decided to implement a system that will warn the miner by flashing the mining light a few times. Using this warning method has the added benefit of using the mining helmet light of the miner who is experiencing the hazardous event. Flashing the light constantly simultaneously show who is experiencing the problem as well as indicate the location of the miner. Also headphone and speaker are used to send the emergency message signal.

2. LITERATURE SURVEY

Yongping Wu and Guo Feng implement coal mine monitoring using the Bluetooth wireless transmission system. As a standard of unified global short-range wireless communication, Bluetooth technology is to establish a common low-power, low-cost wireless air interface and controlling software opening system. This paper describes the development background, technical features and the structure of the protocol stack of Bluetooth technology, and proposed the solutions of the Bluetooth host controller interface (HCI) wireless communication for the complexity of its development [2].

At the same time, the system uses CAN bus technology maturely, has realized the combination of wired and wireless data transmission system. The main difficulty of this system is that the Bluetooth is short distance wireless technology and use of cabling is difficult. When a natural calamity or a roof fall occurred, the cabling is damage. So the reliability and long life of conventional communication system is poor. Due to the harsh environment inside the mine, the installation and maintenance of the wired communication is very difficult.

Zhenzhen Sun proposed DCS Coal Mine Monitoring System Based on RS485 Bus, RS485 bus structure supports multi-point and two-way communication. So, this type of monitoring system can be developed using common 8-bit microcontrollers. It has the advantages of simple circuit structure and low costs. However, due to the adoption of master-slave structure network, it is difficult to guarantee the reliability of the network structure. Furthermore, the data transmission distance is limited with a poor real-time performance [3-4].

Jingjiang Song, Yingli Zhu proposed automatic monitoring system for coal mine safety based on wireless sensor network. This system design monitoring for coal mine safety constructed by MSP430F and nRF2401. The sensor groups of the system intensively monitor temperature, humidity and other parameters in the underground mine, parameters measured are sent to wireless communication module by the micro-controller. The collected information is sent to long-distance monitoring center by cable [5]. The problem of this implementation is that hardware is placed inside the coal mines, when a natural calamity or a roof fall occurred, the system is damage. So the reliability and long life of conventional communication system is poor. Due to the harsh environment inside the mine, the installation and maintenance of the system is very difficult. The another problem is that the working condition of coal mine is very noisy and if the distance of miner and system is long, miner not get proper message.

Y ogendra S Dohare and Tanmoy Maity design surveillance and safety system for underground coal mines based on Low Power WSN. In this system a low power, cost-effective, and Zigbee protocol based wireless sensor network that provides an intelligent surveillance and safety system for underground coal mines. The system consists of wireless connection of several nodes. This network can be easily placed in underground mines and it provides an effectively surveillance and safety system for underground coal miners. Especially, it provides the real-time data communication between miners and surface control room through highly secure, reliable wireless sensor nodes [6]. This system is placed in mine so problem is created when miner are not in range of the system. This system only monitor environmental condition of underground mine but not monitor the health condition of miner.

Valdo Henriques and Reza Malekian developed Mine Safety System Using Wireless Sensor Network. This system describe the design and construction of a mine safety system prototype using a wireless sensor network with the objective of building a safety system to monitor the ambient characteristics of the mining environment. The hardware consisted of electronic circuitry where a microcontroller is the principal processing unit. A graphical user interface is also implemented [7]. While the wireless communication implemented in this design shows success with urban/indoor communication, in order to enhance the system even further, multiple identical sensor nodes could be introduced. This would turn the master/slave (2 node star) topology into a mesh network. By using the proprietary technology from the manufacturer of the Zigbee module known as DigiMesh a smart mesh network can be configured. This would allow for a sensor node to be out of range with the collection node, but as long as that sensor node can communicate to another sensor node, the data can be passed along from the end sensor node to the collection node through intermediary sensor nodes. This would increase the communication range inside the mine.

Pranjal Hazarika presents implementation of safety helmet for coal mine workers. This helmet is equipped with methane and carbon monoxide gas sensor. This sensor sense the gas and the data is transmitted to the control room wirelessly, through a wireless module called Zigbee connected with the helmet. When the methane or carbon-monoxide gas concentration is beyond the critical level, controller in the control room triggers an alarm and keeps the plant and the workers safe by preventing an upcoming accident [8]. This system does not detecting fall down of the person and whether the miner's wear the helmet or not.

Tanmoy Maity and Partha Sarathi Das implement a wireless surveillance and safety system for mine workers based on Zigbee. This system addresses a cost-effective, flexible solution of underground mine workers' safety. A module of MEMS based sensors 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 voice system. The voice system with both microphone and speaker transforms into digital signal and effectively communicate wirelessly with the ground control center computer. ZigBee, based on IEEE 802.15.4 standard is used for this short distance transmission between the hardware fitted with the mine worker and the ground control center [9]. Zigbee is a short distance wireless communication network so it is not possible to intimate to responsible authorities who are at long distance.

3. PROPOSED SYSTEM

The key to controlling coal mine accidents the prediction of outburst by implementing sensors and microcontrollers and to generate an alarm system before critical atmospheric level. A continuous monitoring is necessary which again requires some effective and accurate sensing system. Several technique are adopted to sense the presence of these poisonous gas, among them use of semiconductor type gas sensor is very much effective. These sensors can be mounted in the coal mine area but some time these create some problems in mining too. Accidental damage of the sensor device often took place. Another technique is the use of robot. These robots are effective but cost of robot is very high. However, there is another way of getting effective and low cost solution of sensor implantation; it is on the safety helmet of the coal mine workers. A smart safety helmet having sensor array to sense data and a wireless modem to transmit it.

The helmet is the only safety gear miners tend to keep on, this is where the new safety equipment was added on to. This module does all the processing and also controls the wireless communication between separate helmets. The whole system was analyzed throughout the design process in order to keep the power consumption to a minimum as the system is running on battery power. Different sensors were considered for each separate component in order to keep the power level as low as possible. The system consists of six components, helmet remove sensor, person fall detection sensor, air quality sensor, data processing unit, wireless transmission and alerting unit.

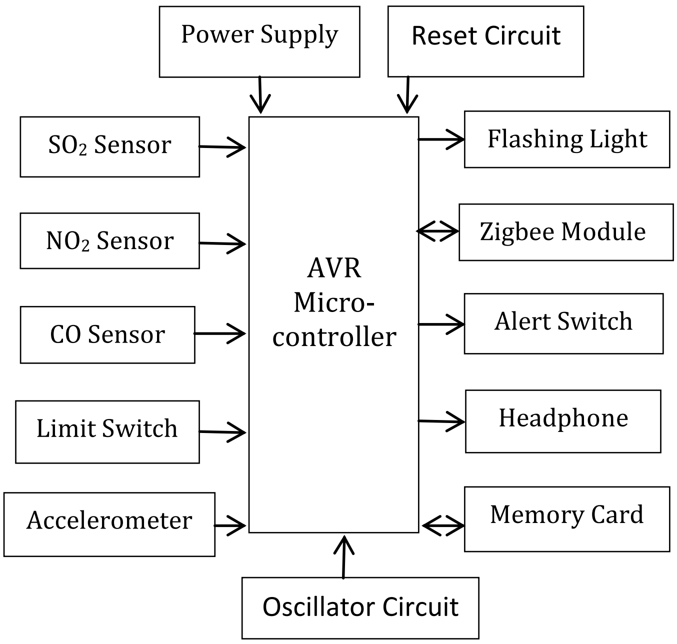

Fig-1: Block diagram of transmitter side of smart helmet

This system has a sensor module consisting of some sensors that measures real-time underground hazardous condition like harmful gas concentration, helmet removal and person fall detection. The semiconductor type sensor MQ7, MQ136 and MICS-2714 monitor the real-time concentration level of carbon monoxide, sulfur dioxide and nitrogen dioxide respectively and send real time data to the base station. When threshold values of gases exceed the flashing light of helmet is ON. If miner fall down and lose consciousness, fall detector made of MEMS- Accelerometer (ADXL 335) are used to detect the angle of helmet to ground and send data to the controller. Controller receive the accelerometer output and to take necessary decision. If angle exceed the particular limit controller alert to the supervisor. The limit switch is use to determine presence or absence of object or whether miner's remove their helmet or not.

All sensor output is amplifying using amplifier before transmission of controller. The AVR microcontroller have inbuilt ADC and fast transmission speed. In system also provide emergency alert switch on helmet. If miner press emergency switch for any emergency the emergency message transmit through Zigbee to base station.

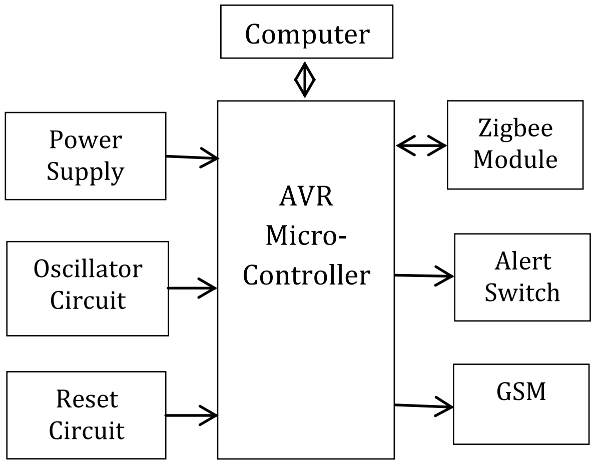

Fig-2: Block diagram of Receiver side of base station

All real time data are received from helmet to the base station through Zigbee and display on PC. Zigbee is a short distance wireless communication network so it is not possible to intimate to responsible authorities who are at long distance. Meanwhile GSM based wireless sensor network are investigated due to their remote environmental monitoring capabilities. By using GSM based technology we can make the system based on IOT.

This system provide an alert button so that miners can directly convey the emergency message to the control room and also control room convey the alert message to the miners.

3.1 Gas Sensor

There are three types of gas sensor biometric sensor, electrochemical sensor and Metal Oxide Semiconductor sensor. Biometric sensor use gels, which change the colour after absorbing certain amount of gas. Advantages of biometric sensor are low cost, low current. The main disadvantages of biometric sensor are it has high false alarm rate and long recovery after alarm.

Electrochemical sensor consists of chemical reactance (electrolytes or gel) and two terminals. Anode is for oxidization and cathode is for reduction. The advantages of electrochemical gas sensor are reliability and few field detection. But it is high sensitive to the ammonia cleaner and costly.
The metal oxide semiconductor sensor work, when tin dioxide reaches its operating temperature, it is capable of changing its resistance in the presence of gas. Advantages of long life span and quick response choose the metal oxide semiconductor gas sensor.

3.2 Fall Detection Accelerometer

The ADXL335 is a low power, thin, small, complete 3-axis accelerometer with signal conditioned voltage outputs. Product processes acceleration with a minimum full-scale range of ±3 g. They can measure the static acceleration of gravity in tilt-sensing device, as well as dynamic acceleration resulting from vibration, shock, or motion.

3.3 Helmet Removal Sensor

There are two types of Helmet removal sensor like IR Sensor and limit switch. The IR Sensor send infra-red light through IR-LEDs, which is then reflected by any object in front of the sensor, to use another IR-LED, to detect the IR light that was emitted from another led of the exact same type. But the infra-red light is harmful for human and large amount of false alarm are generate. So use of limit switch is better. Wireless enabled limit switches can be used for position sensing and presence or absence detection for an endless number of applications. The Limitles Series is especially beneficial for remote monitoring applications where wiring or wire maintenance is not physically possible or economically feasible. When object come into contact with a actuator, the device operates the contacts to make or break an electrical connection

3.4 Wireless Transmission Device

There are mainly three types of wireless transmission device Bluetooth, Wi-Fi, and Zigbee. Wi-Fi needed cabling throughout the mine to the router, which can be damage because of roof fall and some other accident. Bluetooth was not creating larger mesh network so long distance communication is not possible.
Zigbee wireless system is chosen because it is low power, low cost, low maintenance monitoring and control system. Its signals are able to penetrate walls and work very well in mines. Its ability to form mesh structure it provide long distance communication.
To intimate to responsible authorities who are at long distance. Meanwhile GSM based wireless sensor network are investigated due to their remote environmental monitoring capabilities. By using GSM based technology we can make the system based on IOT.

4. CONCLUSION

A real time monitoring system is developed to provide clearer and more point to point perspective of the underground mine. This system is displaying the parameters on the monitoring unit; it will be helpful to all miners present inside the mine to save their life before any casualty occurs. Alarm triggers when sensor values crosses the threshold level. This system also stores all the data in the computer for future inspection.

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