

# Wearable Real Time Health and Security Monitoring Scheme for Coal Mine Workers

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## Abstract

This paper deals with implementing a supervision system for coal mine and underground workers, which is essential to avoid the workers illness and death. The proposed recovery system consists of all primary aspects of the coal mine and underground areas. This system incorporates a sensor array, GSM, RF and controller modules. ARM7 (LPC2148) Microcontroller is fully automated measuring system. ARM7 processor is used for measuring the environment parameters with high reliability and accuracy and smooth control by using sensor networks. Consequently, advance detecting crucial conditions the microcontroller starts alerting the mine workers by the alarm system and sends the alert messages to fire and ambulance services by using GSM modem. In addition, the observed parameter's value will be displayed on a PC by using RF (CC2500) module, which is at the control station. At the hazardous situation, this system shows the shortest and available way out path for the workers to move away from the harmful environment.

**Keywords:** Coal mine; GSM; Sensors array; SMS; PC; RF

## Introduction

Air pollution and gas explosion are increasing day by day and become foremost crisis in the coal mines and other industries. Safety of the human being is an essential aspect in any industry, especially in the field of mining and underground industry. The coal mine has been a very precarious activity which results in a number of detrimental effects on the environment such as suffocation, roof collapse, gas poisoning, gas explosions and hazardous greenhouse gases may be released into the air.

Air pollution leads to the personal and health impacts on lots of people causing illness and fatality. Explosive gas emission panics the human health, occupational safety of the coal mines workers [1]. Consequently these pollutions cause hazardous effects for the coal mines workers. There are a lot of works are carried out in the same manner in the case of coal mine monitoring. However existing and extant security monitoring systems cannot monitor all environmental parameters, therefore workers cannot monitor properly. The remedy for this issue is a wearable cost effective protection system with low power consumption and high performance [2]. This venture aims to increase the occupational safety and to protect the workers effectively in the hazardous air polluted environment.

The major accidents occurred in the coal mine and underground units are based on fire, natural gas and overheating of surroundings. Coal mine safety monitoring system is mainly based on wireless sensor network. Wireless network can provide a timely and accurately reveal energetic condition of staff in the underground regions to control center computer system. This protection system consists of all primary aspects of the coal mine and underground area. Therefore, to precocious systematic understanding of the health impacts of personal exposure to these pollutants, a miniaturized monitoring device is considered necessary for those individuals human can wear or carry to constantly examine their surrounding environment [3].

In this paper we describe Health Gear, a wearable real-time health monitoring system. Health Gear consists of a set of physiological sensors wirelessly connected via Bluetooth to a Bluetooth-enabled cell phone. We describe our experience using Health Gear with an oximeter to constantly monitor and analyze the user's blood oxygen level ( $SpO_2$ ),

heart rate and plethysmographic signal in a light-weight fashion. In this paper, we describe one exemplary application of Health Gear for monitoring users in their sleep in order to detect sleep apnea events. We are currently working on a few other applications of Health Gear, including monitoring pilots during their flights to detect dangerous drops in blood oxygen levels due to altitude, and constant, daily monitoring to identify correlations between contextual information (i.e., date, current activity, location, etc.) and changes in heart-rate and/or blood oxygen levels [4].

## System Design

The proposed protection system covers the most ameliorate and primary necessity aspects of the coal mine workers. This rescue system for coal mine workers is divided into two segments. Miner module and ground station unit. The wearable hardware device (miner module) is attached to the body of the mine workers (Figure 1).

### Miner module

The miner's module consists of the sensor arrays, ARM7 microcontroller, RF transmitter and GSM modem. The sensor module incorporates with various sensors to measure the real-time underground parameters like temperature, humidity, light, fire and position of worker furthermore multiple gas and its concentrations in underground station [5]. During the hazardous situation of the mine, miner's module gives information to the control station through the RF transmitter. The control station will alert the workers after receiving the hazardous information from the ground station by using RF receiver.

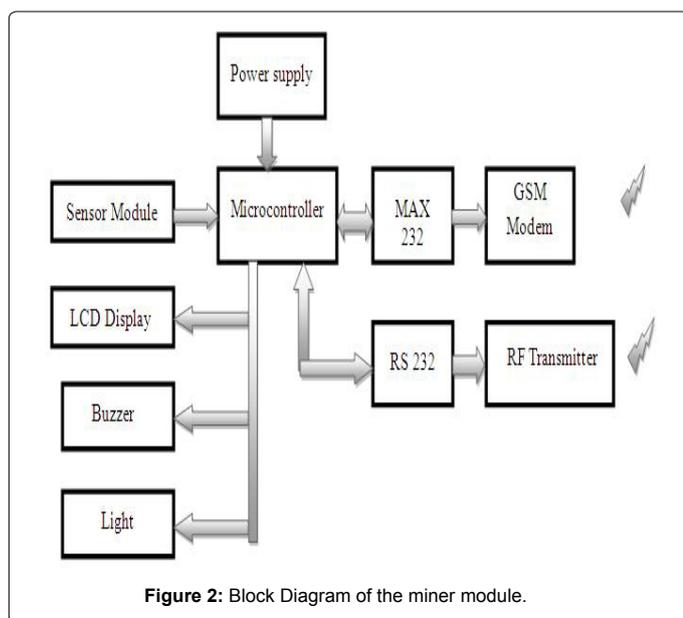
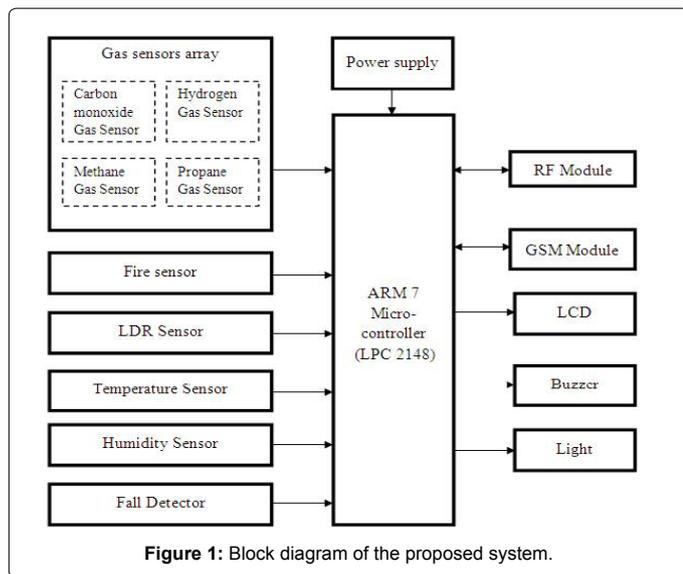
ARM7 Microcontroller (LPC2148) is the heart of this module unit. It is used to take the necessary decision whenever the predefined comfort

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level rises in the underground unit. A 2x16 character LCD module is interfaced to show all the parameters like temperature, humidity etc., at underground miner's module. GSM Modem is interfaced with the Module to send the message to the remote location similar to the fire station and the ambulance service (Figure 2).

### Ground station module

Ground station control unit consists of RF receiver and Personal Computer to monitor the state of affairs in the coal mine (Figure 3). The hazardous conditions of the coal mine unit state will be displayed on the PC by using the serial to USB converters (RS. 232), which is used to take a necessary precaution action for the workers [6]. With the help of this alert system, workers will be alerted in the dangerous environment. Once the measured parameter values are more than the safety level pre-programmed at microcontroller, it decodes different type of beep alarms.

## Hardware Description

Hardware description comprises of four modules namely sensor, controller, GSM and RF modules.

### Sensor network

Sensor network incorporates several sensors to monitor the hazardous environment of the underground unit.

**Gas sensor technologies:** The most common gas sensor technologies are metal oxide sensors (MOS), non-dispersive infrared gas sensors (NDIR), catalytic sensors, photo Ionization detectors (PID), flame ionization detector (FID), thermal conductivity sensor, and electrochemical (EC) sensors. Due to inherent complexity and sophistication, PID, FID and NDIR sensors have high production cost and are difficult to miniaturize. Although catalytic sensors are less sensitive to ambient environment changes and have simple structure, they have very short lifetimes due to poisonings and can only measure combustible gases [7].

Among gas sensor technologies, MOS sensors stand out as candidates for wearable systems, especially because their structures are compatible with modern micro fabrication processes, therefore a suitable device for low cost miniaturization. MOS sensors have low power consumption, low-cost, good selectivity, and can sense a wide range of gases such as CH<sub>4</sub>, NH<sub>3</sub>, CO, NO, NO<sub>2</sub>, H<sub>2</sub>, SO<sub>2</sub>, CO<sub>2</sub>, H<sub>2</sub>S and O<sub>2</sub>. Therefore, MOS sensors were chosen in this system for multi-gas measurement [8-10].

### Fire sensor

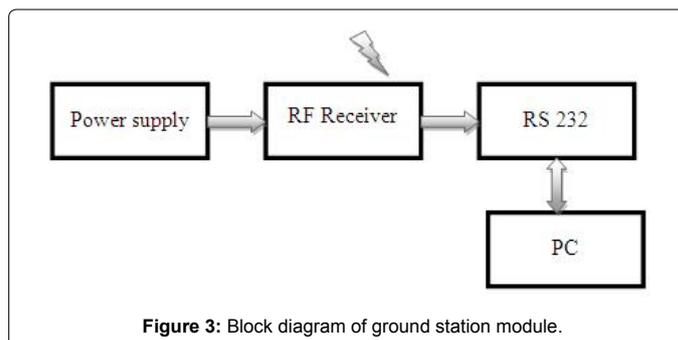
The Fire sensor works on the principle of IR rays or heat radiation detection for protection against fire. When the sensor is detecting any kind of fire it will give an interrupt signal to the microcontroller to alert the workers in underground regions.

### Light Dependent Resistor

LDR used to sense the sense the darkness at the underground unit. The amount of light intensity level reduced in the working area then LDR triggered, circuit will turn ON the LED. For the convenient purpose, possibly the LED will be fixed with the workers helmet. Consequently to provide intensity the LED lights present on miner's module.

### Temperature sensor (LM35)

LM35 is a precision IC temperature sensor. The electrical output voltage is proportional to the Centigrade temperature. It measures the temperature more accurately than a thermistor and no need of amplifying the output voltage.



### Humidity sensor (HSM-20G)

Humidity is the amount of water vapor in the air. The humidity sensor HSM-20G is of resistive type and converts relative humidity into standard voltage output. It is an analog humidity and temperature sensor that outputs analog voltage respects to relative humidity.

### Fall detector (ADXL335)

Fall detector is sensitive to both linear acceleration and the local gravitational field. The ADXL335 is a low power, thin, small, complete 3-axis accelerometer with signal conditioned voltage outputs. The output signals are analog voltages that are proportional to acceleration. Its measurement range is of  $\pm 3$  g. X-axis is connected with controller and continuously checks that -g value change.

**Microcontroller (LPC 2148):** The ARM 7 is a 32-bit RISC instruction set developed by ARM Holdings. It is also known as the Advanced RISC Machine. In this scheme, ARM 7 (LPC 2148) microcontroller is used. The sensor module is connected to LPC 2148 and it takes necessary decisions based on sensor module output [11].

Due to their tiny size and low power consumption, LPC2141/42/44/46/48 are ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. Serial communications interfaces ranging from a USB 2.0 Full-speed device, multiple UARTs, SPI, SSP to I2C-bus and on-chip SRAM of 8 kb up to 40 kb, make these devices very well suited for communication gateways and protocol converters, soft modems, voice recognition and low end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit ADC(s), 10-bit DAC, PWM channels and 45 fast GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers suitable for industrial control and medical systems.

**GSM module:** GSM module is a compact and reliable wireless module. GSM module is used to send the message to the ground or remote station. Plain Text message may be sent through the modem by interfacing only three signals of the serial interface of a modem with microcontroller (TxD, RxD and GND).

In this system, transmit and receive signal from a serial port of the microcontroller is connected respectively with the transmit signal (TxD) and receive signal (RxD) of the serial interface of GSM Modem. The LPC 2148 alerts GSM modem in the miner module to send SMS to fire and ambulance service stations in adverse situations and the acknowledgement SMS is sent to the miner's module from control station.

**RF (CC2500) module:** Effective communication system is an essential in a coal mine and underground area. Wired network communication is inconvenient and inefficient method compared to wireless communication system.

Consequently this coal mine recovery scheme communication is based on RF wireless transceiver module (Figure 4).

RF module provides easy and flexible wireless data transmission between devices. This is based on AVR Atmega8 with serial output which can be interfaced directly to PC. The CC2500 is a low-cost 2.4 GHz transceiver designed for very low-power wireless applications purpose. RF wireless transceiver module establishes communication between the underground and ground station units to communicate about the environmental changes in the underground unit.



Figure 4: GSM module.



Figure 5: Overall recovery system hardware setup.

## Software Description

As this recovery system is based on embedded systems, the firmware enlargement is prepared by using Embedded C language. To simulate this design in hardware various software tools in set up needed for this system. Consequently the most significant among these tools are Keil IDE, Flash Magic Tera Term and HyperTerminal.

### Keil IDE

Most of the embedded programmer uses the Keil software. Keil version 4 is used to compile the Embedded C code. A compiler is used to compile the code and convert the source code to hex files with the help of an IDE.

### Flash magic and tera term

The Flash magic tool is used to flash the Programme in ARM7 microcontroller board. Tera term is used to communicate with the serial port. With the help of the Tera term, user can receive the information about underground unit in the control center PC with the help of RF receiver.

### Hyper terminal

The Hyper Terminal tool is used to monitor the information about underground unit with the help of a Serial Ports in PC. RF receiver is used to send the information to a remote location.

## Results

The Overall system's results are discussed in this section. The LPC2148 Evolution Board is heart of all functionalities in miner module i.e. Monitoring, Processing collected data and taking necessary

action based on the limits given for individual sensors (Figure 5).

The following figure shows the abnormality levels of the parameter in the underground module. The predefined comfort value is programmed in the microcontroller, proposed protection system continuously monitor the underground unit (Figure 6).

Whenever the predefined value is more than the safety level pre-programmed at microcontroller, the controller decodes beep alarms through the speaker connected with controller. Corresponding parameters value displayed in the LCD display and get SMS alert through GSM Module. This above figure shows the emergency shortest and risky free way-out to the workers. With the help of this system worker will move fast and not panic to shift away from the environment (Figure 7).

On detection of Abnormal activity at miner module the core system alerts and sends SMS to either Fire station or Ambulance based on the Interrupt source (Figure 8).

The above figure shows the Hyper terminal screen i.e. Remote Station. In this station information will be send to a PC by using RF receiver to monitor the data in ground station (Figure 9). This statistics records will be displayed in pc, which provides the complete information of workers and statistics of all the parameters.

One such disorder is sleep apnea, which is an under-diagnosed, but common condition that affects both children and adults. It is characterized by periods of interrupted breathing (apnea) and periods of reduced breathing (hypoapnea). Both types of events are generally considered to be equal in terms of their impact on patients. The most common form of sleep apnea, called obstructive sleep apnea (OSA),



Figure 6: Miner's module alert system.



Figure 7: Emergency way-out indications.

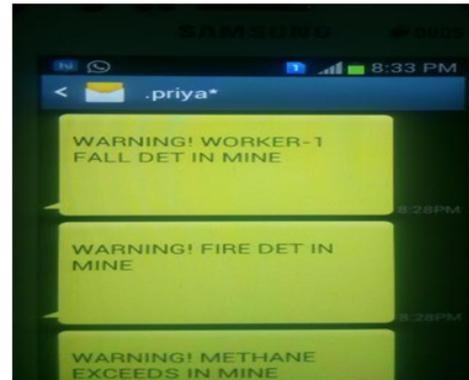


Figure 8: SMS alert system.

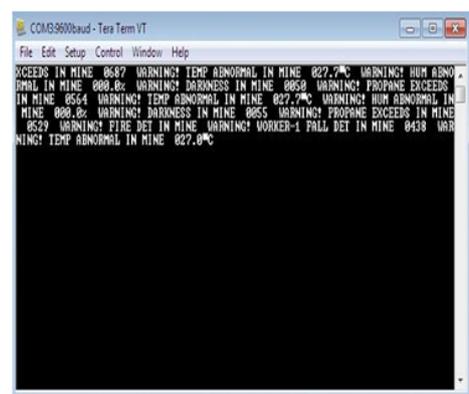


Figure 9: Remote section monitoring screen.

is caused by the partial or complete constriction of the patient upper airway. Regular sleep apnea leads to repeated hypoxemia, as phylxia and awakenings, and produces immediate symptoms such as increased heart rate and high blood pressure and long term symptoms such as extreme fatigue, poor concentration, a compromised immune system, slower reaction times and cardio/cerebrovascular problems.

## Conclusion

This proposed system covered the most Important and Primary necessity aspect of any mine workers safety. More security is provided by GSM module, used to send the message to fire and ambulance service to evade the damages. Furthermore, this system perhaps extended with an ability to find the shortest exit path for the workers in case of fire accidents in the underground mines. Then the ground station alerts the workers using voice over IC fixed in the miner module about the shortest furthermore safest path in case of fire accidents in one or more underground units. All these sensors can be easily placed on Miner's Helmet that helps in continuous monitoring. The extant mine security system can be effectively replaced by this rescue safety system proposed in this paper.

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