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WIRELESS HEALTH MONITORING SYSTEM IN MINE AREAS USING nRF24L01

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Abstract - *The Coal Mine Areas in underground is very harsh. It feels difficult for the miners to work in such conditions. Mining accidents causes serious casualities and economic loses, which occurs due to natural disaster and variety of causes like leakage of poisonous gases such as hydrogen sulfide, carbon dioxide, natural gases, especially firedamp or methane, dust explosions, collapsing of mine stopes, use of improper mining equipment. In earlier days,* ***Cable Monitoring System (CMS)*** *has been used. Researches are going on for the safety purpose of miner's health with involvement of technology. A Protocol has been designed for continuous monitoring of the worker's health. We are here to design a low-cost ,wearable, efficient and a low power consumption device to monitor the workers and sends the information to the control room through wireless technology using* ***nRF24L01(transceiver IC).***

The worst mine accidents – On April 26, 1942, in the ***Benxihu (Honkeiko) Colliery*** *(coal mine), killing 1,549 miners. Last mine accident – January 6, 2019, the Kohistan mine collapse. ref: "The world's worst coal mining disasters" retrieved on 16 August 2015.*

1. INTRODUCTION

The nature of Mining Industries are more dynamic, which loses thousands of human lives and wealth. Frequent coal mine accidents are a big problem in underground mine and the environment conditions are worse and complex. The critical parameters are dust density, temperature, harmful gas density. It is significant to monitor the miner's health, activities, physical condition and the environment. In earlier days Cable Monitoring System (CMS) was used; it is not much efficient and consumes more power, which gets damaged due to the worse environment, therefore device to device communication technology is opted. Then, the wireless technology using Zigbee was earlier introduced, which again falls under the limitation of distance restriction. Later, we move on to the emerging wireless technology using nRF24L01 with more distance coverage, which works in a loop i.e., if one loop get failed it gets detatched from the primary loop and gets connected to the secondary loop. Thus the device to device communication cannot be affected. It works under Radio Frequency. In this paper, we discuss about our system design which monitors the miner's health and environment of the mining areas.

1.1 System Analysis

1.1.1 Existing System

In earlier days, Cable Monitoring System(CMS) has been used for monitoring miner's health. It is of high cost, consumes more time and power, cables were laid which gets damaged or disconnected due to bad environment condition. For example, if a cable is cut, the data is lost and is not updated and transferred to the control room. Many disasters have occurred due to improper monitoring of mining. Later on a wireless technology using Zigbee has been used which sticks to the drawback of distance limitation.

1.1.2 Proposed System

In this model, a wireless technology using nRF24L01 (transceiver IC) is designed for advanced health monitoring. This model identifies the individual's data rate. Here we use various sensors for monitoring different parameters and switches for emergency purpose. The nRF24L01 uses SPI interface protocol for wireless communication between devices such as master and slave. The Microcontroller will act as master and nRF24L01 as a slave. After receiving request from the master, the slave tends to send the data. Data transfer is fast, efficient, low cost and low power consumption. Thus it overcomes the drawback of distance restriction (1.5-1.8 km).

2. LITERATURE SURVEY

During the underground extraction, surface deformation causes progressive damage. The previous method which is based on Interferometric Synthetic Aperture Radar (InSAR) is incapable of preventing dynamic deformation. A novel model combines InSAR with Temporal Probability Integral Method (TPIM) which

predicts the dynamic deformation. This model was tested in Qianyingzi coal mining area of China; the accuracy ranges from 0.03 and 0.041 in horizontal and vertical directions.

Transient electromagnetic method (TEM) is an effective method in detecting underground water in abundant areas. Both the numerical and physical simulation shows that horizontal components as more sensitive, whereas vertical components acts as an interpreter. Hence horizontal components serves as a new approach for coal mine TEM data processing and interpretation.

A lightweight mashup middleware has been used for remote monitoring and automation control for underground physical sensor devices. First a cluster tree based Wireless Sensor Network (WSN) was deployed with the help of Zigbee. An Open Service Gateway initiative (OSGi) is used for accessing framework. The visualization technology and the graphical user interface of different physical sensors were created to combine sensors with other sources. As compared to the previous technology it is cost effective.

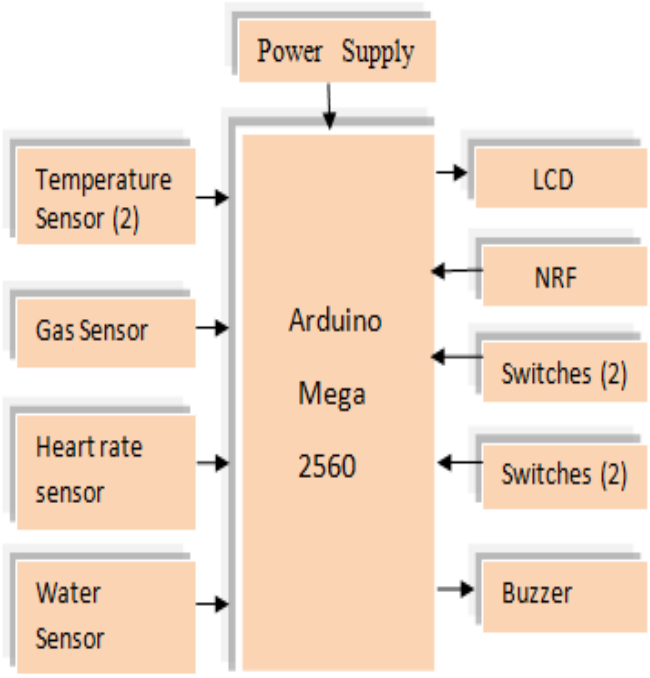
Coal dust deposits on the coal mine leads to coal dust explosion; to prevent these explosions inert rock dust (limestone dust) is applied to roofs and rid areas of coal mine. Incombustible mass ratio is defined as incombustible content of coal dust and rock dust divided by total mass of deposited dust is defined as the Total Incombustible Content (TIC) of the deposited dust in the mine. Safest percentage of TIC ratio is 80%. Optical sensor determines the coal dust by optical reflection, which is described by Beer Law. The performance and accuracy of sensors are compared to the currently established TIC measurement in underground coal mines.

3. MODULE EXPLANATION

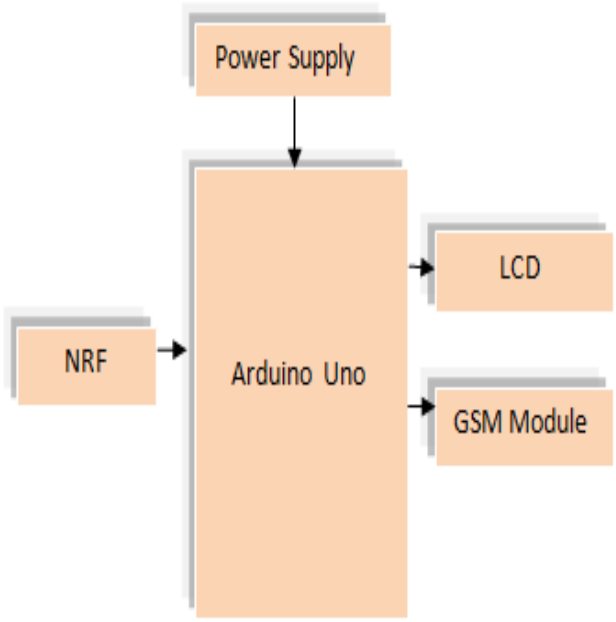
An advanced communication device has been proposed for coal mine workers. Some of the sensors and controllers is used for monitoring the worker's health. The nRF24L01 acts as an tranceiver IC for device to device communication using SPI protocol. Heart rate sensor monitors the worker's pulse rate, gas sensor for detecting the leakage of poisonous gases such as hydrogen sulfide, natural gases, especially firedamp or methane. Water sensor is used to detect the underground water in urban areas. Two temperature sensors are used of which one is monitoring the environment and the other for measuring human body temperature. Switches are used to intimate the emergency need and to update some predefined messages. nRF24L01 plays a role in sending the data to the control unit.

3.1 Block Diagram of Proposed System

a) Transmitter side



b) Receiver side



3.2 Hardware requirements

3.2.1 Arduino Mega

The Arduino Mega 2560 is a Microcontroller board, based on the AT mega2560. The Arduino software (IDE) is used to program the board Mega 2560. It has 256KB of flash memory for storing code (8KB of boot loader), 8KB of SRAM, 4KB of EEPROM. It supports TWI and SPI Communication.

3.2.2 Arduino Uno

The Adriano is a microcontroller board based on the ATmega328P. It has 32KB of flash memory(0.5KB occupied by bootloader), 2KB of SRAM, 1KB of EEPROM. The operating voltage ranges from 6 to 20V. Arduino software(IDE) is used to program the Uno board. Non usage of FTDI USB-to-serial driver chip differentiate it with other board.

3.2.3 Sensors

a) Gas sensor is of porous hydrophobic membrane. The gases diffuses into the sensor, get through the porous membrane where it gets oxidized or reduced. As a result of electrochemical reaction, electric current passes through the external circuit.

Specifications	
Power supply voltage	5v
Output voltage range	0-0.9v
Gain(%)	3%

b)Temperature SensorLM35 is an integrated circuit sensor is used to measure temperature, which has an electrical output proportional to the temperature (in ˚C). It measures accurately than Thermistor. General equation to convert output votage to temperature,

Temperature(˚C) = Vout*(100 ˚C/V)

The sensor circuitry is sealed to restrict the oxidation process. Since, it generates a high output voltage than thermocouple, thus amplification is not required. It maintains an accuracy of +/-0.4˚C at room temperature (measuring environment temperature) and +/-0.8˚C over a range of 0˚C to +100˚C (measuring body temperature). Due to sensor self-heating, there exists less than 0.1˚C temperature rise in still water.

Specification	
Scale factor	0.01v/˚C
Power supply voltage	4-30v
Current	60μA
Sensitivity	10mv/˚C

Applications: Used to avoid thermal shutdown. Employed in HVAC application.

c) Heart Rate Sensor is used to measure heart beat which is sensed by using a high intensity type LED and LDR. Finger is placed between LED and LDR. Red LED is used for illuminating the transmitted light and LDR is used as detector. Light is absorbed by the blood and the transmitted or reflected light is received by the light detector. The amount of light absorbed is equivalent to the blood volume in the human tissue.

BPM=60 * f (f-pulse frequency)

The detector's AC current is converted into voltage and is applied to an operational amplifier LM358 the output of the op-amp is given to another non-inverting input of the same LM358, where second amplification is done. The final value is present in the inverting input and the amplified value is compared with present value if any abnormal occurs an interrupt is send to the controller.

Range of heart rate	
Adults(18+)	60-100bpm
Children(6-15)	70-100bpm

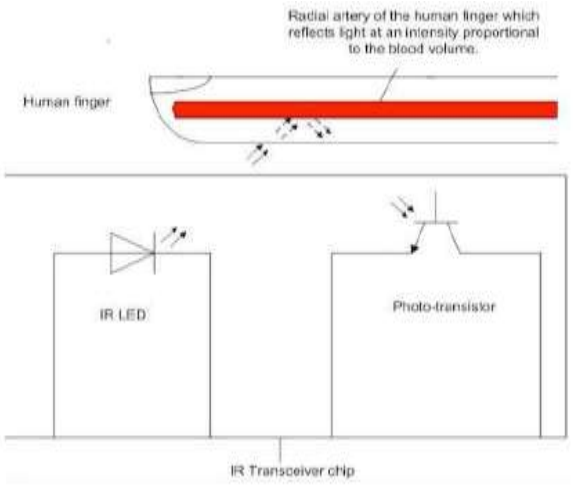


Fig - 1: Relection of IR light from radial artery

d) Water Sensor works under the principle of conduction. When water comes in contact with the circuit (water acts as an electrolyte), it completes the electrical circuit which indicates the water level with the buzzer sound. It detects leakage, rain and flood, spill etc., It acts as a water level controller and monitors the level of surface water. Previously, TEM data processing interpretation was used.

3.2.4 Buzzer (Beeper)

An audio signaling device which may be a mechanical, electromechanical or piezoelectric. As we supply an AC voltage of few kilohertz to a piezo-electric crystal, it deforms back and overshoots with the speed of AC signal to produce an audible sound, which generates a voltage that is fed back to the oscillator and keeps working at resonant frequency. Probably six of these are in your phone. **Applications:** Used in game show lock-out device, Electrical alarms, microwave ovens and other household appliances.

3.2.5 LCD

It is an electronic display module. The very basic module is 16×2. Easily programmable, economical, no limitations of displaying special and custom characters. A 16×2 LCD displays have 16 characters per line and there are two such lines. The command instructions of LCD is stored in the command register. The command instructions are used to perform the predefined task like, initialization, screen clearing, setting the cursor position, controlling display etc. The data contains the ASCII value of the character. The data to be displayed in the screen is stored in the data register. Commonly used Character based LCDs are based on Hitachi's HD44780 controller which are compatible with HD44580.

The commonly used LCD found in the market is 1 or 2 or 4 line LCD, which has only one controller and supports upto 80 characters which makes use of 2 Hd44780 controllers. Most of the LCDs with 1 controller has 14 pins, with 2 controllers have 16 pins(2 pins are extra in both back-light LED connections).

Advantage: Low power consumption for display in the range of "Micro watts", cheap in price.

Application: Used in Computer Monitors (screen), instrumental panels, televisions, Aircraft cockpit displays.

Switches are used for sending data or information regarding the abnormal condition and emergency situation to the control units via nRF24L01.

3.2.6 NRF

NRF – Nordic **R**adio **F**requency Semi Conductor

The nRF24L01 is a 2Mbps transceiver IC. It operates in 2.4GHz ISM (Industrial, Scientific and Medical) band. It is Ultra Low Power (ULP), consumes current less than 14mA, power supply ranges from 1.9 to 3.6V. It is available in a compact 20-pin 4×4mm QFN package. It provides a true ULP solution, which works for months to year by running a coin cell or AA/AAA batteries.

The nRF24L01 takes the good features of 2401 and adds a true SPI interface, multiple pipelines, hardware link layer and so on. It uses SPI (Serial Peripheral Interface) protocol. It is used for device to device communication between a master and a slave. Microcontroller acts as the master and the sensor, display and other module acts as slave. The slave will send the data after getting request from the master. The nRF24L01 consist of the following pins,

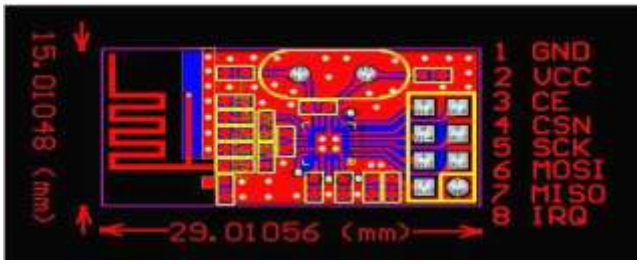


Fig - 2: NRF Module

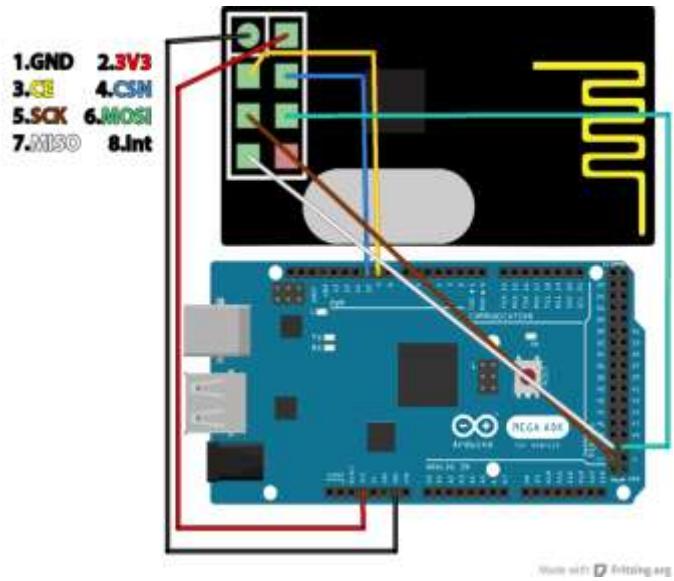


Fig - 3: nRF24L01 connection with Arduino

Pin Description	
CE(Chip Enable)	Acts as input, controls the data during transmission and reception
CSN(Chip Select Not)	It is used to be high. Becomes low while performing SPI operation (like sending SPI command or using SPI bus)
MOSI	Master Out Slave In
MISO	Master In Slave Out
IRQ	Interrupt, it is active low
SCK(Serial Clock)	becomes active(high) for logic 1

The RF modem works at 3.3v and the Arduino works at 5v, hence a 5v-3.3v level convertor is used.

3.2.7 GSM module

GSM/GPRS Modem-RS232 is of Dual-Band GSM/GPRS engine-SIM900A with frequencies 900/1800MHz. This modem is interfaced with RS232, which connects PC and the microcontroller with RS232 Chip (MAX232).

Fig - 4: GSM/GPRS Module

Through AT command the baud rate is configurable from 9600-115200. This modem contains TCP/IP stack protocol for enabling connections with internet via GPRS.

It sends the SMS, voice, data transfer as well as we can make audio calls via M2M interface. Wide range unregulated power supply gets connected with the help of onboard Regulated Power supply. The AT commands are used for reading the SMS, attending the incoming calls and internet.

Features: GSM/GPRS Modem-RS232 is a Dual-Band with operating frequency 900/1800MHz for interfacing computer or microcontroller kit directly, baud rate is Configurable, 29302WU IC acts as Power controller, ESD Compliance, Enables with MIC and Speaker socket, Slid in SIM card tray, Stub antenna and SMA connector, Vcc – 12V(DC), high quality PCB FR4 Grade with FTP certified.

Application: Industrial, home, agriculture automation. Data logging, vehicle tracking, health monitoring, remote monitoring and controlling, weather report logging, security alert and remote terminal for file transfer, IVRS, Bulk SMS sending.

3.3 SOFTWARE REQUIREMENT

3.3.1 Arduino IDE:

The Arduino software IDE(Integrated development environment) is a cross-platform application for Linux, macOS and Windows, which is written in java and provides a software library. Select the board from the tool bar in the menu. The ATmega328 on the Arduino/Genuino Uno is preprogrammed with a bootloader which allows you to upload new code to it without the use of any external hardware programmer. Communication commences with the existing original STK500 protocol. Bypassing is achieved with Bootloader and it program the microcontroller using Arduino ISP ,through the ICSP (In-Circuit Serial Programming) header. Arduino repository contains the ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code, which is loaded with a DFU bootloader. For loading a new firmware, Atmel's FLIP software (windows) or the DFU pprogrammer (MAC OS X and Linux) is opted. To overwrite the DFU bootloader, ISP header with an external programmer is used.

Fig - 5: The button bar

Usage of buttons in Arduino software

Code is verified with the usage of check mark, the arrow icon uploads the code to the Arduino board, new file can be created with dotted paper, existing project gets opened with upward arrow, downward arrow for saving the current file, debugging is done with serial monitor(far-right corner) for sending data from Arduino to PC.

3.3.2 Embedded C

Embedded C is a set of language extensions of the C language for different embedded system. Non-standard extensions to the C language supports exotic features such as arithmetic, floating, named address spaces, multiple distinct memory banks and basic I/O operations (hardware addressing). Most of the syntax and semantics of standard C are used by embedded C such as main() function, datatype declaration, variable definition, conditional statements(if, switch case), functions, arrays and strings, loops(while, for), structures and union, macros, bit operations, etc.,

Advantage: Small, simpler to learn, fairly efficient understandable programming and debugging. C code is more reliable, scalable and portable between different platforms as compared to assembly language. In many embedded system the JAVA program requires Java Virtual Machine (JVM), which consumes a lot of resources. Hence, Java is not used for smaller embedded devices. Embedded applications needs to read or write data on a given address; C is easy to access and modify addresses using pointers, which are language features.

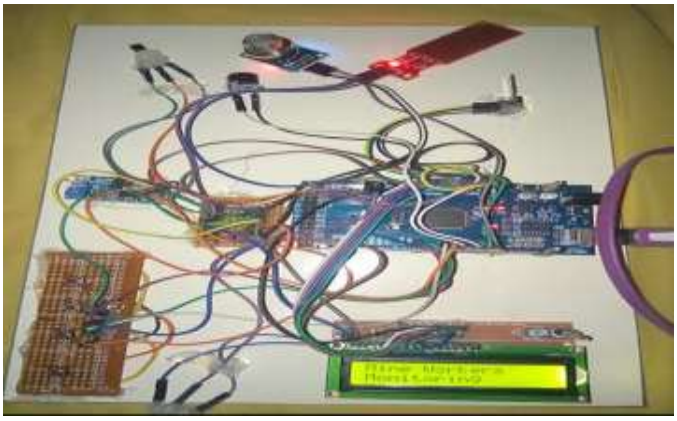


Fig - 6: (Transmitter kit)

Fig - 7 : Output of Heart Rate Sensor

Fig - 8: Output of Temperature, gas and water sensor

Fig - 9: Display of LCD for switches

Fig - 10: (Receiver kit)

Fig - 11: Display of abnormal condition

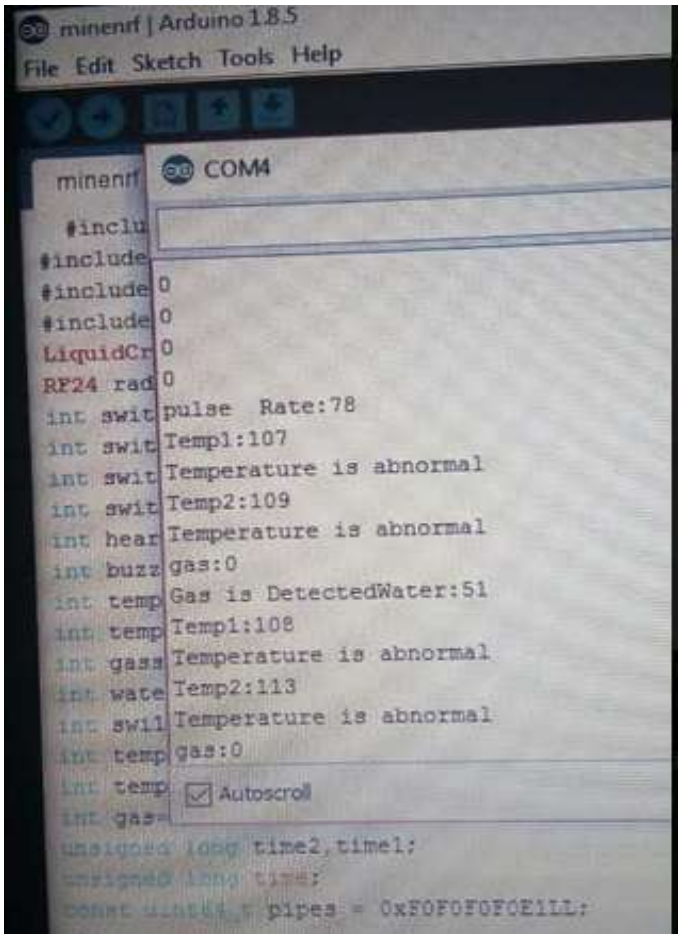


Fig - 12: Stimulation Output

Fig - 13: SMS send to the mobile via GSM

4. Conclusion

The interactive communication between different types of system becomes a tedious process; power supply and the wired equipment interconnection are more susceptible and it becomes prone to many accidents. Poor flexibility and expense are the main drawbacks of using traditional system. The main characteristics of wireless sensor networks includes self organization, wireless communication, distributed autonomous and simple maintenance. WSN have better perceptive function than wired network. In advance, it is helpful to predict the majority of accidents that are vulnerable and thus helps the miner's to somehow manage their existence.

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