

Spectrum Management using Cognitive Radio for Safety and Security of Coal Mine Workers

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Abstract

Objectives: Underground mine communication is the most vital factor today to monitor different parameters continuously and to take necessary actions accordingly to mitigate all hazards that happen inside mines. Accidents in coal mines occur due to inadequacy of information from the mine environment due to inefficiency of existing phone systems. **Methods/Statistical Analysis:** In this paper, cognitive radio technology is used in underground coal mines to wirelessly transmit crucial parameters such as temperature, humidity and methane gas levels to enhance the safety and security of coal mine workers. To depict cognitive radio, two communication channels, Bluetooth and RF have been used. These wireless channels are used to transmit data from the hardware circuit fitted on the miner's gear to the ground control center. **Findings:** To test the working of proposed technique it is subjected to several test cases. Experiments have proved feasibility and good stability of the system. Using the proposed technology the network sensor scalability has been improved. **Application/Improvements:** The deployment of a module of cognitive radio sensors is made on the miner's gear to monitor the aforementioned parameters. Various traffic issues like routing algorithm, handoff problems are identified as the extension of the proposed cognitive radio networks.

Keywords: Cognitive Radio (CR), Coal Mine, Monitoring System, Personal Protective Equipment (PPE), Tracking and Positioning, Wireless Sensor Networks (WSNs)

1. Introduction

Ensuring the safety of coal mine workers is one of the major issues in mines across the globe. In accordance to a report by the Directorate General of Mines Safety (DGMS) more than 23,000 mine workers have died in coal mines since 1901¹.

Work safety for mine workers is highly regulated worldwide and the mining industry follows basic precautionary measures to avoid any untoward phenomena that may result in the injury or loss of human lives. Communication is the most vital factor today, to monitor different parameters continuously and to take necessary actions accordingly to mitigate all hazards. The paper proposes the use of a reliable communication system such as cognitive radio technology in the interior of the under-

ground mines² Cognitive radio establishes a reliable, uninterrupted and full connectivity medium between workers, who are moving inside the mines, and a stationary base station.

A Multi-parameter Monitoring System for Coal Mine based on Wireless Sensor Network Technology is discussed by³. Authors presented a wireless sensor network monitoring system based on ZIGBEE technology for coal mine tunnels^{4,5}.

Hardwired communication systems like trolley wire or carrier phones are not robust. The connecting wires are easily broken by a phenomenon such as landslides. The cost to deploy and maintain a wired communication networks is very high in such landslide prone mine regions. Further, it is expensive to reinstall a wired communication system post any unwanted phenomena that results

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in damage of the cables. Leaky Feeder Systems are also used in coal mines. The Figure 1 illustrates an example of a leaky feeder system⁶.

In the eventuality of a phenomenon such as a roof slide, the continuity of the communication system may be disrupted. In present days Though-the-earth (TTE) communication technology is used in such disastrous scenarios⁷. TTE communication technology transmits an electromagnetic signal between a transmitter and a receiver with a worker inside the mine and another on the surface without relying on a network or any other additional infrastructure.

At the heart of the block diagram lies the AVR development board using an Atmega 328 A microcontroller. Three sensors, namely, LM35 (temperature sensor), SYHS 220 (humidity sensor) and MQ4 (methane sensor) are interfaced with it. A LCD display depicts the sensor values. To depict cognitive radio, two wireless channels are used – RF operating at a frequency of 434 MHz and Bluetooth HC05 operating at a frequency of 2.4 GHz as shown in the Figure 2.

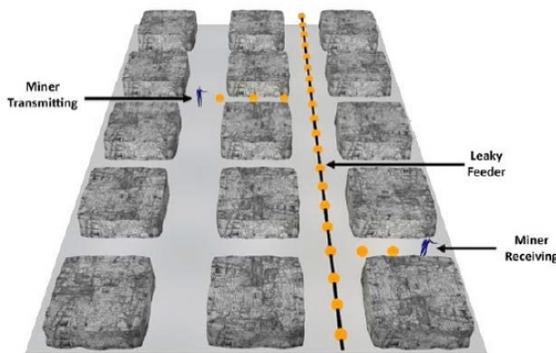


Figure 1. Leaky feeder system.

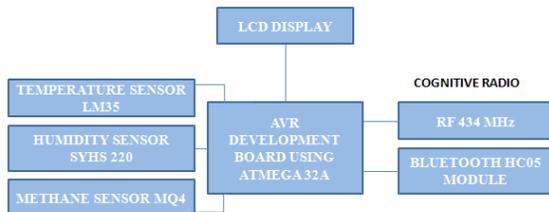


Figure 2. Proposed Block Diagram.

2. Interfacing Sensors and LCD Display

The proposed cognitive radio system consists of three sensor modules, a display module, a Bluetooth module,

a RF module and a control module. In the sensor module we have three types of sensors, temperature sensor, humidity sensor and gas sensor. These sensors collect information from the region and pass them to the control module. Control module decides which wireless communication module to be used, Bluetooth or the RF module.

In this section we are introducing different sensors and LCD display that are used in this cognitive radio system.

2.1 Temperature Sensor LM35

The output voltage of the LM 35 temperature sensor is linearly proportional to the temperature which is measure in degree Celsius (centigrade). From Figure 3, we can see that this sensor consist of three pins, the first pin is for the power supply, that is the VCC , the second pin is for the output of the sensor and the third is for the Ground supply. The output pin of LM35 is connected to the analog pin PA0 of the AVR board.

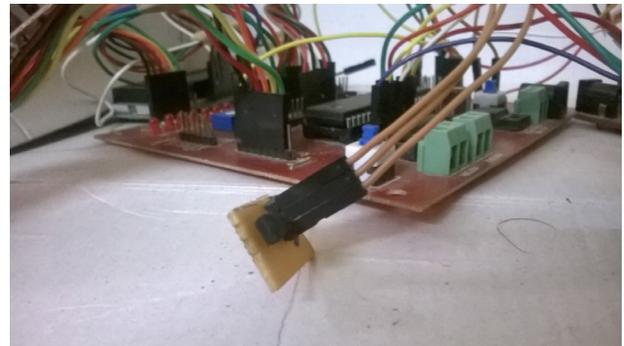


Figure 3. Interfacing LM35 with AVR.

2.2 Humidity Sensor SYHS 220

The humidity sensor responds to the change in humidity and sends the corresponding analog values. It consists of three pins, VCC, Ground and the Output pin. The output of the humidity sensor is given to the Analog pin PA1 of the microcontroller and the corresponding output analog values are noted. Interfacing of SYHS 220 with AVR development board is shown in Figure 4.

2.3 Gas Sensor MQ4

Figure 5 shows the interfacing of MQ-4 with the AVR development board. The MQ-4 gas sensor is an analog sensor. Three pins are given to the Supply 5V; one is for heating the heater element. The sensor detects the presence of methane, butane, propane and LPG gas and the

amount of gas is measured in terms of ppm(parts per million). The Ground supply is given to the other pin and output is taken from the output pin. The output of the gas sensor is connected to the Analog pin PA2 of the micro-controller.

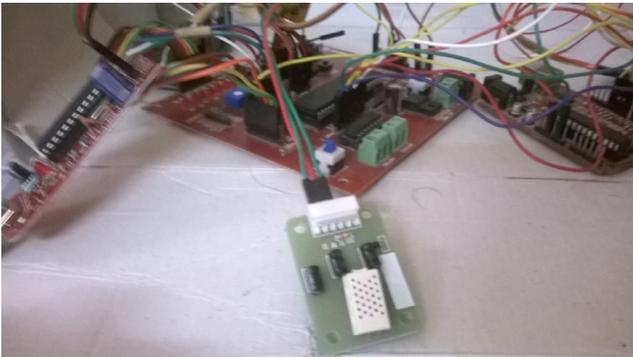


Figure 4. Interfacing SYHS 220 with AV.



Figure 5. Interfacing MQ4 with AVR.

2.4 LCD Display JHD 162A

The LCD display JHD 162A shown in the Figure 6 exhibits the value of the sensors.



Figure 6. Interfacing LCD Display with AVR.

3. Cognitive Radio Systems

To depict cognitive radio, two communication channels are established – RF 434 MHz and Bluetooth 2.4 GHz^{8,9}.

Table 1 shows the temperature sensor calibration as 5 levels, with level 1 being lowest and level 5 highest. For humidity and gas sensors, the values have been calibrated with 4 levels as shown in the Table 2 and 3: level 1, level 2, level 3 and level 4 respectively with level 1 being the least severe and level 4 being the most severe. The levels can be recalibrated in accordance with the mine conditions and industry regulations. For now, the following calibrations have been done:

Table 1. Temperature Sensor Calibrations

Temperature range	Level
Less than 20 Degrees Celsius	Level 2
20 Degrees Celsius to 30 Degrees Celsius	Level 3
30 Degrees Celsius to 40 Degrees Celsius	Level 4
Greater than 40 Degrees Celsius	Level 5

Table 2. Humidity Sensor Calibrations

Humidityrange	Level
Lessthan70%	Level1
70%to80%	Level2
80%to90%	Level3
Greaterthan90%	Level 4

Table 3. Methane Sensor Calibrations

Methane range (in ppmv)	Level
< 1500	Level 1
1500 - 2000	Level 2
2000 - 2500	Level 3
> 2500	Level 4

3.1 Bluetooth HC05

The Bluetooth terminal used is Bluetooth SPP Pro which is an Android app. Figure 7, shows the interfacing of Bluetooth module HC05 with the AVR development board and Figure 8, and shows that data is successfully received by Bluetooth SPP via HC05.

3.2 RF434 MHz

The RF spectrum is the backup transmission channel in case the Bluetooth channel fails to transmit. When K0

switch of the AVR board is pressed, the Bluetooth channel gets disconnected and the output on the Bluetooth terminal is shown as 'BT Disconnected' and the RF channel starts transmitting. The RF output is visible on the four LEDs present on the receiver module indicating the level of severity in accordance with the previously defined levels. Figure 9 and 10, shows the RF 434 transmitter and receiver respectively.



Figure 7. Interfacing Bluetooth HC05.

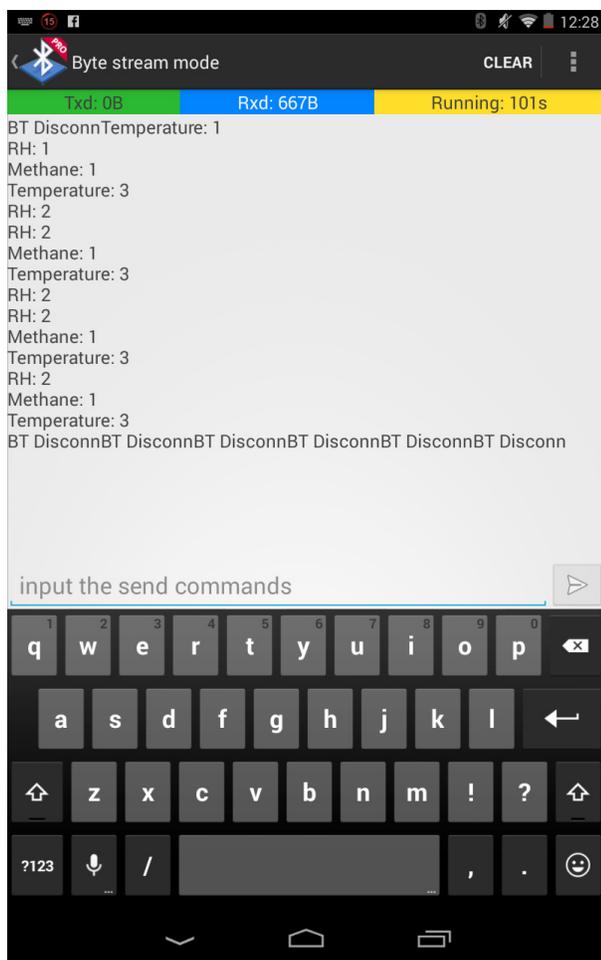


Figure 8. Data Reception via HC05.

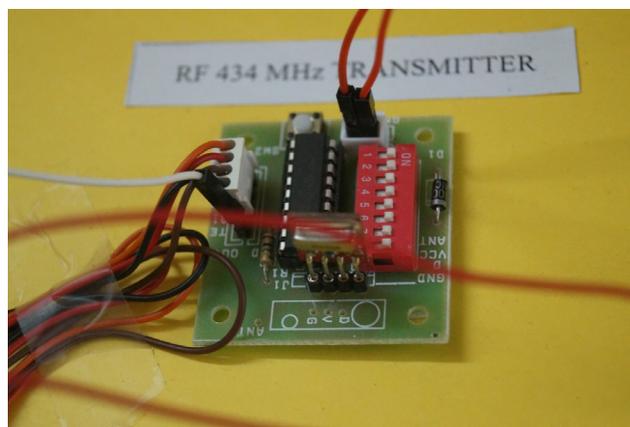


Figure 9. RF 434 MHz Transmitter.

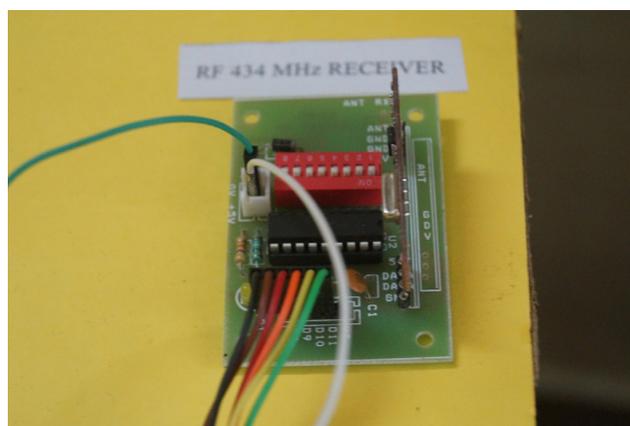


Figure 10. RF 434 MHz Receiver.

4. Results

We test the cognitive radio system after mending all parts of hardware and software. The Figures 11-13 shows the experiment output levels that is obtained for the temperature, relative humidity and methane respectively. Experiments result also shows that signals can be well transmitted to suitable distance with good communication quality.

5. Conclusion

The output was observed in various environments as the mine environment is difficult to replicate. The temperature sensor was tested using a matchstick, where the temperature increased when the ignited matchstick was brought near it whereas the humidity sensor was tested using a moist cloth, where the relative humidity increased when brought near the sensor.

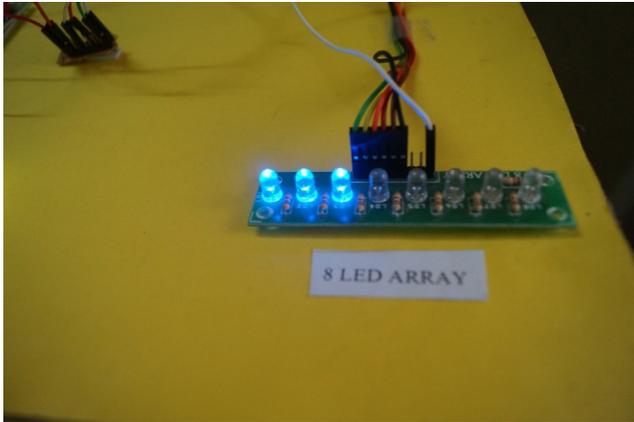


Figure 11. RF Output: Temperature Level 3.

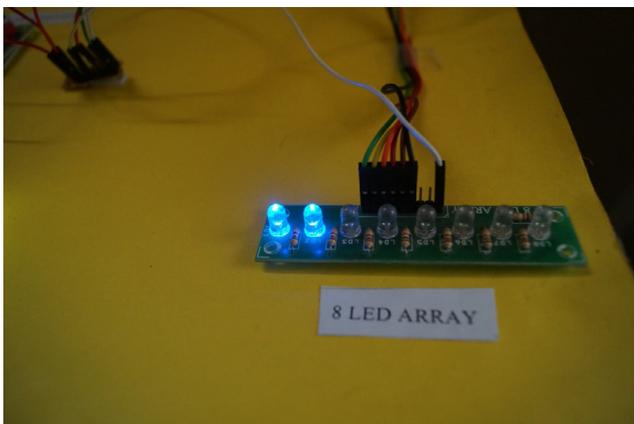


Figure 12. RF Output: Relative Humidity Level 2.

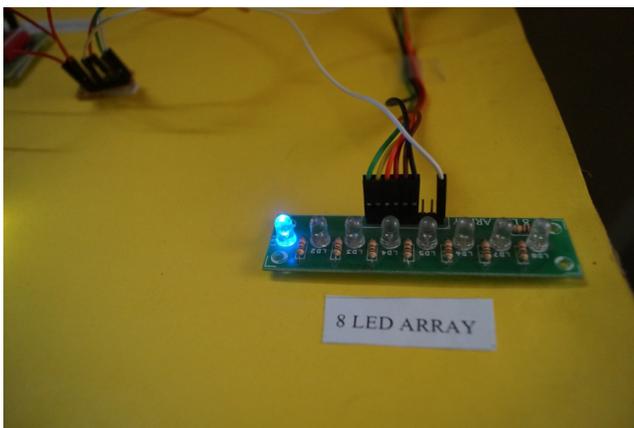


Figure 13. RF Output: Methane Level 1.

The future work of the project can include designing a multilayered PCB to make the setup compact so that it can be fixed on the miner's helmet. Moreover, a voice codec can also be added.

6. References

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