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Iot Based Smart Helmet for Mining

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ABSTRACT

IoT has been recently expanded across the different application which brought a huge attention to its construction. In the mining field, where a noisy industrial environment can take place in. The main objective of this research is to design and develop a smart helmet system for mining industry application. Where the provided system will keep on monitoring the hazardous events such as temperature, humidity, gas, removal helmet of the miner and obstacle damage to the helmet. The finalized design was built and enhanced with real environmental testing took place in GuaTempurung cave located at Gopeng, Malaysia. The power of the designed helmet system circuit was evaluated with respect to a previous work. The programming and troubleshooting were conducted on mainly two sections, helmet section and control room section. Based on the on the preliminary calculation the outcome results were obtained.

KEYWORDS: Smart helmet; industrial application; detection system; wireless communication.

INTRODUCTION

Mining Industry can be categories as the most essential application for any developed country. It provides extraction and discovery of the underground materials. From Iron, gold, coal and diamond. Internet of Things is an information and Communication Technology (ICT) used to represent Wireless Sensor Network (WSN) communications, using the defined protocol IEEE

802.14.5 that enables Low Rate- Wide Area Network (LR-WAN) to communicate using specific modulation technique. The basic examples are, ZigBbee, LORA and Sigfox network and more. Each of them has its own benefits and disadvantages, depending on the project application and requirements the protocols are shortlisted. LR-WAN is the defined protocol to be used for technique which provides long transmission range over low bit rate power while the operating frequency is fixed. Which in return benefits the material fabrication cost. IOT can be used in most of the developed application such as, smart parking system, smart building managementand smart energy monitoring system. The architecture of IOT consists of three techniques materials web-based model (things), protocol (Wireless) and monitoring devices (Sensors) (GYU, 2014)(NAGARAJA, 2017)(Raed et al, 2018).

Pranjal Hazarika (2016) proposed the implementation of safety helmet system for coal mining industry, to outdo the hazardous gas using methane and carbon monoxide gas sensor. After that, the sensors are deployed to sense and identify the level of sensed gas. In addition, whenever the sensed gas exceeds the specified amount an alarm trigger will occur alerting the miners and preventing an upcoming incident. (NAGARAJA, 2017), proposed a smart helmet model for mining industry to identify that occurs with dangerous events. The proposed system is able to measure quality of air, removal of minor helmet, and object crash on the helmet. Quality of air is used to measure humidity and gas using sensors. Gas is determined by the demarcation level of carbon monoxide as well as humidity sensor to detect the humidity in the environment.

An IR sensor used to detect the removal helmet from the minor's head. And Pressure sensor is placed in the helmet by fixing the neck injury criteria to 34 PSI it is considered as hazard events when it overcome the value. Rashmi Vashisth&Sanchit Gupta (2017), proposed smart helmet to reduce the incrimination of motorbike accidents. Where the system consists of two sections helmet and bike. Each of them works in synchronization using Radio Frequency module to send Wireless communication between each other. GSM module is established for SMS message. Praveen Kulkarni & Sangam (2017) proposed a new method of monitoring the environment surrounded by a smart helmet, which can achieve variety of safety factors (temperature, gas, collision) gases that is poisoned to be around the minor. The researchers developed the system with ARM processor and communicated with ZigBee protocol to retrieve and send the data. Lathapriya&Dhanalakshmi (2017)proposed a new smart and safety system that is capable of providing the environment information such as, Temperature, pressure and alert the control roomwhen a collision happens or helmet is being removed by the minor. Panic switch button is applied to provide supportive methods for the minor in case of emergency situations.

The underground mine is not fully discovered yet. Hence, their critical work in the underground may results in dangerous events that can increase the concentration of the harmful gases. Hazardous gases and surrounding climate may change significantly without being noticed by them are the first problem that may causes death to them. Moreover, the complex structure of the mine can trigger obstacle to fall down on the miner's head that may results in serious injuries was considered the second problem to the miners. Therefore, the objectives of the proposed system are to design SHS for mining industry application with the usage of IoT automated system to detect and control the significant results from the LPG, Smoke and CO gases and alert the control room center with the help of a Graphical User Interface. To design a monitoring system that monitors the climate changes and update the management with real time data. To Integrate both systems and evaluate the power consumption of the designed helmet system.

Propose System Methodology Block Diagram

The system is developed in two main sections. Where the first section is helmet section used for Sensor networks connected with RF transceiver modules, Temperature and humidity,IR, Pressure and gas sensor to sense the environmental events and LED indicator to display the danger status of the minor. The second section is the control room section which consists of RF module, IOT and GUI system. The wireless communication used is ZigBee due to its robustness in closed area. Clearly, WiFi or Bluetooth protocols will not be a sufficient solution for underground systems. The overall block diagram as shown in Fig 1. consists of 4 sensors (Temperature and humidity, IR, Pressure and Gas sensors) that will be collecting data from the surrounding environment of the helmet and will transfer each data to Arduino Mega which is considered connected with 1 channel Relay circuit that is used as a switch to turn on or off the power supplied to Solenoid Valve. However, Solenoid Valve operates on a given small pressure of input gas approximately 3 PSI. Arduino is communicating with XBee Transmitter in UART ports where Tx is continuously sending the information to the Rx through Digi mesh topology. LED and LCD are used to specify the status of the miner condition weather he is safe, in danger or needs rescue team. On the output side a GSM module is used to send the message and was configured in Node Red with JavaScript code. GUI was created by Node Red and the GPIO ofthe Raspberry Pi are used to trigger the buzzer based on the force sensing resistor data received. The data received by XBee Rx are sent through the serial communication with Raspberry Pi.GUI was created by Node Red and the GPIO of the Raspberry Pi are used to trigger the buzzer based on the force sensing resistor data received.

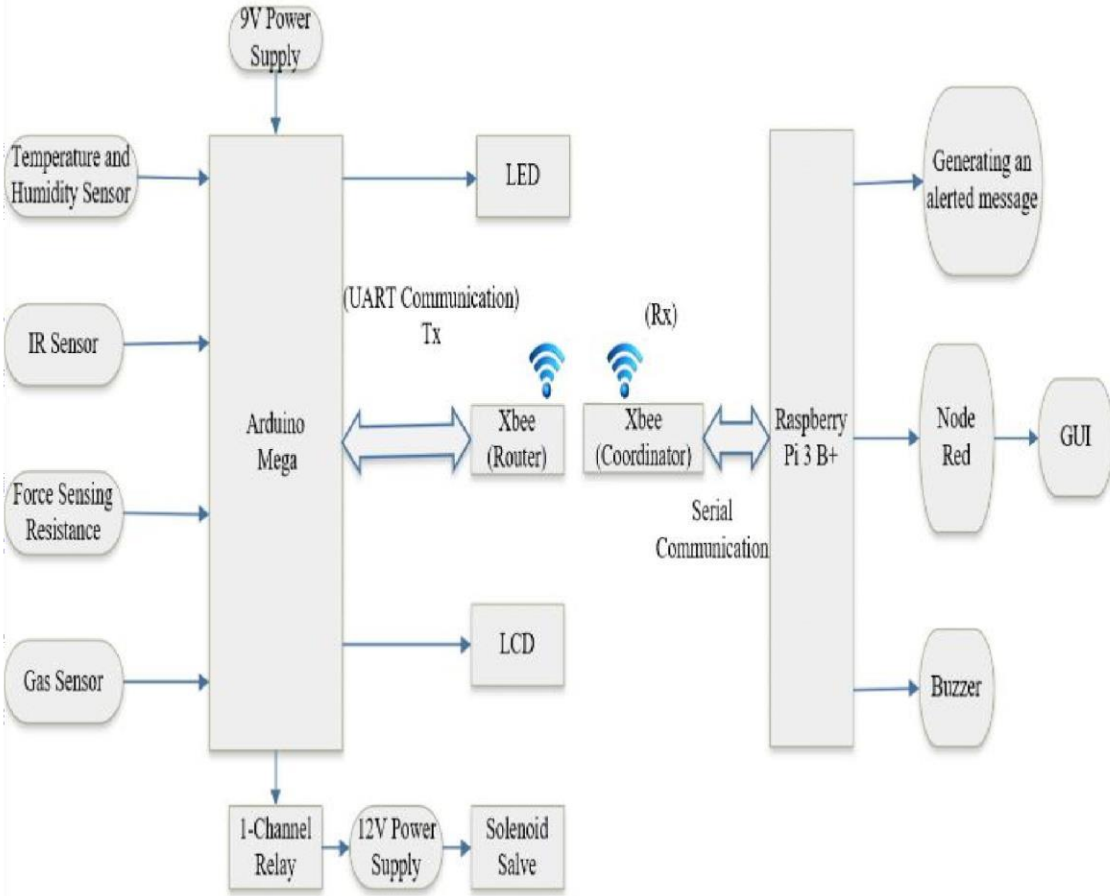

Figure1. Block Diagram of the proposed system

Working Principle

The working principle of the smart helmet was used to outline the flaw of the entire system without a detailed flaw. As this research mainly contains Gas Control, Force Detection and Temperature and Humidity Monitoring System, LCD [9], LED and 9v power supply battery. These systems are integrated with the aid of the IoT platform (Node-Red) whereas the integrated systems are used to send their data every 6 seconds. the main flow chart is as shown in Figure 2.

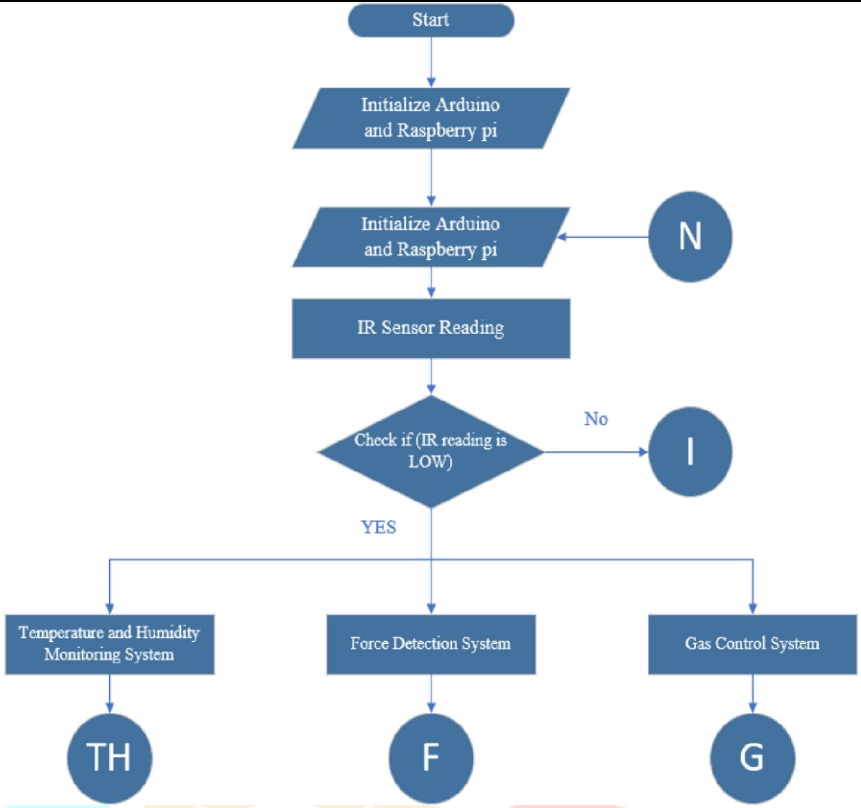

Figure 2. Main Flow Chart

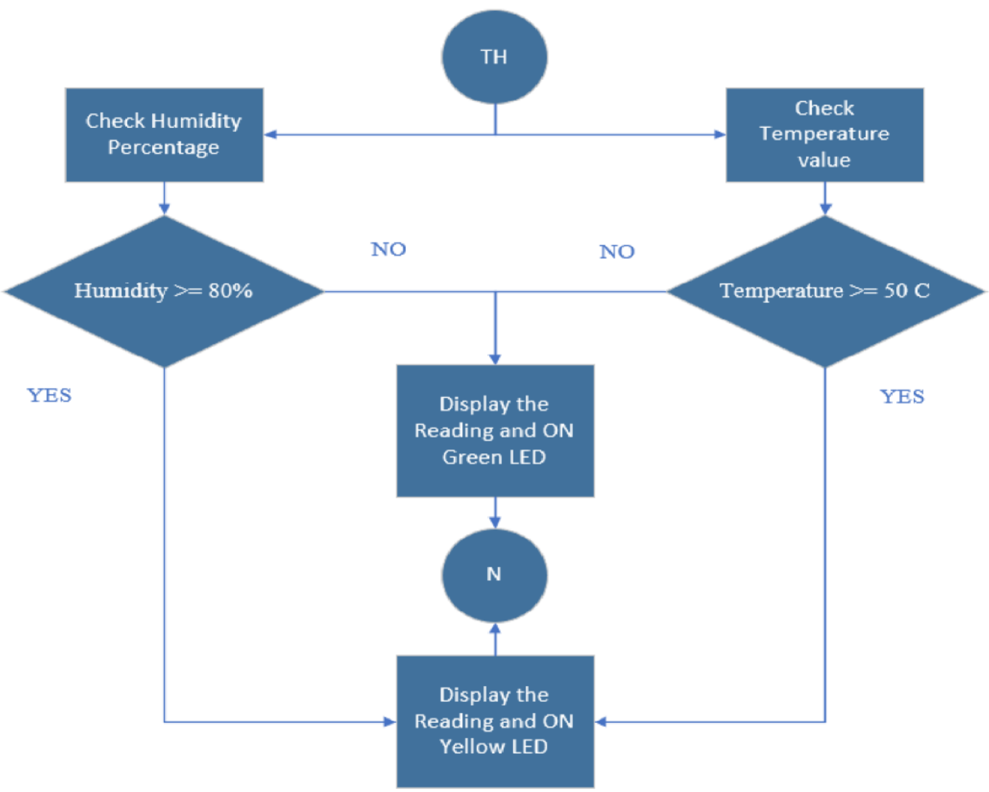

Figure 3. Temperature and Humidity Flow Chart

Figure 2. displays the initializing point of the microcontroller, microprocessor and IoT platform. A decision is made based on the detection of the IR data if it is low then the sensor detects the miner's head and will proceed to the three different systems (TH which stands for Temperature and Humidity, F which is Force and G which is gas) otherwise the signal will be directed to I (which stands for IR) connection. N is stated and used to represent Node-Red platform as Each of the connection nodes specified above will be directed to a sub flaws as shown in Figure 3.

The signal is sent to be further checked by Node-Red and/or Arduino if it is humidity andgreater than or equal to 80%. In addition, if the temperature exceeds 50 C yellow LED on the helmet will be triggered and the LCD will be updated with the reading and sent to Node-red as shown in Figure.4.

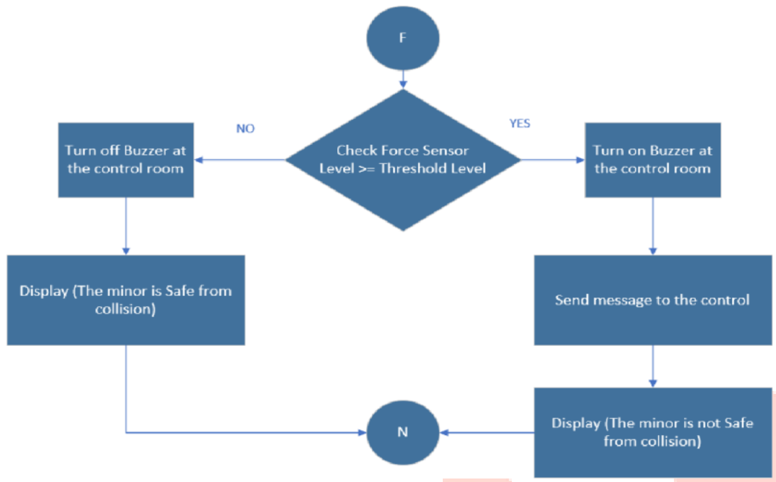

Figure 4. Force Detection System Flow Chart

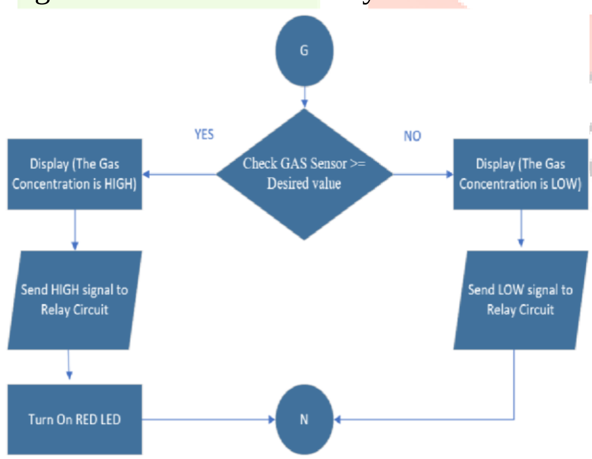

Figure 5. Gas Control System Flow Chart

The signal will be checked if the force is higher than the threshold. The signal will trigger the buzzer in the control Room using Node-Red, Send SMS message to the rescue team otherwise the buzzer will be off and the Serial display will be used to display the miner is safe from collision.

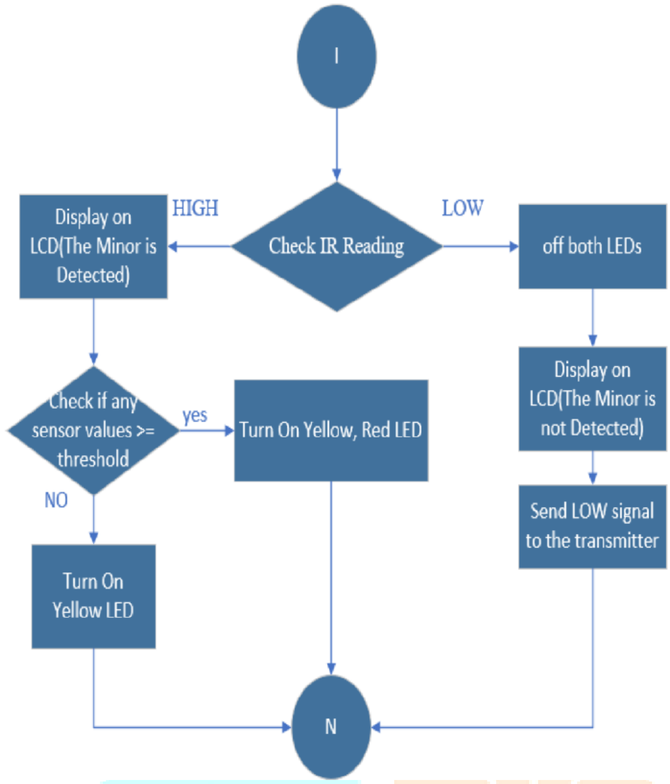

Figure 6. IR Flawchart

All flow charts of each node are connected and are sending the data to N node which stands for Node Red IoT platform to be updated in the GUI by ZigBee wireless. TH is used to monitor the temperature and humidity of the surrounding environment of the miner, F is used to detect the force over the force sensing resistor and trigger the buzzer and prepare SMS message to the rescue team.

Final Design

In this section the finalized design of the IoT Based Smart Helmet for Mining Industry Application is demonstrated and implemented. The implemented design will be shown. The finalized block diagram and flow chart of the overall system will be stated. As the next figure shows the Helmet with the circuit representing the prototype along with the transmitter circuit only (Helmet Section).

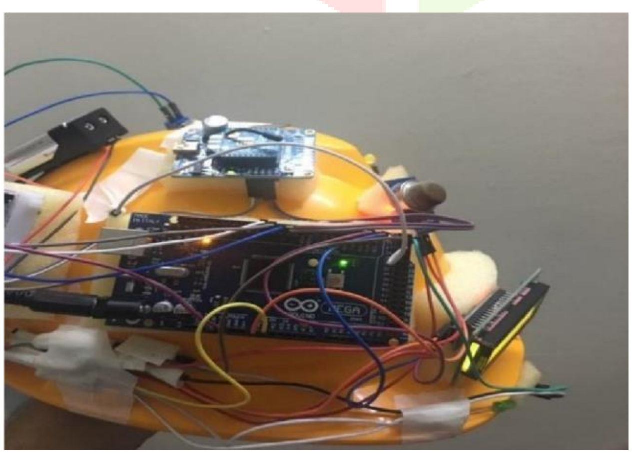

Figure 7. Final design of the transmitter node

Fig 7 shows that the helmet contains of I2C LCD, MQ 2, XBee Transmitter, 9V battery and Arduino connected with 3 LED, green, yellow and red. Relay which is connected on theback of the helmet as well as DHT11 were used to implement the hardware circuit. Where the gas was used to monitor the 3 gases level continuously and output the data collected in order to control the valve connected to a relay which is used to be switch controlled with Arduino. However, the solenoid valve was used to require minimum pressure of 3 PSI. Hence, thesolenoid was not operated by the microcontroller with 12 V power supply provided. Therefore, a simulation of the Oxygen tank level was simulated on Node-Red that can be used to represent thelevel of the tank in the software results. Each data of the system is expected to be sent over Software Serial protocol.

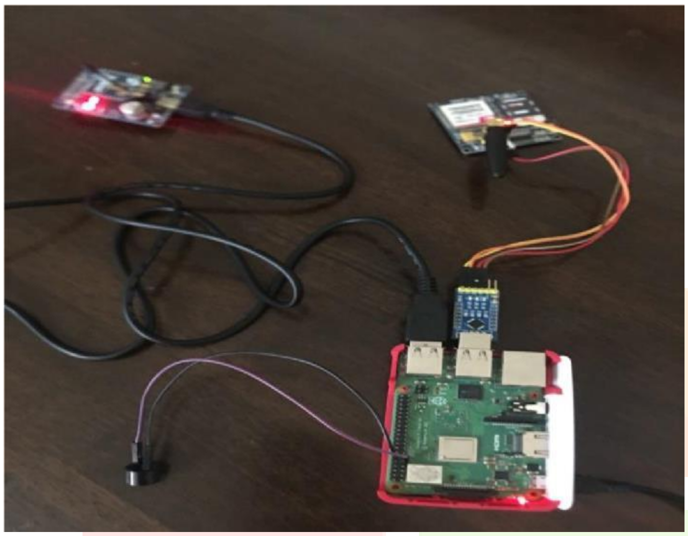
Figure 8. Final design of the receiver node

XBEE uses 2.4 GHZ as an operating frequency to be able to share information with the microcontroller in which is used to use 2 digital pins of the microcontroller to act as transmitter and receiver. Therefore, the data sent over these pins will be shared over the XBee UART pins. And from the UART pins the XBee are configured to send it to the same PAN ID network over ZigBee wireless protocol. Fig 8 displays the receiver design that indicates the receiver XBee, GSM, buzzer and raspberry pi. GUI was created after implementing the hardware component asit is essentially used to perform the testing stage. In Fig 8, the GUI was constructed with NodeRed Environment. Which is useful to eliminate the intensive web programming as it is a drag and drop based on JavaScript platform.

Figure 9. GUI of Smart Helmet monitoring and controling system

The helmet is sending all the information from the sensors used into the XBee receiver where it is connected with Wi-Fi module in this case (Raspberry Pi). Furthermore, it sends the data to the IoT platform which is sitting on the IP address of the Pi. These values are directed using Programming language and node functions to be updated in the GUI.. GUI shows the data of Temperature, humidity, amount of force on the miner's helmet and gas monitoring system. Every sensed information has a triggering threshold in which the output of SMS alerting message, Gas Valve and UI controlling is triggered based on the flaw chart. Hence, the control room team have a major control and eyes on the miners during their operation field.

Testing and Findings

This testing was developed to obtain the sensor reaction (detection of the 3 different gases) in a caving environment. The testing of the developed experiment was conducted in GuaTempurung which was located GopengPerak state in Malaysia. So that, the aim of this experiment was to detect the 3 gases reading with respect to aa caving environment and the response of the gas detection system.

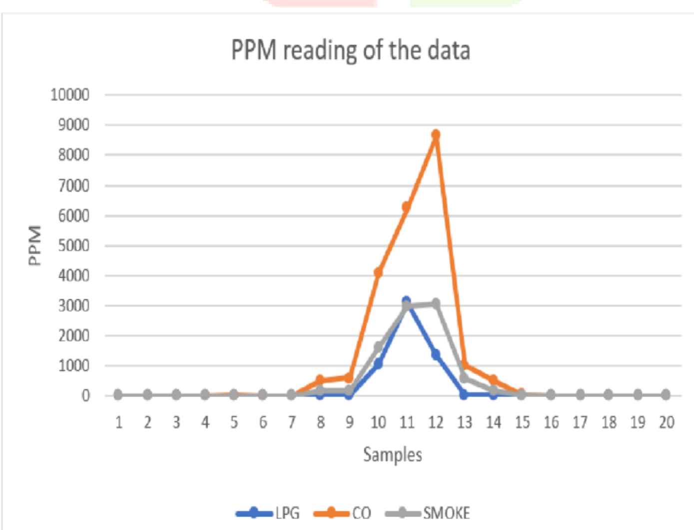

Figure 10 Gas Flawchart

As the graph in Fig 10 is displayed the high peak of the response was located at samples 9-13 which were the same samples indicated for high output voltage in FIG VI. Hence, the peak response of the developed detection system is high to differentiate and to identify the changes. However, due to the 0 PPM readings in the samples which indicated output voltage reading lesser than 0.7 V the sensor is considered as inaccurate and had to be calibrated first in the room temperature environment. As the temperature and humidity will cause major changes in the output voltage.

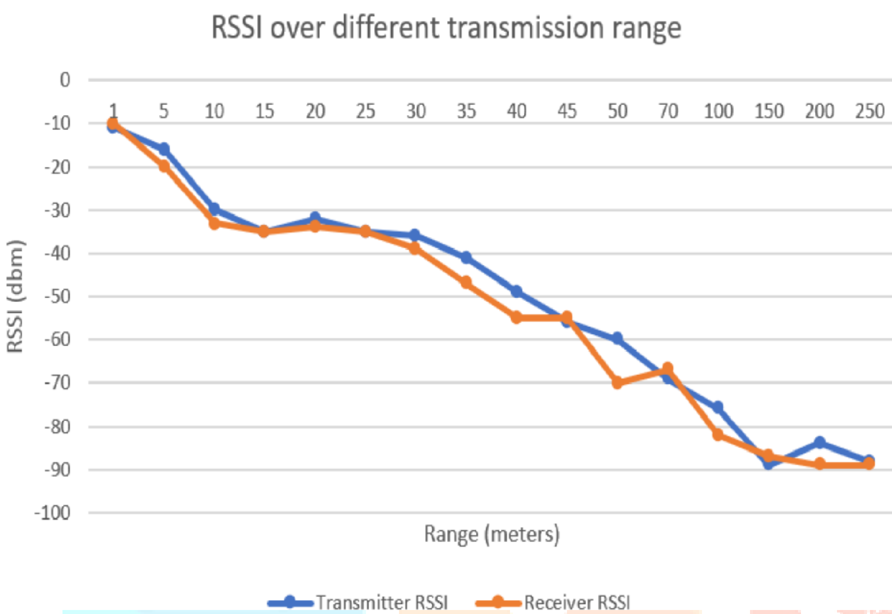

Figure 11. Gas Flowchart

Fig 11 displays the plotted graph of the two recorded RSSI values which is a necessary indicator in the mobile communication systems for both modules. And from the graph the relation between the RSSI and Transmission range is an inverse proportional. At the very close range 10-25 meters the readings were recorded RSSI was given in between -30 up to -35 which indicates that up to small range even though the range is increasing the RSSI doesn't linearly decreases. The reason that can be behind that is that the cave environment is not an open area where the signal can be propagated in one direction. However, the signal can be transmitted with RSSI of higher than or equal to -82 in the range of less than 100. Which is sufficient enough for the assumptions that were made based on the datasheet. Moreover, the signal can even be transmitted for a higher range of up to 200 where 250 the signal was failed with RSSI of -88 in the Transmitter and -89 in the Receiver.

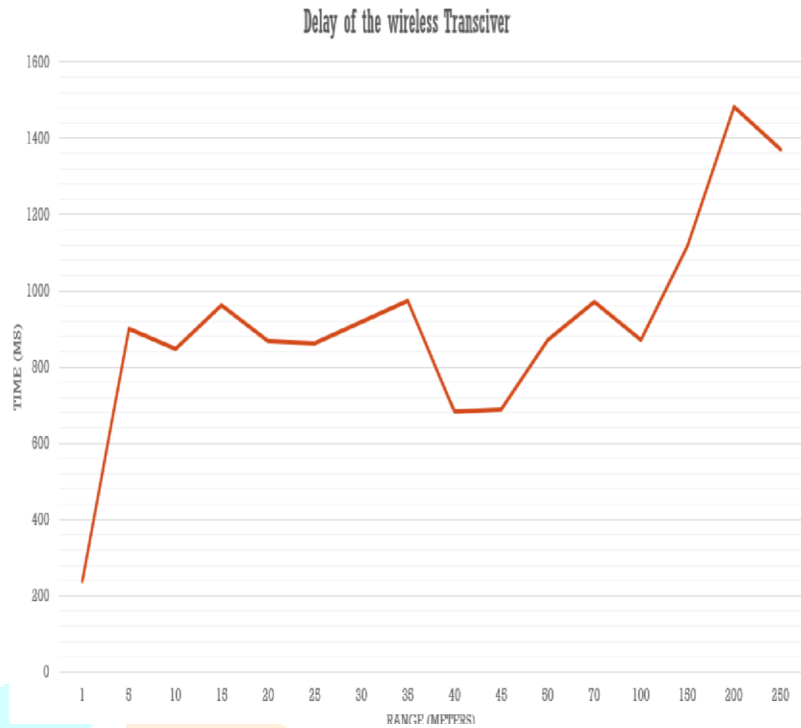

Figure 12. Gas Flawchart

Fig 12 shows the data being plotted in terms of time in milliseconds and range in meters. Whereas the range of the time started from 239 going up to 1483 milliseconds. The variations of the graph as in high peak incrimination from 1 to 5 meters for example, the delay was higher 700 milliseconds whereas the delay average was indicated in between 900 to 800. The reason behind this sudden change can be due to the different types of delay as the delay calculated in this testing is only the transmission delay and there are different types of delay such as queuing, spread delay and so on. However, as the distance goes higher than 100 meters the delay increases. Which concludes that the assumption stated in chapter 3 the maximum range of the transceiver modules doesn't exceed 100 is supported by this experimental testing. Hence the maximum range of the transmitter and receiver at the highest delay time is considered to be 200 meters which will be used for the following testing.

TABLE1. COMPARISON OF IDLE AND SLEEP MODE WITH PREVIOUS WORK DONE

	IDLE Current modemA	Sleep current mode mA	Power (IDLE mode) mW	Power (sleep mode) mW
XBEE Tx of SHS (Experimental results)	39.2	6.05	129	19.96
Slave RF Module	9.3	0.0157	30.69	0.05

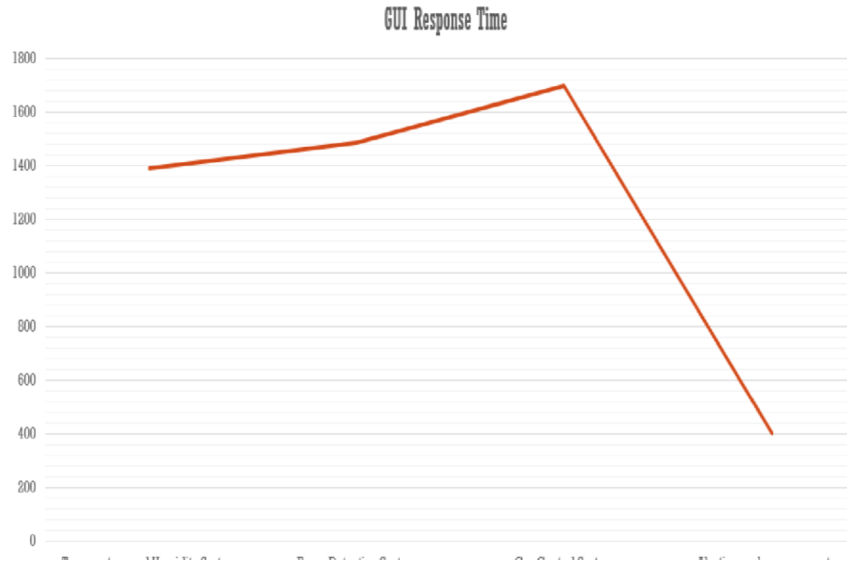

Figure 13. Gas Flawchart

As shown in Fig 13 the alerting and message system has the lowest delay time of 0.404 seconds. As the process of the alerting will be executed on the GSM and buzzer where the buzzer is connected to the GPIO pins which doesn't affect the delay much. However, GSM uses AT commands where the serial of TTL to USB has to be accessed two times from the platform therefore, requesting the serial causes the delay. Temperature and humidity monitoring system has an average delay of 1988ms compared with Force Detection System and Gas Control Systemwhich contains delay of 2185ms and 1695ms.

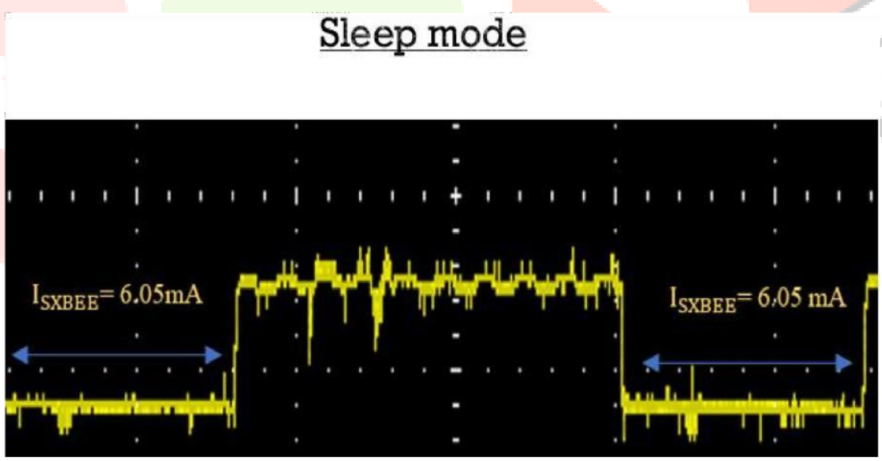

Figure 14. Gas Flawchart

Fig 14. displays the minimum amount of power consumed by the XBee module during sleep mode which was derived from the voltage and current (Ohm's Law). Therefore, XBee current was being recorded as 42.4 mA, 39.2 mA and 6.05 mA as for Transmission, IDLE and Sleep mode. The power of the overall system was calculated to be 1.341, 1.251 and 0.963 W for Transmission, IDLE and Sleep mode. Whereas Table 1 shows the power values obtained by the End-Device XBEE and that indicates the value obtained by the Literature Review is higher than the value obtained by the implemented system due to the number of IO connected devices in SHS is higher than the proposed method in the literature Review. However, SHS offers wide and variety of features. Another reason of the high-power consumption is that XBee in SHS uses breakout board which uses more power.

Sustainable development

The implemented design aims to reduce the hazardous gases and noisy environment by implementing the solenoid valve which works as flow control connected to the oxygen tank. All oxygen tanks come with a prefixed valve that sets the threshold pressure and it is set to be always open at the minimum operating pressure. By monitoring the hazardous gas in terms of LPG, CO and Smoke the microcontroller are used to detect the high threshold gas to operate the valve or not. By designing such system, it can be used to save the miner from the gases before their concentration increases more. The power consumption of the system was evaluated which can bea very good factor to save the energy by using sleep mode of XBee. As it is considered to save twice the time of the battery life. As the power consumption of SHS during Transmission mode is 146 mA and in sleep mode is 107 mA which is reducing 39 mA during the sleep modecompared to the Transmission mode.

Conclusion

In this paper the proposed project was introduced with a literature review, methodology, system limitations, findings and testing were explained. From the summary points it is seen that the aim related to the project are successfully achieved by designing Automated system that detects the hazardous gas surrounded by the miner's helmet was achieved, designing a monitoring system to update the control room with real time data was achieved and to integrate both design systems and evaluating the power consumption of the proposed system was integrated and achieved.

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