International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 03 | Mar-2016 www.irjet.net p-ISSN: 2395-0072

Wireless Mines: The Next Generation Communication System for Intelligent Mines

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Abstract – *Many Coal mines safety monitoring systems use cables and fixed sensor networks, but with the mining face moving, monitoring blind spot will appear. Coal mine safety monitoring system based on wireless sensor network can accurate and show dynamic situation of staff in the underground regions to ground computer system. A wireless sensor network (WSN) consists of many sensors, of different types, interconnected by a wireless communication network. Sensor data is shared between these sensor nodes. Fundamental design objectives of sensor networks include reliability, accuracy, effectiveness, flexibility.*

The Project presents design and development of underground coal mine monitoring using AVR and ZigBee. A sensor node is developed for sensing different environmental parameters of underground mine. The sensor node has feature of wireless communication using ZigBee transreceiver. Thus, sensor node can be deployed in the helmet of mine workers. All sensed data is digitized by the microcontroller which gives low power platform with fast execution. The system prototype developed has many advantages that makes it convenient to work in harsh environment of underground mine, monitoring concentration of deadly gases in its atmosphere along with temperature, any land slide and humidity.

Key Words: Zigbee, coal mine, Security system, WSN, AVR, etc.

1. INTRODUCTION

Coal is a very important fossil in India and the risks related with this mining are also very dangerous. In a coal mine supervising system, the important aspect is to observe the temperature, humidity and toxic gas released in the Mines in real time so that the rescue of coal mine workers in the event of any catastrophe is made easier and safety of the workers during production is ensured. The safe production level of coal mine is still low, especially in recent years, disasters of coal mine have been occurring frequently, which has led to great loss of possession and life, the safety problems of coal mine has gradually become the focus of the nation and society's concerns. Xbee is a wireless communications technology, with a short distance, safe and reliable, you can use Xbee technology to collect the various parameters of the terminal transmitted to the sensor on the tunnel gateway, and then the data is transmitted wirelessly to the gateway on the ground central control computer, by computer analysis and comparison of the data in order to assess the security situation in the Mine. Underground mine environments, due the complexity of the power consumption and interference immunity, have more stringent requirements. The disasters of coal mine happening are due to the complexity of mine environment and the variety of work condition of coal mine, so it is very necessary to monitor mine working environment. The various environmental parameters of mine safety monitoring and controlling system, such as methane, carbon monoxide, temperature, oxygen and so on, are currently using the traditional cable transmission.

Objective:

The main objective of the project is:

1) Monitoring: To monitor the parameters like carbon monoxide, temperature, humidity levels and land slide.

2) Communication: Monitored data will be transmitted to a central unit which is located in the underground section and from there to the pc side (ground level receiver unit) via xbee wireless communication.

3) Rescue: Whenever the sensor data exceeds the specified threshold (preset) value of temperature, carbon monoxide, force sensor and humidity level, the GSM will send message to the authorized person and the levels will also be indicated on the main server screen.

4) Protection: Due to the wireless communication system, employees will be alerted by an audio playback system as compared to present underground system. Therefore, rapid action can be taken by rescue teams, in critical situations. So the chances of accidents due to the underground mines environmental factors will be reduced.

2. BLOCK DIAGRAM DISCRIPTION

The system is divided into three parts

1. Miners unit(helmet)
2. Central unit
3. Ground unit

Miners unit consists of MEMS based sensors like temperature, force, humidity and gas concentration; it also consists of a xbee module for communication with the ground unit, and a memory card module which has

prerecorded voices which are played in the headphones of the workers when value exceeds the threshold. This control action allows the workers to evacuate the place before the disaster happens. Xbee is used for real time monitoring of the undermine conditions wirelessly. The xbee send all the data to the central unit

The Central unit consists of a LCD, a piezoelectric sensor and an xbee module to communicate with the ground unit.

The Ground unit on the receiver side consists of an xbee module, a GSM module and a PC for monitoring and taking necessary actions for safety and recue.

A. Ground Unit:

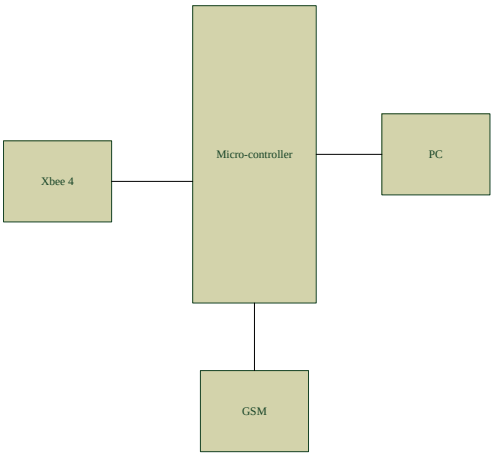


Fig-1: Ground Unit

It is located at ground level outside the mine. The number of mining units developed will communicate with single monitoring unit.

B. Miners Unit:

The miners unit will be deployed in the helmet of the mine worker. This unit consists of sensor node and a audio system for the security purpose.

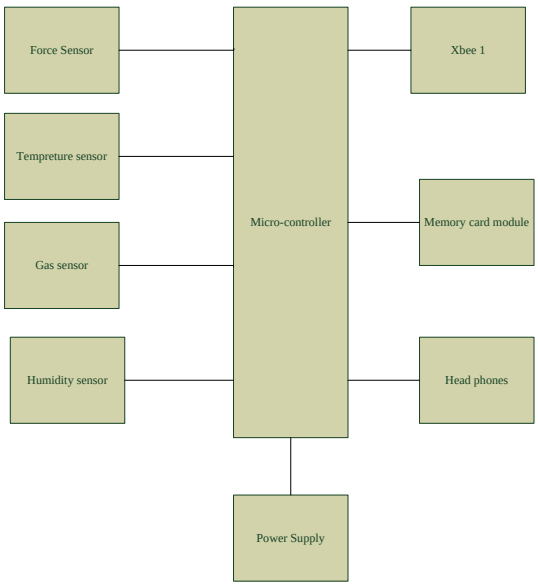


Fig-2: Miners Unit

C. Central Unit:

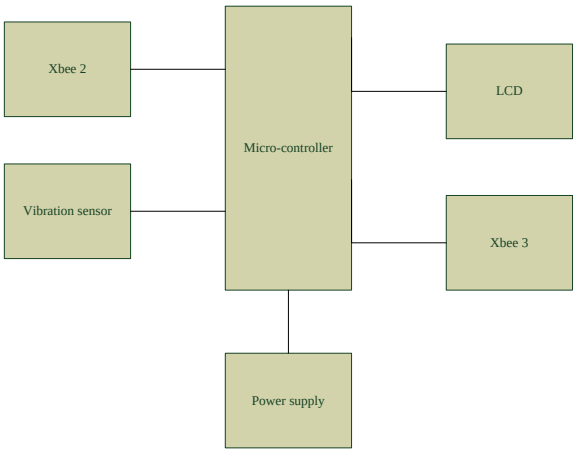


Fig-3: Central Unit

The central unit is deployed in different underground parts to communicate effectively eith the miners unit.

For installing the central unit different topologies for the zigbee communication can be used, out of all the topologies cluster tree topology is the most effective for the mine environment. The topologies are shown in the figure below

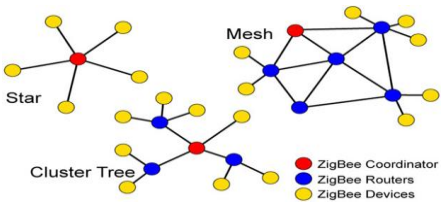


Fig-4: Zigbee topologies

2.1 HARDWARE DISCRIPTION

ZigBee Communication:

ZIGBEE is a new wireless technology guided by the IEEE 802.15.4 Personal Area Networks standard. It is primarily designed for the wide ranging automation applications. It currently operates in the 868MHz band at a data rate of 20Kbps in Europe, 914MHz band at 40Kbps in the USA, and the 2.4GHz ISM bands Worldwide at a maximum data-rate of 250Kbps. The ZIGBEE specification is a combination of Home RF Lite and the 802.15.4 specification. The specification operates in the 2.4GHz (ISM) radio band - the same band as 802.11b standard, Bluetooth, microwaves and some other devices. It is capable of connecting 255 devices per network. Range of the transceiver module can be 30-70m in urban areas and 1- 1.5km in outdoor (LOS). The transceiver has an on-chip wire antenna and it operates at a frequency of 2.4GHz. The data received from the microcontroller is organized based on the ZIGBEE protocol standards and then modulated. The specification supports data transmission rates of up to 250 Kbps at a range of up to 30 meters.

ZIGBEE's technology is slower than 802.11b (11 Mbps) and Bluetooth (1 Mbps) but it consumes significantly less power. Here a pair of Zigbee modules is used one to transmit the data from underground section and another to receive this data at ground or monitoring section.

Microcontroller:

The ATmega328 is a single chip micro-controller created by Atmel and belongs to the megaAVR series. The high-performance Atmel 8-bit AVR RISC-based microcontroller combines 32KB ISP flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts,serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts.

By executing powerful instructions in a single clock cycle, the device achieves throughputs approaching 1 MIPS per MHz, balancing power consumption and processing speed.

Parameter	Value
Flash (kBytes):	32 kBytes
Pin Count:	32
Max. Operating Freq. (MHz):	20 MHz
CPU:	8-bit AVR
Max I/O Pins:	23
Ext Interrupts:	24
SPI:	2
TWI (I2C):	1
UART:	1
ADC Channels:	8
ADC Resolution (bits):	10
ADC Speed (ksps):	15
Analog Comparators:	1
SRAM (kBytes):	2
EEPROM (Bytes):	1024
Self Program Memory:	Yes
Operating Voltage (Vcc):	1.8 to 5.5

GSM Modem:

GSM/GPRS Modem-RS232 is built with Dual Band GSM/GPRS engine- SIM900A, works on frequencies 900/ 1800 MHz. The Modem is coming with RS232 interface, which allows you connect PC as well as microcontroller with RS232 Chip(MAX232). The baud rate is configurable from 9600-115200 through AT command. The GSM/GPRS Modem is having internal TCP/IP stack to enable you to connect with internet via GPRS. It is suitable for SMS, Voice as well as DATA transfer application in M2M interface. The onboard Regulated Power supply allows you to connect wide range unregulated power supply . Using this modem, you can make audio calls, SMS, Read SMS, attend the incoming calls and internet ect through simple AT commands.

Fig-5: GSM 900A Modem

Gas Sensor:

This is a simple-to-use Carbon Monoxide (CO) sensor, suitable for sensing CO concentrations in the air. The MQ-7 can detect CO-gas concentrations anywhere from 20 to 2000ppm. This sensor has a high sensitivity and fast response time. The sensor's output is an analog resistance. The drive circuit is very simple; all you need to do is power the heater coil with 5V, add a load resistance, and connect the output to an ADC.

Fig-6: Gas Sensor

Temperature Sensor:

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling.

The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1/4°C at room temperature and ±3/4°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package.

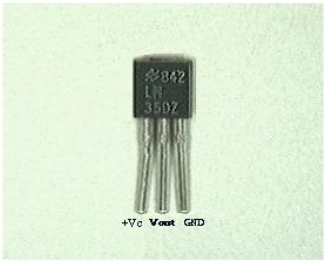


Fig-7: Temperature Sensor

Humidity Sensor:

These sensors convert humidity into output voltage. Based on a unique capacitive cell, these relative humidity sensors are designed for high volume, cost sensitive applications such as office automation, automotive cabin air control, home appliances, and industrial process control systems. They are also useful in all applications where humidity compensation is needed.

Force Sensor:

This is a force sensitive resistor with a round, 0.5" diameter, sensing area. This FSR will vary its resistance depending on how much pressure is being applied to the sensing area. The harder the force, the lower the resistance. When no pressure is being applied to the FSR its resistance will be larger than 1MΩ. This FSR can sense applied force anywhere in the range of 100g-10kg.

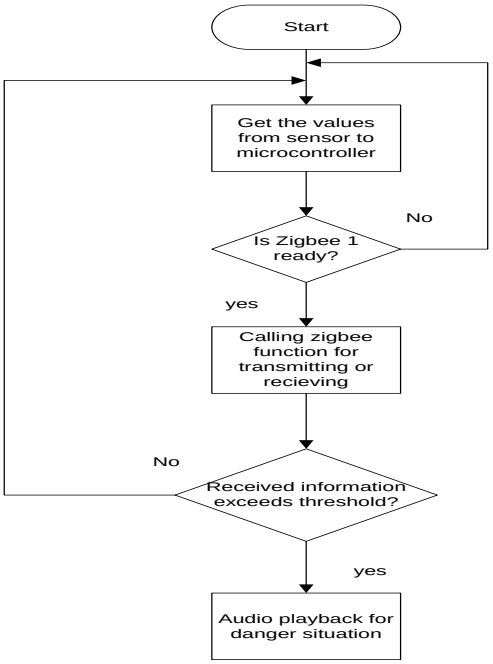
Two pins extend from the bottom of the sensor with 0.1" pitch making it bread board friendly. There is a peel-and-stick rubber backing on the other side of the sensing area to mount the FSR.

These sensors are simple to set up and great for sensing pressure.

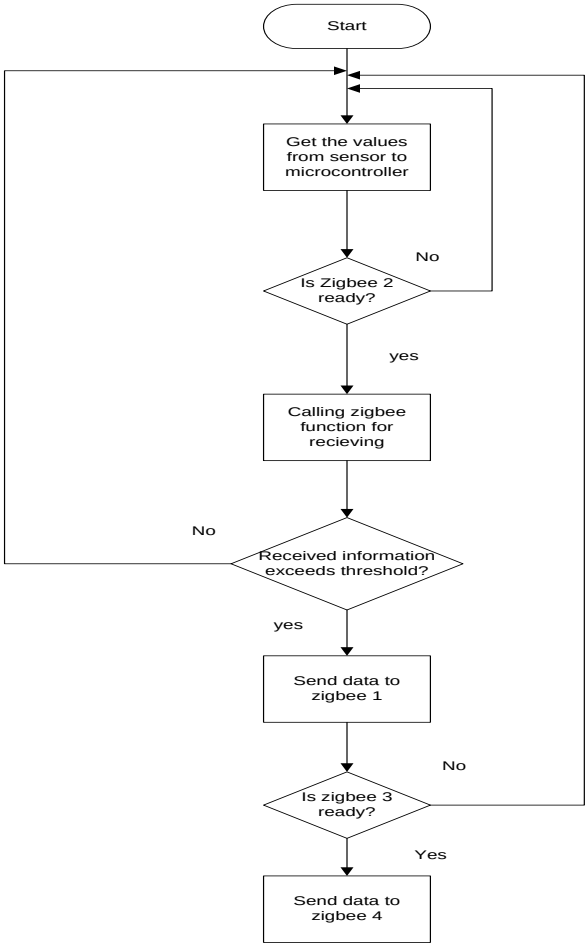
Fig-8: Force Sensor

2.2 SOFTWARE DISCRIPTION

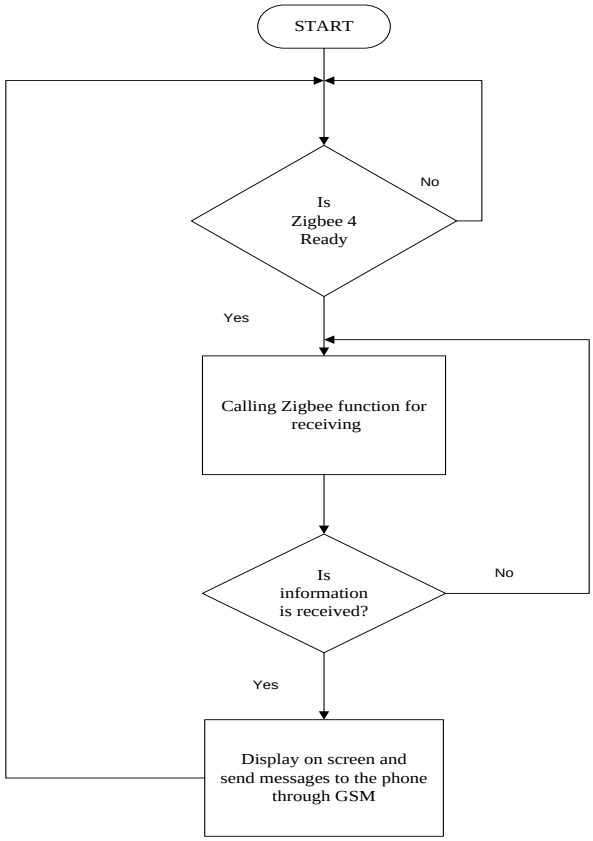
Flow of miners unit



Flow of central unit



Flow of Ground unit



3. CONCLUSIONS

The system developed in this article is reliable and works under harsh environmental conditions and gives a safer environment to the workers. The communication being wireless provides a lot of convenience for wireless transmission. The system is reliable, faithful, uninterrupted, economical and user friendly. The system consists of a low power, low cost Zigbee based high frequency wireless data transmission technology with MEMES based small size sensors. More sophisticated sensors can be used to make this system accurate.

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