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Wireless Disaster Alerting System for Coalmines

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Abstract

A battery powered wireless disaster alerting system informs the control room about emergencies arising in coalmines. The system is loaded with sensors to check for potentially damaging conditions such as excessively high temperature and humidity, and highly concentrated gas in the mine. These parameters are processed using a microcontroller and transmitted to the ground station. A ZigBee module is used to establish short distance communication between the underground station and the ground station just outside the coalmine. The collected data is relayed through an SMS from the ground station to a remote management center using GSM (Global System for Mobile communication). The system ensures safety of coalmine workers and enables them to connect with the control room personnel easily from the mines.

Keywords: Wireless communication, ZigBee, SMS, GSM, ARM7 controller, disaster alerting, temperature sensor, gas sensor.

1. Introduction

Several articles and research papers have highlighted the grave danger and safety threats to workmen inside coalmines in the face of an accident. Research work of authors has resulted in development of solutions to overcome this problem using various techniques, including the use of wired systems. However, wired systems are difficult to employ over long distances; cannot reach every nook and cranny of the mine; may fail when losses through wires increase beyond a certain acceptable level, or when there is a breakage in one or more wires; and may distract work men from their job as they have to always be on the lookout to not touch wires. Many of the wireless systems that have been developed involve advanced algorithms and are complex.

Wireless Coal Mine Disaster Alerting System presents a simple method to monitor coalmines and alert the relevant personnel in case of a disaster. The system involves the measurement of parameters such as temperature, humidity and amount of harmful gas inside the mine; ringing an alarm to alert personnel inside the mine when conditions inside the mine deviate from normal; and relaying information about the undesirable conditions to personnel outside and far away from the mine in a two-step process - first, by transmitting information from the mine to the ground using ZigBee and second, by sending this information through an SMS using GSM.

2. Background and Related Work

This section summarizes the findings of the literature survey that was carried out to study the technologies that have been employed to solve the aforementioned problem.

A combination of sink and sensor nodes was employed for environment monitoring. Sink nodes were supplied with continuous power and mobile data acquisition nodes were mainly powered by battery. ZigBee limited communication to a short distance data-monitoring site. Em GIS software showed the location of the place where the disaster broke out. [1]

A dense network of sensor nodes was implemented in the mine section and the parameters monitored in the underground section were sent to a long distance monitoring center by cable. [2]

Data was sent from a controller in the mine to a PC stationed on the ground by conversion of Zigbee protocol to Ethernet protocol. The PC transmitted results to a mobile phone through GPRS. LAN was also used to directly publish monitored data on the web. [3]

A data acquisition host computer collected data from the underground lower computer terminals via a 100 Mbps industrial Ethernet. ZigBee was also used for data transmission and reception. Low power microprocessor S3C2410 was also used. [4]

A solar panel was used to charge the battery, to provide continuous supply to the system at all times. [5]

Another design involved the division of the system into two sections – the mining unit (underground) and monitoring unit (on the ground). Low power microcontroller ARM7 was used for data processing. [6]

3. Salient Features

This section captures the salient features of the system developed with regards to the electrical/electronic components employed.

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3.1 LPC 2148

LPC 2148 [7] is a low power and high performance ARM 7 microcontroller that is pre-loaded with many inbuilt peripherals. It is thus an efficient and a reliable option for application developers. LPC 2148 has inbuilt ISP, hence it can be programmed within the system using serial communication on COM0 or COM1. MAX 232/233 IC must be used for voltage logic conversion.

3.2 ZigBee S2

The role of ZigBee is critical as it forwards the data from the microcontroller to a personnel's phone over the GSM band. It is not possible to send an SMS from inside a mine as GSM signals have zero to weak coverage inside it owing to its depth. Therefore ZigBee establishes short distance communication between regions where there is no GSM signal to a region where GSM coverage exists. Series 2 ZigBee protocol 1mW with wire antennas, which is good for point-to- point, multipoint and mesh networks, is used. The actual system uses a mesh of repeaters to repeat the signals in order to overcome attenuation.

Table 1: ZigBee S2 specifications [8]

Parameter	***Value***
TX Peak Current	40 mA
RX Current	40 mA (@3.3 V)
Power-down Current	< 1 µA
Range- Indoor/Urban	< 133 feet (40 m)
Range- Outdoor line-of-sight	< 400 feet (120 m)
Transmit Power	2 mW (3 dBm)
Receiver Sensitivity	-96 dBm

3.3 GSM SIM300 MODEM

A GSM modem modulates and demodulates GSM signals. SIMCOM SIM300 is a tri-band GSM/GPRS Modem as it can detect and operate at three frequencies (EGSM 900 MHz, DCS 1800 MHz and PCS 1900 MHz). Default operating frequencies are EGSM 900 MHz and DCS 1800 MHz.

3.4 Gas sensor MQ-6

MQ-6 [9] is used in gas leakage detecting equipment and is suitable for detection of LPG, iso-butane, propane and LNG. It has high sensitivity to LPG, iso-butane and propane; and small sensitivity to alcohol and smoke. It is suitable for this application owing to its fast response, stable and long life.

3.5 Temperature cum humidity sensor DHT11

The DHT11 [10] is a sensor used for the detection of both temperature and humidity. It includes a resistive type humidity measurement and an NTC measurement temperature coefficient. This 4-pin sensor is calibrated with a digital output. The exclusive digital signal acquisition technique ensures good reliability and excellent long-term stability of the sensor. The measurement range of humidity and temperature varies from 20-90% RH and 0-50 degree Celsius. The maximum error percentage in humidity and temperature is +- 5%RH and +-2 degree Celsius respectively. A complete data transmission from the sensor is of size 40-bit.

4. System Description

The system is divided into two subsystems: underground section/station and ground section/station. This section highlights the composition and working of the above mentioned two subsystems.

4.1 Underground section

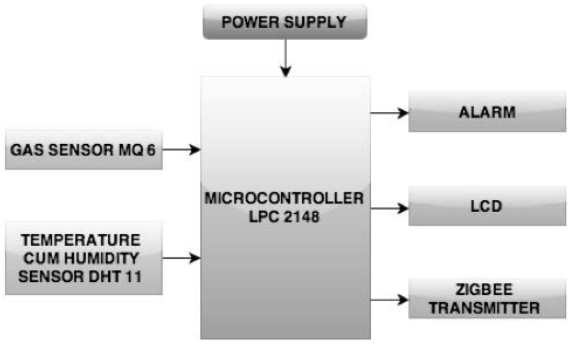

Fig. 1. Underground section

Sensors MQ6 and DHT11 collect LPG concentration; and temperature and humidity respectively of the coal mine. The sensed signals are given to MPC 2148 for processing; where they are converted to digital form if already not digital. The controller displays the value on an LCD screen and runs an algorithm to determine if the sensed values are out of the safe range. If so, then an alarm is rung to alert the personnel about the hazardous environment so that they may vacate the mine or take necessary precautions. It also transmits the data to the ground station using ZigBee S2 using UART module of LPC 2148 as an intermediate

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step to send the data through an SMS to control room personnel from the mine.

4.2 Ground section

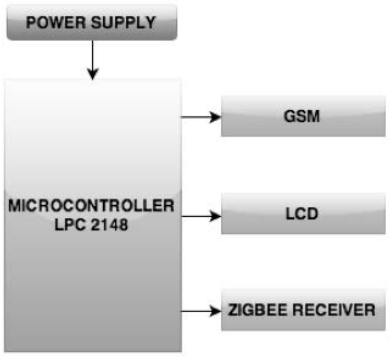

Fig. 2. Ground section

The ZigBee S2 receiver connected to LPC 2148 on the ground station catches the signal sent by the transmitter and forwards it to the microcontroller. From here, the data is sent to a personnel's mobile phone over the GSM band using SIM300 modem. The phone number of the person to whom SMS has to be sent is entered in the code of the microcontroller. Multiple SMS can be sent to multiple people. The data about the coalmine environment stored in the microcontroller is also displayed on an LCD screen on the ground station so that its conditions can be monitored from outside the mine also.

5. Software Design

Firmware development of the device is done in embedded C on Keil µVision4 and the code is burnt to the controller using Flash Magic.

5.1 Keil µVision4

Keil µVision is a Windows based software development package that helps expedite the development process of embedded applications by providing the Integrated Development Environment. It greatly simplifies the process of creating and testing an embedded application.

5.2 Flash Program Utility

The program code generated in C language after processing produces object code to hex form. It is referred as .hex file. To load this hex code into the flash ROM of the controller, Flash Magic software is used.

5.3 Flowchart

The flowcharts below, figures 3 and 4, describe the program flow in the underground and ground stations respectively.

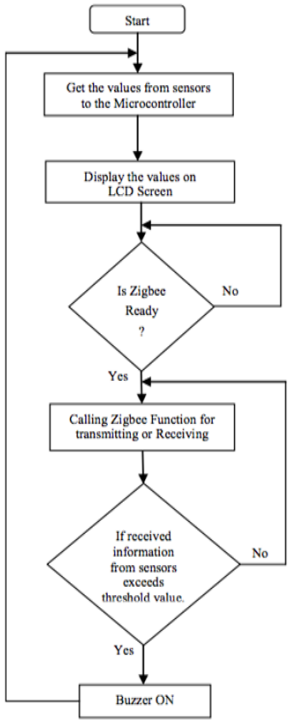

Figure 3: Flowchart of underground section

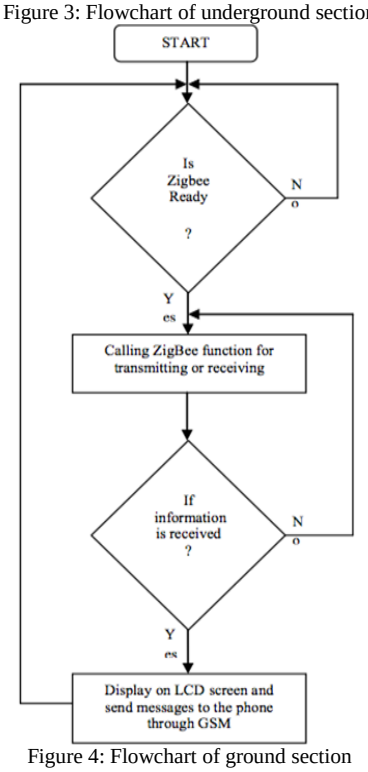

Figure 4: Flowchart of ground section

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6. Conclusions

The underground and ground section circuits were implemented and communication between the underground and ground ZigBee; and controller to GSM module were established. Undesirable conditions such as high temperature, high concentration of flammable gas and high humidity, to check for system response, were simulated using flame, a burning incense stick and water vapour.

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