Sensors & Transducers, Vol. 153, Issue 6, June 2013, pp. 53-59

Sensors & Transducers

Gas Detection Instrument Based on Wireless Sensor Networks

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Received: 19 April 2013 /Accepted: 14 June 2013 /Published: 25 June 2013

Abstract: The wireless sensor network is used to simulate poisonous gas generating system in the Fire-Fighting Simulated Training System. In the paper, we use the wireless signal to simulate the poisonous gas source and use received signal strength indicator (RSSI) to simulate the distance between the fireman and the gas source. The gas detection instrument samples the temperature and sphygmus of the trainee and uses the wireless signal as poisonous gas signal. When the trainee enters into the poisonous gas area, the gas detection instrument warns with sound and light and sends the type, density value, the location of the poisonous gas and vital signs of the trainee to host. The paper discusses the software and hardware design of the gas detection instrument. The system has been used to the several of Fire-Fighting training systems. *Copyright © 2013 IFSA.*

Keywords: Wireless sensor network, Fire-fighting simulated training system, RSSI, Gas detection instrument.

1. Introduction

Along with the rapid development of economy, the new energy, new materials and new products are required in large numbers. At the same time high-rise building fires, chemical explosion, subway fire and the others special circumstances fire occurred frequently. The fire army, responsible for dealing with fire, unexpected disasters and other burst characteristics disasters, faces with the problem how to do well with the relief work. In order to reduce casualties and property loss and improve the success rate of dealing with special fires and other disasters, it is necessary to strengthen the construction of fire control team and improve the equipment construction. In addition, it is the most important to strengthen the training center, improve training simulation facilities and promote the training means. Therefore, it is necessary to take advantage of fire training system to realize the simulation of real fire environment [1-4].

Generally, there are two kinds of fire training systems, namely the virtual system and the simulation system. The virtual system takes advantage of computer graphics and virtual reality technology to realize the 3D representation of the fire scene in the computer [2, 3]. For example, virtual reality modeling language is used to model and combine with the actual building and construct a realistic training scene. Therefore trainees can interact with the scene. This training means made the recruit to overcome the psychological barrier, but this method is different from the actual fire scene. For example, the fireman deals with the fires in movement, facing with all kinds of the poisonous gas. This method don't simulate the fire scene overall. The simulation system, a real simulation of the fire scene, provides a more personal feeling closed to the fire scene to trainees [4]. Therefore, trainees are able to be familiar with the fire scene and realize adaptation of psychological aspect and perception.

The simulated indoor training system for fire-fighters has been used practically at present [4]. But in practical simulated training system, the real poisonous gas isn't used due to safety. It is important to design the simulated poisonous gas system and use it in the simulated training system. The training system can't simulate the poisonous gas at present. According to the requirement of the fire simulated training system, this paper proposed the method to simulate poisonous gas.

According to the technology requirement of the fire training system, the simulated system has to realize several functions. Firstly, it is necessary to simulate the poisonous gas and test the gas treatment response of the fire-fighter. The scope of poisonous gas has to be considered to make sure that when the fireman enters into a certain area, the system can warn with sound and light. Secondly, in order to realize the test of the response of the fire-fighter, the fire-fighter's identity has to be accessed automatically. Finally realizes the on-line monitor of the fire-fighter's vital signs that includes the sphygmus measurement and the temperature detection. Therefore, the design can prevent any unexpected circumstances and other dangerous situations from appearing during the training.

Wireless sensor network (WSN) technology has been used for fire-fighting rescue and mine rescue [5-11]. The paper selects the Wireless sensor network to simulate the poisonous gas producing. The system is composed of the gas detection instrument, the poisonous gas generator, gateway and the software of command management.

The paper uses the wireless signal to simulate the poisonous gas source and use received signal strength indicator (RSSI) to simulate the distance between the fireman and the gas source. The poisonous gas generator sends the wireless signal data packet that includes ID, warning density value and type of the source poisonous gas and simulates the poisonous gas circumstances. The gas detection instrument that has individual ID detects the wireless signal, receives the data of the poisonous gas source, samples the temperature and sphygmus of the trainee and sends the poisonous gas and vital signs to the host by the gateway [12, 13]. The gas detection instrument detects the RSSI of the wireless signal and judge if the trainee enters into the poisonous gas area. The RSSI value varies inversely as the square of the distance [14-17]. The poisonous gas generator sets up the threshold value of the poisonous gas. It expresses that the trainee enters into the poisonous gas area when the RSSI value that is detected by the gas detection instrument is higher than the setting value. But the consistent function relation between RSSI and the distance is difficult to obtain due to different environments. The value of the relation between RSSI and the distance is set up dynamically by gateway according to the actual circumstance. The sphygmus and the body temperature are collected by the wrist sensor that is connected to the poisonous gas detection instrument. With small LCD, the poisonous gas detection instrument shows the poisonous gas information. It also contains several function buttons. The poisonous gas detection instrument is mobile node and is installed into the trainer.

The gas detection instrument is kernel instrument in the system. The paper discusses the design of the poisonous gas detection instrument.

2. The Hardware Design of the Gas Detection Instrument

The hardware of the instrument is composed of the power supply circuit, LCD display circuit, the sound and light warning circuit, key circuit, detecting temperature circuit, detecting sphygmus circuit and main control circuit. Its circuit is shown in Fig. 1.

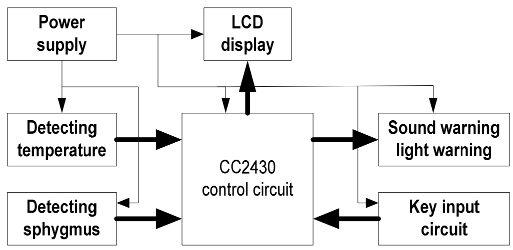

Fig. 1. The hardware diagram of the instrument.

2.1. The Power Supply Circuit

The supply voltage of the instrument is 3.3 V. Four 7# charge batteries is serially linked to produce 5 V. A low power positive-voltage regulator (AS1117) is selected to transfer 5 V into 3.3 V. Its circuit is shown as Fig. 2.

2.2. Main Control Circuit

The main control circuit completes the control function. It includes the detecting poisonous gas, ID identity system, the detecting temperature and sphygmus, management and maintenance. The CC2430 is selected as the core CPU. It is a true System-on-Chip (SoC) solution specifically tailored for IEEE 802.15.4 and ZigBee™ applications. It enables ZigBee™ nodes to be built with very low total costs. The CC2430 combines the excellent performance of the leading CC2420 RF transceiver with an industry-standard enhanced 8051 MCU, 32/64/128 KB flash memory, 8 KB RAM and many other powerful features. In this paper, RF transceiver is used to complete to detect poisonous gas and ID identity functions, the enhanced 8051 MCU is used to complete detecting temperature and sphygmus and management and maintenance.

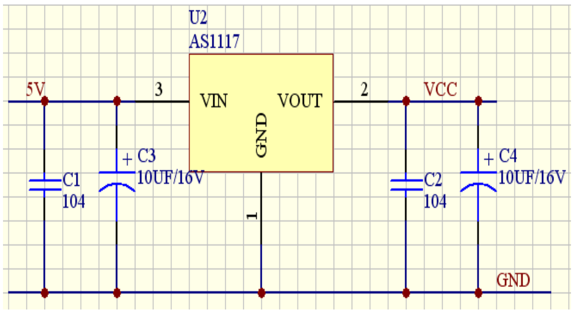

Fig. 2. The circuit of the power supply.

2.3. LCD Display and Sound and Light Warning Circuit

LCD displays the ID, temperature and sphygmus of the trainer, the type and density and location of poisonous gas when the trainee enters into the poisonous gas area.

LED and Buzzer form the sound and light warning circuit. When the trainee enters into the poisonous gas area, the LED is lighted on and buzzer warns. The sound and light warning circuit is shown as Fig. 3.

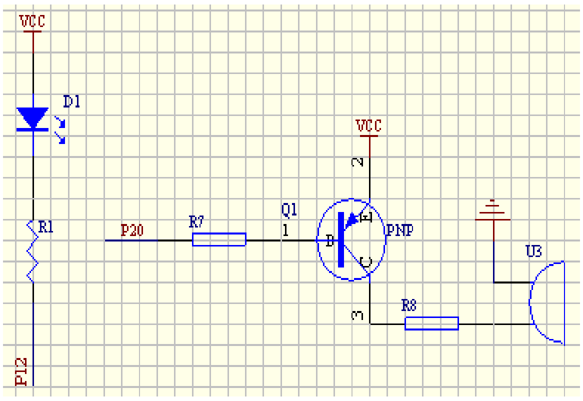

Fig. 3. Warning circuit.

2.4. Key Input Circuit

The key input circuit consists of three keys. They are defined as Setup key, Add key, Enter key. The key input circuit is used to set up the ID of system and change the displaying interface. When the trainee enters into the poisonous gas location, the trainee presses the Enter key and expresses to detect the poison gas message. The circuit is shown as Fig. 4.

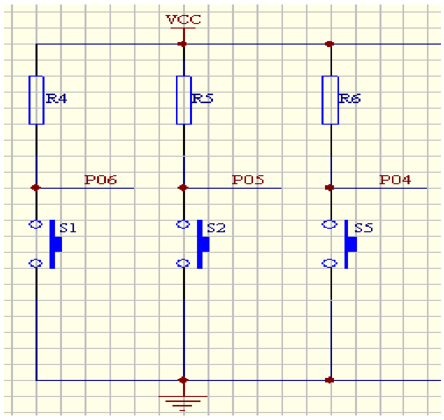

Fig. 4. The key circuit.

2.5. Detecting Temperature and Sphymgus Circuit

The circuit is used to detect the temperature and sphygmus of trainee.

The DS18B20 is used to detect the temperature. The DS18B20 communicates over a 1-Wire bus for communication with a central microprocessor.

The sphygmus sensor is used to detect the sphygmus of trainer. This type of sensor is specially used to detect the moving people and its output doesn't be disturbed by the movement. When the heart beats once, the output of the sensor produces the pulse signal. The number of sphygmus is computed by detecting the time between the twice pulse signal.

3. The Software Design of the Gas Detection Instrument

The software design of the instrument accomplishes the all function of system. Its diagram is shown as Fig. 5.

3.1. Initialization

Initialization accomplishes the clock initialization, I/O initialization, timer initialization, configure initialization, LCD initialization and ADC initialization. Its diagram is shown as Fig. 6.

1. The CC2430 has one internal system clock. The source for the system clock can be either a 16 MHz high-frequency RC oscillator or a 32 MHz crystal oscillator. Clock control is performed using the CLKCON SFR register described. In RF function, a 32 MHz crystal oscillator need be selected. In the clock initialization, a 32 MHz crystal oscillator is configured to use.

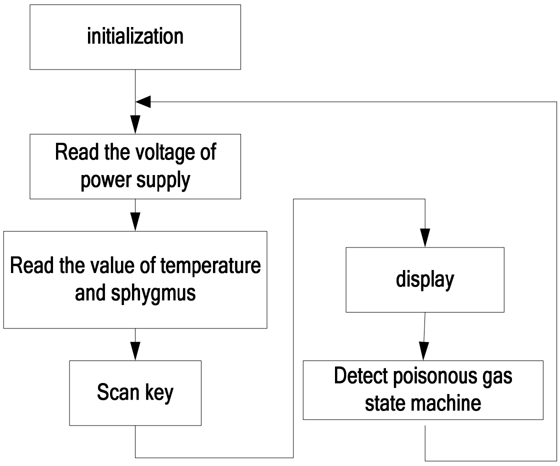

Fig. 5. The software diagram of the instrument.

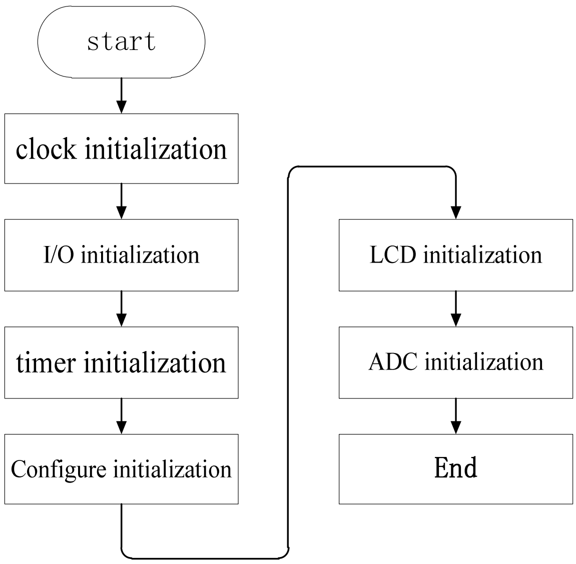

Fig. 6. The diagram of initialization.

2. In the I/O initialization, the using port is configured as input or output or peripheral I/O.

3. In this paper, the value of temperature is sampled per one second. The timer1 is used to accomplish 1 second timing.

4. In the configure initialization, read the configured value from the EEPROM and set up the ID of instrument, Max/Minimum warning temperature value and Max/Minimum warning sphygmus value.

5. LCD initialization accomplishes the LCD register configure.

6. In the ADC initialization, configure the VDD/3 as the ADC input.

3.2. Read the Voltage of Power Supply

The charge batteries supply the power for the instrument, so the voltage of batteries need be sampled. In CC2430, its ADC can also be input with a voltage corresponding to VCC/3. This input allows the implementation of a battery monitor. Its diagram is shown as Fig. 7.

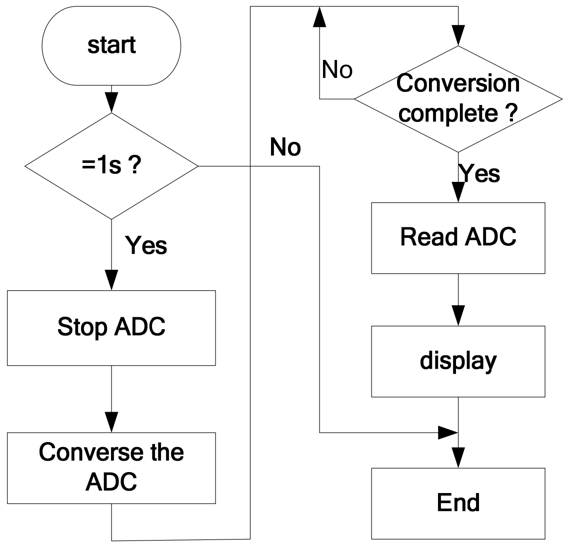

Fig. 7. The diagram of read the voltage of power supply

In this part, the value of trainee's temperature and sphygmus is read. DS18B20 is selected as the temperature sensor. The sample routine is referred as DS18B20 datasheet and its diagram is shown as Fig. 8.

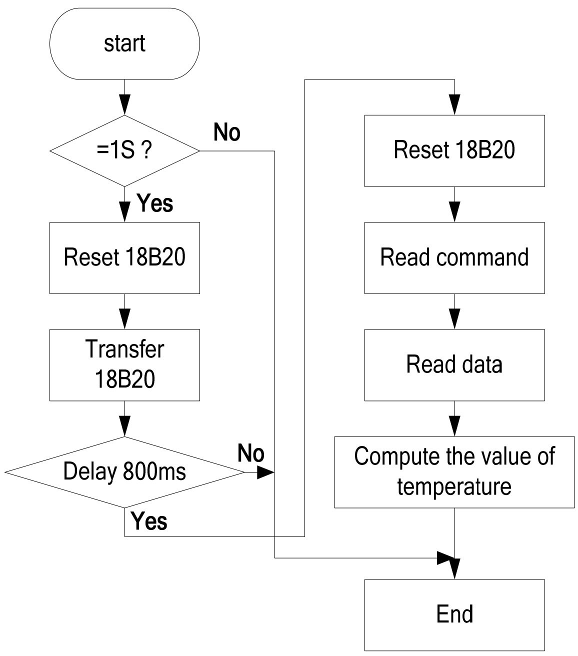

Fig. 8. The diagram of read temperature.

The value of sphygmus is obtained by computing the time between the twice pulse. Its value is filtered. Its value is shown as formula 1.

$$C = \sum_{i=0}^{9} C(i)/10, \quad (1)$$

where C is the value of sphygmus, the $C(i)$ expresses the last ten times value.

3.4. Scanning Key Routine

Scanning key routine scans the key and sets up the state of system. The system has three states. These states display the normal show, ID configure show and the RSSI value show separately. The state is transferred to press the different combination key. Its diagram is Fig. 9. The instrument is normal state after power on. When Pressing the Setup key + Add key + Setup key successively, the instrument is transferred to ID configure state. In the state, press Add key to add the ID of instrument and press Setup key to set up ID of instrument and enter into normal state. In the normal state, press the Setup key + Enter key + Setup key successively, the instrument is transferred to the state of displaying RSSI value. In ideal circumstances, the signal received power varies inversely as the square of the distance. But normally, the consistent function relation between RSSI and the distance is difficult to get due to different environments. The dynamic setting depends on the actual circumstance. In the state, the RSSI value of poisonous gas generator is displayed.

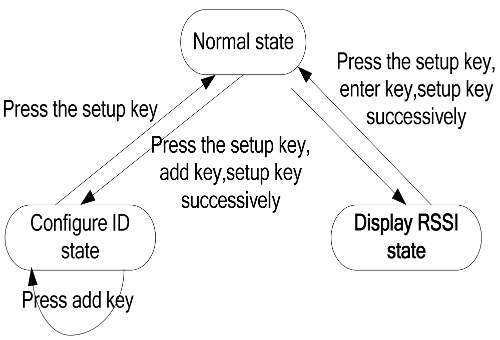

Fig. 9. The key state diagram.

When the trainee enters into the poisonous gas location, pressing the Enter key expresses that the trainee has entered into the gas area.

3.5. Display Routine

Display routine displays temperature and sphygmus of trainee, the type, density and location of poisonous gas when the trainee enters into the poisonous gas area in the normal state and displays the ID setup interface in the setup ID state and displays the RSSI value of poisonous gas producing instrument.

3.6. Detect the Poisonous Gas State Machine

The part is core of software and accomplishes the poisonous gas detecting and communicates with gateway. Its state diagram is shown as Fig. 10. The state machine is composed of four states, namely receive signal state, receive data judge state, send data state and gas detecting state. The four states are discussed.

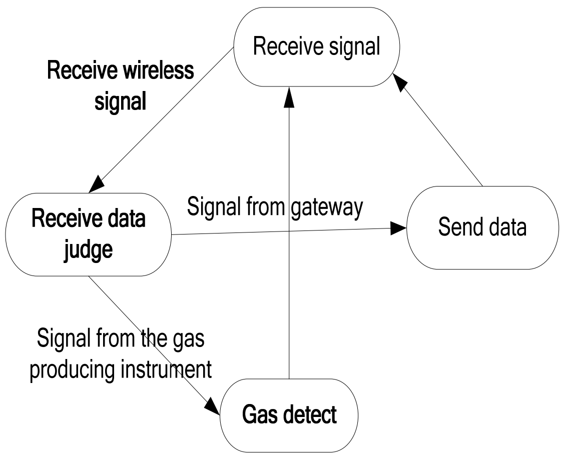

Fig. 10. The state diagram of detecting the poisonous gas state machine.

1. Receive signal state. In this state, it is ready to receive wireless signal (namely poisonous gas signal). The wireless signal of CC2430 realizes by the DMA mode. Its processing is composed of setup waiting state, setup destination address, setup DMA length, setup DMA channel, setup Radio control state machine and turn on receiving interrupt. After this, it waits for receiving. When receiving the wireless signal, it transfers to receive data judge state.

2. Receive data judge state. Firstly, the source address of the wireless signal is read. If the address is from the poisonous gas generator, the state machine is transferred to Gas detecting state. If the address is from the gateway, the state machine is transferred to Send data state.

3. Gas detecting state. In the state, the instrument receives the signal from the poisonous gas generator. The format of signal is shown as Table 1. If the value of RSSI of wireless signal from the poisonous gas producing instrument is greater than the RSSI threshold (see Table 1), the instrument enters into the poisonous gas location. If the trainee enters firstly, the device warns with sound and light, displaying the type, density, location of poisonous gas on the LCD. At this time, pressing the enter key, the buzzer is turn off and LED is still lighten on. Its diagram is shown as Fig. 11.

Table 1. The format of the poisonous gas signal.

Content	Length (byte)
0x12	1
Gas type	1
Gas density	4 (float)
RSSI threshold	1
Gas location	1

4. Send data state. In this state, the instrument transmits its state message to gateway. The format of message is shown as Table 2. The send process of data is composed of setting up destination address, setting up the data length, setting up Radio control state machine and turning on transmit interrupt.

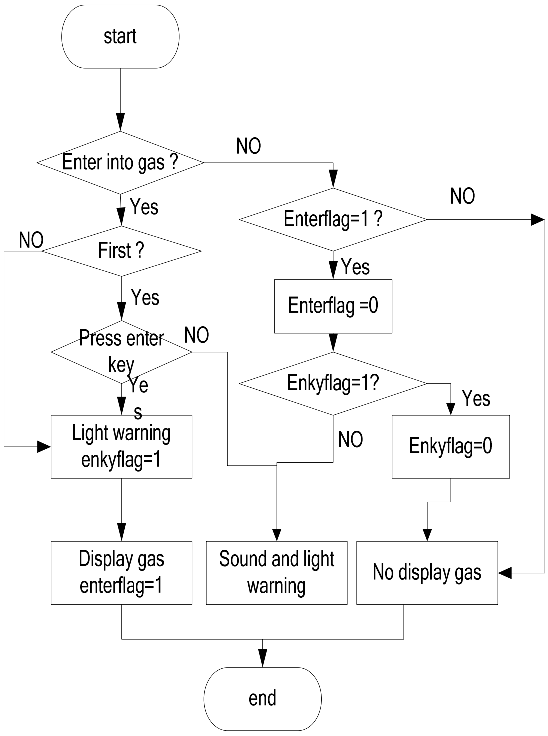

Fig. 11. The diagram of detecting the poisonous gas.

Table 2. Format of message of instrument.

Content	Length (byte)
0x22	1
Value of Sphygmus	1
Value of temperature	4 (float)
Voltage value of power	1
Gas type	1
Gas location	1
Gas density	4 (float)
Warning message	1

4. Conclusion

By debugging, the instrument accomplished to detect temperature and sphygmus of trainee and simulate the poisonous gas. When the trainer enters into the poisonous gas area, the instrument warns with sound and light and sends the type, density value, the location of the poisonous gas and vital signs of the trainer to host. The system was used to the several of fire training systems.

In contrast with the others training system, the system, using the WSN to simulate poisonous gas and monitor the vital signs of the trainer, solved the problem of the simulating the poisonous gas and made the simulated system more similar to the real environment.

We found the entering the poisonous gas area isn't accurate due to the relation of the RSSI and distance. It is the problem to research in the future.

Acknowledgements

This work was supported by Chinese National 863 Project 2011AA040103.

References

[1]. H. Guo, Z. Li, Preliminary discussion of fire-fighting simulated training system, *Fire Science and Technology*, Vol. 3, Issue 1, 2007, pp. 86-88.

[2]. S. Smith, D. Trenholme, Rapid prototyping a virtual fire drill environment using computer game technology, *Fire Safety Journal*, Vol. 44, Issue 4, 2009, pp. 559-569.

[3]. M. Cha, S. Han, J K. Lee, et al., A virtual reality based fire training simulator integrated with fire dynamics data, *Fire Safety Journal*, Vol. 50, Issue 4, 2012, pp. 12-24.

[4]. L. Lou, Design and Implementation of a Supervision Software System for Fire-Fighting Simulated Training System, *Automation & Information Engineering*, Issue 4, 2007, pp. 22-24.

[5]. B. Son, Y. Her, J. Kim, A Design and Implementation of Forest-Fires Surveillance System based on Wireless Sensor Networks for South Korea Mountains, *International Journal of Computer Science and Network Security*, Vol. 6, Issue 9B, 2006, pp. 124-130.

[6]. D. Arnoldo, A. Luis, A. Jorge et al., Wireless Sensor Networks and Fusion Information Methods for Forest Fire Detection, *Procedia Technology*, Vol. 3, 2012, pp. 69-79.

[7]. K. Sha, W. Shi, O. Watkins, Using Wireless Sensor Networks for Fire Rescue Applications: Requirements and Challenges, in *Proceedings of the Conference on Electro-information Technology*, 7-10 May 2006, pp. 239-244.

[8]. S. Bhattacharjee, P. Roy, S. Ghosh, et al., Wireless sensor network-based fire detection, alarming, monitoring and prevention system for Bord-and-Pillar coal mines, *Journal of Systems and Software*, Vol. 85, Issue 3, 2012, pp. 571-581.

[9]. C. Zhao, X. W. Hai, X. H. Jiang, B. Gao, Coal Mine Environment Monitoring with Wireless Sensor Networks, *International Journal of Advancements in Computing Technology*, Vol. 5, Issue 1, 2013, pp. 505-514.

[10]. B. Sudipta, R. Pramit, G. Soumalya et al., Wireless sensor network-based fire detection, alarming, monitoring and prevention system for Bord-and-Pillar coal mines, *Journal of Systems and Software*, Vol. 85, Issue 3, 2012, pp. 571-581.

[11]. A. Yunus Emre, K. Ibrahim, U. Özgür, A framework for use of wireless sensor networks in forest fire detection and monitoring, *Computers, Environment and Urban Systems*, Vol. 36, Issue 6, 2012, pp. 614-625.

[12]. X. Li, Research on Application of Wireless Sensor Network in Ecological Monitoring, *International Journal of Digital Content Technology and its Applications*, Vol. 7, Issue 3, 2013, pp. 374-380.

[13]. A. Tiago Faustino, Q. Manuel Rodrigues, D. Carlos Moreira et al., Wireless communication solution for health care equipment, *Sensors and Transducers*, Vol. 142, Issue 7, July 2012, pp. 95-104.

[14]. Y. Liu, X. Yuan, Y. Chen et al., Dynamic Localization Research for the Fire Rescue System, *Procedia Engineering*, Vol. 15, 2011, pp. 3282-3287.

[15]. X. Wu, D. Tang, A Centralized Location Algorithm based on RSSI in Large-Scale Wireless Sensor Network, *Procedia Engineering*, Vol. 15, 2011, pp. 2004-2009.

[16]. F. Nicolas, C. Yoann, C. Eric, Embedded wireless system for pedestrian localization in indoor environments, *Sensors and Transducers*, Vol. 14, Special Issue, 2012, pp. 211-227.

[17]. J. Chen, RSSI-based indoor mobile localization in wireless sensor network, *International Journal of Digital Content Technology and its Applications*, Vol. 5, Issue 7, 2011, pp. 408-416.