Wireless Sensor Network based Smart Home with Object Locating system for old age population

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Abstract— The objective of this paper is to monitor environmental parameters and find lost objects, based on Wireless Sensor Networks built using ZigBee technology. Existing indoor positioning systems help find objects using technologies like RFID, Wi-Fi, Bluetooth, etc. Recent advances in the industry standards and lightweight wireless networking hardware suggest that ZigBee is found to be well suited for Smart homes and automation systems. This paper aims at developing a Smart Home system integrated with an object locating system. In this system, various sensors like temperature sensor for fire detection, LPG sensor gas leakage detection and Magnetic contact sensor to determine whether any door has been left open, are deployed. In case of any emergency, a warning message is generated, and played through a loudspeaker and an SMS is sent to the caregiver, simultaneously. When the user wants to find an object he/she can click on the relevant icon on the front panel of the LabVIEW screen which transmits a message to the lost object. The tag attached to the lost object then calculates the RSSI from each reference tag and replies the reader with the identity of the nearest reference tag along with the distance from that tag. An indication of the object location is then provided within a circle of radius of this distance. Thus, safe, sound and secure living can be provided to older people.

Index Terms— Wireless Sensor Networks, Smart Home, ZigBee, LabVIEW, Object Locating System, temperature, LPG, door sensor, Arduino.

1 INTRODUCTION

IT is observed that the population of older people is growing rapidly. There are surveys which have revealed that the percentage of elderly population has gone up from 6.0 to 8.0 percent during the period of 1991 to 2011 due to better education, health facilities and increase in life expectancy [1]. These days many older people have to stay alone, independently instead of old age homes. People generally experience memory loss as the age increases. They tend to forget basic things like switching off lights/fan, etc. They may forget switching off any electrical appliance or gas stove, which may be dangerous for them. In case they forget to close the doors, it may lead to thefts. Also, it is common for them, to misplace daily use objects like walking stick, medicine box, etc. and keep searching for them.

Hence, a wireless sensor network based smart home and object locating system for older people is developed to assure them a safe, sound and secure living with the convenience of finding misplaced objects.

Nowadays, WSNs has become an attractive field for research as well as scientific and technological developments. WSNs are different from traditional wireless networks and hence, pose more challenges like limited energy, restricted life time, limited security, etc. with the benefit of easy installation, low maintenance, etc. Wireless Sensor Networks (WSNs) comprise of a large number of tiny devices equipped with one or more sensors, some processing circuits, and a wireless transceiver. Such devices are called sensor nodes or motes. These *sensor nodes* are densely deployed either inside the phenomenon to be sensed or very close to it. The size of a sensor node is small enough to allow easy and random deployment of a large number of motes into remote and inaccessible environment. Parameters like temperature, pressure, humidity, light, and chemical activity are constantly reported by these motes which are deployed and left unattended in the field [2].

In a Smart home [3], sensors are used for monitoring general parameters like temperature, humidity, LPG leakage, etc. Thus, with the development of wireless network technology, we prefer low data rate, long battery life, less complex protocols, for such applications as an alternative to wasting bandwidth of high data rate protocols. Short distance wireless communication technologies mainly include Bluetooth, Wi-Fi, ZigBee.

Indoor location sensing systems have become very popular in recent years. These systems provide a new layer of automation called automatic object location detection [4]. Many Real-world applications depend on such automation. For instance, estimating location of products stored in a warehouse, or medical personnel or equipment in a hospital, or firemen in a building on fire.

For the system described in this paper, to monitor various parameters and to locate lost objects in a home, ZigBee technology is employed. ZigBee is a worldwide open standard for wireless radio networks in the monitoring and control fields. The development of ZigBee technology was done by the IEEE 802.15.4 committee and ZigBee Alliance, to meet the following principal needs [5]: (1) low cost, (2) ultra-low power consumption, (3) use of unlicensed radio bands, (4) cheap and easy installation, (5) flexible and extendable networks.

In this paper, mesh topology [4] is employed for communication between devices wherein, each device can communicate directly with any other device by establishing a successful communication link.

In Section II, the block diagram of the entire system is

explained. Section III gives the details of the system with the components used in designing the system. The implementation and results obtained by the system are mentioned in Section IV followed by conclusions and future developments in Section V.

2 System Overview

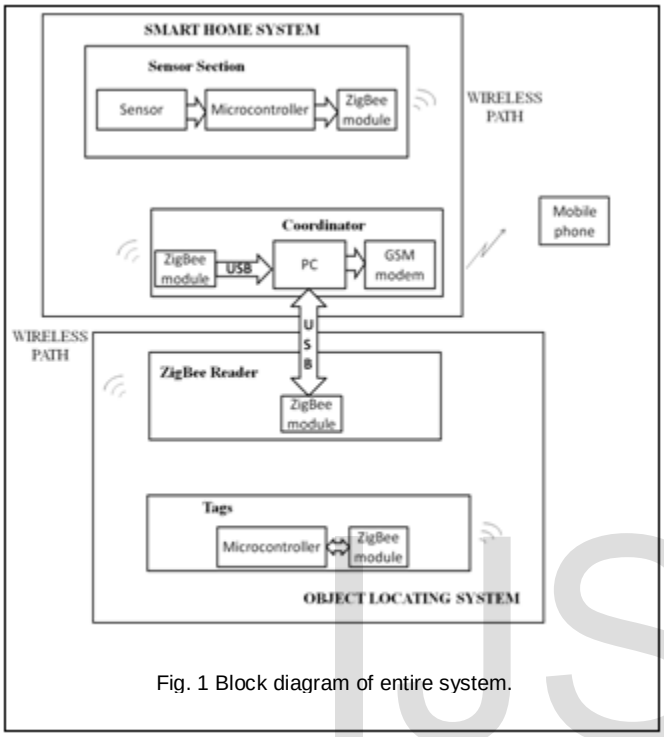

Fig. 1 Block diagram of entire system.

Fig. 1 shows the block diagram of Smart Home with Object Locating system. In Smart Home system, various sensors monitor parameters and transmit to the coordinator. The coordinator then takes action if any critical condition occurs. In Object Locating system, user clicks on the lost object on the front panel, which then transmits back the identity of the nearest reference tag along with the distance from that tag. Accordingly, the region where the object may be present is marked on the layout of the room in LabVIEW.

The sensor section in Smart Home consists of a temperature sensor for sensing the environment temperature, LPG leakage sensor for sensing LPG concentration and Contact sensor to sense whether any door is left open. The sensors generate analog voltage which is fed to the analog pin of the microcontroller. The microcontroller then converts this analog data into digital and forwards it to the ZigBee module for transmission. ZigBee module transmits the received values to the Coordinator. At the coordinator, another ZigBee module receives the data and sends it to LabVIEW installed on the host computer. In LabVIEW, the received data is compared to a set threshold. If the received value exceeds the set threshold, a warning alarm is played through the loudspeaker and a SMS is simultaneously sent to a caregiver through a GSM modem.

A ZigBee module along with a microcontroller is called as a *Tag*. Four reference tags are deployed at four corners of a room. ZigBee reader is equipped with a PC installed with LabVIEW and a ZigBee module. User clicks on the object to be found on the front panel in LabVIEW which transmits a message to the lost object. The lost object then calculates the RSSI from each reference tag and replies the reader with the identity of the nearest reference tag along with the distance from that tag. Taking this distance as radius a circle is drawn indicating the region in which the object may be located.

3 Details of the System

The hardware components used for designing the prototype described in this paper are:

3.1 LM35 Precision Centigrade Temperature Sensor

LM35 sensor [6] is an accurate integrated-circuit temperature sensor. The output voltage of LM35 is linearly proportional to the Celsius (Centigrade) temperature. External calibration need not be done for LM35. LM35 measures temperature within the range of -55°C to +150°C and detects fire.

3.2 *MQ-6 Gas Sensor*

It is a simple gas sensor [7] which is highly sensitive to LPG, iso-butane and propane. The output of MQ-6 is an analog resistance. MQ-6 can detect LPG gas in concentration of 200-10000ppm.

3.3 Magnetic contact switch

This magnetic contact switch or door sensor [8] is used to determine the door position. It is used to detect whether a door is open or closed.

3.4 Arduino MEGA 2560

The ATmega2560 AVR [9] comes with an entire set of program and system development tools including: macro assemblers, C compilers, in-circuit emulators, program debugger/simulators and evaluation kits. The ATmega2560 has excellent interfacing capability with XBee modules.

3.5 XBee Series 2 module

XBee [10] is a microcontroller made by Digi which uses the Zigbee protocol. The RF data rate given by this XBee module is 250kbps since it operates in ISM 2.4GHz band. There exists a simple connectivity between Arduino and XBee modules. Arduino TX directly connects to XBee RX (Data in) while Arduino RX directlyconnects to XBee TX (Data out). Also, data sent to Serial.print() will go out to TX port of Arduino which is then connected to the RX port of XBee. The XBee module is configured using X-CTU software.

3.6 Arduino XBee Shield

The XBee shield [11] allows an Arduino board to communicate wirelessly using Zigbee. It is based on the XBee module. It can be used as a serial/USB replacement or you can put it into a command mode and configure it for a variety of broadcast and mesh networking options. The shields breaks out each of the Xbee's pins to a through-hole solder pad. It also provides female pin headers for use of digital pins 2 to 7 and the analog inputs, which are covered by the shield.

3.7 GSM SIM 300 modem

This GSM Modem [12] can recognize any GSM network operator SIM card and act just like a mobile phone with its own unique phone number. Advantage of using this modem is that you can use its RS232 port for communication. The modem can either be connected to PC serial port directly. It can be used to send and receive SMS or make/receive voice calls.

3.8 Arduino Nano 328

The basic requirement of the microcontroller used for designing a tag is small size. Since Arduino Nano is small in size, it is selected. The Arduino Nano [13] is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.x) or ATmega168 (Arduino Nano 2.x). It works with a Mini-B USB cable instead of a standard one.

The softwares used for designing the system described in this paper are:

3.9 Arduino IDE

The Arduino integrated development environment (IDE) [6] is a cross-platform application written in Java, and derives from the IDE for the Processing programming language and the Wiring projects. The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. It runs on Windows, Mac OS X, and Linux. The environment is written in Java and based on Processing and other open-source software. A program or code written for Arduino is called a "sketch". Arduino programs are written in C or C++. The Arduino IDE comes with a software library called "Wiring" from the original Wiring project, which makes many common input/output operations much easier.

3.10 X-CTU

X-CTU is open-source software. X-CTU is XBee-Configuration and Test Utility software. X-CTU [16] is a Windows-based application provided by Digi. This program was designed to interact with the firmware files found on Digi's RF products and to provide a simple-to-use graphical user interface to them.

3.11 Fritzing

Fritzing is an open source software initiative to support designers and artists ready to move from physical prototyping to actual product [17]. The software is created in the spirit of the Processing programming language and the Arduino microcontroller and allows a designer, artist, researcher, or hobbyist to document their Arduino-based prototype and create a PCB layout for manufacturing. Fritzing can be seen as an electronic design automation (EDA) tool for non-engineers: the input metaphor is inspired by the environment of designers (the breadboard-based prototype), the output is offering nearly no options and is focused on accessible means of production.

3.12 Edraw Max

Edraw Max is licensed software. Edraw Max is a2D business technical diagramming software which help create flowcharts, organizational charts, mind map, network diagrams, floor plans, workflow diagrams, business charts, and engineering diagrams [18]. It is only available for Windows. Edraw Max gives users a Visio-like, professional quality diagramming tool.

3.13 LabVIEW

LabVIEW [7] is licensed software. LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a highly productive graphical programming language for building data acquisition and instrumentation systems. It is a graphical programming language that uses icons to create applications instead of lines of text to create applications. LabVIEW programs are called virtual instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters. Although there are many different software's in market for building virtual instruments such as LabWindows/CVI (C for Virtual Instrumentation), HP VEE (Hewlett-Packard's Visual Engineering Environment), TestPoint and Measurement Studio, LabVIEW has superseded all of these due to its unique features.

4 Designed System and Results

Fig. 2(a) shows the implemented temperature sensor module. Fig. 2(b) shows the implemented LPG sensor module. Fig. 2(c) shows the implemented magnetic contact sensor module. Fig. 2(d) shows the implemented tag used in Object Locating system. Fig. 2(e) shows the coordinator for Smart Home system and the reader for Object Locating system connected to a laptop. The GUI is designed in LabVIEW.

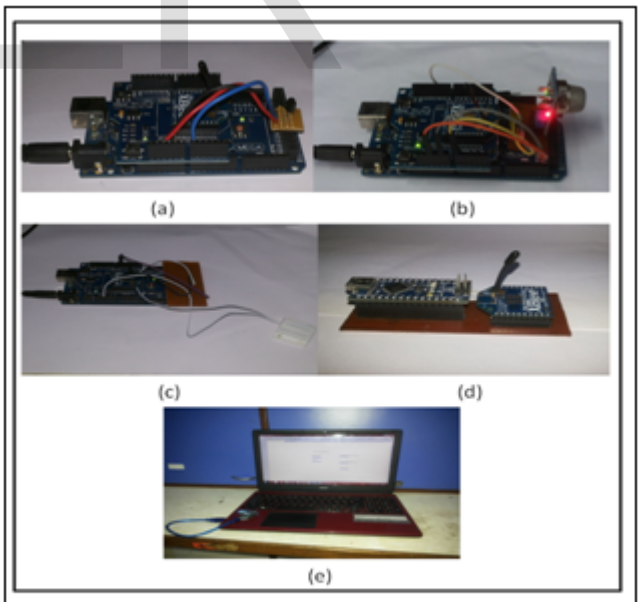

Fig. 2 (a) Setup of the temperature sensor, (b) Setup of the LPG sensor, (c) Setup of the door sensor, (d) Designed tag, (e) Coordinator and reader.

Fig. 3 shows the front panel of the Smart Home system. First tab is for the Parameter Monitoring system wherein the parameters like Temperature, LPG concentration and door status are displayed. Second tab is for the Object Locating system.

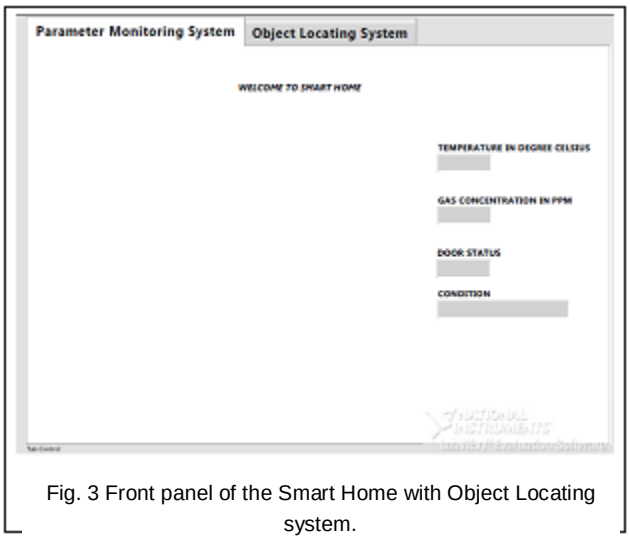

Fig. 3 Front panel of the Smart Home with Object Locating system.

As shown in Fig. 4, the lost object is found and region where it is present is marked. The nearest reference module is displayed as 2 and its distance from lost object is 3.68 metres. The actual distance of reference module 2 from lost object is 3.3 metres.

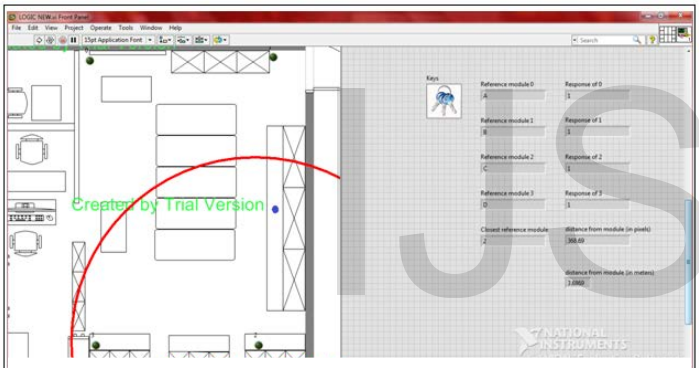

Fig. 4 Front panel showing the location of object near reference module 2 at a distance of 3.68 metres.

As shown in Fig. 5, the lost object is found and region where it is present is marked. The nearest reference module is displayed as 0 and its distance from lost object is 2.15 metres. The actual distance of reference module 0 from lost object is 2.1 metres. Also, the lost object is placed 0.42 metres below the height of the reference module 0.

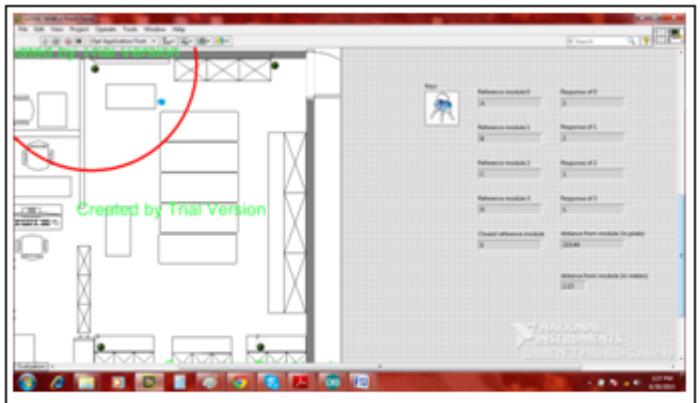

Fig. 5 Front panel showing the location of object near reference module 0 at a distance of 2.15 metres.

TABLE 1
Results obtained by the Object Locating system in a room of 7.74 metres x 5 metres

Sr. No.	Nearest reference module	Actual distance from nearest reference module (in metres)	Estimated distance from nearest reference module (in metres)	Error (in metres)
1	1	2	2.51	0.51
2	3	2 (0.4 metres below)	1.84	-0.16
3	2	0.56	0.73	0.17
4	2	0.9	1.16	0.26
5	3	1.5	1.35	-0.15
6	0	2.1 (0.42 metres below)	2.15	0.05
7	1	2.5	1.99	-0.51
8	3	3.2	2.92	-0.28
9	2	3.3	3.68	0.38
10	0	4.3	4.29	0.01

The mean square error (MSE) for one room is found to be less than or equal to 0.08902 metres.

As shown in Fig. 6, the lost object is found and region where it is present is marked. The nearest reference module is displayed as 3 and its distance from lost object is 1.16 metres. The lost is placed at a height of 1.2 metres above a metallic cupboard just besides the reference module 3.
Fig. 7 shows the front panel when a lost object is detected near reference module 1. The closest reference module is detected as 1. The distance from the nearest module to the lost tag is shown as 1.58 metres. Actually the tag is placed 1.6 metres away from the reference module 3 as illustrated by blue spot. A red colour circle with radius of 1.58 metres is drawn on the layout of the room which is the region where the object may be located.

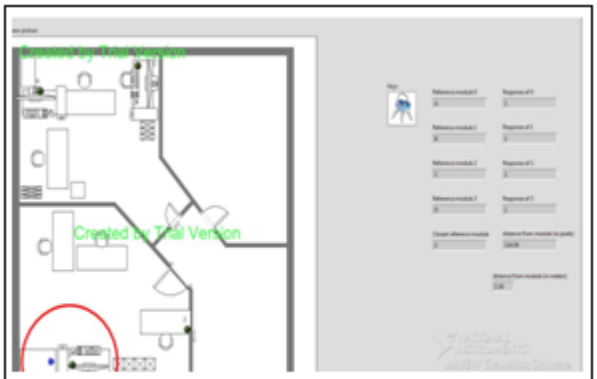

Fig. 6 Front panel showing the location of object near reference module 3 at a distance of 1.16 metres.

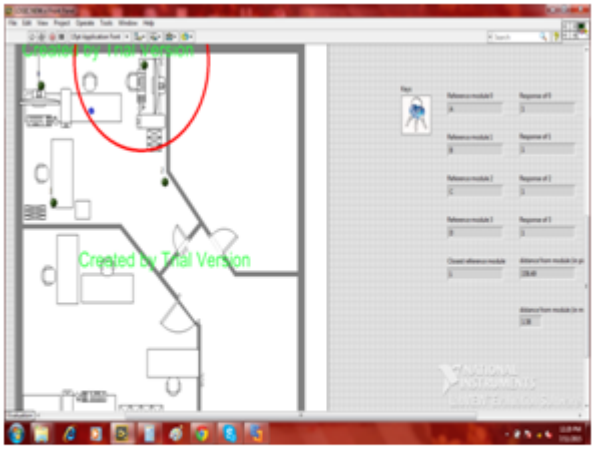

Fig. 7 Front panel showing the location of object near reference module 1 at a distance of 1.58 metres.

TABLE 2
RESULTS OBTAINED BY THE OBJECT LOCATING SYSTEM IN AN AREA OF 7.9 METRES X 8 METRES WITH 3 ROOMS AND WALLS AND GLASSES AS INTERFERENCE BETWEEN THEM.

Sr. No.	Nearest reference module	Actual distance from nearest reference module (in metres)	Estimated distance from nearest reference module (in metres)	Error (in metres)
1	3	0.2 (0.76 metres below)	2.51	2.31
2	3	0.5 (1.24 metres above, on a metallic cupboard)	1.16	0.66
3	2	1.4	2.92	1.52
4	1	1.6	1.58	-0.02
5	1	1.73	1.71	-0.02
6	0	2.1 (at height of 0.4 metres)	2.32	0.22
7	1	2.55	2.71	0.16
8	1	3.0	2.92	-0.08
9	2	3 (at height of 0.5 metres)	1.35	-1.65
10	2	1 (0.76 metres below)	1.35	0.35
11	0	0.8 (0.5 metres above, on a metallic cupboard)	1	0.2

The mean square error (MSE) for three rooms with walls and glasses as interference is found to be less than or equal to 0.9989 metres

5 CONCLUSIONS AND FUTURE DEVELOPMENTS

The ZigBee protocol is an ideal selection for the parameter monitoring application because of its features like low data rates, low power consumption, etc. The Smart Home system displays the parameters like temperature, LPG concentration and door status continuously and alerts the user under any critical conditions. The location of the object obtained is approximate and can be within a cylinder of radius of circle drawn on layout with any height above or below the reference tags. The mean square error in locating objects in a room of size 7.74 metres x 5 metres is less than equal to 0.08902 metres while in a room of size 7.9 metres x 8 metres with walls and glass panes as interferences is less than equal to 0.9989 metres. Thus, ZigBee also serves as a good technology for tracking devices. Whenever any wooden or glass structure is between the lost object and the reference modules, the RSSI decreases. If the object is enclosed in a metallic cabinet, the lost object will not receive any data and cannot be located. The Object Locating system is found to be scalable to a home of 3 rooms as mentioned. The Smart Home system can be extended by integrating more number of sensors to measure various parameters for, instance, a humidity sensor or an optical sensor to determine the humidity. Also, any other system like intrusion detection may be integrated with this system.

More number of objects can be accommodated in Object Locating system so as to find them in the home. The object finding algorithm can be made more accurate and precise by using techniques like Triangulation, Trilateration, Scene analysis, etc. The geometrical method can also be used to show the precise position of the lost object on the layout.

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