Implementation of a WSN based Home/Office Automation (HOA)

Usha Sharma, S.R.N. Reddy

Abstract -Wireless sensor network in home/offices are easy to establish without using cables and offers a greater coverage. This paper presents the design and implementation of a wireless sensor network for automating the home or offices. The developed system consists of sensor node and master node which are organized into a star topology network by ZigBee communication. The system is used to monitor and control the temperature, light, fire, gas leakage, water leakage and intrusion in home/office environment. User can take action to restrain the alert condition through computer or switches connected to master node. Through the experiments, the feasibility and practicability of the system has been checked and the results are interpreted in this paper. The designed system provides a flexible and low cost solution for us to make our home/office smarter.

Keywords- Home/office automation, WSN, Zigbee, sensor node

1 INTRODUCTION

Nowadays, home automation using wireless communication is replacing the wired system which was difficult to setup. Wireless sensor networks (WSNs) have been utilized all over the world. The wireless sensor networks can be used in many consumer and industrial applications, such as machine health monitoring and control, environment and habitat monitoring, biomedical health monitoring, home automation, traffic control, natural disaster relief, and seismic sensing. There are a number of studies which says that Wireless sensor networks are a cost effective solution for collecting, receiving and transmitting data. The home/office automation consists of security, heating, ventilation, and air-conditioning (HVAC), lighting control, access control, electrical appliance control.

To understand methods and technology required for the design of a home/office automation based on WSN, wide varieties of Monitoring and Control Systems for home applications have been studied [1-22]. The primary difference was in the application area; the communication link used for the exchange of monitoring and control information and the H/W, S/W platform used for the implementation.

Ming Xu et. al. [1] design and implemented a WSN for smart home WSN consisting of sensor nodes and the coordinator node. To solve the problem of routing for multi-hop communication, an improved Dijkstra algorithm has been used. The nodes communicate with each other using Zigbee technology. A monitoring system is built using the GPRS network. For the sensor node MSP430 Microcontroller is used which is ideal choice for wireless applications and embedded systems.

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The coordinator node communicates with the sensor node through the GSM modem. A case study of low power WSN implementation for forest monitoring using GPRS module is introduced in [15].A Zigbex ubiquitous sensor network is another approach for home electrical appliance control is described in [2]. Zigbex is a physical simulator consisting of hardware and software programmes that can replace wired home appliance control. The hardware part of this paper consists of a server, personal computer, a base node and another node as the actuator part. The software application is programmed using the TinyOS programming code and also the nesC programming. A Zigbex mote is used as a home module that consists of an 8-bit low power micro-controller namely ATmega128L, C2420 low power RF transmitter/receiver which supports IEEE 802.15.4, a 2.4 GHz PCB antenna, sensors and LED indicator.

In [3] Jun Zhang presents the design and implementation of a wireless monitoring system for smart room architectures in home environments. The proposed system consists of wireless sensor nodes and actuator nodes which are organized into a monitoring network using ZigBee protocols. A base station and some general wireless nodes have been developed to form a prototype system to demonstrate the working of smart homes. The general wireless node can be easily integrated with various sensor and actuator modules for various home automation applications. Besides the sensors used for detecting physical environmental changes such as temperature, humidity and light, some other sensors for detecting event status changes are also considered. The RS232 interface is also used to establish connections to fixed user terminals nearby, such as the desktop PCs and other terminals equipped with serial ports. The USB port has been used to connect peripherals and is also used to install and update the embedded operating system. The provision for Bluetooth interface is used to provide wireless access for local users holding a handheld or wearable terminal such as a PDA or a mobile phone.

The home automation system with zigbee communications are described in [4, 9, 12]. In [4] Zigbee based WSN for HA uses a CC2430 SoC platform has been used for the implementation. This system has simple structure, high practicability and high reliability. The two way remote control ability via sms in WPAN with multi-hop capability is described in [9] which is an attractive feature. While in [12] a workspace having sufficient coverage for the house using WSN was prepared. It consists of development board, evaluation H/W, and smart code generator BeeKit, CodeWarrior IDE for S/W.

Some other applications like environmental monitoring, detection of gas leakage, habitat monitoring with WSN were proposed in [13, 14, 18, 19].A wireless sensor node has been implemented to assist in extinguishes fire with real time information regarding the location and spread of the fire in [13]. To indicate the specific location of fire accident and

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no. of people struck inside the room, PIR sensors are used. In [14] a polyhouse application has been designed using a wireless sensor node based on ATmega8L microcontroller. The RF module Zigbee has been used to provide secure data transmission. A multi-functional heat-pulse probe with wireless communications for measurement of temperature, thermal properties, water flow, and water content of the soil has been proposed in [18]. JVM is used to hide the system heterogeneity in developing the environmental application. Yu Chengbo design a WSN based on zigbee technology using CC2430 board for the greenhouse of vegetables in [19].

In [5], home automation system controlled by internet is described. The master node establishes the communication to the computer via an RS232 interface. The communication between the master and the slave nodes is established through RF mode. The modulation of the RF communication is done using an FM modulator working at 433MHz frequency and 9600Kbps speed. The RF is a low cost communication decision and the reliability has proved to be sufficient for a reliable communication. The master node is connected to the sub nodes and to the computer through a switching circuitry. The information that is sent and received is simultaneously displayed on the output device like LED. The system is secured for access from unauthorized user through an SSL algorithm protected server. The users have to acquire login and password to access to the site. This adds protection from unauthorized accesses.

Dipanjan Bhattacharjee [6] presents design and development of intelligent sensor node for environmental monitoring. The node have with multimode sensors for sensing different environmental parameters, the node can sense four different environmental parameters, light, temperature, humidity, and three different types of gases. The node has half duplex wireless communication feature and to achieve it an IEEE 802.15.4 standard compliant transceiver is used. Here various intelligent protocols have been used to achieve intelligent power management and precision sensing. The nodes have various error detection and correction capability which enhanced the performance of the node.

In [7] various aspects and challenges for home and building automation applications are discussed. Relevant standards are surveyed. A wireless extension to KNX/EIB based on tunneling over IEEE 802.15.4 has presented. The properties of the KNX/EIB wired medium are emulated by this design which allows a seamless extension.

There are three alternate control mechanisms for the home automation: GSM, Internet and Speech [8]. Remote Monitoring station (Home automation server) is implemented on the PC and has four main elements namely: Web Server, Database, Main Control Program and Speech Recognition Program. The engine running on the server communicates with the devices using the main control program which in turn communicates with the transceiver node using serial communication. It monitors the status of the various devices in the home and allows the user to change their settings. Each transceiver unit communicates with the appliance nodes using RF to monitor and control them. Each appliance node has a RF transceiver, Microcontroller and the I/O device. GSM modem is connected to the home automation server to receive the SMS from the control unit for controlling and checking the status of the various elements. When the user is inside the home then devices can be controlled using voice based commands. For this purpose another engine is written for speech recognition which receives voice commands from the microphone and processes them in order to control the appliances. Dynamic Time Wrapping algorithm is used in the implementation. The control unit is implemented on the mobile phone in the form of the interactive software written in J2ME platform and can be used in any JAVA enabled phone. The system is highly reliable as it provides three alternate mechanisms of communication. It provides complete, powerful and user friendly way of real-time monitoring and control. It is secured with login and password. Limitation of the system is that it is quite complex and voice processing when the user is inside the house is found to be too impractical as it leads to constant processing overhead as well as false voice activation.

A different kind of approach is presented by Erich Leder [13]. A special sensor interface has been developed, which allows the measurement of (slow) analog signals to be determined by inexpensive digital PLC input terminals. The communication is digitized with the digitalization of the sensor modules, based on the implementation of a PIC Microcontroller. It provides more intelligence to the module, which increases the power and flexibility of the whole system. Finally a wireless sensor-system consisting of a base station and of a mobile measuring unit is developed. This microcontroller based structure offers digital and analog input-ports and makes the sensor module suitable for the flexible use with different types of analog and digital sensors. A user interface is provided with an alphanumerical LCD and push-buttons which allows the user to configure the settings of measurement and data communication.

Most of the previous researches focus on monitoring system and specific application scenarios. How to design a complete wireless monitoring and controlling system architecture for HA applications still need to be further investigated. The parameters like gas and water leakage are untouched.

2 HOA SYSTEM OVERVIEW

Wireless sensor network (WSN) refers to a group of spatially dispersed and dedicated sensors intended to monitor and record the physical conditions of the environment and organizing the collected data at a central location. The WSN is built of sensor nodes, from a few to several thousands, where each node is connected to one or several sensors.

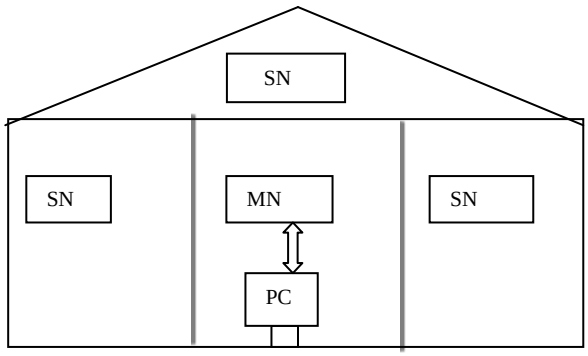

Figure 1 General architecture of WSN for HOA

The flowing of data ends at special nodes called base stations (master node).

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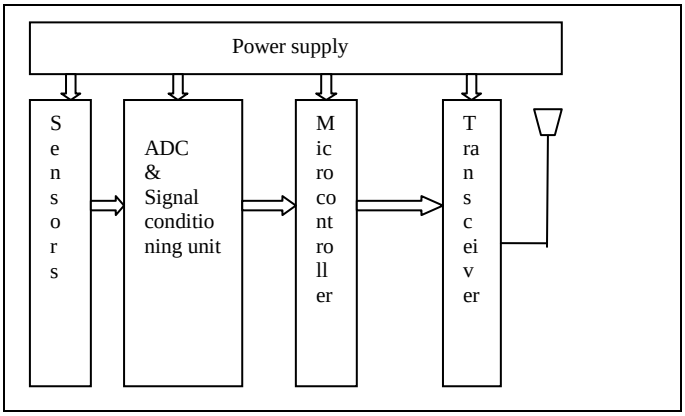

Figure 2 Block diagram of sensor node

A base station links the sensor network to another network (e.g. gateway) to distribute the data sensed for further processing. Base stations have enhanced capabilities over sensor nodes since they must do complex data processing. Therefore base stations have laptop or PC for enough memory storage and computational power to perform their tasks well. Sensor nodes are organized into any topology. The communication within a network must travel through the sensor node, then it is forwarded to a sink or head of the nodes until it reaches its destination, the base station. For saving energy, it is required to set the nodes to go into sleep mode if they are not needed and wake up when required. The main components of a typical sensor node include an antenna and a radio frequency (RF) transceiver to allow communication with other nodes, microcontroller, ADC, the sensor and the power source which is usually provided by batteries. The WSN's master node consists of transceiver to communicate data from sensor nodes, microcontroller, power supply and interface to PC or other network.

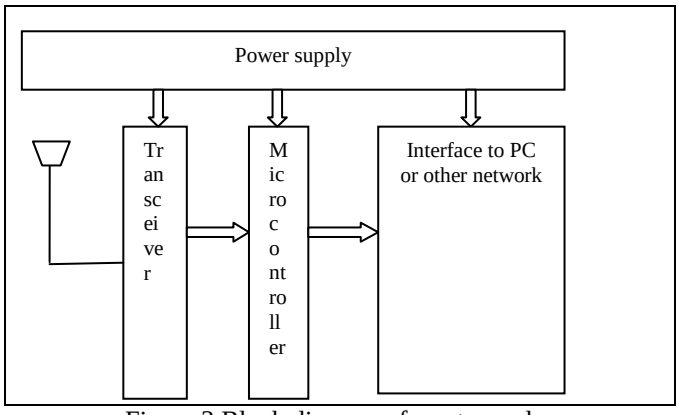

Figure 3 Block diagram of master node

3 HARDWARE ARCHITECTURE OF HOA

Broadly the system may be classified into following two sections.

- Sensor node
- Master node

A master node and sensor node have been developed to form a prototype system. The heart of Wireless Sensor Network based HOA system is the Sensor Node. Sensor node is designed to detect and compute the values of the physical parameters in engineering units. The master node's duty is to transmit the information directed by the computer to the sensor nodes and to transmit the status of physical parameter back to the computer. The master node is connected to the computer via an RS232 interface. The communication between the master node and the sensor nodes is established through Zigbee module. The master node is designed such that it can work as a standalone unit where the computer connectivity is not absolutely necessary to maintain the regular operation of the devices. The modifications or controlling action can also be taken by the switches connected on master node itself.

3.1 Sensor node

Sensor node consists of smart sensors, signal conditioner, the PIC microcontroller, display unit, buzzer, relay and power supply unit. Moreover, for the wireless communication the Zigbee module is employed.

Sensor used – In order to develop the WSN few suitable sensors are used for detecting different physical values. For detecting the temperature, gas leakage, intrusion, fire, and light LM35, MQ2, IR, thermistor, LDR sensor are respectively used. To detect water leakage a simple arrangement of two wires are used. Normally both wires are not connected i.e. open, but whenever there is presence of water, they get connected i.e. short and complete the circuit.

Microcontroller – PIC16F877A is chosen due to its low cost, wide availability, in-built ADC, 33 I/O, powerful interrupt structure, Harvard architecture, on-chip UART, ISP and SPI facility, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability. It is popular with both industrial developers and hobbyists.

Signal conditioning unit -The resistive sensor outputs (MQ-2, IR sensor) are converted to analog voltage by using voltage divider network followed by high impedance amplifier (opamp), this analog voltage is digitized and processed by centralized PIC16F877A µc. PIC has internal 10-bit-ADC which converts analog signal to digital form.

Display unit – A high quality 16 character by 2 line intelligent display module, with back lighting is used as a display unit. It can work with almost any microcontroller and has 5x7 Dot Matrix Character, Cursor.

Actuator unit – These units actually drives the appliances or triggers the devices on master node commands. The driving capability of microcontroller is very low. Thus, we have to use some mechanism to drive the devices operated on higher voltage.

Communication unit - The wireless transceiver xbee S2 module is connected to the port C of the µc and UART protocol has been used for communication. Xbee S2 modules allow a very reliable and simple communication between microcontrollers or computers with a serial port. It can supports point to point and multi-point communication in a network.

Power supply unit - 7805 IC is managing the power supply to the PIC, sensors, buzzer and relays. LM1115 IC is used to generate 3.2 volt which drives zigbee module of the node.

3.2 Master node

Master node consists of a microcontroller, RS-232 unit, power supply unit, buzzer, a zigbee transceiver to communicate with the sensor node and switches.

RS-232 Unit - The serial communication is used between the master node and the computer.

Transceiver - The wireless transceiver xbee S2 module is connected to the port C of the PIC and UART protocol has been used for transmitting and receiving the information.

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Master node sends the commands from the PC unit and takes the statuses of the sensors to be monitored in the main control program of the sensor node.

I/O devices - These are the devices which perform the orders given by the microcontroller or display the results through appropriate interfaces. Switches are used to give command to operate relay manually, while buzzer is used to indicate the alert conditions.

Microcontroller - PIC16F877A is used due to its on-chip UART facility which enables serial communication to and from the computer. It is responsible for processing the input conditions and applying the requests that come from the master node.

Power supply - The power supply unit depends on the power requirement of microcontroller and other components used. The main components used in power supply unit are:

- Transformer
- Rectifier
- Input & output filter
- Voltage regulator and
- Output indicator

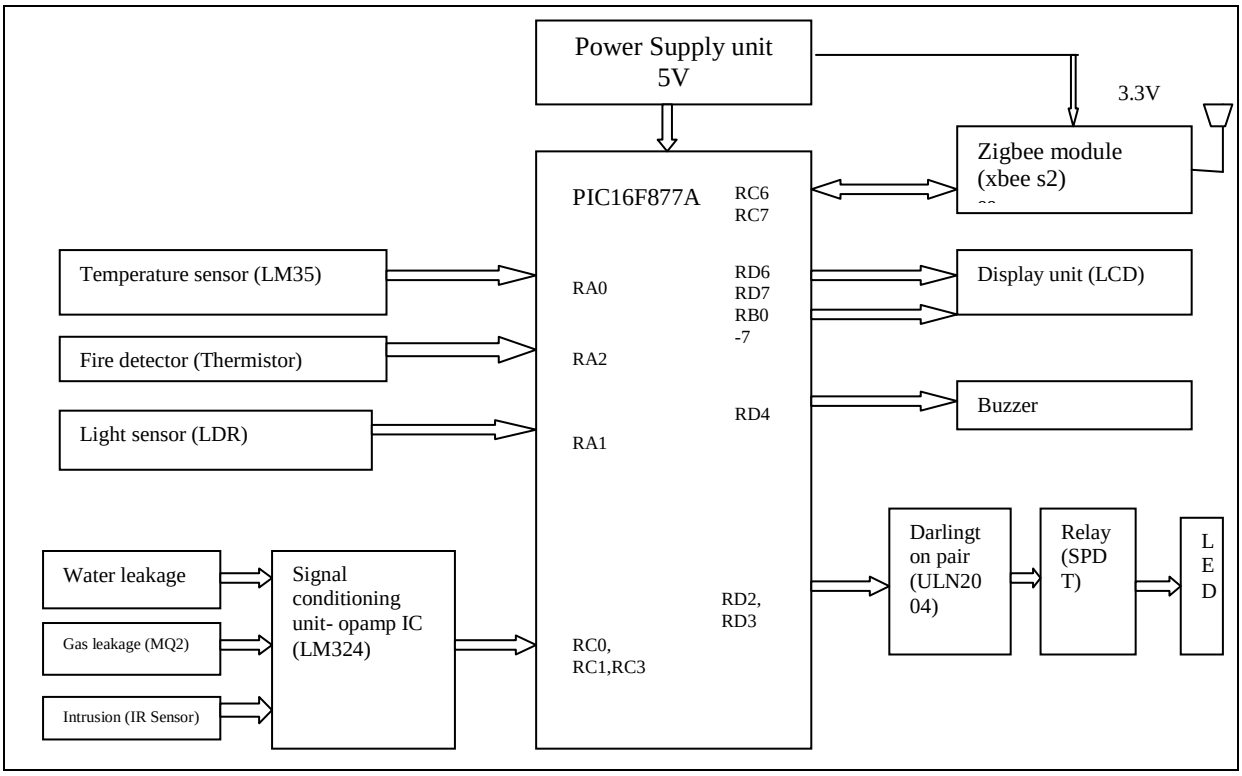

Figure 4 Internal architecture of developed sensor node

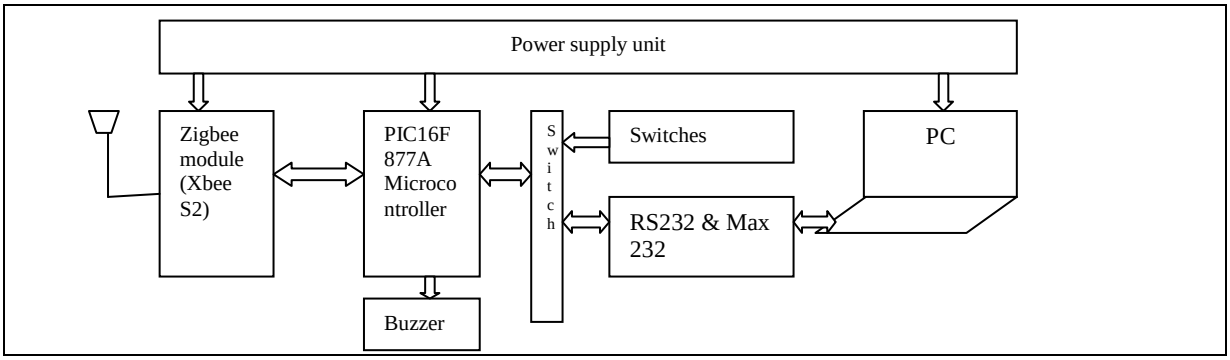

Figure 5 Internal architecture of master node

4 SOFTWARE ARCHITECTURE OF HOA

The HOA system is based on PIC16F877A. Therefore, MPLAB is employed as the IDE and firmware is developed in C language. Along with the main programme the firmware comprises various modules developed for specific tasks. The software part consists of programmingPIC16F877A microcontroller using Hi tech ansi C compiler from Hi-tech Universal Tool suit. The scope of programming includes UART communication programming, LCD character display module programming, BCD to ASCII converter and analog to digital converter programming. All of this programming is done using C language. Figure 6 illustrate the software architecture of HOA system.

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5 IMPLEMENTATION OF HOA SYSTEM

A prototype WSN has been implemented by designing one master node and one sensor node. The developed master node size is 19cm×15cm and sensor node is about 21cm×14cm in size. The PCB of master and slave node are shown in fig. 7 & 8. The communication range of one hop can exceed 40 meters in cluttered indoor environments. The nodes are placed in different room and a communication is setup through ZigBee (XBEE S2) module. Before the commencement of communication, zigbee devices must be configured as coordinator, router or end devices and there PanID should be matched according to their network topologies. The configuration of ZigBee devices is done through X-CTU software.

The developed HOA system offers two important features of a smart home that are security and automation. In home/office security system, the sensor node indicating an unauthorized intrusion, gas and water leakage or a fire by sending an alert signal to the master node through the zigbee serial communication. When the master node receives the alert signal, user will then send the command signal to the sensor node to turn ON or OFF the relays to actuate the required action. PC is attached to the master node controller using RS232 connector. Figure 8 shows the developed master node. In home/office automation system, user can control their house appliances automatically by comparing the required threshold values of light, temperature to turn ON & OFF the chillers, bulbs, tube light etc.

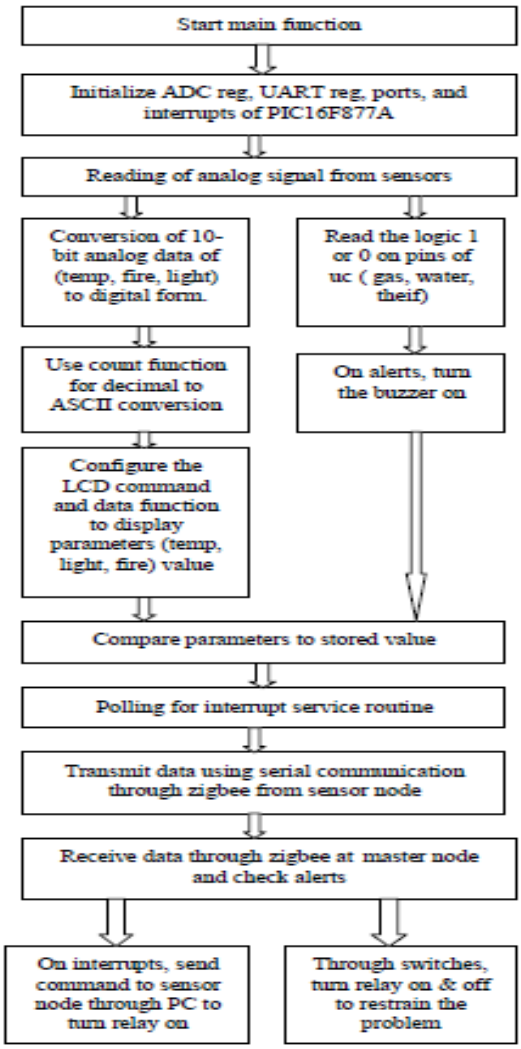

Figure 6 Software architecture of HOA

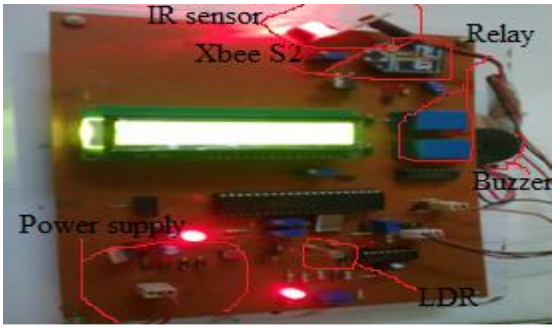

Figure 7 Developed sensor node

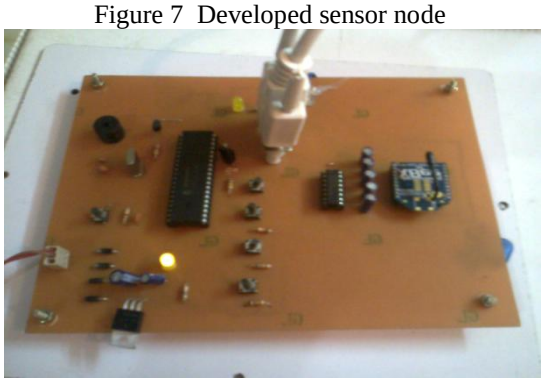

Figure 8 Developed Master Node

6 RESULTS

The sensor node is deployed in star network within 50 meter distance from the master node successfully. However, Xbee S2 can communicate up to 100m without any error. The master node is connected to a personal computer, all data are stored in the computer memory for offline statistical analysis. Figure 9 shows the snapshots of data received on hyper terminal in case of alerts. This light intensity data can be used as the basis for providing additional lighting, and to determine the duration and intensity of supplemental lighting, if necessary. The graph of light against time is depicted in figure 10

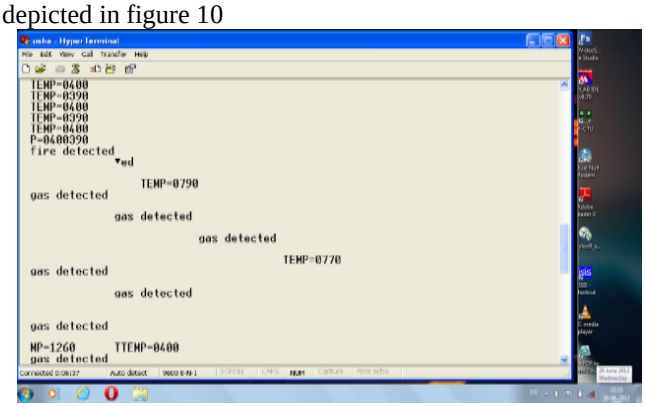

Figure 9 Snapshot of Hyperterminal

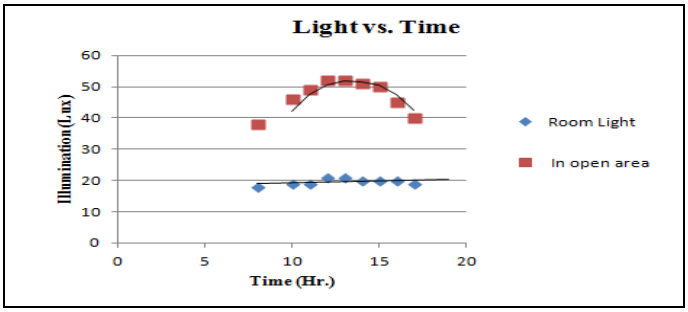

Figure 10 Graph of light reading of open area & inside the room vs. time

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From this graph, it is found that the light of the room remains constant with time compared to open area light.
As the sun moves towards the equator from pole it is observed that the temperature gradually increases to the ambient house temperature at about 12.00 pm. From figure 11, it can be seen that temperature rises to higher than 25°C when the chillers are not ON. Obviously, the heat gain in the house is greater than the cooling capacity of the fans, and action may be required to reduce the house temperature by turning ON the coolers or ac.

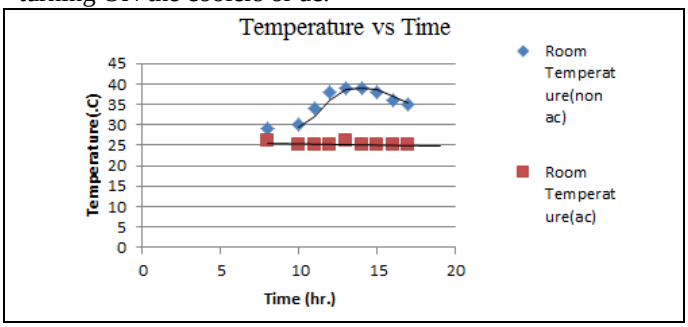

Figure 11 Graph of observed temperature of ac and non ac room vs. time

The temperature (°C) is plotted against time is depicted in figure 12. From this graph, it is found that the temperature of the ac room remains constant with time. Table1 summarizes the actions taken by the user as the alert arrived through the switches or keyboard on the master node. In case of intrusion detection or water leakage only alert will be displayed on the computer. No buzzer will beep to alert the unauthorised person.

Alert received	**Response time**	**Switch /Key pressed**	**LED Indicator 1**	**LED Indicator 2**	**Buzzer**
Fire detected	1-2 sec	SW 1/A	Relay1ON LED 1 ON	LED 2 OFF	Beeps 2 times
----		SW 2	Relay1OFF LED 1 OFF	LED 2OFF	
Gas detected	1-2 sec	SW 3/B	LED 1 OFF	Relay 2 ON LED 2 ON	Beeps 1 times
-----		SW 4	LED 1 OFF	Relay2OFF LED 1 OFF	
Fire & Gas detected	1-2 sec	SW 1/A & SW 3/B	Relay1ON LED 1 ON	Relay 2 ON LED 2 ON	Beeps 3 times
-----		SW 2 &SW4	Relay1OFF LED 1 OFF	Relay2OFF LED 2 OFF	

Table 1 Result table

7 CONCLUSION

Employing embedded technology, based on PIC16F877A microcontroller, the Wireless Sensor Network is designed and implemented for development of WSN for home/office automations. We introduced a low cost, rugged, flexible, reliable and wireless solution to the home/office automation. Zigbee communication makes the system easy to install and in addition, the nodes in the system can easily be expanded to cover more space. The Zigbee module operated at 2.4GHz ISM band really help for secure data transmission. The temp, and light data is continuously observed on the monitor of the sensor node. The supervisor could also get the alerts about fire, gas leakage, water leakage, intrusion in the house or office environment, which could be helpful to provide safe and secure environment to the residents. This system can not only meet the need of the practical use, but also helpful for demonstrate the home automation application to the students. However, there are still many challenges that need to be solved in sensor networks.

REFERENCES

[1] Ming Xu, Longhua Ma"Design and Implementation of a WSN for smart home" 2010 symposia and Workshop on ubiquitious, Autonomic and trusted computing.

[2] Ruhani Ab Rahman, Murizah Kassim "Home Electrical Appliance Control Application Using Zigbex Ubiquitous Sensor Network" 2011 IEEE International Conference on System Engineering and Technology (ICSET).

[3] Jun Zhang, Guangming Song "Design of a Wireless Sensor Network based Monitoring System for Home Automation" 2011 International Conference on Future Computer Sciences and Application.

[4] Yang Li, Ji Maorong "Design of Home Automation System based on ZigBee Wireless Sensor Network" The 1st International Conference on Information Science and Engineering (ICISE2009).

[5] Ali Ziya Alkar "An Internet Based Wireless Home Automation System for Multifunctional Devices" IEEE Transactions on Consumer Electronics, Vol. 51, No. 4, NOVEMBER 2005.

[6] Dipanjan Bhattacharjee "Design and Development of Wireless Sensor Node" (IJCSE) International Journal on Computer Science and Engineering Vol. 02, No. 07, 2010, 2431-2438.

[7] Christian Reinisch, Wolfgang Kastner "Wireless Technologies in Home and Building Automation" 1-4244-0865-2 IEEE 2007.

[8] Baris Yuksekkaya "A GSM, Internet and Speech Controlled Wireless Interactive Home Automation System" IEEE Transactions on Consumer Electronics, Vol. 52, No. 3, AUGUST 2006.

[9] Mohd Adib B. Sarijari ,Rozeha A. Rashid "Wireless Home Security and Automation System Utilizing ZigBee based Multi-hop Communication" Proceedings of IEEE 2008 6th National Conference on Telecommunication Technologies.

[10] Miroslav Mahdal "Implementation of WSN" Transaction of the VSB vol.LVI, article No. 1789, 2010.

[11] Michal VARCHOLA "Zigbee Based Home Automation Wireless Sensor Network" Acta Electrotechnica et Informatica No. 4, Vol. 7, 2007.

[12] B. P. Ladgaonkar and A. M. Pawar "Design and Implementation of Sensor node for WSN to Monitor Humidity of High-tech Polyhouse Environment" International Journal of Advances in Engineering & Technology, July 2011,©IJAET ISSN: 2231-1963.

[13] Erich Leder, Alexander Sutor "Sensor Interfaces for Private Home Automation: From Analog to Digital, Wireless and Autonomous" Sensors & Transducers Journal, Vol.82, Issue 8, August 2007, pp. 1389-1404.

[14] P. N. Narendra Reddy, P. I. Basarkod "Wireless Sensor Network based Fire Monitoring and Extinguishing System in Real Time Environment" Int. J. Advanced Networking and Applications Volume: 03, Issue: 02, Pages:1070-1075 (2011).

[15] Inderpreet Kaur "Microcontroller Based Home Automation System with Security" (IJACSA) International Journal of Advanced Computer Science and Applications, Vol. 1, No. 6, December 2010.

[16] Zoltan Gy. "Case study of a simple, low power WSN implementation for forest monitoring" 12th Biennial Baltic Electronics Conference 2010.

[17] Niladri Sekhar TRIPATHY, Sagarika PAL "Online Remote Recording and Monitoring of Sensor Data Using DTMF

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Technology" Sensors & Transducers Journal, Vol. 128, Issue 5, May 2011, pp. 66-72.
[18] Fredrik Osterlind, Erik Pramsten "Integrating Building Automation Systems and Wireless Sensor Networks" 1-4244-0826-1/0700 © 2007 IEEE.
[19] Yu Chengbo" Zigbee Wireless Sensor Network in Environmental Monitoring Applications" article 978-4244-3692 IEEE 2009.
[20] Niladri Sekhar" Online Remote Recording and Monitoring of Sensor Data using DTMF Technology" Sensor and Transducer Journal, Vol.128, Issue5,May2011, pp.66-72.
[21] S. Edward Jero"Implementation of a simple Wireless Sensor Node for the detection of Gaseous Substances Leakage" International Journal of Smart Sensing and Intelligent System, Vol.4 Sept 2011.
[22] Alan Mainwaring "Wireless Sensor Network for Habitat Monitoring" WSN journal sept.2002 Atlanta.

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