ZigBee Based Wireless Sensor Network Application for Monitoring Health Data of Elderly People

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***Abstract*: Recent developments in wireless technologies and the fabrication of semiconductor miniature sensors are sizing wireless sensor networks smaller and more cost-effective for their applications in various fields of interest. The prospects for wireless sensor network (WSN) technology are strong. Moreover, the ZigBee based WSN is capable to provide reliable, cost-effective, low-power, wirelessly networked monitoring and control products based on an open global standard. It can play an important role in the adoption of Assistive Technology by enabling wireless low-power communication between devices and services that foster safe, healthy and independent living conditions for the disabled or elderly. In this paper, a ZigBee based simple circuit is developed for heath data monitoring application at remotely located systems/subjects. The performance specifications are identified and have been incorporated in the development of the system. The ZigBee provided by digi key XBee Z Net 2.5 series 2 module pair is used as coordinator and router and is interfaced with ATmega 8 micro controller. The microcontroller is programmed for intrusion detection using LDR sensors. The maximum range achievable with a single coordinator-router pair is 2 km. The developed circuit has been tested and found to provide the desired results in terms of distance range and data reliability.**

***Index Terms*--ZigBee, wireless sensor network, miniature sensor, embedded systems, microcontroller, intrusion detection, LDR sensors**

I. INTRODUCTION

A wireless sensor network is made up of a group of sensor nodes or devices. Each device possesses the ability to monitor some aspect of its environment, and each is able to communicate its observations through other devices to a destination where data from the network is gathered and processed. Recent developments in wireless technologies and the semiconductor fabrication of miniature sensors enable the engineers and scientists to reduce the size of wireless sensor networks to a great extent and making the WSN more cost-effective for their growing applications in a number of fields. The prospects for WSN technology are strong in near future. The ZigBee based wireless sensor networks are very effective to provide reliable, cost-effective, low-power, wirelessly networked monitoring and control products based on an open global standard. Its goal is to provide the consumer with ultimate flexibility, mobility and ease of use by building wireless intelligence and capabilities into everyday devices. ZigBee technology is being embedded in a wide range of products and applications across medical, commercial, consumer, industrial and government markets worldwide. Also, for the first time, organizations have a simple, reliable, low-cost and low-power standards-based wireless technology optimized for the unique needs of remote monitoring and control applications. ZigBee can play an important role in the adoption of Assistive Technology by enabling wireless low-power communication between devices and services that foster safe, healthy and independent living conditions for the disabled or elderly. In addition to Assistive Technology, ZigBee applications in the health and fitness domains can address several other market segments and needs.

II. LITERATURE REVIEW

The wireless sensor networks have been applied to so many fields these days due to their reliability and ease of operation. Wan-Chung and Lian et. Al [1] have applied WSN for health data monitoring system using cell phones. They have used a wireless dongles prototype as the intermediary devices to remotely monitor the physiological signs of patient's from a tiny wireless sensor to transmit directly to medical center monitoring/PDA wirelessly within 802.15.4 wireless LAN or using cell phone to relay the medical data through CDMA network when outside the coverage LAN. The external standalone ECG diagnosis was implemented to enable continuous monitoring and evaluation of the ECG signal locally before any medical data could be sent to the medical center. Ling, Li and Gao [2], in their work , have described the green house effect monitoring using ZigBee module. The node and the network coordinator are in normal communication condition, the network stability is fine, the data is consistent with the real environment, and thus wireless sensor networks can meet the requirements in the applications. Barbara , Bencini,

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Magrini and Manes [3] have devised an Intelligent Transportation Systems (ITS). Real time systems capable of providing prompt information, like loop detectors, laser/radar systems and video cameras, were proposed in the past but they are affected by some straits in deployment. In this paper a Traffic Monitoring Wireless Sensor Network system based on acoustic arrays and powered by effective post-processing, is proposed. The system is composed by a hierarchical scheme of Master Nodes and Sensor Nodes linked with a multi-hop protocol. Key features are traffic monitoring and queue detection to be performed in real-time at unprecedented space scale. In [3], have made the art lighting system more artificial intelligent by making them into a whole cluster in which they can monitor and do reaction effects on the environment by using pulse width modulation algorithm. The light-nodes in the system can communicate with each other to transmit commands and data e.g. visitor going across, and then diffuse it to all the light-nodes according to the genetic simulation algorithm. Cullen, Jader and Shaw [4] have i investigated a system that utilises an array of sensors, including current, voltage, infrared and ultrasonic that is capable of monitoring the spot welding process as it is performed. This system utilises wireless sensor technology to transmit data from the welding arms to a sensor connected to a base computer where the data can be analysed. The wireless link is particularly useful when retrofitting the sensor cluster to existing installations. Li, and Li [5] have proposed a multi-parameter wireless sensor network monitoring system based on ZigBee technology for coal mine tunnel. The system can monitor the underground environment and production parameters and intelligently give early warning by using a variety of sensors and wireless sensor network. It is flexible to add sensors and enhance stability of monitoring computer software through RS-485 communication protocol and hardware modular. Experiments have proved feasibility and good stability of the system. In their work ,Wang and ZOU and ZHU [7], have used a web service approach to access ZigBee based wireless sensor networks (WSN) from the Internet by designing a gateway between the internet and WSN in such a way that each node in the WSN has a unique IP as its identifier, and it can be accessed by the IP directly. This enables the building automation users to access the data of the sensor networks flexibly via web services. Jia [9] have described an intelligent LED lighting system based on STC microcontroller. Barbagli, Manes, Langer, and Bacchi [10] have designed a distributed sensor network for real-time acoustic traffic monitoring.

III. ZIGBEE COMMUNICATION PROTOCOL

ZigBee operates at power levels similar to Bluetooth devices and at significantly lower levels of average cell phones. Also, ZigBee's duty cycles (i.e. amount of time the radios are actually on versus off) are thousands times less than Bluetooth devices. There are hundreds of millions of wearable Bluetooth headsets sold every year, and a billion cell phones used everyday. Besides, there are many advantages of ZigBee communication protocol over the others, few of them are as follows.

A. General Features

- ZigBee is very robust and has demonstrated superb tolerance to extreme interference. The Las Vegas Convention Center is one of worst places for wireless devices, especially during the annual Consumer Electronics Show. Interference at that show often impedes many cell phones and Bluetooth headsets from operating correctly. ZigBee has always performed flawlessly in these extreme environments.
- Point-to-point and point-to-multipoint topologies mean the data packet only has a single path to follow and is therefore more vulnerable to interference or blockage. Their ability to cover greater physical distances is limited and the access point in star networks can only talk to a small number of radios on the network. However,
- ZigBee uses Mesh-Networking. Radios in a mesh network can talk to many other radios devices in the network, not just one. The result is that each data packet communicated across a wireless mesh network can have multiple possible paths to its destination. This flexibility makes the mesh network very flexible for accommodating interference in the radio spectrum or something blocking the radio path. Wireless mesh networks also enable networks to grow in size and cover greater physical distances.
- Addition of more devices as and when necessary is very easy in ZigBee network. ZigBee's pairing process allows for fast and easy association between devices.
- Additionally, ZigBee offers a variety of routing algorithms for data packets to find the correct destination, including hierarchical tree, neighbor, and table-based routing. These approaches result in a high degree of flexibility and stability ensuring that devices in the network stay connected and that network performance remains constant even as it is dynamically changing.
- ZigBee is an open, publicly available standard and is equally available to all. As a result there are multiple competitive sources of supply for ZigBee semiconductors creating more choice for product manufacturers. ZigBee also offers quality performance at a lower cost, and provides more standards for use in other markets including health care, energy management and home automation.
- ZigBee is more secured. It is developed with many layers of security. At the strongest level, ZigBee uses AES 128 encryption (government, commercial and military grade encryption used across the internet). In addition, ZigBee defines a security toolbox for key generation and distribution that can

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support multiple modes for residential, commercial, and even industrial applications.

The ZigBee Health Care public application profile has specific security features for rapid key generation and distribution suitable in the medical environments insuring privacy and integrity. No other solution offers a comparable security system.

B. Customized Security

The ZigBee technology based WSN

- Offers out-of-box security for easy use
- Conforms with regional regulatory environments
- Supports access control for consumer, service provider, care provider, or shared networks
- Features scalable support for data security and privacy
- Efficient key generation, distribution and management for home and professional settings

C. Other Features of ZigBee Based WSN

- Long battery life from low-cost coin cells for wearable devices
- Wireless range up to 70m indoors and 400m outdoors with full control of transmitted output power
- Networking flexibility to cover entire campuses
- Open and freely available specification based on international standards
- Supports multiple network topologies encountered in home and professional settings
- Highly scalable solutions for thousands of Devices
- Enables home televisions to display data from medical and non-medical devices
- Integrates control and monitoring devices for lighting, security, occupancy, motion detection and convenience

D. Supported Devices

It is able to provide support for

- IEEE 11073 device specialization profiles
- Medical devices such as glucometer, pulse oximeter, electrocardiograph, weight scale, thermometer, blood pressure monitor, respirometer
- Non-medical devices including social alarm device, personal activity monitor, pill minder, independent living activity hub, fitness equipment
- Data management devices such as mobile phones, PDAs, PCs and notebooks
- In-home data management using low-cost standalone devices such as refrigerator magnets and bedside/desktop health displays

IV. VARIOUS ZIG BEE MODULES

The XBee is very easy and popular wireless device. It is a transceiver, it can transmit data wirelessly and it can also receive data wirelessly. There are several types of XBee modules. The very popular XBee is Series 1 (802.15.4), available with the firmware to create connection of point to point or star network. The XBee Series 1 is not compliance to ZigBee because it uses the low layer of ZigBee protocol only. Therefore, XBee Series 1 (S1) cannot communicate with ZigBee device in the market. The XBee or XBee PRO is basically the same protocol, just PRO modules have better transmit power and better receiver sensitivity. The XBee Series 2 (ZB) does not offer any 802.15.4-only firmware; it is always running ZigBee mesh firmware. It is the latest XBee module available in the market. The XBee S2 have better performance when you talk about mesh networking where it involves lot of nodes: coordinators, routers and end devices. The XBee S2 can not communicate with XBee S1, it is not compatible in term of wireless communication. The XBeeZNet 2.5 modules from Digi are more advanced than the popular XBee Series 1 .

V. MODEL UNDER CONSIDERATION

To accomplish simple remote control between the control panel and the computer or microcontroller to any device such as robot we need two units of XBee S2 pair to configure one of the XBee S2 as Coordinator, another as Router. The major advantage is that beside sending control command to it, it can also give feedback such as light, temperature, battery voltage, etc. We have designed a circuit for re-flashing two XbeeZnet modules with the appropriate firmware and setting them to communicate with each other. The circuit is interfaced with ATmega 8 micro-controller and it is programmed to interface with LDR sensors for intrusion detection. The following components are used to fabricate this model:

1) Two XBeeZNet 2.5 Modules (Digikey Part#: XB24-BWIT-004-ND)
2) XBee Breakout Board (Sparkfun SKU#: BOB-08276 or from NKC Electronics)
3) 2mm, 10 pin XBee socket (Sparkfun SKU#: PRT-08272 or included with NKC kit)
4) Male Header row for XBee breakout (Sparkfun SKU#: PRT-00117 or included with NKC kit)
5) FT232RL Breakout Board (Sparkfun SKU#: BOB-00718) male or female headers for the FT232RL Breakout board, depending on your

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preference
6) LEDs
7) Reset Switch (optional, see below)
8) Breadboard
9) Jumper wires
10) USB miniB cable
11) ArduinoDiecimila
12) XBee Shield from NKC Electronics
13) A computer running Windows

VI. THE FUNCTIONAL CIRCUIT DIAGRAM

The circuit diagram of the model considered in the present study is described in Fig. 1. The circuit is realized using the components listed in the above section of the paper. First XBee bread board is realized and then one of the XBee's plugged into it. All the connections are carried out on bread board as shown in circuit diagram. Instead of using a reset switch, just one end of a jumper wire is plugged into the XBee reset pin and the other end of that jumper is left hanging off the edge of the board. In case the need to reset the XBee is required, momentarily, the bare end of the jumper is touched to ground.

A. Operation of Circuit

The XBeeZNet modules can operate by drawing a maximum current of 40mA. However, the FT232RL can supply a maximum of 50mA on 3.3V pin. Also XBee Pro version, an external 3.3V supply is sufficient for its operation. A suitable circuit as voltage regulator is designed for converting the 5 V power supply into 3.3 V needed for the XBee. Following the switching on the XBee, the software is set to run. For safety point of view, a double checking of the connections, before using the USB-miniB cable to plug the FT232 breakout into a USB port on the computer is recommended. To ensure that the the proper connections are made, both LEDs connected to the XBee must be glow and stay on (assuming that the XBee shipped as a Router/End Device and there is no Coordinator around to connect to). Now the circuit is ready to run X-CTU with XBee. After successful execution of X-CTU software, a screen associated with various output data sheet is obtained. This data sheets are described in Fig.2. A single-click on the USB COM port that the XBee is connected will give the COM port number. The Test/Query" button is used to identify the COM port which has the XBee.

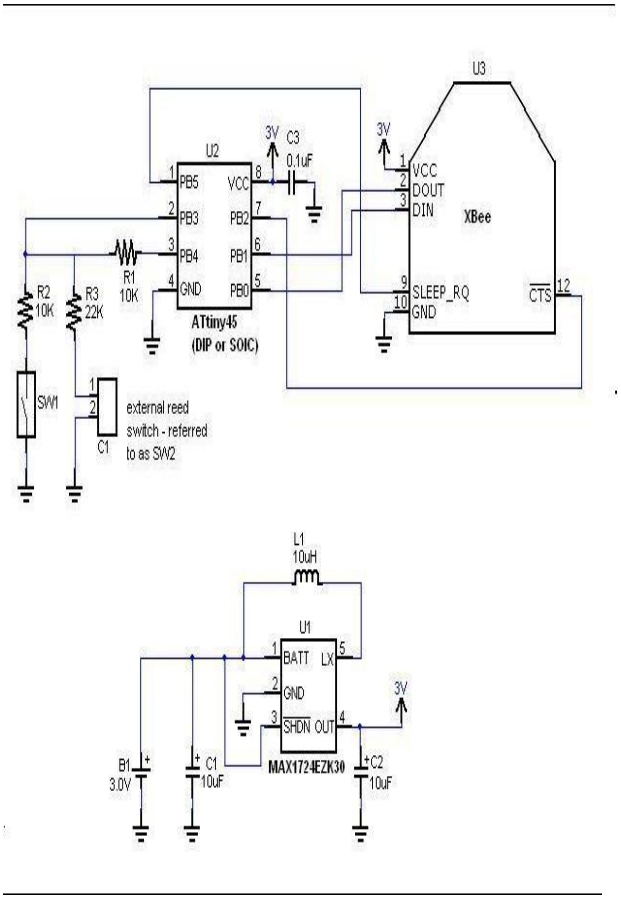

Fig. 1: Circuit Diagram

B. Update the Firmware

For updating the firmware, first "Modem Configuration" tab is clicked and then the "Download new versions…" button is used to download all of the updated firmware. After the completion of firmware downloads, the "Read" button is activated. The window will display all of the current settings of the attached XBee. Select "ZNet2.5 Router/End Device AT" as the firmware in the pull-down menu. Change the "NodeIdentifier" to something like "router1". We can change the "PAN ID" to a unique number ifXBee is used in a place where others will be using their own XBees.Check the box that says "Always update firmware" and click the "Write" button. The X-CTU software may ask you to push the reset button during the firmware upgrade process.

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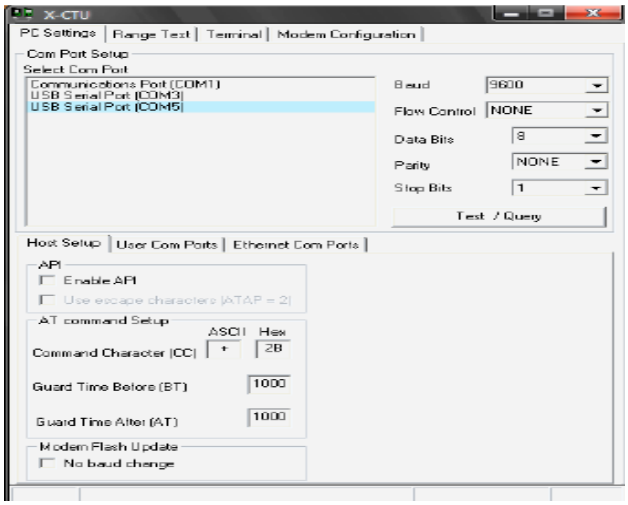

Fig. 2: GUI 1

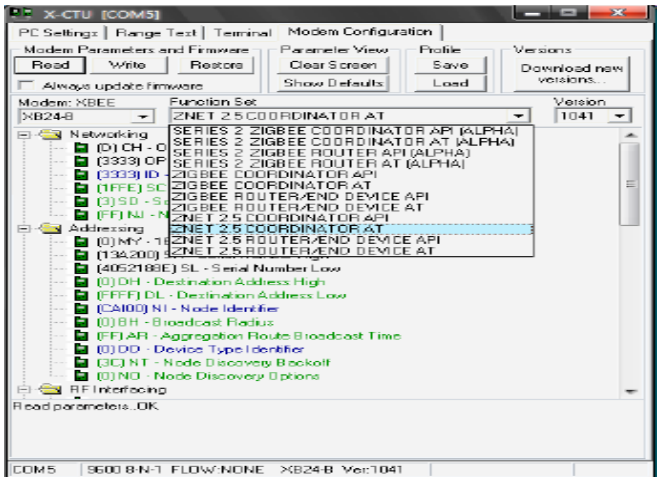

Fig. 3: GUI 2

Test the XBee properly using this procedure, before you do it since once you enter command mode, you'll need to enter a new command within 5 seconds or the XBee will exit command mode and you'll need to start this step again. Click on the terminal tab and type "+++" in the window to enter command mode. The XBee should respond in a second or two with "OK". Type "ATVR" to check the firmware version on the XBee. This should match the firmware version that you upgraded to (1241 for Router/End Device or 1041 for Coordinator).Type "ATID" to check the PAN Network ID that the XBee is using. It should respond with "123" or whatever unique PAN ID you set in step 4.Type "ATNI" to check the Node Identifier. The XBee should respond with "router1" or whatever unique Node Identifier you set in step 4. Type "ATCN" to exit command mode. The XBee will respond with "OK". If those commands returned the correct information, then congratulations, you've successfully updated this XBee! Quit the X-CTU program and disconnect the USB-miniB cable from the computer. If any of those commands did not return the correct information, click back to the "Modem Configuration" tab, change the desired settings, and click the write button. Now both the XBee S2 modules are setup linked together, once they are powered, they are paired. Sending data via UART to one of the XBee module will automatically being transmitted wirelessly to the other XBee module and further transmit out from the UART, and this apply for both way.

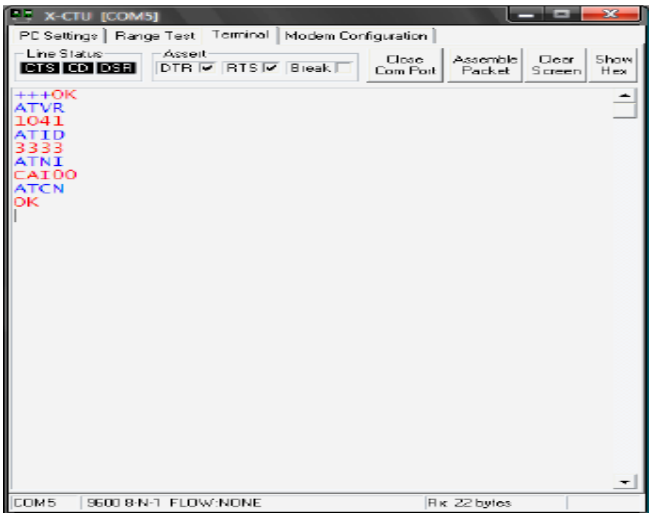

Fig. 4: GUI 3

Fig. 5: GUI 4

In the work carried out in this paper, 2 SKXBee are installed with Coordinator and Router connected to COM10 and COM25 respectively. The DL and SL are paired up at this point. To grab the information, the configured enter command mode and exit command mode with ATCN are used. The following text after ATCN and OK is actually happening in transparent mode. The test typed in Router1 XBee will transmit to Coordinator1 XBee and will display on terminal and vice versa. Now, this pair of XBee S2 can be used as wireless point to point communication device. It will behave like XBee S1 if you configure the DL and SL correctly. The overall procedure as described in this section may be executed as per the commands outlined in the Figs. 3-5.

VII. CONCLUSIONS

By the use of wireless sensor technology, it has been shown that the health data can be transmitted from the patient room to a server room, without having to run additional cables through the two destinations. The developed circuit detects any intrusion and transmits the data wirelessly over a range of two kilometres by means of ZigBee module. The ZigBee wireless sensor network have

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been successfully tested giving ATmega micro controller distant data monitoring and control. Experiments have proved that signals can be well transmitted in the whole floor from upstairs to downstairs with good communication quality. And penetrating ability of signals under 2.4 GHz is higher than that in other bands. Monitor nodes can easily be added or removed in the system, it is also convenient to expand the network. As an expansion of existing wired security systems it can enhance the flexibility of information collecting, while reducing the cost of building safety system communication network in residential buildings. So it improves the applied value of safety monitoring and practical value of control information system.

Further work on the system needs to be done to expand the scope of the system. This system is only a demonstrator of a single room communicating with a base station, it can be expanded further to have multiple rooms communicating with a single base station. The distance range of the proposed wireless sensor network can be extended using Wi_Max technology up to fifty kilometres. This ZigBee-Wi_Max hybrid wireless communication module needs to be developed and tested in the next phase of the on-going DST sponsored research project.

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