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Zigbee IEEE 802.15.4 Standard for Building Automation

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Abstract— Wireless building automation is one of the emerging technologies nowadays. Currently, InfraRed, Radio Frequency, Wi-Fi and Bluetooth are been used for this purpose but they have numerous disadvantages associated with them such as high complexity and higher power consumption. But, certain wireless monitoring and control applications for building automation demand lower power consumption, less complexity, more reliability and increased range of communication. In order to achieve this, we have proposed the use of low cost, low power, easy to use, efficient and reliable technology called Zigbee that is based upon IEEE 802.15.4 standard for Building Automation. The hardware has been implemented successfully using XBEE Pro Series1 radios (XBP24-AWI-001) and has been tested for validation effectively.

Keywords— Building Automation, emerging technologies, IEEE 802.15.4, wireless monitoring, Zigbee

I. INTRODUCTION

The Wireless Building Automation is replacing the traditional wired systems which suffer from disadvantages such as high setup and maintenance costs, complexity and limited range. These have been replaced by the wireless technologies like Radio Frequency, InfraRed, Bluetooth and Wi-Fi. The RF module operates at the Radio Frequency, the range of which varies from 30 KHz- 300GHz. This RF module is made up of RF transmitter and RF receiver which operate at frequency of 434MHz and the transmission rate is 1Kbps- 10Kbps [1]. The module has no protocols associated with it and it sends broadcast signals which are less secure. The range covered is only up to 100m and the only topology supported is star. Bluetooth is a wireless technology that is used for communication over shorter distances in the ISM band from 2400–2480 MHz [2]. This has been developed such that it can be used only for Personal Area Networks (PANs) for the devices such as phones, Personal Computers, PDAs. Bluetooth only supports the star topology. The range for Bluetooth devices is limited and varies up to 10m and power consumption is 2.5mW [3]. In [4] a Bluetooth based home automation system has been introduced. Wi-Fi is a wireless technology that is based upon IEEE 802.11 Standard. Initially it used the 2.4GHz band for 802.11b and later 802.11a was also added to it. It uses the radio waves for communication [5]. RF module, InfraRed, Bluetooth and Wi-Fi are being used currently for building automation. The InfraRed module operates for shorter distances and uses half duplex communication and is highly error prone. Bluetooth has higher data rate and limited network capacity. It can only support a maximum of 7 nodes. Due to the high data rate, the power consumption also increases. Wi-Fi on the other hand requires more power and thus is not feasible to be used in the applications with low power requirements. For the building automation, many sensors like motion detectors, smoke sensors, gas sensors, Door sensors, Window sensors, water level sensors, etc. are used throughout the building (home or office) to detect and monitor the physical conditions. These sensors send the input data to the owner (house/ office) and alert him if any event is detected such as gas leakage, intrusion in the building, water overflow in the overhead/ underground tanks, etc. This requires proper communication among the end device sensors and coordinator. If the communication is lost due to link failure or battery power loss, it would lead to the failed operation of the system and thus affect the building security.

In order to achieve a highly reliable, low cost and lower power consumption communication among the sensors in the network, we have proposed the use of Zigbee standard over the existing wireless technologies for the building automation. It provides a robust, reliable, low cost, lower power, self-configuring mesh network with strong security tools and total interoperability [6].

II. GENERAL DESCRIPTION OF 802.15.4 AND ZIGBEE TECHNOLOGIES

This section gives the generalized description of the background technologies 802.15.4 and Zigbee.

A. IEEE 802.15.4

IEEE 802.15 is a group given by IEEE for Wireless Personal Area Networks (WPAN). IEEE 802.15.4 is one among the 7 task groups of IEEE 802.15.This defines the OSI communication layer two. The main purpose is to provide communication between 2 devices. It specifies the PHY layer MAC layer for low-rate wireless personal area networks (LR-PAN). It was in May 2003 that the first version of 802.15.4 standard was released [7]. WPANs are used to communicate over shorter distances with low cost and low speed. These infrastructure less networks have numerous advantages associated with them-small, low power, inexpensive and can be used for a wide variety of devices. Their communication range is around 10m and transfer rate is 250kbps. Some of the important characteristics include star or

peer to peer topology, guaranteed time slots, carrier sense multiple access with collision avoidance (CSMA/CA), lower power consumption, energy detection, fully acknowledged protocol for transfer reliability, link quality indication and secure communication. Some of the standardized network layer protocols that run over 802.15.4 standard include: Zigbee, IEEE 802.15.5, 6LoWPAN, Wireless HART and ISA100.11a. They have been used in numerous applications like home/office automation and building automation, telecommunication, commercial applications.

B. Zigbee

Zigbee is a low cost, low power wireless technology developed by Open Global Standard. It is built upon PHY layer and MAC layer for IEEE 802.15.4 standard which operates in unlicensed bands at 2.4GHz, 900MHz and 868MHz for low rate WPANs [8]. The Zigbee protocol stack is given in fig 1. The ZigBee protocol is designed for RF communication in industrial and commercial applications. Table 1 shows the comparison of the 3 basic wireless technologies for building automation.

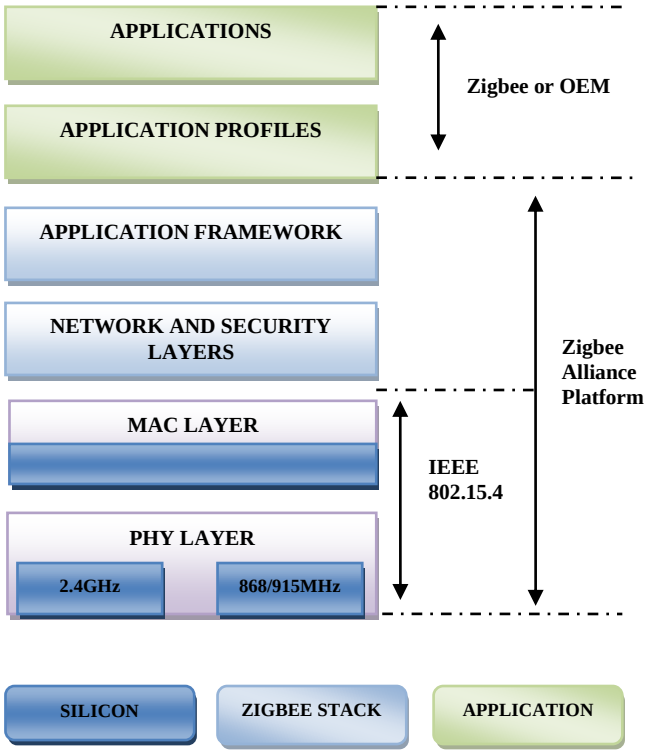

Fig.1. Zigbee Protocol Stack

Some of the Zigbee are:-

- Have a longer battery life due to low duty cycle
- Supports multiple network topologies like Star, P2P, P2MP, Mesh
- Uses Direct Sequence Spread Spectrum
- Provides low latency
- Can have 65,000 nodes per network
- Secure connections using 128 bit AES encryption
- Collision Avoidance, acknowledgement and retry

TABLE I

COMPARISON OF 3 BASIC WIRELESS TECHNOLOGIES FOR BUILDING AUTOMATION

CHARACTERISTICS	ZIGBEE	BLUETOOTH	WIFI
Standard	**802.15.4**	**802.15.1**	**801.11b**
Transmission range	**10-100m**	**1-10m**	**1-100m**
Battery life	**100-1000 days**	**1-7 days**	**0.5-5.0 days**
Number of nodes in network	**>65000**	**7**	**many**
Stack size	**<64Kb**	**>250Kb**	**>1000Kb**
Throughput	**20-250Kbps**	**720Kbps**	**11,000Kbps**
Bandwidth	**250Kbps**	**1000Kbps**	**>11000Kbps**
Cost	**$3**	**$5**	**$9**

Security	**128 bit AES**	**64 bit, 128 bit**	**nil**
Operating Frequency	**868MHz, 902-928MHz, 2.4GHz ISM**	**2.4GHz**	**2.4GHz & 5GHz**
Network Topology	**Star, peer to peer mesh, adhoc, hybrid**	**Adhoc piconets**	**Point to hub**
Complexity	**low**	**high**	**high**
Scalability	**Very high**	**low**	**high**
Flexibility	**Very high**	**medium**	**high**
Reliability	**Very high**	**medium**	**high**
Applications used in	**Monitoring & control, building automation, games, toys**	**Wireless connectivity between phones, laptops, etc.**	**Web, email, video**

III. SYSTEM ARCHITECTURE

The Zigbee follows a mesh topology and uses multi-hop communication for packet data transfer. It consists of three types of nodes: Zigbee End device, Coordinator and Router. The Coordinator forms the ' Master node' for a cluster, the end device is the 'Slave node' and the router is placed between two networks/ clusters such that it forwards the data packets from one network to another. Thus, the communication in this case is multi-hop which provides an extended range as compared to the existing wireless technologies. This Zigbee topology is given in the fig 2 below.

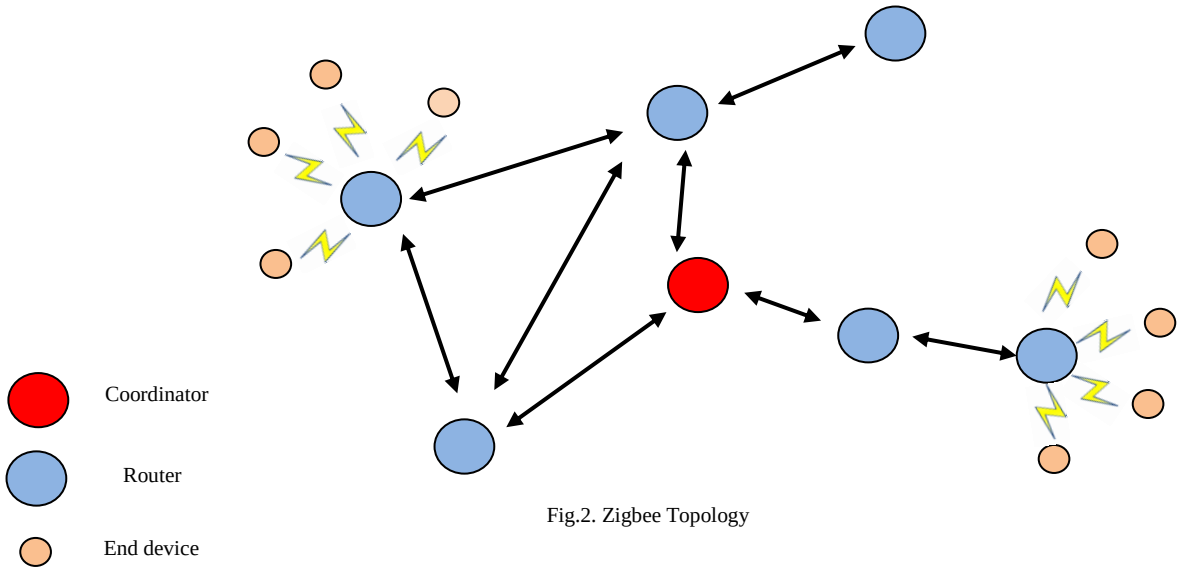

Fig.2. Zigbee Topology

IV. PROPOSED SYSTEM

The proposed system uses Zigbee for building automation because of the advantages associated with it. Building Automation for smart homes and smart office environments includes many features such as:-

- Smart light control
- Smart temperature control
- Building security: prevention of intrusion, fire due to gas leakage, etc.
- Location tracking
- Water level monitoring in home and office overhead and underground tanks
- Other user convenience

In all these scenarios, the sensors are deployed all over the building and each sensor has its own specific features. The sensor s sense the area under observation continuously and send the data to the RF module-Zigbee which transfers the data to the coordinator connected to the PC or server which takes necessary action. Our proposed system using Zigbee can be used effectively for all the above scenarios and is particularly very useful in case of Home/ Office security systems which prevent intrusion in these buildings and detect the occurrences of fires or gas leakages.

V. SYSTEM IMPLEMENTATION

This section consists of the hardware and software implementation.

A. *Hardware Implementation*

The hardware has been implemented using the XBEE Pro Series1 radios (XBP24-AWI-001). Any sensor can be used as a prototype (e.g. Passive InfraRed sensor as motion detector, water level measurement sensor, etc.) The XBEE Pro Series1 radios Digi International® follow the IEEE 802.15.4 standard and are used for providing wireless connectivity

for fast point to multipoint and peer to peer networking. They are easy to use, ideal for low cost, low power applications that require low latency and predictable communication timings [9]. The specifications are given in table 2 below. The pin diagram for XBEE Pro is given in fig. 3.

TABLE 2
SPECIFICATIONS OF XBEE PRO SERIES 1 RADIO

PARAMETERS	VALUES
Indoor range	**300ft (90m)**
Outdoor range	**Up to 1 mile (1600m)**
Transmit power	**63mW**
RF data rate	**250,000bps**
Supply voltage	**2.8-3.4 V**
Transmit current	**250 mA at 3.3V**
Operating frequency	**ISM 2.4GHz**
No. of channels	**12 direct sequence channels**
Addressing options	**PAN ID, channel and addresses**

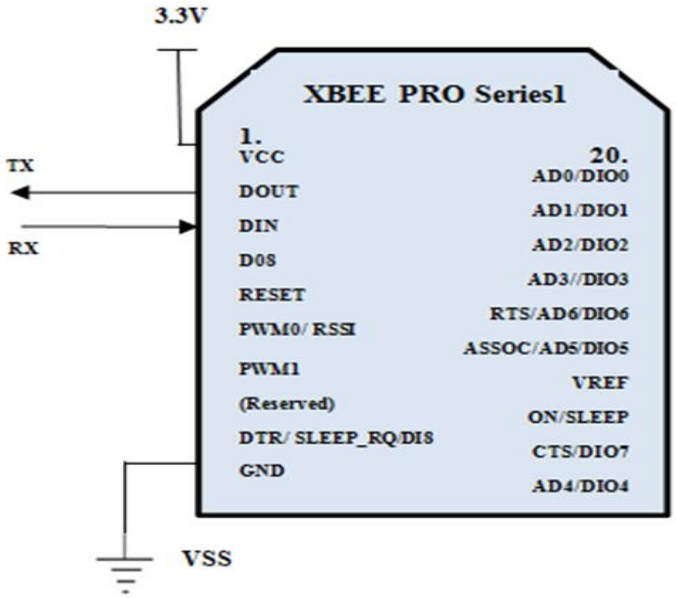

Fig.3. Pin diagram for XBEE Pro Series 1

The pictures (from fig 4-fig 7) given below show that the hardware has been implemented successfully. Fig 4 depicts the XBEE mounted on a breakout board, fig 5 shows the XBEE mounted on breadboard, fig 6 shows the configuration of XBEE using XCTU, and fig.7 shows the communication of XBEE end device with coordinator.

Fig.4. XBEE mounted on breakout board

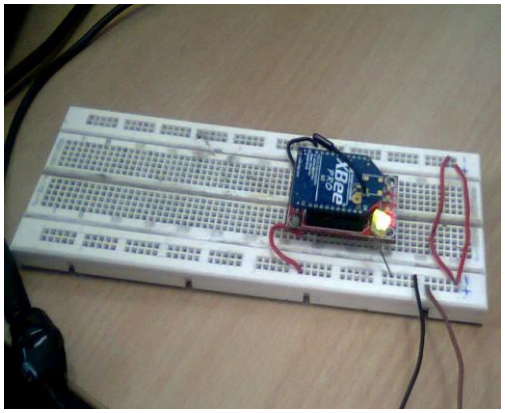

Fig.5. XBEE mounted on a breadboard

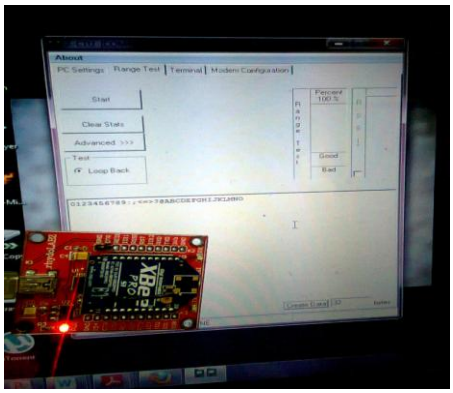

Fig.6. Configuration of XBEE Pro Series 1

Fig.7. XBEE end device communicating with coordinator connected to PC

B. *Software Implementation*

X-CTU software is used for configuring and testing of MaxStream radio modems like XBEE [10]. This is a programming module for XBEE. It is designed to use on Windows platforms only from Windows 98 and above. The user is able to upgrade the firmware, update certain XBEE parameters and used for communication of XBEEs. This is user friendly and supports many features like integrated terminal window support, range test support, support for up gradation of firmware, creation of test packets in ASCII or hexadecimal format, RSSI value indicator, restoring default factory parameters, etc. XBEE consists of 20 pins. The DIO pins are used for communication purpose. XBEE is configured as end device and coordinator. The configuration settings are given in table 3. Fig. 8 indicates the initial window of XCTU software while configuring. Fig 9 and fig 10 indicate the settings for XBEE as coordinator and end device respectively. Various parameters that have been used in the configuration are explained in detail as given below.

1) **Channel Indicator (CH)** - This parameter sets the channel number for our device according to IEEE 802.15.4 Standard. The range is from 0xC to 0x17. The channel for Coordinator and End device should be same.
2) **PAN ID (ID)** - This sets the Personal Area Network ID for each device. The Coordinator and end device should have the same ID such that they can communicate.
3) **Destination Address Low (DL)** - This sets the lower 32 bits of 64-bit destination address. The range lies from 0 to 0xFFFFFFFF.
4) **MY Address (MY) –** This sets the 16 bit source address for the device. The range lies from 0 to 0xFFFF.
5) **Coordinator Enable (CE)** – Sets the coordinator. If CE=0x0, then the device is set as End device and if CE=0x1, the device is configured as Coordinator.
6) **D0-D7-** These are the Input-Output pins for XBEE radio. For end device, set (any number of pins as required) D0-D7= 0x3 i.e. data input and for Coordinator, set D0-D7= 0x4 i.e. data output low.
7) **Change Detect (IC) -** This sets/ reads the bit values for any change detected in the pins DIO0-DIO7.The range is 0-FF.
8) **Input/ Output Enable (IU) -** This feature of XCTU, allows configuring the XBEE Radio to receive and send the data continuously from one device to another. This should be set as 1 for continuous communication.
9) **Sample rate (IR)** - This sets the interval for the packet transfer for the DIO pins. The range is from 0-FFFF x 1MS.

Fig.6. Configuration of XBEE Pro Series 1

10) **IT**- Number of sample packets. This is set to 0x1, if one packet is transferred.
11) **Input Address (IA) -** This sets the address of the device from which data is coming.
12) **T0, T1-** These set the timer values for the DIO pins that are enabled (in our case D0 and D1). Timer is reset when valid IO packet is received. The range is from 0-FF x MS.

TABLE 3
CONFIGURATION SETTINGS FOR XBEE RADIOS

End Device	Coordinator
CH=C	**CH=C**
ID=0x1	**ID=0x1**
DL=0x1234	**DL=0x4567**
MY=0x5678	**MY=0x1234**
CE=0x0	**CE=0x1**
D0=0x3	**D0=0x4**
D1=0x3	**D1=0x4**
IC=0x18	**IU=0x1**
IU=0x1	**IT=0x1**
IT=0x1	**IR=0xFF, IA=0x4567 (or FFFF)**
IR=0xFF	**T0,T1=0x64**

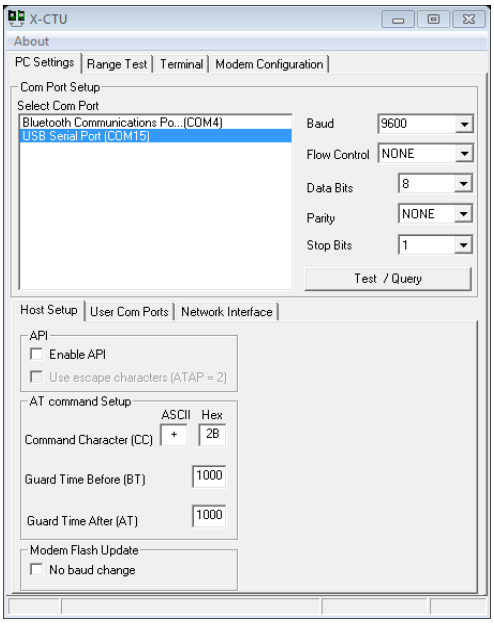

Fig.8.Initial window for XCTU

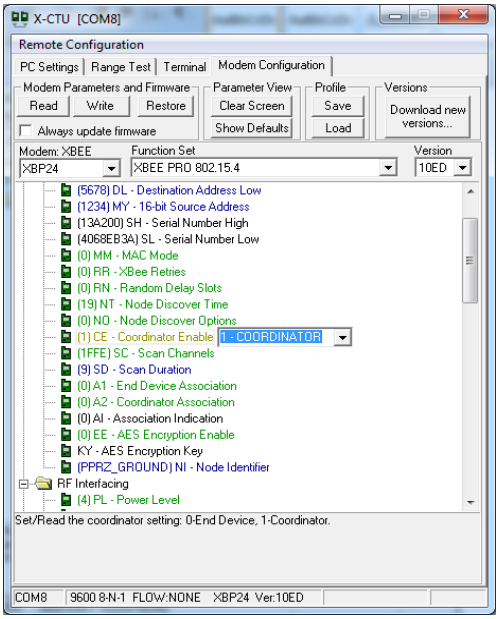

Fig.9.Configuration of XBEE as coordinator

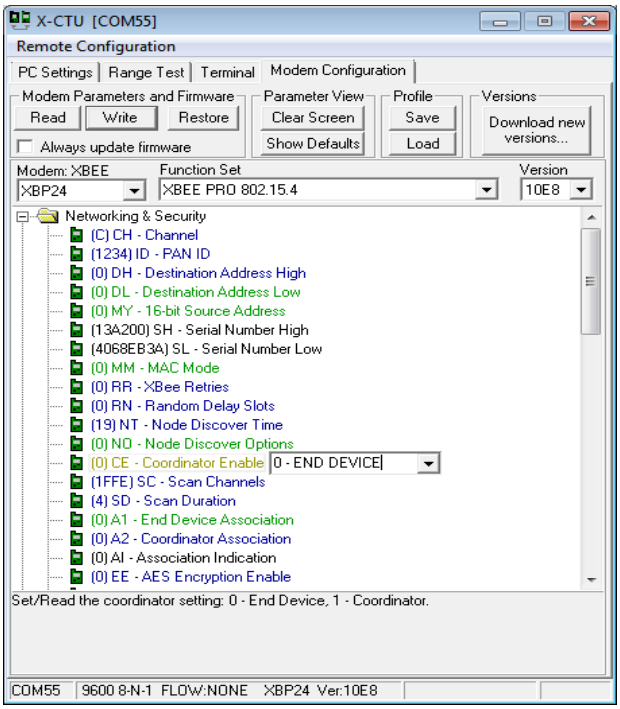

Fig.10.Configuration of XBEE as End device

VI. CONCLUSIONS

In this paper we have given a description about the existing wireless technologies for building automation and we have compared them with the Zigbee that we are using for our proposed system. The advantages of Zigbee over the existing wireless technologies have been explained. Our proposed system is very effective especially in case of Building security and automation features. The features of Zigbee like limited delay and low energy consumption makes it more robust and reliable than the existing wireless technologies and it has great future scope.

ACKNOWLEDGMENT

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