Zig Bee-Based Smart Power Management in Intelligent Buildings

Tirupati Naga Vaishnavi,
M.Tech, VLSI Design & Embedded System,
R V College of Engineering,
Bangalore,
India.

Akshatha G,
M.Tech, CNE,
BNMIT,
Bangalore,
India.

Abstract **- Energy is a precious resource and as electronic devices, the demand for energy will continue to increase. Hence the paper focuses on human-friendly technical solutions for monitoring and easy control of household appliances. The inhabitant's comfort will be increased and better assistance can be provided. The focus of the paper is on adapting the functionalities of electronic appliances based on the surrounding environment conditions i.e., we can control the speed of the fan, the brightness of the light bulb etc., Here different sensors are placed in the building which senses the data and it is given to the microcontroller. The microcontroller sends the data to the wireless sensor node through Zig Bee module. The data's can be monitored by the PC at the end system.. The developed system is a low-cost and flexible in operation and thus can save electricity expense of the consumers.**

Index Terms—Energy management, home automation, intelligent control system, wireless sensor network, Zig Bee.

I. INTRODUCTION

Now- a- days people are more dependent on automated mechatronic systems than manual devices & very curious about implementing new technologies in their everyday life. As it is foreseen that service and personal care wireless mechatronic systems will become more and more ubiquitous at home in the near future and will add dignity, self-sufficiency, comfort and luxurious life particularly for the senior citizens. Wireless mechatronic systems consist of numerous spatially distributed sensors with limited data collection and processing capability to monitor the environmental situation. Wireless sensor networks (WSNs) have become increasingly important because of their ability to monitor and manage situational information for various intelligent services. Due to those advantages, WSNs has been applied in many fields, such as the military, industry, environmental monitoring, and healthcare.

A sensor network is an infrastructure comprised of sensing, computing and communication elements that gives an administrator the ability to instrument, observe & react to the events and phenomenon in a specified environment. The four basic components in a sensor network:-

1) An assembly of distributed or localized sensors.
2) An interconnecting network.
3) A central point of information clustering.
4) A set of computing resources at the central point.

Power efficiency in wireless sensors is generally accomplished in three ways:-

1) Low duty cycle operation
2) Local/ in- network processing to reduce data volume
3) Multi hop networking reduces the requirement for large range transmission.

Each node in the sensor network can acts as a repeater, thereby reducing the link range coverage required and in turn the transmission power [1].

The WSNs are increasingly being used in the home for energy controlling services. New technologies include cutting-edge advancements in information technology, sensors, metering, transmission, distribution, and electricity storage technology, as well as providing new information and flexibility to both consumers and providers of electricity. The Zig Bee Alliance, wireless communication platform is presently examining Japan's new smart home wireless system implication by having a new initiative with Japan's Government that will evaluate use of the forthcoming Zig Bee, Internet Protocol (IP) specification, and the IEEE 802.15.4g standard to help Japan to create smart homes that improve energy management and efficiency It is expected that 65 million households will be equipped with smart meters by 2015 in the United States, and it is a realistic estimate of the size of the home energy management market [2]

Zig Bee, the IEEE 802.15.4 standard), has low complexity, low-rate, low power and low-cost characteristics. Compared with other wireless network technology, the unique advantages of Zig Bee technology are data transmission secure, simple and flexible network, low equipment cost, and long battery life. As it has low-power and low-cost characteristics, it enables to be widely used in home and building environments.

As Energy demand is the rising problem in today's world, it is necessary to solve the energy crisis problem. It is essential to monitor the energy consumption in Buildings and household devices. The paper focuses on human-friendly technical solutions for monitoring and easy control of household appliances. The inhabitant's comfort will be increased and better assistance can be provided. In this paper, we are dealing with the Light Controlling like LED's, Bulb and Ceiling Fan. Here different sensors are placed in

the building which senses the data and it is given to the microcontroller. The microcontroller sends the data to the wireless sensor node through Zig Bee module. The data's can be monitored by the PC at the end system. The software CUBE SUITE+ has been used to create source files, automatically compile, link and debugging on the hardware. RENESAS FLASH PROGRAMMER has been used to dumb the code into the software. Embedded C & .net has been used as programming languages. The software OrCAD Capture has also been used.

II. ZIG BEE NETWORK

A. *Overview of Zig Bee Protocols*

Zig Bee works in 2.4 GHz ISM band without the need for registration. Its transmission rate is 10 ~ 250 kbps, and transmission distance is much longer than 100 meters. It is designed for low-rate controlling network with standards based on wireless network protocol. Zig Bee protocol uses IEEE802.15.4 specification as the medium access layer (MAC) and Physical Layer (PHY). 2.4 GHz frequency bands provide data rate of 250kpbs. The maximum length of data packets for IEEE802.15.4MAC is 127 bytes. Each data packet is composed of the first byte and 16-bit CRC values which used to verified the frame integrity. In addition, IEEE802.15.4 can also use the response data transport mechanism selectively. Using this method, all the special positions of frame marked by ACK will be responded by their receivers. Finally, it can determine that the frame has been transmitted [3].

Zig Bee is one of the global standards of communication protocol formulated by the relevant task force under the IEEE 802.15 working group. The fourth in the series, WPAN Low Rate/ Zig Bee is the newest and provides specifications for devices that have low data rates, consume very low power and are thus characterized by long battery life. Other standards like Bluetooth and IrDA address high data rate applications such as voice, video and LAN communications.

Table 1 shows the comparison between Zig Bee with several other wireless sensor network technologies.

TABLE I
COMPARISON OF SEVERAL WSN TECHNOLOGIES

Network Technology	**Wi-Fi**	**Bluetooth**	**UWB**	**Zig Bee**
Cost	Higher	Lower	Highest	Lowest
Battery Life	Several days	Several days	Several hours	Several years
Effective range	100m	10m	30m	10~75m
Transmission Rate	5.5/11 Mbit/s	1~3 Mbit/s	40~600 Mbit/s	20/40/250 Kbit/s
Adoption agreement	802.11b	802.15.1		802.15.4
Communication channels	2.4 GHz	2.4 GHz	3.1~10.6 GHz	868MHz/ 915MHz/ 2.4GHz

The Zig Bee network layer natively supports both star and tree networks, and generic Mesh networking. Every network must have one coordinator device, tasked with its creation, the control of its parameters and basic maintenance. Within star networks, the coordinator must be the central node. Both trees and meshes allow the use of Zig Bee routers to extend communication at the network level.

Zig Bee builds on the physical layer and media access control defined in IEEE standard 802.15.4 for low-rate WPANs. The specification includes four additional key components: network layer, application layer, Zig Bee device objects (ZDOs) and manufacturer-defined application objects which allow for customization and favor total integration. ZDOs are responsible for a number of tasks, including keeping track of device roles, managing requests to join a network, as well as device discovery and security.

B. *Types of Zig Bee Wireless Network*

Zig Bee Technology supports three kinds of network topologies: Star (star-like network), Cluster Tree (cluster-like network) and Mesh (mesh-like network). All the terminal equipments in Star-like network can only be connected with the coordinator. Coordinator's main function is to establish networks, transmit networks beacons, manage network nodes, and storage information of network nodes and router. The largest number of terminal equipment can be connected up to 65535. Each device must be in the range of the RF tuner. Cluster-like structure is a star-shaped network extended through the router. It can coverage a large area, and contain numerous child nodes of network. Router has function of both accessing terminals and routing functionality. It can serve as a relay among the remote devices to expand the scope of network. Additionally, it can be used to search available network, transmit and forward data connected with router or terminal devices. Mesh-like network has self-healing function, which is a network with high level redundancy. Generally, it can choose the best communication path to improve the quality of links. When the router node deployment density is large enough, network will choose another appropriate path automatically within other redundant paths to maintain normal communication in case of the optimal communication path was interrupted.

C. *Device Types and operating modes*

Zig Bee devices are of three types:

1) ***Zig Bee Coordinator (ZC):*** The most capable device, the Coordinator forms the root of the network tree and might bridge to other networks. There is exactly one Zig Bee Coordinator in each network since it is the device that started the network originally (the Zig Bee Light Link specification also allows operation without a Zig Bee Coordinator, making it more usable for over-the-shelf home products). It stores information about the network, including acting as the Trust Center & repository for security keys.
2) ***Zig Bee Router (ZR):*** As well as running an application function, a Router can act as an intermediate router, passing on data from other devices.
3) ***Zig Bee End Device (ZED):*** Contains just enough functionality to talk to the parent node (either the Coordinator or a Router); it cannot relay data from other devices. This relationship allows the node to

be asleep a significant amount of the time thereby giving long battery life. A ZED requires the least amount of memory, and therefore can be less expensive to manufacture than a ZR or ZC.

The current Zig Bee protocols support beacon and non-beacon enabled networks. In non-beacon-enabled networks, an unslotted CSMA/CA channel access mechanism is used. In this type of network, Zig Bee Routers typically have their receivers continuously active, requiring a more robust power supply. However, this allows for heterogeneous networks in which some devices receive continuously, while others only transmit when an external stimulus is detected. The typical example of a heterogeneous network is a wireless light switch: The Zig Bee node at the lamp may receive constantly, since it is connected to the mains supply, while a battery-powered light switch would remain asleep until the switch is thrown. The switch then wakes up, sends a command to the lamp, receives an acknowledgment, and returns to sleep. In such a network the lamp node will be at least a Zig Bee Router, if not the Zig Bee Coordinator; the switch node is typically a Zig Bee End Device.

In beacon-enabled networks, the special network nodes called Zig Bee Routers transmit periodic beacons to confirm their presence to other network nodes. Nodes may sleep between beacons, thus lowering their duty cycle and extending their battery life. Beacon intervals depend on data rate; they may range from 15.36 milliseconds to 251.65824 seconds at 250 kbit/s, from 24 milliseconds to 393.216 seconds at 40 kbit/s and from 48 milliseconds to 786.432 seconds at 20 kbit/s. However, low duty cycle operation with long beacon intervals requires precise timing, which can conflict with the need for low product cost.

In general, the Zig Bee protocols minimize the time the radio is on, so as to reduce power use. In beaconing networks, nodes only need to be active while a beacon is being transmitted. In non-beacon-enabled networks, power consumption is decidedly asymmetrical: Some devices are always active, while others spend most of their time sleeping.

Except for the Smart Energy Profile 2.0, Zig Bee devices are required to conform to the IEEE 802.15.4-2003 Low-Rate Wireless Personal Area Network (LR-WPAN) standard. The standard specifies the lower protocol layers—the physical layer (PHY), and the Media Access Control portion of the data link layer (DLL). The basic channel access mode is "carrier sense, multiple access/collision avoidance" (CSMA/CA). That is, the nodes talk in the same way that human's converse; they briefly check to see that no one is talking before they start, with three notable exceptions. Beacons are sent on a fixed timing schedule and do not use CSMA. Message acknowledgments also do not use CSMA. Finally, devices in beacon-enabled networks that have low latency real-time requirements may also use Guaranteed Time Slots (GTS), which by definition do not use CSMA.

III. SYSTEM DESCRIPTION AND WORKING

The system has been designed for adding dignity, self-sufficiency, comfort and luxurious life especially for senior citizens. To implement this, we require Microcontroller RENESAS RL78, LCD, TRIAC, Relay, Temperature sensor, LDR (Light Dependent Register), PIR sensor (Passive Infrared), Zig Bee, L293, LEDs, PC (.net).

RENESAS micro controller is a 16 bit micro controller, made by NXP manufacturers. R5F100LE has 64 pins in it. It has 64 KB on-chip FLASH programming. Its internal RAM size is 4096 bytes for 64 pins. It has on-chip self programming. It has programmable watchdog timer, Inbuilt-ADC with ADC resolution as 10 bits and has three UARTs in it.

A photo resistor or light-dependent resistor (LDR) or photocell is a light-controlled variable resistor. The resistance of a photo resistor decreases with increasing incident light intensity; in other words, it exhibits photo conductivity. A photo resistor can be applied in light-sensitive detector circuits, and light- and dark-activated switching circuits.

A photo resistor is made of a high resistance semiconductor. In the dark, a photo resistor can have a resistance as high as a few mega ohms (MΩ), while in the light, a photo resistor can have a resistance as low as a few hundred ohms. If incident light on a photo resistor exceeds a certain frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electrons (and their hole partners) conduct electricity, thereby lowering resistance. The resistance range and sensitivity of a photo resistor can substantially differ among dissimilar devices. Moreover, unique photo resistors may react substantially differently to photons within certain wavelength bands [4].

The L293 is an integrated circuit motor driver that can be used for simultaneous, bi-directional control of two small motors for controlling LED lights brightness control [5]

A relay is an electrically operated switch. It acts as a electromagnetic switch.

The TRIAC is a three terminal semiconductor device for controlling AC current. It gains its name from the term TRIode for Alternating Current [6].

A passive infrared sensor (PIR sensor) is an electronic sensor that measures infrared (IR) light

A light-emitting diode (LED) is a semiconductor device that creates light using solid-state electronics. A diode is composed of a layer of electron rich material separated by a layer of electron deficient material which forms a junction. Power applied to this junction excites the electrons in the electron rich material leading to photon emission and the creation of light. Depending on the chemical composition of the semiconductor layers, the color of light emission will vary within the electromagnetic spectrum [7].

The users (inhabitants) have the options of switching the device on/off in two modes :-

1) AUTO MODE
2) MANUAL MODE

AUTO MODE:

In this AUTO mode, different sensors has been used such as PIR, Temperature sensor, LDR are placed in the building which senses the data and it is given to the Microcontroller. PIR sensor is used to detect human motion in building. If any motion is detected in the building, bulb will turn ON. If the motion is not detected, bulb will turn OFF. ON/OFF state will be controlled by relay circuit. Thus wastage of power consumption is reduced.

Temperature sensor senses the temperature of the building. If the temperature is high, the Ceiling Fan speed gradually increased by itself. If surrounding temperature of the building is low, Speed of the Ceiling Fan gradually decreased by itself. This is monitored and controlled by the TRAIC circuit. Here the TRAIC circuit is used to control the speed of the fan by triggering the pulses. Wherever trigger pulses are applied to the input signal, output voltage gets reduced. Thus speed of the fan gets decreased.

More the Brightness Outdoor, Less the brightness of the LED, Vise Versa Less the Brightness, More the Brightness of the LED. The LED brightness depends on LDR state.LDR is a light dependant register .This is controlled through PWM(Pulse Width Modulation). The temperature data and LDR data is given to the ADC for digital conversion. The converted data is sends to the controller. This data will be displayed on the LCD. All these processes are controlled by Microcontroller.

Zig Bee is used for wireless communication between controller and PC. The microcontroller sends the data to the wireless sensor through Zig Bee module. The data's can be monitored by the PC at the end system.

The operation of AUTO Mode is shown in Figure 1.

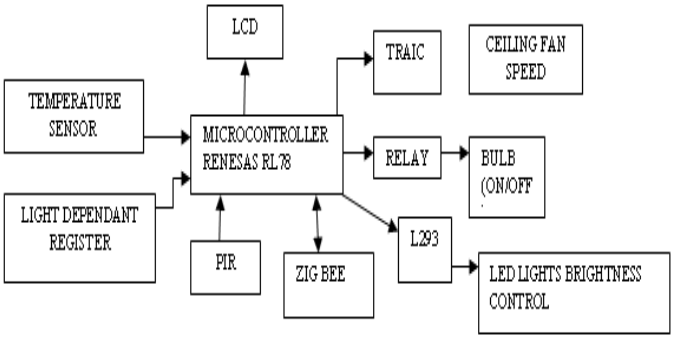


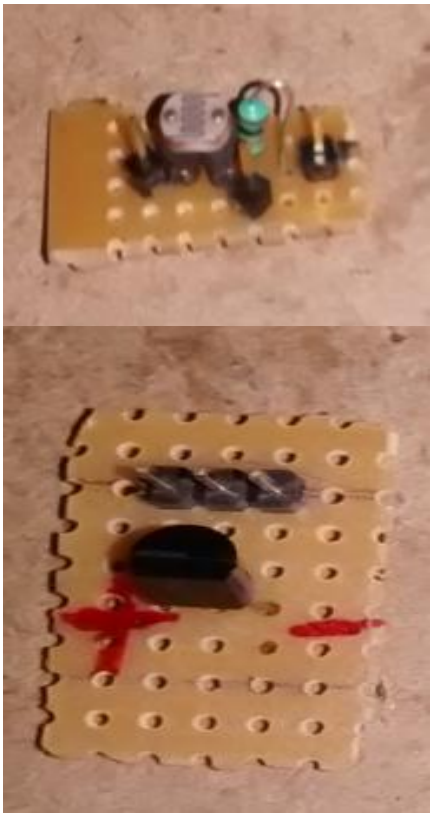
Fig 1: Operation in AUTO Mode

MANUAL MODE:

In manual mode everything controlled by PC, like turn off/on bulb, LED brightness control, fan speed controlled by sending particular command from the PC. The operation of MANUAL Mode is shown in Figure 2.

Fig 2: Operation in MANUAL Mode.

The RENESAS Micro Controller RL78 & LCD, Zig Bee Transmitter and Receiver, Temperature sensor, Relay, Light Dependent Register which has been used in our paper is shown in Figure 3



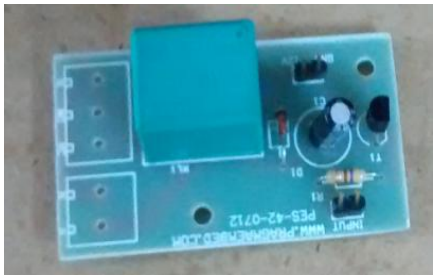


Fig 3:- RENESAS Micro controller & LCD, Zig Bee Transmitter & Receiver, Temperature sensor, LDR, Relay which are being implemented in our paper

Thus Zig Bee Based Smart Power Management using intelligent buildings has been designed and its prototype has been working successfully.

IV. CONCLUSION AND FUTURE WORK

A smart power monitoring and control system has been designed and developed toward the implementation of an intelligent building. The developed system effectively monitors and controls the electrical appliance usages at an elderly home.

The sensor networks are programmed with various user interfaces suitable for users of varying ability and for expert users such that the system can be maintained easily and interacted with very simply.

The developed system is robust, flexible in operation, cost-effective, reliable & low power consumption and thereby adding more dignity, self-sufficiency, comfort, luxurious life especially for senior citizens and disabled persons.

In future, the system will be integrated with co-systems like smart home inhabitant behavior recognitions systems to determine the wellness of the inhabitant in terms of energy consumption.

REFERENCES

[1] Kazem Shoraby, Danien Minoli, Taieb Zanti, “Wireless sensor networks – technology protocol and applications”.

[2] Nagender Kumar Suryadevara, Subhas Chandra Mukhopadhyay, Sean Dieter, Tebje Kelly, Satinder Pal Singh Gill, “WSN-Based Smart Sensors and Actuator for Power Management in Intelligent Buildings”, IEEE/ASME TRANSACTIONS ON MECHATRONICS.

[3] Tongjaun Liu, Jun Liu, Bingwu Lu, “Design of intelligent warehouse Measure and control system and Control system based on Zigbee WSN”, IEEE International Conference on Mechatronics and Automation, August, 2010.

[4] Open source website Wikipedia.

[5] http://www.me.umn.edu/courses/me2011/arduino/technotes/dcmotors/L293/L293.html

[6] http://www.radioelectronics.com/info/data/semicond/triac/what-is-a-triac-basics-tutorial.php

[7] http://www3.nd.edu/~leds/how/How.htm