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# A Review on ZIGBEE Smart Energy Implementation for Energy Efficient Building

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***Abstract***
The consumption of energy in residential buildings is increasing day by day due to the use of various advanced technologies and therefore represents a potential source of energy savings. The use of smart energy management system can assist in reducing the energy usage in an efficient way.This paper gives a review of a smart energy system in the development of an energy efficient management system for residential building using ARM7 and ZigBee. A Home section or Device unit is developed using four different devices (or household appliances) with an auxiliary load (device which is occasionally used) each connected to the ARM7 microcontroller unit respectively. The priority modes are given to the four devices as specified by the user. The auxiliary load is provided with reference wattage such that if the power value of auxiliary load goes beyond this reference wattage then the four devices will be switched according to the priorities given to them in the specified modes. The controlling action and selection of modes can be done at the monitoring unit through ZigBee communication. Thus, a smart system can be developed for energy efficiency in a building.
***Keywords***— ARM7, ATmega8, µVision, RISC, ZigBee.

## I. INTRODUCTION

Residential energy consumption is increasing day by day due to the use of advanced technologies and the rising demand for it. In this age, energy control is now a top priority. We must have a smart energy system so as to meet the requirement of energy to the increasing population. The smart energy implementation can contribute to major reductions of energy use in the buildings. Energy savings and user happiness are two major design considerations for intelligent home system [1].

ZigBee is one of the standards for short-distance wireless networking like the Bluetooth or NFC (Near Field Communication) standards. It is a low cost and low power technology with a maximum signal rate of 250kbps having a range of 10 to 100m. Approximately 65,000 or more nodes can be associated using a ZigBee communication technology [6]. ZigBee communication module is the most appropriate network module to reduce the unnecessary power consumption such as standby power [2]. For device control and energy management we require two types of ZigBee networks including neighbourhood area networks for energy, using ZigBee for sub-energy within an apartment and using ZigBee to communicate to devices within the home [4, 5]. In this paper, the architecture of a smart energy system using the ZigBee communication technology is discussed. Both the hardware and the software overview are taken. The flow of the entire process is also discussed with the help of a flow chart. Conclusion and the future work are discussed at the later stage of the paper.

## II. LITERATURE REVIEW

Plenty of research works published in last few years related to smart energy management has been studied giving following information.

### *A. Need of Smart Energy Implementation*

Major problems are discussed in the paper [2] regarding energy consumption in residential building consisting of power strips and standby power. Standby power is the power consumed even though the electrical appliances which are plugged in the sockets are not in use. According to the IEA (International Energy Agency), the standby power occupies approximately 10% to 15% of the total power consumption of OECD (Organization for Economic Cooperation and Development). Review article [16] explains about the smart grid and methods to obtain full benefit of smart grids. Article [7] reviews several limitations regarding the existing system. It discusses the centralized system architecture of the existing systems along with the fixed rule-based control and a limited network lifetime due to a sensor node using a finite battery. Paper [12] discusses about the major causes of energy consumption and the wastage of energy. It informs that a significant part of the energy consumption in buildings is due to an improper use of various appliances and devices.

### *B. Different Schemes for Smart Energy Implementation*

The paper [3] focuses on the Embedded Systems for Energy Efficient Buildings (eDIANA) project. It was funded by the European Commission through the ARTEMISIA framework, addressing the need of energy efficiency through innovative solutions based on networked embedded systems. Its architecture has a hierarchical organization. The first level is the Cell which could be a single house or apartment or working unit. The second unit is Macro-Cell which is a group of Cells. It also consist a Cell Device Concentrator (CDC) which manages each cell and gathers information provided by the cell level devices. The Macro-Cell Concentrator (MCC) decides the general energy consumption strategy of the group of cells attached to it. According to paper [1], each home of a building consists of a living room, a bedroom, a kitchen and a rest room with necessary load, a power outlet including a power measurement function to measure the power consumption and a ZigBee Hub respectively. A ZigBee Hub gathers power information report of power outlet and transfers it to Home Server. The Home Server displays power consumption of each appliance. A user can analyse the Real-Time Active power consumption and Accumulated power consumption from this information. Paper [7] proposed a system which consists of the self-adapting intelligent gateway (SIG) and the self adapting intelligent sensor (SIS). The SIG is divided into four parts: the main processor part, the network interface part, the system interface part and the power part. The SIS consists of various sensors modules and some optional modules. Paper [4] gives the Smart Home Energy Management System (SHEMS) architecture which consists of a number of sensor nodes. The sensor nodes are deployed in the various sections of home which senses the data. Paper [6] discusses various aspects of Base node, Smart node and Wireless communication platform. Smart node measures parameters like current, voltage and power and transmits the data through ZigBee to the Base node. The Base node calculates total current of branch circuit according to the data sent by Smart node and send back the data on removing current value as a threshold value of Smart node overload protection function. The three layer architecture is discussed in paper [17]. The Sensing layer is the lowest level and uses small and cheap sensors and actuators. The second layer is Middleware layer providing standard interface between physical sensors and AmI algorithm. The third layer is Application layer which consists of user interface and system installation. The implementation of a system using a client and a home server is discussed in paper [18]. The client consists of real-time monitoring sub-system and the on/off control panel with either using a web service or a smart phone. The server consists of video device (home camera), the RTM sub-system and the light control sub-system consisting of the ZigBee network. A ZigBee network consists of devices like coordinator, end devices, switch node and a light. The home server responds to the client and sends the data to the ZigBee coordinator through RS232 serial communication. It further sends the data to the end devices through RF communication and finally to the switch nodes with a light. In the test bed of paper [2], a copy machine, a microwave and a server computer are connected to the SEMS (Smart Energy Management System). The power consumption is measured for 5 days using (a) motion sensor (b) common power strip (c) by setting time of power usage. The power consumption values can be obtained by using the above methods and can be compared. Paper [16] proposed the smart grid consisting of four vital blocks. It includes Power System Infrastructure, Sensor, Communication Infrastructure and Decision Intelligence. The Power System Infrastructure includes the power conversion, transportation, consumption and actuation devices. The Sensors enables fault detection and isolation. The Communication Infrastructure binds all other layers together. The Decision Intelligence Block can be used for the control strategies.

### *C. Role of Wireless Technology in Smart Energy Implementation*

Wireless technology plays an important role in the development of smart energy management system. Various features and the importance of several wireless technologies are discussed in paper [6]. A brief and tabulated comparison of ZigBee, Bluetooth and Wi-Fi can be obtained for the wireless communication platform. Such technologies help the communication between the Smart node and the Base node of the architecture which constitutes the smart energy system. Advanced Metering Infrastructure (AMI) and ZigBee are discussed in paper [8]. AMI becomes powerful when teamed with a building automation system such as a HAN (Home Area Network). Research and development of the "ZigBee" short-range wireless communication standard is discussed in paper [9]. Development of ZigBee smart energy products is discussed in paper [10] which elaborates a standard for energy efficiency. Role of ZigBee network in monitoring and controlling system is explained in paper [18]. It also discusses several ZigBee devices such as coordinator, end-devices and switch node. All these devices together forms the required ZigBee network for the energy management system. The ZigBee network is one of the important part of the entire energy management system.The comparison amongst various wireless technologies can be tabulated including various characterictics.

Comparison of various wireless technologies is as follows [6].

| Features | ZigBee | Bluetooth | Wi-Fi |
|---|---|---|---|
| IEEE standard | 802.15.4 | 802.15.1 | 802.11 a/b/g |
| Maximum signal rate | 250kbps | 1Mbps | 54Mbps |
| Nominal range | 10-100m | 10m | 100m |
| Maximum number of nodes | >65,000 | 8 | 2007 |
| Power consumption | Low | Very low | High |
| Power complexity | Simple | Most complex | Complex |
| Cost | Low | Low | High |

**Table I – Comparison of Various Wireless Technologies.**

## III. SYSTEM OVERVIEW

The proposed system can be studied in two parts as the Home Section and the Monitoring Section. They are shown in Fig. 1 and Fig. 2 respectively.

### *A. Home Section*

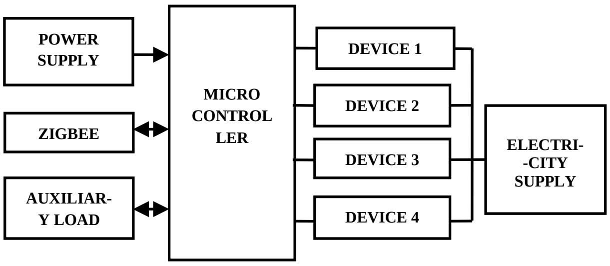


**Figure 1 - Home or Device Section**

The LPC2148 microcontroller unit is used at the home section. Four appliances are connected to the microcontroller unit along with the auxiliary load. The inbuilt ADC of the LPC2148 converts the analogue values into digital values. The ZigBee communication module is used to communicate between the two sections.

### *B. Monitoring Section*

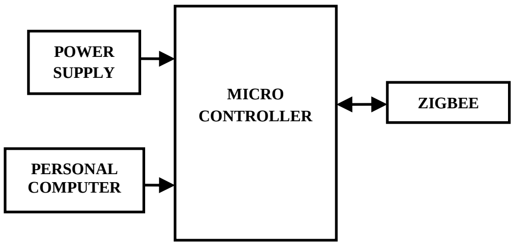


**Figure 2 - Monitoring Section**

The ATMEL ATmega8 microcontroller is used at the monitoring unit. For controlling and monitoring purpose a personal computer is used at the Monitoring Section. The communication with the home section is maintained using a ZigBee communication module.

## IV. HARDWARE DESIGN

Following are the hardware components used to implement this system.

### *A. Microcontroller*

The ARM7TDMI microcontroller is used for the home section of the system. It is a member of the Advanced RISC Machines (ARM) family of general purpose 32-bit microprocessors, which offer high performance for very low power consumption and price. The architecture of the ARM is based on Reduced Instruction Set Computer (RISC). In ARM microcontroller, while one instruction is being executed, its successor is being decoded, and a third instruction is being fetched from memory [28]. A unique architectural strategy known as THUMB is employed in the ARM7TDMI processor. This strategy makes it ideally suited to high-volume applications with memory restrictions, or applications where code density is an issue [29].

The LPC2148 from NXP semiconductors shows the following features.

1. 16/32-bit ARM7TDMI-S microcontroller in a tiny LQFP64 package.
2. 8 KB to 40 KB of on-chip static RAM and 32 KB to 512 KB of on-chip flash memory.
3. In-System Programming/In-Application Programming (ISP/IAP) via on-chip boot loader software.
4. USB 2.0 Full-speed compliant device controller with 2 KB of endpoint RAM.
5. Two 10-bit ADCs provide a total of 6/14 analog inputs, with conversion times as low as 2.44 ms per channel.
6. Single 10-bit DAC provides variable analog output.

7. Low power Real-Time Clock (RTC) with independent power and 32 kHz clock input.

The ATMEL ATmega8 microcontroller is used at the monitoring section which is having advanced RISC architecture. It is having the following features.

1. High-performance, Low-power AVR 8-bit Microcontroller.
2. Up to 16 MIPS Throughput at 16 MHz
3. 8K Bytes of In-System Self-programmable Flash program memory, 512 Bytes EEPROM and 1K Byte Internal SRAM.
4. 8-channel ADC in TQFP and QFN/MLF package while 6-channel ADC in PDIP package with 10- bit accuracy each.
5. Programmable Serial USART and Master/Slave SPI Serial Interface.
6. 23 programmable I/O Lines while it is available in 28-lead PDIP, 32-lead TQFP, and 32-pad QFN/MLF packages.

### *B. Relays*

It's an electrical device that functions like a wired remote control switch.

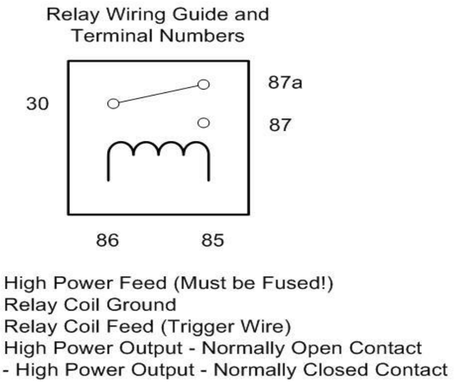


**Figure 3 – Relay Symbol**

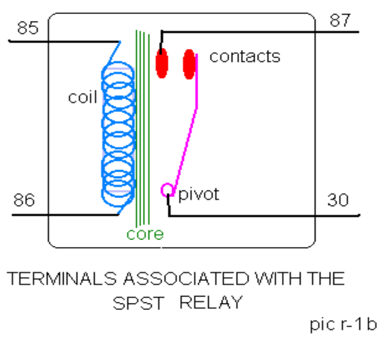


**Figure 4 – Single Pole Single Throw (SPST Relay)**.

### *A. Current and Voltage Transformer*

The auxiliary load in the Home section is employed with the current and voltage transformer respectively for the sake of power measurement. The current transformer connected in series with the load while the potential transformer is connected in parallel with the load. We are using a step down potential transformer with 230V/5V, 20VA rating. The current transformer is used with 100V/5V, 15VA rating. The secondary winding of both the transformers are connected to the microcontroller unit.

### *B. ZigBee Communication*

ZigBee is a new wireless technology guided by the IEEE 802.15.4 Personal Area Networks standard. It supports star, tree and mesh topology. The maximum signal rate for ZigBee is 250kbps. Although the communication rate of 250kbps is lower than the other short-distance wireless communication standards, the most attractive features of ZigBee lie in its low power consumption and a low-cost installation capability [9]. The transceiver operates at a frequency of 2.4GHz with 30 meters range [32]. It is having a Standard UART interface with TTL (3-5V) logic level [32]. There is an automatic switching between TX and RX mode.

## V. SOFTWARE DESIGN

Following are some of the software platforms which are used in the system design.

### *C. Keil µVision4*

µVision is a window-based software development platform. It integrates all the tools needed to develop embedded applications including a C/C++ compiler, macro assembler, linker/locator, and a HEX file generator. Keil can be used to create source files; automatically compile, link and covert using options set with an easy to use user interface. It is used to simulate or perform debugging on the hardware with access to C variables and memory.

### *D. Flash Program Utility*

This utility tool is used for downloading the application program into Flash ROM. It produces the object code in hex form which is referred as .hex file. The facility is provided with Keil version 4 to dump the hex code in the flash ROM of the controller.

### *E. MATLAB*

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB product, we can solve technical computing problems faster than with traditional programming languages, such as C, C++, and FORTRAN. Following are some of its features.

1. High-level language for technical computing.
2. Development environment for managing code, files, and data.
3. Interactive tools for iterative exploration, design, and problem solving.
4. Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, and numerical integration.

5. 2-D and 3-D graphics functions for visualizing data.Tools for building custom graphical user interfaces.

A graphical user interface (GUI) at the monitoring section of the system is designed using MATLAB. Using this GUI a user can select the required mode and priorities to the devices of the home section.

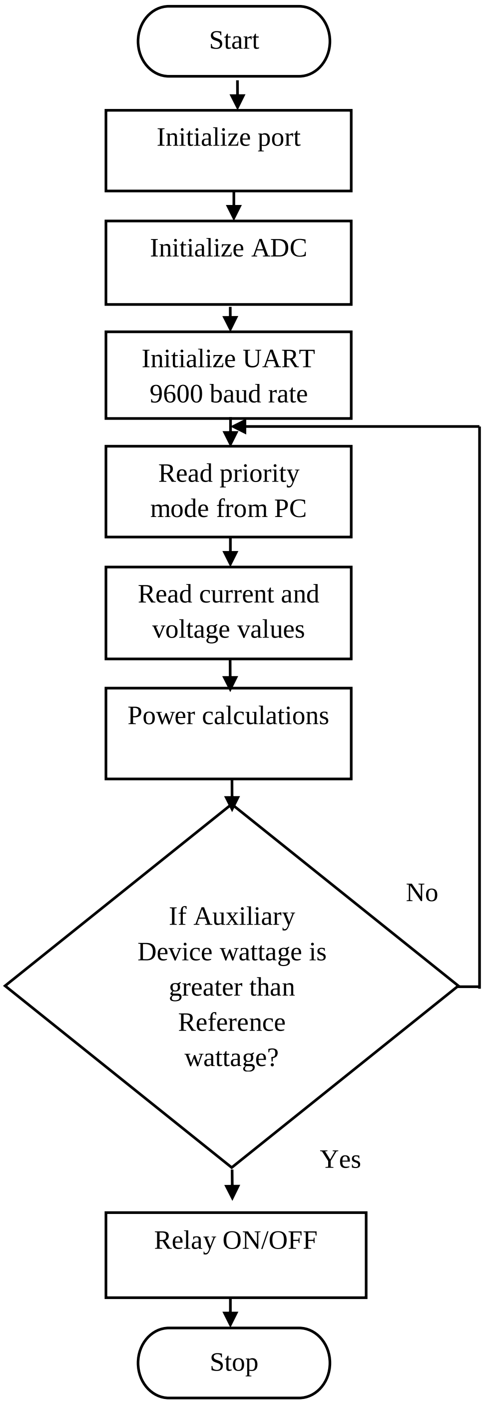


**Figure 5 - Flow Chart**

## VI. Conclusion And Future Work

A smart energy system using ARM7 and Zig Bee for energy efficiency is discussed. The proper implementation of the proposed discussion is a key factor to obtain the accurate results. The priorities and selection of modes for the devices can be done in a manual as well as in an automatic manner. The proposed system can be utilised in the single house, apartment and other residential buildings with the use of added sophisticated sensors like PIR sensor for motion detection, temperature sensors etc.

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