

# ZigBee Based Wireless Sensor Network for Energy Management System

Vishal B. Bhor<sup>1</sup>, Dr. G.U. Kharat<sup>2</sup>, Shekhar H. Bodake<sup>3</sup>

<sup>1</sup> Student, Second Year M.E., E&TC Dept., Sharadchandra Pawar COE, Dumbarwadi, Maharashtra, India

<sup>2</sup> Principal, Sharadchandra Pawar COE, Dumbarwadi, Maharashtra, India

<sup>3</sup> P.G. Head, Sharadchandra Pawar COE, Dumbarwadi, Maharashtra, India

## ABSTRACT

The paper introduces an application design of star topology ZigBee based wireless sensor network for energy management system. The system is divided into three parts: a ZigBee End User Device (ZEUD or ZigBee Node), Base station (ZPC- ZigBee PAN Coordinator) and Web-server. The ZEUD consisting of microcontroller board, current sensors and ZigBee module. Base Station is consisting of raspberry pi with Ethernet shield, HDMI, USB connectivity and ZigBee module for the transmission of data. ZigBee is used as a wireless protocol. This wireless technology offers benefits such as low power, low cost, low data rate and supports on IEEE 802.15.4. A Web server is built up using WAMP which provides specialized application packages for web-server. HTML and PHP framework is used for client and server side application programming. MySQL is used as Database server. All the data received from ZEUD is saved in the database. The proposed system can be used as a framework in web based energy monitoring & controlling applications.

**Keyword:** - Wireless sensor network, Energy management system, ZigBee protocol, Microcontroller, Web server.

## 1. INTRODUCTION

Energy is unavoidable. Energy is the basic necessary for the economic development of a country. Many functions necessary to present-day living grind to halt when the supply of energy stops. Energy is consumed for various applications such as lighting system, electronic devices usage and HVAC- Heating, Ventilating, Air conditioning. Most of the commercial buildings and long operable industries have a tendency of wasteful energy consumption and it is undeniable. In India, The estimated electricity consumption increased from 4, 11,887 GWh during 2005-06 to 882,592GWh during 2013-14, showing a CAGR of 8.84%. The increase in electricity consumption is 7.07% from 2012-13 (824,301GWh) to 2013-14 (882,592 GWh). Of the total consumption of electricity in 2013-14, industry sector accounted for the largest share (43.83%), followed by domestic (22.46%), agriculture (18.03%) and commercial sectors (8.72%) [1]. energy consumption irrespective of reducing productivity. The energy audit's target is focused on the profiling behavior of commercial buildings and the manufacturing industrial sector. The solution for this problem is designing an electricity monitoring system. The system allows measurement and data acquisition of electricity in real time condition. Measurement and data acquisition are important for recognizing conversion efficiency of energy, local resources and failure reports sending using inter communication network systems [2].

Today, wireless technologies are becoming popular which is used in various applications. With Digital communication and the rapid development of computer networks, low cost, low power short range wireless networks became common. The emergence of Bluetooth, Wi-Fi and ZigBee technologies provided excellent opportunities for wireless sensor networks. Wireless Sensor Networks are a technology that can provide ubiquitous computing [3]. For a network based embedded system a web based user interface is considered as a state of an art. This web based interface makes it possible to configure, control and monitor through any device like computer, tablet, cell phone, iPads, iPhones and almost any device that supports a web browser.

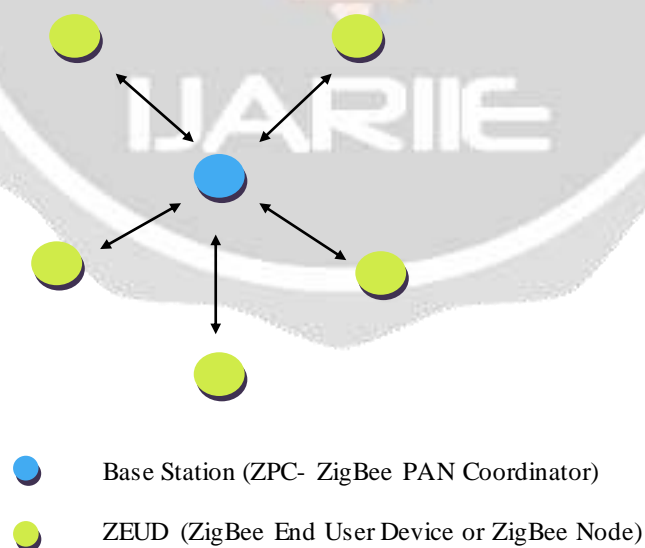
This paper describes the design, implementation of a wireless sensor network for energy management from remote location through the use of microcontroller, ZigBee wireless protocol & webserver [4]. ZigBee is an open source wireless protocol which having advantages such as its low cost, its low data rate, low power and its support on IEEE 802.15.4 [5]. ZigBee protocol has been developed in integration of building electricity monitoring system [6]. HTML and PHP framework is used as client and server side application programming. MySQL is used as Database server. Wireless Network Standards like ZigBee, Bluetooth, and RFID have always been the favorites for embedded engineers working on any data acquisition systems.

## 2. RELATED WORK

In this section we'll have an overview of some of these systems. The system presented in [7] puts forward the design that ensures the electrical power management through wireless standards like ZigBee and GSM. Main aim of the project is that the wireless sensor network will separate and manage the devices in the network on the basis of power consumed by appliances to make the efficient use of power. The system consists of a Control Unit, End Device Unit having ZigBee module interface. Measurement of Power through microcontroller circuit board and GSM modem [7]. The research paper presented in [8] that uses PIC Microcontroller and Programmable Logic Controller with Ladder Logic programming interface for the efficient energy management. The system presented in [9] that is based on AVR Microcontroller that is used for monitoring the voltage, current and temperature of a distribution transformer in a substation and to protect the system from the rise in mentioned parameters. Protection provided to the distribution transformer can be accomplished by shutting down the entire unit with the use of the Radio frequency Communication. The paper presented in [10] ensure that the power consumption monitoring. The basic working principle of this project solely depends on one of the features of a digital energy meter. Monitoring system consisting of AT89S52 Microcontroller circuit with SIM900 GSM module.

## 3. GENERAL OVERVIEW

Our proposed wireless energy management network has three major function modules: ZigBee End User Device (ZEUD/ZigBee Node), Base Station (ZigBee PAN Coordinator) and the Web server. ZEUD can play the role as 'Energy Measurement Module' in wireless sensor network where ZigBee End User Devices have two-way communication with the central Base Station. The Communication link between ZEUD and Base Station is implemented in ZigBee module by ZigBee protocol. Star Network topology is used as wireless network system, where there are several ZEUD (ZigBee Nodes) and one Base Station. The star network topology is shown in fig. 1.



**Fig -1:** Star Network Topology is used in Wireless Network System

### 3.1 System Architecture

Architectural block diagram of ZigBee wireless sensor network for energy management system is shown in fig. 2. The System is divided into three parts: a ZEUD, Base Station and Web-server. Block diagram of the system is shown in fig. 2.

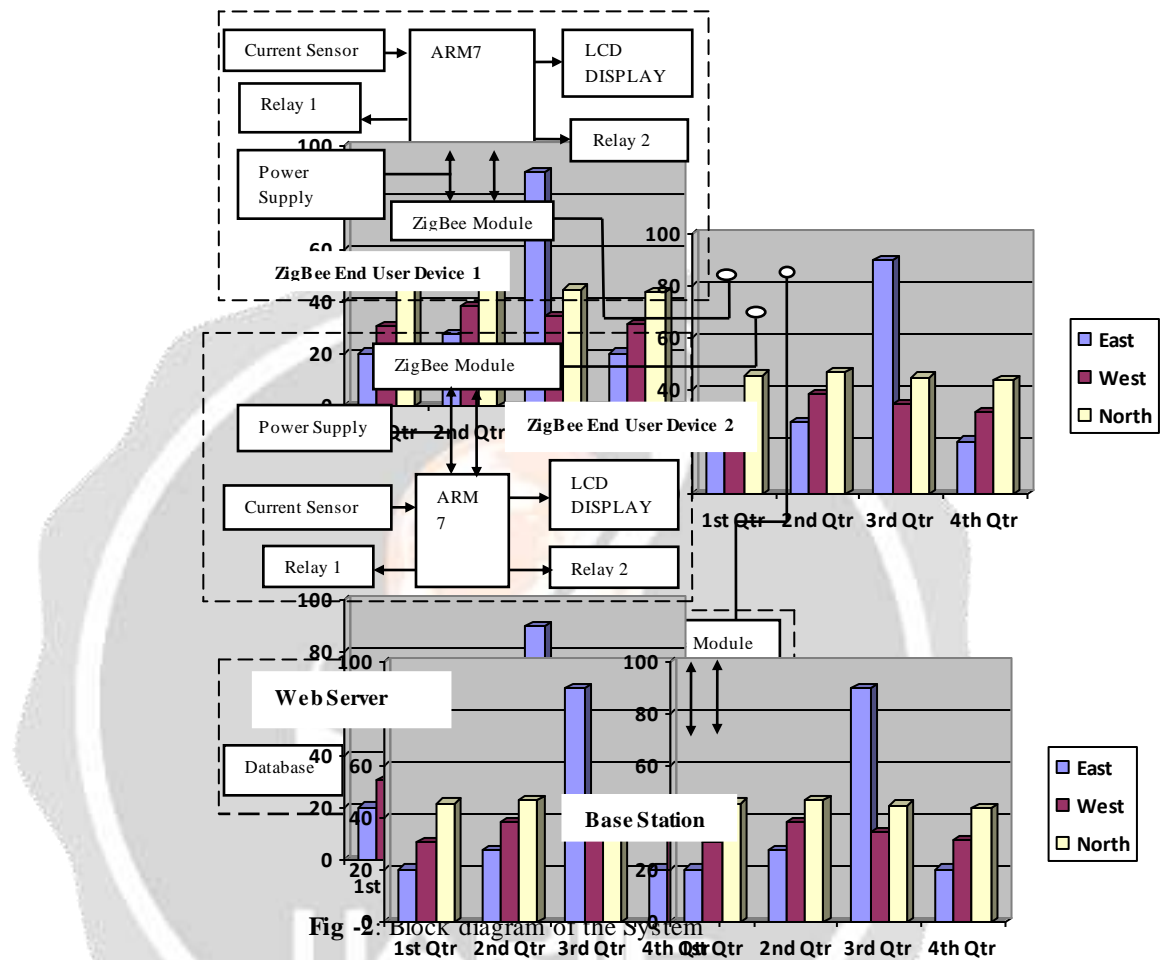


Fig -2: Block diagram of the System

#### 3.1.1 ZigBee End User Device

ZEUD consisting of sensing mechanism of current sensor, digitization, data access by microcontroller circuit, digital

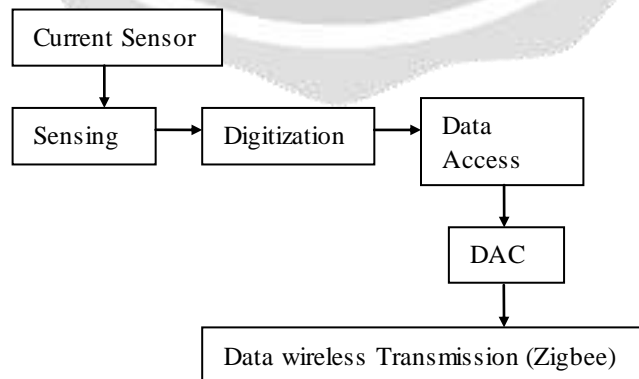
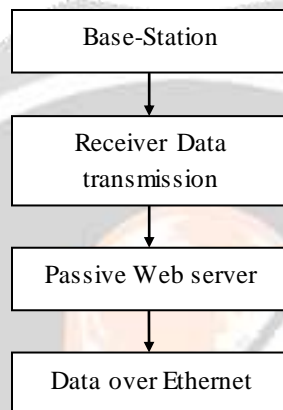


Fig -3: Block diagram of the ZigBee End User Device (ZigBee Node).

to analog conversion and wireless data transmission through ZigBee module. Important values from data register bank will be taken by ARM7 microcontroller & stored into RAM. Values of respective electrical quantity are wrapped (in long message string) and transmitted wirelessly (using ZigBee module from ZEUD to Base Station) after the data conversion process is completed in microcontroller. Block diagram of the ZEUD is shown in fig. 3.

### 3.1.2 Base Station

A message will be received by base station through ZigBee module from End User Device. As per microcontroller algorithm, length of message content will be extracted. Wireless LAN/PAN network is used at base station's hardware (raspberry pi) for data transfer through TCP/IP protocol. Serial Data from Microcontroller will be converted into data frames and transmitted wirelessly over TCP/IP. Block diagram of the Base Station is shown in fig. 4.

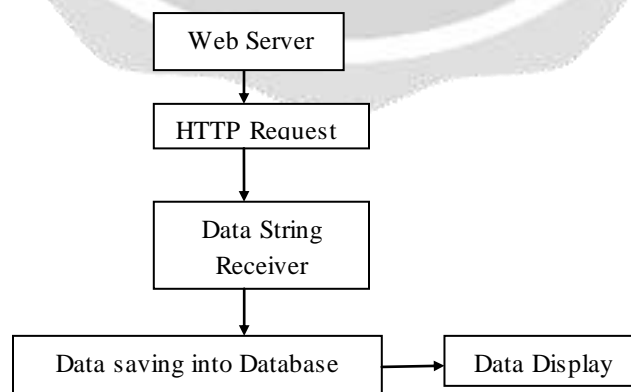


**Fig -4:** Block diagram of Base Station (ZigBee PAN Coordinator).

### 3.1.3 Web Server

Web server received a request of data acquisition from base station. Data gets uploaded on web server through existing functionality developed in PHP programming. Data is directly stored in to the MySQL database that has been configured for the web application. Then data can be used for the purpose of electricity monitoring through web application.

Web server is built up using WAMP which provide specialized application packages for web server. Apache server is used as HTTP web server. HTML and PHP framework is used as client and server side application programming. MySQL is used as Database server for storing the data which is transmitted from base station.



**Fig -5:** Block diagram of Web Server.

Web monitoring is divided into following stages:

1. *Data fetching:*

The process of transmitting data string using HTTP request from base station to base station IP. PHP/HTML file is getting called via AJAX while data fetching process.

2. *Data Storage:*

After fetching; data string is applied to database system where it gets stored into MySQL database.

3. *HTML and PHP based web application user interface:*

It is part of monitoring system that is for interacting with users and providing the data of electricity usage either numerical or graphical display format through web browser.

**3.2 Measurement Test**



**Fig -6:** Experimental Setup.

Given,

Current 1=  $I_1$ = Total Current of Relay 1 and Relay 2 of ZigBee End User Device 1 in ampere,

Current 2=  $I_2$ = Total Current of Relay 1 and Relay 2 of ZigBee End User Device 2 in ampere,

Voltage=  $V=230$  V AC,

Currents  $I_1$  and  $I_2$  sensed by microcontroller hardware, displayed at respective LCD panel at ZigBee End User Devices and then sent to the web server.

Power Factor for resistive loads= $p= 1$ ,

Power= Voltage (V) ×Current (I) ×p,

Power 1=  $P_1 = 230 \times I_1 \times 1$  Watt,

Power 2=  $P_2 = 230 \times I_2 \times 1$  Watt,

**Table -1:** Measurement Test.

| Current values displayed at LCDs in ampere |       | Current values displayed at web-server in ampere |       |                       | Power in Watt |        |
|--|-------|--|-------|-----------------------|---------------|--------|
| $I_1$                                      | $I_2$ | $I_1$  | $I_2$ | Timestamp             | $P_1$         | $P_2$  |
| 0.518                                      | 0.977 | 0.518  | 0.977 | 20-05-2016 5:59:18 AM | 119.14        | 224.71 |
| 0.200                                      | 0.300 | 0.200  | 0.300 | 20-05-2016 6:24:31 AM | 46            | 69     |
| 0.194                                      | 0.300 | 0.194  | 0.300 | 20-05-2016 6:25:05 AM | 44.62         | 69     |
| 0.147                                      | 0.300 | 0.147  | 0.300 | 20-05-2016 9:05:13 AM | 33.81         | 69     |
| 0.144                                      | 0.300 | 0.144  | 0.300 | 20-05-2016 9:05:26 AM | 33.12         | 69     |



## 4. ADVANTAGES AND DISADVANTAGES

### 4.1 Advantages

#### 1. Data rate:

ZigBee standard operates on low data rates. As it operates on rates up to 250 kbps. It becomes an ideal choice for implementing WSN's.

#### 2. Data Security and Reliability:

Direct Sequence Spread Spectrum (DSSS) modulation technique is used by ZigBee. DSSS ensures data security. Reliability of data increases due to the Carrier Sense Multiple Access –Collision Avoidance (CSMA-CA) technique being used for data transmission.

#### 3. Economical and low power consumption:

ZigBee modules are cheaper than conventional RF modules. Also SLEEP mode can be activated when a ZigBee is not transmitting or receiving any data, thus they prove to be power efficient.

#### 4. Compatibility:

ZigBee end devices can communicate with any other device working on IEEE 802.15.4 protocol.

#### 5. Mobility:

Remote ZigBee module, either moving or stationary can convey data as long as it is in the operating range.

### 4.2 Disadvantages

The ZigBee implementation becomes a tedious job if multiple ZigBee End User Devices are being used in a network.

## 5. APPLICATION OF PROPOSED WORK

1. To monitor power usage in different departments. The power usage in different departments can be monitored, so it can be observed that which department is using maximum power. So, if there is wastage of power in any department, it can be limited.
2. System can be used to monitor total power usage of small scale industries, institutes.
3. It can be used in such places where manpower is less or due to environment effects it is difficult to collect the data of power consumed.
4. It can be used in such areas where people manipulate the meter reading.
5. It can be used for monitoring the consumption of the power in houses. It is helpful for the user also because they do not have to wait for the person coming from the Electric Board. Also it reduces the human error.

## 6. CONCLUSIONS OF PROPOSED WORK

This paper puts forward the design of wireless sensor network using ZigBee protocol for management of the electrical energy usage. This network consisting of sensor nodes, end user device, base station and a web-server. This wireless network is a pragmatic approach to the measurement of power using the ZigBee based network. This system efficiently combines the two branches as measurements of Electrical engineering with the high-tech Electronics communication. The basic principle of monitoring and transmitting and management of measured parameters can be applied to many other applications such as gas, flow, temperature measurement. Any other communication system will not require for this system to be set up, since the setup of mobile technology is already there for saving the cost of the final installation. The most challenges and “green” legislation that utilities are facing today, combined with increased demand from consumers for more flexible offerings and cost savings, make a solution like smart meters both timely and inevitable. ZigBee's wireless open standard technology is being selected around the world as the management of energy and efficient technology of choice. Implementing smart meters with an open standard such as ZigBee protocol standard offered cost effective solution, ensure interoperability and future-proof investments made by both utilities and consumers. Consumers and businesses will see changes they never dreamed possible. The information collected through smart energy meters provides unprecedented insight into energy demand and usage, allowing utilities and consumers alike to do their part to ensure continued and affordable supply of essential services into the future.

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