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Wireless Sensor Network Based Controlling and Monitoring for Smart Homes using Sigsbee

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Abstract: ***ZigBee is a wireless communication protocol which finds application in home-automation environment monitoring, smart metering and industrial automation etc. Here wireless sensor network and ZigBee are utilized for smart home-automation. The proposed system monitors the electrical parameters e.g. voltage, current and power consumption. The novelty of this system is the implementation of a mechanism to control the appliances using a sensor network on ZigBee. The developed system is a low-cost, compact, and flexible in operation. Further it will help in reducing carbon footprint as it will allow the appliances to work only when desired and thus can save electricity expenses of the consumers. The prototype has been extensively tested in real-life situations and experimental results are very promising.***

Index Terms: Home Automation, Monitoring, Wireless Sensor Network, ZigBee.

I. INTRODUCTION

The leading applications of wireless sensor network (wsn) are house monitoring and automation where a number of mixed sensors are installed to find out different actions of users. In WSN, many nodes which include sensors, actuators, controllers, and Radio frequency chips for wireless communication are used. First international standard for WSN IEEE 802.15.4 standard implemented in 2003 [1]. ZigBee communication protocol IEEE 802.15 was standardized by ZigBee Alliance and its Mesh network along with IPv6. Encryption, verification of network nodes, an effective and modern routing that leads to mesh. The WWW services is used from a smart house view point to connect households, objects, mainly electrical and electronic appliances with sensors and actuators by internet of things (IOT). The interests to create and outline the smart house are; enhancing extravagance, openly living, security and well-being, and successful use of power. To discover the issues and difficulties of the real execution of efficient home vigilation, we need to know present and progressing research here. A scope of brilliant home frameworks for encompassing helped living has been anticipated and grown, however there are, similarly few houses that utilize savvy advancements. Aware Home Research Initiative (AHRI) at GIT (Georgia Institute of Technology) [2], CASAS (The Center for Advanced Studies in Adaptive Systems) at Washington State University [3], AgingMo at University of Missouri [4], PlaceLab at MIT [5] and Smart home Lab at Iowa State University [6],[7] are checking the activity of everyday living, enhancing the solace by creating mindful relative circumstances through heterogeneous sensor positioned appropriately. These sensor units are accompanied with cameras as well. Electronic House by McDonough in New York, Toyota dream house in Japan, W.S at Stuttgart, and Crystal House by Hung at Taichung, Taiwan, House R128 by Intgeniere, in Germany which have focused on vitality protection objectives and maintainability and solace and offer accommodation through the mental aptitude of nature [8]. Many activities including the use of flag helped wearable gadgets are proceeding in various research labs Senswear Armband by Body Media Inc [9], SmartShirt [10], and PROETEX extend by CSEM focus [11], LifeShirt by Vivometrics [12] are wearable gear to quantify ECG. Other research has focused on fall location utilizing wearable sensors [13] in view of accelerometers. In this paper we developed a system which is low-cost, compact, and flexible in operation, also help in reduce in energy consumption thereby reducing carbon footprint.

The remaining sections of this paper are organized as follows. Section II related to literature review on automation in home appliances. In Section III discusses system architecture. Section IV related to working of system. Section V explain the controlling of electrical appliances. Section VI describe the hardware and software implementation. Section VII discusses the result of smart home automation section VIII conclude the paper.

II. LITERATURE REVIEW

The system explained in [14]- [16] provides different ways to control home appliance such as the Global System for Mobile (GSM), Zigbee, Bluetooth and internet. The microcontroller PIC16F887 is used to control the home appliances with GSM communication modulator and demodulator receives instruction from the mobile phone via GSM network [17]. It is a Short Message Service (SMS) based system. In system [18] is a Machine to Machine system and communication occurs through the GSM module. GSM has option for Machine to Machine communication which include the Dual Tone Multi-Frequency (DTMF), SMS and General Packet Radio Service (GPRS).

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The server at the home is based on the SMS/ GPRS mobile cell module and controller [19]. This can be used by the user to monitor and control the different home appliance at the home by using the Java enabled cell phone. A voice operated control system is proposed [20] that used to enable or disable the home appliance remotely. The complete system utilized [21] the GSM communication network and all peripheral controlled by the Microcontroller of AVR. The proposed system was based on the SMS. The client provides the commands sent via SMS. The application of the Bluetooth technology and cell phone is to manage and control the home application [22]. The Personnel computer that is interface via Universal Serial Bus to the Bluetooth card, sensing network and a PWM circuit. The main disadvantage is that it has very limited range of operation about 10 meters only. Power point control using wireless technology hardware detailed given [23]. The main objective of this proposed network to manage the power of all devices and instruments at remote places. The instructions are sent through the telephone lines. The DTMF technique is provided by the telephone's lines [24]. The ZigBee Home application appliances can be used wirelessly [25]. Voice recognition and controller system is used for this aim. Wi-Fi communication technology [26]and Arduino board is used in this system. Light and temperature sensor can be used to control the home appliances. A detailed explanation of different technologies that can be applied to home appliance automation is done [27]. It provides the basic idea how modern technology networking can be applied for the home appliance applications. [28]. This paper presented a ZigBee based wireless air-conditioner remote controller architecture. [29] Design of an embedded system which improves the energy utilization rate, reduces the waste of energy consumption. In [30] the proposed study focuses on the usages of ZigBee and WSN in smart home automation system. In this, a Simulink model of different levels of energy consumption in household electrical appliances for monitoring consumption rate numerically and graphically is designed.

Table I Consolidated comparison of all systems:

System	Primary Communication	Remote Access	Number of devices	Speed	Real Time
GSM Communication	SMS	world wide access	Unlimited	Slow due todelivery issue	No
Bluetooth	Bluetooth and Attention commands	Restricted to range 10m	Unlimited	Fast due to proximity	Yes
Phone based	Phone lines	world wide with phone line	12 due Freq of DTMF	Fast	No
Zigbee	Zigbee and Attention commands	Around 10m	Unlimited	Fast	Yes
Wireless	IR or Other waves	Depending on range and spectrum of waves used	Unlimited	Slow due to interference	Yes

III. System Architecture

The system has been designed for the Control of connected household appliances and measurement of their electrical parameters remotely. Salient features of the system are the easiness of modeling, setup and user friendly. Electrical power consumption of various appliances in a house along with drawn current and supply voltage is the key parameter. Fig. 1 demonstrates the operational explanation of the proposed designed and developed system to control apparatuses in view of the consumer prerequisites and monitor electrical parameters. The electrical parameters of home appliances have been measured by interfacing with fabricated sensing modules. The functional details of the design and development of the sensing modules are explained in the following sections.

- Master Unit
- Slave unit

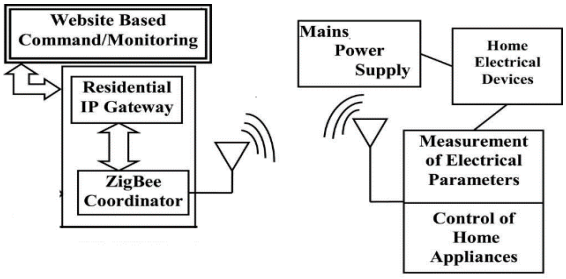

Fig.1 Functional Block Diagram of the System

The output signals from the sensors are integrated and connected to Microcontroller and ZigBee module for transmitting electrical parameters data wirelessly.

Master Unit: The master unit uses ATMega 328 Microcontroller based Aurdino as main controlling device which is interfaced with the following modules - Wi Fi, Zigbee, SD card, RTC and LCD. Block diagram of Master unit is shown in Fig 2. The level shifter in block diagram is used to provide appropriate power supply for the devices used as the power supply requirement are different for Wi Fi, ZigBee and Microcontroller.

The coordinator ZigBee Module communicates with Master Microcontroller and Slave ZigBee module. The SD card module stores the Data like voltage, current and power of each connected device with slave unit. The Real Time Clock (RTC) is used to generate time stamping for each log so that the exact time instance is known. The LCD displays present status of device (ON/OFF) with (1/0), voltage, current and power. LM2596 & LM1117 voltage regulator are used to generate fixed 5V and 3.3V supply. The microcontroller, **Level shifter**, RTC, SD and LCD module operate on 5 Volt whereas 3.3 volt is used to operate ZigBee, **Level Shifter** and Wi-Fi module.

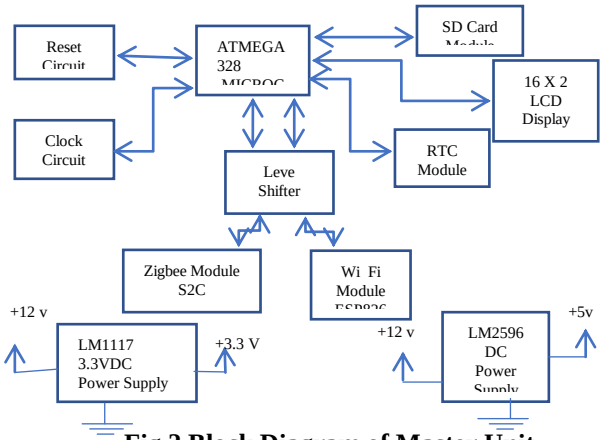

Fig.2 Block Diagram of Master Unit

Slave Unit: The microcontroller communicates with variety of sensors such as voltage sensors, current sensors and temperature sensors, along with switching circuit, ZigBee module and Power cutoff circuit. The voltage sensor includes a step down transformer that converts the voltage from 220V to 12V which is passed through voltage divider circuit and further converted to a digital signal by the ADC which is displayed on the LCD of Master Unit. Current sensors (ACS712) are placed in series of Loads. Microcontroller processes its values and display it on LCD of Master Unit. Temperature sensor (LM35) is used to measure the temperature of Slave unit area. In switching circuit, Solid State Relay (SSR) is used to switch ON/OFF the devices. Microcontroller sends a signal to SSR for switching purpose. It consists of Opto-coupler and the Triac. The Zigbee Module communicates with Slave Microcontroller and Coordinator Zigbee module and receives the status of each device from the slave microcontroller. It also receives the On/OFF instructions from the coordinator ZigBee. Its send the received slave microcontroller data to coordinator ZigBee and Coordinator ZigBee data to slave Microcontroller. LM7805 & LM1117 voltage regulator are used to generate fixed 5V & 3.3V supply respectively.

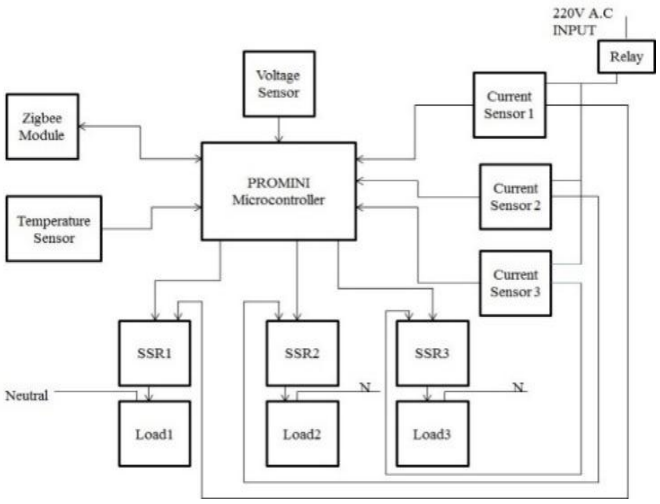

Fig. 3 Block Diagram of Slave Unit

IV. WORKING OF THE SYSTEM

The three Web pages, User / Admin login page, User web page and Admin web page were developed for complete operation of the system. Login user ID and Password are required to access User web page from the web login page. In user web page first check the status of the connected devices then user press the ON switch of device 1, which results into a command through MQTT to Wi Fi module, if Wi Fi module is connected to authorize internet connection then Wi Fi forward this command to Microcontroller, which sends a signal to Coordinator Zigbee module (Master). The coordinator Zigbee further sends command to Slave Zigbee, Slave Zigbee send a command to Slave microcontroller, the microcontroller generates a trigger command to SSR and which activates device 1. Voltage and current sensor interfaced with slave microcontroller, Slave microcontroller senses the voltage and current and sends to slave Zigbee, slave Zigbee sends status of devices, voltage and current to the master controller, which forwards all these signals to LCD. LCD will display status of devices, voltage, current and power of each device. The sensed data is also displayed on the user web page for monitoring and controlling the devices. A SD card is used to store information that comes from Master microcontroller. The stored data is used for data analysis for Load Management and other uses. A scheme has been setup where the system figures out the peak hour of electricity usage and it accordingly controls power consumption at home by switching off the un-important appliances. The system is connected to the mains (220- 240 V, 50 Hz) through monitoring circuit.

V. CONTROL OF ELECTRICAL APPLINCES

Our system is unique from other similar literature because of its feature of controlling. To give flexibility to consumer in controlling the device triac-BT139 along with intelligent Metering system has been used for switching device on/off. The user can turn the device off and on three different ways.

A. Automatic control

Our system can be programmed in such a way that it can automatically scrap webpage of electricity distributor of the particular user to get the tariff rate of electricity. And the system has the capability of deciding the peak hour and accordingly it will switch off or switch on the connected device, giving user some sort of automation

B. Manually control

The user is provided with a manual control of system. A OFF/ON switch is directly provided to user to control the system at his/her own wish. Our system is designed in such a way that a manual command will always override the automatic command

C. Remotely control

Users can remotely control the system from a remote location. It can be controlled from a webpage or even from an app. This is pretty useful for users who often forget to switch off their electric appliances before stepping out of home.

The webpage will show the user about the current status of appliance and the user can turn the appliance on or off from the webpage

VI. HARDWARE DESIGN

The complete system has been designed and developed hardware wise in two units, called Master Unit and Slave Unit. Following Hardware Components Used in these Units.

- AVR ATMega328 Microcontroller working on Arduino UNO Platform
- Wi Fi Module - ESP 8266
- ZigBee Module 2C
- DC-DC Converter - LM 2596
- Voltage Regulator - LM 7805 & LM 1117
- Triac with optocoupler - BT139
- Current Sensor - ACS712
- Micro SD card Module
- RTC - DS 1307 module
- Level Shifter
- 16 x 2 LCD MATRIX
- Temperature sensor - LM 35

A. Hardware setup for master and salve unit

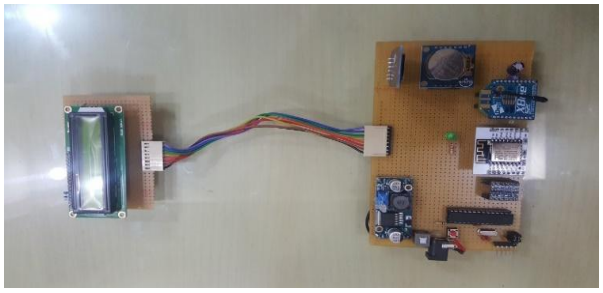

Fig. 4 Setup of Master Unit

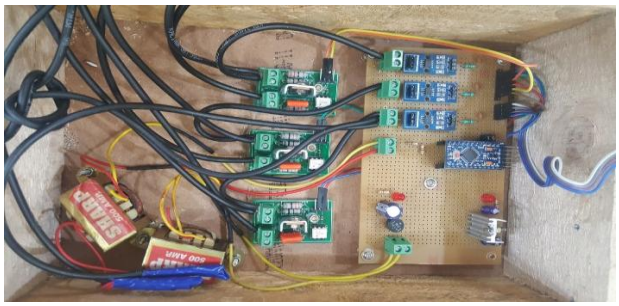

Fig.5 Setup of Slave Unit

B. Software implementation

Development of Web pages For remotely control and monitor of electrical appliances, the three web pages have been developed using HTML, Java script, PHP. Login Web page has been developed for secure login in the internet for user and Admin. For login, user name and password are required. The Fig.6 has been given below for login the user or Admin.

Fig. 6 Login Page of user

In Fig.6 user name and password is entered. Here two pages was developed for Appliance user and Admin. Appliance user can control and monitor the all appliances which is connected through the developed Slave system. But admin can only monitor and ON or OFF the all appliances at a time in emergency condition. After proper authentication by verifying the user name and password, the page with the information about remotely operating the three electrical appliances can be accessed. We also measure the voltage, current and power of each appliance and Temperature of Slave unit. Every status symbol represents its corresponding appliance condition. Here status symbol colour is blue, which indicate Master unit is not connected with internet hence cannot operate or monitor the appliances. When Master unit is connected with internet the colour of status symbol will change Red or Green. Red indicates particular appliance is OFF. Green indicates particular appliance is ON condition.
In the Fig.7 Admin page has been shown. This page gives information on the input voltage, current, Power of all appliances along with this the Temperature of Slave unit is also monitored.

Fig.7 Admin Webpage

Here also check the status of each device by the colour. Blue colour means Master unit is not connected with the internet. Red colour shows that appliance in OFF condition. While Green colour of status shows device in ON condition. Here Admin can OFF or ON all the devices in the emergency or as per requirement.

VII. RESULTS

The system designed here is best suited for smart homes. Our system tested on loads like Air Conditioner, Geyser, Television, Refrigerator, Water kettle, Toasters, Microwave oven etc. However, any number of electrical appliances can be put as load provided each load is below 4000W. AC operation and Monitoring of electrical parameters was tested using developed system has been shown in Fig.8.

The AC was connected to Device 2 position. It was operated remotely through internet (webpage), the status of Device 2 will change from Red to Green. The web page also shows the input voltage 228 Volt, Current drawn by AC 6.284 Ampere and power consumption 1435 Watt. This also shows the temperature of slave unit 30°C.

Fig.8 Controlling and Monitoring of Air Conditioner

Electric Iron operation and Monitoring of electrical parameters was tested using developed system has been shown in Fig.9.

Fig.9 Controlling and Monitoring of Electric Iron

The Electric Iron was connected to device 3 position. The Iron was operated remotely through internet (webpage). When Iron operated, the status of Device 3 will change from Red to Green. The web page also shows the input voltage 229 Volt, Current drawn by AC 4.96 Ampere and power consumption 1139 Watt. This also shows the temperature of slave unit.

Fig.10 Controlling and Monitoring of all three devices

All three Devices were connected with the developed system for controlling and monitoring of electrical parameters of Water cooler, Freeze and Electric Iron shown in Fig.10. All the three devices connected respectively at Device 1, Device 2 and Device 3. All the devices were operated remotely through internet (webpage).

Table 2: Device status and current or power consumption

Device	status	current	Power consumption
1(water cooler)	on	1.131Amp.	275W
2(freeze)	on	1.482Amp.	361W
3(iron)	on	5.06Amp.	1233W
Total	All device on status	7.673 Amp	1871W

The system warns regarding failures to users. We have designed the system in such a way that it would automatically sense the peak hour of power consumption and it would automatically turn off the devices which are not in use at that particular time and a notification is sent to the user. The system has been tested on many household electrical appliances and the results that were achieved are shown in the result sections. The 0 to 5 % error for all measured parameters. It can be seen that maximum error for household appliance is less than 5%.

VIII. CONCLUSION AND FUTURE SCOPE

An intelligent system that faithfully monitors and controls electrical appliance, for smart homes and intelligent buildings has been developed. A continuous watch on electrical appliances can be kept through a website. By an extension of these ideas, we can keep a watch on the entire building or City. Our aim here is to come up with an optimized low-cost solution that minimizes electricity consumption during peak hours. In future, this framework will be part of user's day to day life. People will be aware of possible power wastage and help reduce carbon footprint.

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