WSN Based Home Energy Management System Using Raspberry Pi: A Novel Cost-Effective Solution

Talha Khan, Muhammad Alam, Kushairy Kadir, Zeeshan Shahid, MS. Mazliham

Abstract— **This research work has been proposed and designed keeping many factors in the mind like easy implementation, energy saving, and security features. The research work streamlined the Home Automation System so that electrical appliances and devices like (Fans, bulbs/lights, door activation etc.) in the house can be monitored or controlled globally by a single touch of a user using android application in a very cost-effective manner. The system design is comprised of raspberry pi, sensors, wireless and android application for controlling processes. The proposed research is a novel integration of hardware and software technology to save the energy. Several approaches like power line communication, zigbee, Z wave, general packet radio service (GPRS), Bluetooth and wireless fidelity (Wi-Fi) have been studied and implemented to achieve the accuracy and efficiency in home energy management system. The proposed cost-effective solution showed that the equipment execution of a multiple structure control framework for house digitalization worked better and consolidated both equipment and programming advancements. The proposed research has been tested. Results proved that it worked better than other existing approaches in a very cost-effective manner. It has been observed that approximate 30% energy consumption can be saved by using the proposed research.**

Keywords: Raspberry pi; Android Application; Relays; Appliances; Home automation, energy management.

I. INTRODUCTION

In the recent era electricity is the most used form of energy that are being utilized by the human beings. Several researches have been carried out for the proper load management and utilization to save the energy. Optimization of the load management of the home has been done by using power line communication [1], [2].

The generation of energy from the renewable energy resources has been observed and recorded using Zigbee and power line communication [3]. The automated devices must have the capabilities of flexibility, adaptability, rapid processing and with least false alarm rate [4]. Automated devices and systems do have less human intervened and can be regarded as cost effective as it saves the time and energy both [5], [6]. Around 1.5 million automated devices for the home automation have been successfully deployed in U.S and their use got increased up to 45.2 % [7]. New innovations in the field of science and innovation play extraordinary role in the daily lives of individuals and groups making their way of life progress. Many researchers have been involved in doing research for more than a decade now to attain power efficiency. The research development in the field of automation is going to become more and more popular as power efficiency is the most crucial issue now a days. In a research paper results proved that Bluetooth technology can be used for fastest transmission more than the wireless and GSM systems [8].

Home automation is a developing idea that attracts the cooperative energy of a few areas of science and information technology. Home automation can be acknowledged as a latest electronic innovation to coordinate with gadgets and appliances so that the whole home appliances can be monitored and controlled as a solitary device. It can also be explained as an automated home energy system that is commonly used to switch lighting, heating, actuating and electronic devices. These devices can also be controlled remotely by a Smartphone or via the internet. An internet protocol (IP) based home automation framework emphasize on controlling appliances whether inside or outside your home. It actually gives an individual the ability to control load appliances around the home. The implementation of a remote management of household appliances via internet anytime, from anywhere in the world today can be realistic approach. Paralyzed people on bed, patients and people could view the status and manage consumption of energy according to their requirements. Home automation can also be regarded as a technology that is used inside the home to give comfort, convenient accommodation, vitality effectiveness, flexibility and security to its user or residents.

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II. RECENT LOAD MANAGEMENT APPROACHES

Several researches have been carried out to save the energy efficiently like Z-wave [9], General packet radio service (GPRS) [10], wireless fidelity (Wi-Fi) [11], [12] and Bluetooth [13]. Home automation can easily be implemented and deployed using Bluetooth technology and may be regarded as a cost-effective solution [14]. Modifications in the electronic circuitry design of the load management devices can boost the performance of energy consumption devices [15]. Recently energy crisis in Pakistan have highly intensified the need to optimize the load management devices more efficiently [16], [17]. Faraway access, load scheduling, energy saving of home appliances like lighting, refrigerator, air-conditioning and heater could be possible by the combination of smart meter and power line communication technologies [18] – [20]. Network architecture using Power line communication (PLC) based on the home energy management system (HEMS) was proposed for the load management [21]. Real time monitoring of home energy consumption devices was accomplished [22]. Smart and intelligent home load energy management system are designed and develop to provide security, ease and record of consumption by the load [23], [24]. Quality of service (QoS) has become a crucial issue while incorporating two technologies at a time during the streaming, carrying the entertainment and control data using several heterogeneous equipment and devices [25]-[32].

III. PROBLEM STATEMENT

Big loss and misuse of energy have been noticed and observed in current situation all over the world. People are not properly aware for utilizing the available energy as they often forget to turn off the lights and appliances whether staying in or out from home. The application of home automation gives you access to control devices in your home from a distant place in a very easy way. Due to Home Automation System, we never have to worry about switching off the appliances, opening the door and so on.

Usually accidents occur at night time when the home is left alone. Home security is more needed now a day.

IV. METHODOLOGY

a. Raspberry Pi

In this research Raspberry Pi 3 Model B has been used as a basic controller of our research because Raspberry Pi 3 Model B have some specific features like built-in Wi-Fi module, advance speed of the processor, at the same time 40 general purpose input output pins (GPIO).

b. Wi-Fi Router

The wireless fidelity (Wi-Fi) Router has been used for communication between built-in Wi-Fi module in Raspberry pi and android phone application. Ethernet cable was connected to our Wi-Fi router and Raspberry pi Wi-Fi module at the same time android phone was connected with the same router.
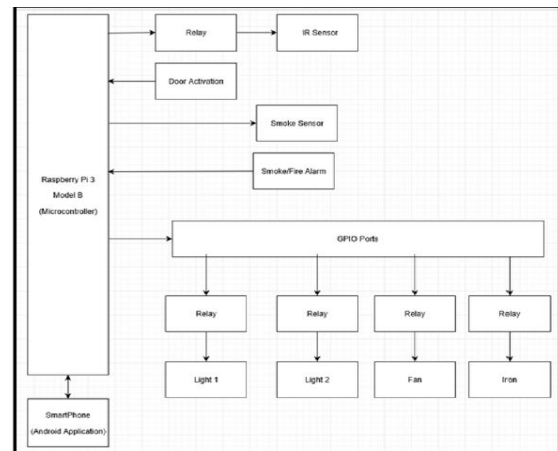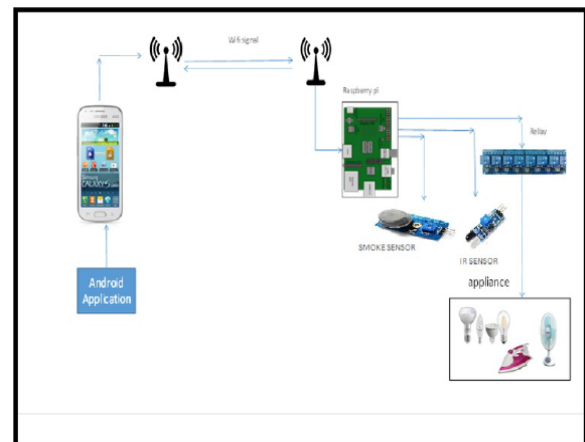

Figure. 1: Main Block Diagram

Figure.2: Proposed Research Diagram

c. Android Application

It is a software-based application that will be executed on the Android platform which has been designed and developed on Android Studio using Java language. It will be used in our proposed research as a user-friendly graphical user interface to control appliances through a single hand-held device.

Fig. 1 represents the main block diagram. Android phone is utilized to execute the application and is utilized to transmit signals for various sorts of directions requested by the user. Smart phones are capable due to their computational resources and capacity to give you most extreme administration. Research has improved the utilization of advanced mobile phone by utilizing it for electrically home automation framework so it requires less human exertion and more control. A Smart telephone can be considered as a multitasking gadget, altogether covers different applications on a single platform. Higher processing speed cell phones perform better due to their higher computational resources. It can illustrate and display useful information graphically and it is exceptionally convenient.

The research diagram defines that the signal is transmitted by the phone which specifically command comes from the user, the signal is communicated through the Wi-Fi module which interfaced with the microcontroller (Raspberry pi 3),
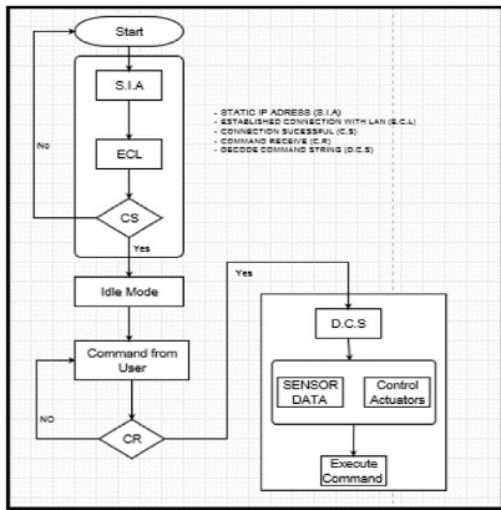
Figure.3: Flow diagram of the whole research mechanism step by step.

Fig. 4 Schematic Diagram

the controller controls sensors and other home appliances and it generates signal to the controller according to our requirements.

Raspberry pi act as a bridge as it generates both input and output signal. If signal was sent from the phone to switch on/off the appliance means that user has sent the interrupt signal from his or her cellular phone.

Fig. 4 explains that raspberry pi is used as main controller of the proposed research pi is like when a person wants to switch on or off the appliance, he sends the input signal from his mobile through an Android Application to the GPIO pins of Raspberry Pi. Every pin is connected with each of the required appliances and whenever controller receives the signal it switch on the appliances or switch off the appliances respectively. The controller use is not for the input purpose as the output of the signal from the appliance is also received
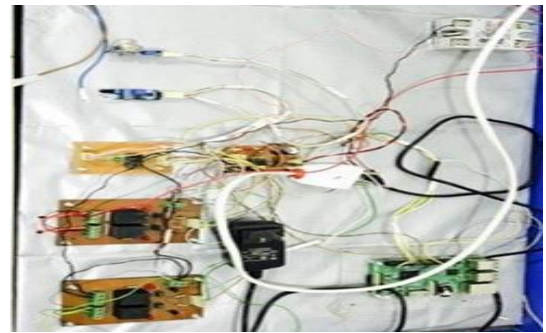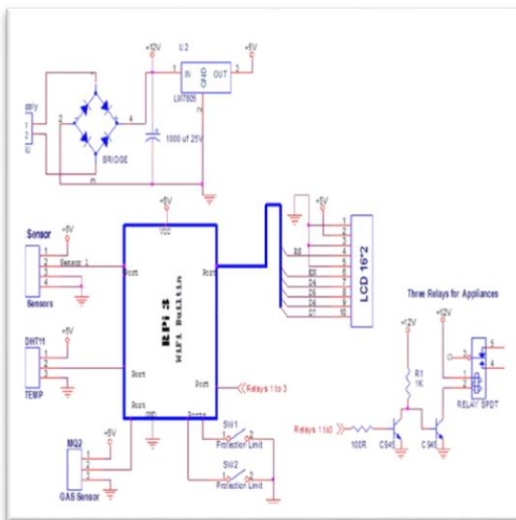

Figure. 5: Internal Hardware architecture

on general purpose input and output (GPIO) pins of Raspberry pi.

The most widely used appliances in any home load management research are lights, fan, air conditioners and heavy voltage, IR sensor for door activation and smoke sensor for smoke detection.

Fig. 5 represents the internal hardware architecture of the proposed research. Sensors have been interfaced with the raspberry pi. WIFI router provides the automatic switching through relays when control signal is received and prevent from manual switching. The main mechanism of the WIFI Router is that when the control signal (user input from mobile) is to be transmitted to the Raspberry pi, then the WIFI Router automatically assign the IP Address and connect with the Raspberry pi built in (WIFI Module).

Android software application has been designed and developed using Android studio and JAVA language. In the software application we can set the parameters according to our desired scenario. Delay time has also been pre defined and can be set according to the requirement and need of the user.

V. RESULTS AND DISCUSSION

From the past decades many techniques have been implemented for home energy management system. This research idea was just to reduce human effort by controlling home appliances from your Smartphone. The switching on/off lights, fans, door activation all can be performed just with a single touch.

To fulfill the objective of the proposed idea, authors completely understood the simple fundamentals of electronics and android programming language. The Raspberry Pi 3 was programmed using Python Language and the android programming was done using Java. In a particular it is helpful to the people who are ill or paralyzed can control their home appliances while staying on a bed rest using the mobile. Fig. 6 demonstrates the graphical user interface of the android based application. It shows the status of IR and smoke sensors. It shows the output status of the sensor whenever it is detected the switching is triggered as per the predefined scenario. Fig. 7 illustrates the graphical user interface of the android application designed and developed by the authors. It displays the detection of the smoke sensor as well to trigger the emergency execution plan and propagate the evacuation routes.
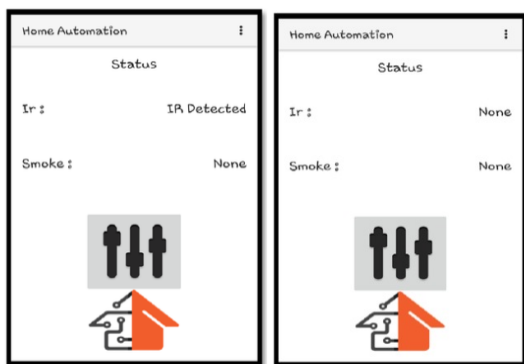
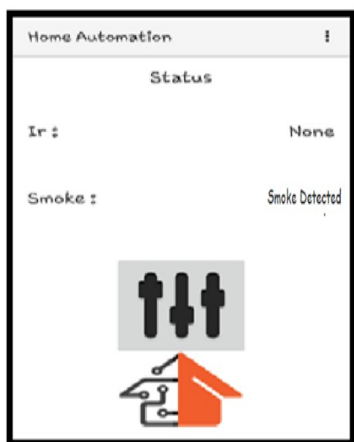Figure. 6: Graphical user interface of android application simulation

Figure. 7: Illustration of Smoke detection in android application
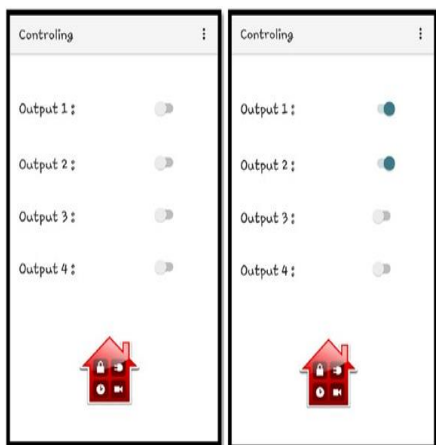

Figure. 8: simulation controlling panel of load management devices

To control the load devices the four parameters have been given. Output 1 and 2 can be used for the controlling of heavy load like air conditioning or iron. Output 3 and 4 can be lighting and fan of the particular location. It can be switched on and off as per the required and need of the user. It also maintains the current consumption log file so that it may be easily analyzed.

For the testing and validation home energy load management system was deployed in a home. Actual energy

Table 1: Comparative analysis of energy consumption with and without using home energy management device.

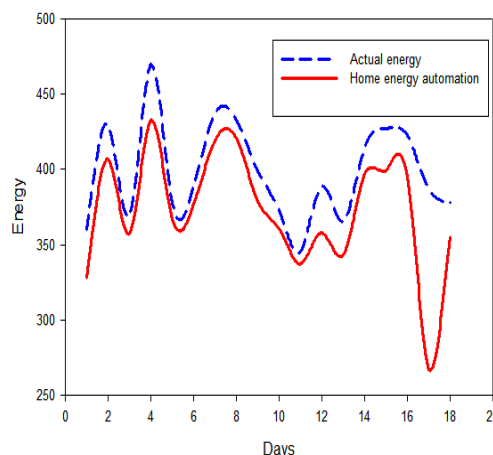| Day	E-act	E-hem
1	360	328
2	430	407
3	369	357
4	470	433
5	378	367
6	389	377
7	437	419
8	433	421
9	399	379
10	373	361
11	345	337
12	389	358
13	365	343
14	415	397
15	427	399
16	423	395
17	387	267
18	378	355

Figure. 9: Comparative analysis

and energy consumption by using home automation device was observed and recorded on daily basis. These energies actual energy without using home energy management and energy consumption by using home energy management system was compared to each other. Reading and graphical analysis showed that home energy management device worked better. Results proved that our proposed research performed better than other existing approaches in a very cost effective manner.

VI. CONCLUSION

Results proved that our proposed research performed better or equal to all other recent trends. Our proposed technique comprising of sensors, raspberry pi and android application with less false alarm rate is a cost-effective solution compared to all other techniques. The design of our proposed research has been tested so many times. To evaluate the proposed

research switching of home appliance has been performed by installing home energy management device. Then on daily basis the actual energy and energy saved by home energy management system was compared. Results proved that home energy management system saves the energy and can be designed and developed in a very cost effective manner. It can be considered user friendly system also compared to the other existing approaches. Approximate 30% energy can be saved by using proposed home energy management system solution.

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