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IoT Based Efficient Power Controlling System: An Approach Towards Smart Homes

[1]Muhammad Rauf, [1]Qazi Raza Ali, [1]Jawwad Ali Bhatti, [1]Abid Muhammad Khan and [2]Muhammad Talha Khan

[1]Electronic Engineering Department, Sir Syed University of Engineering and Technology, Karachi

[2]School of Electronic, Science, and Technology, University of Engineering, Science and Technology of China, China

E-mail: mrauf57@gmail.com

ABSTRACT

Steep increment in the population of the metropolitan cities are causing a boost in energy consumption. Several approaches to address the issue including utilization of recent advancement in the technologies are becoming vital. IoT-based applications are becoming more prevalent in addressing several real-time problems. In cooperating with this new technology, the central idea of the project is the human-machine interaction. Furthermore, the proposed architecture allows energy reducing applications that perform the following main functions: estimating energy utilization of the home environment using metering devices; apply user-defined limits that cut off boundaries providing if it exceeds energy limits. The interactive medium between sever and home appliances is the Internet that monitors remotely and controls minimal energy utilization. The main focus of the proposed idea is the IOT based conversion from IPV4 version to IPV6 so that multiple users can accommodate at a time without violating real-time constraints.

Keywords: Energy monitoring, Wifi module, cloud server, smart home, IoT

1. INTRODUCTION

The advancements in worldwide computer networks have paved the way for a broad idea of smart and wireless interaction objects. The connectivity demands of everything-to-everything gave rise to terms like Machine-to-Machine (M2M), Web of Things (WoT) and Radio Frequency Identification (RFID). The internet of things (IoT) gives permission to objects to be smart and accessed remotely across present network infrastructure [1]. In addition, the network interacting capability and the electrical communication systems have seen a sudden rise in the last few years, giving support to a system development for wellness and home-automated things. This method is used for tracking or monitoring the condition which is of interest in daily energy utilization. The real-time navigation of the utilities consumed by a resident in a house is an example of such a method [2].

Due to such technological advancements, online bill payment for utilities especially electricity has also adopted the aspects of information technology. Such advancement has impacted energy monitoring; thus, providing the concept of energy saving plans. However, the assessment and monitoring of meter values interpretation and controlling of appliances on its bases are not well integrated. It also leads to high revenue loss. For the purpose, AMR (Automated Meter Reading) is one of the advancements that combines an automatic assessment of consumption for billing and payment [3]. To implement AMR, IP address allocation to each energy unit meter is usually required. A device is integrated online to a network of interconnected objects and connecting them to the internet is named as IoT [4] and shown in Figure 1.

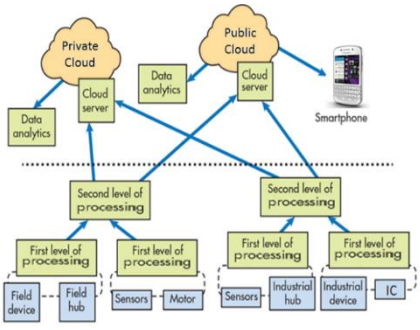

Fig. 1: Overview of IoT Based Systems

Relying on IoT based technologies, nowadays, dealing with efficient power utilization has become a subject of higher interest. There are many routes for its implementation to save energy consumption. The possibilities may include displaying magnified energy information such as working states of devices and the l power utilization of each circuit for users with the help of electric and digital meters. Furthermore, it involves supplying energy-saving ideas or tips for users according to the demands and utilization of energy [5].

There are numerous works documented in the related field where the IoT based system is proposed. An AMR based system is developed to detect energy consumed by the appliances in general. The work used the optocoupler sensor to sense the optical energy produced by the LED installed in the energy meter. Based on the optical response, the energy utilization is computed and then the micro-controller performs further controlling [6, 7]. Keeping the concept of interconnecting devices with the internet, the aim of the authors is to create a model which turns this facility hassle free, less time consuming and portable for the users. Creating an efficient energy saving system in real

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time is yet a challenge especially at the implementation phase. To address the issues at the whole, firstly, it focuses on human behavior against the energy utilization using the commonly found home appliances. In order to in-cooperate the paradigm, the proposed model consists of a remote sensing device, wireless actuators, sensors and a web-based interface for computers and mobile applications. In addition, the wireless communication channel offers a platform to link the data fetched from the sensor node to the outside world, which possibly can be a computer-based network or inter-node interaction [8]. Lastly, by confronting the power from the model, the energy utilization can be manipulated either automatically or manually and even switching on or switching off some devices at the desired time in accordance with its own tariff plan. The proposed work is aimed to provide wide arrays of services in which if the appliance maintains its communication capacity even if it is in standby mode. The network will be capable to examine its status and identify its current condition. From the best knowledge of the author, the idea has currently not been implemented on the energy consuming devices [9].

The modules can be integrated into the variety of devices such as Node MCU [10] and Arduino UNO clones such as Espduino [11] and Wemos D1 [12]. The application of ESP8266 modules is, however, widely implemented and documented in a variety of literature. The application of above domain extends from distributed home automation system [13], smart water management systems [14], vibration sensor network for landslides warning system [15], mobile robot applications [16], temperature monitoring systems [17], and heart rate monitoring system [18], to many other devices. Keeping the wide available application of the proposed system, this paper tends to extend the application for a low cost, efficient and flexible energy monitoring and controlling system. The system integrates the SoC (system on Chip), smart meeting for a residential area, and cloud server in-cooperating respective open source messaging applications.

2. METHODOLOGY

2.1 System Overview

The primary aim of the proposed work is to monitor, control and store the status data of the home-related appliances and related sensors that are controlled by a resident gateway to a cloud-based data server. In this section of the system, an overview of the network topology and associated connectivity is depicted. The proposed scheme consists of a smart identifying unit, wireless sensors, actuators, and a web-based platform for the purpose of the remote and mobile application. The whole system can be distributed into two domains. First is the home interconnection which monitors the dedicated appliances and associated sensors and transmits the information to the data server. Second is the cloud-based data server that arranges the received information and provides services for users by transmitting respective signals and receiving user's commands for controlling purpose. Such monitoring and controlling mechanism have the capacity to advance toward efficient power utilization by a residential unit.

2.2 Architecture

In this paper, the proposed system is partitioned into three sections:

a) Customer Domain

The project consists of an MCU, energy meter, optical sensor and ESP8266 at the customer side. The sensor is used to detect the falling edge of the LED that is mounted on the electric meter. The Wifi router attached to the customer domain is configured with the internet. Subsequent to finalize the authentication procedure, the consumption information is transmitted to the server system.

b) Server and control

Next, the received data is stored in the designated variable in a tabular format. The core server forwards the received data for unit consumption and informs to the users. It also controls all other related functionality of the system. App server functions as a link between the user and the main server by providing messaging facilities.

c) Customer Interface

The messaging application Telegram is selected as the channel to send problems and queries to the core server. The requests produced by the user are processed to the main server, which replies based on defined ways. Fig. 2 elaborates the process.

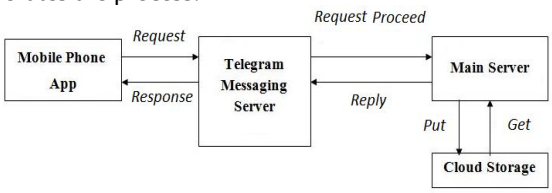

Fig.2. Proposed Baseline Architecture

2.3 Implementation Flow

Subsequent to the system overview and underlying architecture, next this section presents the process flow of the proposed work indicating core processes and decisions and given in Fig. 3.

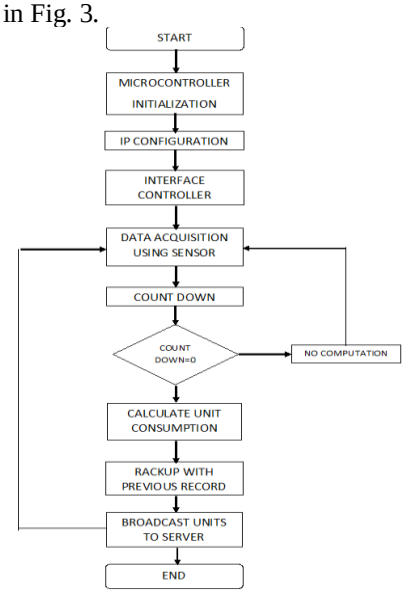

Fig. 3. Proposed Flow Diagram

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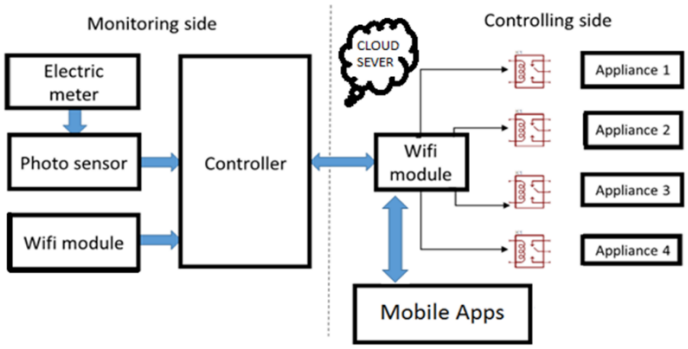

Fig. 4. Proposed Block Diagram of Project

The controller is initialized first then associate with the wireless sensor using the SSID and assigned password. After IP address assignment, energy meter is now internet enabled and ready to guide the utilized data via the internet. On following the authorization steps through the token transferring mechanism, the controller is now capable of sending the data packets to the cloud storage. In parallel, the LED toggling connected on the energy meter is converted as a voltage waveform using an optical sensor that performs as an interrupt to the MCU. The interrupt routine is then used to calculate the energy unit consumed based on the voltage pulse generated by the sensor. On every pulse, the computed unit is updated with the previously accumulated unit in the cloud. The process is updated automatically with every new sensing. The Controller can provide customization and cut off power requirements through different stages. Moreover, different appliances can be controlled through PC's and through Android application. It can be done using specific SSID and password generated by our Wi-Fi module. The sensor detects the range of units consumed by appliances and then displays it on the LCD panel. Additionally, a cutoff boundary on which power is cut off and appliances stop working has been assigned.

2.4 Hardware Design

In this section, the aim of building a network on IEEE 802.11 wireless technology and on ESP8266 cheap Wi-Fi communication modules is discussed. Firstly, the developed circuits to generate link are tested prior to the prototype designing so that the authentic and reliable results should be achieved. The ARDUINO ATMEGA 328 is used that is callable of providing a platform to interface and integrate. The uses of transistors for switching purpose as compared to relay gives the designer freedom of re-developing the prototype for adding the application with varying demands.

3. IMPLEMENTATION PHASES

The project is emphases on the following modes:

3.1 Initiation

In this phase, all necessary requirements for the project are focused including the presently implemented electricity meters. This phase is comprised of three stages: Defining project objectives, scope and phases, and feasibility study. The study is conducted in a model house with a number of household appliances including room lights and fans, and their respective switchboards.

3.2 Planning

The planning phase comprises of the project development plan, resource allocation and determines the ways to integrate the system with implemented meter based systems. In addition, the project scopes in term of size of the proposed prototype are defined where three AC appliances in two different room and an energy meter is planned to study.

3.3 Designing and Debugging

Design of the circuit, development of the server and debugging are the steps involved in it. The previous research parameters especially given in [7] of the project are entailed and utilized for the development of the project. The first work is performed only for optocoupler integration. Subsequently, monitoring and controlling of single load appliance is performed and then only, test the project for multiple loads. In the way, a prototype is developed that is further used to obtain the results.

3.4 Design Analysis

After the tested project design, the analysis is performed at different days and times. Days taken are weekdays and weekends so that reliable results could be achieved. Furthermore, different sets of timing are also taken into account in obtaining the final analyses of the designed prototype. The complete functioning of the proposed model is made available on the internet platform that can be reached by any appliance with a network connection. An android application for monitoring and management purposes has also been developed as shown in Figure 5.

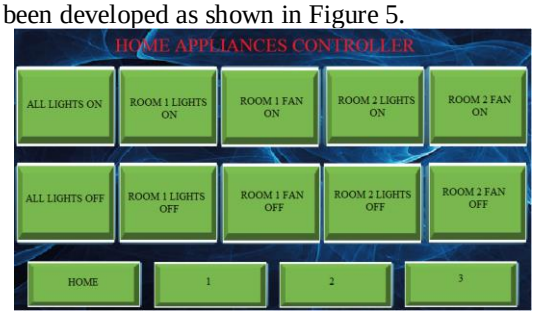

Fig. 5. Software Model at the Base Server

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The user has been given a specific IP address and allotted username and password through which they can access the web page and manage all their appliances remotely. The menu provides control over different appliances present and the user can easily manage. Any user with a given IP address, id and password can easily access the designed web page but the installation of hardware is necessary to avail the technology at its best. When the user gets into the login page, he can access to his confidential area through which he can fully gather the home conditions and the total power utilization of each appliance. Within the menu, the owner can move between the different devices and manually switching some of them accordingly to its necessity. The software-based command and control system at the primary level is depicted in Figure 6.

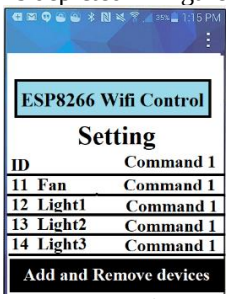

Fig. 6. The depiction of Mobile Server

With the expected implementation of the designed project, a number of advantages are expected. For illustration, mobile applications that control simple interaction, business intelligence report where BI server is a major demand, an analytic application that interprets data for business based decisions and system management control center application.

4. RESULTS AND DISCUSSION

The proposed system is particularly designed to monitor the energy consuming appliances and controlling them on the basis of the monitored values of the unit. The reliability of the project first lies in the efficient monitoring of the electric meter installed at the house. For the purpose, the units of the electric meter are manually noted for three days, Saturday, Sunday and Monday. The days are selected since variable activities are highly expected in these days. At the interval of 2 hours, the consumer units are noted.

The reading will have the possibility to observe a trend in electricity consumption. Then the part of the project with opt coupler is designed and installed on the meter to measure the values. These reading will indicate the reliability of the system since these values are further needed to control the home appliances. Figure 7 shows the manual meter reading whereas Figure 8 shows the presence of the deviation in the design against manually noted values. Figure 8 clearly shows that the deviation between the manual and measured are maximum noted to be 2 units and a minimum of 1 unit per day. It signifies that the data collected for monitoring and controlling is reliable. The next stage is the implementation of the design. The design is later installed as per given in Figure 3 and respective software is developed as given in Figure 4.

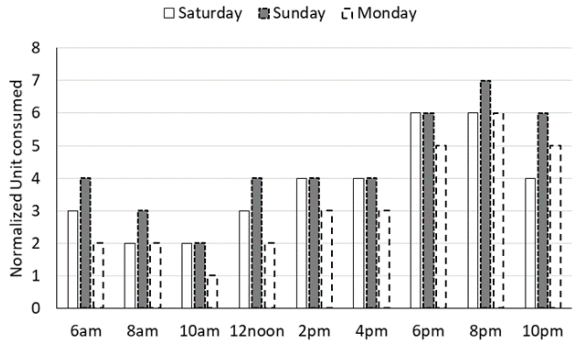

Fig. 7. Manually noted Electricity unit consumed for Three days at the interval of 2 hours

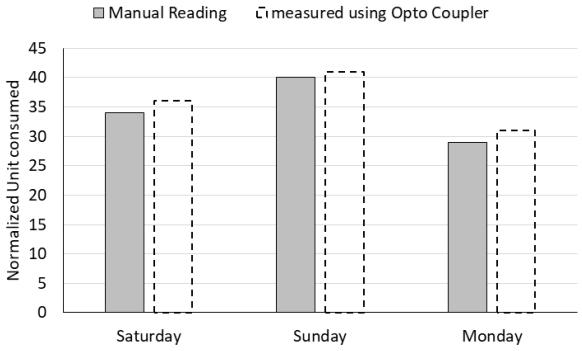

Fig. 8. Comparison of manual and Measured Electricity units consumed

With the successful implementation of the project, the user was able to monitor the units consumed at his house, accessible from anywhere. From the testing phase, it is approximated that the reduction in units by 20 -30 % is possible.

5. CONCLUSION

The proposed work is the development of an energy efficient ad-hoc MAC protocol based wireless network with static modules. This smart home model interconnects various electrical appliances through an MCU in the home and assist in monitoring and controlling them with no or least manual intervention. Besides, on the meter side, a low-cost single board is developed that can sense, process and transmit the real-time energy data. It is also capable of providing a user-friendly platform to customers with cloud storage. With achieving the promising results from the prototype, the implementation of the proposed scheme depends on many environmental and human factors, such as operation of the selected hardware, specific data types, electricity infrastructure and so on. Thus, more research work is definitely required in the future to find the concerned implementation scenarios for this scheme with other related factors. In addition, the effects of very large node densities need to study, and ways to plan the proposed scheme from the transport level viewpoint needs to be investigated.

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